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Transient-Stability Margin as a Tool for Dynamic Security Assessment

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ABSTRACT

This EPRI-sponsored research project deals with the use of the transient stability margin concept as a tool for dynamic security assessment. In this concept, a direct method, namely the energy function method, is used to determine the transient stability of a multimachine power system. The work focused on two major approaches:

- The first was to develop a normalized transient energy margin profile of a power system operating at a given condition. This permitted the ranking of possible contingent disturbances according to their severity.
- The second was to predict, for a given operating condition and an initial disturbance, the additional disturbances that the power system could withstand before instability occurs.

The work dealt with some basic questions about the transient behavior of a multimachine power system. Among them are several issues that are related to the region of stability, the modes of instability of the system (for a particular disturbance), and the components of the transient energy directly responsible for instability. A better understanding of the transient behavior of a multimachine power system has resulted from this work.

The transient energy margin concept was then successfully applied to a 17-generator power network representing a reduced version of the network of the state of Iowa.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

This final report is one of a series of four under RP1355. This portion of the project, RP1355-3, describes the development of a method of recognizing and predicting when a power system is in danger of widespread service interruption due to system instability. Power system engineers have long sought a practical, economical method of foreseeing and preventing transient stability problems. Such a capability would be a major aid in planning and operating bulk power systems.

The results published herein are not intended to be immediately applicable by themselves. Rather they complement other EPRI research and form a basis for further development.

PROJECT OBJECTIVE

The purpose of this project was to develop a new advanced method of quickly, accurately, and inexpensively ascertaining when a power system is in danger of becoming unstable. A moderate-size test system was used to test the practicality and trueness of the method developed.

PROJECT RESULTS

A technique for directly calculating first-swing stability of large power systems without a step-by-step solution was developed. The high speed and low cost of this technique allow the analyst to study a large number of situations quickly and inexpensively. Furthermore, the technique computes how close to instability the system is for a given situation. Thus, an indication of the margin of safety (or insecurity) is provided, and the system planner or operator can be alerted if potentially unstable situations exist.

Although more development and testing of this direct stability analysis method are required, the results of this research are very promising and important. Further development of this method can provide a means to assess power system vulnerability and to complement and enhance traditional stability studies.

James V. Mitsche, Project Manager
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SUMMARY

INTRODUCTION

This final report deals with the work done at Iowa State University from about October 1, 1979 to late July 1980 on the concept of the transient stability margin. This concept is to be used as a tool for predicting the "margin of safety" for the rotor trajectories of the generators following a given disturbance.

The work focused on two major approaches:

1. The first was to develop a normalized transient energy margin profile of a power system at a given operating condition. This permitted the ranking of possible contingent disturbances according to their severity.

2. The second was to predict, for a given operating condition and an initial disturbance, the additional disturbances that the power system could withstand before instablity would occur.

Development of these approaches required us to answer some basic questions about the transient behavior of a multimachine power system. Among them were several issues related to the region of stability, the modes of instability of the system (for a particular disturbance), and the components of the transient energy directly responsible for instability. Considerable progress has been achieved in this area, and we feel a potentially valuable tool for dynamic security assessment has emerged from this research.

This report discusses the technical issues dealt with in the last two years and the progress made on them, and outlines the extensive series of computer simulation studies supporting this work.

The work, which was funded initially by the Electric Power Research Institute (Project RP 1355-3, Dynamic Security Assessment--The Alert State), has been expanded with additional support from the Engineering Research Institute of Iowa State University. The original team of investigators, Dr. A. A. Fouad (principal investigator), Dr. K. C. Kruempel, and Mr. S. E. Stanton, was expanded to include Dr. M. A. Pai (as consultant), Dr. K. R. C. Mamandur, and Mr. Vijay Vittal (graduate assistant). The computer programs incorporated into this project were

provided by Systems Control Incorporated (SCI). Development of those programs was funded by the Department of Energy.

THE TRANSIENT STABILITY MARGIN CONCEPT

The concept is based on using direct methods to determine the transient stability of a multimachine power system subjected to a large disturbance. The direct method used is the so-called energy function method. In this method there is a critical energy associated with the initial disturbed system trajectory and the post disturbance system configuration that determines the transient stability of the system. Transient stability (or instability) is predicted by comparing the value of the system energy function V at the instant the disturbance is terminated (e.g., $V_{clearing}$ at the instant the fault is cleared) with the value of the critical energy $V_{critical}$. If, for example, $V_{clearing} < V_{critical}$, then the system is stable.

The transient stability margin, when stability is predicted, is derived from the value of

$$\Delta V = V_{critical} - V_{clearing}$$

This is perceived to be an energy margin that is indicative of the robustness of the power system at the end of the initial disturbance. This energy margin may in itself be used for comparative assessment of the various disturbances on the sytem, or it may be used to derive other tools for making such an assessment. In the former, the energy margin is normalized by relating it to the transient kinetic energy at the end of the disturbance (e.g., at fault clearing). In the latter, it is translated into additional probable disturbances that the system could withstand.

The investigators believe that the energy margin concept is a versatile indicator of the robustness of the power system for the following reasons:

- It permits the investigation of various types of single disturbances for a given system operating condition. Thus, the energy margin is just as meaningful whether the disturbance is caused by a fault, loss of load, or loss of line, etc.
- It permits the investigation of multiple disturbances. For example, if after the first disturbance an energy margin ΔV exists, a second disturbance (such as tripping a line or losing a load) would be tolerated if that energy margin is not "used up."

- It lends itself to normalized expressions for security assessment purposes. Therefore, it is possible to derive dynamic security indices at a given system operating state.
- It allows, for a given operating condition, the ranking of contingent disturbances for both relative robustness and stability.

The work performed to date has improved our understanding of a wide variety of issues associated with the use of direct methods for predicting the transient behavior of multimachine power systems under the influence of large disturbances.

THE ENERGY FUNCTION METHOD OF TRANSIENT STABILITY ANALYSIS

Since the transient stability margin concept relies upon the successful use of the energy function method of transient stability analysis, an extensive investigation of the method was conducted to ascertain its validity and its limitations, if any. The investigation focused on the following areas:

- The validity of the concept of a controlling unstable equilibrium point (u.e.p.) for the faulted trajectory.
- The meaning of the components of the system energy at clearing and the energy at the u.e.p.
- The system trajectory and how it is affected by the u.e.p. and the principal energy boundary surface (PEBS).
- The system trajectories for simple mode of instability (i.e., for one machine separating from the rest) and for more complicated situations.
- The effect of injecting additional energy into the system during the transient.
- Identification of the components of the transient energy directly responsible for instability.

The method was applied to two networks: a 4-generator, 11-bus network and a 17-generator, 163-bus network.

This investigation has resulted in a much better understanding of the dynamic behavior of a multimachine power system under the influence of large disturbances. This understanding will be helpful not only in developing a tool for security assessment, but will be significant also for other areas of research in power system dynamics.

POWER NETWORKS USED FOR SIMULATION STUDIES

Modified WSCC System

This system is a modified version of the well-known WSCC equivalent. It comprises four generators, eleven buses, and three loads (see Section 2 for description). We have a considerable amount of data on this system. This network is investigated for faults near the remote machine (Generator No. 4); the mode of instability is a simple one where only one machine tends to separate from the rest.

Modified Iowa System

This system is extracted from a much larger power network used by MARCA for generator planning studies (used with permission). The resulting equivalent, which was tested against the original system, comprises 17 generators, including 6 large equivalents, and 163 buses. The system is also described in Section 2.

This network was investigated for faults near the concentrated generation in the Missouri River area. The mode of instability is such that more than one machine usually tends to separate from the rest of the system.

COMPUTATIONAL EFFORT

To support this research project, several simulation and validation studies were run on the networks described above. The computer programs used for these studies included standard programs for stability analysis, special packages developed elsewhere, and specialized programs developed in this project. They were:

- The Philadelphia Electric Company transient stability computer program.
- The SCI package of computer programs on the energy function method. This package was analyzed and put in working order in the summer of 1979 (minor changes were made when needed). Recently, some parts of that package were adapted for use on small interactive computer facilities.
- Special programs to compute u.e.p.'s and their energies and the transient stability margin, correcting for energies not contributing to system separation.
- A special program to simulate network disturbances, e.g., line openings during the transient.

MARGIN CALCULATIONS

As pointed out earlier, our work on the transient stability margin focused on translating the energy margin between the critical energy at the u.e.p. and the system energy at the instant of clearing into: a) a normalized transient energy margin profile, and b) additional disturbances that would "use up" that margin.

- In (a), by relating the transient energy margin to the transient kinetic energy, a relative ranking of contingent disturbances was developed according to severity. So far, this ranking has been confirmed by simulation studies. This technique is particularly suited for dynamic security assessment.
- In (b), much of the work involved determining the additional power perturbations that the system could withstand following the removal of the fault (or the initial disturbance).

To sharpen our margin prediction, for either of the above approaches, certain fundamental issues concerning the dynamic behavior of a multimachine power system had to be addressed. This investigation yielded significant results, the implications of which go beyond its use in security assessment. Among the most important results of this research project is the notion that the gross motion of a group of machines, as determined by their inertial center, determines stability. The direct result of this observation is that not all transient energy directly contributes to machine separation. The resulting correction of the energy margin for that energy not contributing to system separation accounts for much of the success of the margin technique.

CONCLUSIONS

The research effort to date makes us feel confident that the transient stability margin concept is a potentially valuable tool for dynamic security assessment. In its most elementary form, the margin may be expressed as normalized energy margin, derived from the calculation of two key values of the system energy by the energy function method. It may also be presented in the form of additional system disturbances before instability occurs. Through extensive simulation and validation studies, supported by substantial theoretical work, we are now able to predict with confidence the values of these margins. This stage was reached only after several key issues concerning the dynamic behavior of a multimachine power system were resolved.

The results obtained in this research project have led to a much better understanding of the mechanism by which some generators tend to separate from the rest of the system. With this understanding, first swing transient stability analysis can be predicted fairly accurately and without time solutions by direct methods. Therefore, the investigators feel that a valuable tool for dynamic security assessment has emerged from this research.

Section 1

PRELIMINARY DISCUSSION OF DYNAMIC SECURITY ASSESSMENT

REVIEW OF CURRENT PRACTICES AND TOOLS

In a recent IEEE paper (1) written by the Current Operations Problems Working Group of the Systems Operations Subcommittee, the current power system security practices in the United States are reviewed. Security monitoring is performed by quasi steady-state performance consideration. The main features incorporated in the schemes used include: interactive dispatcher's load flow, static-state estimation, and a contingency selection list.

A similar survey by the System Planning and Operations Committee 32-12 of CIGRE in 1972 (2) reports that member systems adopt widely varying security monitoring and analysis schemes. The most common analysis is usually based on calculations of power flows and short circuit levels. Some systems use transient stability analysis data. An interesting aspect of this report is that it points out a certain contradiction that exists between two aspects of security assessment requirements: the need for providing for emergency power exchange and the need for the prevention of propagation of a disturbance from one power system to another.

In Japan, a security monitoring scheme (3,4) used at the Tokyo Electric Power Company consists of operating limit checks and a contingency evaluation procedure. A list of contingencies is used in this scheme and a variety of on-line methods of analysis are employed to assess the transient behavior of the power system as well as its post disturbance performance. Another scheme reported (or proposed) by the Mitsubishi Electric Corporation (5) is for evaluating "dynamic reliability," taking into account probabilities of cascaded failure induced by prior primary faults. It is not clear, however, whether this procedure is actually in use.

In Canada, the Ontario Hydro System utilizes precalculated stability studies to determine transient stability limits for certain network configurations. Computer-monitoring schemes are used to ascertain whether the particular system configuration at any time will not be jeopardized by these limits (6).

To summarize, the security assessment schemes in current use depend primarily on tools developed for system planning procedures and deal mostly with quasi steady-state aspects of power system behavior. When dynamic or transient system behavior is considered, only deterministic-type contingencies are used (4,6).

CHARACTERIZATION OF THE POWER SYSTEM OPERATING STATES

In a pioneering work, Dyliacco (7) introduced the idea that the power system may operate in the following modes: normal, alert, emergency, and restorative. In a recent paper, Fink and Carlsen (8) expanded this concept by identifying the constraints satisfied or violated in each mode of operation (in extremis). The operating states they gave are:

1. Normal: All constraints are satisfied; reserve margins are adequate to withstand stresses.
2. Alert: All constraints are still satisfied; reserve margins are such that some disturbance could result in a violation of some inequality constraint.
3. Emergency: Inequality constraints are violated; system is still intact and control action could be initiated to restore system to at least the alert state.
4. In extremis: Equality constraints and inequality constraints are violated; the system will no longer be intact and a portion of the load will be lost.
5. Restorative: Control action is being taken to pick up the lost load and to reconnect the system.

