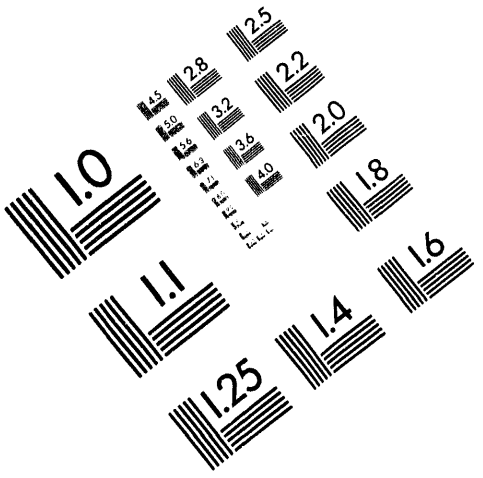

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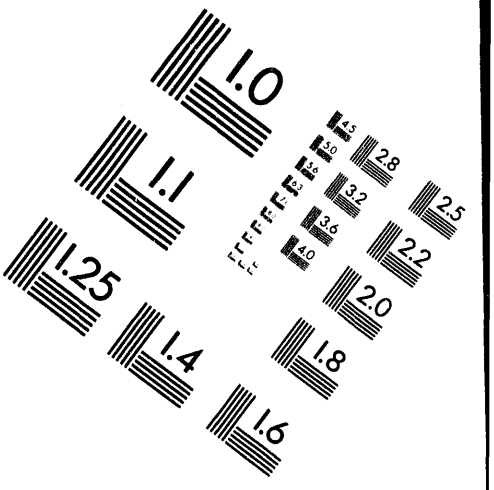

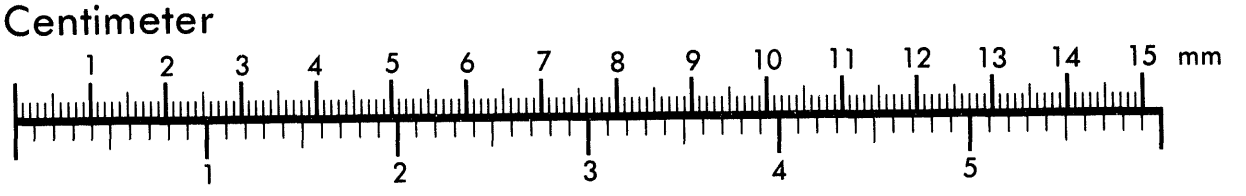

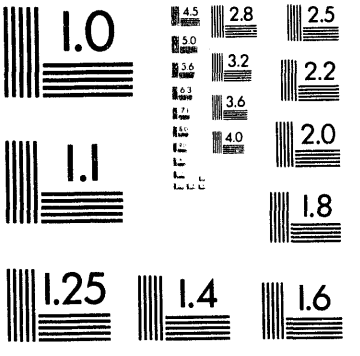

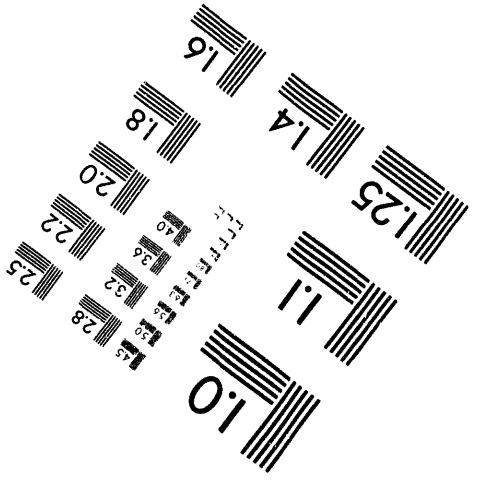

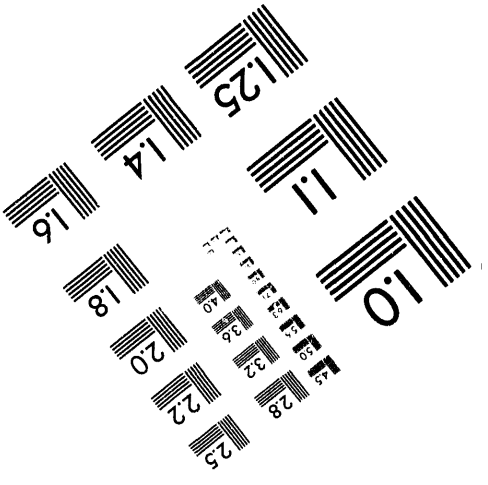

1 of 2

An Annotated Bibliography of High-Voltage Direct-Current Transmission and Flexible AC Transmission (FACTS) Devices 1991-1993

Wayne Litzenberger, Editor

Val Lava, Co-editor
Susan Grace, Co-editor
Nancy Parsons, Co-editor

Presented by the IEEE Working Group (15.05.07) on HVDC Bibliography and Records.

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R.J. Piwko
John Reeve
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Bonneville Power Administration
Western Area Power Administration

TABLE OF CONTENTS

Preface and Acknowledgments

This edition of the Annotated Bibliography of High Voltage Direct Current Transmission continues work begun in 1962 by the late Erik Bromberg, Bonneville Power Administration librarian. His original bibliography covered the period 1932 - 1962. Subsequent volumes have been compiled by Bromberg and Val S. Lava, also of Bonneville Power Administration.

Compilation of HVDC literature for 1991 - 1993 has been supported by Vickie VanZandt and her predecessor Charles F. Clark, Chief Engineer of Bonneville Power Administration, and Lloyd Greiner and his predecessor Thomas L. Weaver, Chief Engineer of Western Area Power Administration, with the cooperation of the IEEE Working Group on HVDC Bibliography and Records. The Working Group is part of the DC Transmission Subcommittee of the Transmission and Distribution Committee of the IEEE Power Engineering Society.

Section II contains a tabulation of worldwide HVDC projects prepared by David Melvold of the Los Angeles Department of Water and Power.

Section III contains a bibliography of SVC and FACTS papers compiled by Dr. Rajiv K. Varma and professor R. M. Mathur at the University of Western Ontario. Their work was completed as a supplement to the 1989 - 1991 Annotated Bibliography. Some duplications will be noted between the Section I of this volume and the Bibliography supplied by Dr. Varma and Prof. Mathur since their work was completed independently.

Additional copies of this document in printed form or on computer disk (in word processor or database formats) are available from:

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Dedication

This bibliography is dedicated to the memory of James Southwell. Jim was co-editor of the 1989-1991 edition and died shortly after its publication. His professionalism, good humor and high standards are missed by many of us at BPA.

Section I

An Annotated Bibliography

of

High-Voltage Direct Current

Transmission

1991 - 1993

1. HVDC SYSTEMS

1A. HIGH-VOLTAGE DIRECT-CURRENT TECHNIQUES

[1992] 1A-1

APPLICATION OF HIGH POWER ELECTRONICS IN ELECTRICAL POWER TRANSMISSION SYSTEMS
Ekstrom, Å. R. Inst. of Technol., Stockholm, Sweden
Power Semiconductor Devices and Circuits
1992. p.351-76 Plenum Press, New York, NY, USA
The author gives a summary of the existing and expected future applications of high power electronics for electrical power transmission systems. Power electronics has been used already during the 1950s in high voltage electrical power transmission in the form of high voltage direct current (HVDC) links and was introduced during the 1970s for reactive power control in the form of static VAR compensators. A number of new concepts, mainly based on the usage of forced-commutated voltage-source converters, are now being studied and some pilot installations have also been built. This is considered further in this paper. The importance of further development of semiconductor devices is also discussed. (5 Refs)

[1992] 1A-2

DIGITAL HIGH VOLTAGE DC, TRANSMISSION MANAGEMENT TECHNOLOGY PROVIDING HIGH AVAILABILITY
Messner, J.; Wild, G.
ETZ
vol.113, no.22-23 p.1422-6 Nov. 1992
High voltage DC transmission enables electrical energy to be transported economically over long distances, and the high availability of such systems depends on the technology used for system management. The principles of bi-directional high voltage DC transmission between stations connected by submarine cable, and the functions of the management system using digital technology are described. Operation and system monitoring uses powerful computers, and additional computer systems deal with control, regulation, data recording, and other aspects. Communication links include fast serial LAN, telephone circuit, carrier frequency high voltage, radio, and optical communication methods. Protection, system structure, reliability, and hardware and software aspects are discussed. (10 Refs)

[1991] 1A-3

ENGINEERING ASPECTS OF HVDC TRANSMISSION
Rao, S.
Electrical India
vol.31, no.10 p.3-12 31 May 1991
The author describes the various types of HVDC transmission systems. Two terminal bipolar HVDC systems are preferred for long distance HVDC transmission all over the world. The configuration, parts and operating modes of a typical bipolar HVDC system have been illustrated. The principles of control of HVDC power flow have been described in brief. (4 Refs)

[1991] 1A-4

HIGH-VOLTAGE CONVERTER TECHNOLOGY
Lytaev, R.A.; Taratuta, I.P.
Elektrotekhnika
vol.62, no.12 p.48-51, 1991 , Russia. Translated in Soviet Electrical Engineering, vol.62, no.12 p.75-80, 1991, USA.
Since the second half of the 1960s VEI has been conducting intensive studies on the creation of high-voltage thyristor rectifiers (HTR) for transmission lines and DC linkups. In the years since several generations of rectifiers have been devised have undergone specific tests. The author describes these rectifiers which have operated on the Kashira-Moscow DC power transmission line (1969-73), and from 1974 through to the present, HTR have been operated on the Volgograd-Donbass transmission line (+or-400 kV, 900 A), and since 1981 have been successfully operated on the largest DC linkup in the world between the USSR and Finland.

[1992] 1A-5

HVDC POWER TRANSMISSION UNLIMITED
Walz, R.
Journal: Power Technology International
p.133-5, 1992
The author outlines how HVDC is vital for reliable and efficient energy transmission. This is not surprising, since AC transmission has technical and economical limitations that HVDC does not, and

HVDC transmission has some important advantages over AC systems. It is, for example, the only economic technical solution for the transmission of energy over long distances. By a back-to-back link it is possible to connect two AC systems with different frequencies. All infeeds are decoupled by the DC link with respect to system frequency, voltage and short-circuit ratio. Almost 50 HVDC plants with a total transmission power of more than 30000 MW are in commercial operation or under construction. (4 Refs)

[1991] 1A-6

HVDC TAPPING STATION: POWER TAPPING FROM A DC TRANSMISSION LINE TO A LOCAL AC NETWORK

Ekstrom, Å.; Lamell, P.

AC and DC power transmission IEE Conference Publication Series 5. International conference on AC and DC power transmission

17-20 Sep 1991 p 126-131

The paper describes a new concept for tapping off a small amount of power from a high voltage direct current (HVDC) transmission line to a local network. The proposed new concept for a series tapping implies power conversion in two steps from the line to a local AC network. This will make it possible to the use a single phase transformer between the DC line potential and ground. The converter bridge connected in series in the DC transmission is of the current source line-commutated type, while the other two converters are of the voltage-source forced-commutated type. The basic functions of the converter are described and illustrated by the results from simulations with the EMPT program.

[1991] 1A-7

HVDC TAPPING STATION: POWER TAPPING FROM A DC TRANSMISSION LINE TO A LOCAL AC NETWORK

Lamell, P.; Ekstrom, Å.

EPE '91. 4th European Conference on Power Electronics and Applications

p.252-7 vol.1 1991

A new type of tapping station for HVDC power systems is presented by the authors. A small amount of power will be tapped off from a high voltage direct current (HVDC) transmission to a local AC-network in two steps. The tapping station is built up of a current-source line-commutated power converter connected in series in the DC transmission circuit, and two converters of the voltage-source forced-commutated power converter type. The basic function of the tapping station is described and illustrated by the results from simulations with the EMTP program. (1 Refs)

[1992] 1A-8

HVDC TECHNOLOGY IN INDIA-AN OVERVIEW

Vasudeva, M.S.

Journal: Electronics Information and Planning

vol.19, no.12 p. 641-56 Sept. 1992

The author discusses the integrated national plan for HVDC technology in India and the integration of commercial HVDC projects with the national plan. HVDC projects in progress are listed. The work being carried out by seven companies is described. Comments from foreign concerns on Indian HVDC are given.

[1991] 1A-9

HVMDC: A NEW CONCEPT TO FEED SMALL LOADS

Lima, A.G.G.; Pilotto, L.A.S.; Alves, J.E.R.; Watanabe, E.H.

AC and DC power transmission (High voltage modulated direct current transmission.) IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 120-125 (443 p)

The High Voltage Modulated Direct Current Transmission (HVMDC) is a new concept to feed small loads which uses basically the same equipment involved on the conventional HVDC transmission. In this scheme, the DC current is used for transmitting large blocks of power to distant parts while a controlled superposed AC ripple is used to supply small loads close to the generating station. These small loads must be located not very far from the rectifier's station due to the usual AC transmission long distance problems which depend upon the AC voltage, frequency and transmission line characteristics. In the HVMDC transmission system proposed here the rectifier's firing angle is modulated in order to generate controlled DC and AC voltages which are transmitted by the same DC transmission line. This single-phase AC voltage can be tapped by using a coupling capacitor at special locations to feed small loads. An AC filter tuned to the AC modulated frequency is connected in parallel with the conventional smoothing reactor in order to allow the AC current to by-pass the smoothing reactor and flow directly into the transmission line. At the small load tap, a DC voltage blocking capacitor must be used in series with the load to pick up only the AC power. It can also be used to compensate the impedance of the transmission line at the transmitted frequency in order to optimize the transmission. The theoretical steady-

state analysis of the HVMDC system and a feasibility of the proposed method, describing its advantages and problems, are presented.

[1992] 1A-10

IEEE RECOMMENDED PRACTICE FOR DETERMINATION OF POWER LOSSES IN HIGH-VOLTAGE DIRECT-CURRENT (HVDC) CONVERTER STATIONS

Inst. Electr. & Electron. Eng., New York, NY, USA

26 Feb. 1992

A set of standard procedures for determining and verifying the total losses of a high-voltage direct-current (HVDC) converter station is recommended. The procedures are applicable to all parts of the converter station and cover standby, partial-load, and full-load losses and methods of calculation and measurement. All line-commutated converter stations used for power exchange in utility systems are covered. Loss determination procedures for synchronous compensators for static VAR compensators are not included. (20 Refs)

[1991] 1A-11

INTERGRATION OF NEW VALVES AND CONTROLS TO NELSON RIVER HVDC BIPOLE 1.

Goodrich, F. G.; Haddock, J. L.; Rowe, B. A.; Thanawala, H. L.; Willis, D. B.

Fifth International Conference on AC and DC Power Transmission

1991 Sep 17-20 IEE Conference Publication n 345. p 147-152, 1991.

The Nelson River HVDC Transmission System in Manitoba presently consists of two bipoles. Bipole 1 has a rating of 1670MW at plus or minus 463kV and transmits this power from the northern terminal at Radisson Station over a distance of approximately 200km to the Dorsey terminal near Winnipeg. Bipole 2 has a rating of 1800/200MW at plus or minus 500kV and transmits this power from the Henday Station, some 40km downstream from Radissor, also to the Dorsey terminal. Bipole 1 which is the subject of this article was the last of the HVDC links to be commissioned using mercury arc convertor valves. The rating of 154.5kV, 1800A per group is the highest used for mercury arc convertor valves. The main features of the new valves and associated equipment such as gapless metal oxide valve arresters and valve capacitors, the cooling system and the largely digital controls are described. 2 Refs.

[1991] 1A-12

PARALLEL LINE SWITCHING IN HVDC SYSTEMS

Electra

no.138 p.66-80 Oct. 1991 France

The viability of parallel line switching in HVDC systems was established some time ago. Successful paralleling and de-paralleling have since been accomplished in the Nelson River HVDC transmission scheme. Facilities for effecting such switching operations exist at Itaipu HVDC transmission system. The purpose of this report is to point out the advantages that accrue for overall system operation from the presence of parallel lines and the ability to switch them, and the synergism that can be achieved when power converter and circuit breaker controls are operated in harmony. The advantages are discussed first and then the implementation of such a scheme is described. (20 Refs)

[1991] 1A-13

SUGGESTIONS TO RAISE THE EFFICIENCY OF THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION PROJECT

Huang Wanyong

Power System Technology

no.3 p.77-80 Aug. 1991 In Chinese

The author analyses the operating condition and efficiency of the Gezhouba-Shanghai HVDC transmission system between the period October 1989 to September 1990, with emphasis on the actual operating conditions between the Huadong and Huazhong power networks. Several efficiency improvement areas are discussed including: the power transmission and transformation efficiency; the power stability level; the power utilisation efficiency; the power regulation and reliability, etc. (0 Refs)

[1991] 1A-14

TAPPING HVDC POWER WITH GTO (GATE TURNOFF) PWM (PULSE WIDTH MODULATION) VOLTAGE SOURCE INVERTERS

Zhao, Z.; Iravani, M.R

Canadian conference on electrical and computer engineering proceedings

25-27 Sep 1991

High voltage direct current (HVDC) transmission lines are mainly used to transmit over long distances. At an intermediate point along the link, economic benefits can often be gained by connecting a small converter station to supply power to a small local load. Such a situation is examined in which a small alternating-current system is supplied from a parallel-connected

gate turnoff pulse-width-modulated (PWM) voltage source inverter. The basics of PWM voltage source inverters are reviewed, and control and protection methods for HVDC taps are described. Simulation results are presented for an energization process divided into 2 stages. Currents and voltages at various points of the DC system are shown before and after the energization of the tap.

[1991] 1A-15

THE INTEGRATION OF NEW VALVES AND CONTROLS TO NELSON RIVER HVDC BIPOLE 1
Goodrich, F.G.; Haddock, J.L.; Rowe, B.A.; Thanawala, H.L.; Willis, D.B.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission:
17-20 Sep 1991 p 147-152
The Nelson River HVDC Transmission System in Manitoba presently consists of two bipoles. Bipole 1 has a rating of 1670 MW at {+-} 463kV and transmits this power from the northern terminal at Radisson Station over a distance of approximately 900 km to the Dorsey terminal near Winnipeg. Bipole 2 has a rating of 1800/2000MW at {+-} 500 kV and transmits this power from the Henday Station, some 40 km downstream from Radisson, also to the Dorsey terminal. Bipole 1, which is the subject of this article, was the last of the HVDC links to be commissioned using mercury arc convertor valves. The rating of 154.5kV, 1800A per group is the highest used for mercury arc convertor valves. The present combined transmission capability of the two Bipoles is 3470MW, plus overload of approximately 10%. The maximum output from the two northern hydraulic stations, Kettle and Long Spruce, totals 2180 MW. By the Autumn of 1992, a new generating station will add 1320 MW to the power to be transmitted by Bipoles 1 and 2. Therefore beyond 1992 there will be 3500 MW of generation to be transmitted on the nominal 3470 MW DC system. In order to avoid transmission capacity shortfall, staged replacement of the valves by thyristor valves has been carried out. This has also eliminated the problems associated with the maintenance and refurbishment of the mercury arc valves. The main features of the new valves and their associated equipment are described.

[1993] 1A-16

USING AN HVDC LINK TO CONTROL THE BEHAVIOUR OF GENERATORS
To, K.W.V.; David, A.K.
IPEC '93. International Power Engineering Conference
18-19 March 1993 Conference Proceedings p.205-9 vol.1
This paper discusses and illustrates the use of some operating properties of an HVDC link in AC/DC power systems to improve the operational margins of stability of such hybrid systems. The converter controls need to be provided with adequate computer control features to achieve the best results. Examples are provided of how these characteristic may be exploited.

[1992] 1A-REF

HYBRID TRANSMISSION CORRIDOR STUDY
Clairmont, B.A.; Johnson, G.B.; Zaffanella, L.E.
EPRI Electric Power Research Inst., Palo Alto, CA (United States)
Jun 1992 EPRI-EL-7487-Vol.1
For Abstract see entry 1B-012.

[1993] 1A-REF

POTENTIAL DC SYSTEM SUPPORT TO ENHANCE AC SYSTEM PERFORMANCE IN THE WESTERN UNITED STATES
Lee, R.L.; Melvold, D.J.; Szumlas, D.J.; Le, L.M.; Finley, A.T.; Martin, D.E.; Wong, W.K.; Dickmander, D.L.
IEEE Transactions on Power Systems
Feb 1993 p 264-274
For Abstract see entry 1B-016.

[1991] 1A-REF

HYBRID TRANSMISSION CORRIDORS-CORONA AND FIELD EFFECTS
Clarimont, B.; Zaffanella, L.; Cabeza, L.; Stillman, G.; Zelingher, S.
CIGRE Symposium. Compacting Overhead Transmission Lines
p.600-03/1-6 Conference held on 3-5 June 1991 in Leningrad, USSR.
For Abstract see entry 3A-002.

[1992] 1A-REF

DECENTRALIZED HIERARCHICAL OPTIMAL CONTROL OF DYNAMIC INSTABILITY IN AC/DC POWER SYSTEMS
Ngan, H.W.; David, A.K.; Lo, K.L.
International Journal of Electrical Power and Energy Systems
Oct 1992 p 358-363
For Abstract see entry 5A-013.

[1991] 1A-REF

NONLINEAR FEEDBACK STABILIZATION OF AC/DC POWER SYSTEMS
Kaprielian, S.R.
Worcester Polytechnic Inst.
1991 (208 p). Thesis (Ph.D)
For Abstract see entry 5A-032.

1B. HIGH-VOLTAGE TRANSMISSION (ALTERNATING AND DIRECT CURRENT)

[1991] 1B-1

AC AND/OR DC SUBSTANTIAL POWER UPGRADING OF EXISTING OHTL CORRIDORS.
Clerici, A.; Valtorta, G.; Paris, L.
Fifth International Conference on AC and DC Power Transmission
1991 Sep 17-20 IEE Conference Publication n 345. p 220-225
The ever increasing difficulty to find new right of ways (ROW) for the construction of overhead transmission lines (OHTL) is forcing the study of possible alternatives for substantial power upgrading of existing AC line corridors. The two main possible solutions are: appropriate modifications to existing OHTL's without major new construction elimination of the old AC transmission line and its substitution with a new line. In both solutions a substantial power increase can be obtained by increasing the rated voltage and in both solutions both AC and DC can be considered for the modified/new line. Emphasis in the paper is placed on two methods: a) Conversion of both double circuit and single circuit HV AC lines to bipolar and monopolar lines, respectively b) Substitution of both double circuit and single circuit old HV AC lines with new compact EHV lines having horizontal V assemblies and with the possible reutilization of existing tower location. The upgrading possibility offered by the above methods is analyzed in the paper with due considerations to the various design criteria relevant to conductors, structures/insulation/losses/environmental effects.

[1991] 1B-2

AN ALTERNATIVE APPROACH TO POWER FLOW CONTROL
Bonheimer, D.; Lim, E.; Dudley, R.F.; Castanheira, A.
Modern Power Systems
vol.11, no.12 p.61-5 Dec. 1991
As utilities expand their transmission facilities and interconnections with neighbouring systems a number of power flow related problems arise. Such problems include overloading of lines and/or equipment, loop flows (difference between scheduled and actual power flow) with the associated increase in losses and reduction of security margins (usually in neighbouring systems) and increase of fault levels beyond equipment ratings. There are a number of approaches to overcome or mitigate these problems. These may include construction of new lines, insertion of series capacitors on selected lines, installation of phase shifting transformers and the use of back-to-back DC links for interconnections. Although these are technically sound alternatives, they are often expensive and require a long lead time for implementation. A more recent possibility is the installation of high volume dry type series reactors which in some cases may prove to be the overall best economic/technical alternative.

[1992] 1B-3

APPLICATION OF HVDC TECHNOLOGY TO THE INTERCONNECTION OF POWER RESOURCES
Muttik, P.K.; Eggleston, J.F.; Baker, M.H.
Electric Energy Conference 1992. EECON '92. 'Driving Systems Harder'. (Nat. Conf. Publ. No.92/13)
p. 349-59 19-21 Oct. 1992
There are moves in Australia to establish a national grid linking different power utilities through interstate interconnections. There are strong parallels between Australia and Canada in both cultural and geographic senses and the authors seek to point out the relevance of experience gained in Canada with HVDC interconnections to the possibilities in Australia. The authors first list different types of HVDC interconnections and the reasons which may justify their use. The 150 MW back-to-back HVDC converter station at McNeill which is the first interconnection between the western and central electrical networks of Canada is described and used to illustrate the type of equipment required for HVDC interconnections. The excellent service performance of Canadian and other

HVDC schemes is described and it is concluded that HVDC is a mature reliable technology which can be readily adapted into Australia.

[1992] 1B-4

CONAWAPA TO WINNIPEG POWER TRANSMISSION COMPLEX. DORSEY-RIEL TRANSMISSION LINK: ROUTE SELECTION AND ENVIRONMENTAL ASSESSMENT STATUS REPORT

Manitoba Hydro, Winnipeg, MB (Canada)

Mar 1992 MH-92-07159 MICROLOG--92-07159

A new 500 kV DC transmission line is being planned to connect the Henday Converter Station in northern Manitoba to a new southern terminus (Riel Station) near Winnipeg. A new link is also proposed between the existing Dorsey station and the Riel station in order to provide a backup DC connection and to reinforce the existing 230 kV AC Southern Receiver System in the Winnipeg area. This link will be required to function as a high voltage AC transmission line operating at either 230 kV or 500 kV, or as a 500 kV DC line. There are two possible routes for the proposed line, either north or south of Winnipeg. Construction of the line will be over existing rights-of-way owned by Manitoba Hydro, but some additional land will be required to widen portions of the selected right-of-way. Potential environmental impacts of the transmission line and its construction are discussed, and the two alternative routes are compared on the basis of technical, financial, socio-economic, and biophysical criteria. Manitoba Hydro's preliminary conclusion is that the north route is preferable, based mainly on the lower cost of development along this route. There is little significant difference between the two routes in terms of potential environmental impacts.

[1991] 1B-5

CONCEPTS OF VOLTAGE INSTABILITY AT CONVERTER BUS IN HVDC LINKS

Padiyar, K.R.; Sreedhar, P.N.

AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991

The Interconnection of AC systems through HVDC links is generally characterized by weak AC systems. The relative strength of the AC system at the point of coupling is measured by short circuit ratio (SCR) which is defined as the equivalent admittance of the AC system on the base of DC power rating. The AC system is considered to be weak when SCR is less than three. There are several operational problems associated with weak AC systems of which a major one is voltage instability at converter bus. This paper presents a general steady state analysis of voltage instability which is applicable to multi terminal d.c. (MTDC) systems and also permits the comparison of various controller strategies. In a parallel connected MTDC system of which two terminal link is a special case, one of the terminals, called the voltage setting terminal (VST), sets the DC voltage reference for all other terminals acting on either constant current of constant power control. The VST can have different control strategies. A case study of an asynchronous two terminal HVDC link is presented to illustrate the analysis and compare the various novel converter control strategies.

[1992] 1B-6

DESIGN AND MANAGEMENT OF HYDRO-QUEBEC'S POWER TRANSMISSION SYSTEM

Mercier, A.; Rodrigue, J.-C.

Energy Exploration and Exploitation (United Kingdom) v 10:3.

1992 p 163-173. Translated and updated from Revue de L'Energie, Feb-Mar 1991.

Hydro-Quebec has developed a transmission system to carry power over long distances to load centres that consist of 30 substations, ten 735 kV lines with over 10,000 km of circuits and a 450 kV DC line 1,000 km long. If 18,800 MW of undeveloped hydroelectric potential is to be integrated into the system eight new high voltage lines will be required. The demands of the domestic and export markets have necessitated improvements in reliability through series compensation coupled with special protection systems. Systems management is based on strategies derived from digital simulations of power flow, stability and transient phenomena. Operation is controlled through a hierarchal system.

[1991] 1B-7

DEVELOPMENTS IN HVDC AND THE IMPLEMENTATION OF HVDC IN INDIA

Isacsson, G.

Indian Journal of Power and River Valley Development

vol.41, no.12 p.257-65 Dec. 1991 India

The development of the HVDC technique started back in 1929. It took ABB 25 years of hard pioneering effort until the Gotland link in Sweden was commissioned in 1954. This first HVDC transmission used mercury arc valves and was rated 20 MW at 100 kV. The mercury arc technique was used until the end of the 1960s when thyristors were introduced. The largest HVDC transmission in operation today is the Itaipu scheme, rated 6300 MW at +or-600 kV. This uses the thyristor technique. Developments in HVDC

technology to date, and in particular their implementation in Indian projects are outlined.

[1992] 1B-8

ELECTRIC ENERGY AND ITS TRANSPORTATION TECHNOLOGIES IN THE 21ST CENTURY. ADVANCEMENT OF POWER SYSTEM CONFIGURATION AND OPERATION
Tsuchimori, N.; Nagasawa, T.
Denki Gakkai Zasshi (Japan)
15 Aug 1992 p 592-596. In Japanese.
This paper describes the improvement of configuration and operation of electric power systems. A direct current power transmission system consists of conversion of power from alternating current to direct current, a direct current line, and conversion from direct current to alternating current. The system has high stability because of controlling transmitted power using firing angles of a converter. The system having a number of advantages including reducing short circuit current is effective as a means to stabilize large power transmission over long distances, but requires technical development in converters. The paper describes also system stabilizing devices utilizing power electronics including active power control that uses superconducting magnetism storage and static var generator. A system controlling technology is available to control adequately power demand and supply balance changing hourly, while maintaining frequencies and voltages and preventing a large scale power failure. The paper introduces demand and supply control for controlling frequencies and active power, voltage and reactive power control, and a fault propagation preventing system. Contribution to improving monitoring and controlling techniques is expected from automation by introducing computers and remote control, as well as information processing technique using AI, and information communicating technique in the future.

[1992] 1B-9

ELECTRIC ENERGY AND ITS TRANSPORTATION TECHNOLOGIES IN THE 21ST CENTURY. PROGRESS OF POWER TRANSMISSION FACILITY
Horikoshi, M.; Nosaka, T.
Denki Gakkai Zasshi (Japan)
15 Aug 1992 p 587-591. In Japanese
This paper describes the current status and future prospects of technological developments to improve performances in power transmission facilities. Requirements for larger capacity and longer distance in power transmission have been dealt with increasing transmission voltages and cable sizes, using more conductors, and reducing line inductances. The limited land problem requires making the facilities more compact by using direct current power transmission. With regard to the supply reliability, the power cable faults include lightning damages accounting for 71% to 72%, and weather and animal damages for the remainder. Zinc oxide element with high-energy withstand capacity has been developed as a lightning arrestor for power transmission, and is under verification tests in actual lines. For the purpose of harmonizing power cables with surrounding environments, environment harmonizing steel towers have been developed that have functionally aesthetic forms and space saving effects. A total environmental harmony is desired further including heights and intervals of support facilities. Underground cables have restrictions in their capacity because of thermal problems caused from embedment. Development in technologies to reduce dielectric loss, conductor loss, and sheath loss has enabled achieving a power transmission capacity of 800 MVA at maximum in 275 kV class cables, with concurrent use of the conventional technologies of voltage and size increase and forcible cooling. 4 refs., 14 figs., 2 tabs.

[1992] 1B-10

HARMONIC INTERFERENCE OF HVDC IN TRANSMISSION SYSTEMS
Brauner, G.; Moraw, G.; Welfonder, E.; Lausterer, G.K.; Weber, H.
International IFAC symposium on control of power plants and power systems Munich (Germany)
9-11 Mar 1992 p 299-304
The HVDC-link in Duernrohr (Austria) has now nine years of operational experience as the first interconnection between the western and eastern transmission systems in Europe. At the moment two further HVDC-links are under erection, one in South-East Austria and the other in Germany. The influence of the existing HVDC-link on the harmonic distribution in the transmission network and the subordinated distribution level has been investigated and simulated. Comparisons between advanced measurements and simulation predictions confirmed the modelling accuracy. The influence of a second HVDC-link in Austria could then be evaluated. (author)

[1991] 1B-11

HVDC CONVERSION OF HVAC LINES TO PROVIDE SUBSTANTIAL POWER UPGRADING

Clerici, A.; Paris, L.; Danfors, P.

IEEE Transactions on Power Delivery

Jan 1991 p 324-333

Due to the ever increasing difficulty in constructing new overhead electric transmission lines, there is a need to look at alternatives that substantially increases the power transfer capability of the existing right of ways without any major new construction. This paper analyzes the feasibility of conversion of AC lines to DC lines for a substantial power upgrading and illustrates that increases of 3.5 times or more is quite feasible. The main design objective is to permit the conversion to be carried out as a simple retrofit or maintenance operation, rather than a new construction operation, thereby reducing outage times and simplifying possible new licensing procedures. The data presented provides a reference framework to facilitate preliminary evaluations, although detailed conversion studies can only be made on a case by case basis.

[1992] 1B-12

HYBRID TRANSMISSION CORRIDOR STUDY

Clairmont, B.A.; Johnson, G.B.; Zaffanella, L.E.

EPRI Electric Power Research Inst., Palo Alto, CA (United States)

Jun 1992 EPRI-EL-7487-Vol.1

Hybrid Transmission Corridors are areas where High Voltage Alternating Current (HVAC) transmission lines and High Voltage Direct Current (HVDC) transmission lines exist in close proximity of each other. Because of the acceptance of HVDC as a means of transporting electric power over long distances and the difficulties associated with obtaining new right-of-ways, HVDC lines may have to share the same transmission corridor with HVAC lines. The interactions between conductors energized with different types of voltages causes changes in the electrical stresses applied to the conductors and insulators. As a result, corona phenomena, field effects and insulation performance can be affected. This report presents the results of an investigation of the HVAC-HVDC interaction and its effect on corona and AC and DC electric field phenomena. The method of investigation was based on calculation methods developed at the EPRI High Voltage Transmission Research Center (HVTRC) and supported by the results of full and reduced-scale line tests. Also, a survey of existing hybrid corridors is given along with the results of measurements made at one of those corridors. A number of examples in which an existing AC corridor may be transformed into a hybrid corridor are discussed. The main result of the research is an analytical/empirical model for predicting the electrical/environmental performance of hybrid corridors, a definition of ACDC interaction and a set of criteria for specifying when the interaction becomes significant, and a set of design rules.

[1991] 1B-13

IMPACT OF INTEGRATING ADVANCED POWER SYSTEM TECHNOLOGIES ON REAL-TIME CONTROL AND OPERATION OF ELECTRIC POWER SYSTEMS

Tam, K.S.; Balcksburg, VA

Workshop on real-time control and operation of electric power systems

19-21 Nov 1991

In view of future challenges and the fact that the existing facilities are pushing closer and closer to their limits, improvement on real-time control and operation becomes very important for reliable and economic operation of power systems. This paper concentrates on the impact of advanced power system technologies and their integration into the electric power system. The topics include power electronics, energy storage technologies, advanced power generation technologies, renewable energy sources, advanced power transmission technologies, load management and distribution automation.

[1992] 1B-14

INCREASING WSCC POWER SYSTEM PERFORMANCE WITH MODULATION CONTROLS ON THE INTERMOUNTAIN POWER PROJECT HVDC SYSTEM

Martin, D.E.; Wong, W.K.; Dickmander, D.L.; Lee, R.L.; Melvold, D.J.

IEEE Transactions on Power Delivery

Jul 1992 p 1634-1642

The interconnected power system in the western US and Canada, designated as the Western Systems Coordinating Council (WSCC), has two DC lines that transmit power for long distances across the system. One of these DC lines, the Intermountain Power Project (IPP) DC transmission system, parallels the east to west AC system transmission. The existing AC system has some limitations on power transfers due to power system oscillations at the higher power transfer levels. Utilizing the fast power control available in DC systems, modulation controls on the IPP DC transmission system for improving the performance of the interconnected power system were investigated. This paper describes the improvements in power transmission capacity that can be achieved by adding modulation to this DC system.

1991] 1B-15

INSTITUTIONAL FACTORS AFFECTING THE GRID
Weiss, L.; Spiewak, S.
The Wheeling and Transmission Manual, Second Edition
1991 p 29-38 (251 p)
The existing transmission system described here more reflects market structure and state lines than efficiency. To a large extent, this is emblematic of the manner in which the system has evolved. Until fifteen years or so ago these lines were used primarily to bring power from remote generating sites and for reliability transfers. This now has changed as a result of disparate fuel prices, increasingly expensive capacity additions, and differing supply situations. Utilities now engage not only in short-term exchanges of energy for reliability purposes, but also contract for longer term capacity as well. Despite the growing importance of the transmission system, lines generally reflect individual utility service areas. Although interconnections obviously require coordination among contiguous utilities, each system has tended to plan and construct capacity for its own needs. However, imperfect, this system has led to the construction of a large amount of line. At the end of 1987 the bulk transmission system (lines of 230 kV and above) in North America consisted of 180,549 circuit miles of AC transmission lines and 3,527 circuit miles of DC lines. New transmission planned over the next ten years includes 17,201 miles of AC and 1,448 miles of DC circuits.

[1993] 1B-16

POTENTIAL DC SYSTEM SUPPORT TO ENHANCE AC SYSTEM PERFORMANCE IN THE WESTERN UNITED STATES
Lee, R.L.; Melvoid, D.J.; Szumlas, D.J.; Le, L.M.; Finley, A.T.; Martin, D.E.; Wong, W.K.; Dickmander, D.L.
IEEE Transactions on Power Systems
Feb 1993 p 264-274
Economics dictates the heavy utilization of the major AC and DC transmission paths in the Western US. To achieve interconnected network stability with these heavy power transfers, extensive remedial action schemes have been implemented by the various transmission projects. These remedial action schemes often pose an operate reliability problem as well as undesirable impacts on non-project systems since activation of these schemes could result in network separation. This paper explores the potentials of utilizing the controllability of the DC lines to reduce the complexity of the remedial schemes or to increase the stability performance of the system so that the impact of existing and future projects on non-project systems can be minimized.

[1992] 1B-17

POWER ELECTRONICS IN HIGH VOLTAGE TRANSMISSION SYSTEMS
Clark, G.R.; Baker, M.H.
Revue Generale de l'Electricite
no.11 p.102-7 Dec. 1992
The installation in a network of static VAR compensators (SVC) provides a precise control of reactive power and voltage, thus increasing the power capability of the system. The authors briefly explain high voltage direct current (HVDC) power transmission from which today's technologies derive, and examine SVC specification, design, behaviour and expected future developments. (3 Refs)

[1991] 1B-18

PRELIMINARY DESIGN OF A HIGH-VOLTAGE POWER NETWORK FURTHER DEVELOPMENTS OF THE EXPERT SYSTEM PROTOTYPE TRANSMISSION
Galiana, F.D.; Bernard, J.P.; McGillis, D.; Krishnayya, C.; Naser, J.A.
Expert systems applications for the electric power industry conference 5-8 Jun 1989
Published in 1991 pp 749-764
This paper describes an expert system prototype for the preliminary design of an AC/DC transmission network. Several aspects of this process are presented: Motivation and justification, objectives and benefits, interaction between knowledge engineer and domain experts, characteristics of the prototype, examples of expert system designs.

[1994] 1B-19

PROPOSED HVDC CONTROL METHODS FOR STABILIZATION OF AN INTEGRATED AC/DC SYSTEM
Georgantzis, G.J.; Vovos, N.A.; Giannakopoulos, G.B. Dept. of Electr. Eng., Patras Univ., Greece
Proceedings of the Eleventh IASTED International Conference. Modelling, Identification and Control
1994 p.298-301. In English.
Centralized suboptimal stabilizing methods for HVDC links feeding weak AC power systems are presented. The proposed control systems are easily superimposed to the classical control systems of the HVDC links and the corresponding controllers are calculated with the projective control technique. Constant current control in the rectifier and constant current control in the inverter are the two investigated control modes.

Simulation results of an integrated AC/DC power system are presented.

[1991] 1B-20

REVIEW OF THE DESIGN OF THE JAMES BAY-BOSTON DC SYSTEM

Peixoto, C.A.O.

AC and DC power transmission IEE Conference Publication Series 5. International conference on AC and DC power transmission

17-20 Sep 1991

The paper has as its backbone an attempt to question in general, HVDC transmission technology as a valid alternative to be considered by power utilities in carrying out planning studies for the expansion of their transmission system. The above-mentioned attempt is based on the analysis of the results obtained in the planning studies for the Quebec-New England phase II interconnection. In such studies certain simplified criteria were used based on a concept that is not generally considered technically sound and is the main reason for the disappointing results obtained by the authors in these studies. It should also be mentioned that the paper contains conclusions that are not in agreement with the results obtained in the operation of existing AC/DC transmission systems.

[1991] 1B-21

SELECTION OF DESIGN PARAMETERS OF EQUIPMENT FOR 800 KV TRANSMISSION SYSTEMS IN INDIA

Swarup, S.K.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 235-240 India

India has made rapid progress in the power sector during the last four decades. The installed capacity in Utilities which was 1362 MW in 1947 now stands at about 64,000 MW. Side by side, there has been progress in the area of transmission and at present about 20,000 ckt. kms. of 400 kV lines are in operation. This is the highest voltage level in operation and was introduced in 1978. The generation programme for the coming ten years envisages the installation of large generating stations with capacity ranging from 2000-2500 MW. The present voltage level of 400 kV would be inadequate for the transmission of power from these stations. Tt was therefore decided in 1989, that 800 kV should be introduced as the AC transmission voltage in the country. At the same time, steps were taken to select the parameters of major substation and transmission line equipment to produce uniformity in the development of future 800 kV systems. Representatives from utilities, industries and research organisations were associated with the Central Electricity Authority in the standardisation work. This paper outlines the procedure followed in selection of parameters for 800 kV class transmission and briefly discusses the design parameters selected for equipment. (author).

[1991] 1B-22

SYSTEM PERFORMANCE AND BASIC DESIGN ASPECTS FOR THE ETZENRICHT 600 MW BACK-TO-BACK HVDC CONVERTER STATION

Schmitt, H.; Christl, N.; Gampenrieder, R.; Liegl, K.; Gartmair, H.

AC and DC power transmission IEE Conference Publication Series 5. International conference on AC and DC power transmission

17-20 Sep 1991 p 171-176

Cooperation between Bavaria in Germany and Czechoslovakia in the area of energy exchange has been established for many years (for example supply from Czechoslovakian coal mines to power plants in Bavaria). This cooperation has been increased significantly, at the end of 1988 by an agreement between Bayernwerk AG, Munich and the Czechoslovakian partners Metalimex and Ceske Energeticke Zavody (CEZ) for mutual energy assistance and electric energy exchange especially with regard to reduced air pollution. This exchange of energy will be carried out interconnecting both asynchronous 420 kV AC-systems by a 600 MW back-to-back HVDC converter station, which will be located at the Etzenrich substation in the north-eastern region of Bavaria/Germany. Because the asynchronous power grids have different power system control philosophies and different power system management practices the direct coupling of the AC-systems is not possible. In this specific case the only practical solution will be an HVDC converter station involving power thyristor electronics to interconnect both power grids. In addition to electrical performance and the economic benefits of this interconnection the environmental compatability of such a link enables both partners to reduce significantly the emission of power plants located in the vicinity of the common border by substitution of energy from other remotely located power plants during smog conditions. (author).

[1992] 1B-23

THE BEHAVIOR OF SEVERAL HVDC LINKS TERMINATING IN THE SAME LOAD AREA
Szechtman, M.; Pilotto, L.A.S.; Ping, W.W.; Wey, A.; Salgado, E.; Carvalho, A.R.; Long, W.F.; Alvarado, F.L.; Demarco, C.L.; Nilsson, S.L.
CIGRE Proceedings of the 34th Session
p.14-201/1-7 vol.1 30 Aug.-5 Sept. 1992
The intention of this paper is to present a general insight into the potential problems and solutions resulting from HVDC multiinfeed situations. A study system representative of possible practical cases was developed, envisioned to identify either contradictory situations, as far as DC to DC interactions are concerned, or enhancements that could be achieved by a coordinated action of the DC controls. The studies were conducted on this system to evaluate the technical issues of the various AC/DC and DC/DC interactions. The issues addressed were small signal stability, overview of the entire system transient and dynamic stability, AC voltage stability and voltage collapse, HVDC control stability including its VDCOL (voltage dependent current order limiter) and the possible occurrence of commutation failures at inverter stations after recovery from faults. Digital computer programs and an HVDC simulator were the main tools used for the studies. (6 Refs)

[1991] 1B-24

THE EUROPEAN MARKET AND EDF
Bergougnoux, Jean
Modern Power Systems
Dec 1991 p 9-10, 12
Once the necessary physical infrastructure the interconnected grid had been developed, European electricity utilities were able to start developing a European market. Large interconnected electricity generation and transmission systems, UCPTE, NORDEL and CDO, were set up both in east and west in Europe. Thus EDF (Electricite de France) has been able to become a major electricity exporter. Twelve per cent of its output is exported and covered by long-term contracts. This will rise to 20 per cent before the end of the century. EDF is a member of the British pool and also has commercial dealings with Portugal via the Spanish network. EDF is interconnected to the British power system by a 2000MW DC cross-channel link, and it takes part in the pool, where supply and demand are confronted on a competitive basis. Beyond the physical exchange of power, which will remain limited by the cost of transmitting electricity over long distances and the scarcity of sites, new forms of electrical industry internationalization are also developing. The nuclear industry of the beginning of the next century will necessarily be of a European, or even wider, conception. There will be international convergence on safety requirements and environmental protection. In Eastern Europe, we are developing cooperation and partnership arrangements with utilities to help with the necessary reconstruction of the electrical power systems in this region. The result is that the European electricity market is a concrete reality today.

[1992] 1B-25

THE PAST AND FUTURE OF HIGH VOLTAGE TECHNOLOGY
Mitsui, T.; Saba, S.
Journal of the Institute of Electrical Engineers of Japan
vol.112, no.5 p.291-8, May 1992 , Japan. In Japanese .
The author reviews the history of high voltage technology development and describes how high voltage technology has contributed to technology development and management of the electric power company, referring to insulation technology for high-voltage transmission, 1000 kV power transmission, high reliability systems, cost reduction for the related equipment construction, and future development of UHV transmission technology and other high voltage technologies. In the 21st century, long-distance DC power transmission and new power electronics technology in addition to UHV transmission are expected to be applied to power systems. High-voltage measuring technology is also expected to be developed in the future.

[1993] 1B-26

THE PECULIARITIES OF USING THE SIBERIA-KAZAKHSTAN-URALS-CENTRAL RUSSIA TRANSMISSION LINES FOR DIRECT TRANSMISSION OF POWER UNDER NEW ECONOMIC CONDITIONS
Kutovoi, G.P.
Izvestiya Vysshikh Uchebnykh Zavedenii, Energetika
no.5-6 p.21-4 May-June 1993. In Russian
In the last two decades, the main strategic directions in the development of the unified power grid in the eastern part of the former Soviet Union was the creation and commissioning of 1500 kV AC power lines and 1500 kV DC power lines. These power lines connect the Siberian power stations via the North Kazakhstan power systems, with those of the Urals, from Itat to Chelyabinsk over a 2000 km route. The strategic directions of the formation of these power lines are now re-interpreted, and new proposals made for the operation and economic utilisation of the existing HV power lines. The review was necessitated, firstly, by the disintegration of the Soviet Union into

independent states, with the potential of the 1500 kV lines remaining only with the Russian Federation and the Republic of Kazakhstan; secondly, by the ecologically-related obstacles in the generation of power in the two areas. It is estimated that new generating plants, capable of satisfying the necessary ecological requirements may become available by the end of this century. An intermediate solution is outlined for overcoming the present difficulties.

[1992] 1B-27

THE RESEARCH ON OPERATING PERFORMANCE OF AC/DC TRANSMISSION SYSTEM
Cai Bin
Power System Technology
no.1 p.2-8 Feb. 1992 China Language: Chinese
The author described the studies on operating performance of an AC/DC transmission system. The author is particularly emphasizing the interaction between AC and DC systems, the optimization of power distribution between AC and DC in parallel, and the selection of AC voltage grade for the AC/DC junction bus. The author considers the experience of the commissioning test and the operation of the Gezhouba-Shanghai HVDC transmission project. (4 Refs)

[1993] 1B-28

THE TECHNICAL CONCEPT OF THE HVDC CONNECTION BETWEEN THE NETHERLANDS AND NORWAY
King, W.L.
Energie Technologie (Netherlands) v 3:nos.1-2. ISSN: 0924-7319
Jan-Feb 1993 p 18-27. In Dutch
In the Electricity Plan 1993-2002 of the Dutch Cooperative Electric Power Generating Companies (SEP) mention is made of a basic decision to realize a high voltage direct current (HVDC) connection between the Netherlands and Norway. The transport capacity will be 500 MW. Because of the overseas distance of 500 km the application of direct current appears to be the only technical solution. The coupling of the Dutch high voltage network will be at the harbour Eemshaven in the northeast of the Dutch province Groningen. Attention is paid to the components of a HVDC system, the basic principles of AC/DC conversion and the control of HVDC systems. Also some aspects of the DC sea cable are dealt with.

[1992] 1B-29

TLWORKSTATION TRADEMARK CODE: VERSION 2.3: VOLUME 7, ACDCLINE MANUAL
Zaffanella, L.E.
Jun 1992 EPRI-EL-6420-Vol.7
ACDCLINE is a software package consisting of several integrated FORTRAN programs designed to operate in the EPRI TLWorkstation environment. ACDCLINE provides designers and planners with the tools to evaluate the operational characteristics of AC, DC, and AC/DC hybrid transmission lines. ACDCLINE provides information about conductor surface voltage gradients, corona losses, audible noise, radio noise ozone, electric field, ion density, ion current, human sensation levels to electric fields, coupling to objects, shielding by objects, magnetic field, surge performance of towers, and selection of insulators based on surface contamination. Graphics options are also available for viewing both the line geometry specified by the user, and profiles of the computed results.

[1992] 1B-REF

NATIONAL HVDC PROJECT-CONCEPT TO COMMISSIONING AND BEYOND
Nene, P.L.; Balarami Reddi, K.; Vasudeva, M.S.; Gupta, D.P.; Raizada, S.K.
Electronics Information and Planning
vol.19, no.12 p.670-7 Sept. 1992 India In English
For Abstract see entry 1D-003.

[1991] 1B-REF

THE AMAZON TRANSMISSION TECHNOLOGICAL CHALLENGE
Praca, J.C.; Salomao, J.C.; Drummond, M.; Guimaraes, E.B.; Ribeiro, D.R.; Pimentel, G.
AC and DC power transmission (Power transmission in Brazil.) IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 79-84
For Abstract see entry 1F-017.

[1992] 1B-REF

QUALITY ASSURANCE FOR THE NEW ZEALAND INTER-ISLAND POWER TRANSMISSION PROJECT
Bell, R.E.; Buyers, R.
Quality Forum
vol.18, no.1 p.36-42 March 1992
For Abstract see entry 7A-017.

[1991] 1B-REF

THE FENNO-SKAN HVDC SUBMARINE CABLE TRANSMISSION. SYSTEM AND DESIGN ASPECTS, COMMISSIONING AND INITIAL OPERATING EXPERIENCE
Carlsson, L.; Nyman, A.; Willborg, L.; Hjalmarsson, G.
AC and DC power transmission, IEEE Conference Publication Series 5, international conference on AC and DC power transmission
17-20 Sep 1991 p 344-349
For Abstract see entry 7A-018.

1C. ECONOMICS

[1991] 1C-1

EFFICIENT LONG DISTANCE ELECTRICITY TRANSMISSION
Glavitsch, H.; Blahous, L.
Bulletin des Schweizerischen Elektrotechnischen Vereins & des Verbandes Schweizerischer Elektrizitaetswerke
vol.82, no.2 p.17-21, published on 23 Jan. 1991 in German .
The transmission from Africa to Europe of electricity generated in an environmentally-compatible manner plays an important role in various future projects. The author presents the possibilities and limits of the direct transport of electricity using high-voltage three phase AC and high-voltage DC transmission. The transmission on a large scale of electricity over long distances using technologies available today is basically possible but is, above all, a matter of costs.

[1991] 1C-2

SMALL SERIES CONVERTER STATION SPECIFICATION AND COST EVALUATION
Ponte, J.R.R.; Ellery F, E.H.; Azevedo, D.C.B.; Gama, C.A.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 132-137
An HVDC transmission system is being considered between power generation sources in the Amazon Basin and the main load centres in the South of Brazil. The technical and economic viability of supplying small loads along these transmission lines is being examined. An investigation of Series Convertor Stations (SCS) for this purpose is presented. It is concluded that the SCS is technically suitable and has economic advantages over local thermal generation.

[1991] 1C-REF

SUGGESTIONS TO RAISE THE EFFICIENCY OF THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION PROJECT
Huang Wanyong
Power System Technology
no.3 p.77-80 Aug. 1991 In Chinese
For Abstract see entry 1A-013.

[1993] 1C-REF

PROPOSED ICELAND/UNITED KINGDOM POWER LINK-AN INDEPTH ANALYSIS OF ISSUES AND RETURNS
Hammons, T.J.; Olsen, A.; Kacejko, P.; Leung, C.L. Glasgow Univ., UK
IEEE Transactions on Energy Conversion
vol.8, no.3 Nov 1993 p. 566-75
For Abstract see entry 1F-013.

[1992] 1C-REF

STATIC VAR COMPENSATORS (SVC) VERSUS SYNCHRONOUS CONDENSERS (SC) FOR INVERTER STATIONS COMPENSATION-TECHNICAL AND ECONOMICAL ASPECTS IN ELETRONORTE STUDIES
Gama, C.A.; Ellery F.E.H.; Barbirato Azevedo, D.C.; Ponte, J.R.R.
CIGRE Proceedings of the 34th Session
p.14-103/1-6 vol.1 30 Aug.-5 Sept. 1992
For Abstract see entry 2C-022.

1D. COMMISSIONING AND TESTING

[1991] 1D-1

COMBINED VERSATILE HIGH VOLTAGE TEST SYSTEM FOR INSULATION TESTING IN LABORATORY AND ON-SITE
Zhu Xudong; Huang Jing-Ming; Chen Wen-Zhen
Seventh International Symposium on High Voltage Engineering
p.53-6 vol.5. Conference held 26-30 Aug 1991, Dresden Germany. Published by Dresden University
The impulse voltage generator and the DC voltage generator are two basic pieces of insulation test equipment in a HV laboratory. Most equipment now available is not suitable for onsite testing and two individual test systems are required. For solving these problems, a newly combined versatile high voltage test system has been developed. In an easy and quick manner, the test system can be employed to generate a

standard lightning impulse, switching impulse, two individual impulses with opposite polarity, DC voltage, etc. The authors present the circuit design and main test results of the newly system.

[1991] 1D-2

END TO END SYSTEM TEST FOR GESHANG +/-500 KV HDVC PROJECT
Zeng Nanchao; Ni Lin Lin
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management (Conf. Publ. No.348)
p. 694-7 vol.2 1991
An extensive end-to-end system test of China's first +/-500 kV HVDC line, the Gezhouba to Shanghai HVDC project, was completed in August, 1990. The items and results of this test are discussed. Several important events which occurred during the test as well as their reason and effects are described. Same valuable experiences are also discussed. (2 Refs)

[1992] 1D-3

NATIONAL HVDC PROJECT-CONCEPT TO COMMISSIONING AND BEYOND
Nene, P.L.; Balarami Reddi, K.; Vasudeva, M.S.; Gupta, D.P.; Raizada, S.K.
Electronics Information and Planning
vol.19, no.12 p.670-7 Sept. 1992 India In English
The authors give details of how the National HVDC Project, a major R&D mission was conceived and implemented, ultimately resulting in the successful transfer of 100 MW of rated power over the first HVDC line. The success in spite of heavy odds and with no major rework, is indicative of capabilities that exist in India to handle R&D projects in high-tech areas. In the execution of the project several firsts in the country and some in the world have been established. Project specifications have been so framed that the power transfer capability can be enhanced from 100 MW in Stage I to 200 MW in Stage II and 400 MW in Stage III. Subsequently, it may be possible to convert the bipole to a multi-terminal HVDC system and capability raised to around 1000 Mw. This project has generated enough confidence to attain the goal of self reliance and handle future HVDC projects with maximum indigenous content and tailored to suit the local conditions.

