COO-5014-3

AN ASSESSMENT OF RESEARCH DIRECTIONS FOR HIGH VOLTAGE DIRECT CURRENT POWER SYSTEMS

Quarterly Technical Progress Report
October 1, 1978 through December 31, 1978

Willis F. Long
University of Wisconsin-Madison
Madison, Wisconsin 53706

January, 1979

Prepared for

The U.S. Department of Energy
under Contract No. ET-78-S-02-5014.A000

DISCLAIMER

ABSTRACT

Two Priority One activities have received major attention during this reporting period. "Application credits" for HVDC systems imbedded in ac links are expected to evolve out of a system study wherein dc is introduced into a system where the breakeven criterion is not satisfied. Alternative benefits of the dc link will be quantified in an attempt to develop an expanded economic basis for HVDC systems.

HVDC circuit breaker development is being examined, as there appears to be a relationship between the acceptance of multiterminal dc systems and the availability of a dc breaker. At the present time there is a large technical gap between laboratory status and field availability. Further investigation of dc interruption techniques is recommended, together with the establishment of operating criteria and design specifications.

A variety of other HVDC activities was undertaken, including proposal review, contract progress report assessment, inverter commutation with series capacitor assistance, and conference planning.

QUARTERLY REPORT

This is the first quarterly report under Contract No. ET-78-S-02-5014.A000, "An Assessment of Research Directions for High Voltage Direct Current Power Systems." The items reported herein are listed chronologically to evidence the evolutionary nature of this investigation. This is appropriate in view of the objective of the study, as quoted from the statement of work in the original proposal:

"The objective is to identify hardware developments and, where appropriate, system applications which can exemplify cost and operational advantages of integrated ac/dc power systems."

Initial discussions were held at the DOE Electric Energy Systems Division offices in Washington regarding directions to be pursued in this study. Reference is made to the final report for Contract ET-78-X-01-2836, "HVDC Power Transmission Technology Assessment Study." A number of research directions were listed by priority in that report, and discussion centered around ways to initiate activity on the two Priority One items. Immediate attention is to be given these items as follows:

1. An investigation of "application credits" obtainable from an interconnected ac-dc system. GEC Switchgear through Alex Gavrilovic has expressed interest in a study of inverter infeeds into a weak ac system (low short circuit ratio). It appears that a study involving an actual ac system having repeated operating difficulties could provide the basis for defining these application credits.

Talks with several utilities are to be scheduled. Florida Power and Light Company is reported to be investigating an underground line through swamplands; overhead transmission is difficult because of tower footing problems. HVDC might have an application here, perhaps in coordination with the ac ties along the east coast that are vulnerable to disturbances

because of geography. Another candidate for HVDC is Utah Power and Light because of the inadvertent flows on the "western donut". These and other system applications for HVDC will be explored to see if "application credits" can be quantified.

2. HVDC circuit breaker development. This investigator participated in a quarterly review meeting of the General Electric Company's dc breaker project. A number of questions were raised about the efficiency of the techniques, especially as relating to the size of the capacitor bank. Another area of uncertainty is the simultaneous interruption of a string of eight vacuum interrupters--can the recovery voltage be made to share equally among the interrupters?

The draft final report on this circuit breaker project was reviewed in depth. A number of items (26 in all) in the report merited specific comment; this information was transmitted to DOE. Among the more important items were simulation study results relating to energy absorption and overvoltage, two critical design parameters for any dc circuit breaker. Interim reports from the EPRI DC Circuit Breaker Specification Studies at IREQ are being reviewed by the investigator. It is hoped that when the final report is available, some quantification of design parameters can be achieved.

At the present time there is a large technical gap between laboratory status and field availability of all dc circuit breaker concepts. Further exploration of all dc interruption techniques will be recommended, together with the establishment of operating criteria and design specifications.

This investigator attended the Transmission Static VAR Systems Seminar jointly sponsored by EPRI and Minnesota Power and Light Company October 24-25, 1978. This seminar was enlightening, in that Static Var Controllers can perform many of the system dynamic stabilizing feats that HVDC systems

can. Cost estimates indicate that Static Var Systems can be installed for $30/kVAR, which is below the cost of dc terminal equipment. Capacitor banks, however, can be installed for about $6/kVAR, so a substantial cost differential exists.

A preliminary interim report from Commonwealth Associates on Assessment of Power Delivery Alternatives was reviewed. Issue was taken with the cost figures for HVDC terminal equipment, as the historical trend for this equipment appears to be contradicted. No verification of these data appears in the interim report.

Two unsolicited proposals were reviewed; recommendations were made that neither be pursued at this time.