ISSUES TO BE RESOLVED

To develop a methodology for dynamic security assessment, we must deal with the transition between the normal, alert, and emergency states. The emphasis should then be on alerting the system operator to potential situations where a breach of security may occur. This should be done continually, and performed in such a way as to give the operator time to take preventive measures if deemed desirable.

The development of such a methodology, however, requires that two fundamental questions be resolved. These questions (9-11) reflect serious obstacles that need to be overcome:

1. System security in the dynamic sense is not well defined. It deals with the transition of the power system, under the influence of contingent disturbances, from one operating state to another. Assessment of this transition requires:

--An assessment of the final state of the system, which would define acceptable and unacceptable projected operating conditions.

--An assessment of the system trajectory in the transition period, which would define what constitutes an acceptable dynamic performance.

2. Analysis of the power system dynamic behavior has traditionally been conducted for planning purposes. Study objectives, as well as the deterministic tools of analysis used, have reflected the perspective of the planning engineer. The new methods for analyzing the dynamic behavior of a power system must reflect the perspective of the system operator.

We feel that a successful methodology for dynamic security assessment must deal with these issues and must resolve them satisfactorily. Thus, a successful security assessment scheme must be capable of:

- Offering a clear definition of the operating states of a power system and of what constitutes an acceptable dynamic system performance, hence establishing criteria for failure.
- Recognizing the dynamic state of the system (in real time).
- Detecting imminent contingent situations (that may lead to emergencies).
- Assessing the security of the system by recognizing alertable situations and the degree of alert.
- Identifying the weak links (when detecting contingent emergencies) and suggesting preventive measures.

The importance of this scheme has been recognized by a working group of the CIGRE Committee 32 (System Operation). In a recent two-part paper (12) presented by U. G. Knight, the present state of the aids for emergency control of power systems is surveyed and near-term projections for their evolution are summarized. Mr. Knight projects that

> ...the technical development of aids to control in an emergency will be concentrated in four areas--improved operational planning, improved recognition of potentially dangerous situations, improved identification of system conditions during and after a disturbance and improved actions to contain the fault conditions and return to normal.

In discussing the second of the four areas, Mr. Knight identifies the need.

> ...because of the difficulty of predicting random combinations of events, the most that can be done is to make sure that potentially dangerous operating states, either of the system as existing or following any defined contingency, are recognized. The major developments needed are improved and more rapid evaluation of transient

(aperiodic and oscillatory) stability limits, extending ultimately to on-line evaluation. Coupled with this, and in fact representing only a minor technical extension, would be a predictive facility whereby the control engineer could superimpose, for contingency analysis, on current data the switching or redisposition of generation and loads which in his judgment, might rectify the situation.

CHARACTERIZING THE TRANSITION BETWEEN OPERATING STATES

From the security standpoint, analysis of the transitions must be conducted from two points of view: 1) to examine whether, in the post disturbance operating state, all the constraints (equality and inequality) are satisfied, and 2) to ascertain whether in the transient process the system integrity is not seriously threatened. Typical of the manifestations of the degraded transient behavior are: loss of synchronism of one or more generators, loss of lines or segment of the network due to relay operation, shedding of loads by under-frequency relays and, in the extreme situations, system islanding and cascading outages.

Any of the attributes of system behavior described can be dealt with in terms of a margin for acceptable operation. Margins are in common use in the analysis of power system security in terms of satisfying equality and inequality constraints (the term is implied in many of the techniques used). The literature in this area is vast and only a small representative sample will be cited. A number of authors (13-16) deal with analysis of power dispatch in terms of meeting the network constraints. Garver et al. (17) calculated the load-supplying capability of the generator-transmission network. Optimization techniques using linear programming are given by some authors to develop optimal scheduling from the security standpoint (18). Rescheduling of generators and loads in an emergency is dealt with by Chan and Schweppe (19) and Blaschalk et al. (20); while Jarjis and Galiana (21) calculated the steady-state stability limit for a given set of network constraints.

While the margin concept is easily defined (and often used) in various aspects of system performance in the post-transition state, it is little used in assessing dynamic system behavior (although the margin concept is implied in the traditional use of the terms "transient stability limit" and "critical clearing time"). Recently, a few authors have suggested the term for assessing the quality of the system dynamic behavior. In 1970, Tiechgraeber et al. (22) proposed a parameter to measure the relative transient stability of a power system using direct methods. Rahimi et al. (23) defined transient stability indices based on the concepts of potential and kinetic energies. DiCapprio (24,25), by modeling a multi-area power system classically, used direct methods for determining the maximum (positive and negative) values of perturbations allowable in each area without loss of synchronism, and related these allowable perturbations to a stability margin. Fouad (26) proposed the use of the stability margin concept to deal with multiple disturbances and suggested that the allowable perturbations can be related to either load (generation) changes or network changes. The concept of transient margins also appeared in the Soviet literature as a means of assessing the dynamic system behavior (27).

SCOPE OF THIS PROJECT

This research project deals with the development of a tool for the dynamic security assessment of a power system. The project also illustrates the potential of this tool for use in assessing the degree of robustness (or vulnerability) of a power system following a disturbance.

The approach used is founded on the premise that such a tool must be capable of assessing the quality of the system dynamic response to various stimuli or disturbances. The basis for making such an assessment is presented in the form of a margin for acceptable operation. This margin would characterize the quality of the transition from the predisturbance operating condition to the post disturbance operation, and would offer a sound framework for building a security assessment scheme.

The investigators have selected one of the most important, and perhaps most complex, attributes of power system behavior to conduct their research, namely, transient stability. The work has focused on exploring the concept of transient stability margin and on developing the desired tool for assessing the quality of power system dynamic behavior during the transient following a large disturbance. To assess this quality, more than just a yes or no answer is sought, i.e., more is asked than whether the system is stable or unstable. Rather, if the system can withstand this particular disturbance, it is important to know how far from instability the rotor trajectories of the generators will be, following the disturbance.

The proposed tool for assessing the quality of the transient response of the power system is the transient energy margin. It is predicted on the assumption that the faulted power system, initially at the post disturbance period, possesses an excess energy that must be absorbed by the system (i.e., converted to other forms of energy) for stability to be maintained. The maximum capacity of the system to absorb this excess energy is indicative of the critical amount of transient energy that the system can initially have. The transient energy margin, then, is the difference between that critical amount and the actual values of transient energy the system has at the beginning of the post disturbance period. This margin is indicative of the margin of safety for the rotor trajectories, i.e., it provides us with the means of assessing the quality of the system transient response.

Viewing transient stability from the point of view of the system transient energy required for loss of synchronism is very much in accord with the approach used by direct methods of stability analysis. One such method, recently developed by Systems Control, Inc., calculates the system energy values of interest, namely, the critical energy and the post disturbance initial energy, i.e., at fault clearing. This method, called the energy function method, is the method used in this project.

In exploring the transient energy margin concept, the Iowa State University team found it necessary to develop a fundamental understanding of the issues associated with the use of direct methods in the transient stability analysis of multimachine power systems. Analysis of the system trajectories following a large disturbance has contributed valuable information on: the concept of controlling unstable equilibrium point, the manner in which some machines tend to lose synchronism, and the various components of the system's transient energy. A significant contribution to the state of the art in this subject has been made in clearly identifying the components of the transient energy directly responsible for system separation (and hence causing instability when it occurs).

In developing the transient energy margin concept as a tool for dynamic security assessment, the work at Iowa State University has explored two main approaches. In the first approach, the particular emphasis has been on predicting, for a disturbance the system can withstand, the additional disturbances that would entirely "use up" this energy margin and make the system critically unstable. The thinking has been that these additional disturbances, e.g., loss of a line or load, would be indicative of the robustness of the system. Furthermore, they can be readily translated into a probabilistic framework for assessment of system dynamic security. Investigation of this approach has revealed certain complexities caused by the change of the system trajectories due to the additional disturbances. Many theoretical issues were dealt with in the course of this investigation (see Section 6 of this report).

In the second approach, a transient energy margin profile for the system is developed for a given operating condition. The procedure is to compute the transient energy margin for various credible network configurations, i.e., with various breaker operations (or failures) following a specified disturbance. The process is repeated for other (hypothetical) disturbances at the same initial operating condition. This transient energy margin profile is then examined for potentially unacceptable or alertable situations. Throughout the project, simulation and validation studies were conducted on two test power networks: a 4-generator, 11-bus system and a 17-generator, 163-bus system. The latter is a reduced version of the actual power network of the state of Iowa.

Section 2

TEST POWER NETWORKS USED IN SIMULATION STUDIES

Two power networks have been used in the validation studies: a 4-generator test system and an equivalent of the Iowa system (referred to here as the Reduced Iowa System).

4-GENERATOR, 11-BUS TEST POWER SYSTEM

This test system, shown in Figure 2-1, is a modified version of the 9-bus, 3-machine, 3-load system widely used in the literature and often referred to as the WSCC test system. The modifications adopted are:

- Changing the rating of the transmission network from 230 kV to 161 kV to avoid having an excess VAR problem; the R and X values of the lines in per unit remain the same.
- Adding a fourth generator, connected to the original network by a step-up transformer and a double-circuit, 120-mile, 161-kV transmission line; the new generator has the same rating as one of the original generators. The new system has a generation capacity of 680 MW.

The network is shown in Figure 2-1. The generator data and the initial operating condition, including the internal generator voltages, are given in Table 2-1.

This small test system was used primarily for validation of new procedures and/or computer programs developed in the project. For faults at or near Generator No. 4, the mode of instability is simple and the system's dynamic behavior is rather predictable.

17-GENERATOR, 163-BUS TEST POWER SYSTEM (REDUCED IOWA SYSTEM)

The Power System Computer Service of Iowa State University has been involved in several full-scale stability studies for new generating units in the Iowa area. The Philadelphia Electric Transient Stability Program was used in these studies. The base set of data and the results of one of these studies, the NEAL 4 stability study, were used (with permission) to develop a Reduced Iowa System model.

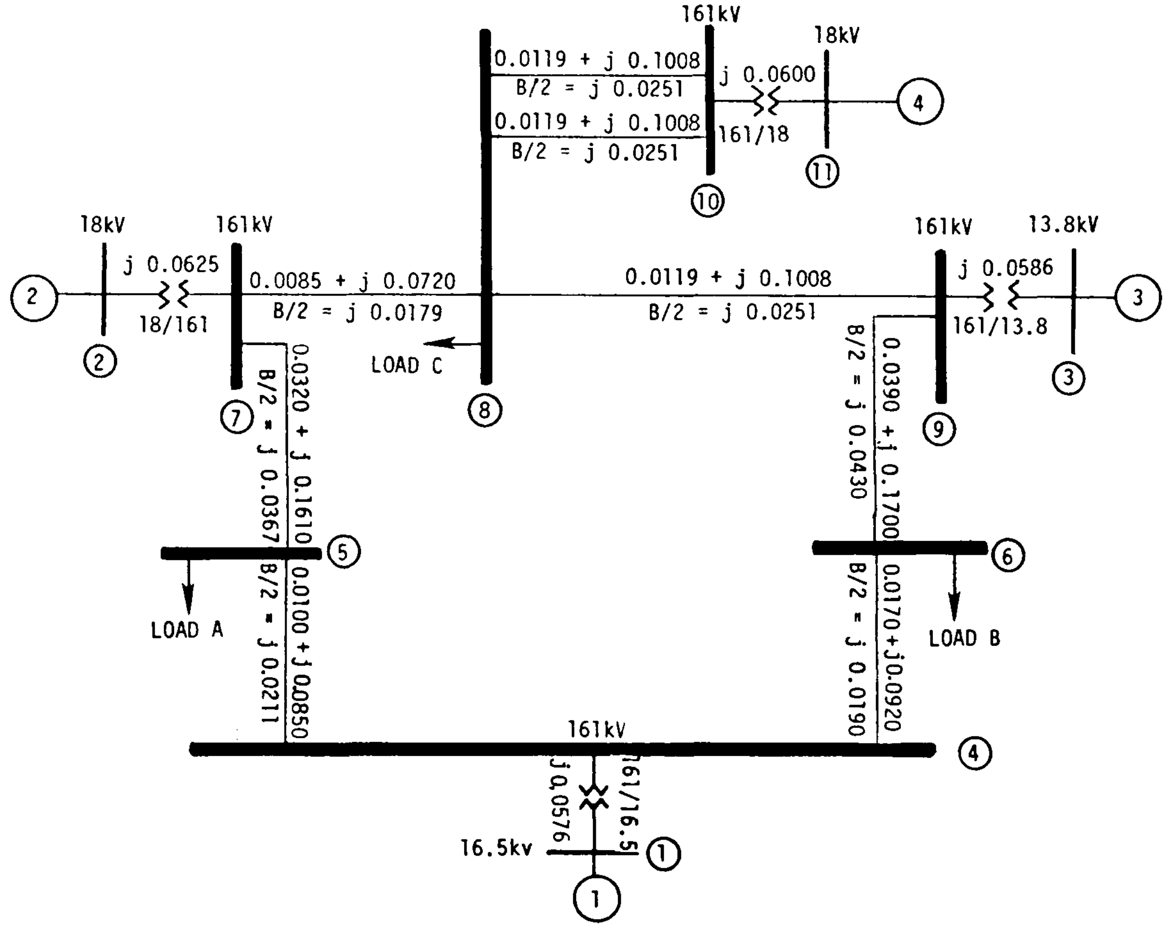


Figure 2-1. 4-generator test power system.