[1993] 1D-4

PERFORMANCE TESTING OF THE SANDY POND HVDC CONVERTER
Donahue, J.A.; Fisher, D.A.; Raling, B.D.; Tatro, P.J.
IEEE Transactions on Power Delivery
vol.8, no.1 p.422-8 Jan. 1993
Results of several performance tests for the 1800 MW Sandy Pond HVDC converter terminal are presented and discussed. The work included tests for power line carrier interference, audible sound, AC and DC line faults, and DC harmonic performance. The testing was conducted as part of the commissioning program for the first stage of the Quebec-New England Phase II multiterminal system. During the testing period, Radisson (Quebec) was operating as a rectifier and Sand Pond (New England) operated as an inverter. As expected, the performance testing discovered areas where

[1991] 1D-5

THE FENNO-SKAN HVDC LINK COMMISSIONING.
Nymar, A.; Jaaskelainen, K.; Vaitomaa, M.; Oy, Imatran Voima; Jansson, B.; Danielsson, K-G.
1991
The commissioning of the Fenno-Skan HVDC link between Finland and Sweden, with the longest submarine DC cable in the world, is described. The main pre-commissioning activities, important for an efficient commissioning, are discussed together with time schedules and suitable organization forms. The procedures to test special control features, such as subsynchronous oscillations (SSO) damping control are presented. The full scale network interaction tests which are an important part of the commissioning are also discussed. These tests succeeded very well and provided a lot of information about the system behavior for future operation and planning purposes.

[1992] 1D-REF

ANALYSIS OF ABNORMAL SHUT DOWN IN SYSTEM TESTS FOR POLE II AND BIPOLE OF THE GEZHOUBA-SHANGHAI HVDC PROJECT
Zeng Nanchao; Ni Linlin
Power System Technology
no.1 p.9-14 Feb. 1992 China In Chinese
For Abstract see entry 2E-002.

[1991] 1D-REF

NETWORK INTERACTION TESTS OF THE FENNO-SKAN HVDC LINK
Pottonen, L.; Hirvonen, R.; Jaeaeskelaeinen, K.; Vaitomaa, M.
AC and DC power transmission IEE Conference Publication Series 5. internationc' conference on AC and DC power transmission
17-20 Sep 1991 p 285-289
For Abstract see entry 5D-014.

[1992] 1D-REF

OVERVOLTAGES AND INSULATION COORDINATION AT DC SIDE OF CONVERTER STATIONS FOR GE-SHANG HVDC TRANSMISSION PROJECT
Li Tongsheng
Power System Technology
no.1 p.15-22 Feb. 1992 China Language: Chinese
For Abstract see entry 5F-005.

[1993] 1D-REF

EASTERN EUROPE CONNECTS TO UCPTE VIA ETZENRICHT LINK
Reischi, A.; Weingarten, U.
Modern Power Systems
Jun 1993 p 31-32
For Abstract see entry 7A-009.

[1991] 1D-REF

NEW ZEALAND HVDC LINK UPGRADED TO 1240 MW
Gleadow, J.; Paeaejaervi, B.
Modern Power Systems
Sep 1991 p 37, 39, 41, 43, 45
For Abstract see entry 7A-014.

1E. SYSTEM DYNAMICS, PERFORMANCE

[1993] 1E-1

DYNAMIC BEHAVIOR OF FORCED COMMUTATION STATIC VAR COMPENSATOR APPLIED FOR REACTIVE POWER COMPENSATION OF HVDC CONVERTER
Kimura, N.; Funaki, T.; Li, A.; Matsu-ura, K.
Conference Record of the Power Conversion Conference - Yokohama
19-21 April 1993

A conventional power converter used in an HVDC system needs line voltage to turn off the current flowing through a thyristor. Hence a HVDC system has some difficulties to operate with a weak AC system. Moreover, a HVDC system cannot supply electric power into a system which has no AC source. The recent development of high power and high frequency semiconductor devices with fast gate turn-off abilities suggests the application of a voltage source type forced commutation (VSFC) power converter to a static VAR compensator (SVC). This paper shows, by computer simulation, that the installation of VSFC-SVC can improve the performance of HVDC systems remarkably.

[1991] 1E-2

DYNAMIC BEHAVIOR OF HVDC LINKS AFTER AC SYSTEM DISTURBANCES AS INFLUENCED BY RECTIFIER CONTROLLER PARAMETERS AND PARTIAL LOSS OF VAR COMPENSATION
El-Sadek, M.Z. Dept. of Electr. Eng., Assiut Univ., Egypt
Computers & Electrical Engineering
vol.17, no.2 p.91-104 1991 , USA, in English.
Dynamic behavior of HVDC systems is mainly determined by its rectifier controller parameters and the VAR compensator size at the rectifier AC side. Effects of critical rectifier controller parameters on system operation stability are determined through eigenvalues scanning technique of the linearized system model. Time simulations with numerical integrations of the non-linear system model subjected to large disturbances is used for dynamic system behavior studies. The paper investigates the dynamic behavior of a two-terminal HVDC link operating with different rectifier controller parameters or with partial loss of VAR compensation at the rectifier side subsequent to step voltage disturbances in the AC voltage at the inverter side, which was previously reported as a frequent and important disturbance. Power, reactive power, DC current, delay angles and extinction angles oscillations are presented for both stable and unstable situations. Effects of partial loss of VAR compensation on reactive power response which can lead to voltage instability in these systems are discussed. System modeling is presented in adequate detail. (18 Refs)

[1991] 1E-3

DYNAMIC BEHAVIOR OF HVDC LINKS AFTER AC SYSTEM DISTURBANCES AS INFLUENCED BY RECTIFIER CONTROLLER PARAMETERS AND PARTIAL LOSS OF VAR COMPENSATION.

El-Sadek, M. Z.

Computers and Electrical Engineering

Vol. 17, No. 2 1991, pp.91-104

Dynamic behavior of HVd.c. systems is mainly determined by its rectifier controller parameters and the VAR compensator size at the rectifier a.c. side. Effects of critical rectifier controller parameters on system operation stability are determined through eigenvalues scanning technique of the linearized system model. Time simulations with numerical integrations of the non-linear system model subjected to large disturbances is used for dynamic system behavior studies. The paper investigates the dynamic behavior of a two-terminal HVd.c. link operating with different rectifier controller parameters or with partial loss of VAR compensation at the rectifier side subsequent to step voltage disturbances in the a.c. voltage at the inverter side, which was previously reported as a frequent and important disturbance. Power, reactive power, d.c. current, delay angles and extinction angles oscillations are presented for both stable and unstable situations. Effects of partial loss of VAR compensation on reactive power response which can lead to voltage instability in these systems are discussed. System modeling is presented in adequate detail.

[1991] 1E-4

DYNAMIC BEHAVIOR OF HVDC SYSTEM USING FORCED COMMUTATION CONVERTER IN AC SYSTEM FAULT

Kimura, N.; Kishimoto, M.; Matsu-ura, K.

EPE '91. 4th European Conference on Power Electronics and Applications

p.225-30 vol.1 3-6 Sept. 1991

The authors show the dynamic behavior of an HVDC system which uses a forced commutation power converter when an AC fault occurs in it. The model HVDC system gives unidirectional transmission into a load system without any AC voltage source. A computer simulation program using transient analysis has been developed to perform many runs changing several parameters. First, the results of computer simulation when load impedance changes in the receiving system are shown and they indicate the superiority of the voltage-source converter in dynamic behavior. Then, the results of computer simulation when an AC fault occurs in the receiving system are shown. Simulated AC faults are (1) line-to-ground (1LG); (2) line-short-circuit (2LS); and (3) line-to-ground (3LG). The results of computer simulation indicate that the voltage-source converter must be turned off quickly to protect the switching devices while the current-source converter has no severe problem in the AC fault condition. The overcurrent and overvoltage for the voltage-source converter are shown with the parameters of AC reactance and turn-off delay. (12 Refs)

[1991] 1E-5

EXPERIENCES ON POWER QUALITY MONITORING RELATED TO HVDC CONNECTIONS

Lahtinen, M.; Kuussaari, M.; Senttula, A.; Koeturius, C.

First international conference on power quality: end-use applications and perspectives

15-18 Oct 1991 EPRI-TR-101260 CONF-911067--

The report describes power quality measurements in the Finnish transmission network related to two HVDC links as well as the previous and new monitoring systems used for the measurements. The results produced by the monitoring systems are described referring to certain incidents which have been solved or explained using the measured results.

[1993] 1E-6

SUPPRESSION OF DC LINE CURRENT OSCILLATION OF HV DC TRANSMISSION SYSTEM USING VOLTAGE SOURCE FORCED COMMUTATION CONVERTER

Funaki, T.; Kimura, N.; Matsu-ura, K.

Electrical Engineers of Japan.

20 Jan 1993 p 57-64

Suppression of DC line current oscillation of HV DC transmission systems equipped with a voltage source forced commutation converter was studied by computer simulation inserting an L-R parallel damper circuit into a DC line. The long-distance submarine cable line (50 km overhead line + 50 km submarine cable + 50 km overhead line) and long-distance superconducting line (150 km superconducting cable) were used as model lines, and their harmonic analysis, eigenvalue analysis, instantaneous value simulation and transient response analysis were conducted. As a result, as the DC reactor and damper circuit were inserted in series of a DC line for suppressing higher harmonics, their suppression effect of higher harmonics was the same as DC reactor alone without any increase in transmission loss, and the dynamic performance of the whole system was enhanced. Such a effect was stronger in the submarine cable or superconducting line with a large ratio of L and C to R of lines.

[1991] 1E-REF

NETWORK INTERACTION TESTS OF THE FENNO-SKAN HVDC LINK
Pottonen, L.; Hirvonen, R.; Jaeaeskelaeinen, K.; Valtomaa, M.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 285-289
For Abstract see entry 5D-014.

[1991] 1E-REF

OPERATING CHARACTERISTICS OF A HVDC LINK WITH AC/DC HYBRID POWER TRANSMISSION
Ni Linlin; Zeng Nanchao
Power System Technology
no.2 p.2-7 May 1991 In Chinese .
For Abstract see entry 5D-015.

[1993] 1E-REF

DYNAMIC SYSTEM MONITORING (DSM) FOR HVDC MODULATION CONTROL
Grund, C.E.; Sweezy, G.; Hauer, J.F.; Balser, S.J.; Nilsson, S. (Electric Power Research Inst., Palo Alto, CA (United States))
IEEE Transactions on Power Delivery
Jul 1993 p 853-860
For Abstract see entry 5G-005.

[1993] 1E-REF

AC-DC LOAD FLOW WITH UNIT-CONNECTED GENERATOR-CONVERTER INFEEDS
Arrillaga, J.; Arnold, C.P.; Sankar, S.
IEEE Transactions on Power Systems
May 1993 p 701-706
For Abstract see entry 6B-007.

[1991] 1E-REF

ANALYSIS ON THE OPERATING CONDITIONS OF THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION SYSTEM DURING AUG. 1989 TO AUG. 1990
Huang Wanyong; Sun Peijing
Power System Technology
no.3 p.70-6 Aug. 1991 China In Chinese .
For Abstract see entry 7A-002.

[1993] 1E-REF

PLANT CONCEPT OF DC SHORT CONNECTION ETZENRICHT
Gampenrieder, R.; Liegl, K.; Weinmann, T.; Schmitt, H.; Weingarten,
Elektrizitaetswirtschaft
1 Jun 1993 p 725-733
For Abstract see entry 7A-015.

[1992] 1E-REF

IEEE RECOMMENDED PRACTICE FOR DETERMINATION OF POWER LOSSES IN HIGH-VOLTAGE DIRECT-CURRENT (HVDC) CONVERTER STATIONS
Inst. Electr. & Electron. Eng., New York, NY, USA
26 Feb. 1992
For Abstract see entry 1A-010.

1F. PLANNING STUDIES, SYSTEM STUDIES

[1991] 1F-1

A BENCHMARK MODEL FOR HVDC SYSTEM STUDIES
Szechtman, M.; Wess, T.; Thio, C.V.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991, v no. 345., p 374-378
The idea of establishing a benchmark system to study certain phenomena is not new. However this is a first attempt to create a common reference for HVDC studies, especially one related to control strategies and recovery performance. Another benefit that results from such a standard system is the possible comparison of different simulation methods and results. In a previous paper by the authors, results obtained from distinct simulators/computer programs have been shown, indicating that the "well-established" simulation sources led to nearly identical results, for the same set of parameters. In this paper, some aspects that were not discussed earlier are presented, such as assumptions and reasons for selecting the HVDC benchmark model as it is now, with the objectives of promoting more discussions on this subject, and evolving the degree of information and exchange among power system engineers.

[1991] 1F-2

A STUDY OF A +/-500 KV, 2400 MW COMPACT CONVERSION

Lebow, M.A.; Mauro, R.; Fletcher, D.E.; Harrison, R.E.; Gordon, D.L.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 165-170

Consolidated Edison has been involved in a number of research projects aimed at the development and demonstration of HVDC equipment for use in urban environments. The most notable of these projects has been the installation, in conjunction with EPRI, of a compact HVDC station in Astoria, New York. The Astoria experiment was recently concluded. As part of Consolidated Edison's ongoing program to ensure the availability of transmission equipment to meet its possible future needs, work was carried out in 1989 to develop a conceptual design of a 2400 MW HVDC compact terminal station based on available equipment suitable for installation in New York City. The study also identified areas where additional research could reduce the cost or space requirements of the installation. For the purpose of this study, the converter station was assumed located on a 61m (200 ft) by 122m (400 ft) site in downtown Manhattan. This area is approximately 5% of the area that would be required by a conventional HVDC station of this capacity. Both the AC and DC connections to the station are made by cable. The AC side of the converter would be connected to the 345 kV AC network. Existing 345 kV cables plus additional new 345 kV cable circuits would be looped into the converter station. The power to the DC side of the converter station was assumed to be supplied via an overhead transmission line and then by 64 km (40 miles) of underground or submarine cable, laid in a river waterway, to the converter station.

[1991] 1F-3

A STUDY OF A +OR-500 KV, 2400 MW COMPACT CONVERTER STATION

Melvold, D.J.

AC and DC Power Transmission (Conf. Publ. No.345)

p.153-8 Conference held on 17-20 Sept. 1991 in London, UK.

For many years now CIGRE has been collecting operating data on existing HVDC systems and periodically publishing updates of that material to the benefit of the entire industry. Recently a utility survey was made of HVDC projects operating worldwide. With the information on these additional important factors, the CIGRE data will be more informative and provide increased practical value. This paper addresses four areas-availability, outage rate, thyristor failure rate, and maintainability. The latter will cover spare parts, maintenance staffing and training levels, and maintenance effort. Responses were received from 70 percent of the 42 questionnaires sent out to 37 utilities on 37 HVDC projects-both operating and nearing final construction. (7 Refs)

[1992] 1F-4

A STUDY ON THE NETWORK CONSTRUCTION OF POWER TRANSMISSION OF THREE GORGES PROJECT

Zheng Meite

Power System Technology

no.3 p.9-15 Aug. 1992 (In Chinese)

The results of studies on network construction for power transmission from the Three Gorges project by the Power System Department at EPRI in their various stages are briefly summarized. A large number of mathematical models, methods and calculation programs have been developed by researchers at EPRI. The network construction for power transmission from the Three Gorges hydroelectric power station using an HVAC/HVDC hybrid scheme is recommended and considered appropriate and advantageous for this project.

[1991] 1F-5

AC AND/OR DC SUBSTANTIAL POWER UPGRADING OF EXISTING OHTL (OVERHEAD POWER TRANSMISSION LINES) CORRIDORS

Clerici, A.; Valtorta, G.; Paris, L.

AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 220-225

The ever increasing difficulty in finding new rights of way for the construction of overhead transmission lines (OHTL) is forcing the study of possible alternatives for substantial power upgrading of existing AC line corridors to be pursued. Particular emphasis in this paper is placed on the two main methods of achieving this: a) conversion of both double circuit and single circuit HVAC lines to bipolar and monopolar lines respectively; b) substitution of both double circuit and single circuit old HVAC lines with new compact EHV lines having horizontal V assemblies and with the possible reutilization of existing tower location. The upgrading possibility offered by the above methods is analyzed in the paper with due consideration to the various design criteria relevant to conductors, structures, insulation power losses and environmental effects.

[1991] 1F-6

COMPARISON BETWEEN HIGH-VOLTAGE DIRECT-CURRENT TRANSMISSION AND HYDROGEN TRANSPORT

Kaske, G.; Schmidt, P.; Kannglesser, K.W.

International Journal of Hydrogen Energy

1991 p 105-114

Transportation of solar energy from North Africa to Western Europe is investigated from the point of view of technique and cost in the form of a project study. It is assumed that 43% of the final energy consumption of the Land of North Rhine-Wesphalia for 1986 can thus be provided with an electric power proportion of 20%. The techniques and costs of three different transport systems are put forward: transport of energy by high-voltage direct-current transmission (HVDC transmission), via hydrogen in gas pipelines and a combination of the two systems. It emerges from this that the combined transport system has clear advantages over pure HVDC transmission and H2 transport.

[1993] 1F-7

DEVELOPMENT OF THE NETWORK TO SATISFY EXCHANGES (INTERNATIONAL POWER SYSTEM INTERCONNECTION)

Meslier, F.

Bulletin Scientifique de l'Association des Ingenieurs Electriciens sortis de l'Institut Electrotechnique Montefiore

vol.106, no.2 p.3-9 1993 , Belgium, in French.

Three different scenarios are constructed on hypotheses concerning trends in behaviour of interconnection network operators, in the balance between regions producing and consuming electric power, and in homogenisation of performance and practice among different electrical systems. The foreseeable consequences are compared and the dilemma posed by increasing interconnection needs together with decreasing acceptability of visible structures is highlighted. Arguments in favour of 800 kV and HVDC links and use of power electronics to improve real-time distribution are summarised. The financial effects of less than 1% variation in Western European exchange rates are shown. Methods of decision at organisational and economic planning levels are suggested and recommendations deduced for better regional balance, 400 kV AC international linkage and improved cooperation.

[1992] 1F-8

EFFECT OF A MODULATED HVDC LINK ON POWER SYSTEM TRANSIENTS.

Teshome, Asrat

Electric Power Systems Research

v 25 n 2 Nov 1992 p 101-109

This paper presents the details of a digital computer study of the effects of transient interactions, during large system disturbances, between an AC system and an associated high voltage DC transmission line with the rapid change in power transfer capability (modulated HVDC). The combined system consists of a large turboalternator synchronized to an infinite bus through two long-distance high voltage AC lines in parallel with an equally long controlled HVDC link. In the analysis, a rigorous nonlinear mathematical model, based on Park's equations, is formed by transforming the machine variables and the AC and DC transmission line parameters to a rotating reference frame attached to the alternator rotor, thereby providing the detailed transient behavior of the interconnected AC/DC system. Results of the studies demonstrate that a modulated HVDC link can provide significant increases in the loadability of AC lines by reducing or eliminating the constraints imposed by transient stability limitations. It appears, however, that, for certain systems, adverse stability behavior may result if the modulation setting exceeds 50%. Possible effects of HVDC modulation on the incidence of turboalternator torsional interactions are also considered. These interactions, however, are dependent upon parameters such as AC transmission, configuration, and the control mode characteristics of the HVDC terminals.

[1993] 1F-9

FEASIBLE EIGENVALUE SENSITIVITY FOR LARGE POWER SYSTEMS

Smed, T.

IEEE Transactions on Power Systems

May 1993 p 555-563

Traditional eigenvalue sensitivity for power systems requires the formulation of the system matrix, which lacks sparsity. In this paper, a new sensitivity analysis, derived for a sparse formulation, is presented. Variables that are computed as intermediate results in established eigen value programs for power systems, but not used further, are given a new interpretation. The effect of virtually any control action can be assessed based on a single eigenvalue-eigenvector calculation. In particular, the effect of active and reactive power modulation can be found as a multiplication of two or three complex numbers. The method is illustrated in an example for a large power

system when applied to the control design for an HVDC-link.

[1991] 1F-10

GEOTHERMAL ELECTRIC POWER GENERATION IN ICELAND FOR THE PROPOSED ICELAND/UNITED KINGDOM HVDC POWER LINK

Hammons, T.J.; Palmason, G.; Thorhallsson, S.

IEEE Transactions on Energy Conversion

Jun 1991 p 289-296

The paper reviews geothermal electric power potential in Iceland which could economically be developed to supplement hydro power for the proposed HVDC Power Link to the United Kingdom, and power intensive industries in Iceland, which are envisaged for development at this time. Technically harnessable energy for electricity generation taking account of geothermal resources down to an assumed base depth, temperature distribution in the crust, probable geothermal recovery factor, and accessibility of the field, has been assessed. Nineteen known high-temperature fields and 9 probable fields have been identified. Technically harnessable geo-heat for various areas is indicated. Data on high temperature fields suitable for geothermal electric power generation, and on harnessable energy for electric power generation within volcanic zones, is stated, and overall assessments are made. The paper then reviews how the potential might be developed, discussing preference of possible sites, and cost of the developments at todays prices. Cost of geothermal electric power generation with comparative costs for hydro generation are given. Possible transmission system developments to feed the power to the proposed HVDC Link converter stations are also discussed.

[1991] 1F-11

NEW SYNCHRONOUS COMPENSATORS FOR THE NELSON RIVER HVDC SYSTEM--PLANNING REQUIREMENTS AND SPECIFICATION.

Thio, C. V.; Davies, J. B.

IEEE Transactions on Power Delivery

v 6 n 2 Apr 1991 p 922-928

For the first units of the Limestone Generating Station on the Lower Nelson River in northern Manitoba, scheduled to come into service in the fall of 1990, additional VAR compensation equipment is required at the inverter end of the Nelson River HVDC system to accommodate power from Limestone. The authors describe the system requirements of and the overall specification for the synchronous compensators selected to supply the reactive power and voltage support. The purpose of the synchronous compensators is to optimize power delivery by the DC links. Proper specification of parameters for synchronous compensators applied at the terminal of a DC link ensures that the compensators will provide support to the operation of the DC system.

[1992] 1F-12

PROPOSAL FOR A COMMERCIAL INTERCONNECTION AMONG THE HAWAIIAN ISLANDS BASED ON THE RESULTS OF THE HAWAII DEEP WATER CABLE PROGRAM

Arnaud, U.; Bazzi, G.; Valenza, D.

IEEE Transactions on Power Delivery

Oct 1992 p 1661-1666

After the successful completion of the development program of the 2000 m water depth HVDC Hawaii Deep Water Self Contained Fluid Filled Cable, the interconnection between Hawaii island and Oahu island is examined. Thermal, electrical, mechanical, hydraulic, corrosion, length aspects are developed for both fluid filled and paper impregnated (SOLID) cables which are foreseen in different portions of the approximately 250 km length connection. Considerations are also presented for the requirements of the cable ship: 12 m sheave diameter, 7000 t capacity for the rotating platform. The feasibility of manufacturing, transporting and laying such cables within a practical schedule is discussed in this paper.

[1993] 1F-13

PROPOSED ICELAND/UNITED KINGDOM POWER LINK-AN INDEPTH ANALYSIS OF ISSUES AND RETURNS

Hammons, T.J.; Olsen, A.; Kacejko, P.; Leung, C.L. Glasgow Univ., UK

IEEE Transactions on Energy Conversion

vol.8, no.3 Nov 1993 p. 566-75

This paper examines issues and makes an indepth engineering analysis of the profit which would be expected from electricity from Iceland using possible scenarios considering variables which could impact on the viability of the link. Considered is fluctuation of pool purchase price over half-hour periods of a complete year, discount rates, nonfossil fuel premiums, possible price movements in future years, and carbon taxes which it is expected could be imposed by the time the link is operational, as well as capital which is tied up during construction periods, availability of plant, and transmission losses etc. It is concluded that the link is viable for all but the very worst scenarios, but if development costs could be reduced by 10% or more the link would be more attractive to developers and investors on account of uncertainty and risk involved, unless EC and governmental guarantees are

forthcoming. These conclusions are in agreement with an independent assessment which has recently been made by an International Energy Consulting Group. (8 Refs)

[1992] 1F-14

REVIEW OF THE DESIGN AND PERFORMANCE FEATURES OF HVDC SYSTEMS CONNECTED TO LOW SHORT CIRCUIT RATIO AC SYSTEMS

Thallam, R.S. (Salt River Project, Phoenix, AZ (United States))

IEEE Transactions on Power Delivery
Oct 1992 p 2065-2073

The design and performance of an HVDC system is significantly impacted by the relative strength of the AC system to which it is connected. In this paper, design and performance features of ten HVDC systems are discussed. All of these systems are connected to AC systems that are relatively weak compared to the rating of the DC system. Six of these systems are back-to-back, two are overhead lines, and two are undersea cable connections. AC and DC system interaction problems and how they are addressed in the design and specification of each of these systems, are described.

[1991] 1F-15

SPECIFICS OF THE FUNCTIONAL PROPERTIES OF THE UNITED POWER GRID OF THE USSR

Volkov, Eh.P.; Barinov, V.A.; Manevich, A.S.

Elektrichestvo
n 9 Sep 1991. p 7-12 In Russian

The authors present the analytical results for the aperiodic static stability of the network of the eastern are in the United power grid (UPG) for the 1150kV electric transmission like Siberia-Kazakhstan-Ural and formulater suggestions concerning conceptions of further development. The substitution circuit being studied contains 221 modal points, 320 paths and 67 generators. To develop the system-like united power grid of the highest voltage classes, the paramount aim is to put into operation of all 1150kV sections of the transmission line at Cheljabinsk and to select the version to complete 2nd construction of the 1500 kV DC transmission line.

[1991] 1F-16

STUDY OF A +/- 500 KV, 2400 MW COMPACT CONVERTER STATION.

Lebow, M. A.; Mauro, R.; Fletcher, D. E.; Harrison, R. E.; Gordon, D. L.
Consolidated Edison Co of New York Inc, NY, USA

Fifth International Conference on AC and DC Power Transmission
1991, Sep. 19-20

Consolidated Edison has been involved in a number of research projects aimed at the development and demonstration of HVDC equipment for use in urban environments. The must notable of these projects has been the installation, in conjunction with EPRI, of a compact HVDC station in Astoria, New York. For the purpose of this study, the converter station was assumed located on a 61 m (200. ft) by 122 m (400 ft) site in downtown Manhattan. This area is approximately 5% of the area that would be required by a conventional HVDC station of this capacity. Both the AC and DC connections to the station are made by cable. The AC side of the converter would be connected to the 345 kV AC network. Existing 45 kV cables plus additional new 345 kV cable circuits would be looped into the converter station. The power to the DC side of the converter station was assumed to be supplied via an overhead transmission line and then by 64-km (40 miles) of underground or submarine cable, laid in a river waterway, to the converter station.

[1991] 1F-17

THE AMAZON TRANSMISSION TECHNOLOGICAL CHALLENGE

Praca, J.C.; Salomao, J.C.; Drummond, M.; Guimaraes, E.B.; Ribeiro, D.R.; Pimentel, G.

AC and DC power transmission (Power transmission in Brazil.) IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 79-84

The Brazilian Power System consists of two interconnected systems, Southeast/West-Central/South and North/Northeast. As power resources near the country's major load centres become exhausted, the transmission system will enlarge its interconnection as part of the long range expansion strategy. The energy resources to be exploited in the near future are located in the Northern region (Amazon basin), where there is great hydroelectric potential. Major power markets on the other hand are expected to be in the Southern sector of the Southeastern region and at the coastal side of the Northeastern region. The distances between these Amazon hydro power plants and the main load centres range from 2000 to 2800 km. Therefore a great challenge will have to be faced in the future, namely

the transmission of large amounts of energy from very remote sources. Studies of possible transmission technologies have been carried out and are reported here.

[1991] 1F-18

THE CHARACTERISTICS OF FUNCTIONAL PROPERTIES OF THE UNITED POWER GRID OF THE USSR

Volkov, E.P.; Barinov, V.A.; Manevich, A.S.

Elektrichestvo

no.9 p.7-12 Sept. 1991

Results are reported of analysing the steady-state conditions and the aperiodic static stability, the modal structure and the transients in the united power grid circuits, for different stages of the development of the 1150 kV Siberia-Kazakhstan-Ural transmission network. The factors influencing the functional properties of the united power grid are investigated, and proposals are formulated for a further development of the united power grid. The investigations show that certain features of the functional properties of the united power grid impose considerable constraints on the transport of the electrical energy; these should be considered when choosing the most suitable approach to the development of transmission liner for 1150 kV AC and 1500 kV DC, and, the development of railroad and gas-main transport for power industry. (7 Refs)

[1991] 1F-19

THE HAWAII GEOTHERMAL/INTERISLAND TRANSMISSION PROJECT

Fesmire, V.R.; Richardson, J.F. Jr.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 85-89

In May 1989, the Hawaiian Electric Company, the electric utility serving Honolulu and the island of Oahu, issued a Request for Proposal for the purchase of electricity produced from geothermal resources on the island of Hawaii and transmitted by a combination of overhead lines and submarine cables to Oahu. This paper describes the project, with attention given to the AC and DC transmission portion. A brief summary of the proposal process and evaluation results is also provided.

[1991] 1F-20

THE SYSTEM STUDY FOR GEZHOUBA-SHANGHAI HVDC PROJECT

Zeng Nanchao; Tao Yu

Power System Technology

no.3 p.65-9 Aug. 1991 China In Chinese

The Gezhouba-Shanghai HVDC transmission project is the first bulk power and long distance HVDC project in China. It was put into operation in August 1990. In the preliminary study of this project, the commissioning tests as well as its technical service in commercial operation, considerable work have been carried out by the power system department of EPRI and the Chinese Ministry of Energy. The authors describe briefly some aspects of this scheme and introduce the research capability into HVDC projects, which has been accumulated from this work. (5 Refs)

[1992] 1F-21

TRANSIENT STABILITY STUDIES OF AC/DC HYBRID POWER SYSTEM BASED ON REAL CONTROL SYSTEMS

Zhou Xiaoxin; Li Hanxiang; Zheng Fangneng

Power System Technology

no.2 p.28-33 May 1992 China In Chinese

The mathematical models of an HVDC transmission system and its control system are introduced in detail. As well as the simulation of a DC line fault and the restarting process, the simulations of the voltage dependent current limit (VDCL) and the restarting process after commutation failure caused by an AC system fault are made. These models are checked with the GESHA HVDC project, the results of simulation are compared with those of commissioning tests. The comparison results show that the models presented are correct. (4 Refs)

[1991] 1F-REF

REVIEW OF THE DESIGN OF THE JAMES BAY-BOSTON DC SYSTEM

Peixoto, C.A.O.

AC and DC power transmission IEE Conference Publication Series 5. International conference on AC and DC power transmission

17-20 Sep 1991

For Abstract see entry 1B-020.

[1991] 1F-REF

SELECTION OF DESIGN PARAMETERS OF EQUIPMENT FOR 800 KV TRANSMISSION SYSTEMS IN INDIA
Swarup, S.K.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 235-240 India
For Abstract see entry 1B-021.

[1993] 1F-REF

A 550 MW HVDC SUBMARINE CABLE LINK: ICELAND-UK-CONTINENTAL EUROPE
Guonason, E.; Henje, J.; Shepherd, P.; Valenza, D.
Third International Conference on Power Cables and Accessories 10kV - 500kV (Conf. Publ. No.382)
p.220-4, 1993
For Abstract see entry 4A-002.

[1992] 1F-REF

DAMPING STRUCTURE AND SENSITIVITY IN THE NORDEL POWER SYSTEM
Eliasson, B.E.; Hill, D.J.
IEEE Transactions on Power Systems:
Feb 1992 p 97-105
For Abstract see entry 5A-011.

[1993] 1F-REF

CONTROLS MODELLING AND VERIFICATION FOR THE PACIFIC INTERTIE HVDC 4-TERMINAL SCHEME
Hammad, A.; Minghetti, R.; Hasler, J.; Eicher, P.; Bunch, R.; Goldsworthy, D.
IEEE Transactions on Power Delivery
Jan 1993 p 367-375
For Abstract see entry 6B-010.

[1991] 1F-REF

A NEW APPROACH TO AC/DC POWER FLOW
Smed, T.; Andersson, G.; Sheble' G.B.; Grigsby L.L.
Transactions on Power Systems
Vol. 6, No. 3, August 1991, pp. 1238-1244
For Abstract see entry 6C-001.

[1992] 1F-REF

A HVDC SUBMARINE LINK FROM ICELAND TO GREAT BRITAIN
Bergmundsson, J.; Olsen, A. Afl Engineering Ltd., Reykjavik, Iceland
Power Technology International
p.125-7 1992
For Abstract see entry 7A-001.

[1992] 1F-REF

CHEJU ISLAND GETS A 300 MW HVDC BOOST
Kim, S.I.; Andersen, B.R.; Burgess, R.P.; Baker, M.H.
Modern Power Systems
1992 p 29, 31, 33
For Abstract see entry 7A-004.

2. CONVERTER STATIONS AND COMPONENTS

2A. CONVERTER ASSEMBLIES AND THEORIES

[1991] 2A-1

24-PULSE HVDC CONVERSION.
Arrillaga, J.; Villablanca, M.
IEE Proceedings, Part C: Generation, Transmission and Distribution
v 138 n 1 Jan 1991 p 57-64
A technique known as DC ripple reinjection, which has already been shown capable of operating a six-pulse rectifier effectively as a twelve-pulse convertor, is extended in the paper to convert the standard twelve-pulse HVDC convertor group into a 24-pulse configuration. Theoretical and experimental results are provided to demonstrate that the modified convertor configuration eliminates the 12-pulse related harmonics on both sides of the convertor.

[1991] 2A-2

A MODIFIED PARALLEL HVDC CONVERTOR FOR 24 PULSE OPERATION
Arrillaga, J.; Villablanca, M.
IEEE Transactions on Power Delivery
Jan 1991 p 231-237
A new concept of convertor design is proposed suitable for large current ratings, such as used in back-to-back HVDC interconnections. It consists of a parallel 12-pulse configuration involving two phase shifted bridges and a thyristor-tapped interphase reactor. The dc. ripple present across the interphase reactor is used to derive a current waveform which, when added to the original phase currents, effectively doubles the converters pulse number. It is shown theoretically and experimentally that the use of dc.-ripple reinjection achieves 24-pulse operations from a conventional 12-pulse HVDC converter configuration.

[1992] 2A-3

A TREND OF CONVERSION TECHNOLOGY IN HVDC AND SVC
Sampei, M.; Ishikawa, M.
Transactions of the Institute of Electrical Engineers of Japan, Part B
vol.112-B, no.1 p.2-5 Jan. 1992 (In Japanese)
HVDC (DC power transmission) has been widely applied to long-range overhead wires and submarine cables making use of its asynchronous interlocking function in various countries of South America, China and India as well as the United States and European countries. The SVC (static VAR compensator) with its high-speed and smooth reactive power control function has been used for maintenance of voltage and stability of AC systems and overvoltage regulation for HVDC or the site where reactive power is relatively easy to fluctuate. The authors describe the use of a semiconductor converter for the major equipment requiring high-voltage power conversion, which is an important example of power electronics applications in the field of the utility industry, and the trend of conversion technology in HVDC and SVC. (5 Refs)

[1991] 2A-4

ANALYSIS OF LOSSES IN A CURRENT SOURCE GTO [GATE-TURN-OFF] INVERTER FOR DC TRANSMISSION
Sun, Y.; Menzies, R.W.
Transactions of the Engineering and Operating Division of the Canadian Electrical Association
1991 p 1-10, Paper 91-SP-145
The development of gate-turn-off thyristors has lead to self-commutated machine drives and small static compensators, and renewed interest in self-commutation for high voltage DC (HVDC) power transmission. The use of a self-commutated current-source inverter for supplying a remote load with no AC system support is described. The pulse width modulation (PWM) techniques are studied with particular emphasis placed on control of harmonics and losses in GTO thyristor valves and filters. A novel switching technique is presented which reduces the magnitude of harmonics while retaining low switching losses in the inverter. Details are presented of the operation of a current source GTO thyristor inverter supplying a passive load, and procedures for calculating power losses. In normal operation the total DC link current commutates from the valve of one phase to the valve of the next almost instantaneously, with firing and blocking of valves taking place simultaneously. In the new switching arrangement, the firing of the incoming valve takes place first and then the blocking of the outgoing valve follows. Between the firing and blocking instants there are three valves conducting, and the current is shared by two phases before blocking occurs.

[1992] 2A-5

APPLICATION OF FORCED-COMMUTATION CONVERTER FOR HVDC TRANSMISSION SYSTEM. COMPARISON OF CURRENT-SOURCE TYPE AND VOLTAGE-SOURCE TYPE CONVERTER

Kimura, N.; Kishimoto, M.; Iida, T.; Matsu-ura, K.

Transactions of the Institute of Electrical Engineers of Japan

20 Jan 1992 p 10-18. In Japanese.

This report describes a study on the dynamic behavior of the HVDC system using a forced-communication converter in the case of fault in the AC system. The model HVDC system was supposed to be unidirectional transmission into a load system without any AC voltage source. A computer program was developed for the transient response analysis, and the dynamic behavior was simulated by changing various parameters. As a result of the simulation on the dynamic behavior for load changes in the receiving system, a voltage-source converter was revealed to be excellent without much voltage fluctuation. Such cases as faults of 1 line-to-ground(1LG), 2 line-short-circuit(2LS), and 3 line-to-ground(3LG) in the AC system of the receiving side were simulated. The result showed that it is necessary to turn off the voltage-source converter quickly to protect the switching devices, while the current-source converter has no severe problem. Overcurrent and overvoltage for the voltage-source converter were also presented.

[1993] 2A-6

APPLICATION OF HIGH-FREQUENCY SWITCHING DEVICES TO POWER FACILITIES

Nakajima, T. (Tokyo Electric Power Inc., Tokyo (Japan))

Transactions of the Institute of Electrical Engineers of Japan

20 Jun 1993

So as to expand the application of the self exciting converter including the DC transmission facility and the frequency converting facility from now on, it is required for solving the technological subjects such as the further higher voltage, larger capacity, higher reliability, more multiple function and so forth. For this purpose, the technological development from both sides, namely the converter itself and the self arc extinguishing element used for the converter, is required. Since making the element to be the higher frequency is especially important, for improving the operation performance by making the pulse width modulation(PWM) control in the converter to be the multiple pulses, and for realizing the multifunction property of the active filter and so forth, however, the self extinguishing element, which is high pressure resistant, can accept the strong current and can perform the high frequency switching, is strongly desired. In this paper, the present status of the self extinguishing element applied for the power system converting facilities is introduced, and furthermore the elements, which are expected to be a larger capacity and higher frequency, are considered. In addition, the examples predicting the effect obtained, when the high frequency switching elements are used, are described.

[1991] 2A-7

BOOST TYPE PWM HVDC TRANSMISSION SYSTEM

Ooi, B.T.; Wang, X.

IEEE Transactions on Power Delivery

Oct 1991 p 1557-1563

This paper reports that conventional HVDC is built around the mercury arc rectifier or the thyristor which requires line commutation. The advances of fast, high power GTO's and future devices such as MCT's with turn off capabilities, are bringing PWM techniques within the range of HVDC applications. By combining PWM techniques to the boost type bridge topology, one has an alternate system of HVDC Transmission. On the AC side, the converter station has active controls over: the voltage amplitude, the voltage angle and the frequency. On the DC side, parallel connections facilitate multi-terminal load sharing by simple local controls so that redundant communication channels are not required. Bidirectional power through each station is accomplished by the reversal of the direction of DC current flow. These claims have been substantiated by experimental results from laboratory size multi-terminal models.

[1992] 2A-8

CHARACTERISTICS OF UNIT-CONNECTED HVDC GENERATOR-CONVERTORS OPERATING AT VARIABLE SPEEDS

Arrillaga, J.; Sankar, S.; Arnold, C.P.; Watson, N.R.

IEE Proceedings, Part C: Generation, Transmission and Distribution

May 1992 p 295-299

A state-variable dynamic simulation algorithm and the fast Fourier transform are combined to analyse the operating characteristics and highlight the harmonic problems of variation-speed unit-connected generator-convertor systems. With reference to a typical hydroelectric test system, it is shown that it is possible to operate the turbogenerator units within a wide range of frequencies, at high efficiencies and with good voltage controllability.

[1991] 2A-9

DC POWER TRANSMISSION SYSTEM
Inokuchi, Haruhisa.
Patent No.CA 1279096 A
1991
An object of this invention is to provide a DC power transmission system which can operate in a stable manner while controlling the reactive power required by the converter and the interchange power between the two AC systems. To achieve this object, according to one aspect of the invention, a current type self-commutated converter capable of pulse width modulation (PWM) controlling is used as the converter operating as an inverter, wherein the reactive power for the converter is regulated by controlling the voltage and current at its AC system, the DC voltage is regulated by the PWM controlling the converter, and the DC current is regulated by controlling the other converter operating as a rectifier.

[1991] 2A-10

DYNAMIC CONVERTER CHARACTERISTIC CURVES AND CAPACITOR BANK SWITCHING STRATEGY
Lee, B.
IASTED International Conference. High Technology in the Power Industry. Power High Tech '91
p.422-6 4-7 March 1991 Tainan, Taiwan In English
A well-known technical merit of HVDC system is its inherent ability to regulate various 'system variables' via rapid firing angle control. The firing angle controller generates firing pulses according to some desirable control objectives. The effective impedance of the AC network constitutes a major component for interaction between AC and DC systems in that control of one variable invariably leads to changes in others thereby, degrading the overall performance. The knowledge of the dynamic voltage/current characteristics of the converters is therefore of importance in understanding the effectiveness of the converter control action as well as in contriving an acceptable switching strategy of the filter/capacitor banks. The author presents a family of static and dynamic converter characteristic curves based on the quasi-steady-state formulations. These curves allow for a better understanding of the basic converter 'behaviors'. Impacts of converter control primitives on shunt capacitor switching strategies are also discussed. (6 Refs)

[1993] 2A-11

FAST TRANSIENT VOLTAGE DISTRIBUTION IN HVDC CONVERTER VALVES
Rajasekharaiah, S.; Chandrasekharaiah, H.S.
International Journal of Energy Systems
vol.13, no.3 p. 69-72 1993
The study of transient voltage distribution in high voltage converter valves is of great importance as it determines the maximum voltage stresses experienced by the power converter modules and thyristor elements. A knowledge of this is essential for the optimum design of insulation and determination of protection level of HVDC converters. The voltage distribution is determined in an integrated network consisting of power transformer, valves and reactor in the converter terminal. The effect of conducting and blocked modes of different valves in the power converter bridge and incidence of the fast front surge at different points of the integrated network are also considered. (13 Refs)

[1993] 2A-12

FORCE COMMUTATED HVDC AND SVC BASED ON PHASE-SHIFTED MULTI-CONVERTER MODULES
Zhongchao Zhang; Jinbo Kuang; Xiao Wang; Boon Teck Ooi
IEEE Transactions on Power Delivery
Apr 1993 p 712-718
This paper examines how the presently available gate-turn-off thyristors (GTOs), which are still relatively slow, may be used in force-commutated HVDC and SVC converters by employing multi-converter modules in conjunction with a phase-shifting principle which cancels the undesirable switching harmonics. It points to the advantages of incorporating the well-known Sinusoidal Pulse Width Modulation (SPWM) technique because it enables feedback control, active filtering and regulatory functions to be performed by the converters. This is because a reasonable bandwidth of the modulating signal is transmitted by the multi-converter station in spite of the low switching rates of the GTO valves.

[1992] 2A-13

HARMONIC REDUCTION IN GROUP-CONNECTED GENERATORS HVDC CONVERTOR

Arrillaga, J.; Yonghe, L.; Crimp, C.S.; Villablanca, M.

ICHPS V International Conference on Harmonics in Power Systems

p.202-7 23-25 Sept. 1992

A technique based on the reinjection of the DC ripple, already proposed for standard HVDC power convertor plant to increase the pulse number, is applied to the group connection of generators and HVDC convertors. Theoretical and experimental waveforms are used to demonstrate the considerable harmonic reductions achieved by the modified configuration. The harmonic problems related to variable speed operation are highlighted as well as their prospective elimination with the use of the reinjection scheme. (4 Refs)

[1991] 2A-14

MULTICELL HIGH-VOLTAGE RESONANCE CONVERTER OF DC VOLTAGE

Kurchik, B.Z.; Pokryvailo, A.D.; Shvarts, A.N.

Elektrotekhnika

vol.62, no.1 p.34-9 1991 USSR Translated in: Soviet Electrical Engineering vol.62, no.1 p.61-70 1991 USA

To obtain the required power high-voltage transistor DC voltage converters are made in multicell versions consisting of several cells connected in parallel relative to the input and in series relative to the output. In so doing the output voltage and input current of each cell are reduced, which permits a reduction in the number of semiconductor elements connected in parallel or series. In order to increase reliability one or several redundant cells are incorporated. In this case all the cells, including the backup ones, function in the normal mode with underload or the backup cell is only connected after a main cell fails. (6 Refs)

[1991] 2A-15

NEW CONCEPT IN HVDC GENERATION.

Arrillaga, J.; Villablanca, M.; Camacho, J. R.

Transactions of the Institution of Professional Engineers New Zealand

Section v 18 n 1 Nov 1991 p 15-20

An alternative unit-connected generator convertor scheme is proposed. It is based on the use of DC ripple re-injection, which permits using a single bridge, instead of two bridges, as a twelve-pulse convertor. The scheme reduces considerably the number of transformers and convertor bridges, without increasing the harmonic levels with respect to the double bridge configuration. In addition, the scheme eliminates the two stumbling blocks of DC generators which are the need for a complex rotating commutator and its inability to produce high voltages. The theory of the scheme is verified by extensive experimentation.

[1991] 2A-16

NEW DIGITAL CONTROL OF FORCED COMMUTATION HVDC CONVERTER SUPPLYING INTO LOAD SYSTEM WITHOUT AC SOURCE

Kimura, N.; Kishimoto, M.; Matsui, K.

IEEE Transactions on Power Systems

Nov 1991 p 1425-1431

This paper describes new digital control technique for forced commutation converter applied to HVDC transmission systems with loads which have no AC source. The proposed technique used direct calculation of the firing angle of inverters. This requires the time constant of the DC transmission line in the calculation, but need not tune the gain or time constant as in conventional proportional-integration control. The results of simulator experiments and computer simulations show good performance for the regulation of the AC voltage of a load system without an AC source.

[1992] 2A-17

NEW N-LEVEL HIGH VOLTAGE INVERSION SYSTEM

Kim, Young-Seok; Seo, Beom-Seok; Hyun, Dong-Seok

Proceedings of the 19th International Conference on Industrial Electronics, Control and Instrumentation IEEE Industrial Electronics Society (IES); Society of Instrument and Control Engineers of Japan

1992

This paper deals with a new multi-level high voltage source inverter with GTO Thyristors. Recently, a multilevel approach seems to be best suited for implementing high voltage conversion system because it leads to harmonic reduction and deals with safely high power conversion system independent of the dynamic switching characteristics of each power semiconductor device. However, a conventional multilevel inverter has some problems; voltage unbalance between DC-link capacitors and overvoltages across the inner switching devices. Therefore, we propose a novel structure of a multilevel inverter improving these problems.

[1992] 2A-18

NEW TECHNOLOGIES APPLIED TO THE RECENT HVDC CONVERTOR STATIONS IN JAPAN

Senda, T.; Horiuchi, S.; Namera, T.; Muraoka, Y.; Horiuchi, T.; Oonishi, K.

CIGRE Proceedings of the 34th Session

p.14-102/1-7 vol.1 30 Aug.-5 Sept. 1992

The extensions of the Shin-Shinano Frequency Convertor Station and the Hokkaido-Honshu HVDC Link are briefly introduced and the new technologies employed are described. Although the HVDC transmission systems in Japan are still limited to relatively small interconnections between power systems, the new technologies introduced constitute a basis that will lead to large-scale HVDC built power transmission systems in the future. (6 Refs)

[1992] 2A-19

NOVEL CONTROL STRATEGIES OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER

Tokiwa, Y.; Ichikawa, F.; Suzuki, K.; Inokuchi, H.; Hirose, S.; Kimura, K.

Denki Transactions of the Institute of Electrical Engineers of Japan:

20 Jan 1992 p 19-26. In Japanese.

This report describes new control strategies of a self - commutated converter applied to the HVDC systems; that is, the cooperative control for a two-terminal transmission system and the terminal control which is applicable to a multi-terminal system. The DC voltage control with an upper and lower power-limiter showed excellent characteristics when applied to the two-terminal transmission system. A voltage margin method was also introduced as a power flow reversal method. These terminal control methods, if required, are able to change interchange power at the receiving end in the case of fault in the communication system. Moreover, the DC voltage control with two-stage voltage control characteristics was proposed for the multi-terminal HVDC system. with this mehtod, the DC transmission system can be operated continuously and stably cooperating electric power at each terminal even when one terminal is collapsed. The terminal control performance in the above two-terminal HVDC system was tested with a simulator. The result showed favorable performance characteristics at the time of power flow reversal and one terminal start-up during other terminal operation. 5 refs., 16 figs.

[1993] 2A-20

OPERATING CHARACTERISTICS OF UNIT AND GROUP CONNECTED GENERATOR-HVDC CONVERTER SCHEMES

Arrillaga, J.; Camacho, J.R.; MacDonald, S.J.; Arnold, C.P.

IEE Proceedings, Part C: Generation, Transmission and Distribution v 140 n

6 Nov 1993. p 503-508

The two alternatives for the direct connection of generators to HVDC converters, i.e. the unit and group connections, are compared under varying steady-state operating conditions at nominal operating frequency. Direct connection is defined as the connection of synchronous generators and converters without AC filters and with the transformer having simultaneously the function of converter and step-up transformer. With all the units in service both schemes display the same characteristics. By reducing the number of generators in service the group connection becomes more efficient at lower power levels. The opposite effect occurs with the unit connection where the efficiency reduces with the power levels, particularly with fewer generators in service. Moreover, in the last-mentioned case the inverter end of the link requires extra reactive power compensation. Therefore for schemes operating at varying power levels and fixed frequency the group connection should be the preferred alternative. (Author abstract) 8 Refs.

[1991] 2A-21

OPERATIONAL CAPABILITY OF GENERATOR-HVDC CONVERTOR UNITS.

Arrillaga, Jos; Sankar, S.; Watson, Neville R.; Arnold, Chris P.

IEEE Transactions on Power Delivery

v 6 n 3 Jul 1991 p 1171-1176

The authors demonstrated the limitations of the formulation based on the concepts of commutating voltage and commutating reactance when applied to unit connected generators-HVDC convertors. In general each individual application requires extensive dynamic analysis to determine the harmonic ratings and the external characteristics of the unit connection scheme in periodical steady state. Such information is derived for a typical test case with the aid of a state variable solution. The results show, as expected, a reduction in harmonic current levels caused by the increased commutation overlaps. However, the generator harmonic voltages in the presence of rotor saliency are considerably higher. While the unit connection can be designed to provide any specified nominal power, the absence of filters limits the operation capability at larger current levels and thus reduces the ability of the HVDC link to provide

temporary power increases. It is pointed out that this reduction in operational capability imposes transient stability restrictions that must be taken into account in economic comparisons between the unit connection and its conventional alternative.

[1993] 2A-22

OPTIMAL FIRING-ANGLE CONTROL OF CASCADED HVDC CONVERTERS FOR MINIMUM HARMONIC CURRENTS
Deib, D.A.; Hill, H.W.; Shepherd, W.
IECON Proceedings (Industrial Electronics Conference) v 2
1993. p 1071-1076
An optimal firing strategy for N cascaded, 6-pulse, phase-controlled converters of a HVDC link is proposed. Minimization of the harmonic currents injected into the AC system (by both the inverters and rectifiers) is achieved through simultaneous control of the firing angles of the N converters. With relatively low values of N (4 12-pulse, or 8 6-pulse), the resultant ac-current harmonics are substantially lower than for comparable 12- or 6-pulse converters. Also, the dc-voltage harmonics are greatly reduced over 12-pulse operation.

[1991] 2A-23

RESEARCH IN FORCE-COMMUTATED CONVERTERS FOR HVDC [HIGH VOLTAGE DIRECT CURRENT] AND STATIC VAR [VOLT-AMPERE REACTIVE] COMPENSATORS
Ooi, B.T.; Galiana, F.; Lee, H.C.; Ziogas, P.; Joos, G.
Transactions of the Engineering and Operating Division of the Canadian Electrical Association
1991 p 1-18, Paper 91-SP-144
A summary is presented of university research on force-commutated converters for high voltage DC (HVDC) and static volt-ampere reactive (VAR) compensators. This research has been pursued in the historical context that gate-turn-off thyristors (GTO), static induction thyristors, etc. are becoming available at high voltage and high current ratings with fast turn-on and turn-off times. Devices and issues addressed include pulse-width modulation (PWM) bridge converters, series-type PWM-static VAR compensators, high power at high frequency, high frequency filter loss, voltage regulators, and switching loss including snubber loss. The research uncovered important advantages in forced-commutated converters which can form the basis of a family of products including shunt-static VAR compensators (SVC), series SVC and HVDC products. It is disputed that PWM techniques increase losses by an order of magnitude, as some research has claimed.

[1991] 2A-24

RESEARCH IN PULSE WIDTH MODULATED HVDC TRANSMISSION
Ooi, B.T.; Galiana, F.D.; Lee, H.C.; Wang, X.; Guo, Y.; McGillis, D.; Dixon, J.W.; Nakra, H.L.; Belanger, J.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 188-193
The advances in high power, high frequency, solid-state switches with gate "turn-off" capability (GTOs) are reaching a level when the initiation of research and development in the pulse width modulation (PWM) generation of HVDC is justified. The paper presents results based on a 1kVA experimental PWM converter and digital simulations, which show that: (1) the PWM HVDC system is technically realizable, (2) the MVA ratings can be raised for bulk power transmission, and (3) the performance improvement is sufficiently significant as to justify further investments in Research and Development.

[1993] 2A-25

SINGLE-BRIDGE UNIT-CONNECTED HVDC GENERATION WITH INCREASED PULSE NUMBER
Villablanca, M.; Arrillaga, J.
IEEE Transactions on Power Delivery
Apr 1993 p 681-688
A true unit-connected generator-HVDC convertor scheme is proposed which removes the need to use two bridges in series to achieve twelve-pulse operation. Moreover, the combination of a single main bridge and an auxiliary feedback DC ripple reinjection bridge is shown to increase the pulse number from 6 to 18. This is achieved purely by natural commutation and is equally valid for rectification and inversion. The theoretical waveforms are validated by extensive experimental verification.

[1993] 2A-26

USING A THREE-LEVEL GTO VOLTAGE SOURCE INVERTER IN A HVDC TRANSMISSION SYSTEM
Lipphardt, G.
Power Electronics in Generation and Transmission, IEE Conference Publication
v 8 n 377 1993. p 151-155
Some aspects of the feasibility of three-level voltage source GTO inverters in HVDC applications are discussed. After presenting the converter topology a simplified point-to-point transmission with a conventional thyristor rectifier station and a three-

level voltage source GTO inverter station is simulated using EMTP (ElectroMagnetic Transient Program). The static behaviour and some aspects of the dynamic behaviour of the transmission are shown. Problems and open questions to be solved in future are mentioned. The results show that the three-level voltage source inverter is a possible alternative for future use of forced commutated inverters in HVDC systems.

[1991] 2A-REF

STUDY OF A +/- 500 KV, 2400 MW COMPACT CONVERTER STATION.
Lebow, M. A.; Mauro, R.; Fletcher, D. E.; Harrison, R. E.; Gordon, D. L.
Consolidated Edison Co of New York Inc, NY, USA
Fifth International Conference on AC and DC Power Transmission
1991, Sep. 19-20
For Abstract see entry 1F-016.

[1992] 2A-REF

HIGH PULSE HVDC TRANSMISSION
Villablanca, M.; Arrillaga, J. Canterbury Univ., Christchurch, New Zealand
CIGRE Proceedings of the 34th Session
p.14-101/1-8 vol.1 1992
For Abstract see entry 2C-014.

[1991] 2A-REF

PHASE ANGLE CONTROL OF VOLTAGE SOURCE CONVERTER IN HIGH POWER APPLICATIONS
Angquist, L.; Lindberg, L.
EPE '91. 4th European Conference on Power Electronics and Applications
p.243-7 vol.2 , 3-6 Sept. 1991 Firenze, Italy In English
For Abstract see entry 5A-034.

[1993] 2A-REF

A PRELIMINARY DESIGN OF HVDC METALLIC RETURN TRANSFER CIRCUIT BREAKER (MRTB)
Zhang Jierong; Xu Guozheng
Proceedings of the CSEE
vol.13, suppl. p.108-11, 1993 In Chinese
For Abstract see entry 5C-001.

[1991] 2A-REF

HIGH-VOLTAGE CONVERTER TECHNOLOGY
Lytaev, R.A.; Turatuta, I.P.
Elektrotekhnika
vol.62, no.12 p.48-51, 1991 , Russia. Translated in Soviet Electrical Engineering, vol.62, no.12 p.75-80, 1991, USA.
For Abstract see entry 1A-004.