A graduate student has begun modeling studies on an inverter feeding an ac system through series capacitors. It is well known that system disturbances cause commutation problems when an inverter feeds an ac system with a low short circuit ratio (e.g., weak system or high system impedance). Additionally, instability in the inverter firing control loop can occur. It has been previously proposed that the addition of series capacitors on the ac side of the inverter can improve commutation by developing a counter voltage. Steady state operation presents no difficulty other than concern for the magnitude of the capacitor voltages. Transient conditions, specifically changing currents, are a different situation. Unbalanced voltages are inherent in start-up, and firing procedures need to be developed with care. It is anticipated that an operational model will be functioning within the next quarter.

A presentation on DOE Research Plans in HVDC was made to a visiting delegation from the USSR Ministry of Power and Electrotechnology. Background was provided regarding DOE's interest in HVDC, especially relating to its inherent controllability features. If some form of national grid

were to be implemented it is clear that HVDC would play a key role in regional interconnections. As there is little dollar volume in HVDC business at the moment, manufacturers are not able to pursue research activities with sufficient vigor.

Specific reference was made to the final report for Contract ET-78-X-01-2836, "HVDC Power Transmission Technology Assessment Study," prepared by this investigator in October, 1978. Copies of this report were provided to the delegation. Ongoing activities were identified:

1. Continue to talk with key persons/organizations regarding research directions in HVDC; e.g., John Bowles at IREQ on dc circuit breaker specifications.

2. Implement an integrated ac/dc system study to identify "application credits."

3. Organize a conference meeting the needs of system planners to understand HVDC applications.

4. Continue to provide assistance to DOE in monitoring ongoing contracts involving HVDC power transmission.

A question was raised by the visiting delegation regarding the status of the national grid study, and whether technical aspects of a national grid would prove to be difficult to solve. The opinion was expressed that technical problems were not likely to be troublesome.

A technical review was made of four proposals submitted under RFP ET-78-R-01-3108, "Technical and Economical Feasibility Study on an HVDC Compressed Gas Insulated Transmission Line." This study is directed towards a total assessment of the technical and economic feasibility of utilizing a CGIT line for an underground HVDC power delivery system.

Specific comments were made relating to the following areas:

1. Proposers' apparent knowledge of the structure and operation of HVDC systems.

2. Proposers' understanding of simulation techniques appropriate to HVDC systems.

3. Proposers' ability to combine 1 and 2 in order to ascertain test parameters suitable for CGIT systems for HVDC.

4. Proposers' apparent ability to extend their present knowledge of ac CGIT cable systems into dc.

5. Capabilities of subcontractors included in the proposal, if any.

The four proposals were ranked according to apparent technical competence; this information was transmitted by letter to Tom Garrity of DOE.

A visit was made to Virginia Polytechnic University to discuss HVDC applications in the American Electric Power Service Corporation System with Dr. Arun G. Phadke. He is Staff Consulting Engineer with AEP, currently on leave as Visiting Professor at VPI.

Increasing short-circuit duties in the AEP system appear to be severe enough that means to limit these fault currents require investigation. AEP has had an ongoing research activity with Hughes Research Laboratories developing and testing a current limiting device (CLD). In a recently completed staged fault test, a prospective 3600 A fault was limited to 1056 A on a 138 kV transmission line. Impedance insertion occurred in about 2 ms. It is not known at this time if the current interrupting capability of this CLD is sufficient for it to be utilized at higher current levels.

If a study were to be proposed to AEP, it should comprise the following:

1. Examine the utilization of dc links as an alternative to CLD's in limiting fault currents.

2. Examine stability enhancement via the dynamic control capabilities

of dc links.

3. Examine other benefits of utilizing dc links in the AEP system (application credits).

Dr. Phadke will pursue this with appropriate persons at AEP.

Planning was initiated for a conference, scheduled for spring, 1980, that would bring utility system planners together with utility "users", equipment suppliers, and other persons knowledgeable about HVDC power systems. Six topics would be explored:

1. What constitutes an HVDC system
2. Present-day operating experience
3. Ongoing research activities
4. Environmental and electrical field effects
5. System studies
6. Future directions and applications.

The purpose of this conference is to facilitate an understanding of the present and future capabilities and economics of HVDC power transmission by system planners and other interested persons. A request for papers will be issued within the next several months.

All requirements of this contract have been complied with to date. Dr. Long has been devoting 40% of his time to this contract, and has engaged the services of a graduate student as well. Travel expenditures are in line with projections in the contract, excepting that more trips were made to Washington to visit DOE than were initially envisioned.