Table 2-1

GENERATOR DATA AND INITIAL CONDITIONS

	Generator Parameters[a]		Initial Conditions		
				Internal Voltage	
Generator Number	H (MW/MVA)	x'_d (pu)	P_{mo}[a] (pu)	E (pu)	δ (degrees)
4-Generator System					
1	23.64	0.0608	2.269	1.0967	6.95
2	6.40	0.1198	1.600	1.1019	13.49
3	3.01	0.1813	1.000	1.1125	8.21
4	6.40	0.1198	1.600	1.0741	24.90
17-Generator System					
1	100.00	0.004	20.000	1.0032	-27.92
2	34.56	0.0437	7.940	1.1333	-1.37
3	80.00	0.0100	15.000	1.0301	-16.28
4	80.00	0.0050	15.000	1.0008	-26.09
5	16.79	0.0507	4.470	1.0678	-6.24
6	32.49	0.0206	10.550	1.0505	-4.56
7	6.65	0.1131	1.309	1.0163	-23.02
8	2.66	0.3115	0.820	1.1235	-26.95
9	29.60	0.0535	5.517	1.1195	-12.41
10	5.00	0.1770	1.310	1.0652	-11.12
11	11.31	0.1049	1.730	1.0777	-24.30
12	19.79	0.0297	6.200	1.0609	-10.10
13	200.00	0.0020	25.709	1.0103	-38.10
14	200.00	0.0020	23.875	1.0206	-26.76
15	100.00	0.0040	24.670	1.0182	-21.09
16	28.60	0.0559	4.550	1.1243	-6.70
17	20.66	0.0544	5.750	1.116	-4.35

[a]On 100-MVA base.

The base load-flow system is a model of 862 buses and 1323 lines and transformers. Most of the transmission lines are 345 kV and 161 kV; some of the lines are 230 kV, 115 kV, or 69 kV. Figure 2-2 shows the main study region; a partial one-line diagram of the area is shown in Figure 2-3. The base load-flow model was reduced by a network reduction program (steady-state) to a model with 163 buses (of which 30 are terminal buses of the equivalent network) and with 304

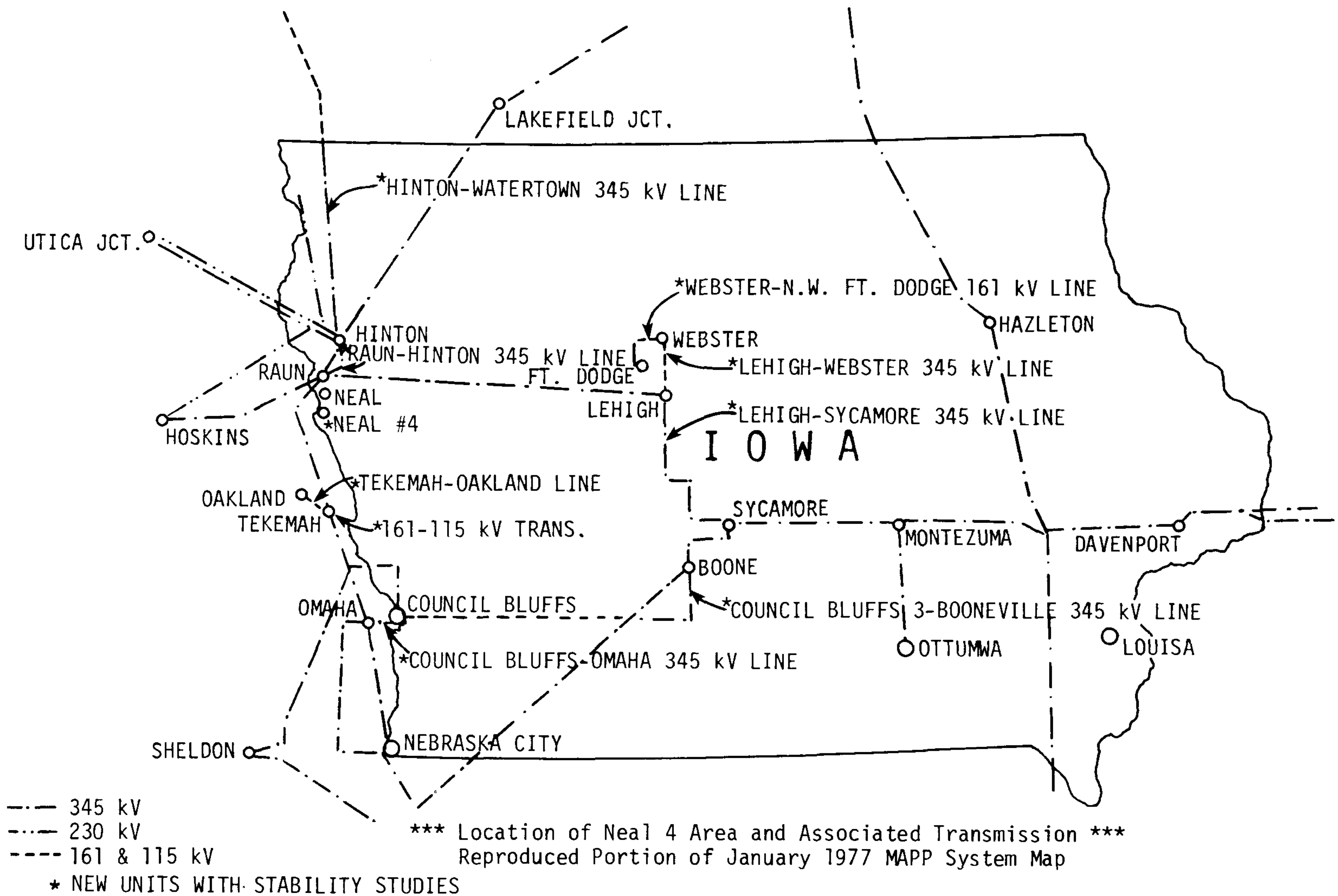


Figure 2-2. The main study region for the 163-bus Reduced Iowa System.

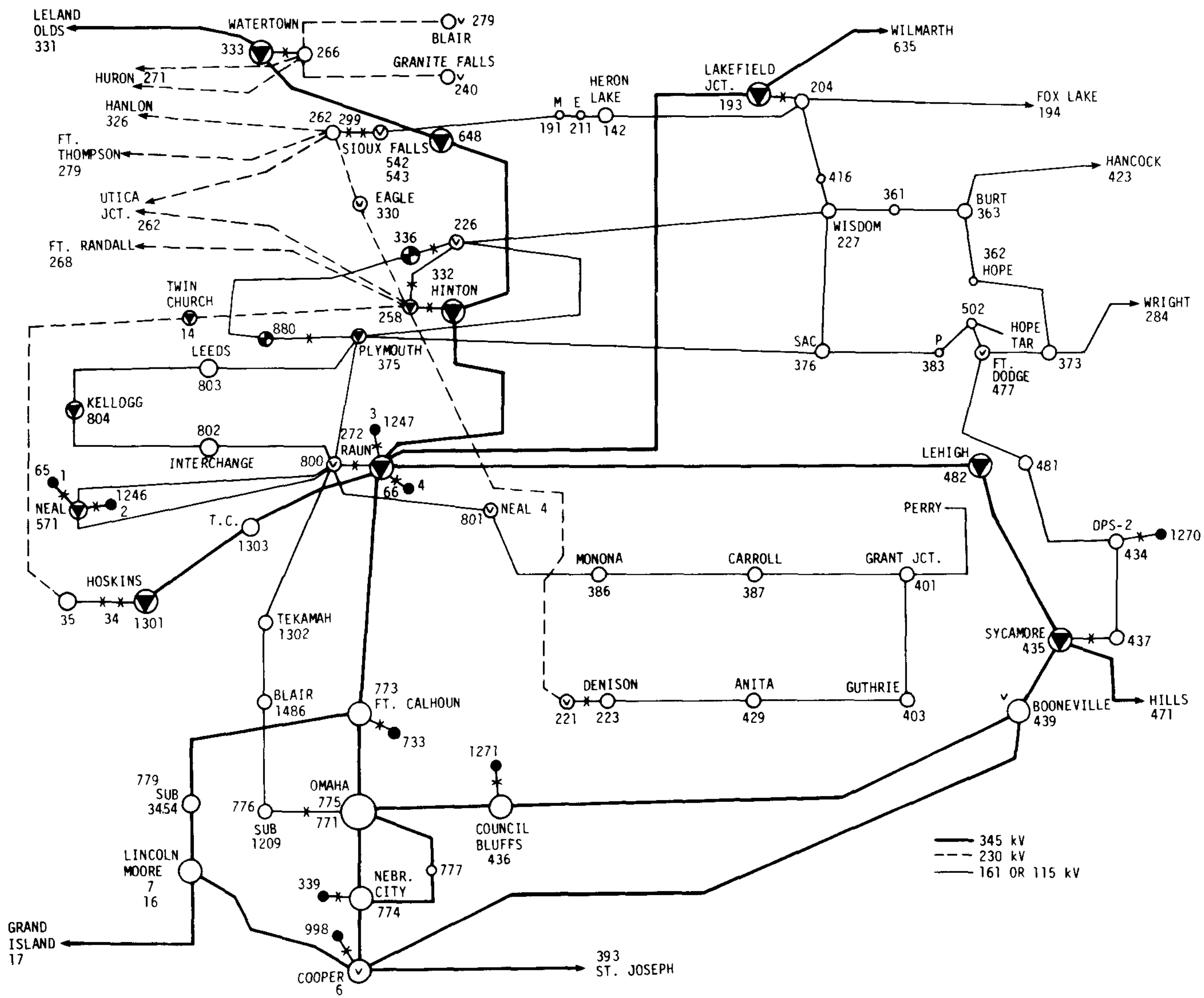


Figure 2-3. One-line diagram of the study area.

lines and transformers (of which 69 are equivalent lines). The resulting Reduced Iowa Network is shown in Figure 2-4.

The Reduced Iowa System was selected to reproduce the "first swing" characteristic of the original full model. This was done with 17 classical generators: seven generators correspond directly to generators in the full model, four generators are single generator equivalents of two-machine pairs from the same generating plants, and six generators are equivalent machines to represent inertia of machines cut off by the load-flow network reduction. The value of inertia constants of the six equivalent machines was reduced from very large values to values of 100 or 200 s (on a 100-MVA base). The location of the generators in the network is shown in Figure 2-4.

The Reduced Iowa System model was tested by running stability studies using the same disturbance as in cases from the full-model NEAL 4 stability study (which included 43 generators modeled by the one-axis model, including exciters and governors, and 80 generators modeled classically). The first swing characteristics in rotor swings and power swings on the area generators and on key 345-kV transmission lines are similar in the reduced system and the original system. Examples of the power swings on a generator and 345-kV line are shown in Figures 2-5(a) and 2-5(b), respectively. This particular disturbance is a three-phase fault at Neal, removed by clearing the Raun-Lakefield 345-kV line.

The generator data, together with the initial conditions including the generator internal voltages, are given in Table 2-1. The line and transformer data and the load-flow data for the operating condition analyzed in this project are given in Appendix B.

This test system was used in the simulation studies. The area of interest is in the western part of the network (near the Missouri River) where several generating plants are located. A disturbance in that part of the network substantially influences the motion of several generators. Thus, very complex modes of instability can occur (and have been encountered in this research project), offering a severe test to the procedures developed.