2B. VALVES AND THYRISTORS

[1991] 2B-1

ADVANCED THYRISTOR VALVE PROJECT
Flairty, C.
Electric Power Research Inst., Palo Alto,
Apr 1991 (93) EPRI-EL-7169
An advanced thyristor value was developed for HVDC conversion applications. New features incorporated in the design include: improved heat transfer from the thyristors, two phase cooling of components, and light firing required the development of both a separate light triggered thyristor with a full forward blocking voltage rating and a special flash lamp employing cesium vapor as the associated light source. A valve rated 133 kV and 2200 A bridge current was constructed and lab tested before shipment to the Sylmar Converter Station, which is the southern terminus of the Pacific DC Intertie. The Los Angeles Department of Water and Power, which operates the Sylmar Station, installed the valve and operated it to gain experience. 36 figs., 5 tabs.

[1991] 2B-2

CALCULATION OF VALVE DAMPING CIRCUIT LOSSES IN 12-PULSE HVDC CONVERTERS.
Tennakoon, Sarath B.; Woodhouse, Michael L.
Proceedings of the 1991 IEEE Power Engineering Society Transmission and Distribution Conference
1991 Sep 22-27 Sponsor: IEEE Power Engineering Soc IEEE Power Eng Soc Transm Distrib Conf.(IEEE cat n 92CH3070-0). p 776-782)
The use of published equations for calculating damping circuit losses in a 12-pulse HVDC converter relies on the assumption that the inductive coupling between the pair of 30 degree phase-displaced 6-pulse converter groups is negligably small. However, there are instances where this coupling cannot be ignored. An analytical method is presented for the calculation of valve damping circuit losses of 12-pulse converters, taking the effects of inductive coupling into account.

The extra commutation notches introduced to the valve voltage waveform are expressed in terms of a notch factor m, and a general equation for the valve damping circuit loss is derived. The equation is divided into two parts so that the effects of valve stray capacitance and multiple valve grading circuits can be accommodated in a logical manner. An additional component of loss arising from the thyristor stored charge phenomenon is also discussed.

[1993] 2B-3

DESIGN AND TYPE TEST OF A LIGHT-TRIGGERED THYRISTOR VALVE FOR BACK-TO-BACK SYSTEMS.

Nakajima, F.; Yamazaki, T.; Itoh, K.; Matsumoto, T.; Sakai, T.

IEEE Transactions on Power Delivery

v 8 n 1 Jan 1993 p 31-37

A direct light-triggered, water-cooled thyristor valve was designed and manufactured as an extension for the Shin-Shinano frequency converter station (back-to-back system, 300 MW, 125 kV-2400 A) of Tokyo Electric Power Co. (TEPCO) This valve incorporates the following features: (1) the world's first commercial light-triggered thyristor (LTT) valve; (2) a light-triggering system, which has long life and high reliability; (3) a gate pulse system with high-speed response; and (4) a small size achieved by using water-cooled components which have high cooling efficiencies. This paper introduces various type tests conducted in the factory and also a seismic test on a real-scale valve model. The facility is scheduled to start operation in May 1992.

[1992] 2B-4

DEVELOPMENT OF VBO-FREE LARGE CAPACITY LIGHT-TRIGGERED THYRISTOR VALVE.

Horiuchi, Susumu; Horiuchi, Tsuneo; Muraoka, Yasuo

IEEE Transactions on Power Delivery

v 7 n 1 Jan 1992 p 276-280

Following the recent development of 6 kV class VBO (voltage break-over)-free light-triggered thyristors (LTTs) in Japan, a field verification test has been conducted by applying these thyristors to an actual 100 MVA class SVC valve, and satisfactory results were obtained. The authors describe the characteristics of the VBO-free large-capacity LTTs, the effects that can be expected when it is applied to SVC or HVDC valves, design and manufacturing, the results of factory tests for the SVC and valve, and the results of a verification test in the field.

[1991] 2B-5

DIFFERENTIAL FIRING-ANGLE CONTROL OF SERIES-CONNECTED HVDC BRIDGES.

O'Kelly, D.

Electric Power Systems Research

v 20 n 2 Feb 1991 p 113-120

The differential firing of the thyristors in two series-connected bridges is shown to give a reduction in both the harmonic generation and the reactive volt-ampere absorption for the rectifier mode of operation. Maximum benefit is obtained when one bridge has a large rating compared with that of the second bridge in series with it. The merits and disadvantages of several different power circuit arrangements and control strategies are examined and a scheme without a conventional transformer tapchanger is described. For the usual bipolar configuration of an HVDC converter station an attractive proposition is to have two converter transformers, each with a combined star-delta winding

[1991] 2B-6

HIGH VOLTAGE CONVERTER EQUIPMENT.

Lytaev, R. A.; Taratuta, I. P.

Elektrotekhnika

12 Dec 1991 p 48-51

Directions and the results of developing high-voltage thyristor valves (HTV) for power transmission lines and DC plugs are considered. The successful tests of the most powerful in the world HTV (3750 kV, 2000 A) are pointed out. It is underscored that although these devices differ from each other by power, voltage and some design and technical approaches they have much in common with basic design conceptions. These conceptions include: module design of inner device; light control systems; the wide introduction of technical diagnostics permitting to prevent emergency situations and to maintain the high reliability of a device. A water cooling system for all elements evolving heat (thyristors, resistors and chokes). It is pointed out, that the technical and economic characteristics, the design and the reliability of HTV are mainly determined by the parameters of power thyristors being used.

[1991] 2B-7

HVDC VALVE WITH LIGHT-TRIGGERED THYRISTORS

Danielsson, B.E.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 159-164

In high voltage direct current (HVDC) applications, the AC/DC thyristor converter is subjected to very high voltages and each valve in the converter bridge must be able to withstand several hundred kV. As the voltage capability of a single thyristor is limited to less than 10 kV, a large number of thyristors must be connected in series to support the voltage. Most thyristors are then located at a high electric potential. Necessary firing and protection facilities at the thyristor level must therefore be energized by current coming from the valve itself at the same level. Furthermore, triggering signals between these facilities and the control system at ground potential must be transmitted optically. Though a rather sophisticated but reliable solution based on a compact thyristor control unit (TCU) has been evolved for conventional electrically triggered thyristors (ETTs), direct optical triggering of the thyristor would be advantageous to simplify the valve electronics and possibly further improve converter reliability. This approach has been considered since the first development work on HVDC thyristor valves in the 1960s, but the concept of using light-triggered thyristors (LTTs) has up to now been economically inferior to the conventional solution using ETTs. The object of this presentation is to compare different circuit configurations based on LTTs and to summarize laboratory and field test experiences of the chosen solution. Some comments will also be made on a new design utilizing recent improvements in optical components.

[1993] 2B-8

INTERFERENCE IMMUNITY TESTS OF AN HVDC VALUE SECTION CONSISTING OF TWO THYRISTOR LEVELS

Ballad, J.P.; Chester, J.K.; Riley, R.C.; Shammas, N.Y.A. GEC ALSTHOM Eng. Res. Centre, Stafford, UK

Fifth European Conference on Power Electronics and Applications (Conf. Publ. No.377)

p.126-31 vol.7 IEE, London, UK., 1993.

The consistent thyristor valves of a high voltage direct current (HVDC) convertor bridges are commonly installed as four-high stacks, presenting the possibility of electric and magnetic coupling into the thyristor gate electronics units in one valve occurring as a result of current and voltage transients in an adjacent valve. These electronic units perform the essential functions of firing, protection and monitoring of the thyristor levels. For reliable long term operation of the convertor bridges, these functions should not be corrupted. In general, immunity to electromagnetic interference (EMI) is demonstrated during the application of type tests on a complete thyristor valve or on valve sections (modules) as described in IEC700. However, during design and development testing and, in particular, when the interactions between adjacent valves must be investigated, special tests on reduced scale test objects are often required. The authors describe three onerous tests designed to represent the most severe levels of coupling expected in practice. The tests were applied to a standard fully equipped valve section comprising two series connected 100 mm diameter thyristors to demonstrate its immunity to such interference.

[1991] 2B-9

OPERATIONAL AND HIGH VOLTAGE TESTS ON THYRISTOR VALVES FOR USE IN A STANDARDIZED BB-SYSTEM

Sachs, G.; Uder, M. Siemens AG, Erlangen, Germany

AC and DC Power Transmission (Conf. Publ. No.345)

p. 417-20 Published by IEE, London, UK. 1991

A new valve design for HVDC BB-systems has been subjected to type tests based on the most stringent requirements from either one of the three documents presently available in the industry. All tests were passed successfully. There was no thyristor failure and the only capacitor failure was demonstrated to be caused by a manufacturing defect. Effects of the failure were limited to the particular thyristor level. Partial discharge measurements confirmed that due to the mechanical design, corona shielding of the thyristor modules is not required. An additional test with a simulated water leak proved that the test object withstood the test voltage well in excess of the time required for the leakage detection to operate. (3 Refs)

[1992] 2B-10

RELIABILITY ENGINEERING OF HVDC THYRISTOR VALVES

Dumrese, H.G.; Holweg, J.; Lips, H.P.; Salanki, T.; Thiele, G.; Tu, Q.B.

CIGRE Proceedings of the 34th Session

p.14-303/1-8 vol.1 30 Aug.-5 Sept. 1992

HVDC thyristor valves are a complex system of electrical components, fibre optics, insulation, cooling system, and structural components. The paper discusses the reliability requirements and various types

of potential failure mechanisms. The engineering efforts taken and the design strategies followed to ensure reliable operation are described.

[1993] 2B-11

STUDY OF TURN-ON TEST METHOD FOR HIGH-VOLTAGE THYRISTOR VALVE
Kobayashi, S.; Tanabe, S.; Itoh, F.
IEEE Transactions on Power Delivery
Jan 1993 p 83-89
Digital simulations were conducted to analyze the thyristor valve turn-on phenomenon while a valve arrester is conducting which gives the most severe turn-on stress for the valve. The effects of various other parameters were clarified, too. Based on this analysis, two test methods were proposed that verify a valve turn-on during arrester conduction, and their effectiveness was described. Then the non-repetitive turn-on test given in the IEC Standard Pb. 700 and IEEE Standard 857 was studied and a new test voltage level on the basis of these analyses was proposed.

[1991] 2B-12

THERMAL DESIGN OF HIGH POWER THYRISTOR VALVES FOR HVDC AND SVC APPLICATIONS
Davidson, C.C.
IEE Colloquium on 'Thermal Management in Power Electronics Systems' (Digest No.065)
p.4/1-11 1991
High power thyristor valves are used as the switching elements in high voltage direct current (HVDC) power convertors, and to switch shunt capacitive or reactive components for control of reactive power in static VAR compensator (SVC) schemes. The author describes the methods used for cooling the major electrical loss-dissipating components in these thyristor valves, and the analytical techniques employed for the prediction of the thermal response of the valve to transients, both in simulations at the design stage, and in the real-time monitoring systems. (1 Refs)

[1991] 2B-13

TRANSIENT VOLTAGES SUPPORTABILITY OF THYRISTOR VALVES FOR HVDC AND SVC APPLICATIONS
Freire, A.R.F.; Santiago, N.H.C.; Lima, A.G.G.
Univ. Federal de Rio de Janeiro, Brazil
Seventh International Symposium on High Voltage Engineering
p.203-6 vol.8. Conference held on 26-30 August 1991 in Dresden, Germany. Published by Dresden University.
The supportability of thyristor valves submitted to voltage surges is evaluated on the basis of the voltage distribution in arrangements of thyristors in series and in the definition of parameters to characterize the supportability of a single thyristor. A better knowledge of the performance of thyristors submitted to voltage surges will permit a more reliable valves design, mainly in which concerns to insulation coordination. The experimental results obtained with thyristors of low, medium and high power capacity, for different voltage surges wave shapes, surge polarity and junction temperature, will permit to conclude that the supportability of these thyristors is independent from the voltage limits specified by their manufacturers. (5 Refs)

[1992] 2B-REF

A METHOD FOR CALCULATING ELECTRIC FIELDS IN HVDC EQUIPMENT WITH ALLOWANCE FOR TRANSIENTS
Bortnik, I.M.; Vol'pov, E.K.; Filippov, A.A.
Elektrichestvo
no.6 p.24-8 June 1992 Russia In Russian
For Abstract see entry 3F-002.

2C. REACTIVES, HARMONICS AND FILTERS

[1992] 2C-1

AC FILTERS IN HVDC TRANSMISSION
Seth, S.P. Bharat Heavy Electricals Ltd., Bhopal, India
IEEMA Journal
vol.12, no.10 p. 17-18, 20, 22, 24, 26-7, 29-30; Oct. 1992
An HVDC system generates both characteristic and noncharacteristic harmonics of all orders. To limit the flow of these harmonic currents into the AC system (supporting the HVDC system), AC filters are provided. The filters also provide VAR support for the converters. Designing a filter configuration consisting

of single tuned band-pass, double tuned band-pass, and high pass filters is one of the major aspects of a HVDC project. The author deals with the different aspects of harmonic generation and filter design of a HVDC project. The filter configurations of three HVDC projects of the country are also discussed. (0 Refs)

[1993] 2C-2

ACTIVE DC FILTER FOR HVDC SYSTEM--A TEST INSTALLATION IN THE KONTI-SKAN DC LINK AT LINDOME CONVERTER STATION

Zhang, Wenyan; Asplund, G.; Aberg, A.; Jonsson, U.; Loeoef, O.

IEEE Transactions on Power Delivery

Jul 1993 p 1599-1606

The purpose of introducing active DC filters is to meet the more and more stringent requirement from power utilities on limiting telephone interference caused by harmonic currents from HVDC transmission lines, without unnecessarily increasing the cost of HVDC stations. An active DC filter installed in the Konti-Skan HVDC link is described. The active DC filter is connected at the bottom of an existing passive DC filter at the Lindome station. The active DC filter includes optic harmonic current measuring unit, control system, protection and supervision system, PWM power amplifier, high-frequency transformer, surge arrester, and coupling apparatuses. The active DC filter has small physical size and occupies small ground area. The performance of the active DC filter for eliminating the disturbing harmonics is excellent. To achieve comparable results by passive filters would require something like ten times more high voltage equipment.

[1991] 2C-3

ANALYSIS OF NONCHARACTERISTIC HARMONICS OF A LARGE HVDC TRANSMISSION SYSTEM AND COMPARISON WITH SITE TESTS

Witzmann, R.; Schultz, W.; Krueger, K.; Koetschau, S.; Mukherjee, A.

AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 no. 345. p 384-389

The paper describes the analysis of harmonic current on the DC line of an HVDC transmission system. For this purpose, extensive measurements were carried out on a system having a high rating. The basic parameters influencing the currents on the DC side have been theoretically studied and computer models described. The results of the measurements are compared with the results of the simulation. Recommendations and conclusions for analysis of the interference caused by HVDC systems are discussed.

[1991] 2C-4

CALCULATION OF HARMONIC INTERFERENCE IN HVDC SYSTEMS WITH UNBALANCE.

Hu, Lihua; Yacamini, R.

Fifth International Conference on AC and DC Power Transmission

1991 Sep 17-20 IEE Conference Publication n 345. p 390-394

The power converters used in HVDC systems are a major source of the harmonics in their associated DC and AC systems. Under ideal working conditions the well known relationships of n-pk (where p is the pulse number of the converter) on the DC side and n equals pk plus or minus 1 on the AC side can be used to identify the harmonics. Standard tables and graphs which are widely used in the industry can be used to find the amplitude. When the converter is working under non-ideal condition such as unbalanced AC supplies, unbalanced firing control, unbalanced AC impedance or even with harmonic distortion in the AC supplies, a wide range of non-theoretical harmonics will be generated at both of AC and DC side of the converter. A technique which is useful in analyzing the non-theoretical harmonics in the converters is the modulation theory of converters. This paper outlines the basic theory and then uses it to calculate the non-theoretical harmonics in the HVDC systems under unbalanced AC supply conditions. The effects of the commutation overlap and the commutation impedance in the harmonic calculations have been taken into consideration. Examples are given for some typical HVDC schemes with unbalanced AC supplies. The results are compared with those produced by a time domain digital simulation package, SABER.

[1993] 2C-5

CALCULATION OF HARMONICS AND INTERHARMONICS IN HVDC SCHEMES WITH LOW DC SIDE IMPEDANCE

Hu, L.; Yacamini, R.

IEE Proceedings, Part C: Generation, Transmission and Distribution v 140 n

6 Nov 1993. p 469-476

When HVDC schemes are used to join AC systems of different frequencies, frequencies other than the well known characteristics harmonics are produced in the AC systems, and these are often called interharmonics. This paper examines these interharmonics and shows that, for HVDC schemes with low DC side reactance, another set of interharmonics will exist only on the

DC side. These are a function of the impedance of the convertor seen from the DC side. It is shown that this impedance is time varying and, by modulation theory, will produce DC side harmonic frequencies some of which may be at low frequency. It is also shown that the amplitudes of characteristic harmonics and interharmonics will be changed by this effect. The method based upon modulation theory is compared to the results of a time domain computer simulation. The results shown will also be applicable to variable frequency motor drives.

[1991] 2C-6

COMMENTS ON MINIMISATION OF UNCHARACTERISTIC HARMONICS IN HVDC CONVERTORS THROUGH FIRING ANGLE MODULATION (AND REPLY)
Sood, V.K.; Gole, A.M.; Farret, F.A.; Freris, L.L.
IEE Proceedings C (Generation, Transmission and Distribution)
vol.138, no.6 p.567-8 1991 UK
For original paper see ibid., vol.137, no.1, p.45-52 (1990). The authors find that the original paper should provide an insight into the technique of minimisation of uncharacteristic harmonics in HVDC convertors through firing angle modulation. They point out some minor anomalies and look at a recent application of this kind of technique. The authors of the original paper reply by commenting and solving problems found. (2 Refs)

[1992] 2C-7

DESIGN AND INSTALLATION OF 500 V BACK-TO-BACK SHUNT CAPACITOR BANKS
Furumasu, B.C.; Hasibar, R.M.
IEEE Transactions on Power Delivery
vol.7, no.2 p.539-45 April 1992
The Bonneville Power Administration's first 500 kV back-to-back shunt capacitor installation is described. The primary purpose of the capacitor banks is to support AC system voltage for transient stability following an outage of the HVDC Intertie line between Oregon and southern California. Design studies and equipment requirements are detailed in addition to electromagnetic transients program (EMTP) studies and subsequent field test results. Current-limiting reactors are used to limit inrush and outrush currents during capacitor switching. (6 Refs)

[1992] 2C-8

EVALUATION OF HARMONIC DISTURBANCES AT THE COMMON POINT OF COUPLING OF THE EUROTUNNEL AND OF THE HVDC FRANCE-ENGLAND LINK
Chazottes, B.; Deflandre, T.
EDF-Electricite de France
1992
On startup of the Trans Manch Tunnel in 1993, the harmonic currents generated by the railway will raise the harmonic levels in a point of the network already subject to the demand of power convertors of the DC France-England 2000 MW link (IFA 2000). Digital simulations enabled the rise in harmonic voltages at the tunnel termination point as well as its consequences upon the conversion station filtering for a great number of network diagrams and various railway traffic hypotheses to be evaluated. After having described the methodology and the results of the study, the report presents the influence of the network topology upon the harmonic impedance and poses the technical and commercial problems met with the junction in a same point of several large-capacity disturbing elements on the 400 kV system.

[1993] 2C-9

HARMONIC ELIMINATION BY DC RIPPLE REINJECTION IN GENERATOR-CONVERTOR UNITS OPERATING AT VARIABLE SPEEDS
Arrillaga, J.; Yonghe, L.; Crimp, C.S.; Villablanca, M.
IEE Proceedings Part C: Generation, Transmission and Distribution
Jan 1993 p 57-64
A method of increasing the pulse number of a high voltage direct current (HVDC) convertor based on the reinjection of the DC ripple is applied to a unit-connected generator-convertor scheme operating at variable speeds. Theoretical and experimental results are provided which demonstrate that, with the proposed modification, a single-bridge configuration can be made to operate as an 18-pulse convertor for a wide range of generator frequencies.

[1991] 2C-10

HARMONIC LOAD LOSSES IN HVDC CONVERTER TRANSFORMERS
Forrest, J.A.C.
IEEE Transactions on Power Delivery
Jan 1991 p 153-157
Previous methods used to allow for the harmonic loss component of converter transformer load loss have not taken into account variations in transformer inductance, the ratio of winding stray loss to the other

stray loss, or the converter firing angle. As a result of a reduction in converter reactance for some schemes, the harmonic loss allowance has been shown to be inadequate. Short circuit losses were measured in a 213 Mva single phase converter transformer at a number of frequencies between 60 Hz and 6 kHz. Using the results of these tests the harmonic losses during ac/dc converter operation were calculated. Variation of harmonic losses with transformer reactance, transformer winding stray loss factor and converter firing angle were studied. Using exponents of the components of harmonic losses with frequency derived from the tests, a table has been developed for determining the magnitude of the harmonic loss during converter operation. The data required to use the table is derived from design calculations and normal load loss test results.

[1992] 2C-11

HARMONIC TRANSFER THROUGH CONVERTERS AND HVDC LINKS.
Hu, Lihua; Yacamini, Robert
IEEE Transactions on Power Electronics
v 7 n 3 Jul 1992 p 514-525
Power converters are known to be generators of harmonics on both their AC and DC sides. They also transfer existing harmonics from one side to the other side with an associated change of frequency. Analysis techniques that can be used to calculate these transferred harmonics using amplitude modulation (AM) theory are proposed. The authors also show how, in a high-voltage direct-current (HVDC) link, the converters can intercouple the AC and DC systems and can thus act as a transfer medium for harmonics. Examples that show how to calculate these harmonics are given and comparisons are made with a computer-aided design (CAD) model as a check on the accuracy of the method.

[1991] 2C-12

HARMONICS IN 3 PHASE AC NETWORKS IN THE OPERATION OF AN HGUE SHORT COUPLING
Bauer, E.; Winkler, G.
Elektrie (Germany)
1991 p 97-100 In German
The use of an HGUe short coupling was prepared for the 380/220 kV network of the new German Laender. Following the reunification of Germany and the direct connection of the East German network to the West German network which is in preparation, the erection of the HGUe short coupling at Wolmirstedt was unnecessary. The investigations for this development regarding the appearance and reduction in amplitude of voltage harmonics in operating a high voltage DC short coupling enable one to draw generally valid conclusions, which are reported in the article.

[1992] 2C-13

HIGH POWER ACTIVE FILTER USING LC TUNED FILTER
Takahashi, I.; Omura, Y.
Transactions of the Institute of Electrical Engineers of Japan
20 Sep 1992 p 823-828
Usually, to eliminate the higher harmonics of transmission lines, LC tuned filters are employed to let bypass these harmonic components. But the elimination ability is limited by its damping resistance. Therefore, active filters composed of high frequency PWM converters have been desired. In this report, a low cost and high capacity active filter for a DC transmission system was proposed. Its main circuit was composed of conventional LC filters in series with square wave voltage inverters, and calculation of higher harmonics and the control were done by DSP controller (TMS 32010). The proposed active filters were confirmed in their characteristics using two three-phase tuned filters for 5-th and 7-th harmonics at the experiment and simulations. As a result, it was found out that the system functioned as an ideal filter for the objective higher harmonics and could supress the remaining harmonics to less than 1 %. ;

[1992] 2C-14

HIGH PULSE HVDC TRANSMISSION
Villablanca, M.; Arrillaga, J. Canterbury Univ., Christchurch, New Zealand
CIGRE Proceedings of the 34th Session
p.14-101/1-8 vol.1 1992
A generalized DC ripple reinjection scheme is presented which is capable of achieving, by natural commutation, any multiple of the basic pulse number of HVDC convertors and thus provide a complete alternative to the use of AC, and DC filters. The technique is equally applicable to rectification and inversion as required by HVDC convertors. The theoretical considerations, main design principles and extensive experimental verification for up to 48 pulse operation are described. (2 Refs)

[1992] 2C-15

INNOVATIVE FILTER CONCEPT FOR POWER SYSTEM HARMONICS

Amin, A.M.A.; Steelman, J.E.; Ranade, S.J. Center for Energy Studies, Texas Univ., Austin, TX, USA

ICHPS V International Conference on Harmonics in Power Systems

p.184-9, 23-25 Sept. 1992

A modification to conventional harmonic filters used in HVDC substations and similar equipment is proposed. A rectifier is used to recover energy from several tuned filters, and the amount of energy recovered controls the filter quality, Q. Thus, low-Q filters can be designed without the attendant power losses. Such filters are desirable from the point of view of simplicity, robustness, and stability. The 'minimum losses filter' concept is explained through simulation studies of operating characteristics and its application to an existing HVDC terminal. (8 Refs)

[1992] 2C-16

LIMITING TRANSIENT OVERVOLTAGES ON THE ULTRA-HIGH VOLTAGE NETWORK WITH STATIC COMPENSATOR AND NEW-TYPE FILTERS FOR LOW-FREQUENCY HARMONICS

Moraw, G.; Titscher, G.

Elektrotechnik und Informationstechnik

vol.109, no.9 p.441-4 1992 Austria In German.

In order to increase the flexibility of the Austrian high-voltage DC couplings, an investigation was carried out to determine how far the necessary special switching conditions are permissible from the system operation viewpoint. It was shown that, in view of the relatively low short-circuit rating on the eastern side of the DC coupling plant, overvoltages could occur on load disconnection which, on saturation of inductive components and in combination with resonances in the network, could lead to impermissible overvoltages. With the aid of thyristor-controlled inductors and specially developed high-voltage filter circuits it is possible to overcome these problems. (0 Refs)

[1991] 2C-17

NEW SYNCHRONOUS COMPENSATORS FOR THE NELSON RIVER HVDC SYSTEM PLANNING REQUIREMENTS AND SPECIFICATIONS

Thio, C.V.; Davies, J.B.

IEEE Transactions on Power Delivery

Apr 1991 p 922-928

The first units of Limestone Generating Station, the third plant on the Lower Nelson River in northern Manitoba, will come into service in the fall of 1990. Additional var compensation equipment is required at the inverter end of the Nelson River HVDC system to accommodate power from Limestone. This paper describes the system requirements of and the overall specification for the synchronous compensators selected to supply the reactive power and voltage support.

[1991] 2C-18

PARAMETERS AFFECTING THE HARMONIC DISTORTION IN A CONVERTER SUBSTATION.

Christoforidis, G. P.; Meliopoulos, A.; P. Sakis

IEEE Transactions on Power Delivery

v 6 n 4 Oct 1991 p 1727-1734

The authors describe in a quantitative way the effect of specific parameters on the generation of harmonics by converter substations. The parameters investigated are the following: (1) delay angle of the converter control system, (2) converter control type, (3) electric load, (4) capacitor banks, and (5) stiffness of the AC/DC interconnection. The parametric analysis has been conducted using a nonlinear method suitable for accurate harmonic analysis. An appropriate modification of the IEEE Reliability Test System (RTS) has been used as the test power system. A DC transmission system including the converter substation, the DC transmission line, and the load is connected at different locations in the IEEE RTS system (one location at a time), and the effect of the parameters mentioned above on the harmonic distortion is illustrated.

[1993] 2C-19

POWER LINE CARRIER INTERFERENCE FROM HVDC CONVERTER TERMINALS

Tatro, P.J.; Adamson, K.A.; Eitzmann, M.A.; Smead, M.

IEEE Transactions on Power Delivery

Jul 1993 p 827-840

Power line carrier (PLC) equipment typically operates in the frequency range from 25 kHz to 300 kHz. Interference studies for HVDC converters usually concentrate on interference from noise sources within this frequency range. However, operating experience at the Sandy Pond converter terminal has indicated that PLC equipment is also susceptible to interference from sources of power system harmonics below the PLC frequency range. Extensive field testing and analytical studies have shown that each PLC circuit has a resonant frequency below the operating frequency. If excited at this resonant frequency, high voltages may exist within the PLC circuit. The resulting saturation of PLC components leads to local generation of radio frequency (RF) noise that

interferes with proper operation of PLC circuits. Sources of power system harmonics in the 3-10 kHz range, such as line commutated DC converters, are potential sources of this type of interference.

[1992] 2C-20

PROPAGATION OF HARMONICS FROM THE DC INVERTER ELECTRIC POWER TRANSMISSION STATION AT DURNROHR, AUSTRIA
Brauner, G.; Moraw, G.
Elektrotechnik und Informationstechnik
vol.109, no.10 p. 487-94 , 1992 .
The authors outline the need for linking differing national power networks through DC rectifier/inverter links to avoid synchronisation problems. They report that there are power interchange links between Austria, Czechoslovakia, Hungary, Poland, Italy and Yugoslavia, which form parts of the UCPTE network. The power link between Austria and Czechoslovakia is described. This carries 400 megawatts and is expected to transfer 1600 GWh annually. The problems of the generation of harmonics in the AC networks connected to the rectifier/inverter station are discussed, and measurements of the frequency characteristics of AC power transmission networks and elements are recorded. Harmonic currents depend on the instantaneous power transmitted, and may have maxima at medium load levels. Simulation of power systems is referred to. (0 Refs)

[1992] 2C-21

REVIEW OF HVDC SYSTEM HARMONIC ANALYSIS METHODOLOGY AND PERFORMANCE
Prabhakara, F.S.
ICHPS V International Conference on Harmonics in Power Systems
p.128-34 IEEE, New York, NY, USA, 1992 23-25 Sept. 1992 , Atlanta, GA, USA
This paper summarizes the experience regarding harmonic analysis, methodology and performance on both AC and DC sides of HVDC transmission systems. Multiterminal DC systems, and multiple DC infeeds into an interconnected AC system are also discussed. (19 Refs)

[1992] 2C-22

STATIC VAR COMPENSATORS (SVC) VERSUS SYNCHRONOUS CONDENSERS (SC) FOR INVERTER STATIONS COMPENSATION-TECHNICAL AND ECONOMICAL ASPECTS IN ELETRONORTE STUDIES
Gama, C.A.; Ellery F.E.H.; Barbirato Azevedo, D.C.; Ponte, J.R.R.
CIGRE Proceedings of the 34th Session
p.14-103/1-6 vol.1 30 Aug.-5 Sept. 1992
This paper deals with a technical and economical comparison between SVC and SC for reactive power support of HVDC inverter stations. The most important equipment aspects and adopted models are discussed. A detailed description of most relevant price items is also included, based on the already implemented Eletronorte's projects in the Brazilian Amazonic region. Different arrangements which are technically equivalent are investigated, supported by dynamic simulation studies, and an economical comparison is built. Finally, some general conclusions concerning the application of these equipment are highlighted.

[1991] 2C-REF

NEW SYNCHRONOUS COMPENSATORS FOR THE NELSON RIVER HVDC SYSTEM--PLANNING REQUIREMENTS AND SPECIFICATION.
Thio, C. V.; Davies, J. B.
IEEE Transactions on Power Delivery
v 6 n 2 Apr 1991 p 922-928
For Abstract see entry IF-011.

[1992] 2C-REF

HARMONIC REDUCTION IN GROUP-CONNECTED GENERATORS HVDC CONVERTOR
Arrillaga, J.; Yonghe, L.; Crimp, C.S.; Villablanca, M.
ICHPS V International Conference on Harmonics in Power Systems
p.202-7 23-25 Sept. 1992
For Abstract see entry 2A-013.

[1991] 2C-REF

NEW CONCEPT IN HVDC GENERATION.
Arrillaga, J.; Villablanca, M.; Camacho, J. R.
Transactions of the Institution of Professional Engineers New Zealand
Section v 18 n 1 Nov 1991 p 15-20
For Abstract see entry 2A-015.

[1992] 2C-REF

FILTER PROTECTION FOR HVDC PROJECT GESHA
Weibelzahl, M.; Mukherjee, A.; Janke, R.
Modern Power Systems
Feb 1992 p 29, 31, 33
For Abstract see entry 5A-024.

[1993] 2C-REF

OPTIMAL FIRING-ANGLE CONTROL OF CASCADED HVDC CONVERTERS FOR MINIMUM REACTIVE POWER DEMAND
Deib, D.A.; Hill, H.W.
IEEE Applied Power Electronics Conference and Exposition - APEC
1993. Publ by IEEE, IEEE Service Center, Piscataway, NJ, USA. p 662-667
For Abstract see entry 5A-033.

[1992] 2C-REF

PERFORMANCE OF 420 KV CIRCUIT-BREAKERS IN HVDC CONVERTER STATION
Aldrovandi, G.; Bargigia, A.; Bonfanti, I.; Pazienza, G.; Pincella, C.; Polesello, P.
CIGRE Proceedings of the 34th Session
Sep 1992 p.13-304/1-8 , vol.1
For Abstract see entry 5B-006.

[1992] 2C-REF

AC/DC HARMONIC INTERACTION IN HVDC SYSTEMS
Sadek, K.; Christl, N.; Lutzelberger, P. Seimens AG, Erlangen, Germany
ICHPS V International Conference on Harmonics in Power Systems
p.196-201 23-25 Sept. 1992
For Abstract see entry 5D-003.

[1992] 2C-REF

ANALYSIS OF SECOND HARMONIC INSTABILITY FOR THE CHATEAUGUAY HVDC/SVC SCHEME
Hammad, A.E.
IEEE Transactions on Power Delivery
Jan 1992 p 410-415
For Abstract see entry 5D-007.

[1991] 2C-REF

DIRECT MEASUREMENT OF RESIDUAL HARMONIC CURRENTS ON A +OR-450 KV DC LINE USING ROGOWSKI COILS
Mercure, H.P.; Bard, P.; Auclair, Y.; Rodridge, P IREQ, Hydro-Quebec, Varennes, Que., Canada
Seventh International Symposium on High Voltage Engineering
p.195-8 vol.6. Conference held on 26-30 August, 1991 in Dresden, Germany. Published by Dresden University in 1991.
For Abstract see entry 5G-004.

[1992] 2C-REF

POWER STATION LOW FREQUENCY GENERATION AND TRANSMISSION BY HVDC LINE
Zhang Dongsheng
Power System Technology
no.3 p.34-42 Aug. 1992 China In Chinese
For Abstract see entry 6B-028.

[1993] 2C-REF

STEADY-STATE MATHEMATICAL MODELS OF CONVERTORS WITH BIPARAMETRIC REGULATION
Carpinelli, G.; Gagliardi, F.; Sturchio, A.; Russo, M.
IEE Proceedings, Part C: Generation, Transmission and Distribution
Mar 1993 p 105-114
For Abstract see entry 6B-032.

2D. DAMPING CIRCUITS

[1990] 2D-REF

SOLUTION TO THE PROBLEM OF LOW ORDER HARMONIC RESONANCE FROM HVDC CONVERTERS
Kaul, N.; Mathur, R.M.
IEEE Transactions on Power Systems
Vol, 5, No. 4, November 1990
For Abstract see entry 5A-039.

2E. ABNORMAL OPERATING CHARACTERISTICS

[1993] 2E-1

A STUDY OF HVDC-CAUSED SUBSYNCHRONOUS OSCILLATIONS IN MULTIMACHINE SYSTEM
Ni Yixin; Wang Yanchun; Chen Shousun; Zhang Baolin
Proceedings of the CSEE
vol.13, no.2 p.64-72 March 1993
A linearized model for the study of HVDC-caused subsynchronous oscillations (SSO) in multimachine power systems is derived. The eigenvalue analysis method is used to study such HVDC-caused SSO in multimachine power systems. The effects of HVDC control manners, control system parameters and system operation conditions on HVDC-caused SSO are also discussed.

[1992] 2E-2

ANALYSIS OF ABNORMAL SHUT DOWN IN SYSTEM TESTS FOR POLE II AND BIPOLE OF THE GEZHOUBA-SHANGHAI HVDC PROJECT
Zeng Nanchao; Ni Linlin
Power System Technology
no.1 p.9-14 Feb. 1992 China In Chinese
The authors report on the 27 accounts of the abnormal shut downs occurred in the pole II and bipole terminal-to-terminal tests on the Gezhouba-Shanghai HVDC system during the period between May and July 1990. The procedure, causes and actions taken during each abnormal shut down are recorded and discussed.

[1992] 2E-3

FAULT IDENTIFICATION IN AN AC-DC TRANSMISSION SYSTEM USING NEURAL NETWORKS
Kandil, N.; Khorasani, K.; Patel, R.V.; Sood, V.K.
IEEE Transactions on Power Systems
May 1992 p 812-819
This paper explores the possibility of using neural networks to identify faults that may have occurred in an ac-dc power transmission system. Based on the ability of these networks to distinguish reliably between different types of faults, appropriate control measures can be taken to improve the dynamic performance of the ac-dc power system. In this paper, three different neural network architectures to distinguish between different types of faults on the ac-dc system are proposed, and a comparison between them is made.

[1993] 2E-4

SECONDARY ARC EFFECTS IN AC/DC HYBRID TRANSMISSION
Woodford, D
IEEE Transactions on Power Delivery
Apr 1993 p 704-711
Adding a DC circuit to an existing AC transmission line or replacing one AC circuit with a DC circuit is one method of significantly increasing the power transfer capability of the transmission line. Coupling at fundamental frequency from the AC circuit to the DC circuit on the same tower interferes with the clearing of DC line faults. Even though DC current in the fault arc can be brought to zero by the controls of the DC transmission systems, fundamental frequency secondary arc current can delay clearing of the fault. The factors which impact the duration of secondary arc are investigated both for balanced and unbalanced conditions on the ac

[1991] 2E-5

SUBSYNCHRONOUS TORSIONAL INTERACTIONS WITH STATIC VAR COMPENSATORS-INFLUENCE OF HVDC.
Rostamkolai, Niusha; Piwko, Richard J.; Larsen, Einar V.; Fisher, Douglas A.; Mobarak, Mohamed A.; Poltras, Alfred E.
IEEE Transactions on Power Systems
v 6 n 2 Feb 1991 p 255-261
Planning for the installation of a static VAR compensator (SVC) in Chester, Maine was initiated in 1987. The prespecification subsynchronous torsional interaction (SSTI) studies showed that the SVC might have a negative influence on the stability of torsional modes of vibration of the nearby turbine generators. The parameters influencing the level of SSTI have previously been identified by the authors by using a simple system (1989). This work is extended to power systems containing an HVDC transmission system. The combined effect of SVC and HVDC on turbine-generator SSTI is investigated with the use of a hypothetical system. Simulation plots for the large machines of New Brunswick and Maine are included to quantify the level of interaction with the Chester SVC. Filtering as a mitigation measure is proposed to eliminate the small level of SSTI attributed to the Chester SVC.

2F, TRANSFORMERS AND REACTORS

[1992] 2F-1

ALLOWANCE FOR INSULATION AGING IN THE NEW CONCEPT OF ACCELERATED LIFE TESTS OF HIGH-VOLTAGE POWER TRANSFORMERS

Levit, A.G.; Grechko, O.N.; Shchipunova, N.P.
IEEE Transactions on Power Delivery
Jul 1992 p 1089-1096

This paper reports that the existing system of type and acceptance tests of high-voltage transformer insulation does not take into account insulation ageing, which is particularly objectionable with respect to equipment with reduced insulation levels. Suggested in the paper is a new concept of accelerated life tests based on integrated simulation of basic operating loads, both periodic (surge) and long-term ones; by making a long-term accelerated test simulating the working conditions, with exposure of test object and/or its insulation to periodic operating surges (overvoltages and overcurrents). This test replaces a group of conventional individual acceptance tests and provides more ample and more precise information on performance and dependability of the equipment. The test procedure was checked in test of a small lot of 1600 kVA 35 kV power transformers.

[1992] 2F-2

ALTERNATIVES FOR BLOCKING DIRECT CURRENT IN AC SYSTEM NEUTRALS AT THE RADISSON/LG2 COMPLEX

Eitzmann, M.A.; Walling, R.A.; Sublich, M.; Kah, A.; Huynh, H.; Granger, M.; Dutil, A.
IEEE Transactions on Power Delivery
Jul 1992 p 1328-1337

Severe offset saturation results from the passage of direct current through power transformers. Such direct current can arise from geomagnetic disturbances, or resistive coupling of the substation ground to HVDC earth electrodes. This paper documents the development of alternative approaches for the design and application of blocking devices placed between transformer neutrals and the substation ground. System constraints on the impedance and overvoltage limitation of the neutral blocking device (NBD) are covered. Three alternative NBD schemes are developed and optimized. System performance of the NBD is discussed, as are the practical implementation considerations for this unconventional equipment application. Although the paper focuses on the NBD requirements of Hydro-Quebec's Radisson/LG2 complex, the fundamental information is applicable to any situation where DC must be clocked from a power transformer neutral in a system designed for effectively-grounded operation.

[1991] 2F-3

CONDITION MONITORING OF CRITICAL HVDC TRANSFORMERS OF FENNO-SKAN INTERCONNECTION

Heinonen, K.
Transmission & Distribution International
vol.2, no.1 p. 40-2, 44 March 1991, USA

A HVDC submarine cable between Finland and Sweden, called the Fenno-Skan, is an important part of the NORDEL power exchange system. The author presents a power transformer monitoring system to be installed to monitor convertor transformers at the Rauma substation which is at the Finnish side of the Fenno-Skan. The advanced microcomputer-based system provides continuous assessment of loadability and monitors consumed service life. (0 Refs)

[1992] 2F-4

HVDC CONVERTER TRANSFORMERS-A REVIEW OF SPECIFICATION CONTENT

Lindroth, A.; Harrison, T.H.; Calabro, S.; Desilets, G.L.; Fogelberg, T.; Kennedy, W.N.; Peixoto, C.A.O.; Yasuda, E.A.; Bickley, T.A.; Harrison, R.E.; Lokhanin, A.K.; Norton, E.T.; Okuyama, K.; Polovick, G.S.; Pratt, F.C.; Preininger, G.; Stein, W.W.; Tada, K.
Electra
no.141 p.34-49April 1992 France French/English

Cigre Joint Working Group 12/14.10 was set up to consider the service performance of HVDC transformers and relate this to design performance and test specifications. The Joint Working Group were then to consider whether improvements were to be recommended. An important input to the work was the accumulation and correlation of the content of specifications used on a variety of installations. The result of this work was a comprehensive list of specification information considered to be necessary to undertake the supply of an HVDC transformer.

[1993] 2F-5

LOADING CAPABILITY OF HVDC TRANSFORMER BUSHINGS WITH RESTRICTED OIL CIRCULATION FOR USE IN HVDC VALVE HALLS

Johansson, L.; Magnuson, B.; Riffon, P.
IEEE Transactions on Power Delivery
Jul 1993 p 1607-1614

The loading capability of a 500 kV HVDC transformer bushing is calculated with some unusual conditions: the internal oil circulation in the bushing is blocked at

the flange level and the ambient air temperature is raised to 60 C. The theoretical model was verified with a full-scale heat run test on a 7.8 m long bushing. A 220 cu. meter insulated test chamber was required to enclose the test set-up.

[1992] 2F-6

LOADING CAPABILITY OF HVDC TRANSFORMER BUSHINGS WITH RESTRICTED OIL CIRCULATION FOR USE IN HVDC VALVE HALLS.
Johansson, L.; Magnuson, B.; Riffon, P.
IEEE Conference Paper 92 SM 360-8 PWRD
1992
The loading capability of a 500 kV HVDC transformer bushing is calculated with some unusual conditions: the internal oil circulation in the bushing is blocked at the flange level and the ambient air temperature is raised to 60 degrees centigrade. The theoretical model was verified with a full-scale heat run test on a 7.8 m long bushing. A 220 cubic meter insulated test chamber was required to enclose the test set-up. This paper deals with the thermal behavior of HVDC transformer bushings.

[1993] 2F-7

MODELING OF CONVERTER TRANSFORMERS USING FREQUENCY DOMAIN TERMINAL IMPEDANCE MEASUREMENTS
Liu, Yilu; Sebo, S.A.; Caldecott, R.; Kasten, D.G.; Wright, S.E.
IEEE Transactions on Power Delivery
Jan 1993 p 66-72
HVDC converter stations generate radio frequency (RF) electromagnetic (EM) noise which could interfere with adjacent communication and computer equipment, and carrier system operations. In order to calculate and predict the RF EM noise produced by the valve ignition of a converter station, it is essential to develop accurate models of station equipment over a broad frequency range. Models of all station equipment can be characterized by frequency dependent impedances. The paper describes the frequency dependent node-to-node impedance function (NIF) models of power system equipment based on systematic broad frequency range (50 Hz to 1MHz) external driving point impedance measurements, sponsored by the Electric Power Research Institute (EPRI). The regular structure, high accuracy, and virtually unlimited frequency range are important features of the NIF model. Examples of NIF model application in converter station RF EM noise calculations are presented.

[1991] 2F-8

POWER TRANSFORMER RESONANCE - MEASUREMENT
Liu, Yilu; Sebo,Stephen A.; Wright, Selwyn E.; Caldecott, Ross; Kasten, Donald, G.
IEEE Preprint # 91 WM 048-9 PWRD.
1991
HVDC converter stations generate radio frequency (RF) electromagnetic (EM) noise which could interfere with adjacent communication and computer equipment, and carrier system operations. It is important to be able to measure, predict, and mitigate the EM noise and interference. All power system components, including major station equipment, can be characterized as frequency dependent impedances. In order to model and calculate the RF noise transmission, a systematic measurement program of the frequency dependent impedance of major station equipment was performed as part of a series of projects sponsored by the Electric Power Research Institute (EPRI).

[1991] 2F-REF

AN ALTERNATIVE APPROACH TO POWER FLOW CONTROL
Bonhelmer, D.; Lim, E.; Dudley, R.F.; Castanheira, A.
Modern Power Systems
vol.11, no.12 p.61-5 Dec. 1991
For Abstract see entry 1B-002.

2G. MECHANICAL

[1993] 2G-1

DESIGNING ELECTRICAL POWER EQUIPMENT TO WITHSTAND SEISMIC LOADS
Berggren, S.; Enblom, R.
ABB Review
no.10 p.23-32 1993
Equipment and supporting structures for power transmission installations and substations sited in seismically active regions have to be designed to withstand possible earthquakes. Procedures used to verify the seismic design of equipment include simulations based on the finite element method combined with either response spectrum or time history analysis. (12 Refs)

[1993] 2G-2

SEISMIC VERIFICATION OF THE CONVERTER STATIONS FOR NEW ZEALAND'S UPGRADED DC HYBRID LINK

Coad, N.; Berggren, S.; Enblom, R. Trans Power New Zealand Ltd., Wellington, New Zealand

ABB Review

no.8 p.29-38, 1993

The two electrical transmission and distribution systems of the principal islands of New Zealand have been connected by a 600 MW high-voltage direct current (HVDC) link since 1965. A major project has doubled the capacity of the link and allowed low-cost South Island hydropower to be transmitted to the major load centers in the North Island. The link owner required seismic verification for the key electrical equipment. Most of the equipment was seismically qualified by dynamic analysis with the level of sophistication governed by the complexity of the problem. Modal and response spectrum elastic analyses were used as a first choice, with time history and nonlinear analysis used where warranted. The main tool used by ABB for seismic analysis is the finite element code RAMSES. (3 Refs)

[1991] 2G-3

STRUCTURAL COMPOSITES IN HVDC EQUIPMENT

Alexander, W.D. GEC Alsthom TDP Ltd., Stafford, UK

IEE Colloquium on 'Structural Use of Composites in High Voltage Switchgear/Transmission Networks' (Digest No.223)

p.1/1-7. 1991

High voltage DC equipment benefits from the use of composite materials in a number of forms, one of which is in the form of electrical insulating structural members. The author concentrates on how composite materials have been exploited in the HVDC convertor valves to ensure that the function of this equipment is maintained over its working life.

2H. SUPERCONDUCTING APPLICATIONS

[1991] 2H-1

BENEFIT/COST COMPARISONS FOR UTILITY SMES APPLICATIONS

De Steese, J.G.; Dagle, J.E.

Proceedings of the 26th intersociety energy conversion engineering conference in Boston, MA ,

3-9 Aug. 1991, pp 550-554.

This paper summarizes eight cases studies that account for the benefits and costs of superconducting magnetic energy storage (SMES) in system-specific utility applications. Four of these scenarios are hypothetical SMES application in the Pacific Northwest, where relatively low energy costs impose a stringent test on the viability of the concept. The other four scenarios address SMES applications on high-voltage, direct-current (HVDC) transmission lines. While estimated SMES benefits are based on a previously reported methodology, this paper presents results of an improved cost-estimating approach that includes an assumed reduction in the cost of the power conditioning system (PCS) from approximately $160/kW to $80/kW. The revised approach results in all the SMES scenarios showing higher benefit/cost ratios that those reported earlier. However, in all but two cases, the value of any single benefit is still less than the unit's levelized cost. This suggests, as a general principle, that the total value of multiple benefits should always be considered if SMES is to appear cost effective in may utility applications. These results should offer utilities further encouragement to conduct more detailed analyses of SMES benefits in scenarios that apply to individual systems.

[1993] 2H-2

DAMPING OF CURRENT OSCILLATION IN SUPERCONDUCTIVE LINE APPLIED FOR HIGH VOLTAGE DIRECT CURRENT TRANSMISSION SYSTEM

Kimura, Noriyuki; Funaki, Tsuyoshi; Matsu-ura, Kenji

1992 Applied Superconductivity Conference IEEE Transactions on Applied Superconductivity

v 3 n 1 pt 2 Mar 1993. p 223-225

Application of superconductive transmission line to an high voltage direct current (HVDC) transmission is easier and more advantageous than that to an AC transmission system. However, unstable phenomena similar to an AC system are introduced. We suggest installing a damper circuit, which consists of L and R in parallel, to prevent such instabilities. Computer simulation results show the effectiveness of the

damper for damping unstable DC current oscillation and the small loss in damper R.

[1992] 2H-3

ELECTRIC ENERGY AND ITS TRASPORTATION TECHNOLOGIES IN THE 21ST CENTURY. ELECTRIC POWER TRANSMISSION AND STORAGE OF HIGH DENSITY BY MEANS OF APPLIED SUPERCONDUCTING TECHNOLOGY

Nitta, T. (Kyoto University, Kyoto (Japan). Faculty of Engineering)

Denki Gakkai Zasshi (Japan)

15 Aug 1992 p 601-605. In Japanese.

In view of electric power transmission and storage in the 21st century, application of superconductivity is considered. The superconductivity-applied electric power system is expected to be effective for size reduction of the equipment, high efficiency, control of short-circuit current, measures for power system stability, and high density/high reliable transmission. Presently, AC transmission losses are 10% of the overall loss of the electric power system, and for reduction of this loss, superconductive power transmission is considered. However, the system pays only after transmission power is more than several GWs. It is still far from meeting the present needs. Losses in DC transmission are expected to be more lowered. SMES (superconducting magnetic energy storage), which is a storage of energy in superconducting magnet in the form of magnetic energy, has high storage efficiency. It can be used for multiple purposes such as increase in electric power system stability, voltage stability and frequency control. If it is a 5,000MWh class, SMES can be reducible in cost. The problem is production technology of large-capacity superconducting magnet. Also explained are superconducting current limiter, superconducting transformer and superconducting generator.

[1991] 2H-4

FUNDAMENTAL TEST OF NEW DC SUPERCONDUCTING FAULT CURRENT LIMITER

Ishigohka, T.; Sasaki, N.

IEEE Transactions on Magnetics

Mar 1991 p 2341-2344

This paper presents a superconducting DC fault current limiter (SCDCFCL) to suppress a short-circuit current in DC transmission line. The SCDCFCL is composed of two superconducting windings wound on a single iron core. The authors fabricated a small experimental SCDCFCL and confirmed the fundamental operation. The experimental results are presented. And, some considerations for a future full-size design are also presented.

[1991] 2H-5

ON THE OPERATION OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE DEVICES CONNECTED TO POWER NETWORKS

Karner, J.F.

Archiv fur Elektrotechnik

vol.75, no.1 p.51-60 1991 West Germany Language: German

In order to realize superconducting energy storage devices in electric utility systems, attention has to be given to the connecting circuit and the control scheme. The requirements as derived from different modes of operation of the storage module are discussed, and suitable converter types to couple storage and grid are compared. A self-commutated voltage-source converter turns out to be the best solution. As to the superconductor and eddy-current-losses, they depend mainly on the mode of operation of the storage device, while DC side harmonics due to the converter are only of minor influence. An example related to an experimental storage unit to be installed at the TU Munchen is given. (34 Refs)

[1991] 2H-6

POWER CONTROL APPLICATIONS ON A SUPERCONDUCTING LVDC MESH

Johnson, B.K.; Lasseter, R.H.; Adapa, R.

IEEE Transactions on Power Delivery

Jul 1991 p 1282-1288.

The behavior of a high current, low voltage DC system is studied. The DC system is made up of superconducting cables connected in a meshed configuration. The system could be made up of several large rectifiers feeding hundreds of small inverters connected to points in one or more AC systems. A unique aspect of this superconducting configuration is power transmission at the optimal generator voltage level. This voltage level is also close to the subtransmission system voltage, eliminating the need for high voltage insulation and transformers. A reduced system with one rectifier feeding three inverters is studied in this paper. The ability to control the output power from the inverters, both locally and globally is demonstrated. Power control on the circuit with the addition of a superconducting magnetic energy storage coil is also studied. The large inductance of the coil changes the dynamic response of the system, and requires a modification of the control system.

[1993] 2H-REF

STEADY-STATE MATHEMATICAL MODELS OF CONVERTORS WITH BIPARAMETRIC REGULATION
Carpinelli, G.; Gagliardi, F.; Sturchio, A.; Russo, M.
IEE Proceedings, Part C: Generation, Transmission and Distribution
Mar 1993 p 105-114
For Abstract see entry 6B-032.

2I. AUDIBLE NOISE

[1991] 2I-1

A PREDICTION METHOD OF AUDIBLE NOISE AND RADIO NOISE GENERATED FROM HVDC TRANSMISSION LINE WITH 4X3.84 CM CONDUCTOR BUNDLES
Nakano, Y.; Sunaga, Y.
Electrical Engineering in Japan
vol.111, no.7 p.68-77, 1991
Electrical environmental problems are becoming increasingly important in designing HVDC transmission lines and audible and radio noises are key factors for determining the conductor scheme of a transmission line. For this reason, CRIEPI has been developing methods to predict audible and radio noise levels of a bipolar single-circuit transmission line with voltage of less than +or-500 kV. The authors propose a prediction method for audible and radio noises using statistically reliable data of ACSR 810 mm/sup 2/ four conductors, which were collected through the field observation of a 3-year period. Effectiveness and high prediction accuracy of the proposed method are confirmed by a large quantity of measured data. The proposed method is also applicable to the noise level prediction under arbitrary polarity and conductor arrangements. (11 Refs)

2J. INSULATORS, BUSHINGS

[1993] 2J-1

A CALCULATION METHOD AND SOME FEATURES OF TRANSIENT FIELD UNDER POLARITY REVERSAL VOLTAGE IN HVDC INSULATION
Wen, K.C.; Zhou, Y.B.; Fu, J.; Jin, T.
IEEE Transactions on Power Delivery
Jan 1993 p 223-230
A transient electric field takes place in the insulation media with permittivity and resistivity during boundary excitation changing from one steady-state to another, such as a polarity reversal voltage imposing on the insulation of HVDC apparatus. This paper presented a numerical solution and developed a calculation program for such transient field. The method was proved with calculation results of some illustrative examples including a typical bushing barrier system of converter transformers. Some distinguishing features of the transient field were also discussed.

[1992] 2J-2

ARTIFICIAL POLLUTION TESTING OF HVDC INSULATORS: ANALYSIS OF FACTORS INFLUENCING PERFORMANCE
de Decker, D.; Perin, D.; Lambeth, P.J.; Lampe, W.D.; Marrone, G.; Naito, K.; Niklasch, H.; Schneider, H.M.
Electra
no.140 p.98-113 Feb. 1992
Artificial pollution test methods for DC insulators have not yet been established, while those for AC are quite well established. IEC Pub. 507 reflects lengthy discussions and recommends the procedures for AC. The procedures for DC artificial pollution testing are being discussed by IEC TC 36 WG 09 in cooperation with Oigre TF 33.04.01 and TF 33.04.04. Based upon the results of investigations conducted at various international laboratories, it has been recognized that almost the same test methods can be adopted for testing with DC as are being used for AC. Here, the authors analyse the factors influencing the performance of HVDC insulators in artificial pollution tests. (37 Refs)

[1991] 2J-3

CLEAN FOG AND LIVE WASHING PERFORMANCE OF VERTICAL HVDC BUSHINGS.
Schneider, H. M.; Guidi, W. W.; Gleadow, J. C.
IEEE Transactions on Power Delivery
v 6 n 4 Oct 1991 p 1812-1818
An alternative bushing design for HVDC systems is investigated. The bushing is vertical in orientation and intended for roof installation. Methods of maintaining reliable operation of the bushing in a severe marine contamination environment are explored by means of a fixed washing system designed to provide sufficient cleaning to avoid contamination flashover. Results of both clean fog and washing system tests are reported.

[1992] 2J-4

CLEAN FOG RAPID PROCEDURE TEST OF ARTIFICIALLY AND NATURALLY POLLUTED HVDC PORCELAIN BARREL INSULATORS
Vlastos, A.E.; Felju,, Ye ; Boubitsas, Vassiliki.
IEEE Transactions on Power Delivery
Jul 1992 p 1504-1506
The first question asked in this paper refers to the variation of the peak leakage current prior to the flashover and the variation of the time prior to flashover in the test of artificially polluted insulators when using the up-and-down method. To answer this question sums up the test procedure used in the up-and-down method. For each trial represented the insulator was again polluted artificially and then dried following the procedure described in the paper. Then the insulator was transported into the fog chamber and the voltage and fog was switched on simultaneously. In these experiments a low fog injection rate was used.

[1992] 2J-5

CORRECTION TO 'CLEAN FOG RAPID PROCEDURE TEST OF ARTIFICIALLY AND NATURALLY POLLUTED HVDC PORCELAIN BARREL INSULATORS'
Vlastos, A.E.; Feiyu, Y.; Boubitsas, V.
IEEE Transactions on Power Delivery
vol.7, no.3 p.1504-6 July 1992 In English
In the above-named paper by A.E. Vlastos et al. (see ibid., vol.6, no.4, p.1791-8, 1991), a discussion and the closure, which should have appeared after page 1798, were missing. These pages are supplied.

[1991] 2J-6

DC SOURCE CHARACTERISTICS FOR TESTING INSULATORS UNDER POLLUTED CONDITIONS
Ravi, K.N.; Vasudev, N.; Mujumdar, A.K.; Channakeshava; Ratra, M.C.
Seventh International Symposium on High Voltage Engineering
p.119-21 vol.5 26-30 Aug. 1991
The improved technology of thyristor controlled rectifiers and inverters, and increasing awareness of the advantage of HVDC lines over AC lines has made many countries to adopt HVDC transmission systems. The problem of reliability of the lines becomes more severe in an HVDC transmission system. The failure rate of insulators and flashover incidents are more frequent in the case of DC lines especially in pollution prone areas. In order to design the insulators for pollution areas or to check the existing design of insulators to withstand the pollution severity, insulators have to be subjected to tests under specified polluted conditions. Tests were carried out with 150 kV, 1 ampere DC source at the Central Power Research Institute, in order to determine the characteristics of the DC source. (3 Refs)

[1992] 2J-7

DEVELOPMENT OF OPTIMIZED DC STATION POST INSULATORS
Baker, A.C. (Lapp Insulator Co., Le Roy, NY (United States)); Schneider, H.M.; Howes, D.R. (General Electric Co., Lenox, MA (United States). High Voltage Transmission Research Center)
EPRI Electric Power Research Inst. Report Number EPRI-TR-100267
Jan 1992 (124 p)
This report describes research conducted to determine the contamination performance of HVDC station post insulators. The contamination severity on post insulators in four different HVDC converter stations was obtained by a series of field measurements. The data were analyzed to show the effect of polarity, stress, voltage magnitude and distribution of contaminant along and around in the insulators. Recommendations were made for subsequent laboratory evaluation of post insulator flashover strength using the clean fog artificial contamination test, procedure. The effect of shed configuration was investigated in those laboratory tests using full scale station posts with significantly different geometric profiles. Test results were also obtained for naturally contaminated post insulators exposed to DC voltage. Comparisons of HVAC and HVDC contamination performance of post insulators were made in order to relate the DC performance to that of AC where more experience is available. The influence of shape parameters on the accumulation of contaminant was studied by means of a dust deposit chamber. Improvements in the withstand capability of post insulators with special treatments, such as semi-conductive glaze or room temperature vulcanized silicone rubber coatings, were explored

[1991] 2J-8

ELECTROLYTIC CORROSION OF METAL HARDWARE OF HVDC LINE AND STATION INSULATORS
Taniguchi, T.; Watanabe, M.; Watanabe, Y.; Mori, S.; Watanabe, A.; Naito, K.
IEEE Transactions on Power Delivery
Jul 1991 p 1224-1233
Insulators on HVDC lines may be damaged or lose their mechanical strength by electrolytic corrosion of the metal hardware. DC exposure tests of insulators have been conducted for 20 years at the Central Research Institute of Electric Power Industry. This

paper describes the results of investigation on the electrolytic corrosion of the metal hardware of DC disc and cylindrical insulators and on the leakage electricity quantity flowing on their surface. It also describes methods of life estimation of the metal hardware of insulators and prevention against the corrosion.

[1991] 2J-9

FIELD DISTRIBUTION ON AN HVDC WALL BUSHING DURING LABORATORY RAIN TESTS

Lampe, W.; Wilkstrom, D.; Lacobson, D.

IEEE Preprint # 91 WM 125-5 PWRD.

1991

An efficient counter-measure to suppress flashovers across HVDC wall bushing is to make their surface hydrophobic. This laboratory investigation reports the measured electric field along such a bushing under different environmental conditions. A significantly reduced radial strength has been found for the hydrophobic bushing. Moreover, the total field strength distribution becomes almost independent of the prevailing dry zone. The flashover voltage for bushings with a hydrophobic surface is therefore significantly increased.

[1991] 2J-10

HVDC SOURCE REQUIREMENTS IN POLLUTED INSULATOR TESTS

Rizk, F.A.M.

Electra

no.136 p.96-111 June 1991, France In French and English

This paper constitutes a critical review of experimental and analytical work on the interaction between an HVDC test source and a contaminated insulator, with particular reference to critical arcing conditions. The aspects investigated include: the output capacitor; the AC supply; the DC damping resistor; and feedback control. The author provides some basis for the standardization of source requirements and includes guidance for the design of a test source to meet such requirements. (19 Refs)

[1993] 2J-11

IMPROVEMENT OF THE ELECTRICAL PROPERTIES OF GLASS BY LITHIA ADDITION

Chen Guorong; Hu Shuigen

American Ceramic Society Bulletin

Apr 1993 p 85-88

The electrical properties of toughened glass insulators used in transmission lines are of great importance. The electrical properties of glass insulators can be improved, while maintaining low viscosities and other desirable forming properties, by the the depressing effect' (i.e., the effect of substituting alkaline-earth oxides for a part of the SiO_2 when developing a glass composition). To satisfy some specific application needs, a combination of both the depressing effect and mixed-alkali effect should be considered. The common practice of the latter essentially relies on increasing the ratio of K_2O to Na_2O in the glass, which, from a theoretical standpoint, undoubtedly results in better electrical properties of the glass, but with some unfavorable impact on the viscosity of the glass which may preclude its regular use. However, previous studies have shown that the mixed-alkali effect varies with the types of ions present. In the present paper the authors report on an investigation of the substitution of Li_2O for K_2O, which increases the resistivity but maintains the low viscosity.

[1991] 2J-12

INSOLUBLE MATERIALS IN ARTIFICIAL TEST OF CONTAMINATED INSULATORS

Ishii, M.; Kurokawa, M.; Matsumoto, T.; Komatsubara, M.; Naito, K.; Matsuoka, R.

Seventh International Symposium on High Voltage Engineering

p.191-4 vol.4 26-30 Aug 1991, Dresden, Germany. Published by Dresden University

It was reported that the DC flashover voltage under artificial contamination test was sometimes considerably affected by the type of insoluble materials in the contaminant. To clarify the cause of this phenomenon, the surface conductivity and the flashover voltage of the artificially contaminated surfaces are measured under clean fog condition. The experiment leads to a conclusion that the dependence of the flashover voltage on the type of insoluble materials is mainly caused by the characteristics in the formation of water films on the contaminated surfaces. (7 Refs)

[1993] 2J-13

INVESTIGATION OF HVDC WALL BUSHING FLASHOVER IN NONUNIFORM RAIN AND PREVENTIVE MAINTENANCE

Sun Zhaoying; Lai Xiaokang; Chen Xing

Power System Technology

no.3 p.22-7 May 1993

The test methods for nonuniform rain are discussed. The effect of rain conductivities on the flashover voltage is studied. The flashover mechanism is proposed. Booster sheds and RTV coating have been found to improve wall bushing performance greatly. (5 Refs)

[1992] 2J-14

INVESTIGATION OF SINGLE UNIT FLASHOVER IN HVDC INSULATOR STRINGS
Matsuoka, R.; Ito, S.; Sakanishi, K.
Transactions of the Institute of Electrical Engineers of Japan
20 Jan 1992 p 36-41. In Japanese.
There is a specific phenomenon called single unit flashover occured with DC insulator strings. It has been observed under some special contaminated and wet conditions not only in laboratories but also in actualDC transmission lines. The single unit flashover causes higher magnitudes of continuous audible noise, radio interference and television interference in the vicinity of transmission lines. Studies to simulate this phenomenon under normal operating voltage conditions have been made so far. In this paper, the phenomenon is investigated by operating voltage after contaminated insulator strings are wetted beforehand (under cold-wet-switch-on conditions). In the test under such conditions, higher occurrence probability of single unit flashover was obtained compared with the case of conventional conditions where insulator strings were wetted with mist during operating voltage. The noise level was almost equivalent in both cases. Furthermore, effects of some measures to prevent the single unit flashover were examined. One of them is a method to coat the surface of some insulators with silicone grease.

[1991] 2J-15

MECHANISM OF HVDC WALL BUSHING FLASHOVER IN NONUNIFORM RAIN.
Scheider, Herman M.; Lux, Andre E. EPRI High Voltage Transmission Res Center, Lenox, MA,
IEEE Transactions on Power Delivery
v 6 n 1 Jan 1991 p 448-455
A model which assumes a dry zone of changing length is used to determine conditions which may lead to flashover of HVDC wall bushings in nonuniform rain. The key parameter in the proposed mechanism is the ratio of the resistance per unit length of the wet region to the resistance per unit length of the drier region. Measurements of the surface resistivity are presented for horizontal insulators, including wall bushings, with different surface conditions subjected to rain. Such measurements can be utilized to evaluate the potential capability of various materials to prevent wall bushing surface flashover in nonuniform rain.

[1991] 2J-16

MODELLING OF HVDC WALL BUSHING FLASHOVER IN NONUNIFORM RAIN
Rizk, Farouk A.M.; Kamel, Sherif, I.
IEEE Preprint # 91 WM 124-8 PWRD.
1991
This paper presents the first mathematical model to provide necessary and sufficient conditions for flashover of an HVDC wall bushing under nonuniform rain. The findings of the model have been satisfactorily compared with previous experiments and field observations and can, for the first time, account for the following aspects of the flashover mechanism: critical dry zone length, polarity effect, specific leakage path, wet layer conductance per unit leakage length as well as DC system voltage.

[1991] 2J-17

NATURAL CONTAMINATION TEST RESULTS OF VARIOUS INSULATORS UNDER DC VOLTAGE IN AN INLAND AREA IN CHINA.
Li, Qisheng; Wang, Lai; Su, Zhiyi; Liu, Yansheng; Morita, K.; Matsuoka, R.; Ito, S.
Proceedings of the 3rd International Conference on Properties and Applications of Dielectric Materials
Tokyo, Japan 1991 Jul 8-12
The authors describe the natural contamination test results of six types of insulators exposed in the southern suburbs of Beijing. The station stands near the eastern terminal of a DC transmission line. It is also located in a smooth terrain, a typical farming area on the North China Plain. The maximum annual equivalent salt deposit density (ESDD) and nonsoluble deposity density (NDD) on insulator surfaces were 0.038-0.057 mg/cm**2 and 0.144-0.425 mg/cm**2, respectively, in winter or early spring. The contamination on the surface of a DC energized insulator was 20% more than that of an AC energized one. When contaminants grew markedly, the top surface of the insulators attracted more contaminants than the bottom surface, especially in the case of aerodynamic and outside rib type insulators. There has been a heavy decrease in the contamination degree of insulators after the rainy season.

[1992] 2J-18

NONUNIFORM RAIN FLASHOVER MECHANISM OF HVDC WALL BUSHINGS
Rizk, F.A.M.; Beausejour, Y.; Desilets, G.L.; Kamel, S.I.
CIGRE Proceedings of the 34th Session
p.14-301/1-5 vol.1 30 Aug.-5 Sept. 1992
The paper reports on an experimental investigation into surface resistance and minimum flashover stress

of HVDC wall bushings under nonuniform rain. The resistance measurements follow the progression of wetting from dry conditions until quasi-steady conditions are achieved. The dependence of the flashover stress on dry zone length and wet layer conductance is investigated. Also the effect of dry zone position and voltage polarity is reported. The experimental findings are compared to the predictions of a recently formulated mathematical model of the flashover mechanism, resulting in excellent agreement. Finally, the model is used to assess the performance of a bushing coated with new and field aged RTV as well as to compare the strength of an SF/sub 6/ bushing to that of a conventional oil-paper design under nonuniform rain.

[1991] 2J-19

NONUNIFORM RAIN FLASHOVERS ON HVDC WALL BUSHING

Sun Zhaoying; Chen Xing; Lai Xiaokang

Seventh International Symposium on High Voltage Engineering

p.179-81 vol.4 26-30 Aug 1991, Dresden, Germany. Published by Dresden University

The rain flashovers on HVDC wall bushing and the means of improving its performance are studied. By performing the nonuniform rain flashover test on the wall bushing, its critical flashover voltages under various wetting conditions are obtained. The effects of rain conductivities on its flashover voltage and critical dry zone width are investigated. Two test methods are compared. The RTV coating and booster sheds have been found to improve its performance greatly. HVAC voltage rain tests were also carried out. (2 Refs)

[1991] 2J-20

ON THE DESIGN, TESTING AND OPERATING EXPERIENCE OF COMPOSITE DRY BUSHINGS IN HVDC

Rashwan, N.M.; McDermid, W.; Hammer, F.; Kuechler, A.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

London , UK 17-20 Sept. 1991 Conf. Publ. No.345 p.325-30)

As part of the ongoing attempts to solve the external flashover problem of HVDC wall bushings, Manitoba Hydro installed a 500kV DC composite dry wall bushing with hydrophobic silicone rubber sheds. The bushing was installed in the negative pole (-500kV) on the valve winding side of the high voltage converter group at the inverter. The location was chosen from past service experience. In the past the majority of the flashovers had occurred at the inverter and on the negative polarity bushings. These events have been consistent in both bipoles. The choice of the valve winding side of the converter group was based on the fact that when a flashover occurs the resulting overvoltage leads to the sparkover of the top valve arresters; consequently a short circuit between the two AC phases develops. By installing the bushing at this location it will be subjected to: 1. the overvoltage resulting from the flashover of another valve winding bushing; 2. the large short circuit current, if the flashover occurs on the composite bushing. The design and testing of the bushing is described in this paper.

[1991] 2J-21

RAIN AND CONTAMINATION TESTS ON HVDC WALL BUSHINGS WITH AND WITHOUT RTV COATINGS

Schneider, H.M. (EPRI High Voltage Transmission Research Center, Lenox, MA; Hall, J.F. (Electric Power Research Inst., Palo Alto, CA); Nellis, C.L. (Bonneville Power Administration, Portland, OR); Low, S.S. (Los Angeles Dept. of Water and Power, Los Angeles, CA); Lorden, D.J. (New England Power Service Co., Westborough, MA)

IEEE Transactions on Power Delivery

Jul 1991 p 1284-1300

In this paper results of tests made to determine the ability of room temperature vulcanized (RTV) silicone rubber coatings to improve the performance of HVDC wall bushings are described. The behavior of uncoated full scale {plus minus} 500 kV wall bushings is first determined in wetting conditions consisting of nonuniform rain and fog with various amounts of pre-deposited surface contamination. Parameters affecting flashover performance, such as polarity, rain conductivity, and contamination severity are discussed. Results of nonuniform rain tests on an RTV coated wall bushing are reported on hard disk space required to store example applications while still providing quick access to the examples. The catalog system provides the user three options: (1) review examples, (2) retrieval of examples to hard disk, and (3) update capability for new examples to the catalog system.

[1993] 2J-22

SERVICE PERFORMANCE OF HVDC WALL BUSHINGS

Lambeth, P.J.; Schneider, H.M.

Canadian Electrical Association, Montreal,

1993 MIC-93-06063/XAB Available from NTIS

This paper describes a survey of service performance of HVDC converter station insulators, with special reference to wall bushings which have had a record of flashovers and failures which cannot be readily accounted for by common causes. The scope of the

survey is given, and the methods of presentation and analysis of the data collected are demonstrated. The numbers and physical characteristics of the insulators on site together with the details of individual faults comprise the essential data. Suggestions are made for improvements and systemisation for fault reporting. The analysis of the maintenance procedures and means of preventing flashover which have been used give an indication of their effectiveness.

[1991] 2J-23

SOME ASPECTS ON DC POLLUTION TESTS
Braendlin, F.; Freiberg, E.; Truempy, K; Gockenbach, E.
AC and DC power transmission (Polluted insulators in DC power transmission systems.) IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 331-336 (443 p)
The requirements on reliability, safety and availability of DC transmission systems increase with the importance of the equipment. Insulators, which are polluted due to air pollution, rain, snow, fog, etc, are one of the weakest points. Tests on polluted insulators are very difficult, because an interaction between the test source and the test object exists. Therefore no specifications are available, which describes clearly the polluted insulator. Furthermore, flashover development takes a certain time in the range of several tens of minutes and depends on different parameters, like radius of the insulator and design of the insulator shed, the design of the shed overhand, the radius of shed, creepage distance, flashover distance, etc. All these parameters contribute to the probability of flashover, which leads to a large number of tests to define the flashover or withstand voltage. A standardization of the necessary test equipment is therefore very difficult and up to now no recommendation on source requirements for DC tests on polluted insulators exists. In this paper, the requirements for the design of a test source, a test object and test equipment for polluted insulator tests are examined.

[1991] 2J-24

STUDIES ON THE MECHANISM OF FLASHOVER ALONG AN UNEVEN-WETTED INSULATING SURFACE
Zheng Jianchao; Sun Zhaoying; Chen Xing; Lai Xiaokang; Yin Yifeng
Seventh International Symposium on High Voltage Engineering
p.183-6 vol.4 26-30 Aug 1991, Dresden, Germany. Published by Dresden University
Uneven wetting flashover was investigated on a surface discharge model simulating the field pattern of a wall bushing. The influence of field pattern and surface conditions on the flashover voltages was studied experimentally. The field distribution along the surface of wall bushings was simulated using an equivalent network. The mechanism responsible for very low flashover voltage of wall bushings and the remedial measures are discussed. (4 Refs)

[1991] 2J-25

STUDY ON DC BREAKDOWN PHENOMENA OF THE LIQUID/SOLID COMPOSITE DIELECTRICS
Narasaki, N.
Research Reports, School of Science and Technology, Meiji University
no.3 p.41-71 1991 Country of Publication: Japan. In Japanese .
High voltage DC power transmission systems will be used increasingly in Japan in the future. For some of the DC equipment, an oil/polymer composite will be the electrical insulation system. The author describes the investigation of breakdown phenomena of silicone oil/several polymer films composite dielectrics in a point-plane electrode system. In this composite system, it has been generally recognized that the breakdown voltage of such composites was higher than for the oil alone, because the film acted as a barrier. This dielectric phenomenon has been named the barrier effect. In the present investigation, with the needle positive, that was just so. However, with the needle negative, the breakdown voltage of some oil/film composite was lower than that of the oil alone. In this case, the film because a defect of the insulation system. This is attributed to negative ions deposited on the film which create a high field and initiate breakdown in the film. The measurement with partial discharge of composites and electrification at the oil/polymer interface supported it. (31 Refs)

[1991] 2J-26

TRACKING OF PORCELAIN AND GLASS UNDER DC STRESS
Ratra, M.C.; Moorching, S.N.; Hemalatha, B.; Sumangala, M.G.; Poovamma, P.K.
Seventh International Symposium on High Voltage Engineering
p.291-4 vol.2 26-30 Aug 1991, Dresden, Germany. Published by Dresden University
A large number of failures of insulators and bushings on HVDC lines has triggered a worldwide research into the surface behavior of outdoor insulation, under combined DC and environmental stress. Understanding of such a problem needs both

laboratory and theoretical studies. The percentage of alkali content by weight in an insulator strongly influences its surface behavior under DC stress. The present investigations are primarily aimed at studying the effect of varying alkali content on the track and erosion behavior of electroporcelain. The comparative performance of toughened glass shells under similar conditions has been studied and discussed. Microstructural and salt analysis of discharge products have been carried out to give a better insight into the processes leading to surface failure. (4 Refs)

[1991] 2J-REF

MODELLING OF HVDC WALL BUSHING FLASHOVER IN NONUNIFORM RAIN
Rizk, F.A.M.; Kamel, S.I.
IEEE Trans... tions on Power Delivery
Oct 1991 p 1650-1662
For Abstract see entry 6B-025.

[1991] 2J-REF

HIGH POWER HVDC TEST EQUIPMENT FOR POLLUTION TESTING
Trumpy, K.; Brandlin, F.; Freiberg, E.
Seventh International Symposium on High Voltage Engineering
p.115-1... ol. 5 August 26-30, 1991, Dresden Germany. Published by Dresden University
For Abstract see entry 7B-002.

2K. GAS INSULATED SYSTEMS

[1993] 2K-1

ADDENDUM II TO BIBLIOGRAPHY OF GAS-INSULATED SUBSTATIONS WORKING GROUP K9 OF THE GAS-INSULATED SUBSTATIONS SUBCOMMITTEE OF THE IEEE/PES SUBSTATIONS COMMITTEE
Quinata, J.F.; Matulic, R.; Laskowski, L.M.; Nannery, P.R.
IEEE Transactions on Power Delivery
Jan 1993 p 73
This Addendum II to the bibliography of Gas-Insulated Substations, which was published in the IEEE Transactions on Power Delivery, Vol. 4, No. 2, April 1989, was prepared by Working Group K9 of the Gas-Insulated Substations Subcommittee of the IEEE/PES Substations Committee. The new entries included an update of the Bibliography to mid-1991.

[1991] 2K-2

AN APPROACH TO THE SPACER DESIGN OF HVDC SF//6 GAS INSULATED EQUIPMENT.
Akimov, V. V.; Varivodov, V. N.; Volpov, E. K.
Proceedings of the 3rd International Conference on Properties and Applications of Dielectric Materials
1991 Jul 8-12
Some of design and technological measures employed to increase SF//6 insulation reliability are discussed. It is pointed out that the insulation characteristics of SF//6 HVDC equipment markedly differ from those of analogous HVAC equipment. The minimum discharge electric stress values measured with long-term voltage application and reduced to the gas pressure are approximately equal to 20 MV/m multiplied by MPa, which is substantially lower than values measured with smooth voltage rise; a decreased electric strength on the insulator surface is directly associated with transient processes in the insulation, caused by free surface charge distortion. The generalization of the calculated and experimental data concerning the electric characteristics of CEI/SF//6 DC insulation has enabled the formulation of a general approach to choosing proper HVDC SF//6 equipment spacer configurations. This approach is based on the criterion of spacer-accumulated surface charge minimization. As a technological measure the abrasive treatment of the insulation surface as well as using external shielding electrodes with dielectric coating is recommended. 6 Refs.

[1991] 2K-3

AN APPROACH TO THE SPACER DESIGN OF HVDC SF6 GAS INSULATED EQUIPMENT
Varivodov, V.N.; Volpov, E.K.
Seventh International Symposium on High Voltage Engineering
p.41-4 vol.3 1991
It is known that the DC electric strength of pure SF6 gaps is almost the same as that for AC ones. However, the DC electric strength of real insulation systems including epoxy spacer supports is apparently lower than that with AC. One of the major causes of such phenomena is related to the difference between AC and DC spacer electric field formation mechanisms. There are free electric charge accumulation processes on the spacer surface during long-term DC voltage application. This may lead to substantial distortion of an initial (capacitive) field distribution near the spacer surface and as a result to a decrease in flashover voltage. In this connection, the design criteria developed for AC spacers are not valid for their using with DC insulation. The authors discuss some design and technological measures in order to increase SF6 insulation reliability. (6 Refs)

[1991] 2K-4

CHARGE ACCUMULATION ON INSULATING SPACERS FOR HVDC GIS.
Nitta, T.; Nakanishi, K.
Mitsubishi Electric Corp, Hyogo, Japan IEEE Transactions on Electrical Insulation
v 26 n 3 Jun 1991 p 418-427
A capacitive probe measurement that can be used to quantify the charge density on solid insulators is introduced. Studies performed in the development of a plus or minus 125 kV high-voltage DC (HVDC) gas-insulated converter station and plus or minus 500 kV HVDC switchgear (HVDC-GIS) are reviewed. The properties and mechanisms of surface charging, the optimum design of the spacer and its breakdown characteristics are summarized. Problems associated with capacitive probe measurement of surface charge and a practical solution to obtain the charge distribution on the spacer are presented.

2L. SURGE ARRESTERS

[1991] 2L-1

APPLICATION OF ZNO VARISTOR PROTECTION TO CAPACITORS OF ARTIFICIALLY COMMUTATED INVERTER IN MTDC SYSTEM
Manohar, P.; Chandrasekharaiah, H.S.
IEEE Transactions on Power Systems
Feb 1991 p 356-363
The dynamic analysis of a mesh type multiterminal HVDC (MTDC) transmission system including an artificially commutated inverted (ACI) with varistor protected series capacitors is carried out using digital simulation technique. The study shows that the varistor protection is feasible and improves the performance of normal rated inverters which connect weak AC systems. It reduces the magnitude of dynamic overvoltage and the peak direct current at the ACI during abnormal conditions resulting in a significantly improved dynamic performance of the MTDC system.

[1991] 2L-2

DC ARRESTER TEST PHILOSOPHIES ON RECENT HVDC PROJECTS AS USED BY VARIOUS SUPPLIERS
Melvold, D.J.
IEEE Transactions on Power Delivery
Apr 1991 p 672-679
The paper serves to document recent/current practice in DC arrester testing, to open a dialogue leading to the generation of publications and encouragement of discussions in the area, which hasten and ultimately lead to the earlier development of DC arrester testing standards. Included in the paper is a review of current practice and heretofore unpublished material on testing on three recent projects as examples.

[1993] 2L-3

STUDY OF WATT LOSS CHARACTERISTICS OF METAL OXIDE SURGE ARRESTERS FOR HVDC CONVERTER STATIONS AND THEIR EQUIVALENT TESTING VOLTAGE WAVE SHAPES
Fujimoto, T.; Higuchi, T.; Onishi, S.; Azuma, M.; Yasuda, S.; Fujiwara, Y.
Transactions of the Institute of Electrical Engineers of Japan
20 Apr 1993 p 383-389
Watt loss and life characteristics of surge arresters for HVDC converter stations are studied, and the characteristics based on real voltage wave shapes and superimposed DC voltage waveform proposed as an equivalent waveform are compared and the equivalency of the two waveforms are studied. Watt loss characteristics of zinc oxide elements to actual voltage for the HVDC arresters at various operation conditions have been clarified. As a result, it has been revealed that watt loss has increased with the bigger actual waveform of direct current, and the thermal stability has been severe. As a result of the investigation of the watt loss characteristics and life characteristics of zinc oxide elements of superimposed DC voltage wave shape, the imitation wave shape of proposed frequency superimposed DC voltage for commercial purpose could be easily effective in actual practice during the experiment of surge arresters for HVDC converter stations. As for the superimposed alternating frequency, enough equivalency has been achieved with commercial frequency without the use of high frequency.

3. OVERHEAD TRANSMISSION LINES

3A. INSULATION

[1991] 3A-1

EFFECTS OF THE THICKNESS OF ICE AND VOLTAGE POLARITY ON THE FLASHOVER VOLTAGE OF ICE-COVERED HIGH-VOLTAGE INSULATORS
Farzaneh, M.
Seventh International Symposium on High Voltage Engineering
p.203-6 vol4 26-30 Aug 1991, Dresden, Germany. Published by Dresden University
The author studies the influence of the thickness of ice on DC flashover voltage of porcelain-type insulators during the melting periods. Using a cold room at a constant temperature of -12 degrees C, hard rime with a density of 0.87 was formed from supercooled droplets. The minimum flashover voltage as well as the conductivity and volume of water dripping from the insulators were then measured. The results obtained showed that under both DC- and DC+ the V/sub MF/ value decreased when the thickness of the ice measured on a monitoring cylinder increased from 0.5 to 2.0 cm and then remained constant. The melting effect led to more severe conditions under DC- than those under DC+. (7 Refs)

[1991] 3A-2

HYBRID TRANSMISSION CORRIDORS-CORONA AND FIELD EFFECTS
Clarimont, B.; Zaffanella, L.; Cabeza, L.; Stillman, G.; Zelingher, S.
Cigre Symposium. Compacting Overhead Transmission Lines
p.600-03/1-6 Conference held on 3-5 June 1991 in Leningrad, USSR.
Increasing difficulties in obtaining new rights-of-way for transmitting electric power over long distances call for the development of additional transmission options to maximize the power transfer capabilities of transmission corridors. One such option is the sharing of the same corridor by HVAC and HVDC transmission lines. The proximity between HVAC and HVDC conductors causes interactions between the two line types. The authors present the results of an investigation of the AC-DC interactions and its effect on corona and AC and DC electric field phenomena. The method of investigation was to perform numerous tests with a full-scale single test span comprised of adjacent HVAC and HVDC test lines. Tests were made in all weather conditions and in all four seasons. (8 Refs)

[1993] 3A-3

INDUCED OVERVOLTAGES ON AN AC-DC HYBRID TRANSMISSION SYSTEM
Verdolin, R.
Canadian Electrical Association, Montreal, PQ (Canada)
Report Number: MIC-93-05225/XAB - Available from NTIS 1993
Adding a DC circuit to an existing transmission line is one method of significantly increasing the power transfer capacity of the transmission corridor. The resulting hybrid system has significant coupling between the AC and DC circuits, not only because of the proximity of the circuits, but also from the fact that they could share the same sending end or receiving end AC systems. The resultant interaction produces overvoltages on the components of the system that can be somewhat higher than for a conventional DC scheme. The paper presents a study of these overvoltages using digital simulation. It is demonstrated how this approach can be used to select DC system components to avoid excessive system overvoltages and to determine the requirements for the surge arresters used to limit these overvoltages.

[1992] 3A-4

INSULATION CONTAMINATION PROBLEMS AND MITIGATION METHODS RECENTLY EMPLOYED AT BPA [BONNEVILLE POWER ADMINISTRATION]
Renner, P.E.; Gabriel, A.L.; Nellis, C.L.
Canadian conference on electrical and computer engineering Toronto (Canada)
13-16 Sep 1992
Although not a widespread problem at Bonneville Power Administration, contamination in localized areas has caused operating difficulties. Recent experience in three such areas is documented. One is natural contamination (alkali) occurring on the Pacific northwest-southwest 500 kV DC intertie. The other two are situations where substation insulation is contaminated by residual chemicals from evaporating water from nearby cooling towers. Investigation and mitigation measures for these three cases are described. In the first case the contamination was naturally occurring salts from loose alkali soils. Washing of insulators is an expensive, short-term

solution to the problem. Replacement of ceramic insulators by silicone rubber non-ceramic insulators (NCIs) is being implemented as a long-term solution. In the other two cases, the contamination was a highly conductive film caused by chemicals from evaporated cooling tower water. The coatings could not be removed by water washing, requiring abrasives to remove them. Mitigation alternatives under investigation include silicone greases, room temperature vulcanized (RTV) coatings, non ceramic insulators and resistive glaze insulators or coatings.

[1992] 3A-5

THE LIGHTNING PERFORMANCE OF HVDC TRANSMISSION LINES
Du Shuchun; Chen Weijiang
Proceedings of the CSEE
vol.12, no.2 p.58-64 March 1992 In Chinese
The influence of the HVDC transmission line operating voltage on the shielding effect of the earth wire has been studied based on the electrogeometrical theory. On a +or-500 kV HVDC transmission line with a single ground wire of 25 degrees shielding angle, when the lightning stroke is of negative polarity as in most situations, the flashover rate of shielding failure of the positive pole line is six times higher than that of the negative one. The shielding failure hardly occurs for lines with double earth wires. The lightning back flashover occurs only at positive polarity in general and the probability of back flashover for both poles is very low if tower-footing resistance is small. The lightning performance of HVDC transmission lines with a single earth wire is not satisfactory, which is applicable only in the area where lightning is not very active.

[1991] 3A-REF

EFFECTS OF THE THICKNESS OF ICE AND VOLTAGE POLARITY ON THE FLASHOVER VOLTAGE OF ICE-COVERED HIGH-VOLTAGE INSULATORS
Farzaneh, M.
Seventh International Symposium on High Voltage Engineering
p.203-6 vol4 26-30 Aug 1991, Dresden, Germany. Published by Dresden University
For Abstract see entry 3A-001.

3B. CLEARANCES

[1991] 3B-REF

AC AND/OR DC SUBSTANTIAL POWER UPGRADING OF EXISTING OHTL CORRIDORS.
Clerici, A.; Valtorta, G.; Paris, L.
Fifth International Conference on AC and DC Power Transmission
1991 Sep 17-20 IEE Conference Publication n 345. p 220-225
For Abstract see entry 1B-001.

3C. CORONA EFFECTS AND LOSSES

[1991] 3C-1

CORONA DETECTION USING IMAGE PROCESSING TECHNIQUES IN A HIGH VOLTAGE ENVIRONMENT
Moore, P.J.; House, H. , City Univ., London, UK.
Seventh International Symposium on High Voltage Engineering
p.71-4 vol. 7. 26-30 Aug 1991, Dresden, Germany. Published by Dresden University
The authors describe a method for accurate corona position determination on an energised object using image processing hardware specially designed for use in a high voltage environment. The technique allows the corona to be displayed using a colour intensity scale superimposed on a black and white image of the test object. Results are presented for DC corona using a point plane gap and AC corona using the arcing horn of a 132 kV insulator string. (2 Refs)

[1992] 3C-2

FINITE ELEMENT COMPUTATION OF CORONA INJECTED CURRENT IN AC CONDUCTORS OF HYBRID AC/DC TRANSMISSION
Penner, A.F.; Raghuveer, M.R.; Ciric, I.M.R.
International Journal of Energy Systems
vol.12, no.3 p. 124-7 1992 USA
The magnitude of the corona injected direct current in the AC conductors of two AC/DC hybrid transmission geometries has been computed by the finite element method. Computations have also been carried out for a single phase AC/DC hybrid laboratory model line. The effect of AC potential on the injected current is taken into account in an approximate manner by a technique which is shown to yield good results as evidenced by the good agreement between computed and experimental data for the laboratory line.

[1993] 3C-3

INFLUENCE OF LOAD CURRENT ON BIPOLAR DC CORONA
Pedrow, P.D.; Qin, Bai Lin; Wang, Qing Yuan
IEEE Transactions on Power Delivery
Jul 1993 p 1443-1450
Bipolar DC corona is known to be a strong function of conductor voltage but little has been known about the influence of load current on bipolar corona. To evaluate the influence of load current, a bipolar cylindrical corona cage was constructed and operated with simulated DC load current flowing in the conductors. Measurements of load current, corona current, ion-current density, and conductor temperature showed that corona conductance was a function of load current. The dependence on load current was via temperature rather than magnetic field.

[1993] 3C-4

MONOPOLAR CORONA LOSS OF GEZHOUBA-NANQIAO HVDC TRANSMISSION LINE
Fu Binlan
Power System Technology
no.3 p.16-21 May 1993
A simple and convenient measuring method of corona loss in service is presented. The measurement results under various operation conditions are given. The relationship between monopolar corona loss and the line voltage is described. The comparison between monopolar corona loss of one pole line energized and that of two pole lines in parallel energized with the same pole is made. The calculation is discussed and a modified Anneberg equation presented. ;

3D. RADIO AND TELEVISION INTERFERENCE (RI & TVI)

[1992] 3D-1

A STUDY OF THE HARMONICS AND LINE INTERFERENCE DURING TESTING THE GEZHOUBA-SHANGHAI +OR-500 KV DC TRANSMISSION LINE
Fu Jiahua
Power System Technology
no.1 p.23-7, 32 Feb. 1992 China In Chinese
The author presents the study of the line interference during the single-pole and bipole on the Gezhoub-Shanghai +or-500 kV DC transmission line. Through the actual test data and a comparison with AC transmission lines, the characteristics and existing problems of HVDC transmission line interferences are discussed. The test conditions, the line interference short-circuit currents, DC line harmonics and equivalent interference currents, and the condition for controlling the separating distance between DC transmission lines and telecommunication lines are considered. (3 Refs)

[1991] 3D-2

AMERICAN NATIONAL STANDARD GUIDE ON THE APPLICATION AND EVALUATION OF EMI POWER-LINE FILTERS FOR COMMERCIAL USE
Accredited Standards Committee on Electromagnetic Compatibility, C63, USA Inst. Electr. & Electron. Eng., New York, NY, USA
7 Aug. 1991 USA 15 pp. ANSI C63.13-1991
A basic understanding of the application, evaluation, and safety considerations of electromagnetic interference (EMI) power-line filters used in both AC and DC applications is provided. The construction of an EMI power-line filter and its functions in providing suppression of conducted noise are described. The functions and performance of the filter components, particularly the capacitors and inductors, are discussed. It is explained why seemingly identical filters may not give the same performance in a particular application. No-load insertion-loss test methods are presented. Proper installation of the filters in equipment is discussed. Safety regulations are briefly addressed. (18 Refs)

[1991] 3D-REF

A PREDICTION METHOD OF AUDIBLE NOISE AND RADIO NOISE GENERATED FROM HVDC TRANSMISSION LINE WITH 4X3.84 CM CONDUCTOR BUNDLES
Nakano, Y.; Sunaga, Y.
Electrical Engineering in Japan
vol.111, no.7 p.68-77, 1991
For Abstract see entry 2I-001.

3E. AUDIBLE NOISE

[1991] 3E-1

PREDICTION METHOD OF AUDIBLE NOISE AND RADIO NOISE GENERATED FROM HVDC TRANSMISSION LINE WITH 4X3.84CM CONDUCTOR BUNDLES.
Nakano, Yukio; Sunaga, Yoshitaka
Electrical Engineering in Japan
(English translation of Denki Gakkai Ronbunshi) v 111 n 7 1991 p 68-77
This paper proposes a prediction method of audible and radio noises using statistically reliable data of ACSR 810 sq mm four conductors, which are collected through the field observation of a three-year period. Effectiveness and high prediction accuracy of the proposed method are confirmed by a large quantity of measured data. The proposed method is also applicable to the noise level prediction under arbitrary polarity and conductor arrangements.

3F. ELECTRIC FIELDS

[1991] 3F-1

A COMPARISON OF THE ENVIRONMENTAL IMPACT OF ULTRA-HIGH VOLTAGE AC AND DC POWER TRANSMISSION LINES
Sokhranskii, A.S.; Tikhodeev, N.N.
Izvestiya Akademii Nauk SSSR, Energetika i Transport
vol.29, no.5 p.59-66 1991 Russia Translated in: Power Engineering (USSR Academy of Sciences) vol.29, no.5 p.46-52 1991 USA
A comparison is made of the environmental impact (of the electric field and ions concentration near the ground, induced currents and voltages in ground objects, 'electrical discomfort', radio interference, etc.) of ultra-high AC and DC power transmission lines. Based on experimental investigations, it is concluded that with respect to the above-mentioned characteristics, the DC power transmission line has considerable advantages over the AC line.

[1992] 3F-2

A METHOD FOR CALCULATING ELECTRIC FIELDS IN HVDC EQUIPMENT WITH ALLOWANCE FOR TRANSIENTS
Bortnik, I.M.; Vol'pov, E.K.; Filippov, A.A.
Elektrichestvo
no.6 p.24-8 June 1992 Russia In Russian
A mathematical model is formulated and a procedure developed for the analysis of electric fields in high voltage DC equipment, operating under quasi steady-state and transient conditions. The insulation schemes investigated comprise electrodes with induced or free potentials, and hard dielectrics with their boundaries possessing very thin surface layers. The computational algorithm is based on A/D conversion and linearisation for integration of the continuity equation with time. The procedure yields the distribution of surface charges along subareas of the insulators at arbitrary instants of time. In addition, the procedure can also be used for calculating the electric fields, present upon disconnections of DC voltage, reversal of its polarity and superposition of pulses on DC voltage.

[1991] 3F-3

DC-PROBES FOR ELECTRIC FIELD DISTRIBUTION MEASUREMENTS
Hornfeldt, S.P
IEEE Transactions on Power Delivery
Apr 1991 p 524-529
It is desired to measure the external electric field distribution of components for high voltage DC transmission. This information is useful in the development of such components. By measuring the field under a variety of ambient conditions, the performance of both the external and the internal insulation of the component can be assessed. The principles of how DC fields can be measured using an isolated probe coupled by fiber optics to a separate receiver are discussed. The construction of some practical systems are described. The authors have measured the electric fields around a full size wall bushing energized to 600 kV in rain. The results of this and other measurements are presented. They demonstrate the usefulness of isolated DC field measurements.

[1992] 3F-4

EXPERIMENTAL PREDICTION METHOD OF CHARGED VOLTAGE DUE TO ION FLOW ON THE OBJECTS UNDER HVDC TRANSMISSION LINES
Amano, Y.
Transactions of the Institute of Electrical Engineers of Japan
20 Jan 1992 p 49-56. In Japanese.
Electric field, ion current, and ion density under HVDC transmission lines are considered to be important factors with biological effects. Since electric shocks caused by charged voltage due to ion current flows into human bodies under HVDC transmission lines are regarded to be important problems in Japan, the appropriate height of the HVDC transmission lines are being considered to prevent such shocks. In regard to the characteristics of ion flow electrification, long-

term measurements have been carried out under HVDC test lines since 1971 in CRIEPI. The relations between charged voltage due to ion flows and major designing parameters such as conductor height, pole spacing, and pole arrangement have been measured for about one year under the DC test lines at Shiobara testing station. This report outlines the results of this measurement. It is found that the effect of conductor height of UHV level is slightly larger than that of EHV level, and differs with pole arrangement. Moreover, a new equation which takes account of vertical and horizontal pole spacing is proposed as a prediction method for charged voltage applicable to the UHV level double circuit DC transmission lines.

[1992] 3F-5

FIELD-EFFECT RESEARCH AT THE HIGH VOLTAGE TRANSMISSION RESEARCH CENTER
Zaffanella, L.E.
Electric Power Research Inst., Report No. EPRI-EL-7104
1992
This report presents information obtained during five different studies of field effects from high voltage transmission lines performed at EPRI's High Voltage Transmission Research Center. The first study is the development of a methodology for the evaluation of the expected frequency of occurrence of specific short-term effects of spark discharges and induced currents caused by overhead high voltage transmission lines. The methodology is divided into the analysis of the expected frequency of occurrence of situations in which induction effects may occur, and the analysis of the expected severity of the effect. The second study is of the electric field in the surface and on the immediate proximity of the strands of stranded conductors used for overhead high voltage lines. In particular, the cases of deformations of stranded conductors, caused by air expansion or by popped out strands, are analyzed for the purpose of determining the conditions for occurrence of corona in fair weather. The third study is the development of a model which predicts the concentration of air ions and charged aerosol particles near and downwind of overhead HVDC transmission lines. A computer program that runs on a PC was used to obtain several examples of results. The fourth study is a program to measure and assess the interference caused on personal computers by 60 Hz electric and magnetic fields. Magnetic fields produce oscillating patterns on the screens. The origin of the interference and the field values that cause the interference were determined for different PCs using a special magnetic field facility. The fifth study is the development of a simple computer program to evaluate the magnetic fields produced by underwater DC cables and their effect on the earth's magnetic field, particularly the change in the angle of the compass.

[1991] 3F-REF

EVALUATION OF ION COUNTERS USING A FACILITY TO PRODUCE A STEADY STATE ION FLOW FIELD
Suda, Tomotaka
IEEE Preprint #91 SM 501-7 PWRD
1991
For Abstract see entry 5G-006.

[1992] 3F-REF

A METHOD FOR CALCULATING ELECTRICAL FIELDS INCLUDING TRANSIENTS IN HVDC APPARATUS
Bortnik, I.M.; Vol'pov, E.K.; Filippov, A.A.
Journal: Electrical Technology
no.2 p.121-30 1992 (in English, translated from Russian) Originally published in Electrichestvo no. 6, June 1992 in Russian
For Abstract see entry 6B-002.

[1993] 3F-REF

A NEW ALGORITHM FOR EVALUATING THE FIELDS ASSOCIATED WITH HVDC POWER TRANSMISSION LINES IN THE PRESENCE OF CORONA AND STRONG WIND
Yu, Ming; Kuffel, E.
IEEE Transactions on Magnetics
Mar 1993 p 1985-1988
For Abstract see entry 6B-004.

[1992] 3F-REF

PARTICLE-IN-CELL SIMULATION OF A RADIOACTIVE PROBE IN WIND.
Wang, Qing Y.; Pedrow, Patrick D.
IEEE Transactions on Electrical Insulation
v 27 n 2 Apr 1992 p 342-351
For Abstract see entry 6D-005.

3G. SAFETY

[1993] 3G-1

HELICOPTER-BASED LIVE-LINE WORK
Gela, G.
EPRI-TR-102318-Vol.1
Jun 1993
This report presents experimental data on tests of a configuration consisting of a helicopter between two

energized phases (for AC and switching surge) or poles (for DC). The configuration is that related to live-line work from a hovering helicopter. The McDonnell Douglas 500 Series helicopter was used for the tests. All tests were performed with phase-to-phase, or pole-to-pole energization. For AC tests, proper relationship between the phase-to-ground voltages and the phase-to-phase voltage was maintained by energizing the experimental setup from a balanced 3-[phi] AC source. For DC tests, one pole was energized with positive DC voltage to ground, while the other pole was energized with negative DC voltage to ground. For switching surge tests, a surge of positive polarity and a specific peak voltage magnitude was applied to one phase while a surge of negative polarity and the same peak voltage Magnitude was simultaneously applied to the other phase, resulting in [alpha] = 0.5 ([alpha] is the ratio between negative and total surge). In the research program, four conditions were investigated, namely helicopter operating versus not operating, and helicopter bonded to one phase or pole versus not bonded. Results from this research show effects of the rotating main rotor blade of the helicopter, effect of the position of the electrically floating helicopter in the phase-to-phase or pole-to-pole gap, effects of the mannequin, importance of the polarity of the DC poles and switching surges, and effects of inclement weather such as rain. The overall conclusion of this research is that the phase-to-phase or pole-to-pole spacings that cause sparkover with the helicopter between phases (poles) were always significantly smaller than the typical spacings on actual existing overhead transmission lines of the corresponding voltage rating.

[1991] 3G-2

HVDC INTER-ISLAND LINK RE-INSULATED BY BAREHAND LIVE-LINE TECHNIQUES
Forgie, G.C.; Freeman, L.H.E.; Williams, B.A.
Transmission & Distribution International
vol.2, no.1, p. 8-16 March 1991 In English
In December 1990, the Benmore-Haywards +or-250 kV DC line which links convertor stations in New Zealand's North and South Islands through submarine cables crossing Cook Strait, was re-insulated to +or-350 kV DC. Insulators were replaced with fog-type strings by five-man crews using barehand live-line techniques. The utility achieves very high productivity rates.

3H. MECHANICAL

[1992] 3H-1

COMPARATIVE FIELD VIBRATION TESTS ON TRIPLE AAAC [ALL-ALLIED ALUMINUM CONDUCTOR] AND QUAD ACSR [ALUMINUM CONDUCTOR STEEL REINFORCED] BUNDLED CONDUCTORS
Van Dyke, P.; Hardy, C.; St-Louis, M.
Canadian conference on electrical and computer engineering
13-16 Sep 1992
The results of a field test where the aeolian vibration and subspan oscillation responses of a bundle of 4 aluminum conductor steel reinforced (ACSR) Bersfort coductors were measured against a bundle of 3 all-allied aluminum conductor (AAAC) conductors of equivalent electrical conductivity and mechanical tensile strength are presented. Wind exposure, aeolian vibration, subspan oscillations, and subspan oscillations as a function of bundle tilt angle were measured. Test results showed that aeolian vibrations are slightly higher for the AAAC triple bundles, however amplitudes are well under the estimated bending amplitude endurance limit. It is also shown that the AAAC bundle is less susceptible to subspan oscillations than the Bersfort when both are strung at 20% rated tensile strength, but this advantage may be offset by lower tolerance to bending. Yet, triple bundles of AAAC are of considerable interest to 450 kV DC conductor lines, especially on account of their lower mass-to-strength ratio.

[1993] 3H-2

COMPARATIVE FIELD VIBRATION TESTS ON TRIPLE AAAC AND QUAD ACSR BUNDLED CONDUCTORS
Van Dyke, P.; Hardy, C.; St-Louis, M.
Canadian Electrical Association, Montreal, PQ (Canada)
Report Number MIC-93-06256/XAB 1993
The results of a field test where the aeolian (wind induced) vibration and subsequent oscillation responses of a bundle of 4 aluminum conductor steel reinforced (ACSR) Bersfort power transmission line conductors were measured against a bundle of 3 all-allied aluminum conductors (AAAC) of equivalent electrical conductivity and . Hydro-Quebec is considering using AAACs in triple bundles for its 450 kilovolt Radisson-Des Cantons direct current line, however the wind-induced vibration response of bundled AAACs is not known nor easily predictable. The experimental test site, conductor characteristics, instrumentation and data treatment, wind exposure,

aeolian vibrations, subspan oscillations, and subspan oscillations as a function of bundle tilt angle are discussed.

[1991] 3H-3

INTEGRATING OPTICAL COMMUNICATIONS WITHIN THE POWER NETWORK-THE PRACTICE
Bartlett, A.D.; Craddock, K.; Hearnshaw, D.
AC and DC Power Transmission
London, UK 17 - 20 Sept. 1991. Conf. Publ. No.345 p. 211-19
Because of the availability of 'all dielectric self supporting optical cables' (ADSS) offering secure interface free operation, some power utilities are now installing various forms of optical communications on their overhead transmission network, weather on AC of DC lines, for both power system control and general telecommunications duty. Based on successful trials on ADSS systems on overhead lines, East Midlands Electricity has embarked on a programme of installing a network of overhead optical cables to support and supplement its existing digital radio network. The authors discuss the application and experiences of one particular type of ADSS optical cable installed on existing 132 kV tower lines and include a description of the severe snow storms experienced by the midlands region of the UK in December 1990. Recommendations regarding standards for component design, system security future expectations and further development work in ADSS optical cable technology are addressed.

[1991] 3H-4

INVESTIGATION OF THRASHER COMPRESSION FITTINGS ON BPA'S DIRECT CURRENT TRANSMISSION LINE
Reding, J.L.
IEEE Preprint #91 WM 089-3 PWRD
1991
Primary project goals were to predict Thrasher fitting's future performance and develop a reinforcement design. The project correlated fitting test data, field experience, and design parameters into an analytical tool, Bennett Number, capable of ranking relative fitting performance. The Thrasher fittings could, as a population, exhibit unacceptable performance before the end of their expected life. This investigation concluded the best way to mitigate a failed or marginal Thrasher fitting is by reinforcement.

[1991] 3H-REF

HVDC CONVERSION OF HVAC LINES TO PROVIDE SUBSTANTIAL POWER UPGRADING
Clerici, A.; Paris, L.; Danfors, P.
IEEE Transactions on Power Delivery
Jan 1991 p 324-333
For Abstract see entry 1B-011.

[1993] 3H-REF

DESIGNING ELECTRICAL POWER EQUIPMENT TO WITHSTAND SEISMIC LOADS
Berggren, S.; Enblom, R.
ABB Review
no.10 p.23-32 1993
For Abstract see entry 2G-001.

[1991] 3H-REF

ELECTROLYTIC CORROSION OF METAL HARDWARE OF HVDC LINE AND STATION INSULATORS
Taniguchi, T.; Watanabe, M.; Watanabe, Y.; Mori, S.; Watanabe, A.; Naito, K.
IEEE Transactions on Power Delivery
Jul 1991 p 1224-1233
For Abstract see entry 2J-008.

4. CABLE TRANSMISSION

4A. GENERAL

[1993] 4A-1

+/-450 KV DC UNDERWATER CROSSING OF THE ST. LAWRENCE RIVER OF A 1500 KM OVERHEAD LINE WITH FIVE TERMINALS
Bell, N.; Bui-van, Q.; Couderc, D.; Ludasi, G.; Meyere, P.; Picard, C.
CIGRE Proceedings of the 34th Session
p.21-301/1-11 vol.1 1993 France
Following environmental controversies, an underwater cable-crossing had to be built for a 450 kV DC line. Up to now, apart from the 400 kV DC FENNO-SKAN interconnection in Scandinavia, no commercial installation is in operation at this voltage level. Nevertheless, tests conducted since 1988 made it possible to select an oil-filled cable, and accessories for the project. For the construction of this cable-connection in a tunnel under the St-Lawrence River, several technical solutions had to be considered, temperature control systems for the cables were developed, particular cable installation methods had to be used, and last but not least, in order to ensure the utmost reliability of this interconnection, innovative solutions were applied.

[1993] 4A-2

A 550 MW HVDC SUBMARINE CABLE LINK: ICELAND-UK-CONTINENTAL EUROPE
Guonason, E.; Henje, J.; Shepherd, P.; Valenza, D.
Third International Conference on Power Cables and Accessories 10kV - 500kV (Conf. Publ. No.382)
p.220-4, 1993
Iceland has an abundance of not yet utilised hydroelectric and geothermal power while there are potential markets in the UK and continental Europe for electric power. The authors present the results of investigations which show that power transmission by submarine cable to these markets is technically sound and that renewable power from Iceland can be transmitted and offered at prices which are firmly competitive even against gas generated power, the most economic low polluting source in the UK today. The resulting proposal for a 550 MW submarine cable link is also addressed.

[1991] 4A-3

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE CROSSING OF HYDRO QUEBEC 500 KV DC LINE--I: DIELECTRIC AND ACCELERATED AGING TESTS ON PROTOTYPES.
Couderc, Daniel; Trinh, N. G.; Belec, Mario; Chaaban, Mohamed; Leduc, Jean; Beausejour, Yvan
Proceedings of the 1991 IEEE Power Engineering Society Transmission and Distribution Conference
1991 Sep 22-27
The dielectric and accelerated aging tests on prototype plus or minus 500-kV DC oil-filled self-contained cables are discussed. The extensive test program was required to evaluate the high-voltage cables for the St. Lawrence river crossing of the plus or minus 500-kV Quebec-New England HVDC power transmission system. The main elements of the test program are related. The required insulation levels, the characteristics of the cables supplied by three different manufacturers, and the cables' installation for the type tests and accelerated aging tests are described. Details of the test program and procedures followed to carry out the tests are given. Findings of the tests are also reported.

[1991] 4A-4

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500-KV DC LINE--II: CABLE TESTING FACILITY FOR DIELECTRIC AND ACCELERATED AGING.
Trinh, N. Giao; Couderc, Daniel; Faucher, Pierre; Chaaban, Mohamed; Belec, Mario; Leduc, Jean
Proceedings of the 1991 IEEE Power Engineering Society Transmission and Distribution Conference 1991
Sept 22-27 1991 (IEEE cat n 92CH3070-0). p 110-116
For Pt. I, see ibid., pp. 101-109 (1991); for Pt. III, see ibid., pp. 117-121 (1991). The new cable testing facility at IREQ for long-term accelerated aging tests on HV cables is described. This test facility was required as part of an extensive program to evaluate the high-voltage cables for the river crossing of Hydro-Quebec's new transmission lines rated 800 kV AC and plus or minus 500 kV DC. The first application was for the evaluation of self-contained oil-filled (SCOF) cables for the St. Lawrence river crossing of the plus

or minus 500-kV Quebec-New England HVDC power transmission system. The specific dielectric constraints resulting from the insertion of a short length of cable into a long line and the circuits developed for the special tests, which reproduce the specific cable test conditions, are described.

[1991] 4A-5

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500-KV DC LINE–III: THERMAL BEHAVIOUR.

Chaaban, Mohamed; Leduc, Jean; Corderc, Daniel; Trinh, N. Giao; Belec, Mario

Proceedings of the 1991 IEEE Power Engineering Society Transmission and Distribution Conference

1991 Sep 22-27

For Pt. I, see ibid., pp. 101-109 (1991); for Pt. II, see ibid., pp. 110-116 (1991). The thermal analyses conducted during the different stages of Hydro-Quebec's St. Lawrence river crossing project are presented. The important impact of the thermal studies on the choice of cable is described, and the design of the installation is presented. The numerous problems faced during the cable prototype are detailed, and demonstration tests and the solutions obtained by numerical analysis using the finite-element method are addressed. These problems were related in part to the temperature controls of the cable and its accessories, and in particular to the control of the temperature gradient across the dielectric material at various locations along the test loop. 3 Refs.