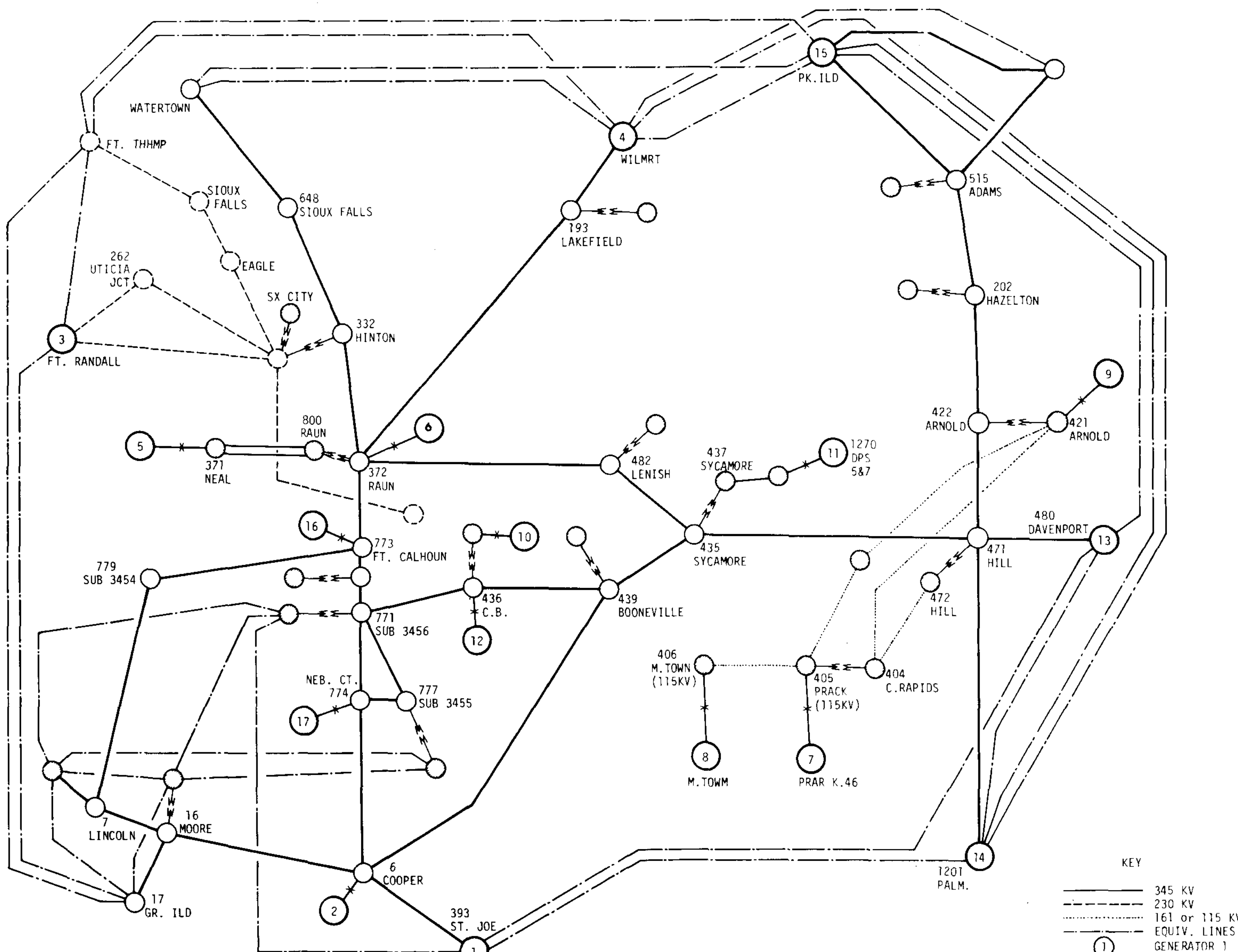


Figure 2-4. 17-generator system (Reduced Iowa System).

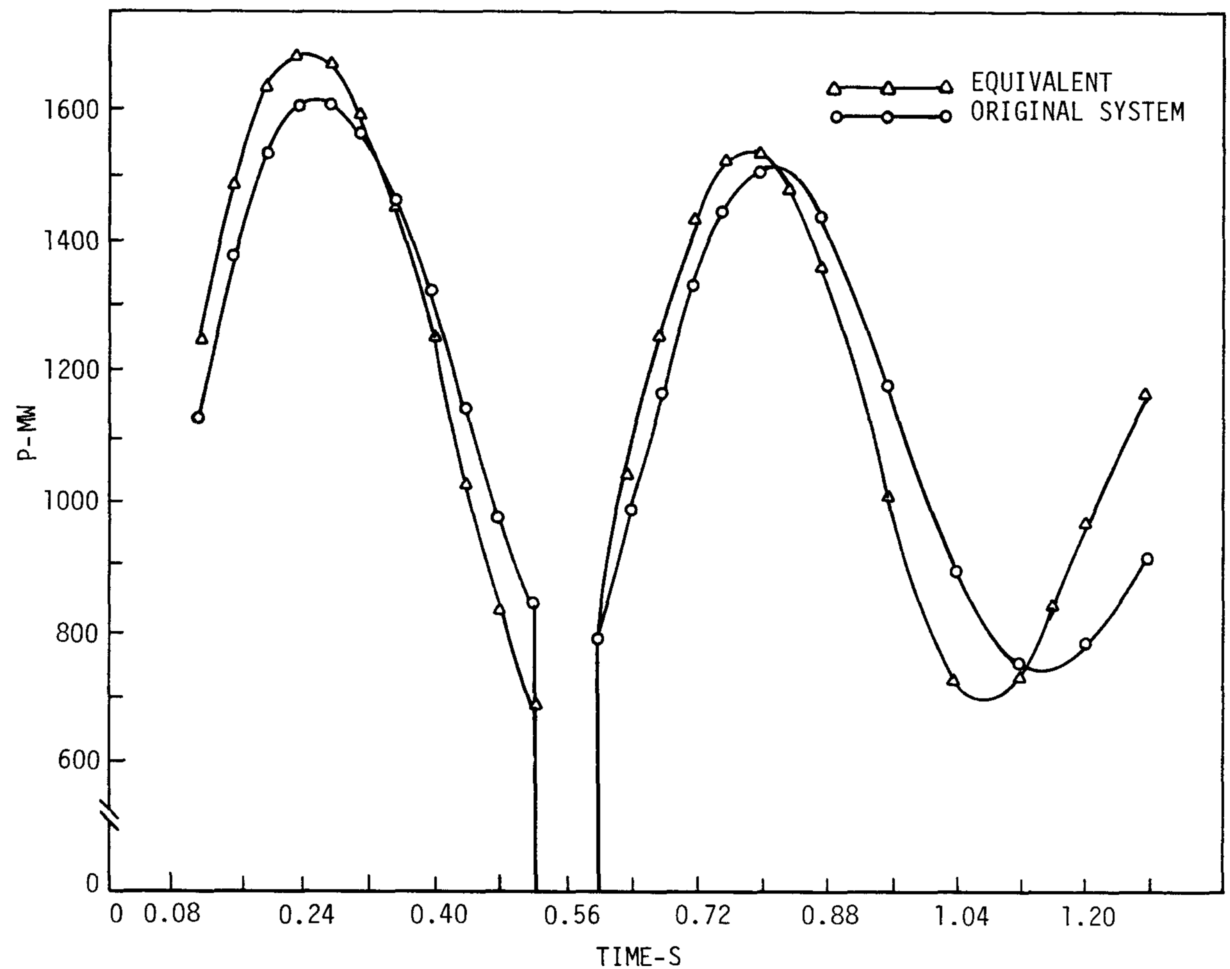


Figure 2-5a. Flow in line 372-773 for original and Reduced Iowa System (Case T80-RM-RU-0).

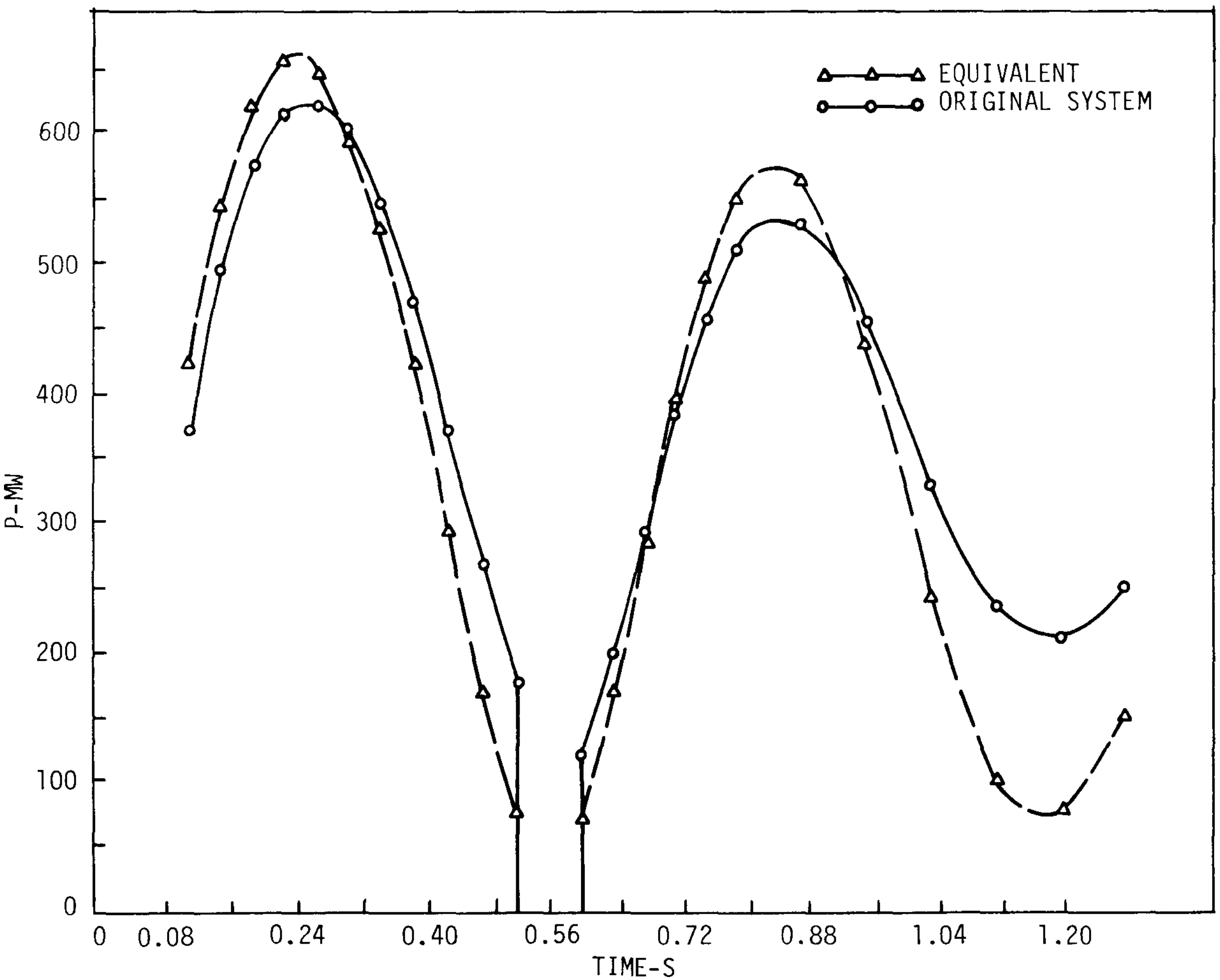


Figure 2-5b. Power of Generator No. 6 (Neal 3, 4 units) for original and Reduced Iowa System (Case T80-RM-RU-0).

Section 3

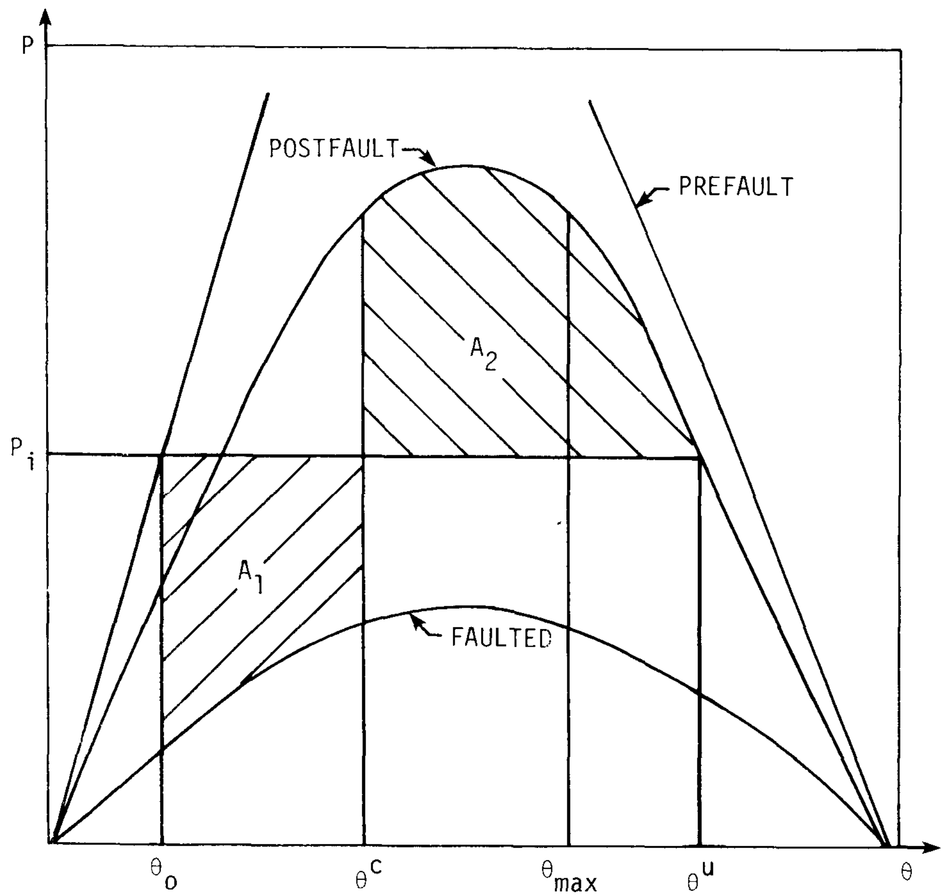
DIRECT METHOD OF TRANSIENT STABILITY ANALYSIS USING ENERGY FUNCTIONS

A VIEW OF TRANSIENT STABILITY

Conceptually, the motion of a power system subjected to a disturbance is simple to understand. When the power system's equilibrium is disturbed, there is an excess (or deficiency) of energy associated with the synchronous machines, setting the machines to move or "swing" away from equilibrium. This motion is indicative of the fact that the excess energy is converted to kinetic energy (or the energy deficiency is extracted from the kinetic energy of the rotating masses). Obviously, if that motion goes on indefinitely, synchronism would be lost. To avoid this, the system must be capable of absorbing this excess energy at a time when the forces on the generators tend to bring them back toward new equilibrium positions.