[1992] 4A-6

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500-KV DC LINE. PART 3 THERMAL BEHAVIOR

Chaaban, M.; Leduc, J.; Couderc, D.; Trinh, N.G.; Belec, M.

IEEE Transactions on Power Delivery

Apr 1992 p 609-613

This paper presents the thermal analyses conducted during the different stages of Hydro-Quebec's St. Lawrence river crossing project. It reveals the important impact of the thermal studies on the choice of HVDC cable and the design of the installations. It also describes the numerous problems faced during the cable prototype and demonstration tests and the solutions obtained by numerical analysis using the finite-element method. These problems were related in part to the temperature controls of the cable and its accessories, and in particular to the control of the temperature gradient across the dielectric material at various locations along the test loop.

[1992] 4A-7

IMPACT OF OVERVOLTAGES ON DESIGN OF HVDC CABLES

Povh, D.; Luoni, G.

CIGRE Proceedings of the 34th Session

p.14-104/1-11 vol.1 30 Aug.-5 Sept. 1992

The Joint Working Group JWG 33/21/14-16 on Overvoltages in DC cables was founded by Study Committees 33, 21 and 14 which are interested in the design of DC cables and in the operation of HVDC schemes. The scope of JWG covers: review of DC cable data in existing HVDC schemes; analysis of withstand capability of DC cables under operating voltage and overvoltages; and the determination of overvoltages which can appear on DC cables. Further, means for reduction of overvoltages should be discussed. Adequacy of existing design and testing procedures should be analysed. In this report, the JWG presents intermediate results of its work. The report also intends to initiate discussions which could give additional suggestions before finalising the work. (41 Refs)

[1992] 4A-8

INSTALLATION OF 350 KV HVDC SUBMARINE POWER CABLES FOR UPRATING THE HVDC SYSTEM IN NEW ZEALAND

O'Brien, M.T.; Larsen, J.E.; Hjalmarsson, G.

CIGRE, 34th Session

30 Aug.-5 Sept. 1992

Three single core 350 kV HVDC submarine power cables of mass impregnated design were installed across Cook Strait in early 1991 as part of the uprating of the New Zealand Benmore-Haywards HVDC transmission link from 600 MW to 1240 MW. This paper outlines the reasons for selection of the cable ratings, aspects of the design and manufacture, the selection of the cable route, and the special features and techniques adopted for cable laying. (9 Refs)

[1991] 4A-9

RELIABILITY OF UNDERGROUND AND SUBMARINE HIGH VOLTAGE CABLES

A Farneti, F.; Riot, B.; Bazzi, G.; Morris, C.

CIGRE Symposium. Electric Power Systems Reliability

p.2-07/1-6 1991 Cigre, Paris, France

The authors summarize the operating experience on both HV AC underground and AC and DC submarine cable systems. Failure rates and average outage times for the various systems and, in some cases, for the relevant components, as well as the systems availability are given. Factors to be taken into account

Considerations concerning the cases of failure and possible provisions to limit them are also dealt with. (5 Refs)

[1992] 4A-REF

PROPOSAL FOR A COMMERCIAL INTERCONNECTION AMONG THE HAWAIIAN ISLANDS BASED ON THE RESULTS OF THE HAWAII DEEP WATER CABLE PROGRAM
Arnaud, U.; Bazzi, G.; Valenza, D.
IEEE Transactions on Power Delivery
Oct 1992 p 1661-1666
For Abstract see entry 1F-012.

[1991] 4A-REF

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500-KV DC LINE--II: CABLE TESTING FACILITY FOR DIELECTRIC AND ACCELERATED AGING.
Trinh, N. Giao; Couderc, Daniel; Faucher, Pierre; Chaaban, Mohamed; Belec, Mario; Leduc, Jean
Proceedings of the 1991 IEEE Power Engineering Society Transmission and Distribution Conference 1991
Sept 22-27 1991 (IEEE cat n 92CH3070-0). p 110-116
For Abstract see entry 4A-004.

[1992] 4A-REF

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500 KV DC LINE. PART 2 CABLE TESTING FACILITY FOR DIELECTRIC AND ACCELERATED AGING
Trinh, N.G.; Couderc, D.; Faucher, P.; Chaaban, M.; Belec, M.; Leduc, J.
IEEE Transactions on Power Delivery
Apr 1992 p 1043-1050
For Abstract see entry 7B-001.

4B. INSULATION

[1993] 4B-1

AFTER-SERVICE ANALYSIS OF THE 32-YEAR-OLD HVDC CABLE GOTLAND 1
Hjalmarsson, G.; Thoren, J.; Grape, U.; Malmquist, G.; Eriksson, R.; Kvarngren, M.
ABB High Voltage Cables AB, Stockholm, Sweden
CIGRE 34th Session
p.21-302/1-7 vol.1 1993
The world's first HVDC submarine cable, the Gotland 1 cable, has been taken up after 32 years of service. Samples of the cable were brought to the laboratory for investigation of its condition. Measurements of dielectric properties were made and different materials of the cable were analysed. In practically all respects the cable showed properties equal to those of a new cable. Only the insulating papers showed some slight ageing. Since this was also valid for cable which had not been in service, the conclusion is that the service had not caused any provable degradation of the cable.

[1991] 4B-2

ANALYSIS OF THE ELECTRIC CHARGE CHARACTERISTIC IN AN LDPE FILM UNDER A NEEDLE-PLANE ELECTRODE SYSTEM BY USING A TSSP MEASUREMENT
Fukuzawa, M.; Iwamoto, M.
Electrical Engineering in Japan
vol.111, no.2 p.1-10 1991 In English
The quality of polymer high-voltage electric insulators has been determined by treeing, and many studies have been carried out in this field. In treeing breakdown, the role of electric field relaxation due to space charge at a needle tip has been examined. A thermally stimulated surface potential (TSSP) measurement was carried out by adding the DC biasing procedure to the treeing experiment on the plane electrode where 20 needle electrodes were inserted into a low-density polyethylene sample. In comparing the electron injected depth Delta r measured by a previous TSP measurement with the results by the TSSP experiment, both results were similar. Based on this experimental result, the charge injected depth was evaluated and the electric field relaxation due to the injected charges was discussed. (12 Refs)

[1992] 4B-3

DEVELOPMENT OF 500/600-KV SOLID-TYPE NONPRESSURIZED OIL-PAPER DC CABLE
Allam, E.M.; McKean, A.L. (Cablec Corp., Yonkers, NY)
Electric Power Research Inst. Report EPRI-TR-100621
Jul 1992
This work investigates the feasibility of developing nonpressurized, solid-type paper cable for DC transmission use in the 500-kV to 600-kV range. The conclusion is that at these voltage levels pressurization is necessary. Investigation of a self-pressurizing cable concept requiring no external fluid storage and pumping facilities concludes that, while technically feasible, such a system would not be economically viable. 18 refs.

[1992] 4B-4

DEVELOPMENT OF NEW POLYMER INSULATING MATERIALS FOR HVDC CABLE. PART 2
Suzuki, T.; Niwa, T.; Takahashi, T.; Miyata, H.
Transactions of the Institute of Electrical Engineers of Japan v 112:10
20 Oct 1992 p 914-920. In Japanese.
Most of extra-high-voltage DC transmission cables now are oil immersed power cables, while the requirements for the plastic insulated cables with XLPE insulated cables as the representative thereof are large due to either the convenience of maintenance or the prevention of disaster. New polymer insulating materials showing the excellent DC characteristics are found by the present authors by carrying out the screening test with numerous polymer insulating materials reported previously. Said new polymer insulating materials, modified HDPE, are high density polyethylene with a few of acidic modified groups introduced onto the side chain thereof. The results of examining the initial DC breakdown characteristics based on the essential material properties and model cables are described in previous report. In this paper, the results obtained from the investigations on the effects of insulation thickness and the long-term V-t characteristics for DC breakdown of the modified HDPE which is applied in the utility of extra-high-voltage DC cables; and the manifest mechanism of DC characteristics of modified HDPE are described.

[1992] 4B-5

DEVELOPMENT OF NEW POLYMER INSULATING MATERIALS FOR HVDC CABLES. I
Kubota, T.; Yoshifuji, N.; Niwa, T.; Takahashi, T.; Miyata, H.
Transactions of the Institute of Electrical Engineers of Japan, Part A
vol.112-A, no.3 p.215-22 March 1992 Japan In Japanese
From the results of tests to establish dielectric breakdown strength (E/sub B/) in various types of polymeric materials (using sheet samples), modified HDPE, which was produced by introducing a small amount of polar group into HDPE, was selected as a promising new material. The outstanding DC breakdown characteristics in modified HDPE were attributed to the improvement of the intrinsic breakdown strength due to the presence of high crystallinity polyethylene, in addition to the control of space charge due to the polar group. These tests have shown that the excellent E/sub B/ of modified HDPE makes it suitable to cable insulation applications, particularly as its DC E/sub B/ is 1.5 approximately 2.0 times as high as that of a conventional XLPE cable. (13 Refs)

[1992] 4B-6

DEVELOPMENT OF THE NEW POLYMER INSULATING MATERIALS FOR HVDC CABLE
Yoshifuji, N.; Niwa, T.; Takahasi, T.; Miyata, H.
IEEE Transactions on Power Delivery
Jul 1992 p 1053-1059
This paper relates to the new polymer insulating material for HVDC cable. The properties of modified HDPE, selected from various polymer materials by evaluations of DC characteristics were examined in both sheet and cable samples. It was found that the modification, which introduced a small amount of polar group into HDPE, considerably enhanced DC breakdown strength to as high as 1.5--2.0 times those of XLPE. Another evaluation was given with TSC method regarding space charge which was considered as a factor contributing to the enhancement of DC characteristics. Under a poling voltage of up to 30 KV/mm, the modified HDPE exhibits particular behaviors, with its space charge decreasing as stress is increasing. In addition, the additives in HDPE have a large influence on space charge characteristics, thereby affecting the DC breakdown strength. The evaluation of cable insulated with optimum modified HDPE was conducted to determine the breakdown strength under various voltage applications. Compared with the XLPE cable, modified HDPE cable exhibited excellent characteristics under all kinds of voltage

applications (DC, ImP, polarity reversal, and DC + Imp), particularly DC dielectric breakdown strength which was almost twice that of XLPE.

[1992] 4B-7

DIELECTRIC PHENOMENA IN THE BREAKDOWN OF NON PRESSURE ASSISTED, IMPREGNATED PAPER INSULATED, HVDC CABLES

Gazzana Priaroggia, P.; Metra, P.; Miramonti, G.

Proceedings of the 4th International Conference on Conduction and Breakdown in Solid Dielectrics (Cat. No.92CH3034-6)

p. 407-17 22-25 June 1992

The authors present an overview of dielectric phenomena in the breakdown of non-pressure-assisted, impregnated-paper-insulated HVDC (high-voltage direct-current) cables. Dielectric breakdown stress results are presented and interpreted. The dielectric phenomena arising in a shrinkage void formed within a cable insulation made of impregnated paper layers are analyzed. (5 Refs)

[1992] 4B-8

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE CROSSING OF HYDRO-QUEBEC 500 KV DC LINE. PART 1 DIELECTRIC AND ACCELERATED AGING TESTS ON PROTOTYPES

Coudere, D.; Trinh, N.G.; Belec, M.; Chaaban, M.; Leduc, J.; Beausejour, Y.

IEEE Transactions on Power Delivery

Apr 1992 p 1034-1042

This paper describes the dielectric and accelerated aging tests on prototype {plus minus}500 kV DC oil-filled self-contained cables. The extensive test program was required to evaluate the High-Voltage cables for the St. Lawrence river crossing of the {plus minus}500 kV Quebec-New England HVDC power transmission system. The paper relates the main elements of the test program. It describes the required insulation levels, the characteristics of the cables supplied by three different manufacturers, as well as the cables' installation for the type tests and accelerated aging tests. Details of the test program and procedures followed to carry out the tests are given. Findings of the tests are also reported.

[1992] 4B-9

FAST AND STABILE OPERATION OF THE HIGH VOLTAGE DIRECT CURRENT (HVDC)-SYSTEM

Burgess, R.P.; Barker, I.E.

Energie Technologie (Netherlands)

Feb 1992 p 37-43. In Dutch

At the end of 1989 GEC Alsthom put the 150 MW HVDC converter coupling station in Alberta, Canada, into operation. This new system is the first connection between the grids of West and Central Canada. Some of the main characteristics are discussed: ethylene glycol cooled thyristors, no direct current choke between the two HVDC thyristor groups, a stabile stationary operation and a good recovery after distortions in a very weak alternate voltage network. The converter station is unmanned in operation for one year now with satisfactory results.

[1992] 4B-10

HIGH VOLTAGE DIRECT CURRENT CABLES WITH POLYMERIC INSULATION: THE STATE OF THE ART

Khalil, M.S., Danish Electr. Res. Inst., Lyngby, Denmark

Nordic Insulation Symposium NORD-IS 92

June 15-17, 1992.

The specific problems of HVDC cables with polymeric insulation are presented with particular emphasis on the combined effects of the temperature as well as space charge accumulation in the insulation on the electric stress distribution and breakdown strength. Based on the above considerations, an attempt is made to put forward the ideal requirements to be met by the insulating materials of this kind of cable and the criteria to assess their performance. A critical review of the development works of HVDC cables with polymeric insulation reported in the literature is given. Different aspects of those works are examined and discussed. The suggested criteria are used in the analysis of their results.

[1992] 4B-11

RESEARCH AND DEVELOPMENT OF XLPE INSULATED DC CABLE

Maekawa, Y.; Yamaguchi, A. (Electric Power Development Co. Ltd., Tokyo (Japan)); Hara, M.; Sekii, Y. (Hitachi Cable, Ltd., Tokyo (Japan))

Transactions of the Institute of Electrical Engineers of Japan

20 Oct 1992 p 905-913

DC cables play the very important roles as undersea cables or overland long distance transmission lines all around the world. At present, all DC cables used in

practical lines are oil immersed paper insulated cables, while the cables with XLPE compound as the insulator have not been put in utility yet. The reason is that, in the previous researches and development relating to XLPE insulated DC cables, neither reliable design elements nor sufficient long-term reliability are obtained. Research and development of XLPE insulated DC cables have been promoted by the present authors since 1984. Simultaneously with the discovery of the possibility of using filler-contained XLPE compound as the insulator of DC cables, the development of the filler-contained XLPE compounds with highly purified inorganic filler, and the development of the cables using such compounds are executed. In this paper, the summary of the research and development relating to the insulating materials applied in XLPE insulated DC cables and cables using such materials are described.

[1992] 4B-12

SPACE CHARGE MEASUREMENT IN DC CABLE MATERIALS
EPRI EL-7301
1992

A DC transmission cable having extruded insulation has potential advantages, including lack of charging-current losses, higher allowable design stresses, ease of installation, and reduced maintenance. However, no satisfactory extruded material exists for this purpose. The aim is to investigate the use of polyethylene blends and charged polymers (ionomers) for extruded DC cable insulation and to develop and apply the thermal-pulse technique for studying space charge.

5. SYSTEM DESIGN AND OPERATION

5A. CONTROL AND PROTECTION

[1992] 5A-1

A DIGITALLY BASED HVDC FIRING-PULSE SYNCHRONIZATION CONTROL - DESCRIPTION AND MODEL DEVELOPMENT
Lorden, D.J.; Clark, K.; Larsen, E.V.
IEEE Transactions on Power Delivery
Jul 1992 p 1405-1414
Modern DC converter firing control systems utilize phase locked loop techniques to synchronize valve firing-pulses with the AC voltage. Moreover, these systems are becoming digitally based with computers used to control the process. An EPRI research project has provided insight to the behavior of these important control functions. This paper describes a digitally based firing-pulse synchronizing control system, examines some basic dynamic performance issues, and describes a model suitable for small-signal stability analysis of this discrete-time process.

[1992] 5A-2

A MULTIPROCESSOR DIGITAL SIGNAL PROCESSING SYSTEM FOR REAL-TIME POWER CONVERTER APPLICATIONS
Guo, Y.; Lee, H.C.; Wang, X.; Ooi, B.T.
IEEE Transactions on Power Systems
May 1992 p 805-811
This paper describes the design of a multiprocessor digital signal processing system for applications in power converters such as those that would be used in the next generation of HVDC and SVC systems. The system incorporates three high-speed digital signal processors operating independently in parallel, but communicating with one another. The fully programmable system is a powerful device which can implement sophisticated control algorithms in real time for converters. A prototype operating at a clock frequency of 40 MHz has been built for testing and evaluation of control strategies with a laboratory model of an experimental HVDC system based on pulse width modulation (PWM). The results from an illustrative application demonstrate that the design is well suited for real-time digital control of converters and the system is a useful tool for research and development.

[1992] 5A-3

A SUBOPTIMAL STATIC CONTROLLER FOR HVDC LINKS SUPPLYING ISOLATED AC NETWORKS
Georgantzis, G.J.; Vovos, N.A.; Giannakopoulos, G.B.
Archiv fur Elektrotechnik
vol.75, no.6 p.451-8 1992 West Germany In English
The design of a centralized suboptimal static controller for HVDC links connected to load systems without AC generators, using the protective control technique, is presented. Frequency and voltage variations at the inverter side are the inputs of the static controller, while the modulation of the DC current settings and the 6 constant extinction angle are the outputs. The design of this controller used to modulate the active power of the HVDC link to meet the various large load disturbances in the isolated AC network is realized, in a near optimal way, by taking into account the strength of the inverter AC voltage. Using a fundamental frequency digital simulation program, the proposed control system has been applied and tested in a realistic electrical AC/DC power system.

[1993] 5A-4

AC LINE PROTECTION OPERATING CONDITIONS IN THE NEAR VICINITY OF HVDC INSTALLATIONS
Anderson, F.; Juhlin, L.E.; Jones, T.
Fifth International Conference on Developments in Power System Protection
IEEE Conference Publication n 368 1993. Publ by IEE, Michael Faraday House, Stevenage, Engl. p 119-122
With the increased use of static VAR compensators and the trend towards high power transmission levels for HVDC system, the a.c. system is no longer always strong in relation to the HVDC transmission. As a result, the possible influence of the HVDC transmission on a.c. line protection has to be considered. Two risk factors for improper a.c. line protection operation will be defined in this paper as well as the influence these have on different types of line protections.

[1991] 5A-5

ACTIVE AND REACTIVE POWER CONTROLS FOR THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION SCHEME

Hammad, A.; Koelsch, H.; Daehler, P.

AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 279-284

The (+/-) 500 kV, 1200 MW HVDC transmission scheme, the first in China, interconnects the Central and Easern China regional power systems over a distance of 1045 km. The scheme, known as GESHA, was commissioned in two stages in 1989 and 1990 respectively. The complete bi-pole HVDC scheme has been in commerical operation since August 1990. The paper first presents a brief description of the HVDC transmission scheme and its principal modes of operation and the operating environment of the interconnected AC systems. Then, the paper focuses on the novel control strategies for active and reactive powers adopted by the HVDC scheme to match the different requirements of the AC systems. Reactive power and AC voltage controls using the HVDC converter terminal - the first application in HVDC transmission systems - is explained in detail. Results of field tests made during the commissioning phases of the scheme to demonstrate these control features are also presented.

[1992] 5A-6

AUXILIARY POWER CONTROLS ON THE NELSON RIVER HVDC SCHEME

Chand, J.

IEEE Transactions on Power Systems

Feb 1992 p 398-402

This paper describes the auxiliary power controls on the Nelson River HVDC scheme. It shows how the fast control feature of the HVDC link can be utilized to enhance the operation of an integrated ac/dc power system.

[1993] 5A-7

COMPARISON OF SUITABLE CONTROL SYSTEMS FOR HVDC STATIONS CONNECTED TO WEAK AC SYSTEMS

Shah, K.; Gole, A.M.

IPEC '93. International Power Engineering Conference 1993. Conference Proceedings

p.358-61 vol.1 18-19 March 1993

In this paper, three different power convertor control firing control systems are modeled using an electromagnetic transient computer simulation package, EMTDC. They are tested on a 12-pulse HVDC back-to-back system, connected to weak AC systems. The system recovery to various operating disturbances are compared-a step change in current order and the performance during faults are presented. (4 Refs)

[1993] 5A-8

CONTROL DESIGN OF SANTO TOME BACK-TO-BACK HVDC LINK

Rostamkolai, N.; Wegner, C.A.; Piwko, R.J.; Elahi, H.; Eitzmann, M.A.; Garzi, G.; Tietz, P.

IEEE Transactions on Power Systems

V8, n3 Aug 1993 pp.

This paper describes the control design of the Santo Tome' back-to-back HVDC. The Santo Tome 'HVDC converter will be second DC link asynchronously connecting the Argentina and Brazil power systems. This paper focuses on the design of the reactive power control, automatic power control, load frequency control, power modulation control. automatic frequency control, and automatic synchronizing control functions of the 50 MW DC link. Time simulation and frequency domain results are included to illustrate the system response and verify the adequacy of the controllers performance in achieving stable operating conditions.

[1991] 5A-9

CONTROL FEATURES OF THE HVDC GEZHOUBA-SHANGHAI TRANSMISSION SCHEME

Hammad, A.; Koelsch, H.; Daehler, P.

APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management (Conf. Publ. No.348)

p. 680-5 vol.2 . Conference held on 5-8 Nov. 1991.

The HVDC transmission scheme, the first in China, transmits 1200 MW at +or-500 kV from the Gezhouba hydro plant, in Central China to Nan-Qiao near Shanghai over a distance of 1045 km. The authors discuss the operating environment of the interconnected AC systems of Central and East China in terms of frequency and voltage variations. This leads to the establishment of the power regulation and the reactive power requirements of the HVDC transmission terminals. The authors then focus on the control strategies adopted by the HVDC scheme to match these requirements. Reactive power and AC voltage controls using the HVDC converter terminals represent the first application of such techniques in long transmission systems. Step-power modulation functions activated by the HVDC control system are also exercised. The features and functions of such a microprocessor based control scheme are presented in detail. A sample of commissioning field tests

demonstrating these control features are also presented. (7 Refs)

[1991] 5A-10

COORDINATING CONVERTER CONTROLS AND SYNCHRONOUS CONDENSER CHARACTERISTICS IN HVDC BACK-TO-BACK LINKS

Delfino, B.; Denegri, G.B.; Invernizzi, M.; Garzi, G.; Ruzza,S.

4th European Conference on Power Electronics and Applications

p.94-9 vol.3 3-6 Sept. 1991 Firenze, Italy In English

HVDC connection via back-to-back link is the usual way to allow power transmission between networks operating at different frequencies. Such installation permits power transfer in either directions regardless of the frequency and voltage in the AC network. If one of these networks is weakly connected to the converter station, isolated operating conditions can frequently occur. In this case the control of the back-to-back tie has a considerable effect upon the design of all the components in order to meet operation requirements. The authors provide issues to justify the choice of project parameters and strategies concerning the HVDC converter control and the synchronous condenser placed at the commutating bus, in order to satisfy the maximum admissible steady-state frequency error and the frequency constraints under transient conditions. (2 Refs)

[1992] 5A-11

DAMPING STRUCTURE AND SENSITIVITY IN THE NORDEL POWER SYSTEM

Eliasson, B.E.; Hill, D.J.

IEEE Transactions on Power Systems:

Feb 1992 p 97-105

This paper reports that, to enhance the inherent damping of power systems due to generators and loads, a variety of stabilizer configurations can be used for the generators, SVCs and HVDC links. A study is made of how the overall damping matrix is built up from these contributions. This is used to develop a technique for systematic siting of damping equipment in power systems with several poorly damped modes in a give frequency window. This technique is applied to the NORDEL system. Special emphasis is given to handling very large systems, voltage dependent loads and alternative measurement schemes.

[1993] 5A-12

DC OVERCURRENT PROTECTION-WHERE WE STAND

Brozek, J.P.

IEEE Transactions on Industry Applications

vol.29, no.5 p. 1029-32 Sept.-Oct. 1993

Most DC systems require some form of overcurrent and/or short circuit protection. As with any fuse selection, the three elements of system voltage, normal load current, and available short-circuit must be considered. For proper application, the fuse's ratings must equal or exceed the system parameters. Manufacturer's published data are usually based on AC ratings, and the burden often falls on the user to determine the DC applicability. Furthermore, the manufacturer's DC test data may not necessarily apply to the DC system at hand. Factors including circuit time constant, voltage, and available short-circuit current may preclude the use of certain DC rated fuses. The procedures used to determine the DC ratings for fuses are addressed. The issues pertinent to insuring a proper DC fuse application are discussed.

[1992] 5A-13

DECENTRALIZED HIERARCHICAL OPTIMAL CONTROL OF DYNAMIC INSTABILITY IN AC/DC POWER SYSTEMS

Ngan, H.W.; David, A.K.; Lo, K.L.

International Journal of Electrical Power and Energy Systems

Oct 1992 p 358-363

It is accepted that the dynamic stability of an integrated AC/DC power system can be enhanced by adopting an appropriate strategy for controlling the power flow in the embedded DC portions. This paper envisages a decentralized optimal control strategy under a hierarchical structure to achieve this objective. Faced with the intrinsic needs of heavy computing resources when the DC system has grown into a multiterminal connection, strong motivation for using a distributed computing environment is envisaged. The scope for the application of this new technological potential is demonstrated with the aid of a dynamic simulation example. (Author)

[1992] 5A-14

DESCRIPTION OF DIGITAL FIRING CIRCUIT OF AN HVDC RECTIFIER FOR ITS REALIZATION

Wang, P.; Fellah, M.K.; Aubry, J.F.; Zanne, C.

Proceedings of the IEEE International Symposium on Industrial Electronics (Cat. No.92TH0371-5)

p.523-7 vol.2, 1992.

High voltage direct current (HVDC) systems are used in energy transmission, especially for large distance transmission and transmission between two asynchronous networks. Recently, with the development of electronics and computer science, more and more control systems are being numerallized since a digital control system may provide, in addition to its flexibility, a solution to the problem of operation security. In this paper, the authors present a description of digital firing circuit of an HVDC rectifier. The aim of the description is to facilitate its realization and, if wanted, to ensure its operation security. (9 Refs)

[1991] 5A-15

DESIGN AND IMPLEMENTATION OF A TRANSMISSION LINE FAULT LOCATOR

Tzyh-Yuan Sheu; Ching-Rong Liaw; Yeng-Feng Sheu; Jin-Shyr Yang; Ming-Huey Ho

IASTED International Conference. High Technology in the Power Industry. Power High Tech '91

p.116-19 4-7 March 1991 Tainan, Taiwan In English

The design and implementation of a single-terminal type of PC-based transmission line fault locator are presented. Electromagnetic interference frequently existing in substations is accounted for in the design of the fault locator's signal conditioning unit by complying with the ANSI C37.90.a standard. The decaying DC and harmonics contaminating the sampled waveform are eliminated by a digital mimic circuit and the discrete Fourier transform technique. The resulted fundamental component phasors of sampled voltage and current are then applied to fault type identification and fault location. In the fault location algorithm, the reduced system network behind the two terminals of the line under evaluation is modeled to account the fault current distribution. As such, the fault resistance affect can be ignored. The laboratory test results show that the maximum error in this study is about 2% of the line length. (11 Refs)

[1990] 5A-16

DESIGN OF A ROBUST MODULATION CONTROLLER OVER A WIDE RANGE OF LOAD CHARACTERISTICS FOR AC/DC SYSTEMS

Choudhry, M.A.; Reza, M.A.; Ellithy, K.A.

IEEE Transactions on Power Systems

Vol. 5, No. 1, February 1990

This paper presents a method to design a robust modulation controller to improve the dynamic performance of ac/dc systems. Static load is modeled as a nonlinear function of load bus voltage and dynamic load is modeled by and equivalent induction motor.. Reactive power and DC power are considered for the modulation control. Static var compensator (SVC) is used for the reactive power modulation.

[1993] 5A-17

DESIGN OF A SUPPLEMENTARY MODULATION CONTROL FUNCTION FOR THE CHESTER SVC

Larsen, E.; Rostamkolai, N. ; Fisher, D.; Poitras, A.

IEEE Transactions on Power Delivery

Apr 1993 p 719-724

The Chester SVC was recently installed in New England on the 345 kV interconnection between Maine and New Brunswick. This SVC provides dynamic voltage support to prevent the rejection of generation in New Brunswick following contingencies related to the Phase II HVDC interconnection between Quebec and New England. As the project evolved from the planning to design stages, a control function referred to as the Supplementary Modulation Control became an important aspect of the overall SVC system. The criteria and analysis necessary to design this control function are described. Considerations for stability and subsynchronous torsional interaction are included.

[1991] 5A-18

DESIGN OF FREQUENCY CONTROLLER FOR RIHAND-DELHI HVDC PROJECT

Dass, R.; Moni, R.S.; Chakravorty, S.; Rao, L.V.; Prasad, M.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 273-278

The Rihand-Delhi HVDC Project is a 814 km long bipolar transmission project. This system will be utilised for transmission of power from the coal fired thermal generation complex at Rihand and Singrauli to the National Capital Region around New Delhi. The scheme includes all the normal controllers typical for

an HVDC transmission scheme. The higher level controls include a power modulation control and a frequency controller. Frequency controllers are generally adopted in HVDC scheme where one of the converters is connected to an isolated system of synchronous machines. This paper describes the frequency controller for a project where isolation of a converter on to a local a.c. system is not a normal mode of operation, but nevertheless can take place under certain system contingencies. At the time of writing, the first pole of the Rihand-Delhi HVDC project is undergoing system tests and is expected to be fully operational by the middle of 1991.

[1992] 5A-19

DIGITAL HVDC TRANSMISSION CONTROL TECHNIQUE WITH HIGH AVAILABILITY
Messner, J.; Wild, G. (Siemens AG, Erlangen (Germany))
ETZ
Dec 1992 p 1422-1426
With the aid of HVDC transmission, electricity can be transported very economically over long distances. However, the erection of such HVDC transmission plant involves high investment costs. The operator of the plant therefore expects correspondingly high availability of the HVDC transmission system, which depends on the digital HVDC transmission control technique and its structure. The control technique components and important aspects to ensure availability are described.

[1991] 5A-20

DIGITAL RECTIFIER PROTECTION FOR HVDC TRANSMISSION
Hugelschafer, L.; Plewka, G.; Zink, W.
ETZ
vol.112, no.21 p.1164-6, 1168, 1170 Nov. 1991
Germany In German.
The basic arrangement for HVDC transmission protection and the types of faults that can be encountered are illustrated. The clearance of a fault with short time response and the protection algorithms, as well as the signal processor application, are referred to the Simadyn D control system. The exchangeable cards, hardware and the mechanical design are discussed together with digital signal tracking, and with the introduction of test requirements in accordance with VDE and IEC rules. (6 Refs)

[1991] 5A-21

EFFECTS OF A VARIABLE PARAMETER CONTROLLER ON THE DYNAMIC PERFORMANCE OF AN HVDC TRANSMISSION SYSTEM.
Hasan, Abul R.; Ula, A.
Electric Power Systems Research
v 21 n 3 Jul 1991 p 173-180
To transfer bulk electrical power over long distances, high voltage direct current transmission is increasingly being considered because of its superior stability compared with AC lines whose stability is limited by their line inductances. The transients in an HVDC system can temporarily change the line current substantially from the reference value, and the behavior of the system depends to a great extent upon the parameters of the current controller. A controller which has a good steady-state performance may not have a sufficiently good performance under transient operating conditions, or vice versa. The performance of the current controller also depends on the impedance at the rectifier and the inverter bus, which may vary according to the operating conditions. An improved controller, the variable parameter controller, is suggested here, where the controller gain and parameters are varied depending upon the rate of change of the direct current and the voltage. A mathematical model based on the linearized equations is also developed by which the controller parameters can be estimated. To demonstrate the improved performance of the variable parameter controller, a parallel AC-DC system was simulated in the computer by using the Electromagnetic Transients Program (EMTP) of Bonneville Power Administration. Various transient studies have been performed with both the fixed and the variable parameter controller.

[1992] 5A-22

EVALUATION OF AN OFF-LINE NEURAL NETWORK BASED CURRENT REGULATOR FOR HVDC [HIGH VOLTAGE DC] TRANSMISSION SYSTEMS
Kandil, N.; Sood, V.K.; Patel, R.V.; Khorasani, K.; Trahanias, P.; Venetsanopoulos, A.N. (eds.)
Canadian conference on electrical and computer engineering in Toronto (Canada)
13-16 Sep 1992
An off-line trained neural network based current regulator for the rectifier in a two-terminal high voltage DC (HVDC) back-to-back tie is presented. The regulator provides fast response dynamics over a limited range when compared to more traditional proportional, integral (PI) current regulators. The HVDC system subsystems, control systems, neural network controller, training, and case studies are

described. It is possible to utilize the neural net controller to function similarly to a PI controller under conditions where the operating point is close to the desired output, ie. the current error is small. However, where the output is far from the desired value, ie. for a large current error, the neural net controller is not able to correct the operating

[1991] 5A-23

EXPERIENCE WITH A DIGITAL FULLY REDUNDANT CONTROL SYSTEM FOR HVDC PLANTS

Knittler, D.; Hugelschafer, L.

EPE '91. 4th European Conference on Power Electronics and Applications

p.82-7 vol.3 3-6 Sept. 1991 Firenze, Italy In English

The transport of electric power is constantly increasing in importance and this is accompanied by a corresponding increase in the importance of interconnections between differing grids, e.g. between the West European UCPTE Grid and neighbouring networks. In the case of two networks which are asynchronous, with slightly differing frequencies and the resulting phase shift, direct power exchange via an AC-link is not possible. HVDC (high-voltage direct current) transmission is the only possibility for power interchange between two such networks. Digital systems (microcomputers) are used for the open-loop, closed-loop and protection systems of the HVDC link. The authors describes the digital closed-loop controls. A standard multiprocessor system which has proven itself in the field of drive controls is used. The closed-loop control has been designed as a two-channel redundant configuration to improve the availability and reliability of the HVDC link. While one channel actively controls the HVDC link, the second channel operates in hot-standby mode and can take over control at any time. Proper functioning of the closed-loop control system was proven by tests in a network analyser. (4 Refs)

[1992] 5A-24

FILTER PROTECTION FOR HVDC PROJECT GESHA

Weibelzahl, M.; Mukherjee, A.; Janke, R.

Modern Power Systems

Feb 1992 p 29, 31, 33

A recently installed 1000 km HVDC link between Gezhouba hydropower plant and Shanghai in China transmits power from the 2715MW plant to the city. Siemens was part of a consortium involved in construction of the project. One of its responsibilities was the design of a protection system for the DC filters. Siemens AG, who built the Nan Qiao converter station, also solved this challenging problem on this remarkable project. The design of the filters and the protection system are described.

[1991] 5A-25

FIRST BENCHMARK MODEL FOR HVDC CONTROL STUDIES

Szechtman, M.; Wess, T.; Thio, C.V.; Ring, H.; Pilotto, L.; Kuffel, P.; Kent, K.; Mayer, K.

Electra

no.135 p. 54-73, April 1991 Published in France In French and In English.

A first benchmark model for studies of different HVDC control strategies is presented. The test circuit is adequate for transient studies up to about 400 ms time scale, in which pole controls' action is predominant, Digital computer and simulator results have been 'calibrated' and are presented. The results show that excellent comparisons can be obtained from different simulation sources, but it was found that near-identical control characteristics and proper representation of controls is very important for a fair comparison. (13 Refs)

[1991] 5A-26

HVDC CONTROLS FOR SYSTEM DYNAMIC PERFORMANCE.

Taylor, C. W.; Lefebvre, S.

IEEE Transactions on Power Systems

v 6 n 2 May 1991 p 743-752

The controllability of HVDC links is often cited as an important advantage of DC systems. This controllability can be valuable in improving the dynamic performance of large power systems. To achieve the promised advantages, control systems must perform appropriately for various disturbances and system conditions. The controls, which can be quite powerful, must not interact unfavorably with other high-performance controls. The application of special (or supplementary) HVDC controls for power system dynamic performance improvement is addressed. The topics addressed are reactive power regulation, dynamic AC voltage support, damping of frequency oscillations and augmenting transient stability, special controls during faults, operating experience, and future trends.

[1993] 5A-27

HVDC SYSTEMS FAULT DIAGNOSIS WITH NEURAL NETWORKS

Lal, L.L.; Ndeh-Che, F.; Chari, Tejedo; Rajroop, P.J.; Chandrasekharaiah, H.S.

Power Electronics in Generation and Transmission IEE Conference Publication

v 8 n 377 1993 p 145-150

This paper describes a neural network and its simulation results for fault diagnosis in HVDC systems. Fault diagnosis is carried out by mapping input data patterns, which represent the behaviour of the system, to one or more fault conditions. The behaviour of the converters is described in terms of the time varying patterns of conducting thyristors and AC & DC fault characteristics. A three-layer neural network consisting of 20 input nodes, 12 hidden nodes and 4 output nodes is used. 16 different faults have been considered and dynamic characteristics of networks for different configurations are studied too. The time performance of the network is also included. Neural networks provide an effective way for fault diagnosis.

[1992] 5A-28

LOW ORDER DYNAMIC CONTROLLERS FOR HVDC LINKS SUPPLYING WEAK SYSTEMS

Georgantzis, G.J.; Glannakopoulos, G.B.; Vovos, N.A.; Welfonder, E.; Lausterer, G.K.; Weber, H.

International IFAC symposium on control of power plants and power systems

9-11 Mar 1992 p 293-298

The design process for centralized suboptimal low order dynamic controllers for HVDC links supplying weak AC power systems, using the projective control technique, is presented. The controllers are simple and easily superimposed on the classical control system of the HVDC links. They exploit the possibility of simultaneous control of active and reactive power at the inverter side in order to achieve very efficient frequency and voltage control for the supplied AC system. The response of the proposed controllers has been tested under large load disturbances on a realistic electrical power system using a fundamental frequency digital simulation program.

[1991] 5A-29

MODULATION CONTROLS FOR THE NEW ZEALAND DC HYBRID PROJECT.

Martin, D.; Wong, W.; Liss, G.; Arnlov, B.; Jonsson, T.; Gleadow, J.; de Silva, J.

IEEE Transactions on Power Delivery

v 6 n 4 Oct 1991 p 1825-1830

The New Zealand HVDC Project is being upgraded from a rated 600 MW to 1240 MW. The result is a hybrid system with the addition of thyristor valves in combination with the original mercury-arc valves. The additional DC power required developing modulation and control functions for voltage stabilization at the inverter. Other specified requirements are control functions for spinning reserve sharing, frequency stabilization, and constant frequency control. Constant frequency control was defined for those system conditions where the Haywards converter may be isolated with load. The modulation function for frequency stabilization was developed to enhance overall AC system response to disturbances. The various modulation functions implemented for this hybrid HVDC system are described. 4 Refs.

[1991] 5A-30

NEURAL NETWORK BASED CURRENT CONTROLLER FOR HVDC TRANSMISSION SYSTEMS.

Sood, V. K.; Kandil, N.; Patel, R. V.; Khorasani, K.

2nd International Conference on Artificial Neural Networks

1991 Nov 18-20 IEE Conference Publication n 349 p 373-378

This paper presents a Neural Network (NN) based current controller for a rectifier in a two-terminal HVDC back-to-back tie. This controller adapts its gain parameters to provide better or similar recovery dynamics when compared to the more traditional PI current controller. Comparisons between the proposed NN and traditional PI controller responses are provided by means of results obtained from digital simulations made with the EMTDC simulation package.

[1991] 5A-31

NEW DIGITAL CONTROL OF FORCED COMMUTATION HVDC CONVERTER SUPPLYING INTO LOAD SYSTEM WITHOUT AC SOURCE

Kimura, Noriyuki; Kishimoto, Masashi; Matsui, Kuniyuki.

IEEE Preprint #91 WM 242-8 PWRD

1991

This paper describes new digital control technique for forced commutation converter applied to HVDC transmission systems with loads which have no AC source. The proposed technique uses direct calculation of the firing angle of inverters. The results of simulator experiments and computer simulations show good performance for the regulation of the AC voltage of a load system without an AC source. In particular, it works well when ZnO arrester is installed to suppress overvoltage which occurs when the load in the receiving system is suddenly rejected.

[1991] 5A-32

NONLINEAR FEEDBACK STABILIZATION OF AC/DC POWER SYSTEMS

Kaprielian, S.R.

Worcester Polytechnic Inst.

1991 (208 p). Thesis (Ph.D)

The ability of an HVDC link to enhance the stability of a parallel AC/DC power system was recognized early and several operational two prove the stability of their AC networks. Methods have been sought to optimize the response of the AC system to this control and research in this area has produced several control strategies. The majority of them were derived from a small signal (linear) analysis of the system and were therefore dependent on the system operating point. They also neglected the nonlinear nature of the problem and ignored system constraints. Therefore, although these control strategies proved effective during small disturbances, acceptable behavior during large disturbances was not guaranteed. The primary contribution of this work is the design of a combined observer-controller (compensator) which is less dependent on any single, system operating condition. The formulation is developed from a nonlinear descriptor-variable model of an AC/DC power system, consisting of nonlinear coupled differential and algebraic equations. The compensator enforces a control law which is based on feedback linearization principles. The underlying concept of this control method is to use feedback to linearize a portion of the entire nonlinear system. The resulting linear subsystem may then be controlled by applying well-known linear systems theory. The design technique is illustrated with two AC/DC systems and simulation results are given to support the effectiveness of the method.

[1993] 5A-33

OPTIMAL FIRING-ANGLE CONTROL OF CASCADED HVDC CONVERTERS FOR MINIMUM REACTIVE POWER DEMAND

Delb, D.A.; Hill, H.W.

IEEE Applied Power Electronics Conference and Exposition - APEC

1993. Publ by IEEE, IEEE Service Center, Piscataway, NJ, USA. p 662-667

An asymmetrical firing strategy for the cascaded converters of a HVDC link is proposed, resulting in minimum reactive power compensation at both ends of the DC link. Both 6- and 12-pulse converters, in unipolar and bipolar operation, are considered. In addition to reactive power reduction, AC and DC harmonics are greatly reduced.

[1991] 5A-34

PHASE ANGLE CONTROL OF VOLTAGE SOURCE CONVERTER IN HIGH POWER APPLICATIONS

Angquist, L.; Lindberg, L.

EPE '91. 4th European Conference on Power Electronics and Applications

p.243-7 vol.2 , 3-6 Sept. 1991 Firenze, Italy In English

Voltage source converters for high-power applications like HVDC and SVC will encourage the use of low commutation frequency which restricts the attainable control performance. In spite of the low switching frequency, the control system must be fast-acting in order to handle start-up and different fault conditions. A control strategy is required that brings the converter into stationary state as fast as possible. The authors describe a control method for a voltage source converter. The proposed control method is based on measured converter flux (time integral of converter voltage) and DC voltage, exemplified in a six pulse unit. The time to next commutation is calculated in real-time so that the converter flux is guided in minimum time from an arbitrary point in the flux plane towards the stationary orbit. (5 Refs)

[1993] 5A-35

PROTECTING A HVDC LINK AGAINST ACCIDENTAL ISOLATION FROM ITS RECEIVING AC SYSTEM
Whitehouse, R.S.
IEEE Transactions on Power Delivery
Jul 1993 p 1586-1590
When an HVDC scheme is isolated from its receiving AC system, the inverter may continue to operate, generating its own AC bus voltages; this is defined here as islanding. If islanding is allowed to continue unrestricted, then main circuit components may in some conditions be damaged and it is therefore necessary to provide a suitable protection system. This paper outlines the protection scheme developed for the McNeill Back-to-Back HVDC link in Alberta, Canada, to prevent damage due to islanding while still permitting the link to automatically restart on reclosure of the isolating breaker. Oscillograms showing the protection in operation on both the GEC ALSTHOM HVDC simulator and during tests carried out as part of the commissioning of the McNeill HV DC link are included.

[1991] 5A-36

PROTECTION OF HVDC CONVERTER STATIONS AGAINST LIGHTNING OVERVOLTAGES
Chen Weijiang; Du Shuchun
Power System Technology
no.1 p.17-24 Feb. 1991 Published in China.
Language: Chinese
By summing up the study results of EPRI in protection of HVDC converter stations during recent years and the operation experience in HVDC transmission projects abroad, the authors analyse the main features of the overvoltage stressing on the major apparatus in convertor stations and protection schemes. Some typical protection schemes are recommended. (5 Refs)

[1993] 5A-37

RULE BASED CONTROLLER FOR AN HVDC TRANSMISSION SYSTEM
Parekh, B.R.; Banerjee, S.K.
Electric Power Systems Research
vol.27, no.2 p.83-90 July 1993
Rule based techniques for controlling processes have existed for over a decade, incorporating expert systems in their design. This paper outlines the theory behind a simple rule based controller (RBC) and its application to an HVDC system as a current (pole) controller. HVDC systems having different configurations, namely, a two-terminal HVDC system and a three-terminal star-connected HVDC system, were simulated to study the performance of the RBC, using Manitoba HVDC Research Centre's EMTDC package. This paper also compares the results obtained using the RBC with those obtained with a conventional current controller.

[1993] 5A-38

SELF-TUNING CONTROL OF A TWO-TERMINAL HVDC SYSTEM
Ghosh, A.; Pandey, R.K.; Sachchidanand
IPEC '93. International Power Engineering Conference 1993. Conference Proceedings
p.380-5 vol 1, 18-19 March 1993
The design of self-tuning controllers for HVDC power converters is presented in this paper. Noting the discrete nature of power convertor operation, a suitable linearized discrete-time converter model is first derived. This model takes into account the cyclic sampling behavior of the converter which arises due to the firing and commutation of valves periodically. This cyclic-rate sampling based converter model is then used for self-tuning controller design. Two different self-tuning controllers are presented in a generalized framework Also, for the coordinated control of a two-terminal HVDC model, the rectifier current controller requires information of the inverter end current and voltage. These quantities are estimated based on the measurements of the rectifier end quantities only. The proposed controllers are tested through digital computer simulations.

[1990] 5A-39

SOLUTION TO THE PROBLEM OF LOW ORDER HARMONIC RESONANCE FROM HVDC CONVERTERS
Kaul, N.; Mathur, R.M.
IEEE Transactions on Power Systems
Vol, 5, No. 4, November 1990
The paper identifies a severe form of Low Order Harmonic Resonance problem in an HVDC/ac system. It then seeks solutions to the problem by HVDC control means. This is achieved by a proper design of the Voltage Dependent Current Order Limiter (VDCOL), the Current Regulator and Timing Pulse generator. Supplementary control loops have also been introduced to result in a satisfactory performance as compared to that obtained with the use of uncharacteristic harmonic filter on the AC side. Robustness of all the options has been demonstrate through recovery performance of the DC link in response to 3-phase 5 cycle faults on both rectifier and inverter commutating busses.

[1992] 5A-40

STABILITY ANALYSIS OF A DIGITALLY BASED HVDC FIRING-PULSE SYNCHRONIZATION CONTROL
Larsen, E.Y.; Clark, K.; Lorden, D.J.
IEEE Transactions on Power Delivery
Jul 1992 p 1415-1424
This paper presents a step-by-step analysis of the performance and stability characteristics of a digitally based DC firing-pulse synchronizing control. The performance of the loop is dependent upon parameters of the AC system, DC system, an the primary DC regulators. The synchronizing loop at the inverter tends to destabilize low frequency modes of the overall system. Control loop filtering is an effective means of stabilizing this interaction.

[1991] 5A-41

STABILITY OF PWM HVDC VOLTAGE REGULATOR BASED ON PROPORTIONAL-INTEGRAL FEEDBACK
Ooi, B.T.; Guo, Y.; Wang, X.; Lee, H.C.; Nakra, H.L.; Dixon, J.W.
EPE '91. 4th European Conference on Power Electronics and Applications
p.76-81 vol.3. 1991
The authors show that the voltage regulator, as in all feedback systems, has possibility of instability. The danger can be avoided by understanding its origins. One eigenmode is the capacitor charging mode. This mode can be stabilized by proportional and integral feedback. Analytical insights for the design of this mode have been developed through simplified equations. Experimental results are given from 5 kVA laboratory converter driven by multi-DSP real time controller. There is a second eigenmode which becomes unstable when the line resistance is low. (8 Refs)

[1993] 5A-42

SUPPLEMENTARY DC CONTROL IN A TWO AREA AC/DC POWER SYSTEM
Castellanos, J.M.; Fleming, R.J.
Communications, Computers and Power in the Modern Environment
1993 IEEE Wescanex 1993. Publ by IEEE, IEEE Service Center, Piscataway, NJ, USA,Sask. p 247-255
The research reported in this paper concerns the performance of supervisory control associated with a high voltage Two Area Power System interconnected by HVAC and HVDC tie lines. The system includes supplementary DC control interacting with the conventional AC area controls. Taking advantage of the fast controllability of DC links, supplementary control utilizing DC power modulation could simultaneously improve system dynamic stability, reduce area control error and inadvertent energy interchange. The supplementary DC power modulation is based on variation of the net power interchange due to step load disturbances in one of the control areas. A linear model was used for the power system to study small changes around a base reference state and only the power-frequency control aspects of the overall power system control problems were considered. Eigen-structure analysis of the state space model of the power system was used to evaluate system stability. Control optimization was achieved by minimization of a performance index which is a function of the Area Control Error (ACE). Computer simulation was used to obtain power system dynamic responses to step load disturbances and to estimate the optimal controller parameters.

[1993] 5A-43

UNIFIED CONTROL STRATEGY FOR BACK-TO-BACK HVDC CONVERTOR STATIONS
Wood, A.R.; Arrillaga, J.; Saavedra, A.R.
IEE Proceedings, Part C: Generation, Transmission and Distribution
Mar 1993 p 77-86
Control of high voltage direct current (HVDC) back-to-back links is normally maintained with separate controllers at each end. This paper proposes a single unified controller for both ends, and assesses its performance. Two new measures of the difficulty of connecting a DC link to a weak AC system are developed, which take into account the link control strategy. Simulation results are used to investigate the performance of the unified controller, and the validity of the proposed measures.

[1993] 5A-44

UTILIZING HVDC TO DAMP POWER OSCILLATIONS
Smed, T.; Andersson, G.
IEEE Transactions on Power Delivery
vol.8, no.2 p.620-7 April 1993
Damping of slow oscillations with active and reactive power modulation of high-voltage direct current (HVDC)-links is analyzed with the aim of gaining a physical insight into the problem. The analysis shows that active power modulation is efficient when applied a short mass-scaled electrical distance from one of the swinging machines, and reactive power modulation is most efficient when a well-defined power flow direction exists and the modulation is made at a point close to the electrical midpoint between the swinging machines. It is shown that the intuitively appealing

feedback signal frequency and derivative of the voltage are appropriate for active and reactive power modulation. The impact of the constraints imposed by the HVDC equations is analyzed, and it is determined when the implicit reactive power modulation resulting from constant gamma control may be detrimental for the damping. (9 Refs)

[1992] 5A-REF

ANALYSIS OF SECOND HARMONIC INSTABILITY FOR THE CHATEAUGUAY HVDC/SVC SCHEME
Hammad, A.E.
IEEE Transactions on Power Delivery
Jan 1992 p 410-415
For Abstract see entry 5D-007.

[1994] 5A-REF

PROPOSED HVDC CONTROL METHODS FOR STABILIZATION OF AN INTEGRATED AC/DC SYSTEM
Georgantzis, G.J.; Vovos, N.A.; Giannakopoulos, G.B. Dept. of Electr. Eng., Patras Univ., Greece
Proceedings of the Eleventh IASTED International Conference. Modelling, Identification and Control
1994 p.298-301. In English.
For Abstract see entry 1B-019.

[1992] 5A-REF

THE BEHAVIOR OF SEVERAL HVDC LINKS TERMINATING IN THE SAME LOAD AREA
Szechtman, M.; Pilotto, L.A.S.; Ping, W.W.; Wey, A.; Salgado, E.; Carvalho, A.R.; Long, W.F.; Alvarado, F.L.; Demarco, C.L.; Nilsson, S.L.
CIGRE Proceedings of the 34th Session
p.14-201/1-7 vol.1 30 Aug.-5 Sept. 1992
For Abstract see entry 1B-023.

[1991] 5A-REF

A BENCHMARK MODEL FOR HVDC SYSTEM STUDIES
Szechtman, M.; Wess, T.; Thio, C.V.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991, v no. 345., p 374-378
For Abstract see entry 1F-001.

[1992] 5A-REF

EFFECT OF A MODULATED HVDC LINK ON POWER SYSTEM TRANSIENTS.
Teshome, Asrat
Electric Power Systems Research
v 25 n 2 Nov 1992 p 101-109
For Abstract see entry 1F-008.

[1991] 5A-REF

BOOST TYPE PWM HVDC TRANSMISSION SYSTEM
Ooi, B.T.; Wang, X.
IEEE Transactions on Power Delivery
Oct 1991 p 1557-1563
For Abstract see entry 2A-007.

[1992] 5A-REF

CHARACTERISTICS OF UNIT-CONNECTED HVDC GENERATOR-CONVERTORS OPERATING AT VARIABLE SPEEDS
Arrillaga, J.; Sankar, S.; Arnold, C.P.; Watson, N.R.
IEE Proceedings, Part C: Generation, Transmission and Distribution
May 1992 p 295-299
For Abstract see entry 2A-008.

[1991] 5A-REF

DC POWER TRANSMISSION SYSTEM
Inokuchi, Haruhisa.
Patent No.CA 1279096 A
1991
For Abstract see entry 2A-009.

[1992] 5A-REF

NOVEL CONTROL STRATEGIES OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER
Tokiwa, Y.; Ichikawa, F.; Suzuki, K.; Inokuchi, H.; Hirose, S.; Kimura, K.
Denki Transactions of the Institute of Electrical Engineers of Japan:
20 Jan 1992 p 19-26. In Japanese.
For Abstract see entry 2A-019.

[1993] 5A-REF

OPTIMAL FIRING-ANGLE CONTROL OF CASCADED HVDC CONVERTERS FOR MINIMUM HARMONIC CURRENTS
Deib, D.A.; Hill, H.W.; Shepherd, W.
IECON Proceedings (Industrial Electronics Conference) v 2
1993. p 1071-1076
For Abstract see entry 2A-022.

[1991] 5A-REF

DIFFERENTIAL FIRING-ANGLE CONTROL OF SERIES-CONNECTED HVDC BRIDGES.
O'Kelly, D.
Electric Power Systems Research
v 20 n 2 Feb 1991 p 113-120
For Abstract see entry 2B-005.

[1991] 5A-REF

COMMENTS ON MINIMISATION OF UNCHARACTERISTIC HARMONICS IN HVDC CONVERTORS THROUGH FIRING ANGLE MODULATION (AND REPLY)
Sood, V.K.; Gole, A.M.; Farret, F.A.; Freris, L.L.
IEE Proceedings C (Generation, Transmission and Distribution)
vol.138, no.6 p.567-8 1991 UK
For Abstract see entry 2C-006.

[1993] 5A-REF

SECONDARY ARC EFFECTS IN AC/DC HYBRID TRANSMISSION
Woodford, D
IEEE Transactions on Power Delivery
Apr 1993 p 704-711
For Abstract see entry 2E-004.

[1991] 5A-REF

NEW DIGITAL CONTROL OF FORCED COMMUTATION HVDC CONVERTER SUPPLYING INTO LOAD SYSTEM WITHOUT AC SOURCE
Kimura, Noriyuki; Kishimoto, Masashi; Matsui, Kuniyuki.
IEEE Preprint #91 WM 242-8 PWRD
1991
For Abstract see entry 5A-031.

[1993] 5A-REF

PROTECTING A HVDC LINK AGAINST ACCIDENTAL ISOLATION FROM ITS RECEIVING AC SYSTEM
Whitehouse, R.S.
IEEE Transactions on Power Delivery
Jul 1993 p 1586-1590
For Abstract see entry 5A-035.

[1991] 5A-REF

APPLICATIONS OF EXACT LINEARIZATION TECHNIQUES FOR STEADY-STATE STABILITY ENHANCEMENT IN A WEAK AC/DC SYSTEM,
Kaprielian, S.; Clements K.; Turi J.
IEEE Preprint #91 SM 418-4 PWRS
1991
For Abstract see entry 5D-009.