The power system's ability to absorb excess energy depends largely on its ability to convert that energy to potential energy. This in turn depends mostly on the post disturbance network configuration. Naturally, that capacity is finite and, given sufficient information on the system, it can be readily calculated, assuming a simple power system model and some effects such as damping are neglected. This basic picture is correct even when more complex models are used. Thus, for a given system configuration, there is a maximum or critical amount of transient energy that the network can absorb and convert to other forms of energy. If the system starts with an amount of transient energy less than this critical energy, the generator rotors will swing as far as the system requires for the excess energy to be absorbed by the network, but will remain stable. The difference between the system's transient energy at the beginning of the post disturbance period and the critical value of the transient energy is the transient energy margin.

To illustrate these ideas in familiar terms, a one-machine-infinite-bus system is used with the well-known equal area criterion. This is illustrated in Figure 3-1, where the power angle curves for prefault, faulted, and postfault networks are shown. If the clearing angle is θ_c, the area A_1 is proportional to the



ENERGY MARGIN $\triangleq \Delta V$

$= A_2 - A_1$

Figure 3-1. Energy margin for one-machine-infinite-bus system.

transient kinetic energy of the disturbed machine. The area A_2 represents excess energy that can be converted to potential energy. The maximum angle θ_{max} occurs when A_2 and A_1 are equal. The transient stability limit is reached when θ_c is such that θ_{max} coincides with θ^u, where P_i intersects the postfault curve. At a value of θ_c less than critical, A_2 (extending to θ^u) is greater than A_1, and the transient energy margin for this simple system is $(A_2 - A_1)$.

This simple qualitative picture is the basis for many attempts to make an analysis of power system transient stability using direct methods. Quantitative description of the system energies, particularly the critical energy, has been the subject of extensive investigations for many years (28).

TRANSIENT KINETIC ENERGY AND THE INERTIAL CENTER

One fundamental step in defining the energy contributing to system separation is the so-called inertial center formulation of the system equations. (This formulation is also referred to in the literature as center-of-angle.) In it, the equations describing the behavior of the synchronous machines are formulated with respect to a fictitious inertial center (in contrast to the usual situation where the machine's equations are formulated with respect to a synchronously moving frame of reference). The importance of this formulation is in clearly focusing on the motion that tends to separate one or more generators from the rest of the system and in removing a substantial component of the system transient energy that does not contribute to instability, namely, the energy that accelerates the inertial center (29,30). With this formulation, the forces tending to separate some generators from the rest of the system and the energy components associated with their motion can be easily identified (31,32).

POTENTIAL ENERGY SURFACES AND THE CRITICAL ENERGY

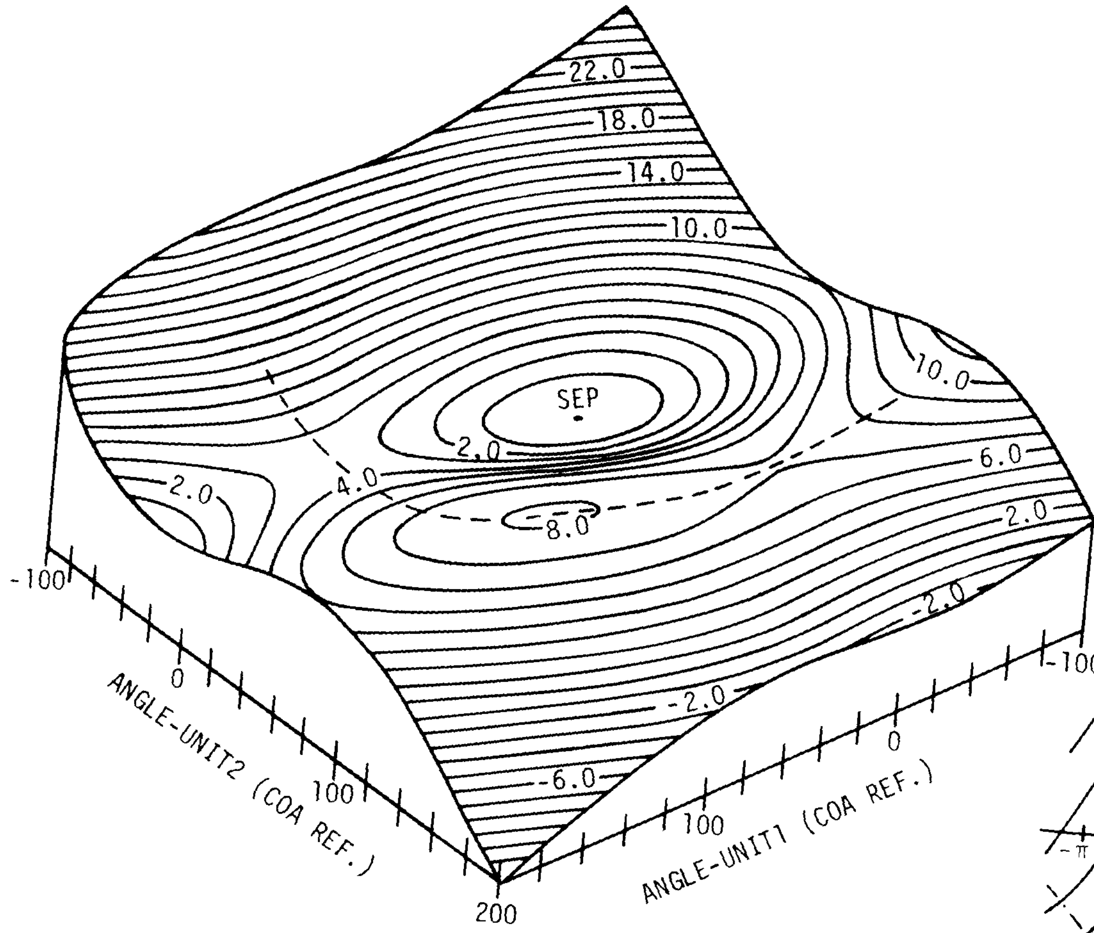
The following simplified picture seems to emerge from recent research (32,33). The ability of the system to absorb (or convert) the energy component that contributes to instability depends upon the following: the potential energy contours or "terrain" of the post disturbance system, and the particular segment of this terrain traversed by the faulted trajectory. The former depends upon using a good mathematical accounting of the system energy that describes the energy surfaces encountered by the generator rotors as they swing away from their equilibrium positions. The energy terrain, as reflected in the potential energy contours, accounts for the amount of the rotor displacement per unit of fault energy resulting from the disturbance. The latter simply recognizes that those energy surfaces have higher rides in some segments that in others; thus, the amount of rotor motion (and the corresponding energy absorbed) necessary to reach instability will vary from one trajectory to another. If the system trajectory moves in a segment of higher potential energy values, the network's capacity to absorb (and convert) the initial excess transient enegy is greater; hence, it can withstand a greater initial disturbance. On the other hand, if the faulted trajectory moves in a region where the potential energy surfaces are "shallow," the network's ability to absorb excess transient energy is much reduced and instability occurs with a smaller disturbance. Thus, the faulted trajectory is analogous to a particle "climbing up" the potential energy "hills" around this valley. In some directions, the ridge or peak of the hill is higher than in others.

To help visualize this concept, we illustrated it for a 3-dimensional system (shown in Figure 3-2). The potential energy contours are illustrated and the stable equilibrium point for the (post disturbance) system is shown at the bottom of the valley in the middle of the figure.

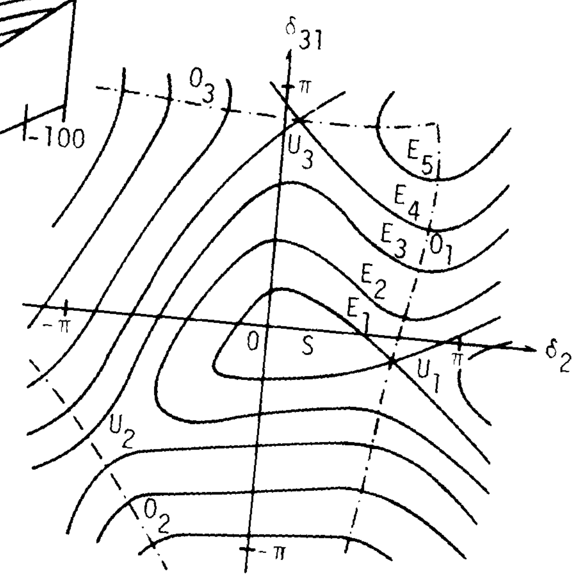
The ridge of the potential energy surfaces has several "humps" and "saddle points." These are the so-called unstable equilibrium points (u.e.p.'s). The u.e.p. closest to the trajectory of the disturbed system is the one that decides the system transient stability. This is called the controlling (or relevant) u.e.p. for this trajectory. Thus, the critical transient system energy is that which corresponds to the energy of the closest or controlling u.e.p. For a one-machine-infinite-bus system, the u.e.p. is the angle θ^u shown in Figure 3.1. To complete the picture, we mention that if the system is faulted and the fault is cleared before the critical clearing time t_c, the system trajectory peaks before reaching the "ridge" of the potential energy surface contours, or the relevant u.e.p. At a clearing time exceeding t_c, the ridge is crossed (usually at some point other than the u.e.p.) and stability is lost. There is only one critical trajectory that can actually go through the controlling u.e.p.

THE ENERGY FUNCTION METHOD

In the following discussion, the mathematical model describing the transient power system behavior is the classical model: generators represented by constant voltage behind transient reactance, constant impedance loads, etc. See Chapter 2 of (34).



a. From reference (32).



b. From reference (33).

Figure 3-2. Potential energy function for 3-machine system (from the literature).

For an n-generator system with rotor angles δ_i and inertia constants M_i, i = 1, 2,...,n (where $M_i = 2H_i/\omega_R$), the position δ_o and speed ω_o of the inertial center are given by

$$\delta_o = \frac{1}{M_o} \sum_{i=1}^{n} M_i \delta_i$$

$$\dot{\delta}_o = \frac{1}{M_o} \sum_{i=1}^{n} M_i \dot{\delta}_i \qquad (3\text{-}1)$$

where

$$M_o = \sum_{i=1}^{n} M_i$$

The generators' angles and speeds with respect to the inertial center are defined by

$$\theta_i = \delta_i - \delta_o$$

$$\omega_i = \dot{\delta}_i - \dot{\delta}_o \qquad i = 1,2,\ldots,n \qquad (3\text{-}2)$$

Using the terminology commonly found in the literature

E_i = voltage behind transient reactances of generator i
$Y_{ii} = G_{ii} + jB_{ii}$
= driving point admittance for internal node of generator i
$Y_{ij} = G_{ij} + jB_{ij}$
= transfer admittance between internal nodes i and j
P_{mi} = mechanical power of generator i (constant)

We can show that the system transient energy V is given by

$$V = \sum_{i=1}^{n} \frac{1}{2} M_i \omega_i^2 - \sum_{i=1}^{n} P_i \left(\theta_i - \theta_i^s\right) - \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \left[C_{ij}\left(\cos\theta_{ij} - \cos\theta_{ij}^s\right) + \int_{\theta_i^s+\theta_j^s}^{\theta_i+\theta_j} D_{ij} \cos\theta_{ij} \, d(\theta_i + \theta_j)\right] \qquad (3\text{-}3)$$

where

θ_i^s = stable equilibrium angle for generator i

P_i = $P_{mi} - E_i^2 G_{ii}$

C_{ij}, D_{ij} = $E_i E_i B_{ij}$, $E_i E_j G_{ij}$

The system transient energy components in Eq. 3-3 are identifiable. The first term is the kinetic energy. The second term is a position energy, which is part of the system's potential energy. The third term is the magnetic energy, which is also part of the potential energy. The fourth term is the dissipation energy, which is the energy dissipated in the network transfer conductances (which includes part of the load impedances). Following the terminology used in the literature, we will use the term "potential energy" to indicate the last three components.