[1992] 5A-REF

POWER SYSTEM PROTECTION IN HVDC ENVIRONMENTS. HOW HVDC STATIONS INFLUENCE AC LINE PROTECTION
Andersson, F.; Juhlin, L.E.
ABB Review (Asea Brown Boveri) (Switzerland) v 3.
1992 p 27-32
For Abstract see entry 5D-016.

[1991] 5A-REF

SUBSYNCHRONOUS OSCILLATION CONTROLLER FOR VINDHYACHAL BACK-TO-BACK HVDC LINK
Prasad, M.; Rao, L.V.; Roy, A.K.; Kaul, N.; Madan, S.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 290-294
For Abstract see entry 5D-018.

[1993] 5A-REF

EVALUATION OF NONCONVENTIONAL HVDC CONVERTER CONTROLS IN AN AC/DC POWER SYSTEM USING PRONY SIGNAL ANALYSIS
Emmanuel, P.A.; Nehrir, M.H.; Pierre, D.A.; Adapa, R.
Electric Power Systems Research
v 26 n 1 Jan 1993. p 31-39
For Abstract see entry 6B-011.

[1993] 5A-REF

EASTERN EUROPE CONNECTS TO UCPTE VIA ETZENRICHT LINK
Reischl, A.; Weingarten, U.
Modern Power Systems
Jun 1993 p 31-32
For Abstract see entry 7A-009.

[1993] 5A-REF

AN EVALUATION OF A THYRISTOR CONTROLLED PHASE ANGLE REGULATOR APPLICATION IN THE MINNESOTA POWER TRANSMISSION SYSTEM
Kappenmann, J.G.; Norr, S.R. ; Klein, M.
EPRI-TR-101932
May 1993
For Abstract see entry 8-003.

[1991] 5A-REF

PARALLEL LINE SWITCHING IN HVDC SYSTEMS
Electra
no.138 p.66-80 Oct. 1991 France
For Abstract see entry 1A-012.

[1992] 5A-REF

DIGITAL HIGH VOLTAGE DC, TRANSMISSION MANAGEMENT TECHNOLOGY PROVIDING HIGH AVAILABILITY
Messner, J.; Wild, G.
ETZ
vol.113, no.22-23 p.1422-6 Nov. 1992
For Abstract see entry 1A-002.

5B. CIRCUIT SWITCHGEAR

[1992] 5B-1

A SUPER HIGH SPEED INTELLIGENT CIRCUIT BREAKER
Collart, P.; Pellichero, S.
GEC ALSTHOM Technical Review
no.9 p.35-42 June 1992 , France, In English.
Direct current electrical networks are becoming increasingly complex and powerful in the industry and railway sectors. It is consequently essential to protect these networks against overcurrents. Protection equipment must react very quickly by limiting and interrupting hazardous currents almost instantaneously, the ideal solution being to break them in a highly selective manner without the formation of an electric arc. The DHR circuit breaker makes it possible to achieve this ideal. The DHR interrupts direct current within an extremely short time period (1 to 3 ms) while ensuring negligible contact wear since no electric arc is formed. A microcontroller provides users with a complete range of new capabilities which are easy to utilize. (0 Refs)

[1992] 5B-2

AN EXPERIMENTAL INVESTIGATION ON THE ARC INSTABILITY IN HVDC INTERRUPTION
Sun Guangsheng; Wang Yongrong; Fen Rongqiong; Yan Ping
Proceedings of the Tenth International Conference on Gas Discharges and Their Applications
p.168-71 vol.1 1992. University College, Swansea, UK
Results of a series of self-excited oscillatory interrupting tests are described. Arc instability and commutating circuit parameters effect on interruption are studied to find the suitable coordinate relation for reliable interruption. (5 Refs)

[1993] 5B-3

ANALYSIS AND CALCULATION OF OPERATING CONDITION OF HVDCCB AND MRTB IN GEZHOUBA-SHANGHAI 500 KV HVDC TRANSMISSION LINE
Shen Li; Ji Jiaqin Dept. of Electr. Eng., Tsinghua Univ., China
Journal of Tsinghua University
vol.33, no.4 p.13-21 1993. In Chinese.
The analysis and calculation have been made with the Electro-Magnetic Transients Program. The influence of the system inductance and interrupting current is analysed. In the most serious situation, when I=4kA, the dissipated energy is 15.7 MJ, and the current duration 11.6 ms. At the same time, the operating conditions of HVDC circuit breakers and metallic return transfer breakers are compared.

[1993] 5B-4

CALCULATION AND ANALYSIS OF OPERATING CONDITIONS OF MRTB IN GEZHOUBA-SHANGHAI 500 KV HVDC SYSTEM
Shen Li; Ji Jiaqing; Zhang Jierong Dept. of Electr. Eng., Tsinghua Univ., Beijing, China
Proceedings of the CSEE
vol.13, suppl. p.103-7, 1993. In Chinese.
This paper calculates and analyses the operating conditions of a metallic return transfer breaker

(MRTB) with the Electro-Magnetic Transients Program under the conditions of the Gezhouba-Shanghai 500 kV HVDC system. The dissipated energy in the energy absorber of the MRTB when interrupting normal current is more than 1 MJ and the current duration is more than 20 ms. This paper compares the operating conditions of MRTB with those of a 500 kV HVDC circuit breaker (CB), and points out that in some aspects the MRTB faces more serious conditions than the 500 kV HVDC CB.

[1992] 5B-5

CRITICAL CONDITIONS AND ESCALATION RATE OF SELF-EXCITED OSCILLATION IN HVDCCB COMMUTATING CIRCUIT
Zhang, J.R.; Zhang, L.C.; Ji, J.Q.
Proceedings of the Tenth International Conference on Gas Discharges and Their Applications
p.172-5 1992
The simplest method for DC interruption is to use an uncharged capacitor in parallel with a interrupter to induce a escalation oscillation current in passive commutating circuit which forces the DC current to zero and causes consequent arc extinction. The authors present the expressions for the critical arc time constant and optical resistance. The escalation rate of the oscillation current is an important parameter in the design of HVDCCB. The influence of this parameter on arcing time of the interrupter is also discussed. (2 Refs)

[1992] 5B-6

PERFORMANCE OF 420 KV CIRCUIT-BREAKERS IN HVDC CONVERTER STATION
Aldrovandi, G.; Bargigia, A.; Bonfanti, I.; Pazienza, G.; Pincella, C.; Polesello, P.
CIGRE Proceedings of the 34th Session
Sep 1992 p.13-304/1-8 , vol.1
Switching of filter banks can have a severe impact on circuit breaker requirements and performances, due to the high harmonic content in the current to be interrupted and to the distortion of the transient recovery voltage. Attention must be paid to some particular operations which are likely to cause stresses exceeding the figures stated by present standards and have to be analyzed in detail. In some cases, these stresses could determine the number of breaking units of the circuit breaker better than other system requirements like rated short circuit breaking capability, short line fault, etc. The situation can also be more complicated if the circuit-breaker has to be subjected to stresses coming from conversion transformers and harmonic filters switching. The paper presents the results of extensive studies to establish the worst stresses applied to the circuit breaker for SACOI 2 HVDC link between Sardinia and mainland Italy through Corsica. Moreover, the testing activities carried out to verify the ability of the circuit-breaker to withstand the above mentioned stresses are also presented. The peculiarity of these stresses required the setting up of a suitable test circuit to verify the performance of the circuit breaker.

[1993] 5B-7

PHYSICAL DESIGN OF EXTINGUISHING ARC FASHION IN HVDC BREAKERS
Wang Yongrong; Sun Guongsheng; Feng Rongquing; Yan Ping Inst. of Electr. Eng., Acad. Sinica, Beijing, China
Proceedings of the CSEE
vol.13, suppl. p.90-3, 1993 In Chinese.
The artificial creation of a current zero in order to extinguish the arc is the first important technical problem to solved in the development of HVDC circuit breakers. The parameters of the commutation circuit and structure of the commutation significantly affect the interrupting capacity of self-excited oscillation. Based on interrupting test results of such circuit breaker units with different parameters and structures, the physical design principles of extinguishing arcs in HVDC circuit breakers are introduced. (5 Refs)

[1993] 5B-8

SELF-EXCITED OSCILLATION IN HVDC INTERRUPTION
Sun Guangsheng; Wang Yongrong; Feng Rongqiong; Yan Ping
Proceedings of the CSEE
vol.13, suppl. p.94-7 1993 In Chinese.
Self-excited oscillation is widely used in HVDC interruption due to its simple circuit configuration and reliable operation. Good coordination between the parameters of the commutation circuit and the properties of commutation switch's blast arc is the key to producing self-excited oscillation, realizing artificial current zero, transferring current and interrupting DC current. Through a series of interruption tests conducted on a synthetic test circuit for HVDC interruption and analyses of the experimental results, the interrelationship between parameters of commutation capacitance, inductance, interrupting current, and properties of a commutation switch's blast are are obtained. The selection rules for the parameters of a commutation circuit are also introduced.

[1993] 5B-9

SIMULATING CALCULATION OF DC INTERRUPTING
Yan Ping; Wang Yongrong; Sun Guangsheng; Feng Rongqiong Inst. of Electr. Eng., Acad. Sinica, Beijing, China
Journal: Proceedings of the CSEE
vol.13, suppl. p.85-9 1993 In Chinese
Simulation calculations are an efficient method which can be used to investigate and design the commutation circuit of self-excited oscillation HVDC circuit breakers. They offer the influence of the arc characteristics and the parameters of the passive commutation circuit on the interrupting circuit. In this paper, calculations of the interruption process are presented and proven by comparison with experiments. (3 Refs)

[1991] 5B-10

SWITCHING DEVICES OTHER THAN CIRCUIT BREAKERS FOR HVDC SYSTEMS. II. DISCONNECTORS AND EARTHING SWITCHES
Electra
no.135 p.32-53 April 1991. Published in France, In French and in English.
For pt.I see ibid., no.125, p.41-55 (1989). The disconnectors and switches considered are not required to handle significant energy when operating. Only DC side switches are reviewed. For each disconnector and switch the function, mode of operation, and duty are discussed. The disconnectors discussed are: converter disconnector, substation and line pole disconnectors, neutral bus disconnector, DC-filter disconnector, line to neutral disconnector, electrode line disconnector, neutral bus grounding disconnector, bipole paralleling disconnector, substation pole reversal disconnector, and substation pole paralleling disconnector. The earthing switches discussed are: DC line pole earthing switch, DC neutral bus earthing switch, DC filter earthing switch and general earthing switches. (5 Refs)

[1991] 5B-11

SWITCHING PHENOMENA IN HIGH-VOLTAGE CIRCUIT BREAKERS
Nakanishi, K.
Marcel Dekker Inc.
1991 p 163
Paper reports that in 1954 the first high-voltage direct-current (HVDC) transmission system was put into operation between Gotland and the mainland of Sweden. Its system voltage and capacity were 100 kV and 20 MW, respectively. Since then many HVDC transmission systems have been planned, constructed, or commissioned in more than 30 places worldwide, and their total capacity is close to 40 GW. Most systems commissioned to date are two-terminal schemes, and HVDC breakers are not yet used in the high-potential main circuit of those systems, because the system is expected to perform well using only converter/inverter control even at a fault stage of the transmission line. However, even in a two-terminal scheme there are not a few merits in using an HVDC breaker when the system has two parallel transmission lines, that is, when it is a double-circuit system.

[1991] 5B-12

VACUUM CIRCUIT-BREAKER INTERRUPTING DIRECT CURRENT OF HIGH-TENSION POWER
Ouchi, S.
Journal of the Institute of Electrical Engineers of Japan
vol.111, no.2 p.147-50 Feb. 1991 Country of Publication: Japan In Japanese.
The author describes the outline of interruption of direct current using the high-speed vacuum circuit-breaker, its technological point and applications, referring to various kinds of DC circuit breakers, characteristics and mechanisms of the vacuum circuit breaker. (3 Refs)

5C. EARTH RETURN, GROUND ELECTRODES AND MONOPOLAR OPERATION

[1993] 5C-1

A PRELIMINARY DESIGN OF HVDC METALLIC RETURN TRANSFER CIRCUIT BREAKER (MRTB)
Zhang Jierong; Xu Guozheng
Proceedings of the CSEE
vol.13, suppl. p.108-11, 1993 In Chinese.
In this paper the operating principle and the requirement of technical parameters of MRTB are discussed. An AC 35 kV puffer type SF6 circuit breaker is used as an interrupter in an MRTB. A capacitance of 6 mu F and an inductance of 100 mu H are selected for the commutating circuit. The operating conditions of the energy absorber, which consists of ZnO varistors, are also calculated. In addition, the general arrangement, overall dimensions and the cost of MRTB are given.

[1993] 5C-2

EXPERIENCES OF THE MITIGATION OF CORROSION OF BURIED METAL STRUCTURES IN THE SURROUNDINGS OF MONOPOLAR HVDC EARTH ELECTRODES
Jonsson, U.; Nyman, A.; Kuussaari, M.; Orivuori, S.
CIGRE Proceedings of the 34th Session
p.36-201/1-8 vol.2 1993
Measures to be taken at different stages of a monopolar HVDC project, to avoid adverse effects and possible consequent high costs due to corrosion on buried metal structures, are presented. These include the determination of potential fields around the earth electrode, mapping buried metal structures in the vicinity, choosing the place for the earth electrode in relation to critical buried objects and protecting those structures in which excessive corrosion is caused. Methods for field and current density calculations and measurements are presented. Protecting gas pipelines, low-voltage and telephone network earthings, cables and small objects are described. (8 Refs)

[1993] 5C-REF

CALCULATION AND ANALYSIS OF OPERATING CONDITIONS OF MRTB IN GEZHOUBA-SHANGHAI 500 KV HVDC SYSTEM
Shen Li; Ji Jiaqing; Zhang Jierong Dept. of Electr. Eng., Tsinghua Univ., Beijing, China
Proceedings of the CSEE
vol.13, suppl. p.103-7, 1993. In Chinese
For Abstract see entry 5B-004.

5D. STABILITY, AC-DC SYSTEM INTERACTIONS

[1991] 5D-1

A NEW METHOD FOR AVOIDING OVERVOLTAGES WHEN CLEARING D.C.-LINE FAULTS WITH A LOW SCR HVDC STATION
Joetten, R.; Zong, Y.
AC and DC power transmission, IEE Conference Publication Series Institution of Electrical Engineers, London 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 401-403
Two promising variants for avoiding a.c.-side overvoltages at d.c. line faults in low short circuit ratio HVDC systems are presented. Both use commutation switches. The first makes moderate demands on the speed of the switches, but requires further investigation as regards arc extinction. The second uses the converters to extinguish the arc, requires almost no commutation on duty by the switches, but demands fast acting switches (20-30ms).

[1993] 5D-2

AC AND DC SYSTEM DYNAMIC INTERACTION WITH SYNCHRONOUS AND STATIC VAR COMPENSATOR AT THE HVDC INVERTER BUS
Nayak, O.; Gole, A.M.
IPEC '93. International Power Engineering Conference
18-19 March 1993. Conference Proceedings p.491-6 vol.2
Dynamic compensators are often employed at the AC side of an HVDC converter connected to weak AC systems to improve stability and to control voltage. The authors present the transient simulation results of such an application with a mix of static and synchronous compensators at the inverter bus connected to a very weak AC system. An equal mix of static and synchronous compensators offers a better performance in controlling temporary overvoltages than the individual compensators. Interaction between AC and DC systems increases with decreasing AC system strength. This is illustrated by comparing the results of simulations conducted on an AC/DC system having varying AC system strength. (9 Refs)

[1992] 5D-3

AC/DC HARMONIC INTERACTION IN HVDC SYSTEMS
Sadek, K.; Christl, N.; Lutzelberger, P. Seimens AG, Erlangen, Germany
ICHPS V International Conference on Harmonics in Power Systems
p.196-201 23-25 Sept. 1992
The harmonic interaction between AC and DC systems has been discussed in various publications with respect to both characteristic and noncharacteristic harmonic phenomenon injected into AC power transmission systems by HVDC power converters. However, in recent converter power substations different magnitudes of harmonic currents than the theoretical predicted values have been measured. This paper describes a circuit analysis to determine the transfer of harmonics from the supplying AC grid to the receiving AC system and vice versa connected by HVDC links. In general there are mathematical rules, which type and magnitude of harmonics (dependent on the positive or negative sequence system components) will be transferred through the DC circuit and injected into the receiving

power grid. A mathematical model is represented to describe the transfer of harmonics (harmonic voltage distortion from the sending AC-system) through the HVDC link and its impact on the receiving AC side. The contribution of these harmonic voltages has been analyzed and will be considered for modelling the harmonic current source for the inverter terminal. The model is valid for power flow in both directions. (5 Refs)

[1991] 5D-4

AC/DC SYSTEM STRENGTH AS INDICATED BY SHORT CIRCUIT RATIOS

Gavrilovic, A.

AC and DC power transmission: IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 27-32

The "strength" of an AC system is represented by its impedance and by its mechanical (rotational) inertia. System strength expressed as an absolute numerical value, such as short circuit MVA, is useful only if compared to the power and reactive power values of its load. The short circuit ratio (SCR), defined as the ratio of system short circuit level MVA to the DC power MW, has been used to indicate system strength. A system consisting of a number of generators and transmission lines representing a network has more than one value of system strength because loads connected at different locations in the same interconnected network will see different values of the system impedance and the loads themselves will have different values; changes by switching generators, lines, transformers, etc., will also occur from time to time. Describing a system by its SCR is an approximation and it has its pitfalls. SCR is based on a reduced equivalent AC system impedance and data for its calculations must be carefully specified. This paper comments on suggestions that one should avoid using approximations, such as those based on short circuit ratios, because a variety of accurate digital programs capable of full system representation are now available. A brief review of the history of short circuit ratios is given. The reasons for introducing effective, operational and critical short circuit ratios and the influence of the convertor reactive power on these ratios are considered. The effects of AC system inertia on operation of HVDC are also discussed.

[1992] 5D-5

ANALYSIS AND CONTROL SCHEME OF VOLTAGE OSCILLATION IN AC/DC POWER SYSTEMS

Takasaki, M.; Kato, K.; Takenaka, K. (Central Research Inst. of Electric Power Industry, Tokyo (Japan))

Transactions of the Institute of Electrical Engineers of Japan) v 112:11.

20 Nov 1992 p 977-986

The problem about stability due to interaction with AC system is an important technological problem in recent AC/DC power systems for which increase in DC power transmission capacity is desired. Using a model system simulating a future typical DC system introduction, it is clarified that the voltage oscillation phenomenon of AC/DC power system can be accurately analyzed as the stability of the voltage oscillation mode obtained by eigenvalue analysis. Appropriate simulation of dynamic voltage controlling characteristics such as AVR of the generator near the transforming station is necessary for the analysis of voltage instability oscillation. Characteristics of the main oscillation mode and its stability limit are verified based on an AC/DC power system simulator verification test. In addition, the effects of main parameters on the voltage oscillation phenomenon are analyzed, and a stabilization method using voltage modulation control is proposed the effect of which is confirmed by a digital simulation.

[1991] 5D-6

ANALYSIS OF POWER/VOLTAGE STABILITY OF HVDC CONVERTERS IN AC SYSTEMS

Smed, T.; Andersson, G.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 395-397

In this paper, a new approach for analysing power/voltage stability in ac/dc systems is developed. The method is based on power flows in a well-established 'quasi steady-state' model and complex system configurations can be analyzed. In addition to traditional measurements such as the effective short circuit ratio (ESCR) and dV/dQ, the smallest singular value of the power flow Jacobean is used and found to be a feasible measure of the voltage stability. (author).

[1992] 5D-7

ANALYSIS OF SECOND HARMONIC INSTABILITY FOR THE CHATEAUGUAY HVDC/SVC SCHEME
Hammad, A.E.
IEEE Transactions on Power Delivery
Jan 1992 p 410-415
The Chateauguay HVDC back-to-back scheme with interconnections to the 765 kV transmission to U.S.A. and to Beauharnois generators can exhibit, under certain operating conditions, second harmonic resonance problems. This paper presents a thorough analysis of the problem using an eigenvalue and frequency domain approach. The analysis explains the mechanism of exciting the second harmonic instability by the presence of HVDC converters. The influence of changing the control parameters of the static VAR compensatory at the Chateauguay terminal is also studied. Finally, an assessment is made for the effectiveness of present countermeasure schemes, namely; the auxiliary DC stabilizing controls and the installation of second harmonic filters.

[1991] 5D-8

ANALYSIS OF THE DYNAMIC STABILITY IN PARALLEL AC-DC POWER SYSTEM
Hee-Seog Koh; Joon-Tark Lee; Hae-Jae Kim; Hyeng-Hwan Chong
Transactions of the Korean Institute of Electrical Engineers
vol.40, no.9 p.851-8 1991 Language: Korean , Journal Paper (JP)
The authors deal with the problems related to the analysis of stability for a single machine infinite bus system which has AC-DC transmission lines in parallel. They consider the improvement of a stable operation power limit for the generator with an excitation control system and a speed governing system. Specifically, it is assumed that the general coefficients of a converter in a DC transmission line be constant. They deal with the stable operation power limit for dynamic stability, in which the gain coefficients and time constant of the DC current controller varies. The results presented show the relationship between gain/time constants and stability. (11 Refs)

[1991] 5D-9

APPLICATIONS OF EXACT LINEARIZATION TECHNIQUES FOR STEADY-STATE STABILITY ENHANCEMENT IN A WEAK AC/DC SYSTEM,
Kaprielian, S.; Clements K.; Turi J.
IEEE Preprint #91 SM 418-4 PWRS
1991
A nonlinear control strategy to improve the steady-state stability of a weak AC/DC power system is presented. The approach described in this paper is based on the extension of feedback linearization techniques to nonlinear descriptor system models. This method produces a nonlinear control strategy which is capable of enhancing system performance for various system operation conditions. This claim is supported with simulation results.

[1992] 5D-10

EFFECT OF DURATION OF COMMUTATION FAILURE OF AN INVERTER ON TRANSIENT STABILITY IN A HYBRID EHV LONGITUDINAL AC-DC SYSTEM FOLLOWING LINE CONTINGENCY AND AUTO-RECLOSURE
Chakrabarti, A.; Mukhopadhyay, A.K.
Journal of the Institution of Engineers (India) Electrical Engineering Division
vol.72, no.EL-6 p.225-8 Feb. 1992
The authors make an attempt to obtain analytically the magnitude of the power angle of the generating system, running in conjunction with an HVDC system and an EHV longitudinal AC system at which inverter recovery should take place in order to maintain transient stability following a transient fault in one of the EHV lines of the longitudinal type AC system. In the simulation, autoreclosing has been assumed to be operative to clear the AC line fault. The effect of the duration of commutation failure of the inverter, following a system disturbance, on the transient stability of a longitudinal EHV AC system, has also been investigated. (9 Refs)

[1991] 5D-11

EIGENVALUE AND FREQUENCY-DOMAIN ANALYSIS OF THE INTERMOUNTAIN POWER PROJECT AND THE WSCC NETWORK.
Piwko, Richard J.; Othman, Hisham A.; Alvarez, Oscar A.; Wu, Chuck-Yan
IEEE Transactions on Power Systems
v 6 n 2 Feb 1991 p 238-244
The Western Systems Coordinating Council (WSCC) has several interarea modes of oscillation in the range of 0.3 to 0.8 Hz. The results of an investigation of how

various network parameters and operating conditions affect the stability of those modes are presented. Eigenvalue and frequency-domain techniques are used. The study results show that numerous system parameters can have a significant impact on overall network stability. These parameters can include control settings, such as those in HVDC systems or power system stabilizers, or operational parameters, such as scheduled tie-line flows. The results show that careful analysis and tuning of all significant controls in a large network are necessary to ensure overall system stability and satisfactory performance.

[1992] 5D-12

IMPACT OF HVDC LINKS ON TORSIONAL STRESSING OF TURBINE-GENERATOR SHAFTS
Hammons, T.J.; Bremner, J.J. Glasgow Univ., UK
Proceedings. International Conference on Electrica Machines
p.69-73 vol.1 15-17 Sept. 1992
It is known that ripple currents on the DC side of both HVDC synchronous and asynchronous links together with cleared HVDC and AC system disturbances can excite torsional vibrations in large steam turbine-generator shafts. The authors discuss and analyse the excitation of shaft torsional vibrations in steam turbine/generator/exciter shafts in close proximity to HVDC converters. Excitation of the vibrations by variable-frequency ripple currents superimposed on the DC current in asynchronous links, and disturbances at bi-polar converter stations such as a three-phase to ground, or a HVDC line fault are examined. (6 Refs)

[1993] 5D-13

IMPACT OF INVERTER STATION ON TORSIONAL DYNAMICS OF PARALLEL HVDC-AC POWER SYSTEM
Iravani, M.R.; Zhao, Z.; Hamouda, R.M.
IEEE Transactions on Power Systems v 8 n
3 Aug 1993. p 997-1003
This paper investigates the impact of an inverter station on the torsional dynamics of a turbine-generator set which is located at the rectifier side of a parallel HVDC-ac power system. The studies show that depending on the stiffness of the inverter AC bus and electrical coupling between the inventor and rectifier AC buses, the inverter closed loop control can have noticeable contribution to the instability of torsional dynamics. This adverse torsional impact is observed in the study results even when the inverter AC bus is fairly strong (ESCR larger than 5.0). 12 Refs.

[1991] 5D-14

NETWORK INTERACTION TESTS OF THE FENNO-SKAN HVDC LINK
Pottonen, L.; Hirvonen, R.; Jaeaeskelaeinen, K.; Valtomaa, M.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 285-289
The network interaction tests of the Fenno-Skan HVDC link between Finland and Sweden are described. The paper deals with the objectives, execution and analysis of the tests on the Finnish side. The purpose of the tests was to verify the compatibility of the link with the AC system. Besides this, the tests presented an opportunity for verifying the quality of the system modelling. The large scale network interaction tests proved to be very valuable. A lot of experimental information on AC/DC interaction was gained. The link operated in the predicted and specified way. Based on the test results the modelling of hydroturbine governors was improved.

[1991] 5D-15

OPERATING CHARACTERISTICS OF A HVDC LINK WITH AC/DC HYBRID POWER TRANSMISSION
Ni Linlin; Zeng Nanchao
Power System Technology
no.2 p.2-7 May 1991 In Chinese.
Referring to the results of the end to end system tests for Gesha HVDC Project, the authors describe the important operating characteristics of a HVDC link within an AC/DC hybrid power system. It is useful for considering the functions of a HVDC link in studying interconnection of regional power grids in China. (4 Refs)

[1992] 5D-16

POWER SYSTEM PROTECTION IN HVDC ENVIRONMENTS. HOW HVDC STATIONS INFLUENCE AC LINE PROTECTION
Andersson, F.; Juhlin, L.E.
ABB Review (Asea Brown Boveri) (Switzerland) v 3.
1992 p 27-32
When a large high-voltage direct current (HVDC) scheme is connected to a comparatively weak AC system, transients from the HVDC converters may disturb the AC line protection. However, proper operating of the protection can be ensured by observing some rules during the project engineering.

[1991] 5D-17

SMALL SIGNAL STABILITY PROGRAM ANALYSIS OF SVC AND HVDC IN AC POWER SYSTEMS.
Arabi, S.; Rogers, G.J.; Wong, D.Y.; Kundur, P.; Lauby, M.G.
IEEE Preprint # 91 WM 217-0 PWRS.
1991
HVDC transmission links and SVCs have controllable characteristics with potential for affecting system stability. To study these effects and to design their controllers for improving system stability, there is a need for their representation in small signal stability programs as well as time simulation programs. In this paper, we address the formulation of DC link and SVC models and their controllers for small signal stability. Several examples are studied to show the capability and application of the small signal DC link and SVC models. The small signal results are verified by the time domain simulation results of the same study cases.

[1991] 5D-18

SUBSYNCHRONOUS OSCILLATION CONTROLLER FOR VINDHYACHAL BACK-TO-BACK HVDC LINK
Prasad, M.; Rao, L.V.; Roy, A.K.; Kaul, N.; Madan, S.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 290-294
The Vindhyachal back-to-back HVDC link interconnects the 400 kV AC networks of Northern and Western power systems in India. Due to possible variations in the frequency of the two regions, it forms an asynchronous tie between the two regions. The link is designed to transfer power in both directions. The phenomena of subsynchronous oscillations due to adverse interaction between turbine generator torsional modes of oscillations and an HVDC system was first discovered in 1977, when one of the units of the Square Butte generating station was slightly damaged during testing of the HVDC transmission system. It was found that due to a high gain damping controller, which was being tested for the project, there was a large amount of interaction between the HVDC and the turbine generator sets at subsynchronous oscillatory modes of the turbine generator sets. Since then, this phenomena of subsynchronous oscillations has been thoroughly studied and reported in the literature. A simplified explanation of the adverse interaction between generator torsional modes of vibration and an HVDC converter is that within the bandwidth of power or DC current controller, an HVDC system appears as a constant power load when viewed from the AC system. To avoid damage to turbine - generator sets, it is therefore necessary to get a positive damping contribution for frequencies of interest from the HVDC system. The present paper presents results from such a study performed for the Vindhyachal back-to-back HVDC link on a simulator.

[1993] 5D-19

SUBTRANSMISSION REDUCTION FOR VOLTAGE INSTABILITY ANALYSIS
McCalley, J.D.; Dorsey, J.F.; Luini, J.F.; Mackin, R.P.; Molina, G.H.
IEEE Transactions on Power Systems
Feb 1993 p 349-356
In this paper, the authors present a new method for creating power flow subtransmission equivalents to be used in voltage instability analysis. They present the motivating reasons for performing subtransmission reduction, and they show how the subtransmission reduction problem differs from more traditional reduction problems. Criteria for an acceptably reduced subtransmission system are stated, and Pacific Gas and Electric Company's (PG and E's) reduction method is presented which utilizes the program LODRED (from the EPRI Dynamic Equivalencing Reduction Software) to perform load bus elimination and a new program called GALRED to perform generator bus aggregation. Unlike most reduction methods, this method produces equivalents that are independent of base case voltages and flows and consequently highly accurate for voltage instability analysis. Validation of the new method is performed using a 71% reduced model (29% of its original size) of PG and E's transmission system to simulate bipole outage of the Pacific DC Intertie.

[1992] 5D-20

TRANSIENT AC VOLTAGE RELATED PHENOMENA FOR HVDC SCHEMES CONNECTED TO WEAK AC SYSTEMS
Pilotto, L.A.S.; Szechtman, M.; Hammad, A.E.
IEEE Transactions on Power Delivery
Jul 1992 p 1396-1404
In this paper a didactic explanation of voltage stability associated phenomena at HVDC terminals is presented. Conditions leading to AC voltage collapse problems are identified. A mechanism that excites control-induced voltage oscillations is shown. The voltage stability factor is used for obtaining the maximum power limits of ac/dc systems operating with different control strategies. Correlation to Pd {times} Id curves is given. Solutions for eliminating the risks of voltage collapse and for avoiding control-induced oscillations are discussed. The results are

supported by detailed digital simulations of a weak ac/dc system using EMTP.

[1991] 5D-21

VOLTAGE COLLAPSE IN ELECTRIC POWER SYSTEM
Srivastava, S.C.; Kalra, P.K.; Bose, R.; Agarwal, M.
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management
p.69-75 vol.1 1991
Some of the factors affecting the voltage stability of a electric power system are the loadings and transformer tap settings. In addition, different system parameters may also alter the proximity to the voltage collapse point. The authors present certain important observations on the voltage collapse phenomenon established through system studies on a sample EHV AC transmission network and a HVDC network. The authors bring out the effects of changing the transmission line and transformer tap and parameters in EHV AC network, different short circuit ratio of receiving end and sending end AC systems in HVDC network. (24 Refs)

[1991] 5D-22

VOLTAGE STABILITY AT RECTIFIER BUS OF A TWO TERMINAL HVDC LINK AND ITS ON-LINE CONTROL UTILISING A MICROPROCESSOR BASED STATIC VAR COMPENSATOR
Chakrabarti, A.; Mukhopadhyay, A.K.
Modelling, Simulation & Control A
vol.40, no.1 p.13-31 1991
Analytical expressions have been derived to obtain the condition of voltage stability at the DC as well as AC bus in the rectifier substation of a two terminal HVDC link interconnecting weak EHV AC power system. The feasibility of operation of the 'constant current' mode of the rectifier substation is investigated from the view point of AC bus voltage instability, and the use of controllable VAR compensators has been highlighted to achieve an acceptable voltage profile in the convertor station. An online microprocessor based static VAR compensator has been developed for this purpose and a prototype has been applied to a real time simulated model in the laboratory to observe its efficacy. (11 Refs)

[1992] 5D-REF

INCREASING WSCC POWER SYSTEM PERFORMANCE WITH MODULATION CONTROLS ON THE INTERMOUNTAIN POWER PROJECT HVDC SYSTEM
Martin, D.E.; Wong, W.K.; Dickmander, D.L.; Lee, R.L.; Melvold, D.J.
IEEE Transactions on Power Delivery
Jul 1992 p 1634-1642
For Abstract see entry 1B-014.

[1993] 5D-REF

SUPPRESSION OF DC LINE CURRENT OSCILLATION OF HV DC TRANSMISSION SYSTEM USING VOLTAGE SOURCE FORCED COMMUTATION CONVERTER
Funaki, T.; Kimura, N.; Matsu-ura, K.
Electrical Engineers of Japan.
20 Jan 1993 p 57-64
For Abstract see entry 1E-006.

[1992] 5D-REF

APPLICATION OF FORCED-COMMUTATION CONVERTER FOR HVDC TRANSMISSION SYSTEM. COMPARISON OF CURRENT-SOURCE TYPE AND VOLTAGE-SOURCE TYPE CONVERTER
Kimura, N.; Kishimoto, M.; Iida, T.; Matsu-ura, K.
Transactions of the Institute of Electrical Engineers of Japan
20 Jan 1992 p 10-18. In Japanese.
For Abstract see entry 2A-005.

[1992] 5D-REF

AC FILTERS IN HVDC TRANSMISSION
Seth, S.P. Bharat Heavy Electricals Ltd., Bhopal, India
IEEMA Journal
vol.12, no.10 p. 17-18, 20, 22, 24, 26-7, 29-30; Oct. 1992
For Abstract see entry 2C-001.

[1991] 5D-REF

SUBSYNCHRONOUS TORSIONAL INTERACTIONS WITH STATIC VAR COMPENSATORS-INFLUENCE OF HVDC.
Rostamkolai, Niusha; Piwko, Richard J.; Larsen, Elnar V.; Fisher, Douglas A.; Mobarak, Mohamed A.; Poltras, Alfred E.
IEEE Transactions on Power Systems
v 6 n 2 Feb 1991 p 255-261
For Abstract see entry 2E-005.

[1992] 5D-REF

ALTERNATIVES FOR BLOCKING DIRECT CURRENT IN AC SYSTEM NEUTRALS AT THE RADISSON/LG2 COMPLEX
Eitzmann, M.A.; Walling, R.A.; Sublich, M.; Kah, A.; Huynh, H.; Granger, M.; Dutil, A.
IEEE Transactions on Power Delivery
Jul 1992 p 1328-1337
For Abstract see entry 2F-002.

[1993] 5D-REF

AC LINE PROTECTION OPERATING CONDITIONS IN THE NEAR VICINITY OF HVDC INSTALLATIONS
Anderson, F.; Juhlin, L.E.; Jones, T.
Fifth International Conference on Developments in Power System Protection
IEEE Conference Publication n 368 1993. Publ by IEE, Michael Faraday House, Stevenage, Engl. p 119-122
For Abstract see entry 5A-004.

[1993] 5D-REF

COMPARISON OF SUITABLE CONTROL SYSTEMS FOR HVDC STATIONS CONNECTED TO WEAK AC SYSTEMS
Shah, K.; Gole, A.M.
IPEC '93. International Power Engineering Conference 1993. Conference Proceedings
p.358-61 vol.1 18-19 March 1993
For Abstract see entry 5A-007.

[1990] 5D-REF

DESIGN OF A ROBUST MODULATION CONTROLLER OVER A WIDE RANGE OF LOAD CHARACTERISTICS FOR AC/DC SYSTEMS
Choudhry, M.A.; Reza, M.A.; Ellithy, K.A.
IEEE Transactions on Power Systems
Vol. 5, No. 1, February 1990
For Abstract see entry 5A-016.

[1993] 5D-REF

DESIGN OF A SUPPLEMENTARY MODULATION CONTROL FUNCTION FOR THE CHESTER SVC
Larsen, E.; Rostamkolai, N. ; Fisher, D.; Poitras, A.
IEEE Transactions on Power Delivery
Apr 1993 p 719-724
For Abstract see entry 5A-017.

[1993] 5D-REF

UTILIZING HVDC TO DAMP POWER OSCILLATIONS
Smed, T.; Andersson, G.
IEEE Transactions on Power Delivery
vol.8, no.2 p.620-7 April 1993
For Abstract see entry 5A-044.

[1991] 5D-REF

VALIDATION OF DIGITAL SIMULATION FOR STUDIES OF TORSIONAL INTERACTION BETWEEN A TURBO-GENERATOR AND AN HVDC LINK
Adam, P.H.; Yao, Z.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 295-300
For Abstract see entry 6B-033.

5E. ELECTROMAGNETIC COMPATIBILITY

[1993] 5E-REF

POWER LINE CARRIER INTERFERENCE FROM HVDC CONVERTER TERMINALS
Tatro, P.J.; Adamson, K.A.; Eitzmann, M.A.; Smead, M.
IEEE Transactions on Power Delivery
Jul 1993 p 827-840
For Abstract see entry 2C-019.

5F. INSULATION COORDINATION

[1991] 5F-1

BIBLIOGRAPHY ON OVERVOLTAGE PROTECTION AND INSULATION COORDINATION OF HVDC CONVERTER STATIONS, 1979-1989.
Melvold, D. J.
IEEE Transactions on Power Delivery
v 6 n 2 Apr 1991 p 744-753
This bibliography is a listing of references on the subject of overvoltage protection and insulation coordination of HVDC converter stations for the years 1979 through 1989. References are sorted by year of publication and alphabetically based on first author's name within each year. Each reference includes the title, author, abstract, and publication information. 19 Refs.

[1992] 5F-2

CALCULATION OF HVDC TRANSMISSION LINE INSULATION COORDINATION WITH STATISTICAL APPROACH
Li Peiguo; Liao Weiming; Yang Yinmei; Wang Zun
Power System Technology
no.4 p.31-6, Nov. 1992.
The authors introduce the main characteristics of a computer program, Statistical Insulation Coordination Program of Transmission Towers, developed by EPRI. Taking the Gezhouba-Shanghai +or-500 kV HVDC transmission line as an example, the insulation failure rates of the line under operation voltage, switching and lightning overvoltage are calculated and analyzed. Some recommendations for construction of new HVDC lines and operation of existing ones are presented. computing

[1993] 5F-3

INSULATION COORDINATION FOR LIGHTNING OVERVOLTAGES ON A LONG HVDC SUBMARINE CABLE
Mader, D.J.
Canadian Electrical Association, Montreal, PQ (Canada)
Report Number MIC-93-05228/XAB Available from NTIS 1993
This paper demonstrates by detailed modelling and simulation a statistical approach to determining the lightning-induced overvoltage stresses on the insulation of a 220 km HVDC submarine cable due to lightning strikes to the overhead line, and explores methods of controlling these overvoltages to levels that will allow lightning impulse withstand levels as low as 2.0 per unit of working voltage with an adequate safety margin.

[1991] 5F-4

OVERVOLTAGE STUDIES FOR THE ST. LAWRENCE RIVER 500-KV DC CABLE CROSSING.
Bui-Van, Que; Beaulieu, Germain; Huynh, Hieu; Rosenqvist, Roger
IEEE Transactions on Power Delivery
v 6 n 3 Jul 1991 p 1205-1215
An exclusive insulation coordination study has been conducted for the 500-kV DC cables that will be installed in a tunnel under the Saint Lawrence river. These cables will be part of the Radisson-Nicolet section of the Quebec-New England HVDC line. The authors provide an overview of the studies and the phenomena that will cause decisive overvoltage stresses on the cable insulation. The basic assumptions and the simulations of these phenomena with the Electromagnetic Transients Program (EMTP) are also discussed. Finally, the results of the overvoltage studies and the specified insulation levels for the DC cables are presented.

[1992] 5F-5

OVERVOLTAGES AND INSULATION COORDINATION AT DC SIDE OF CONVERTER STATIONS FOR GE-SHANG HVDC TRANSMISSION PROJECT
Li Tongsheng
Power System Technology
no.1 p.15-22 Feb. 1992 China Language: Chinese
The field test results on DC overvoltages at the converter stations during the commissioning test for the Ge-Shang +or-500 kV HVDC transmission project are presented. DC equipment faults taking place during the field tests are analysed, and the overvoltages and insulation coordination problems for some equipment at the converter stations are discussed.

[1993] 5F-REF

FAST TRANSIENT VOLTAGE DISTRIBUTION IN HVDC CONVERTER VALVES
Rajasekharaiah, S.; Chandrasekharaiah, H.S.
International Journal of Energy Systems
vol.13, no.3 p. 69-72 1993
For Abstract see entry 2A-011.

[1992] 5F-REF

A METHOD FOR CALCULATING ELECTRIC FIELDS IN HVDC EQUIPMENT WITH ALLOWANCE FOR TRANSIENTS
Bortnik, I.M.; Vol'pov, E.K.; Filippov, A.A.
Elektrichestvo
no.6 p.24-8 June 1992 Russia In Russian
For Abstract see entry 3F-002.

[1991] 5F-REF

PROTECTION OF HVDC CONVERTER STATIONS AGAINST LIGHTNING OVERVOLTAGES
Chen Weijiang; Du Shuchun
Power System Technology
no.1 p.17-24 Feb. 1991 Published in China. Language: Chinese
For Abstract see entry 5A-036.

5G. MEASUREMENTS AND INSTRUMENTS

[1992] 5G-1

A HOTSTICK INSTRUMENT FOR ESTIMATION OF THE POTENTIAL OF AN HVDC CONDUCTOR

Feldman, J.M.; Teixeira, J.; Pileggi, D.J; Kuehn, K.

IEEE Transactions on Power Delivery Publication

Jul 1992 p 1533-1541

In 1989-90, New England Power Service Co. (NEPS) and Bonneville Power Administration (BPA), jointly sponsored the UHVDC Live-Line Voltage-Estimator Project with three principal goals: To develop a technology which would permit moderately accurate estimates of the DC potential of a UHVDC line without requiring an electrical connection to ground or any other reference point; to develop an instrument embodying this technology which could be applied by a lineman in the field and to demonstrate that the system functioned are expected; to develop and incorporate in the instrument a technique for estimating the induced AC component of the potential. As demonstrated at the BPA outdoor test facility at The Dalles, OR on 15 Aug, 1990 and reported herein, the first goal has been fully met. We report a demonstration that a properly located field mill can determine the DC potential to better than 10% of full scale over a range from 0 t {plus minus} 500 KV, even in the presence of wind and corona. Solutions to the remaining pair of goals have been defined and an effort is now underway to develop a field-hardy engineering prototype of a production instrument.

[1991] 5G-2

CABLE TESTING PAYS OFF AT SAN ONOFRE

Pentecost, L.; Weir, T.

Nuclear Engineering International

vol.36, no.442 pp.42, 44-5. May 1991, UK

The ECAD system has been proving its value in condition monitoring and troubleshooting of the electrical systems at the San Onofre plant. The ECAD (Electronic Characterization and Diagnostics) System 1000 was developed by the ECAD Division of Pentek to detect the cause and location of circuit degradation, and to provide the basis for a predictive maintenance and troubleshooting programme. ECAD views a plant circuit as a radio-frequency transmission line with a load, and analyzes reflected electromagnetic pulses in the time domain. This technique, time domain reflectometry (TDR), identifies the distributed resistance, inductance, and capacitance of the circuit, and can accurately detect the location of circuit degradation. ECAD uses direct current or low frequency measurements to indicate circuit degradation by providing the lumped values of circuit loop resistance, shunt resistance, inductance and capacitance. An automatic data acquisition system records the measurements, which form the ECAD database. (0 Refs)

[1991] 5G-3

DC PARTIAL DISCHARGE MEASUREMENT OF ELECTRICAL EQUIPMENTS

Fu Jun; Zhang Sai

Power System Technology

no.3 p.81-5 Aug. 1991 (In Chinese)

A measuring method for DC partial discharge in high voltage equipment is discussed and studied by the authors. Several measuring systems for the DC partial discharge are developed. Test results of DC partial discharge measurements carried out on some of the HV equipment installed in the Gezhouba (China) converter station are also presented.

[1991] 5G-4

DIRECT MEASUREMENT OF RESIDUAL HARMONIC CURRENTS ON A +OR-450 KV DC LINE USING ROGOWSKI COILS

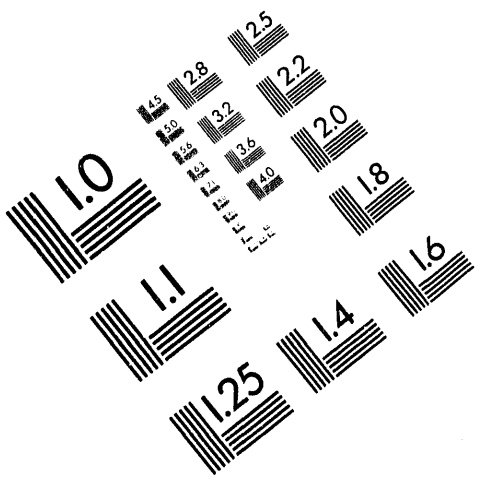
Mercure, H.P.; Bard, P.; Auclair, Y.; Rodridge, P

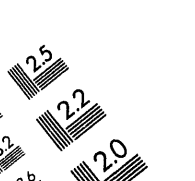
IREQ, Hydro-Quebec, Varennes, Que., Canada

Seventh International Symposium on High Voltage Engineering

p.195-8 vol.6. Conference held on 26-30 August, 1991 in Dresden, Germany. Published by Dresden University in 1991.

The authors describe the various steps taken to achieve a successful application of Rogowski coils in a very demanding measurement situation on a power system. Selection of the coil parameters is described and a practical coil design is discussed. The residual harmonic currents are computed from the coil signals using a simple algorithm. A sensitivity of about 20 mA at 60 Hz can be achieved with good accuracy, while the nominal DC current is over 2 kA at full voltage (+or-450 kV). The transducer package is easy to install on conductor bundles or busbars. The signals are transmitted for processing using a special insulator fitted with fibre optic channels. (3 Refs)





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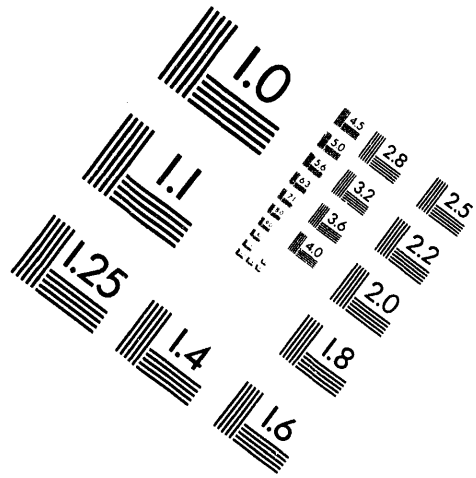

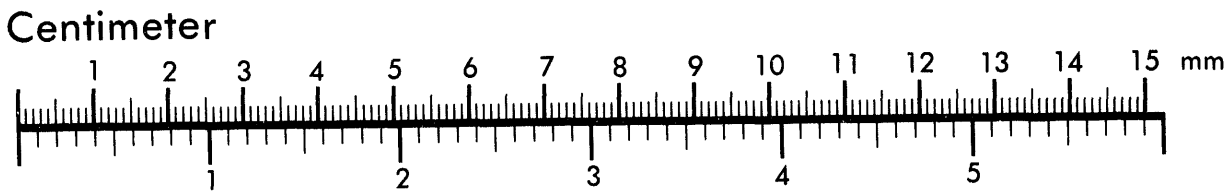

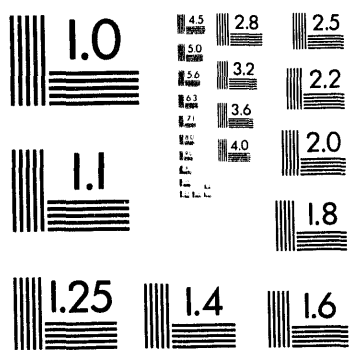

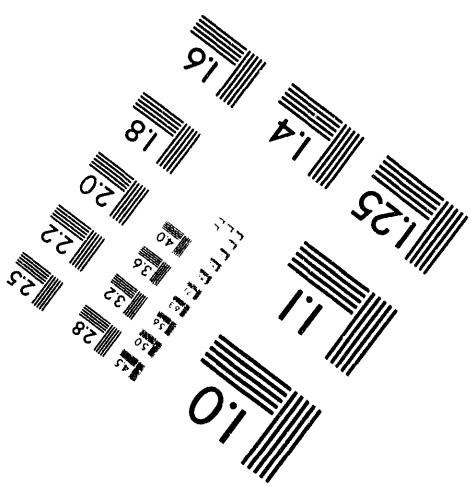

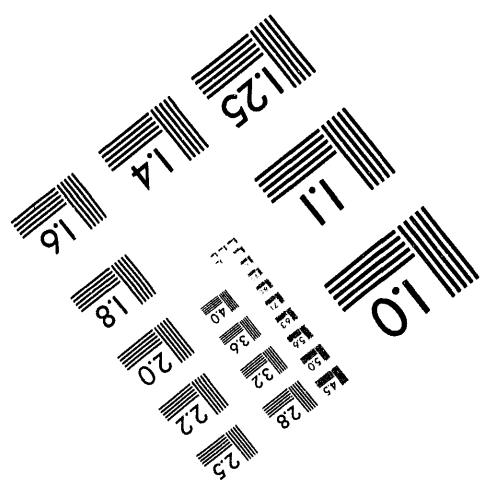

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BY APPLIED IMAGE, INC.

2 of 2

[1993] 5G-5

DYNAMIC SYSTEM MONITORING (DSM) FOR HVDC MODULATION CONTROL
Grund, C.E.; Sweezy, G.; Hauer, J.F.; Balser, S.J.; Nilsson, S. (Electric Power Research Inst., Palo Alto, CA (United States))
IEEE Transactions on Power Delivery
Jul 1993 p 853-860
As a part of an EPRI-sponsored development on advanced power modulation control system for HVDC lines, dynamic system monitors (DSM) were installed at the DC terminals of the Square Butte system. The monitors were used to validate the computer models used for the controller design and will be used to validate the performance of the controllers after installation. The paper describes the use of Prony analysis and Fourier techniques to analyze system disturbances and to validate the computer models. As described in the paper, excellent results have been achieved at least for parts of the system for some well defined disturbances.

[1991] 5G-6

EVALUATION OF ION COUNTERS USING A FACILITY TO PRODUCE A STEADY STATE ION FLOW FIELD
Suda, Tomotaka
IEEE Preprint #91 SM 501-7 PWRD
1991
Because of the environmental problems of small air ions near HVDC power lines, it is desirable to have accurate and reliable ion counters. A facility to produce a steady state ion flow field (a low speed wind tunnel) was developed for the mutual comparison of aspirator-type ion counters. Ion densities achieved in this facility are comparable to those actually found near HVDC transmission lines, but are free from the accompanying large electric fields. This facility is useful for comparing different ion counters because it can supply constant ion density temporally within 9% variation. It was clarified that the flow-rate specifications of three ion counters were inaccurate after the mutual comparison of four ion counters using this facility.

[1991] 5G-7

FUNDAMENTAL STUDIES OF ELECTROSTATICS MEASUREMENT USING OPTO-ELECTRONICS
Watanabe, S.; Hironaka, K.; Ono, Y.
Seidenki Gakkaishi (Japan)
31 Mar 1991 p 152-158 In Japanese
A study was made on the possibility of DC voltage measurement using an optical fiber voltage sensor which utilizes the Pockels effect. Amorphous silicon hydride was used as the light transmission element to structure a switching element" utilizing its nature of changing its resistance value by light, and means for avoiding polarization phenomenon of electro-optic crystals was studied. As the result, it was confirmed that a resistance bridge made with amorphous silicon hydride as the material could function as a switch without decreasing the input impedance of the sensor. when DC high voltage was applied to the sensor, the value of applied DC current could be learned from the modification factor value of the output light obtained through an optical fiber. No moving part such as rotating mechanism was required, and insulating material could be used between the sensor member and the measuring member. It was confirmed that DC voltage could be measured using a solid-state device.

[1991] 5G-8

MICROWAVE TRANSCEIVER FOR REMOTE SENSING OF HIGH VOLTAGES.
Evans, D. R.
Measurement Science & Technology
v 2 n 7 Jul 1991 p 679-681
A microwave transceiver is described which is designed for remote sensing of high DC and AC voltages in applications where complete electrical isolation is required between the signal and the measurement system. The isolator was specifically designed for the measurement of voltages up to 30 kV DC on a CO//2 laser where neither side of the supply was at earth potential. The isolator provided infinite isolation between the laser and the computer data acquisition system. The bandwidth of the system was sufficient to enable signals from DC to around 6 MHz to be transmitted across a laboratory (including a colour video signal). The unit is unusual in that it can transmit both true DC levels and high frequency signals with infinite electrical isolation.

[1991] 5G-REF

DC-PROBES FOR ELECTRIC FIELD DISTRIBUTION MEASUREMENTS
Hornfeldt, S.P
IEEE Transactions on Power Delivery
Apr 1991 p 524-529
For Abstract see entry 3F-003.

[1992] 5G-REF

PARTICLE-IN-CELL SIMULATION OF A RADIOACTIVE PROBE IN WIND.
Wang, Qing Y.; Pedrow, Patrick D.
IEEE Transactions on Electrical Insulation
v 27 n 2 Apr 1992 p 342-351
For Abstract see entry 6D-005.

5H. MULTI-TERMINAL TRANSMISSION SYSTEMS AND TAPS

[1991] 5H-1

A STUDY OF MULTI-TERMINAL DC MODULATION CONTROL
Hanchu Zheng; Shousun Chen; Yixin Ni; Baolin Zhang
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management Conf. Publ. No.348)
p.615-20 vol.2 Conference 5-8 Nov, 1991
First, the comparable sensitivity, an index to indicate the effectiveness of multi-terminal DC modulation controller is presented. Then, through several typical AC/MTDC systems, the usefulness of a multi-terminal DC modulation controller in improving the dynamic performance, and the main factors of influencing it are studied. (9 Refs)

[1992] 5H-2

ANALYSIS OF VOLTAGE INSTABILITY PROBLEMS IN TWO- AND MULTITERMINAL HVDC SYSTEMS CONNECTED TO WEAK AC SYSTEMS.
Dash, P. K.; Panigrahi, A. K.; Sharaf, A. M.; Hill, E. F.
Electric Power Systems Research
v 25 n 1 Oct 1992 p 1-7
In this paper, the conditions of voltage collapse, feasibility of operation, and reactive power compensator requirement to provide voltage support are established analytically for a two-terminal back-to-back HVDC system. For a multiterminal HVDC system, the voltage stability factor for each converter as well as the sensitivity of the AC bus voltage with respect to changes in DC power are also presented in this paper. Simple formulas for each converter operation under different control modes are derived.

[1991] 5H-3

CONSIDERATIONS FOR MODELING MTDC SYSTEMS IN TRANSIENT STABILITY PROGRAMS
Lefebvre, S.; Wong, W.K.; Reeve, J.; Baker, M.; Chapman D.
IEEE Transactions on Power Delivery
Jan 1991 p 397-404
This paper describes the development and selection of DC line, DC converter and DC control models suitable for studies of multiterminal DC (MTDC) systems with transient stability programs. Features of MTDC systems and relevant characteristics of transient stability programs are discussed, as well as experience with the models.

[1991] 5H-4

IMPEDANCE FREQUENCY ANALYSIS ON THE AC SIDE OF A HIGH-VOLTAGE MTDC SYSTEM WITH HIGHER-ORDER FILTERS AND STATIC VAR COMPENSATORS (SVCS)
Narendra, K.G.; Chandrasekharaiah, H.S.
International Journal of Energy Systems
vol.13, no.2 p.44-7 April 1991
In this paper, the impedance frequency analysis on the AC side of a multi terminal direct current (MTDC) system with higher-order filters and static VAR compensators (SVCs) is carried out. Effect of weakness of the AC system on the driving point impedance with a transmission line of varied length is also investigated. This study is useful in estimating the possibilities of lower order resonance and economical design of filters for MTDC-AC system. Some interesting results are reported. (8 Refs)

[1991] 5H-5

MULTITERMINAL HVDC SYSTEM CONTROL USING A DISTRIBUTED COMPUTING TECHNIQUE
Ngan, H.W.; David, A.K.; Lo, K.L.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 114-119
Under certain circumstances, for basic power transfer, the fast response to power control commands of an HVDC system is a major attraction which enables enhancement of the performance of the AC system in which it is embedded. This can be achieved through an effective control of d.c. power in response to signals derive from the a.c. side subject to an appropriate control strategy. Derivation of the control strategy for a multiterminal case, however, requires the handling of a significantly larger number of state variables. This

implies a need for more demanding computational power which will increase out of proportion to the increase of terminal numbers in the on-line control of multiterminal systems. The work presented in this paper gets around this problem by adopting a distributed computing approach in which a number of computers are coordinated so as to share out what would otherwise be a large computing burden if the conventional approach of extremizing a single objective function through centralized computation were attempted. The paper sees the rudimentary structure of the control strategy as that of an overall goal originating at the level of the a.c. grid and then dispatching more specific commands down to lower levels of d.c. controllers. Taking advantage of recent advances in computer networking a hierarchy of heterogeneous computers can interact at a task-to-task communication level to form a closely integrated computing environment in which tasks can be distributed. The various features used to establish this distributed computing environment and the employment of this technique to facilitate the system controller in generating and coordinating commands for the overall optimal control of the a.c.-d.c. system are illustrated.

[1992] 5H-6

NEW MAIN CONVERTER STATION FOR OLD IN SACOI HVDC REBUILDING
Garzi, G.
Power Technology International
p.136-9 1992
The author describes how the SACOI-2 HVDC link (300 MW, 200 kV thyristor valve system) has been recently designed to uprate the existing HVDC link (SACOI-1, 200 MW, 200 kV equipped with mercury valve system) by rebuilding the two main converter stations. The SACOI-1 is the first multi-terminal DC system (SArdinia, COrsica, Italy) designed for continuous operation. The SACOI-1 DC system is now expanded from a two-terminal to a three-terminal DC system. The third terminal at Lucciana (island of Corsica) is a 50 MW thyristor valve converter station set up by Electricite de France (EdF). (2 Refs)

[1991] 5H-7

SIMULATOR STUDY ON LINE FAULT CLEARING BY DC CIRCUIT BREAKERS IN A MESHED MTDC SYSTEM
Kanngiesser, K.W.; Ring, H.; Wess, T.
AC and DC Power Transmission
Conference 17-20 Sept 1991. London, UK. (Conf. Publ. No.345 p. 102-7)
HVDC multiterminal power systems, here referred to as MTDC systems, request increasing interest after the first schemes of this kind are in operation or under commissioning, respectively. A variety of system configurations can be defined whose properties concerning flexibility, reliability and economics are significantly different. Amongst them the meshed MTDC system offers the important advantage that an outage of a line section-even a permanent one-does not prevent the desired energy transfer amongst all of the terminal stations. It is an unavoidable consequence of a DC side fault that the energy transfer in the affected pole of the entire MTDC system is interrupted until fault clearing. Fast fault clearing is therefore an essential requirement in MTDC systems. The authors detail how, DC breakers can render valuable services to fulfil this requirement. (9 Refs)

[1991] 5H-8

STABILITY AND SAFETY MARGINS OF A WEAK STATION WITHIN A MULTITERMINAL HVDC SYSTEM
Joetten, R.; Ring H.; Wess, Th.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 108-113
In a multiterminal HVDC system an inverter station which is weak in rated power, in the short-circuit-ratio, or both, poses some difficult problems. There are some obvious reasons for running the weakest station preferably in the current-control-mode, with a sufficient reserve of available direct voltage, hence an increased extinction angle. It is not advisable to assign voltage control to this inverter. In the control-mode, the system voltage would decrease with the load of the weakest station. The weakest station would have to absorb transient current imbalances due to disturbances. Thus it would become vulnerable to commutation failures consequential to such disturbances. With commutation failures due to faults in its a.c. system there is the tendency to attract the currents of the other inverters, thus increasing the fault current in relation to its own rating and the difficulty for the recovery of the whole system. Conventional converter theory is sufficient for calculating the reserve margins of the weak station with regard to commutation failures and required voltage reserve for the current control. Transformer saturation reduces the rms value of the voltage, it leaves however the crest value basically unchanged. Thus we know also the reserve margin against changing unintentionally into the voltage setting mode. If this occurs, the constant {gamma} mode is worst, the constant {beta} mode in some cases is still difficult, the constant-voltage-mode is more stable even more so if the et value is increased with the current. The more stable arrangements imply lower

voltage at partial load and hence higher losses and reactive power. Dynamical problems in this context are favourably investigated on a real-time-simulator. We have used the simulator described in for this purpose.

[1991] 5H-9

STATE ESTIMATION IN MULTITERMINAL AC-DC POWER SYSTEM.

Quan, Yinan; Tian, Xiujun; Ma, Zhaoyan

Proceedings of the Chinese Society of Electrical Engineering

v 11 1991 p 75-83

The state estimation of multiterminal AC-DC power system is discussed in the paper. A new and simple model of HVDC Link with a select of 4 state variables and 10 possible measurements (including 2 pseudomeasurements) at each terminal of the link is assumed. The DC state variables so chosen not only assess the performance state of the HVDC link,simplify the formation of the Jacobian matrix, but also characterize the interconnection of the AC and DC systems. With this modelling, the unified method and various decoupled methods (AC-DC,P-QDC,P-Q-DC) of state estimation are investigated under random noise statistical simulations both in 'strongly' and 'weakly' connected AC-DC systems. The simulation tests show that the proposed DC modelling is feasible, and the results of estimation of these methods are all acceptable in strongly connected AC-DC systems. The problem of detectability and identifiability of bad data in HVDC link measurements has not been discussed fully so far. Result of simulation tests in the paper shows that the theory of detection and identification of bad data in AC system can be extended to multiterminal AC-DC system. This problem has been fully considered and the proposed measurement set in HVDC link in the paper proves to be meeting the requirements of bad data detectability and identifiability.

[1991] 5H-10

STATIC STATE ESTIMATION OF MULTITERMINAL DC/AC POWER SYSTEM IN RECTANGULAR CO-ORDINATES

Roy, L.; Sinha, A.K.; Srivastava, H.N.P.

Electric Machines and Power System v 19:1.

1991 p 69-80

This paper describes a simple, efficient and reliable method for estimating the state of an integrated multiterminal HVDC/AC power system in the rectangular coordinate form. A six variable model is used to represent the converter system. The proposed algorithm performs successfully in obtaining the state of an AC system with a DC link or a multiterminal DC network. It is possible to implement it for an on-line state estimation. Simulation results of a 30-busbar system are presented for illustration.

[1991] 5H-11

STUDY OF TORSIONAL INTERACTIONS IN MULTI-TERMINAL DC SYSTEMS THROUGH SMALL SIGNAL STABILITY ANALYSIS

Padiyar, K.R.; Geetha, M.K.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission.

17-20 Sep 1991 p 411-413

Turbo-generators can be subjected to negatively damped subsynchronous frequency oscillations caused by the interactions between the generator and the external network. This phenomena is termed as subsynchronous resonance (SSR) and it is well known that series compensated AC lines are the major contributors. In recent years, it has been established that HVDC systems with converter controllers can also cause unfavourable torsional interactions. The first experience of such an interaction occurred at Square Butte. There is a need to analyze this phenomenon for the planning and design of HVDC systems. The analysis can be based on the calculation of electrical damping torques (in the frequency domain) or eigenvalues based on linearized state space models. While it is possible to study the torsional interactions using simulation, an analytical approach using small signal stability analysis can give an insight into the nature of the problem and its solutions. This paper reports the development of a mathematical model based on small signal stability analysis for the study of torsional interactions in HVDC systems. The formulation is general enough to include multi-terminal DC (MTDC) systems. The case study of two terminal and three terminal systems is presented to illustrate the effect of converter controller gains on the damping of subsynchronous frequency oscillations.

[1993] 5H-12

STUDY OF VOLTAGE COLLAPSE AT CONVERTER BUS IN ASYNCHRONOUS MTDC-AC SYSTEMS

Padiyar, K.R.; Kalyana Raman, V.

International Journal of Electrical Power & Energy Systems

vol.15, no.1 p.45-53, Feb. 1993 Country of Publication: UK

The authors present the analysis and study of voltage collapse at any converter bus in an AC system interconnected by multiterminal DC (MTDC) links. The analysis is based on the use of the voltage sensitivity factor (VSF) as a voltage collapse proximity

indicator (VCPI). In this paper, the VSF is defined as a matrix which is applicable to MTDC systems. The VSF matrix is derived from the basic steady state equations of the converter, control, DC and AC networks. The structure of the matrix enables the derivation of some of the basic properties which are generally applicable. A detailed case study of a four-terminal MTDC system is presented to illustrate the effects of control strategies at the voltage setting terminal (VST) and other terminals. The controls considered are either constant angle, DC, voltage, AC voltage, reactive current and reactive power at the VST and constant power or current at the other terminals. The effect of the strength of the AC system (measured by short circuit ratio) on the VSF is investigated. Several interesting and new results are presented. An analytical expression for the self VSF at VST is also derived for some specific cases which help to explain the number of transitions in VSF around the critical values of SCR. (10 Refs)

[1991] 5H-REF

TAPPING HVDC POWER WITH GTO (GATE TURNOFF) PWM (PULSE WIDTH MODULATION) VOLTAGE SOURCE INVERTERS
Zhao, Z.; Iravani, M.R
Canadian conference on electrical and computer engineering proceedings
25-27 Sep 1991
For Abstract see entry 1A-014.

[1991] 5H-REF

APPLICATION OF ZNO VARISTOR PROTECTION TO CAPACITORS OF ARTIFICIALLY COMMUTATED INVERTER IN MTDC SYSTEM
Manohar, P.; Chandrasekharaiah, H.S.
IEEE Transactions on Power Systems
Feb 1991 p 356-363
For Abstract see entry 2L-001.

[1991] 5H-REF

EXPERIENCE WITH MODELING MTDC SYSTEMS IN TRANSIENT STABILITY PROGRAMS
Lefebvre, S.; Wong, W.K.; Reeve, J.; Gagnon, J.M.; Johnson, B.K.
IEEE Transactions on Power Delivery
Jan 1991 p 405-413
For Abstract see entry 6B-012.

[1991] 5H-REF

HVMDC: A NEW CONCEPT TO FEED SMALL LOADS
Lima, A.G.G.; Pilotto, L.A.S.; Alves, J.E.R.; Watanabe, E.H.
AC and DC power transmission (High voltage modulated direct current transmission.) IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 120-125 (443 p)
For Abstract see entry 1A-009.

5I. RELIABILITY

[1991] 5I-1

A CUT SET APPROACH FOR HVDC CONVERTER RELIABILITY EVALUATION
Sankar, V.; Prasad, V.C.; Prakasa Rao, K.S.
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management (Conf. Publ. No.348)
p. 757-61 vol.2. 5-8 Nov. 1991 , Hong Kong.
Available IEE, London, UK, In English.
The reliability evaluation of HVDC systems has been gaining much significance in the recent past. A new approach for converter equipment failure analysis is proposed. The AC to DC converter equipment circuit in HVDC systems is treated as a flow network by incorporating capacity constraints. An algorithm is proposed to obtain all path sets that give the required flow at the DC terminal. This takes combination of fewer paths only. By multiplying these path sets, using Boolean algebra, all minimal cut sets that do not transmit the required flow can be obtained. From these minimal cut sets, the expression for the probability of failure of transmission of required flow at the DC terminal can be obtained. (12 Refs)

[1993] 5I-2

A SUMMARY OF NORTH AMERICAN HVDC CONVERTER STATION RELIABILITY SPECIFICATIONS
Vancers, I.; Hormozi, F.J.
IEEE Transactions on Power Delivery
Jul 1993 p 1114-1122
This paper summarizes Reliability, Availability, and Maintainability (RAM) specifications that were issued for thyristor based HVDC converter stations in service in North America. A total of twenty project specifications are summarized. A detailed summary by project is shown with specific quantitative requirements categorized. Definitions of terms,

representative design principles, and formulas used in calculating RAM parameters contained in existing reliability specifications are presented.

[1992] 5I-3

AVAILABILITY AND RELIABILITY CONSIDERATIONS FOR NELSON RIVER BIPOLE

Calderbank, H.A.; Haddock, J.L.; Mazur, G.

CIGRE Proceedings of the 34th Session

p.14-304/1-7, vol.1 30 Aug.-5 Sept. 1992

The Nelson River HVDC transmission system in Manitoba, Canada, is briefly described with reference to modernisation of major equipment where technology has vastly changed since the initial installation of some 20 years ago. Design targets for reliability and availability of the replacement valves and associated cooling equipment have been chosen, with reference to the historical details of the newer technology of Bipole 2. Overall targets for replacement controls have been based upon Bipole 1 history. (3 Refs)

[1991] 5I-4

IMPROVEMENT IN THE RELIABILITY OF THE CHATEAUGUAY CONTINUOUS CURRENT LINK

Gagnon, J.

CIGRE Symposium. Electric Power Systems Reliability

p.3A-05/1-5 , 16-18 Sept. 1991 Montreal, Que.,

The author describes the evolution of the reliability of the back to back Chateauguay substation DC link. Composed of two 500 MW DC converters, the link was commissioned in 1984. Within a few days of commissioning, commutation failures were provoking trips. Once this problem was solved, second harmonic resonances that triggered commutation failures and frequent power drops were noted. This was first corrected with operating constraints and then with new equipment and additions to the control systems. (0 Refs)

[1992] 5I-5

INCORPORATION OF A DC LINK IN A COMPOSITE SYSTEM ADEQUACY ASSESSMENT - COMPOSITE SYSTEM ANALYSIS

Billinton, R.; Ahluwalia, D.S.

IEE Proceedings, Part C: Generation, Transmission and Distribution

May 1992 p 221-225

The paper illustrates a procedure for adequacy evaluation of a composite generation and transmission system containing a direct current (DC) link. The transportation model option of the composite reliability (COMREL) program, developed at the University of Saskatchewan, is used to evaluate the composite system adequacy indices. The IEEE Reliability Test System (RTS) is augmented by adding a DC link and is used as the test system. The composite system load point and the overall system indices are calculated to quantify the adequacy of the composite system. The basic COMREL program was modified to accept a remote generation source connected to a composite system through a DC link. The analysis involves the construction of a generating capacity model at the remote bus and the movement of each generating capacity state through the DC line contingency state, without violating the carrying capability of the transmission line state or the generator state capability restriction. (Author).

[1992] 5I-6

INCORPORATION OF A DC LINK IN A COMPOSITE SYSTEM ADEQUACY ASSESSMENT - DC SYSTEM MODELLING

Billinton, R.; Ahluwalia, D.S.

IEE Proceedings, Part C: Generation, Transmission and Distribution

May 1992 p 211-220

Direct current (DC) links are finding increasing use throughout the world in the form of long-distance transmission and asynchronous interconnections. System reliability studies of a composite generation and transmission system containing a DC link involve modelling and evaluation of the reliability of the DC transmission line and performance of an overall composite system study with the DC link forming an integral part. The paper illustrates a technique for DC system reliability analysis using the contingency enumeration approach. A key element in this system reliability analysis is the creation of the reliability diagram from the single line diagram. A digital computer program was developed to evaluate the probability of failure, frequency of failure, and the mean duration of the possible performance levels for a DC link. The procedure and program were tested on a model DC system, and the results are presented to illustrate a proposed technique.

[1992] 51-7

SURVEY OF THE RELIABILITY OF HVDC SYSTEMS THROUGHOUT THE WORLD DURING 1989-90

Ahlgren, L.; Skoghelm, O.; Burtnyk, V.

CIGRE Proceedings of the 34th Session
p.14-302/1-7 vol.1. 30 Aug.-5 Sept. 1992 , Paris, France.

Working Group 04 of Cigre Study Committee 14 (DC Links) collects data annually on the reliability performance of HVDC systems in operation throughout the world. The data is compiled and a summary report is prepared every second year covering performance for the two year period. The report is presented at a Study Committee Meeting at each Cigre General Meeting. This report contains data covering performance during 1989-90. The data in this report, together with that of previous years, provides a continuous record of reliability performance of HVDC systems for the past 23 years.

[1992] 51-REF

RELIABILITY ENGINEERING OF HVDC THYRISTOR VALVES

Dumrese, H...; Holweg, J.; Lips, H.P.; Salanki, T.; Thiele, G.; Tu, Q.B.

CIGRE Proceedings of the 34th Session
p.14-303/1-8 vol.1 30 Aug.-5 Sept. 1992

For Abstract see entry 2B-010.

6. SIMULATION OF HIGH-VOLTAGE DIRECT CURRENT SYSTEMS

6A. ELECTROMAGNETIC TRANSIENTS PROGRAM (EMTP)

[1991] 6A-1

A COMPARISON OF HVDC TRANSIENT SIMULATION ALGORITHMS
Arrillaga, J.; Sankar, S.; Watson, N.R.; Arnold, C.P.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep., 1991 v no. 345. 1991 p 368-373
By setting up an identical test system, this paper shows that the two main algorithms currently used for the simulation of ac/dc disturbances, namely the Transient Converter Simulation (TDS) and the Electromagnetic Transient Program combined with a diakoptical solution (EMTDC), can be made to agree in their prediction of the dynamic responses. The TCS algorithm uses fewer approximations and provides automatic selection of optimal integration steps. As a result TCS responses are very consistent. With careful selection of the integration step the EMTDC program can produce practically the same responses at the state variable technique for reasonably symmetrical conditions. However, some deterioration occurs with highly asymmetric disturbances. This has been traced to the phase advance prediction, required by the subsystem concept. Thus the EMTDC algorithm provides a very efficient solution at the expense of some accuracy. It can be concluded that both the EMTDC and TCS algorithms can be used with confidence to simulate the transient response of ac/dc converters.

[1992] 6A-2

CALCULATION OF INITIAL STEADY-STATE CONDITIONS IN DIGITAL MODELLING OF MULTI-SUBSTATION ELECTRIC POWER TRANSMISSION OF DIRECT CURRENT
Borodulin, M.Yu.
Tekhnicheskaya Elektrodinamika
no.5 p.93-9 Oct. 1992 Ukraine Russian Paper (JP)
The principles are set out and the basic stages described of the calculation of an initial steady-state regime in the digital modelling of electromagnetic transient processes of multi-substation transmission of direct current. An examination is made of questions regarding the assignment of initial values for the variables used in a mathematical description of a power circuit, e.g. those concerning the calculated circuits of an electric power system, the electrical equipment at the busbars of substations, converter transformers, etc. Algorithms of determination of the initial conditions of conductivity of converters are suggested, providing synchronization of the control pulses of the rectifiers and the voltages at DC busbars.

[1993] 6A-3

DETAILED TRANSIENT SIMULATION OF AN INTEGRATED AC/DC POWER SYSTEM
Junyong Wu; Shijie Cheng; Deshu Chen
IPEC '93. International Power Engineering Conference
March 18-19 1993. Conference Proceedings p.503-8 vol.2
The authors present a new simulation method for an integrated AC/DC power system with the emphasis on the DC converter. Based on a time-varying network topology algorithm, the method presented can greatly simplify the formulation of the converter circuit equation and reduce the computer memory needed for the simulation. Other advantages of the proposed method are the lower order of the circuit equation and the better numerical calculation stability. In the simulation, a linear interpolation and a variable integration step length algorithm are used to determine the exact switching time and the voltage variation of the converter valves switching. The proposed method also helps in eliminating the numerical oscillations. Developed DC transmission system transient simulation software has been connected with an EMTP program. Satisfactory results are obtained when tested on a +/-500 kV DC transmission system in China. (6 Refs)

[1993] 6A-4

DEVELOPMENT AND VALIDATION OF DETAILED CONTROLS MODELS OF THE NELSON RIVER BIPOLE 1 HVDC SYSTEM
Kuffel, P.; Kent, K.L.; Mazur, G.B.; Weekes, M.A.
IEEE Transactions on Power Delivery
Jan 1993 p 351-358
With the Nelson River Bipole 1 mercury arc valve group replacement project and planning for the expansion of the Nelson River HVDC system with a third bipole underway, it was decided to pursue a program to develop and validate detailed models of the existing HVDC transmission facilities and their

associated AC systems for use in system studies. The first phase of the program concentrated on the development of detailed controls models associated with the Bipole 1 transmission facility. Based on previous experience at Manitoba Hydro with the Electromagnetic Transient DC simulation program (EMTDC), it was decided that model development and validation would use this program. This paper presents the reasons behind the development of detailed models, the methods used in developing models related to Bipole 1, results of validation tests, difficulties encountered during the process, and the overall benefits resulting from the project. An example of applying the models to investigate a low frequency oscillation which has occurred on the DC system in the past is also presented.

[1991] 6A-5

DIGITAL SIMULATION OF FLEXIBLE TOPOLOGY POWER ELECTRONIC APPARATUS IN POWER SYSTEMS
Maguire, T.L.; Gole A.M.
IEEE Preprint # 91 SM 414-3 PWRD
1991
FACTS (Flexible AC Transmission System) apparatuses employing many alternative configurations of power-electronic switching devices are being considered by others for increasing the power transfer capability of AC transmission lines. This paper introduces special modifications to the basic Dommel algorithm to expedite simulation of systems including arbitrary configurations of individual power-electronic switching devices. The described techniques have been implemented in a prototype transients simulation program. Simulation results are presented for an example power-electronic apparatus.

[1991] 6A-6

EMTP COMPATIBLE HVDC AND SVC CIRCUIT MODULES
Liu, C.T.; Ong, C.M.
IASTED International Conference. High Technology in the Power Industry. Power High Tech '91
p.177-81 4-7 March 1991 Tainan, Taiwan In English
The potential of adverse interactions between the AC network and the converters of HVDC transmission and static VAR compensation systems has created a need for not only better models but also more efficient simulation programs to conduct detailed simulation studies involving a larger part of the AC system in the neighborhood of the converter buses. The authors present a modular approach that integrates the flexible tensor approach of simulating time-varying circuits to the efficient Bergeron's method of implementing the distributed parameter line representation, presenting, therefore, a viable alternative to using TACS for the converter simulation. (16 Refs)

[1993] 6A-7

HYBRID ELECTROMAGNETIC TRANSIENT SIMULATION WITH THE STATE VARIABLE REPRESENTATION OF HVDC CONVERTER PLANT
Zavahir, J.M.; Arrillaga, J.; Watson, N.R.
IEEE Transactions on Power Delivery
Jul 1993 p 1591-1598
The two alternative methods in current use for the transient simulation of HVDC power systems are Electromagnetic Transient Programs and State Variable Analysis. A hybrid algorithm is described in this paper which combines the two methods selecting their best features. The relative performances of conventional and hybrid algorithms are discussed. Simulation results of typical back-to back HVDC link show that the hybrid representation provides more stable, accurate and efficient solutions.

[1992] 6A-8

INTERFACING STATE VARIABLE HVDC MODELS WITH ELECTROMAGNETIC TRANSIENT SIMULATION PROGRAMS
Zavahir, J.M.; Arrillaga, J.; Watson, N.R.
Journal of Electrical and Electronics Engineering, Australia
vol.12, no.4 p.362-70 Dec. 1992
The two alternative methods in current use for the transient simulation of HVDC power systems are electromagnetic transient programs and state variable analysis. A hybrid algorithm is described which combines the two methods selecting their best features. The relative performances of cnventional and hybrid algorithms are discussed. Simulation results show that the hybrid representation provides more stable and efficient solutions. (9 Refs)

[1993] 6A-9

MODELING OF THE HYDRO-QUEBEC--NEW ENGLAND HVDC SYSTEM AND DIGITAL CONTROLS WITH EMTP
Morin, G.; Bui, L.X.; Casoria, S.; Reeve, J.
IEEE Transactions on Power Delivery
Apr 1993 p 559-566
The commissioning of the Quebec-New England multiterminal DC transmission system underscores the increasing need to develop numerical models for simulation purposes. The modern microprocessor-based HVDC converter controls used in this scheme

make the modeling a real challenge since Electro-Magnetic Transient Program (EMTP) usually employed for simulation purposes and its Transient Analysis of Control Systems (TACS) was designed to simulate analog, not digital controls. This paper gives details about the modeling of digital controls with a modified EMTP version and presents some comparisons with HVDC simulator results which show good agreement between the two power system analysis tools. A case of validation with field test result is also included in the paper.

[1991] 6A-10

MODELLING OF THE PACIFIC INTERTIE 4-TERMINAL HVDC SCHEME IN EMTP
Hammad, A.; Minghetti, R.; Hasler, J. ; Goldsworthy, D.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 362-367
This paper presents a complete and elaborate model for the 4-terminal HVDC transmission scheme of the Pacific Intertie in mono-pole and bi-pole configurations. All actual systems main hardware components and principal control and protection functions are faithfully represented. The model is primarily used for transient simulations using the well known EMTP (electro-magnetic transient program). It can, however, be used with other compatible software tools. All possible modes of operation and configurations of the HVDC scheme as well as all possible faults within and outside the HVDC converter stations can be simulated. Numerous field tests made during the commissioning phase of the HVDC scheme have been used to verify the correctness and accuracy of the digital model. (author).

[1991] 6A-11

NUMERICAL SIMULATION OF THE CROSS CHANNEL HVDC LINK DURING AC SYSTEM FAULTS. COMPARISON WITH SITE TEST RESULTS
Jeunehomme, A.; Charles, P.; Roguin, J.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 313-318
The Cross Channel HVDC link consists of two independent bipoles of 1000 MW each (1852A, {+/-}270 kV). The first bipole was commissioned in 1986. During the period of commissioning, acceptance tests aiming to verify the behaviour of the link during insulation failures on the 400 kV sub-station supplying the French end were performed. The records made at that time were also used as a reference for comparison with the results provided by a digital model of the same HVDC link. This digital model, obtained with the EMTP program, was developed as part of a study being made to check the behaviour of the interconnection subsequent to some insulation fault scenarios on the 400 kV lines close to the French station. This check it made by field tests on an installation operating commercially, would be in fact very difficult and would involve prohibitive costs. As a matter of fact the aim of these studies was to find a proper strategy to limit overvoltages on future 420/225kV autotransformers. The main strategy tested being to restart the converters even in case of large overvoltages. Consequently, it was decided to develop a digital model using EMTP. This model would be sufficiently accurate and detailed to provide valid results concerning the behaviour of real installation. To validate this mode, two different tests performed while the installation was being commissioned were selected and simulated, strictly under the same conditions, to be able to compare the results directly.

[1991] 6A-12

SIMULATION OF HVDC CONVERTERS USING CURRENT INJECTION METHOD
Bingjyr Lee; Lasseter, R.H.
IASTED International Conference. High Technology in the Power Industry. Power High Tech '91
p.234-8 4-7 March 1991 Tainan, Taiwan
A modeling technique suitable for HVDC system simulations is described. It is characterized by the injection of a fundamental frequency AC current into the AC network. This simple, yet effective method can be used as a first approximation for the analysis of the transients produced by the DC converter from the AC system point of view. Fundamentals of HVDC are covered followed by a description of the current injection method. Effectiveness of this technique is demonstrated by showing the results from EMTP runs. (4 Refs)

[1991] 6A-13

SOFTWARE-BASED EMTP REAL-TIME SIMULATOR
Marti, J. R.
Canadian Electrical Association. Analytical Techniques of Insulation Coordination Subsection, Montreal (Quebec).
1991
A real-time, software-based, fast transients simulator was developed that is suitable for the testing of protective relaying equipment. The simulation program RTNS is based on well established EMTP models and solution techniques that have been highly

optimized to achieve the required timing benchmarks using off-the-shelf workstation equipment. Additional models are currently being developed to extend the capabilities of the simulator for the testing of HVDC control equipment

[1993] 6A-REF

USING A THREE-LEVEL GTO VOLTAGE SOURCE INVERTER IN A HVDC TRANSMISSION SYSTEM
Lipphardt, G.
Power Electronics in Generation and Transmission, IEE Conference Publication
v 8 n 377 1993. p 151-155
For Abstract see entry 2A-026.

[1993] 6A-REF

INDUCED OVERVOLTAGES ON AN AC-DC HYBRID TRANSMISSION SYSTEM
Verdolin, R.
Canadian Electrical Association, Montreal, PQ (Canada)
Report Number: MIC-93-05225/XAB - Available from NTIS 1993
For Abstract see entry 3A-003.

[1993] 6A-REF

COMPARISON OF SUITABLE CONTROL SYSTEMS FOR HVDC STATIONS CONNECTED TO WEAK AC SYSTEMS
Shah, K.; Gole, A.M.
IPEC '93. International Power Engineering Conference 1993. Conference Proceedings
p.358-61 vol.1 18-19 March 1993
For Abstract see entry 5A-007.

[1991] 6A-REF

EFFECTS OF A VARIABLE PARAMETER CONTROLLER ON THE DYNAMIC PERFORMANCE OF AN HVDC TRANSMISSION SYSTEM.
Hasan, Abul R.; Ula, A.
Electric Power Systems Research
v 21 n 3 Jul 1991 p 173-180
For Abstract see entry 5A-021.

[1993] 6A-REF

RULE BASED CONTROLLER FOR AN HVDC TRANSMISSION SYSTEM
Parekh, B.R.; Banerjee, S.K.
Electric Power Systems Research
vol.27, no.2 p.83-90 July 1993
For Abstract see entry 5A-037.

[1992] 6A-REF

TRANSIENT AC VOLTAGE RELATED PHENOMENA FOR HVDC SCHEMES CONNECTED TO WEAK AC SYSTEMS
Pilotto, L.A.S.; Szechtman, M.; Hammad, A.E.
IEEE Transactions on Power Delivery
Jul 1992 p 1396-1404
For Abstract see entry 5D-020.

[1993] 6A-REF

INSULATION COORDINATION FOR LIGHTNING OVERVOLTAGES ON A LONG HVDC SUBMARINE CABLE
Mader, D.J.
Canadian Electrical Association, Montreal, PQ (Canada)
Report Number MIC-93-05228/XAB Available from NTIS 1993
For Abstract see entry 5F-003.

[1991] 6A-REF

OVERVOLTAGE STUDIES FOR THE ST. LAWRENCE RIVER 500-KV DC CABLE CROSSING.
Bui-Van, Que; Beaulieu, Germain; Huynh, Hieu; Rosenqvist, Roger
IEEE Transactions on Power Delivery
v 6 n 3 Jul 1991 p 1205-1215
For Abstract see entry 5F-004.

6B. DIGITAL MODELING AND SIMULATION, TRANSIENT STABILITY

[1991] 6B-1

A MATHEMATICAL MODEL FOR CALCULATING ELECTROMECHANICAL TRANSIENTS IN A DC TRANSMISSION SYSTEM.

Chesachenko, V. F.; Malyshev, A. V.
Elektrichestvo
10 Oct 1991 p 16-22

The calculation is initiated from the determination of a steady mode for a DC transmission system (DCT). The parameters of the reference mode are used for calculating initial constraints for equations of dynamics with derivatives equal to zero. A mathematical model given provides for a set of outer control means which has been partly tested in other countries during operations of DCT s. The model chart of a power system includes controlled sources of reactive power maintaining the voltage of converters. A method developed for algorithm construction is used to simulate a variety of nonlinear processes in power systems.

[1992] 6B-2

A METHOD FOR CALCULATING ELECTRICAL FIELDS INCLUDING TRANSIENTS IN HVDC APPARATUS

Bortnik, I.M.; Vol'pov, E.K.; Filippov, A.A.
Journal: Electrical Technology
no.2 p.121-30 1992 (in English, translated from Russian) Originally published in Electrichestvo no. 6, June 1992 in Russian

In high-voltage DC apparatus, conduction currents play a dominant role in forming the electrical field, which means that the conductivity of the insulation has also to be accounted for. The authors describe the mathematical model and the method for calculating electrical fields in DC apparatus taking account of the transients and charge accumulation. The method proposed is illustrated by an example, in which a DC voltage is switched on to the insulation. (6 Refs)

[1992] 6B-3

A NEW ALGORITHM FOR CALCULATING HVDC CORONA WITH THE PRESENCE OF WIND.

Yu, Ming; Kuffel, E.; Poltz, J.
IEEE Transactions on Magnetics
v 28 n 5 pt 2 Sep 1992. p 2802-2804

A novel algorithm for calculating HVDC (high-voltage direct-current) corona based on the boundary element method (BEM) is presented. This algorithm takes a different approach to the process of updating the space charge density during the iteration. The iteration process is convergent even for a uniform initial space charge distribution. It takes into account the effect of wind. A variable mobility can be used in the algorithm, which makes it possible to investigate the effects of such parameters as humidity and pollution on the corona. 4 Refs.

[1993] 6B-4

A NEW ALGORITHM FOR EVALUATING THE FIELDS ASSOCIATED WITH HVDC POWER TRANSMISSION LINES IN THE PRESENCE OF CORONA AND STRONG WIND

Yu, Ming; Kuffel, E.
IEEE Transactions on Magnetics
Mar 1993 p 1985-1988

A new algorithm for calculating HVDC fields in the presence of corona and strong wind based on boundary element method is presented. The new algorithm uses an auxiliary Poisson's equation for updating the space charge density during the iteration. The iteration process is convergent for wind velocities tested up to 12 m/s.

[1992] 6B-5

A NOVEL METHOD-COMBINATION AND SEPARATION OF NODES FOR DIGITAL SIMULATION OF HVDC CONVERTOR

Yixuan Tang; Bo Zhou
Journal: Proceedings of the CSEE
vol.12, no.5 p.62-7 Sept. 1992

A novel method for digital simulation of an HVDC convertor is presented. The switching-on and switching-off of valves in the convertor circuit is expressed as a combination and separation of nodes respectively. The circuit equation coefficient matrix for the new topology structure of the circuit can be easily obtained by simply correcting the original one. The proposed method is characterized by its simplicity of principle, quick computation and small memory space needed. The numerical oscillation is completely eliminated by calculating the jump voltages in the case of using the implicit trapezoidal integration method to

convertor simulations. The method is programmed and used for the simulation of a HVDC system with one pole and two bridges, the results are satisfactory. (8 Refs)

[1992] 6B-6

A VECTOR ENERGY FUNCTION APPROACH FOR SECURITY ANALYSIS OF AC/DC SYSTEMS

DeMarco, C.L.; Canizares, C.A.

IEEE Transactions on Power Systems

Aug 1992 p 1001-1011

This paper examines dynamic behavior in system models that reflect reasonably detailed (third order) HVDC dynamics along with AC system models that include reactive flows, and frequency and voltage dependent load models. A vector Lyapunov function approach is employed to define a system wide energy function that can be used for general security analysis. The paper describes the derivation of individual component Lyapunov functions for simplified models of HVDC links connected to infinitely strong AC systems, along with a standard AC only system Lyapunov function. A novel method of obtaining weighting coefficients to sum these components for the overall system energy function is proposed. Use of the new energy function for transient stability and security analysis is illustrated in a test system.

[1993] 6B-7

AC-DC LOAD FLOW WITH UNIT-CONNECTED GENERATOR-CONVERTER INFEEDS

Arrillaga, J.; Arnold, C.P.; Sankar, S.

IEEE Transactions on Power Systems

May 1993 p 701-706

It is demonstrated that the conventional ac-dc formulation is not directly applicable to the unit-connected generator-converter. Alternative steady state models are derived which are considered reasonable for cylindrical rotor machines but not for salient-pole generators. Finally an accurate algorithm of general applicability, called the Equivalent Inverter, is proposed which uses unit-connection characteristics derived from a time domain simulation.

[1992] 6B-8

ADAPTIVE APPROACH TO FINITE ELEMENT MODELLING OF CORONA FIELDS

Adamiak, K.

Conference Record of the IEEE Industry Applications Society Annual Meeting (Cat. No.92CH3146-8)

p.1632-9 vol.2 1992

A methodology is proposed for simulating the corona field under a high-voltage DC (HVDC) transmission line. In the finite element modeling of corona fields, the area close to the corona electrode needs the finest discretization due to a significant difference in size and curvature of electrodes. User-defined discretization may yield insufficient accuracy. In the approach presented here, the domain is discretized adaptively according to an algorithm based on information about the solution error. There are two advantages of such an approach: mesh generation is completely automatic, and the resultant mesh has the optimum density for the assumed accuracy. This adaptive algorithm has been demonstrated for several HVDC transmission line configurations. (18 Refs)

[1993] 6B-9

AN ANALYSIS OF GENERATOR-HVDC CONVERTOR UNITS

Sankar, S.; Arrillaga, J.

IPEC '93. International Power Engineering Conference

18-19 March 1993. Conference Proceedings p.200-4 vol.1

The operating characteristics of the generator-HVDC power convertor units are normally discussed with reference to the conventional steady state formulation. However, in the absence of harmonic filters, the use of such formulation must be reconsidered. This paper assesses the validity of conventional steady state formulation and shows the need for dynamic simulation to derive the steady state characteristics of generator-HVDC power convertor units. (5 Refs)

[1993] 6B-10

CONTROLS MODELLING AND VERIFICATION FOR THE PACIFIC INTERTIE HVDC 4-TERMINAL SCHEME

Hammad, A.; Minghetti, R.; Hasler, J.; Eicher, P.; Bunch, R.; Goldsworthy, D.

IEEE Transactions on Power Delivery

Jan 1993 p 367-375

A detailed digital model for the actual control system of the Pacific Intertie HVDC scheme is presented. The scheme is operated as multi-terminal bipole HVDC with four terminals in parallel. Each pole comprises

two separately located converter stations with independent converter controls at each end of the transmission line. The control model includes bipole, pole, station and converter control systems. Special control techniques for providing safe and stable operation of the parallel converters are described. The techniques also result in fast recovery of the HVDC transmission scheme following severe AC and DC system disturbances. Verification of the completeness and accuracy of the model are made using field tests made on the actual HVDC scheme.

[1993] 6B-11

EVALUATION OF NONCONVENTIONAL HVDC CONVERTER CONTROLS IN AN AC/DC POWER SYSTEM USING PRONY SIGNAL ANALYSIS

Emmanuel, P.A.; Nehrir, M.H.; Pierre, D.A.; Adapa, R.

Electric Power Systems Research

v 26 n 1 Jan 1993. p 31-39

This paper presents an evaluation of various nonconventional high voltage DC (HVDC) converter controls in an AC/DC power system. A method based on Prony signal analysis is used to obtain reduced-order models of the system with different nonconventional HVDC converter control schemes. The linear models provide information on local and interarea modes of the system and the degree of damping that each control scheme provides for the system. A detailed swing program is used to simulate the system. The evaluation procedure is explained and results are presented. The system studied is a 42-bus, 17-machine test system which exhibits some steady-state and dynamic characteristics of the western North American power system.

[1991] 6B-12

EXPERIENCE WITH MODELING MTDC SYSTEMS IN TRANSIENT STABILITY PROGRAMS

Lefebvre, S.; Wong, W.K.; Reeve, J.; Gagnon, J.M.; Johnson, B.K.

IEEE Transactions on Power Delivery

Jan 1991 p 405-413

A typical ac/dc transient stability program is used to illustrate the selection of DC system and control models for multiterminal DC (MTDC) studies. Experience with developing and using the models is emphasized rather than their implementation within particular programs. Three models with different degree of details are presented. Typical applications of different existing models are discussed in the context of early planning studies of the Hydro-Quebec New England shunt MTDC interconnection.

[1993] 6B-13

EXTENDED TRANSIENT-MIDTERM STABILITY PROGRAM: VERSION 3.0

Kundur, P.; Rogers, G.J.; Wong, D.Y.; Yan, A.

EPRI-TR-102004-Vol.1

Apr 1993

This report details the techniques employed in EPRI's Extended Transient Midterm Stability Program (ETMSP) version 3.0. The work on this program commenced in 1988, and was completed in 1992. The program is radically different from the original version of ETMSP, version 1.0. The code is completely new, based on Ontario Hydro's SIMU rather than ETMSP version 1.0. ETMSP has many advanced features, both in terms of modelling and solution capability and in user friendliness. It is fast and economical in computing facilities: it is up to 16 times faster than ETMSP version 1.0, and its system size limit is 6 times greater with only twice the computer storage requirement. ETMSP version 3.0 has both explicit and implicit differential equation solution methods it models. Its model complement includes: Detailed generators: Excitation systems, Prime Mover/Governor systems; Two terminal and multi-terminal HVDC links; Dynamic and static loads; Under load tap changers; Flexible AC transmission systems (FACTS); and Relays. User defined models are available for generator controls, FACTS and HVDC controls. Input of both power flow and dynamic data can be in a variety of commonly used formats which are compatible with other EPRI programs which form the Power System Analysis Package (PSAPAC).

[1991] 6B-14

FIELD TEST COMPARISON, CONTROL, AND MODELING OF THE SIDNEY CONVERTER STATION.

Hedin, Ronald A.; Stump, Keith B.; Vossler, Brent A. Siemens Energy & Automation, Inc, Roswell, GA, USA

IEEE Transactions on Power Systems

v 6 n 2 May 1991 p 536-542

A procedure is presented for modeling a complex back-to-back DC converter station and its controls. The model is required for accurate transient stability analysis of the power system. A high-frequency model was developed, and its performance was compared to field test results. The model was modified to include only longer time effects significant for transient stability analysis. The final transient stability model was verified against both available field tests and the detailed high-frequency model. The model in conjunction with a transient stability program helps assure that the power system can be operated in a safe and prudent manner.

[1991] 6B-15

HIGH SPEED DIGITAL COMPUTER SIMULATION OF THE VIRGINIA SMITH DC CONVERTOR STATION

Hedin, R.A.; Stump, K.B.; Vossler, B.A.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 350-355

The Virginia Smith converter station is a back-to-back DC converter station located in Sidney, Nebraska. It connects with two AC power grids which operates asynchronously. The station is designed to transfer 200 MW of power either west to east or east to west. The nominal DC voltage is 50 kV and rated direct current is 4140 amps. The station has several special features required by the relative strengths of the two AC systems, electrical locations of generation relative to the station, possible network configurations, and system power transfer requirements. These special features and general considerations for the station have been described in other papers. In a prior paper, the development of a detailed model of the station for a transient stability program was described. The procedure involved using the digital simulator to initially develop the model and convert the model to one which could use an 8.33 millisecond step time required for stability programs. This paper describes the model of the converter station developed for the study of both relatively fast transients (10 to 20 Hz) and the slower electromechanical swings (1 Hz). Comparison of field test results and computer model results are given.

[1992] 6B-16

HVDC-TRANSMISSION LINE MODEL FOR TRANSIENT SIMULATION PURPOSES

Navarro-Adlemo, R.; Breitholtz, C.; Welfonder, E.; Lausterer, G.K.

International IFAC symposium on control of power plants and power systems

1992 p 305-310

A lumped bipolar HVDC-transmission line model, based on least squares fitting of orthogonal polynomials which are space dependent and have time dependent coefficients, is presented and examined in this paper. The model enables the line voltage and current to be approximately determined for arbitrary points along the line and at arbitrary times. The model is not restricted to lossless lines or to the steady state. An example is given showing how the transmission line model is extended to include arbitrary linear terminal dynamics. It is also demonstrated that the model is useful as a simulation tool.

[1991] 6B-17

IMPROVING VOLTAGE STABILITY IN POWER SYSTEMS WITH HVDC CONVERTERS

Andersson, G.; Liss, G.

APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management (Conf. Publ. No.348)

p. 698-703 vol.2 1991

When analysing HVDC systems connected to weak AC systems it is important to have a model that is simple and still captures the important features of the system. Such a model is presented and a number of conclusions are drawn from simple arguments based on physical observations of this system. These findings are verified by a more rigorous mathematical treatment of the problem. This analysis includes both steady state and dynamic conditions. It is also demonstrated how an appropriate control of the convertors can be used to stabilize a voltage instability in the system. (4 Refs)

[1991] 6B-18

INCORPORATING FEATURES OF THE PACIFIC HVDC INTERTIE IN A REDUCED-ORDER MODEL OF THE WESTERN NORTH AMERICAN POWER SYSTEM

Emmanuel, P.A.; Nehrir, M.H.; Pierre, D.A.; Adapa, R.

Proceedings of the American Power Conference v 53

1991 p 582-587

This paper describes the development and evaluation of two-terminal and multi-terminal DC line models for the Pacific HVDC intertie that exhibit similar characteristics and carry the same voltage and power as the actual system. The DC system model has been implemented in a reduced order equivalent of the western North American power system that exhibits some of the important characteristics of the actual system. Simulation results are presented for different types of faults with the DC system represented by constant real and reactive loads, by a two-terminal model and by a multi-terminal model. A comparative study of the results is made using Fast Fourier Transform (FFT) analysis of the generator angle responses. films using resonant-cavity techniques.

[1991] 6B-19

MATHEMATICAL MODEL OF DC POWER TRANSMISSION FOR USE IN THE CALCULATIONS OF ELECTROMECHANICAL TRANSIENTS

Chesachenko, V.F.; Malyshev, A.V.

Elektrichestvo

no.10 p.16-22 Oct. 1991 USSR Russian

The analysis of transient electromechanical phenomena commences with the examination of steady states in an AC power system, incorporating an add-on DC power tranmission system; the constants for this combination are defined. A mathematical model for the DC power system, for application in calculations of electromechanical phenomena is constructed, and used for examining the effect of major disturbances in the main and add-on DC systems on the behaviour of AC power systems. On the basis of the theory developed, and using the algorithms for the steady states and transient states in DC systems, a program was constructed for electromechanical transients and for the dynamic stability of the system, comprising any number of separate DC power systems and add-on power systems. The procedure for electromechanical transients is noniterative and can be applied for the modelling of other nonlinear units in power systems, induction stores, etc. (6 Refs)

[1993] 6B-20

MODELING AND SIMULATION OF LARGE HVDC SYSTEMS

Jin, H.; Sood, V.K.

Report Number MIC-93-05185/XAB

1993 Available from NTIS

This paper addresses the complexity and the amount of work in preparing simulation data and in implementing various converter control schemes and the excessive simulation time involved in modelling and simulation of large HVDC systems. The Power Electronic Circuit Analysis program (PECAN) is used to address these problems and a large HVDC system with two DC links is simulated using PECAN. A benchmark HVDC system is studied to compare the simulation results with those from other packages. The simulation time and results are provided in the paper.

[1991] 6B-21

MODELING DC LINKS WHEN ANALYSING POWER SYSTEM STABILITY

Lusyak, G.N.; Danilyuk, A.V.; Konoval, V.S.

Izvestiya Vysshikh Uchebnykh Zavedenii, Energetika

no.5 p. 14-21 May 1991 Byelorussian SSR, USSR, in Russian

The authors discuss the various problems that arise when simulating DC links in an AC transmission system. A method based on generalised models of independent variables of the DC link enables the quasi-steady-state conditions of the adjacent systems to be calculated when investigating the stability of a power pool. Controlled or uncontrolled operating conditions of the links can be simulated by varying the composition of the reference base. (6 Refs)

[1993] 6B-22

MODELING OF HIGH VOLTAGE DIRECT CURRENT TRANSMISSION SYSTEMS FOR OPERATOR TRAINING SIMULATORS

Kuruneru, Ravindra S.; Bose, Anjan; Bunch, Richard

IEEE Power Industry Computer Applications Conference

p. 262-268 1993

This paper presents a generic bipolar or monopolar multi-terminal multi-converter High Voltage Direct Current (HVDC) system model suitable for Operator Training Simulators (OTS). This model is designed to train operators for AC-DC system operations and controls so that they can take appropriate actions quickly under emergency conditions. This model can handle the most complex HVDC configurations and controls like those, for example, in the Pacific Intertie.

[1993] 6B-23

MODELLING AND CONTROL OF AN HVDC LINK IN ELECTRIC POWER SYSTEMS

To, K.W.V.; David, A.K.

IPEC '93. International Power Engineering Conference

1993. p.210-13 vol.1

This paper compares the conventional and optimal controllers of HVDC links for large disturbance performance. The objective is to extend the operational margins of stability by introducing a co-ordinated control on excitation of generations and power converter firing angle controls. The system dynamics are modelled in terms of measurable state variables and control inputs. This is achieved by using recursive least squares identification. On the basis of this identified model, a co-ordinated optimal controller is achieved by minimizing a quadratic performance

index using dynamic programming techniques. Digital simulation results are encouraging for co-ordinated optimal control scheme over a wide range of operation points. (9 Refs)

[1991] 6B-24

MODELLING OF A DISTRIBUTED COMPUTER CONTROLLED MULTITERMINAL HVDC SYSTEM FOR DYNAMIC SIMULATION
Ngan, H.W.; David, A.K.; Lo, K.L.
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management
p. 599-604 vol.2 1991
The authors describe a MTHVDC simulation model incorporating DC power control in a multimachine model based on the extension of the Heffron-Phillips representation. The system control strategy consists of a distributed computing environment and the simulation is supported by a simulation language expressly suited to the modelling of dynamic systems. (7 Refs)

[1991] 6B-25

MODELLING OF HVDC WALL BUSHING FLASHOVER IN NONUNIFORM RAIN
Rizk, F.A.M.; Kamel, S.I.
IEEE Transactions on Power Delivery
Oct 1991 p 1650-1662
This paper presents the first mathematical model to provide necessary and sufficient conditions for flashover of an HVDC wall bushing under nonuniform rain. The suggested mechanism is initiated by streamer bridging of the dry zone enhanced by nonuniform voltage distribution along the bushing and within the dry zone. Fast voltage collapse across the dry zone die to energy stored in the bushing stray capacitance to ground leads to impulsive stressing of the wet part of the bushing. The nonuniform distribution of the impulse stress and the process of streamer bridging, fast voltage collapse as well as subsequent recharging of the bushing capacitances can lead to continued discharge propagation and flashover of the complete bushing. The findings of the model have been satisfactorily compared with previous experiments and field observations and can, for the first time, account for the following aspects of the flashover mechanism: critical dry zone length, polarity effect, specific leakage path, wet layer conductance per unit leakage length as well as the DC system voltage.

[1993] 6B-26

POINT OF COLLAPSE AND CONTINUATION METHODS FOR LARGE AC/DC SYSTEMS
Canizares, C.A.; Alvarado, F.L.
IEEE Transactions on Power Systems
Feb 1993 p 1-8
This paper describes the implementation of both Point of Collapse (PoC) methods and continuation methods for the computation of voltage collapse points (saddle-node bifurcations) in large ac/dc systems. A comparison of the performance of these methods is presented for real systems of up to 2,158 buses. The paper discusses computational details of the implementation of the PoC and continuation methods, and the unique challenges encountered due to the presence of high voltage direct current (HVDC) transmission, area interchange power control regulating transformers, and voltage and reactive power limits. The characteristics of a robust PoC power flow program are presented, and its application to detection and solution of voltage stability problems is demonstrated.

[1992] 6B-27

POINT OF COLLAPSE METHODS APPLIED TO AC/DC POWER SYSTEMS
Canizares, C.A.; Alvarado, F.L.; DeMarco, C.L.; Dobson, I.; Long, W.F.
IEEE Transactions on Power Systems
May 1992 p 673-683
This paper describes an extension of the Point of Collapse method developed for AC systems studies to the determination of saddle-node bifurcations in power systems including high voltage direct current (HVDC) transmission. Bus voltage profiles are illustrated for an ac/dc test system, which significantly differ from the profiles of pure AC systems for typical system models. In particular, voltage dependent current order limits (VDCOLs) are shown to affect the voltage profiles (nose curves) and the loadability margin of the system. It is also shown that Hopf bifurcations, which are not possible in purely AC lossless systems with second-order generator models, become plausible when the dynamics for the HVDC system are included.

[1992] 6B-28

POWER STATION LOW FREQUENCY GENERATION AND TRANSMISSION BY HVDC LINE
Zhang Dongsheng
Power System Technology
no.3 p.34-42 Aug. 1992 China In Chinese
Some aspects of simulating tests for the Three Gorges hydroelectric power project are discussed, such as the

voltage levels and power ratings under low frequency as well as the steady state, and dynamic operation of the AC/DC power system under various frequencies. (4 Refs)

[1992] 6B-29

REAL TIME SIMULATOR TO INVESTIGATE THE SYSTEM INVERTERS AND MAINS SUPPLY

Kaufhold, W.; Retzmann, D.; Schultz, W.

Elektrotechnische Zeitschrift

vol.113, no.3 p.116-17, 120-3 Feb. 1992 West Germany In German

With the growing demand for high voltage DC transmission plants, static compensators and controlled series compensation, real time simulation on a model of the mains supply network is gaining in importance. Main points of use of the simulator are development and optimisation close to the mains supply network of special control and protection functions, and the investigation of the effects of inverters back on to the mains supply network and on each other. Tests are possible in the pre-setting to work of original controls in the simulator, for which there will be no opportunity later.

[1991] 6B-30

REAL-TIME DIGITAL AND HARDWARE-IN-THE-LOOP SIMULATION OF A HVDC LINK

Rathjen, O

Modelling and Control of Electrical Machines. New Trends. Proceedings of the Third International Symposium

p.305-10 1991

Digital simulation of HVDC systems has been continuously investigated. With the advent of powerful signal processors and vector processing units, real-time digital simulation has become feasible. After briefly reviewing the mathematical model of the power converter and the numerical algorithms for fulfilling the real-time conditions, the authors discuss the hardware-in-the-loop simulations with industrial control equipment of HVDC plants interfaced to the real-time simulator. The structure of the simulator, a parallel vector processing system and special interfaces asynchronously receiving firing pulses and providing end-of-conduction signals, is described. Experimental results are presented which have been obtained from simulating an HVDC link under various operating conditions. (9 Refs)

[1991] 6B-31

SIMULATION OF HIGH VOLTAGE DC TRANSMISSION AND STATIC COMPENSATORS

Karlecik-Maier, F.; Retzmann, D.; Rittiger,

J.Elektrie (Germany) v 45:3.

1991 p 100-103. In German

A complete simulation accompanying the project of an HGUe or SK system is possible and necessary from the tender phase to operation of the plant. In this way and from the necessary engineering knowledge, the operating safety and economy of an HGUe or a static compensator can be guaranteed. The simulation models are designed so that according to the state of execution, a project can be worked on technically correctly and in a realistic way, but also economically and with saving of time. Apart from the HGUe and SK simulations acting as examples, an analysis of nearly all problems of all energy technology including the necessary regulation tasks, is possible with the real time model and the simulation program NETOMAC.

[1993] 6B-32

STEADY-STATE MATHEMATICAL MODELS OF CONVERTORS WITH BIPARAMETRIC REGULATION

Carpinelli, G.; Gagliardi, F.; Sturchio, A.; Russo, M.

IEE Proceedings, Part C: Generation, Transmission and Distribution

Mar 1993 p 105-114

Independent and rapid control of both active and reactive power can be achieved by convertors with biparametric regulation, whose behaviour is strongly influenced by their AC power system interactions and which can work in nonideal conditions such as those arising from voltage harmonics and unbalances. This paper presents mathematical models of convertors with biparametric regulation with a view to carrying out a complete analysis in steady-state nonideal conditions; the models are developed so that they are applicable for studies both at fundamental and at harmonic frequencies. Numerical applications to convertors connected to a superconducting coil for energy storage are also discussed. (author)

[1991] 6B-33

VALIDATION OF DIGITAL SIMULATION FOR STUDIES OF TORSIONAL INTERACTION BETWEEN A TURBO-GENERATOR AND AN HVDC LINK
Adam, P.H.; Yao, Z.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 295-300
After reviewing the phenomenon of torsional interactions between a turbo-generator and an AC network including an HVDC link, this paper describes a method and a tool for analysing it. It also details the approach used for model validation based on field records obtained during field tests on the Cross Channel 2000MW HVDC link and its interactions with the Gravelines nuclear power plant.

[1992] 6B-REF

TLWORKSTATION TRADEMARK CODE: VERSION 2.3: VOLUME 7, ACDCLINE MANUAL
Zaffanella, L.E.
Jun 1992 EPRI-EL-6420-Vol.7
For Abstract see entry 1B-029.

[1992] 6B-REF

TRANSIENT STABILITY STUDIES OF AC/DC HYBRID POWER SYSTEM BASED ON REAL CONTROL SYSTEMS
Zhou Xiaoxin; Li Hanxiang; Zheng Fangneng
Power System Technology
no.2 p.28-33 May 1992 China In Chinese
For Abstract see entry 1F-021.

[1992] 6B-REF

CHARACTERISTICS OF UNIT-CONNECTED HVDC GENERATOR-CONVERTORS OPERATING AT VARIABLE SPEEDS
Arrillaga, J.; Sankar, S.; Arnold, C.P.; Watson, N.R.
IEE Proceedings, Part C: Generation, Transmission and Distribution
May 1992 p 295-299
For Abstract see entry 2A-008.