Examining Eq. 3-3, we note that at θ^s the transient energy is zero, and at the instant of fault clearing the transient energy is greater than zero. If the system is to remain stable, the kinetic energy at the beginning of the post disturbance period must be converted at various instants along the trajectory to other forms of energy. Thus, the excess (transient) kinetic energy must be absorbed by the network.

It is to be noted that the last term in Eq. 3-3 can be calculated only if the system trajectory is known (which the direct method is trying to avoid in the first place). Various methods for approximating this term have been suggested in the literature (31-35). The method used in this investigation is that suggested by Athay et al. (31,32). The expression for the system transient energy function is given by

$$V = \frac{1}{2} \sum_{i=1}^{n} M_i \omega_i^2 - \sum_{i=1}^{n} P_i\left(\theta_i - \theta_i^s\right) - \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \left[C_{ij}\left(\cos\theta_{ij} - \cos\theta_{ij}^s\right) + I_{ij}\right] \qquad (3\text{-}4)$$

where

I_{ij} = an approximated term to account for the transfer conductances

$$= D_{ij} \frac{\theta_i + \theta_j - \theta_i^s - \theta_j^s}{\theta_{ij} - \theta_{ij}^s} \left(\sin\theta_{ij} - \sin\theta_{ij}^s\right) \qquad (3\text{-}5)$$

From practical considerations, the transient energy is usually evaluated between two points. Since the system θ^s for the post disturbance network may differ from that of the original system, it is important to indicate clearly the reference point for the energy expression. For convenience, the notation $V\Big|_{\theta^a}^{\theta^b}$ will be used to indicate that the transient energy is calculated at point b (θ^b, ω^b) with respect to point a (θ^a, ω^a). For example, for a faulted system at the instant of clearing, $\theta = \theta^c$ and $\omega = \omega^c$. The transient energy with respect to θ^{s1} (the prefault θ^s) is given by

$$
\begin{aligned}
V_{cl} &= V\Big|_{\theta^{s1}}^{\theta^c} \\
&= \frac{1}{2}\sum_{i=1}^{n} M_i\left(\omega_i^c\right)^2 - \sum_{i=1}^{n} P_i\left(\theta_i^c - \theta_i^{s1}\right) \\
&\quad - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left[C_{ij}\left(\cos\theta_{ij}^c - \cos\theta_{ij}^{s1}\right) + I_{ij}^c\right]
\end{aligned}
\qquad (3\text{-}6)
$$

CRITICAL ENERGY

The critical transient energy is associated with the potential energy of the appropriate unstable equilibrium point θ^u for the particular disturbance under consideration. The critical disturbance is assumed to be controlled by this θ^u. The system trajectory is assumed, for the time being, to be reaching θ^u with zero velocities. In this case, the critical energy is the same as the potential energy at θ^u, calculated with respect to the postfault equilibrium point θ^{s2}. Thus

$$
\begin{aligned}
V_{cr} = V_u &= V\Big|_{\theta^{s2}}^{\theta^u} \\
&= -\sum_{i=1}^{n} P_i\left(\theta_i^u - \theta_i^{s2}\right) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left[C_{ij}\left(\cos\theta_{ij}^u - \cos\theta_{ij}^{s2}\right) + I_{ij}^u\right]
\end{aligned}
\qquad (3\text{-}7)
$$

As a point of practical significance, note that V_{cl} and V_{cr} are often computed to different reference points.

ANALOGY WITH THE EQUAL AREA CRITERION

To illustrate the previous ideas, consider a one-machine-infinite-bus system. The power angle curves for that system, neglecting transfer conductances, are shown in Figure 3-3, with some key points of interest marked. Consider the situation at clearing. The energy function, using the postfault network with prefault θ^{s1} used as reference, is given by

$$V_{cl} = \frac{1}{2} M(\omega^{c})^{2} - C(\cos\theta^{c} - \cos\theta^{s1}) - P_{m}(\theta^{c} - \theta^{s1}) \tag{3-8}$$

The first term on the right-hand side of Eq. 3-8 is the transient kinetic energy. From the well-known equal area criterion, this term is associated with the area oabf in Figure 3-3. The second and third terms make up the potential energy of the system. In Figure 3-3, they are equal to area cdf - area oed.

We also note that if θ^{s2} is used as reference (instead of θ^{s1}), the potential energy terms are equal to area cdf.

The critical energy at θ^{u} is given by

$$V_{cr} = -C(\cos\theta^{u} - \cos\theta^{s1}) - P_{m}(\theta^{u} - \theta^{s2}) \tag{3-9}$$

The right-hand side of Eq. 3-8 is the area dgcd in Figure 3-3. If the θ^{c} is the critical clearing angle, $V_{cl} = V_{cr}$.

This equality would correspond to the equal area criterion only if V_{cl} is computed with respect to θ^{s2}, giving the relation

area oabf + area cdf = area dgcd

or

area oabf = area cfg

SIMULATION STUDIES

The two test networks, described in Section 2, were used for simulation studies to investigate various aspects of the energy function method discussed in this section. The 4-generator system was investigated for a three-phase fault at Bus 10 cleared by opening one of the lines 10-8. For the 17-generator system, the disturbance investigated was a three-phase fault at Bus 372 cleared by opening line 372-193 (Raun-Lakefield).

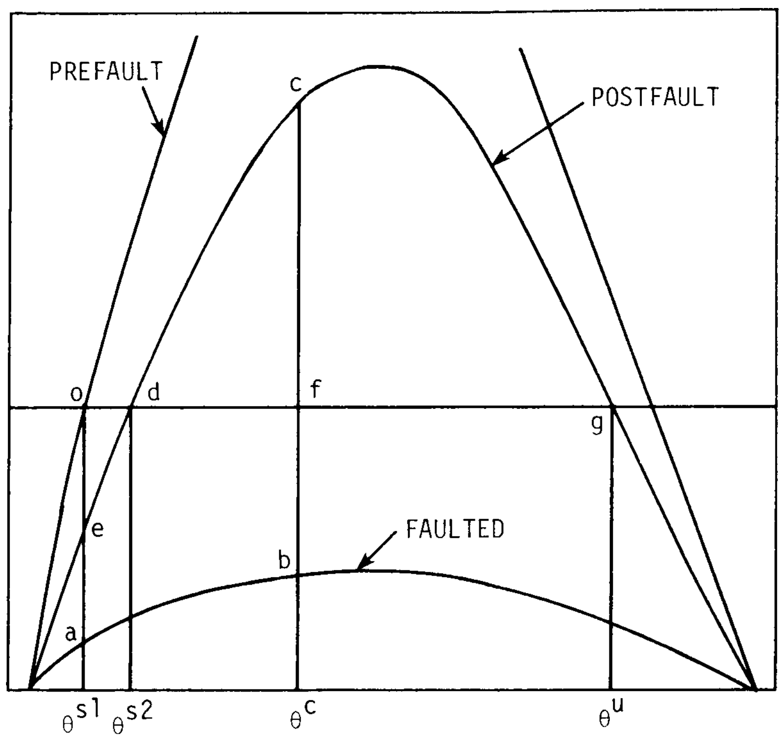


Figure 3-3. Power angle curves for one-machine-infinite-bus system (transfer conductances neglected).

Point o: prefault operating point; $\theta = \theta^{s1}$, $t = t_o^-$

Point a: electrical power at $t = t_o^+$, $\theta = \theta^{s1}$

Point b: electrical power at $t = t_c^-$, $\theta = \theta^{c}$

Point c: electrical power at $t = t_c^+$, $\theta = \theta^{c}$

Point d: operating point when transient subsides, $t \to \infty$, $\theta = \theta^{s2}$

Unstable Equilibrium Points (u.e.p.'s)

For the previously mentioned disturbances, the relevant u.e.p.'s were carefully calculated by the special computer program package and by starting a DFP procedure (Davidon-Fletcher-Powell solution procedure (32)) from the point where the critical machines are at the peak of the rotor angle swings and the remaining machines are at their θ^{s2} angles. The predicted u.e.p.'s and their potential energies are:

4-generator system

$\theta_1^u = -27.7°$ $\qquad$ $\theta_3^u = -11.3°$

$\theta_2^u = -5.5°$ $\qquad$ $\theta_4^u = 113.2°$

$V_{\theta^u} = 0.626$ pu

17-generator system

$\theta_1^u = -1.4°$	$\theta_7^u = -16.0°$	$\theta_{13}^u = -25.8°$
$\theta_2^u = 46.6°$	$\theta_8^u = -8.0°$	$\theta_{14}^u = -23.6°$
$\theta_3^u = 9.7°$	$\theta_9^u = -6.6°$	$\theta_{15}^u = -17.6°$
$\theta_4^u = -24.0°$	$\theta_{10}^u = 47.8°$	$\theta_{16}^u = 63.6°$
$\theta_5^u = 163.6°$	$\theta_{11}^u = 10.3°$	$\theta_{17}^u = 50.1°$
$\theta_6^u = 144.9°$	$\theta_{12}^u = 49.6°$	

$V_u = 17.18$ pu

Casual examination of the data, i.e., from the values of $\theta_i > \pi/2$, reveals which generators tend to separate from the rest of the system for the specific disturbances given. For the 4-generator system, it is Generator No. 4 and for the 17-generator system it is Generators No. 5 and 6. This data is reasonable, since these generators are close to the disturbance.

System Trajectories

Stability runs, using time solutions, were made for the faults indicated earlier and for different clearing times until the system barely went unstable. In addition to the rotor swings, information on the transient energy was obtained at different instants. It should be noted, however, that the energy is calculated with respect to the prefault stable equilibrium θ^{s1}.

4-Generator System. Figures 3-4 and 3-5 show some of the results obtained. Generator angles (with respect to inertial center), as well as the kinetic energy and potential energy, are displayed for the case of t_c slightly less than the critical clearing time and for the case where t_c was such that the system barely becomes unstable.

Examining Figure 3-4, we note that at the peak of the swing of Generator No. 4, the system potential energy is maximum and kinetic energy is minimum (almost zero in this case). This confirms the idea of the conversion of the kinetic energy to potential energy (noting that a portion of that energy is dissipated in the transfer conductances).

Figure 3-5 shows that when the potential energy is maximum and the kinetic energy is minimum, $\theta_4 = 112°$ and $\theta_1 = -20°$, which are almost identical to the values predicted for θ_4^u and θ_1^u. However, the values of θ_2 and θ_3 at that instant are 1.9° and -6.1°. They differ from the predicted values of θ_2^u and θ_3^u by a few degrees. The maximum potential energy is about 0.63 pu and the minimum kinetic energy, occurring at the same instant, is not exactly zero.

The data shows that at critical clearing the critical machine appears to be at the position predicted by θ_4^u, while the other generators are not exactly at their u.e.p. values.

17-Generator System. One of the important features of this particular system is the nature of the swings of the machines affected by the disturbance, namely, Generators No. 5 and 6. Their inertias and their synchronizing forces are substantially different, causing their swings to peak at different instants. Since they represent the machines tending to pull away from the rest of the system, their mode of instability is of interest. To investigate this mode, a series of stability runs was made near the critical clearing time: at t_c = 0.189, 0.192 and 0.1932, respectively. Plots of θ_5, θ_6, and their inertial centers, are given (together with the system's potential energy, kinetic energy, and total energy) in Figures 3-6 through 3-8.