[1993] 6B-REF

A CALCULATION METHOD AND SOME FEATURES OF TRANSIENT FIELD UNDER POLARITY REVERSAL VOLTAGE IN HVDC INSULATION
Wen, K.C.; Zhou, Y.B.; Fu, J.; Jin, T.
IEEE Transactions on Power Delivery
Jan 1993 p 223-230
For Abstract see entry 2J-001.

[1992] 6B-REF

LOW ORDER DYNAMIC CONTROLLERS FOR HVDC LINKS SUPPLYING WEAK SYSTEMS
Georgantzis, G.J.; Giannakopoulos, G.B.; Vovos, N.A.; Welfonder, E.; Lausterer, G.K.; Weber, H.
International IFAC symposium on control of power plants and power systems
9-11 Mar 1992 p 293-298
For Abstract see entry 5A-028.

[1991] 6B-REF

DIGITAL SIMULATION OF HVDC TRANSMISSION AND ITS CORRELATION TO SIMULATOR STUDIES
Rittiger, J.
Institution of Electrical Engineers v no. 345.
1991 p 414-420
For Abstract see entry 6D-001.

6C. POWER FLOW, STATE ESTIMATION

[1991] 6C-1

A NEW APPROACH TO AC/DC POWER FLOW
Smed, T.; Andersson, G.; Sheble' G.B.; Grigsby L.L.
Transactions on Power Systems
Vol. 6, No. 3, August 1991, pp. 1238-1244
A new approach to ac/dc power flow is presented in this paper. The converters are treated as voltage dependent loads and the DC variables are eliminated from the power flow equations. A simple and reliable method for fast decoupled power flow for ac/dc systems is developed. For non-synchronous interconnections, the power flow equations can be solved separately for each area.

[1991] 6C-2

DETERMINATION OF COMMUTATING VOLTAGE AND COMMUTATION REACTANCE AND COMPUTATION OF THREE-PHASE AC/DC POWER FLOW
Zhang Chuan
International Journal of Electrical Power and Energy Systems
Oct 1991 p 263-267
This paper presents a rigorous method of determining the commutating voltage and the commutation reactance, both of which play significant roles in the analysis of AC/DC power systems under unbalanced AC conditions. An accurate but simple three-phase no-mutual equivalent circuit is derived for the AC part connected to the three-phase converter bridge. By using the circuit, the analyses relevant to AC/DC power systems under both steady state and dynamic unbalanced conditions could be performed more precisely and more concisely. As an application, three-phase AC/DC power flow is also discussed. A set of complete but minimized converter equations is developed, with which the computational requirements of the power flow could be reduced.

[1991] 6C-3

THREE PHASE AC-DC LOAD AND HARMONIC FLOWS
Arrillaga, J.; Callaghan, C.D.
IEEE Transactions on Power Delivery
Jan 1991 p 238-244
The validity of assuming fundamental frequency load flow conditions of AC - dc. conversion plant to be unaffected by the presence of harmonics is questioned, and an algorithm is derived which is capable of determining the true load flow conditions in the presence of harmonics. The algorithm is unique in its three phase approach to the problem, which is essential if normally unfiltered uncharacteristic harmonics are to be represented. Results of a realistic and relevant test system are used to demonstrate the interaction which exists between the fundamental and harmonic frequencies in the converter.

[1991] 6C-REF

STATE ESTIMATION IN MULTITERMINAL AC-DC POWER SYSTEM.
Quan, Yinan; Tian, Xiujun; Ma, Zhaoyan
Proceedings of the Chinese Society of Electrical Engineering
v 11 1991 p 75-83
For Abstract see entry 5H-009.

[1991] 6C-REF

STATIC STATE ESTIMATION OF MULTITERMINAL DC/AC POWER SYSTEM IN RECTANGULAR CO-ORDINATES
Roy, L.; Sinha, A.K.; Srivastava, H.N.P.
Electric Machines and Power System v 19:1.
1991 p 69-80
For Abstract see entry 5H-010.

6D. ANALOG, HYBRID SIMULATORS

[1991] 6D-1

DIGITAL SIMULATION OF HVDC TRANSMISSION AND ITS CORRELATION TO SIMULATOR STUDIES
Rittiger, J.
Institution of Electrical Engineers v no. 345.
1991 p 414-420
In order to investigate the behaviour of HVDC transmission in a power system suitable simulation models are required. A detailed commutation model with simulation of the thyristor bridges, while very precise, requires considerable time for calculation. Simplified models, on the other hand, do not always provide sufficiently accurate results. In this article simplified and detailed HVDC simulation models are described and compared. In order to provide a yardstick for comparison, the HVDC Benchmark model study of the EGH analog simulator at Mannheim-Rheinau was used as a reference. The NETOMAC digital simulation program which was employed for all calculations is a powerful and flexible tool by means of which practically all problems of electrical energy transmission including control algorithms can be investigated. The variable time step of NETOMAC is of particular relevance for investigation of HVDC transmission and static VAR compensators thus ensuring that the continuity conditions are always satisfied while a thyristor is fired.

[1992] 6D-2

HVDC SIMULATOR FACILITIES IN INDIA
Ramamoorty, M.; Parameswaran, S.; Babu Narayanan, M.M.
Electronics Information and Planning
vol.19, no.12 p. 657-64 , 1992 , India , In English.
The new-generation HVDC simulator installed in Central Power Research Institute, Bangalore was supplied by ABB, Sweden. The simulator was commissioned in September 1986. It is equipped with the latest generation of microcomputer based control

and protection systems. The entire arrangement consists of 25 cubicles representing the various components of an HVDC system with a fairly good representation of the associated AC systems including magnetic saturation. The simulator consequently has the capacity to model one 12 pulse bi-polar HVDC transmission. The cubicles can be interconnected suitably, for studies on multi terminal mono-polar lines.

[1991] 6D-3

IMPROVEMENTS IN THE REALIZATION OF A REAL-TIME DIGITAL SIMULATOR OF A POWER TRANSMISSION LINE
Zhang, N.; Wang, X.; Eggleston, J.F.; Mathur, R.M.
IEE Conference Publication Series - International conference on AC and DC power transmission:
17-20 Sep 1991 p 356-361
This paper presents the realisation details and results of a real-time simulator of a power transmission line. This digital simulator is tested with controlled power interfaces such that the combination can now be incorporated into a Transient Network Analyzer (TNA) or other analogue type power system simulator. The digital simulator has high speed and good stability.

[1992] 6D-4

MODELING AND SIMULATION OF CONVERTER BRIDGES APPLICATION TO HVDC TRANSMISSION
Bensenouci, A.
Modelling, Measurement & Control A
vol.44, no.1 p.1-22 1992 France In English .
The author deals with the analog simulation of Graetz bridges used in HDVC systems. The control system is equipped with the two most common firing schemes; individual pulse control and equidistant pulse control. Transient behaviour due to full load rejection is also looked into.

[1992] 6D-5

PARTICLE-IN-CELL SIMULATION OF A RADIOACTIVE PROBE IN WIND.
Wang, Qing Y.; Pedrow, Patrick D.
IEEE Transactions on Electrical Insulation
v 27 n 2 Apr 1992 p 342-351
A two-dimensional particle simulation model was developed to investigate wind effects on charge density measurements under HVDC lines using a radioactive probe. The particle simulation technique was successful in macroscopically describing the motion of charged particles under the influence of wind, electric field, and diffusion. The simulation results were in good agreement with wind tunnel experiments. The simulation revealed that at higher wind speeds, the charged particle in the ionization region were convected away faster than at lower wind speeds. This reduced the recombination rate at the probe and thereby resulted in a more negative floating potential. At constant wind speed, the floating potential was less negative when the probe emitting surface was in the wake because wind velocity in the wake was much smaller (assumed zero in the simulation.)

7. HIGH-VOLTAGE DIRECT CURRENT INSTALLATIONS

7A. SPECIFIC PROJECTS

[1992] 7A-1

A HVDC SUBMARINE LINK FROM ICELAND TO GREAT BRITAIN
Bergmundsson, J.; Olsen, A. Afl Engineering Ltd., Reykjavik, Iceland
Power Technology International
p.125-7 1992
Iceland, situated in the North Atlantic Ocean midway between Europe and America, is endowed with vast renewable energy sources which can be tapped in a pollution-free way without any production of greenhouse gases. Harnessable energy totals 50 TWh/year of economical power after considering environmental constraints. These energy sources equal 200 thousand kWh a year per capita of the country's quarter of a million inhabitants. Here the authors describe the export of this electric power by HVDC submarine power cables to mainland Europe, in particular to the UK. 3 Refs)

[1991] 7A-2

ANALYSIS ON THE OPERATING CONDITIONS OF THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION SYSTEM DURING AUG. 1989 TO AUG. 1990
Huang Wanyong; Sun Peijing
Power System Technology
no.3 p.70-6 Aug. 1991 China In Chinese .
The Gezhouba-Shanghai HVDC transmission project was commissioned in May 1989, and the trial operation was carried out in August 1989. Full commercial operation started in August, delivering between 1,4000,000 to 10,000,000 kWh. The authors present the data and results of the first year of operation and analyse the faults which occurred during that period. (0 Refs)

[1993] 7A-3

BALTIC SUBMARINE HVDC LINK IS WORLD'S LONGEST
Eriksson, Kjell; Hjalmarsson, Goergen; Lampe, K.H.; Martinsson, Ulf; Nyman, Anders
Modern Power Systems
Mar 1993 p 47, 49, 51, 53, 55
A major high voltage direct current (HVDC) link connecting the Nordel power transmission system in Scandinavia to the Union for the Coordination of the Production and Transport of Electricity (UCPTE) system in western Europe and beyond is now under construction for operation in 1994. The 250 km long, 600 MW capacity cable, from Malmoe in Sweden to Luebeck in northern Germany, is claimed to be the world's longest and highest capacity single cable submarine transmission link. Vattenfall and Sydkraft in Sweden and PreussenElektra in Germany have founded a joint company - Baltic Cable AB based in Malmoe - to pursue their common strategic interests through the new link.

[1992] 7A-4

CHEJU ISLAND GETS A 300 MW HVDC BOOST
Kim, S.I.; Andersen, B.R.; Burgess, R.P.; Baker, M.H.
Modern Power Systems
1992 p 29, 31, 33
Cheju island, off the southern tip of Korea, has insufficient generating capacity for its growing tourist industry. Korean utility KEPCO and GEC Alsthom plan to solve the problem with the installation of a 300 MW HVDC link from the mainland to the island.

[1991] 7A-5

COMPACT DC LINK
Flairty, C.; Malvern, PA
Electric Power Research Inst., Report Number EPRI-EL-7101
Oct 1991 (163 p)
The EPRI Compact Substation Project (a HVDC Converter Station) was developed, designed, and constructed per EPRI Agreement RP213. In December 1983, the converter station operated at its rating (100 MW power transmission and 300 kV DC bias plus 100 kV operating voltage). From January to May 1984, the

converter station operated at various power transmission levels. Operation was intermittent due to a randomly occurring voltage breakdown. The voltage breakdown was isolated to the steel tanks containing the thyristor valves in an SF{sub 6} environment. The type of insulators stressed within the valve tanks were: (1) the epoxy cone shape insulators providing an interface to the bus entering the valve tank; (2) epoxy fiberglass hydraulic columns for the flow of the R113 refrigerant to and from the thyristor valves; and (3) the epoxy fiberglass support columns supporting the thyristor valves from the floor of the valve tank. The cause of the randomly occurring breakdown was investigated and determined to be the epoxy fiberglass support columns. The random dielectric breakdowns were due to excessive voltage gradients existing at the epoxy fiberglass support columns. This probably was caused by the misplacement of an internal insert within the column with respect to an external shield on the column. The cost and time to retrofit the support columns outweighed the benefits expected from resuming the project. Consequently, work was terminated and the equipment disassembled. Examination of the epoxy fiberglass support columns revealed several arcing tracks along the inside surface confirming the earlier hypothesis.

[1991] 7A-6

DESIGN AND EXPERIENCE OF A BACK-TO-BACK HVDC LINK IN WESTERN CANADA
Baker, M.H.; Burgess, R.P.
APSCOM-91. 1991 International Conference on Advances in Power System Control, Operation and Management (Conf. Publ. No.348)
p. 686-93 vol.2. 1991
The 150 MW back-to-back HVDC convertor station at McNeill is the first interconnection between the western and central electrical networks of Canada and allows Alberta Power and SaskPower to trade energy and share the standby capacity of the two networks. At the heart of the convertor station is a new generation of liquid cooled thyristor valves and electronic controls. In addition to the latest convertor technology McNeill also has many design features which represent advances to DC power transmission. These include: thyristors cooled directly by an ethylene/glycol solution which provides frost protection down to -50 degrees C; no DC reactor between the two HVDC valve groups; and stable steady state operation and good post-fault recovery when operating under very weak AC system conditions. The McNeill convertor station has now been in service for 18 months and, of some 60 stations so far commissioned around the world, is the first to demonstrate a capacity for truly unmanned operation. (3 Refs)

[1992] 7A-7

DESIGN AND OPERATION OF A BACK-TO-BACK DC CONVERTER STATION
deLaneuville, H.; Torgerson, D.R.
Transmission and Distribution
vol.44, no.9 p.24-9 Sept. 1992 USA
The 200 MW back-to-back Virginia Smith Converter Station (SCS) at Sidney, NE, allows WAPA (Western Area Power Administration) to provide a 60 Hz asynchronous AC energy interchange between the Eastern and Western US systems. The authors discuss the reasons why the converter station was constructed and then describe the main features and operating principles. The authors describe the thyristor valves, converter transformers, smoothing reactor, and AC harmonic filters.

[1991] 7A-8

DESIGN STUDIES FOR THE S. TOME' BACK-TO-BACK HVDC CONVERTER
Elahi, H.; Rostamkolai, N.; Wegner, C.A.; Eltzmann, M.A.; Garzi, G.; Tietz, P.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 177-182
The Santo Tome' back-to-back converter station is planned as the second HVDC link to asynchronously connect the Argentina (50 Hz) and Brazil (60 Hz) transmission systems. From the date of commissioning to the year 1996, the S. Tome' converter will be connected to the respective AC networks via single AC ties. In 1996, plans call for a second 132 kV line on the Argentina side, thereby interconnecting the two frequency converters. The purpose of this paper is to describe the technical specifications, engineering studies, and final designs for the S. Tome' frequency converter. Specifications called for a number of special control features to ensure a versatile operating strategy. Even with the Argentina system isolated, the back-to-back converter had to be designed to provide power for loads on the 50 Hz network with the aid of a dedicated synchronous condenser. The steady state and dynamic performance of various control functions, and major equipment, were verified through a collective and coordinated set of engineering studies. These studies utilized both time-domain and frequency-domain analytical techniques.

[1993] 7A-9

EASTERN EUROPE CONNECTS TO UCPTE VIA ETZENRICHT LINK
Reischl, A.; Weingarten, U.
Modern Power Systems
Jun 1993 p 31-32
A brief description is given of a recently installed high-voltage DC link between Germany and the Czech Republic. The rated power is 600 MW and a DC voltage of 160 kV. The system tie between Western Europe where voltage and frequency fluctuate within close limits and Eastern Europe where they are subject to considerable fluctuation improves the quality and security of supply. Topics covered include the digital control system and the switchgear.

[1991] 7A-10

FENNO-SKAN. WORLD'S LONGEST SUBMARINE DC CABLE LINKS THE POWER GRIDS OF SWEDEN AND FINLAND
Carlsson, L.
ABB Review (Switzerland)
1991 p 3-12
The Nordic power system is an impressively long network, starting in southern Finland, then going northwards through Finland and into Sweden north of the Gulf of Bothnia. Continuing southwards through the whole length of Sweden, with connections into Norway, it finally terminates on Zeeland in Denmark. By connecting southwestern Finland to east central Sweden, Fenno-Skan reduces the electrical distance between these two areas from 1500 km to 2000 km. Due to the length of cable needed, HVDC transmission was the only viable proposition for this project.

[1993] 7A-11

HIGH AVAILABILITY - DESIGN AIM OF THE DC SHORT CONNECTION ETZENRICHT
Gampenrieder, R.
Elektrizitaetswirtschaft
1 Jun 1993 p 734-737
Redundant units are installed, especially in the areas of thyristor valves, rectifier transformers, smoothing chokes, filter circuits, house service supplies, valve and transformer cooling and in the ventilation plant. Last but not least, with the installation of modern control equipment for control, regulation and protection, consisting of freely programmable redundant systems tolerant of faults, a faultfree control and fault behaviour of the whole plant with high availability is expected. In the area of buildings (valve room, operating building), a space-saving method of construction was observed and the special aspects of fire, lightning and environmental protection were taken into account.

[1993] 7A-12

JOINING THE DC GRID CONNECTION ETZENRICHT-HRADEC TO THE BAVARIAN EXTRA HIGH VOLTAGE (EHV) GRID
Dietel, W.; Quaderer, S; Rieser, R.; Weingaertner, M.
Elektrizitaetswirtschaft
1 Jun 1993 p 718-724
The DC grid connection Etzenricht-Hradec is the link between the Bavarian and the Czech extra high voltage (EHV) grid. It includes the two 380 kV 3 phase AC switching stations and, as an important part, the DC short connection at Etzenricht and a 162 km long 380 3 phase AC line to Hradec. The environment of the link to the Bavarian EHV grid, the infrastructure of the site, the method of construction of the local switching stations and the characteristics of the 380 kV overhead line in the Bavarian section are described.

[1991] 7A-13

MCNEILL HVDC CONVERTOR STATION
Burgess, R.P.; Barker, I.E.
GEC ALSTHOM Technical Review
no.5 p.3-10 April 1991
The 150 MW back-to-back HVDC convertor station at McNeill is the first interconnection between the western and central electrical networks of Canada and allows Alberta Power and SaskPower to trade energy and share the standby capacity of the two networks. At the heart of the convertor station is a new generation of liquid cooled thyristor valves and electronic controls. In addition to the very latest convertor technology McNeill also has many design features which are unique to GEC ALSTHOM. The overall design and performance of the McNeill convertor station represents a significant advance in HVDC technology and underlines GEC ALSTHOM's on-going commitment to the HVDC market. (5 Refs)

[1991] 7A-14

NEW ZEALAND HVDC LINK UPGRADED TO 1240 MW
Gleadow, J.; Paeaejaervi, B.
Modern Power Systems
Sep 1991 p 37, 39, 41, 43, 45
The high voltage direct current link (HVDC) between the South and North Islands of New Zealand is presently being upgraded from 600 MW to 1240 MW. The existing link will be modified to operate in a bipolar 'hybrid' scheme together with a thyristor

convertor. The first stage, addition of a new 700 MW thyristor convertor, is now being commissioned, while the bipolar scheme is planned for completion in August 1992.

[1993] 7A-15

PLANT CONCEPT OF DC SHORT CONNECTION ETZENRICHT
Gampenrieder, R.; Liegl, K.; Weinmann, T.; Schmitt, H.; Weingarten,
Elektrizitaetswirtschaft
1 Jun 1993 p 725-733
The most important design aims regarding high availability of the DC short connection Etzenricht are shown. The aim of the project phase was to adapt component and system reliability to this and to look for solutions for reducing failure times. The steps on the way to this target are shown. The energy availability guaranteed by the manufacturers was decided to be at least 96% for a maximum of 10 forced failures. Naturally, the DC short connection Etzenricht must first pass its reliability test and show its high availability in daily operation. We are optimistic in this respect and will report on the operating behaviour at a later time. (orig.)

[1991] 7A-16

PROGRESS ON THE NEW ZEALAND HVDC UPGRADE
Gleadow, J.C.; O'Brien, M.T.; McElhinney, W.G.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991, pp 138-146
The upgrading of the existing 600MW New Zealand DC transmission link to the 1240 MW 'DC Hybrid Link' is currently one of the largest capital, infrastructure investment projects in New Zealand. The unique approach to contractual arrangements, project management and technical management of the project is outlined as these are all important areas for any organisation contemplating significant investment in technologically complex equipment. During the course of the design, manufacture and testing a number of technical issues have arisen which are of interest, including stability studies, audible noise design, converter transformer design and type testing, valve hall fire protection, creepage distance selection, control system factory acceptance testing, and bushing testing. The progress of the Submarine Cable sub-project is also discussed.

[1992] 7A-17

QUALITY ASSURANCE FOR THE NEW ZEALAND INTER-ISLAND POWER TRANSMISSION PROJECT
Bell, R.E.; Buyers, R.
Quality Forum
vol.18, no.1 p.36-42 March 1992
Trans Power New Zealand Limited is nearing completion of a major engineering project of national importance-upgrading of the high voltage direct current power transmission link between the North and South Islands. A quality assurance plan was developed for the project as part of management strategy to ensure completion on time, within budget and to the specified technical requirements. This paper describes the development of the quality assurance plan and comments on the authors' experience with its implementation. (1 Refs)

[1991] 7A-18

THE FENNO-SKAN HVDC SUBMARINE CABLE TRANSMISSION. SYSTEM AND DESIGN ASPECTS, COMMISSIONING AND INITIAL OPERATING EXPERIENCE
Carlsson, L.; Nyman, A.; Willborg, L.; Hjalmarsson, G.
AC and DC power transmission, IEE Conference Publication Series 5, international conference on AC and DC power transmission
17-20 Sep 1991 p 344-349
In November 1989, a new high voltage direct current (HVDC) link between Finland and Sweden was put into commercial operation. The link, which has a rated capacity of 500 MW, is called Fenno-Skan. It is the longest submarine cable link in the world, and the single cable transmits more power than any other DC cable. This paper presents some of the power system considerations of importance for the link, and describes the d.c. cable and the converter stations. Finally, some aspects of the commissioning of the link and the initial operating experience are treated.

[1991] 7A-REF

THE INTEGRATION OF NEW VALVES AND CONTROLS TO NELSON RIVER HVDC BIPOLE 1
Goodrich, F.G.; Haddock, J.L.; Rowe, B.A.; Thanawala, H.L.; Willis, D.B.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission:
17-20 Sep 1991 p 147-152
For Abstract see entry 1A-015.

[1992] 7A-REF

HARMONIC INTERFERENCE OF HVDC IN TRANSMISSION SYSTEMS
Brauner, G.; Moraw, G.; Welfonder, E.; Lausterer, G.K.; Weber, H.
International IFAC symposium on control of power plants and power systems Munich (Germany)
9-11 Mar 1992 p 299-304
For Abstract see entry 1B-010.

[1991] 7A-REF

SYSTEM PERFORMANCE AND BASIC DESIGN ASPECTS FOR THE ETZENRICHT 600 MW BACK-TO-BACK HVDC CONVERTER STATION
Schmitt, H.; Christl, N.; Gampenrieder, R.; Liegl, K.; Gartmair, H.
AC and DC power transmission IEE Conference Publication Series 5. International conference on AC and DC power transmission
17-20 Sep 1991 p 171-176
For Abstract see entry 1B-022.

[1991] 7A-REF

THE FENNO-SKAN HVDC LINK COMMISSIONING.
Nyman, A.; Jaaskelainen, K.; Vaitomaa, M.; Oy, Imatran Voima; Jansson, B.; Danielsson, K-G.
1991
For Abstract see entry 1D-005.

[1991] 7A-REF

EXPERIENCES ON POWER QUALITY MONITORING RELATED TO HVDC CONNECTIONS
Lahtinen, M.; Kuussaari, M.; Senttula, A.; Koeturius, C.
First international conference on power quality: end-use applications and perspectives
15-18 Oct 1991 EPRI-TR-101260 CONF-911067--
For Abstract see entry 1E-005.

[1993] 7A-REF

+/-450 KV DC UNDERWATER CROSSING OF THE ST. LAWRENCE RIVER OF A 1500 KM OVERHEAD LINE WITH FIVE TERMINALS
Bell, N.; Bui-van, Q.; Couderc, D.; Ludasi, G.; Meyere, P.; Picard, C.
CIGRE Proceedings of the 34th Session
p.21-301/1-11 vol.1 1993 France
For Abstract see entry 4A-001.

[1993] 7A-REF

A 550 MW HVDC SUBMARINE CABLE LINK: ICELAND-UK-CONTINENTAL EUROPE
Guonason, E.; Henje, J.; Shepherd, P.; Valenza, D.
Third International Conference on Power Cables and Accessories 10kV - 500kV (Conf. Publ. No.382)
p.220-4, 1993
For Abstract see entry 4A-002.

[1991] 7A-REF

ACTIVE AND REACTIVE POWER CONTROLS FOR THE GEZHOUBA-SHANGHAI HVDC TRANSMISSION SCHEME
Hammad, A.; Koelsch, H.; Daehler, P.
AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 279-284
For Abstract see entry 5A-005.

[1992] 7A-REF

NEW MAIN CONVERTER STATION FOR OLD IN SACOI HVDC REBUILDING
Garzi, G.
Power Technology International
p.136-9 1992
For Abstract see entry 5H-006.

[1991] 7A-REF

INTERGRATION OF NEW VALVES AND CONTROLS TO NELSON RIVER HVDC BIPOLE 1.
Goodrich, F. G.; Haddock, J. L.; Rowe, B. A.; Thanawala, H. L.; Willis, D. B.
Fifth International Conference on AC and DC Power Transmission
1991 Sep 17-20 IEE Conference Publication n 345. p 147-152, 1991.
For Abstract see entry 1A-011.

7B. LABORATORIES

[1992] 7B-1

EVALUATION OF HVDC CABLES FOR THE ST. LAWRENCE RIVER CROSSING OF HYDRO-QUEBEC'S 500 KV DC LINE. PART 2 CABLE TESTING FACILITY FOR DIELECTRIC AND ACCELERATED AGING
Trinh, N.G.; Couderc, D.; Faucher, P.; Chaaban, M.; Belec, M.; Leduc, J.
IEEE Transactions on Power Delivery
Apr 1992 p 1043-1050
This paper describes the new cable testing facility at IREQ for long-term accelerated aging tests on HV cables. This test facility was required as part of an extensive program to evaluate the high-voltage cables for the river crossing of Hydro-Quebec's new transmission lines rated 800 kV AC and {plus minus}500 kV DC. The first application was for the evaluation of self-contained oil-filled (SCOF) cables for the St. Lawrence river crossing of the {plus minus}500 kV Quebec-New England HVDC power transmission system. The paper also describes the specific dielectric constraints resulting from the insertion of a short length of cable into a long line and, also, the circuits developed for the special tests, which reproduce the specific cable test conditions.

[1991] 7B-2

HIGH POWER HVDC TEST EQUIPMENT FOR POLLUTION TESTING
Trumpy, K.; Brandlin, F.; Freiberg, E.
Seventh International Symposium on High Voltage Engineering
p.115-18 vol. 5 August 26-30, 1991, Dresden Germany. Published by Dresden University
With the increasing importance of HVDC transmission lines, it is necessary to make investigations on the behaviour of polluted insulators under high DC voltage stress. For these pollution tests, special HVDC generators with high output current capacity and low source impedances are needed. In this paper, some aspects of HVDC tests of contaminated insulators are discussed. Special attention is given to the definition of the basic source parameters which are needed for studying the interactions between the test objects and the test sources. In order to analyse the relationship between source and load systematically, the authors propose a simplified simulation model which contains a few elements only. A new powerful HVDC test generator with an output voltage of 1200 kV and a maximum load current of 2 A which recently has been developed and built for the Swedish Transmission Research Institute (STRI) is described in detail.

[1991] 7B-REF

COMBINED VERSATILE HIGH VOLTAGE TEST SYSTEM FOR INSULATION TESTING IN LABORATORY AND ON-SITE
Zhu Xudong; Huang Jing-Ming; Chen Wen-Zhen
Seventh International Symposium on High Voltage Engineering
p.53-6 vol.5. Conference held 26-30 Aug 1991, Dresden Germany. Published by Dresden University
For Abstract see entry 1D-001.

8. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

[1991] 8-1

A UNIFIED POWER FLOW CONTROL CONCEPT FOR FLEXIBLE AC TRANSMISSION SYSTEMS
Gyugyi, L.
AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission
17-20 Sep 1991 p 19-26
Although present static var compensators and other thyristor-controlled equipments developed for power flow control (i.e., series compensators and phase-shifters) can have the necessary speed for real time control, they are rather large, custom designed and fabricated systems of substantial cost, requiring considerable size facility with significant labor installation. For these reasons, it is unlikely that they will be able to provide the long term, volume-production based economic solution for flexible AC transmission systems. It has been long realized that an all solid-state or advanced, static var compensator, which is the true equivalent of an ideal synchronous condenser, is technically feasible and, with the use of gate turn-off (GTO) thyristors, is economically viable. The extension of this approach to controllable series compensation and phase shifting has been recently proposed. This uniform approach of power transmission control promises simplified system design, reduction in equipment size and installation labor, improvements in performance, and significant reduction in capital cost that is fueled by advances in power semiconductor technology. The objective of this paper is to outline the technical and economical factors which characterize the uniform, all solid-state power-flow controller approach for real time controlled, flexible AC transmission systems.

[1992] 8-2

ADVANCED STATIC COMPENSATOR FOR FLEXIBLE AC TRANSMISSION
Galanos, G.D.; Hatziadoniu, C. I.; Cheng X-j.; Maratukulam, D.
IEEE Preprint #92 WM 104-0 PWRS
1992
The paper presents and advanced static compensator capable of operating in all four quadrants of the P-Q plane. This is achieved by combining a GTO-controlled inverter with a battery energy storage system and a GTO-switched damping resistor. Results from simulation studies presented in the paper demonstrate the effectiveness of this compensator in improving the loadability of long transmission lines and in providing damping of interarea oscillations.

[1993] 8-3

AN EVALUATION OF A THYRISTOR CONTROLLED PHASE ANGLE REGULATOR APPLICATION IN THE MINNESOTA POWER TRANSMISSION SYSTEM
Kappenmann, J.G.; Norr, S.R. ; Klein, M.
EPRI-TR-101932
May 1993
In many cases, FACTS (flexible AC transmission system) is a technically and economically viable alternative to improve use and control of existing transmission systems. This study investigates the technical merits of applying a thyristor controlled phase angle regulator (TCPAR) in the Minnesota Power-to-Ontario Hydro 115-kV intertie. The project team first identified options that could provide the necessary control-TCPARs and high-voltage direct current (HVDC). Due to the high cost of the HVDC option, only the FACTS device alternative was considered further. By examining various circuit configurations, the team attempted to identify the least-cost TCPAR hardware option that would meet their needs. A TCPAR hardware conceptual design was completed, and a preliminary economic assessment was performed. Results of the initial investigation and system studies indicate that a single-tank, single-core TCPAR design with a minimum number of thyristors would provide acceptable transient performance at minimum cost. Improvement in system transient response due to TCPAR control would provide an additional 50 MW of transfer capability between Minnesota Power and Ontario Hydro and would increase stability on parallel corridors. As little as [plus minus]10 degrees of rapid phase angle regulation would be required to improve system transient response and transfer capability. Moreover, a delay of up to 800 ms would be allowable in responding to significant disturbances.

[1992] 8-4

APPLICATION OF POWER ELECTRONICS TECHNOLOGIES IN ELECTRIC POWER SYSTEMS

Kobayashi, S.; Irokawa, S.

Toshiba Review (Japan)

1 Jun 1992 p 463-470. In Japanese.

This paper describes power electronics intended of strengthening wider area utility coordination, improving voltage stability, and increasing transmission capacity to cope with increasing power demand. This paper limits its description to power electronics used in such power transforming departments as DC power transmission, static type reactive power compensating device, and flexible AC transmission system (FACTS). A system optimization is important in applying the DC power transmission and the compensating device to power systems. System analyses require inevitably an analog simulator to verify comprehensively actions of converters, in addition to digital programs. The paper also summarizes the future outlook of power electronics. Application may be conceived of the DC power transmission and the compensating device to self - exciting converters, which is expected to result in an emergence of large-capacity converters. The FACTS is a conception advocated in the U.S.A. associated with increased power demand. Practical use of direct light firing thyristors has been realized enabling them to be used in the DC power transmission and the compensating device as power devices. A thyristor valve of 125 kV and 1200 A has been industrialized and applied to the DC power transmission.

[1991] 8-5

CITY VERSUS COUNTRY - A COMPARISON OF TWO TYPES OF STANDARDISED SVC FOR THE NATIONAL GRID IN ENGLAND

Young, D.J.; Horwill, C.; Mukhopadhyay, S.B.; Haddock, J.L.; Gardner, D.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 248-254

The ongoing development of the power system in the U.K. is likely to require the transmission of large amounts of power from the North of England and the Midlands to the South. Under these conditions faults and outages require substantial amount of var compensation to support the system voltage and permit power transfer to continue without overloading circuits or allowing unstable conditions to develop. Some var compensation equipment is already in service on the National Grid, but existing installations are not sufficient to satisfy the developing situation. For example, the National Grid Company (NGC) identified that additional var compensation would be necessary to assist the 400kV system in the South West of England under various system outage and fault conditions. A static var compensator (SVC) was required at the Exeter 400kV substation, having a range of 150Mvar capacitive to 75Mvar inductive. This installation is described in detail in this paper. Subsequently the NGC identified several other substations at which SVCs would be required, including the need for a second SVC at Exeter. NGC also identified that the 265kV system at St. Johns Wood substation in London would require both absorption and generation capability to deal with the different loading conditions in the City of London during the normal 24 hour load cycle. The different conditions and duty cycle for this application required a slightly larger rating of 150/-106Mvar for each of two 275kV SVCs at St. Johns Wood. The paper makes comparisons between the features of these two designs of SVC. (author).

[1991] 8-6

DIGITAL COMPUTER STUDIES AND SOME TEST RESULTS FOR A STATIC VAR COMPENSATOR IN THE UK TRANSMISSION NETWORK

Gardner, D.; Haddock, J.L.; Thanawala, H.L.; Young, D.J.

AC and DC power transmission, IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 319-324

The load and generation growth for the next 10 years in the United Kingdom is, not expected to be uniform over the country. It is believed that the major load will be in the South whilst the majority of the present and future generation capacity will be in the Midlands and North. The increasing remoteness of generation from the load centres results in increased levels of bulk transmission at 400 kV across the country. There is already a load-generation disparity in the South West as well as to the main load region in and around London. Due to increasing environmental and other restraints, the expansion possibilities for the transmission lines are limited and under critical outage conditions the network tends to operate increasingly close to its performance limits at times of peak demand. This can result in increased risk of voltage collapse under some weakened system conditions following loss of certain transmission circuits. Such critical voltage conditions lead to the need for increased reactive power sources near the load areas in the South and South West. The system performance following fault events which cause the transient power angle variations to occur between

machines can be enhanced by the provision of rapidly varying reactive power support immediately after fault clearance. Such dynamic var support, as provided by Static Var Compensators (SVC), improves voltage levels and can be continuously controlled to dampen the machine swings. The installation of static var compensator plant at various strategic locations within the network can provide these features. The purpose of this paper is:- (a) to present and discuss selected digital computer studies for aspects of design of the SVCs; (b) to present and compare some laboratory model and site test results.

[1991] 8-7

FACTS - FLEXIBLE AC TRANSMISSION SYSTEM

Hingorani, N.G.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 1-7

Often, as power transfers grow, the power system becomes increasingly more complex to operate and can become more insecure with large power flows with inadequate control and inability to utilize the full potential of transmission interconnections. With this in mind, the Electric Power Research Institute representing the collaborative R and D arm of the US utilities, has put forward a concept, a vision of the future based on silicon science, called Flexible AC Transmission System (FACTS). While some of the relevant technology i.e., Static VAR Compensation is already in wide use, the FACTS concept has brought to the table a tremendous potential for thyristor based controllers which will surely revolutionize the power system. The technology offers the utilities the ability to: 1. control power flows on their transmission routes; 2. allow secure loading of transmission lines to their full thermal capacity. The central technology of FACTS involves high power electronics, a variety of thyristor devices for application in future years, supported by advances in digital protective relays, digital controls, integrated communications and advanced control centres.

[1991] 8-8

FACTS OPTIONS PERMIT THE UTILIZATION OF THE FULL THERMAL CAPACITY OF AC TRANSMISSION

Ewart, D.N.; Koessler, R.J.; Mountford, J.D.; Maratukulam, D.

AC and DC power transmission (Flexible AC transmission systems.) IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 13-18 (443 p)

Because of a variety of environmental, land-use and regulatory pressures, the growth of electric power transmission facilities in many parts of the world is restricted even though bulk power transfers and access by third parties are on the increase. The result is transmission bottlenecks, non-uniform utilization of facilities and unwanted parallel-path or loop flows. In the United States, EPRI is supporting the development of FACTS (Flexible AC Transmission Systems) technologies, which enable the control of power flow on AC transmission lines and utilize the existing transmission facilities all the way to its thermal limits without degrading reliability. The work horse of the FACTS technologies are thyristors. Sophisticated controls, monitoring devices and computer codes are also important components of FACTS. EPRI is in the third year of a FACTS research, development and demonstration effort. The first project is a benefit analysis of a study system that represents the characteristics of United States systems. The work described here is this benefit analysis which will provide a basis for further development.

[1993] 8-9

IMPROVING STABILITY OF POWER SYSTEM BY FORCED COMMUTATION STATIC VAR COMPENSATOR

Kimura, N.; Funaki, T.; Dahroji; Matsu-ura, K.; Takenaka, K.

Power Electronics in Generation and Transmission , IEE Conference Publication

v 8 n 377 1993 p 1-6

Recent development of high power semiconductor switching devices with turn off ability makes it possible to use voltage source type forced commutation converters for high power reactive compensation in a large power system. We have investigated to improve the stability of an AC transmission system or an ac/dc interconnected system by installing the VSFC-SVC. Computer simulation results indicate that the voltage source type forced commutation static VAR compensator of even small rating can improve the system stability largely.

[1991] 8-10

INCORPORATION OF FACTS INTO TRANSIENTS PROGRAMS FOR SYSTEM SIMULATION

Reeve, J.; Lane-Smith, S.P.; Wikston, J.M.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 379-383

Flexible AC Transmission Systems (FACTS) concepts rely on a rapidly controlled response to system disturbances. Accurate transient models of the device, the power system in the vicinity and FACTS controls become crucial for system studies. In comparison to industrial applications of high power semiconductors, the performance and consequences of FACTS devices often have to be evaluated over an extensive interconnected network. Consequently, system studies must deploy models which extend beyond the immediate confines of the FACTS device. In other words, the requirement for detailed transient modelling has to be reconciled with large systems studies. This paper addresses transient modelling in the context of emerging FACTS applications. It concentrates on the problem of modelling for larger non-linear disturbances rather than linearized small-signal analysis.

[1992] 8-11

NEW POWER TRANSMISSION SYSTEM BY APPLYING POWER ELECTRONICS

Shimada, T.

15 Jan 1992 p 35-42

An introduction is given on a new power transmission system applying power electronics. The new power transmission system, which utilizes the capacity increased power electronics, allows controlling more actively the system power transmission, that is, adjusting and stabilizing the flows and voltages in the power distribution, by using large-power converters and breakers adopting thyristors as their base. The feature of the flexible AC transmission system (FACTS) proposed in the U.S.A. in 1986 is to take in advance the advantage of the DC transmission with the conventional transmission cables kept as they have been by advancing the introduction of the thyristor technologies into the AC transmission system. Based on the proven technologies of direct current linkage and frequency conversion, and the power factor adjusting facilities using semiconductor converters, which have become used widely in the past few years rapidly, there is a strong tendency to use the new power transmission system applied with the power electronics.

[1991] 8-12

OPTIMIZATION OF THE THYRISTOR VALVES DESIGN FOR TCR STATIC VAR COMPENSATORS

Freire, A.R.F.; Soares, G.A.; Lima, A.G.G.; Afonso, J.L.

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 261-265

Static Var Compensators (SVCs) are being used more and more in power systems. Therefore there is a strong desire to reduce their costs. From the manufacturer's point of view, these systems should be purchased as optimized turnkey projects. On the other hand, the utilities claim that optimized turnkey projects lead to non standard systems, which increase their spare parts and maintenance costs, and that the total cost might be smaller if they buy the SVC piece by piece. In the light of these problems, we have developed a digital program to optimize the design of thyristor valves for Thyristor Controlled Reactors (TCR) with Fixed Capacitor Banks. This program will be used in the future as a subroutine of a complete SVC optimization program. It can give the relative costs of different design alternatives. The design of thyristors valves rests on the choice of the thyristor, the design of the snubber circuit, the design of the refrigeration system and choice of the overvoltage and overcurrent protections. For a specific power system and design criteria there are many possible designs with different costs. Therefore, it is important to have a tool capable of indicating the best one. As an example of the application of the program, this work presents the results of the optimization of a TCR of 5 MVAR capacitive and 15 MVAR inductive to be connected on the 13.8 kV tertiary of a 30 MVAR existent transformer. This example was used to verify the influence of different design criteria on the cost of the SVC and the results will be used by the Brazilian utilities in determining future specifications. (author).

[1991] 8-13

POWER SYSTEM STUDIES AND MODELLING FOR THE KAYENTA 230 KV SUBSTATION ADVANCED SERIES COMPENSATION

Christl, N.; Hedin, R.; Johnson, R.; Krause, P.; Montoya, A.)

AC and DC power transmission IEE Conference Publication Series 5. international conference on AC and DC power transmission

17-20 Sep 1991 p 33-37

The Western Area Power Administration (WAPA) requires additional power low capability between Shiprock substation in New Mexico and Glen Canyon

Power Plant in Arizona. There is strong transmission into both locations, but only a single, 320 kilometer, 153 ohm, 230-kV transmission line between them. To increase power flow capability, it was decided to series compensate the transmission line by 72% at the existing Kayenta Substation. The compensation will consist of two 55 ohm segments. Siemens, in association with Nokia, proposed to install the main capacitor segments but to divide the east 55 ohm bank into a 40 ohm section and an innovative Flexible AC Transmission Device (FACTS) consisting of a Thyristor Controlled Reactor (TCR) in parallel with 15 ohm capacitor section. The FACTS device is known as an Advanced Series Compensator (ASC). The purpose of the ASC installation is to provide research information for both WAPA and Siemens/Nokia as well as to provide continuously variable control of the transmission line's compensation. In addition to the benefit of an adjustable impedance, the thyristor controlled reactor can provide high-speed protection of the 15 ohm capacitor section. This paper presents a discussion of the theoretical aspects of the ASC as well as AC modelling considerations.

[1992] 8-14

STABILITY IMPROVEMENT OF ELECTRIC POWER SYSTEM BY HVDC OR SVC
Hayashi, T.
Transactions of the Institute of Electrical Engineers of Japan, Part B
1992 vol.112-B, no.1 p.6-9 In Japanese
The thyristor converter was developed, verified and applied to HVDC completed in Hokkaido. EPRI (US) has proposed 'flexible AC transmission system (FACTS)' as the advanced tool for reliability improvement for the US power systems. This system aims to stabilize power systems by using a thyristor for controlling current in the power devices such as the phase-shifting transformer, circuit-breaker, breaking resistor, lightning arrester and series capacitor. It is necessary to improve the system control functions and at the same time, improve power transmission capacity by using technology for system stabilization in order to cope with increasing transportation cost and difficulties in obtaining the site.

[1993] 8-REF

DYNAMIC BEHAVIOR OF FORCED COMMUTATION STATIC VAR COMPENSATOR APPLIED FOR REACTIVE POWER COMPENSATION OF HVDC CONVERTER
Kimura, N.; Funaki, T.; Li, A.; Matsu-ura, K.
Conference Record of the Power Conversion Conference - Yokohama
19-21 April 1993
For Abstract see entry 1E-001.

[1991] 8-REF

DIGITAL SIMULATION OF FLEXIBLE TOPOLOGY POWER ELECTRONIC APPARATUS IN POWER SYSTEMS
Maguire, T.L.; Gole A.M.
IEEE Preprint # 91 SM 414-3 PWRD
1991
For Abstract see entry 6A-005.

[1993] 8-REF

EXTENDED TRANSIENT-MIDTERM STABILITY PROGRAM: VERSION 3.0
Kundur, P.; Rogers, G.J.; Wong, D.Y.; Yan, A.
EPRI-TR-102004-Vol.1
Apr 1993
For Abstract see entry 6B-013.

[1992] 8-REF

APPLICATION OF HIGH POWER ELECTRONICS IN ELECTRICAL POWER TRANSMISSION SYSTEMS
Ekstrom, Å. R. Inst. of Technol., Stockholm, Sweden
Power Semiconductor Devices and Circuits
1992. p.351-76 Plenum Press, New York, NY, USA
For Abstract see entry 1A-001.

9. MAJOR PUBLICATIONS AND BIBLIOGRAPHIES

[1992] 9-1

17TH PICA CONFERENCE. 1991 MAY 7-10
IEEE Transactions on Power Delivery
v 7 n 2 Apr 1992. . p 546-1049
Proceedings incorporates 69 papers. Topics considered include: HVDC cables, hydroelectric power plants, cable cleaning solvents, circuit breakers, capacitor banks, HVDC converters, XLPE cables, expert systems, automated fault location, communication cables, distribution networks, reactive power control, accelerated life testing, electric power transmission and distribution, connectors, electric grounding, transformer windings, compensators, EM interference, submarine power cables, gas-insulated transformers, large drives, switched capacitors, fiber optic current sensors, insulated distribution cables, gas-inculated switchgear, GTO inverters, distribution transformers, computer algorithms, silicone rubber coatings, large power transformers, friction measurement, HV conductors, shunt capacitors, lumped parameter models, lightning protection, MV power systems, electric lines, electric corona, and various insulating materials.

[1991] 9-2

MODERN POWER STATION PRACTICE INCORPORATING MODERN POWER SYSTEM PRACTICE. U.K.
Pergamon Press Edition: 3. ed.
1991 (586 p). Published in 12 volume set.
The idea of producing a free-standing comprehensive volume on modern CEGB transmission design practice stemmed from a review of earlier coverage of this topic in the previous edition of Modern Power Station Practice. One of the aims of this volume is to provide a comprehensive review of modern CEGB design practice for both transmission systems and plant for use by young engineers entering the transmission design function or by more experienced engineers wishing to update themselves with recent developments. The content of this volume has been structured to meet this main objective. We have not attempted to duplicate material readily found in standard electrical engineering textbooks but instead have tried to provide a practical guide based on best CEGB practices. The book contains a distillation of many years of experience and it is hoped will be a useful reference book for all practising engineers.

[1993] 9-3

PROCEEDINGS OF THE 28TH ANNUAL MEETING OF THE IEEE
IEEE Industry Applications Society n 93CH3366-2.
p 1799-1804 1993
This paper describes a new iterative method for the analysis of the bipolar ionized field in HVDC transmission lines without resort to Deutsch's assumption. The finite-element technique (FET) is used to solve Poisson's equation where the constancy of the conductors' surface field at the corona inception value is directly implemented in the finite-element formulation. The proposed method has been tested on laboratory and full-scale models. The calculated V-I characteristics agreed well with those calculated and measured before. The dependency of the corona current as well as its monopolar and bipolar components on the conductors' height is discussed. The simplicity in computer programming in addition to the low number of iterations required to achieve convergence characterize the proposed method of analysis.

10. AUTHOR INDEX

Section II

HVDC Projects Listing

JANUARY 1992

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Los Angeles, CA 90051

	HVDC SUPPLIER	YEAR COMMIS-SIONED	POWER RATING (MW)	DC VOLTAGE (KV)	LINE &/OR CABLE (KM)	LOCATION
GOTLAND I#	A	1954	20	± 100	96	Sweden
ENGLISH CHANNEL#	A	1961	160	± 100	64	England-France
VOLGOGRAD-DONBASS*		1965	720	± 400	470	Russia
INTER-ISLAND	A	1965	600	± 250	609	New Zealand
KONTI-SKAN I	A	1965	250	250	180	Denmark-Sweden
SAKUMA	A	1965	300	2x125	B-B***	Japan
SARDINIA	I	1967	200	200	413	Italy
VANCOUVER I	A	1968	312	260	69	Canada
PACIFIC INTERTIE §§	JV	1970	1440	± 400	1362	U.S.A.
		1982	1600			
NELSON RIVER I**	I	1972	1620	± 450	892	Canada
KINGSNORTH#	I	1975	640	± 266	82	England
GOTLAND EXTENSION#	A	1970	30	± 150	96	Sweden
EEL RIVER	C	1972	320	2x80	B-B	Canada
SKAGERRAK I	A	1976	250	250	240	Norway-Denmark
SKAGERRAK II	A	1977	500	± 250		Denmark
SKAGERRAK III	A	1993	440	350	240	Norway-Denmark
VANCOUVER II	C	1977	370	-280	77	Canada
SHIN-SHINANO	D	1977	300	2x125	B-B	Japan
		1993	600	3x125		
SQUARE BUTTE	C	1977	500	±250	749	U.S.A.
DAVID A. HAMIL	C	1977	100	50	B-B	U.S.A.
CAHORA BASSA	J	1978	1920	± 533	1414	Mozambique-So.Africa§§§
NELSON RIVER II	J	1978	900	±250	930	Canada
		1985	1800§	±500		
CU	A	1979	1000	±400	710	U.S.A.
HOKKAIDO-HONSHU	E	1979	150	125	168	Japan
	E	1980	300	250		
		1993 est	600	±250		
ACARAY	G	1981	55	25.6	B-B	Paraguay
VYBORG	F	1981	355	1x170(±85)	B-B	Russia (tie w/Finland)
	F	1982	710	2x170		
	F	1984	1065	3x170		
ZHOU SHAN PROJECT		1982	50	100	42	China
DUERNROHR	J	1983	550	145	B-B	Austria
GOTLAND II	A	1983	130	150	100	Sweden
GOTLAND III	A	1987	260	±150	103	Sweden
EDDY COUNTY	C	1983	200	82	B-B	U.S.A.
CHATEAUGUAY	J	1984	1000	2x140	B-B	Canada
OKLAUNION	C	1984	200	82	B-B	U.S.A.
ITAIPU I	A	1984	1575	±300	785	Brazil
	A	1985	2383			
	A	1986	3150	±600		
INGA-SHABA	A	1982	560	±500	1700	Zaire
PAC INTERTIE UPGRADE	A	1984	2000	±500	1362	U.S.A.
BLACKWATER	B	1985	200	57	B-B	U.S.A.
HIGHGATE	A	1985	200	±56	B-B	U.S.A.
MADAWASKA	C	1985	350	140	B-B	Canada
MILES CITY	C	1985	200	±82	B-B	U.S.A.
BROKEN HILL	A	1986	40	2x17(±8.33)	B-B	Australia
INTERMOUNTAIN	A	1986	1920	±500	784	U.S.A.

	HVDC SUPPLIER	YEAR COMMIS-SIONED	POWER RATING (MW)	DC VOLTAGE (KV)	LINE §/OR CABLE (KM)	LOCATION
CROSS-CHANNEL		1986	2000	2x±270	72	
(Les Mandarins)	H					France-
(Sellindge)	I					England
DES CANTONS-COMERFORD	C	1986	690	±450	172	Canada-U.S.A.
SACOI##	H	1986	200	200	415	Corsica Island
###		1992	300			Italy
ITAIPU II	A	1987	3150	±600	805	Brazil
SIDNEY(VIRGINIA SMITH)	G	1988	200	55.5	B-B	U.S.A.
GEZHOUBA-SHANGHAI	B+G	1989	600	500	1000	China
		1990	1200	±500		
KONTI-SKAN II	A	1988	300	285	150	Sweden-Denmark
VINDHYACHAL	A	1989	500	2x69.7	B-B	India
PAC INTERTIE EXPANSION	B	1989	1100	±500	1362	U.S.A.§§§§
McNEILL	I	1989	150	42	B-B	Canada
FENNO-SKAN	A	1989	500	400	200	Finland-Sweden
SILERU-BARSOOR	K	1989	400	±200	196	India
RIHAND-DELHI	AB	1991	750	±500	910	India
		1991	1500	±500		
HYDRO QUEBEC-NEW ENG.	A	1990	2000****	±450	1500	Canada-U.S.A.
NICOLET TAP	A	1992	2000			Canada
WELCH-MONTICELLO	G	1995 est	600	160	B-B	U.S.A
EZENRICHT	G	1993	600	160	B-B	Germany (tie w/Czech)
VIENNA SOUTH-EAST	G	1993	600	160	B-B	Austria (tie w/Hungary)
DC HYBRID LINK	AB	1993	992	+270/-350	617	New Zealand
CHANDRAPUR-PADGHE	AB	1997 est	1500	±500	900	India
CHANDRAPUR-RAMAGUNDUM	I	1996 est	1000	2x	B-B	India
GAZUWAKA-JEYPORE		1997 est	500		B-B	India
LEYTE-LUZON		1997 est	1600	400	440	Philippines
HAENAM-CHEJU	I	1994 est	300	±180	100	South Korea
BALTIC CABLE PROJECT	AB	1994 est	600	450	250	Sweden-Germany
VICTORIA-TASMANIA			300	300		Australia
KONTEK HVDC INTERCON.	AB	1995 est	600	400	170	Denmark-Germany
SCOTLAND-N. IRELAND		1996 est	250	250		United Kingdom
GREECE-ITALY		1997 est	500			Italy
TSQ-GUANGDONG		1997 est	1800	500	903	China
ICELAND-SCOTLAND LINK		2000 est	500	400	950	
			2000	±400		
SARAWAK-MALAYSIA			1600		620	

NOTES

A - ASEA
B - Brown Boveri
C - General Electric
D - Toshiba
E - Hitachi
F - Russian
G - Siemens
H - CGEE Alstrom
I - GEC Alstrom (Formerly Eng.Elec.)
J - HVDC W.G. (AEG, BBC, Siemens)
K - (Independent)
AB - ABB Brown Boveri
JV - Joint Venture (GE and ASEA)

* 2 V.G.'s replaced with thyristors in 1977.
** 3 V.G.'s in Pole 1 replaced with thyristors by GEC Alsthom in 1991-93.
*** Back-to-back HVDC system.
**** Multi-terminal system. Largest terminal is rated 2250 MW @ 500 kV.
# Retired from service.
50 MW thyristor tap.
Uprate w/thyristor valves.
§ 2000 MW in Winter.
§§ Out of service since Jan.1994.
§§§ Out of service since 1985.
§§§§ Out of service since Oct. 1993.

Section III

Supplement to a Bibliography for Static Var Compensators (SVC) and Related Flexible AC Transmission System (FACTS) Devices

1988 - 1994

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SUPPLEMENT TO A BIBLIOGRAPHY FOR STATIC VAR COMPENSATORS (SVC) AND RELATED FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) DEVICES [1988-1994]

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***Abstract*-This paper presents a comprehensive bibliography of static var compensators (SVC) for the period 1988-1994 which has not been incorporated in any previously published bibliography. As SVC has been identified as one of the elements of Flexible AC Transmission System (FACTS), this bibliography also includes an elaborate listing of papers on related Flexible AC Transmission System devices which are also appearing for the first time in any bibliography.**

***Keywords*- Static Var Compensators, Thyristor Controlled Series Capacitors, Static Phase Shifters, Flexible AC Transmission Systems, Bibliography.**

1. INTRODUCTION

Static var compensator (SVC) is a mature technology today which is finding widespread application in power systems over the world. Recent development and installations of Gate Turn-Off (GTO) thyristor based static reactive power compensators have led to much more efficient compensation schemes. The identification of SVC as an integral component of Flexible AC Transmission Systems (FACTS) and the possibilities of its coordination with other FACTS devices such as thyristor controlled series compensators, thyristor controlled phase shifters etc., has further opened up new horizons in power system control and operation. A significant amount of research initiative has been undertaken in the areas of SVC and FACTS in the past five years and a volume of literature has been generated.

This paper aims at presenting a comprehensive bibliography on SVC and related FACTS devices which is expected to serve as a useful reference guide both for researchers and practising engineers.

The following bibliographies on SVCs have so far been published.

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The bibliography presented in this paper is essentially a supplement to [C] and includes a total of 235 papers. The papers listed in this bibliography have not been included in any of the above-mentioned bibliographies with the exception of a few. These papers are those which have been listed in [C] as papers presented at IEEE/PES Meetings but have been reincluded in this bibliography with the details of their publication in appropriate IEEE Transactions. The papers are arranged in a chronological order for the period 1988-1994. This bibliography includes papers published in the following journals - IEEE Transactions on Power Systems (PWRS), Power Delivery (PWRD), Energy Conversion (EC), and IEE Proceedings, Part. C., CIGRE, Electric Machines and Power Systems, International Journal of Electrical Power and Energy Systems, Electric Power Systems Research, and Canadian Electrical Association (CEA) Transactions of Engineering and Operating Division. Relevant papers from major Conferences are also included.

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II. ACKNOWLEDGMENT

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