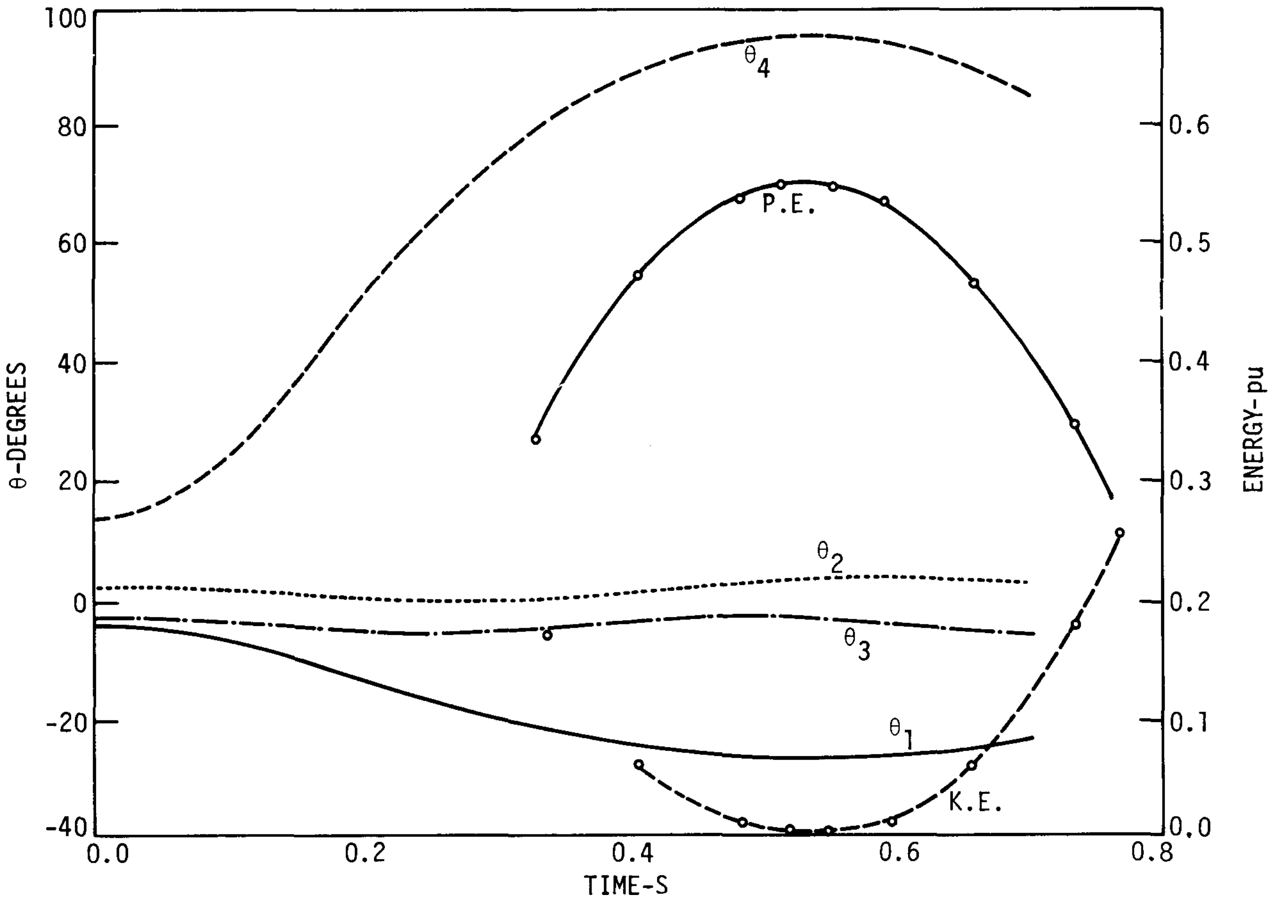


Figure 3-4. 4 -generator system. Fault at Bus 10 cleared in 0.148s.

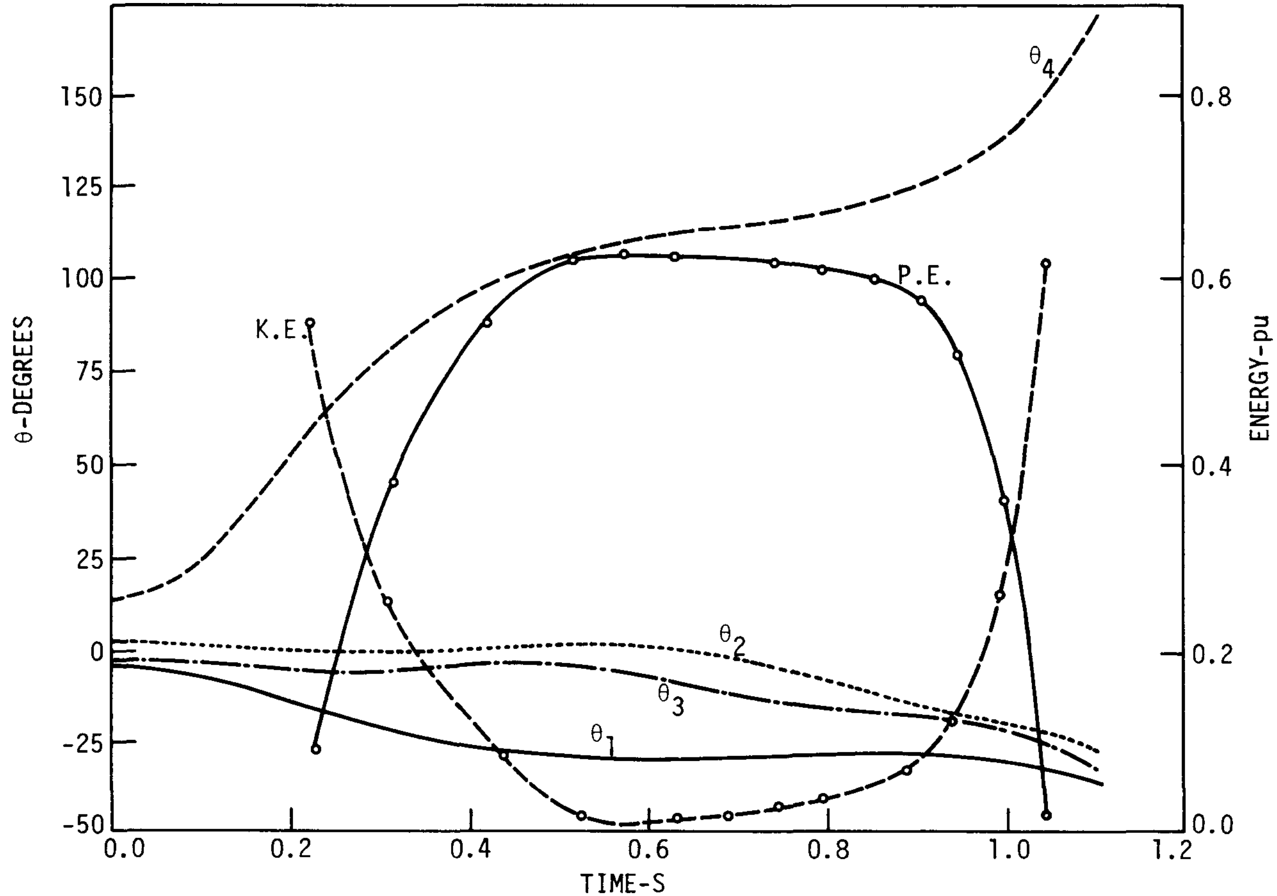


Figure 3-5. 4-generator system. Fault at Bus 10 cleared in 0.159s.

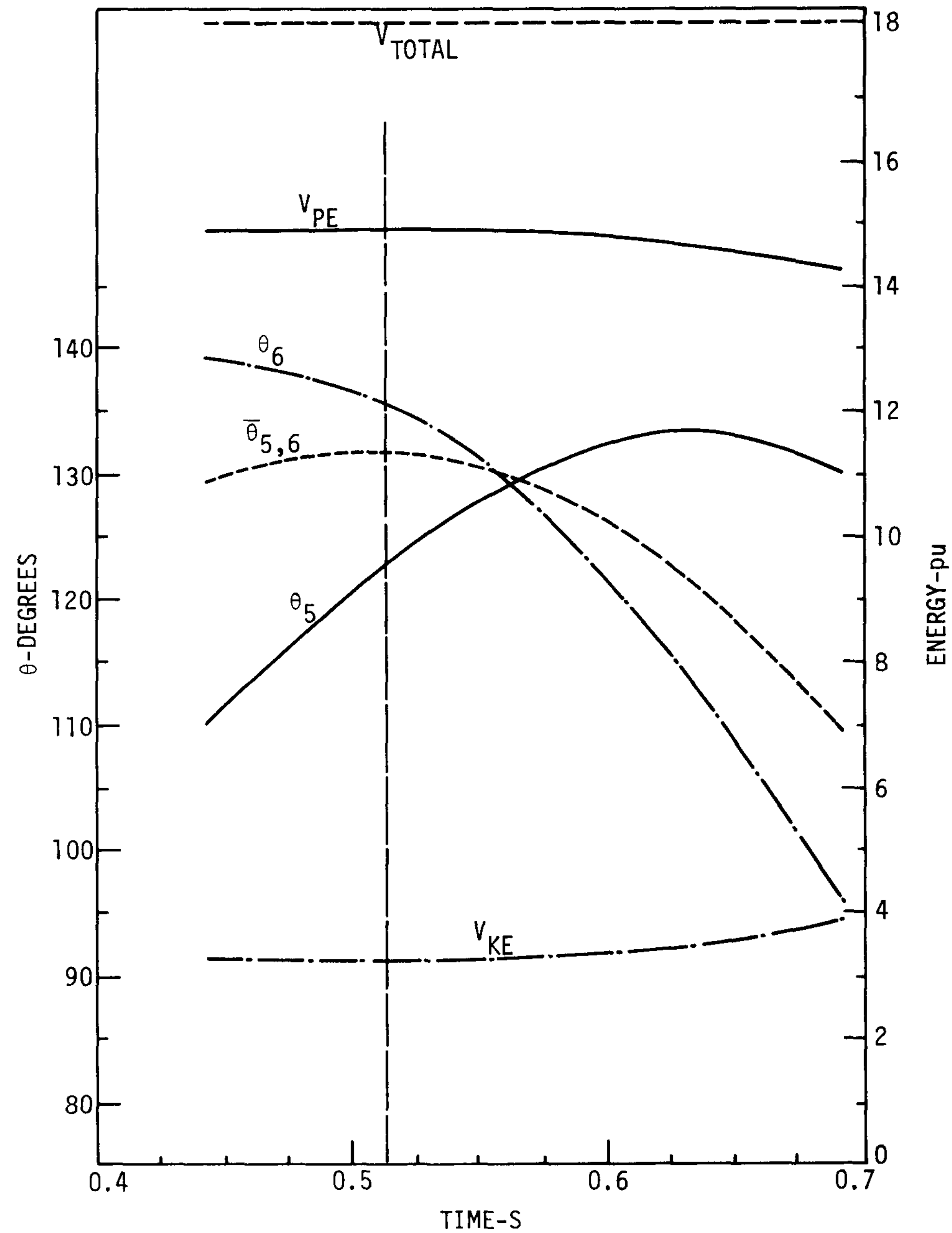


Figure 3-6. 17-generator system. Fault at Bus 372 cleared in 0.189s.

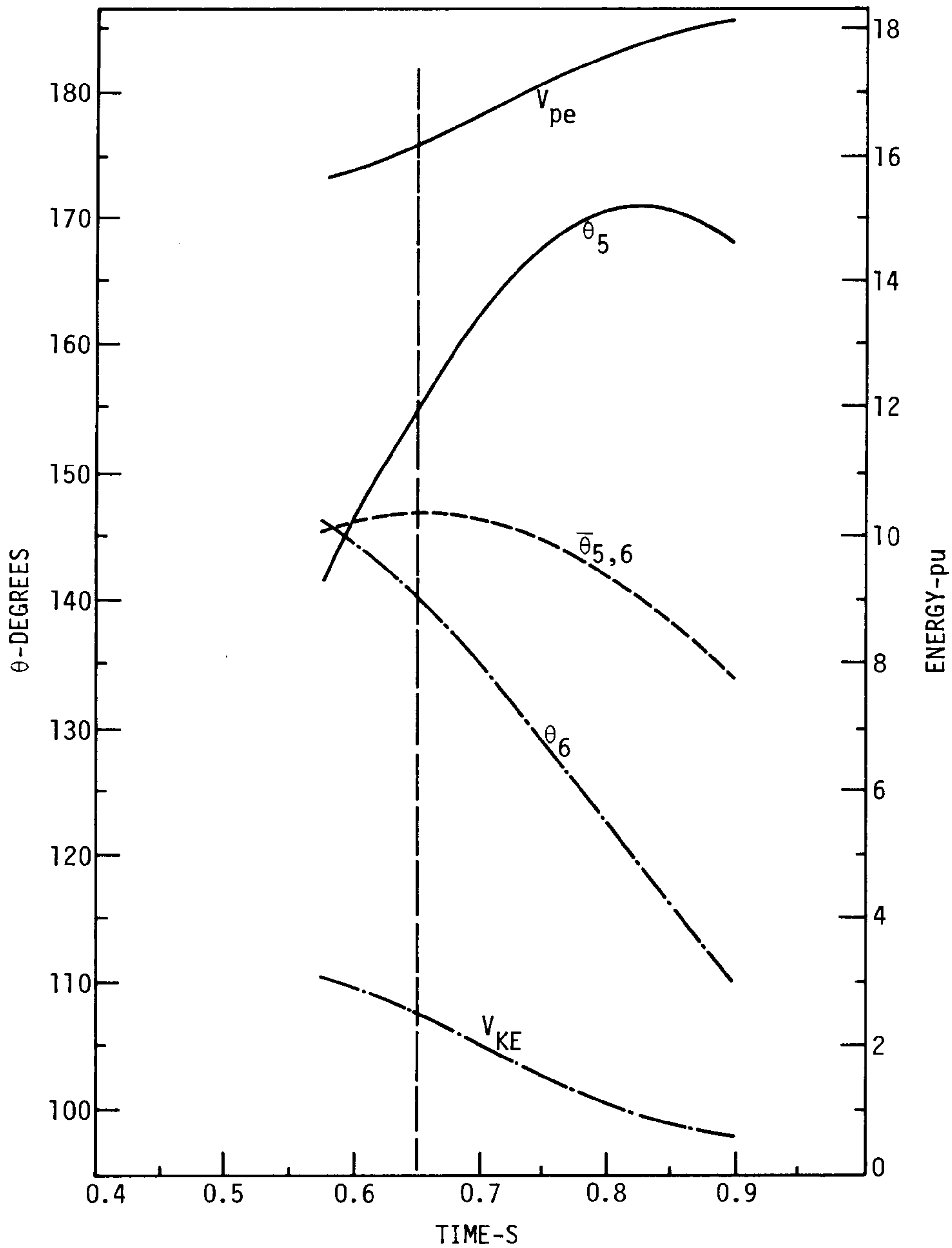


Figure 3-7. 17-generator system. Fault at Bus 372 cleared in 0.192s.

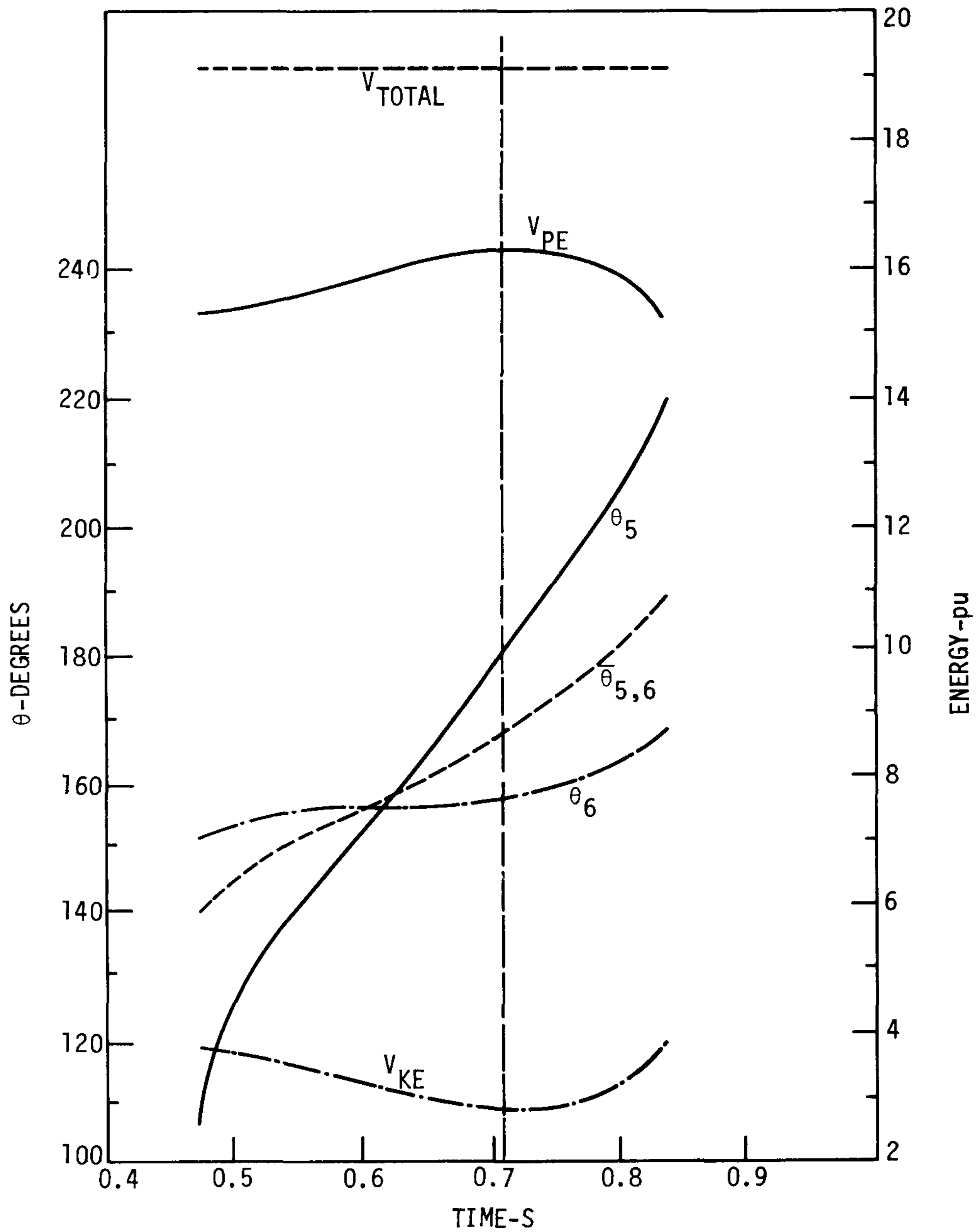


Figure 3-8. 17-generator system. Fault at Bus 372 cleared in 0.1932s.

Examining these runs and the figures, we note the following:

- Swings of Generators No. 5 and 6 peak about 0.3 seconds apart.
- The peak of the potential energy and the minimum of the kinetic energy coincide with the peak of the (fictitious) inertial center of the two generators ($\bar{\theta}_{5,6}$) for t_c under the critical value.
- For t_c just under the critical value (t_c = 0.192 s), the peak of $\bar{\theta}_{5,6}$ coincides with a system potential energy nearly equal to that of the u.e.p. At that instant, $\theta_5^u = 156°$ and $\theta_6^u = 141°$, which are very close to the predicted θ_5^u and θ_6^u. The system trajectory continues toward a maximum potential energy and minimum kinetic energy at a later instant in the other cases.
- From the computer runs (not shown in the figures), we note that at the instant of maximum potential energy, the rotors of the four equivalent machines, which are remote from the disturbance, are given by

$$\theta_1 = 6.6°,\ \theta_{13} = -31.5°,\ \theta_{14} = -30.4° \text{ and } \theta_{15} = -21.1°$$

- Therefore, the system trajectory seems to be passing near, but not exactly through, the controlling u.e.p. Again, while the generators tending to separate from the rest of the system pass at or very near their u.e.p. values, the rotors of the other generators are at positions off by a few degrees from their corresponding values at the u.e.p.
- The kinetic energy minimum is not zero, a point of significance that will be discussed in a later section.
- For $t_c > t_{critical}$ (t_c = 0.1932 s), the system crossed the potential energy "ridge" at a point different from the u.e.p. At that point, the system potential energy is close to that of the u.e.p.

The data presented in Figures 3-4 through 3-8 shows that the concept of a particular u.e.p. controlling the faulted trajectory is a valid one. The "critical machines" appear to be at or very near their θ^u values at critical clearing, and the system potential energy, if corrected for the change in θ^s, is very close to that of V_u. However, there are two additional points of significance to be noted: the system minimum kinetic energy is not zero, and generators other than the critical ones may be off from their θ^u values for trajectories at critical clearing.

Energy Analysis

A more detailed examination of the transient energy of the 17-generator system is carried out at various instants along the system trajectory. Again, the same fault (at Bus 372 cleared by opening line 372-193) is investigated for three instants of clearing:

1. Fault cleared in 0.15 s

   The system is stable and the clearing time is well below critical clearing. Data on this disturbance is displayed in Figures 3-9(a) and 3-9(b). Figure 3-9(a) shows the rotor swings of Generators No. 5 and 6 and their inertial center $\bar{\theta}_{5,6}$, as well as the rotor swings of some other selected generators remote from the disturbance (Generators No. 2, 10, 13, 16). The transient energy for this case and its four components is shown in Figure 3-9(b). The plot of the total energy clearly shows the accumulation of excess energy up to the instant of clearing (0.15 s); afterwards, the total energy remains constant. This shows that no additional excess transient energy is injected into the system following clearing. The variation of the potential energy V_{PE} (position, magnetic, and dissipation) and the kinetic energy V_{KE} is of particular interest. Energy is exchanged back and forth between them. The maximum potential energy V_{PE} approximately corresponds to the minimum kinetic energy V_{KE} and coincides with the instant at which the inertial center of the critical machines, i.e., $\bar{\theta}_{5,6}$, acquires zero velocity.

2. Fault cleared at 0.1923 s and 0.1926 s

   These two cases represent critical trajectories. With t_c = 0.1923 s the system is critically stable, while with t_c = 0.1926 s the system is critically unstable. The data for the former case is shown in Figures 3-10(a) (rotor trajectories) and 3-10(b) (energy); data for the latter case is displayed in Figures 3-11(a) and 3-11(b). We note that the trajectories pass very near the u.e.p. ($\theta_5 = 166°$, $\theta_6 = 144°$) at about 0.7 s. This also corresponds to the instant when $\bar{\theta}_{5,6}$ reaches its peak (or zero velocity) in the stable case, and the inflection point in the un-

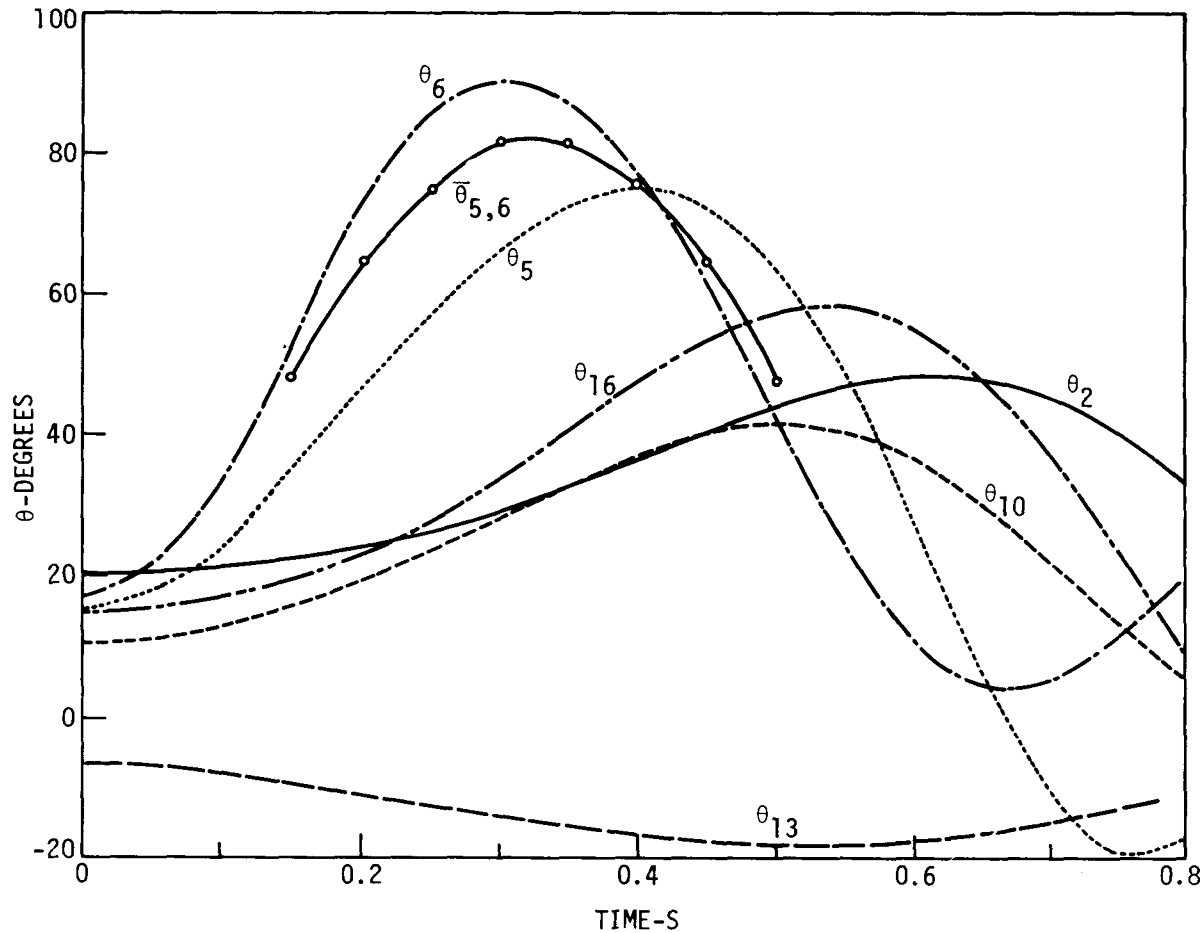


Figure 3-9(a). 17-generator system. Fault at Bus 372 cleared in 0.150s. Rotor Angles.

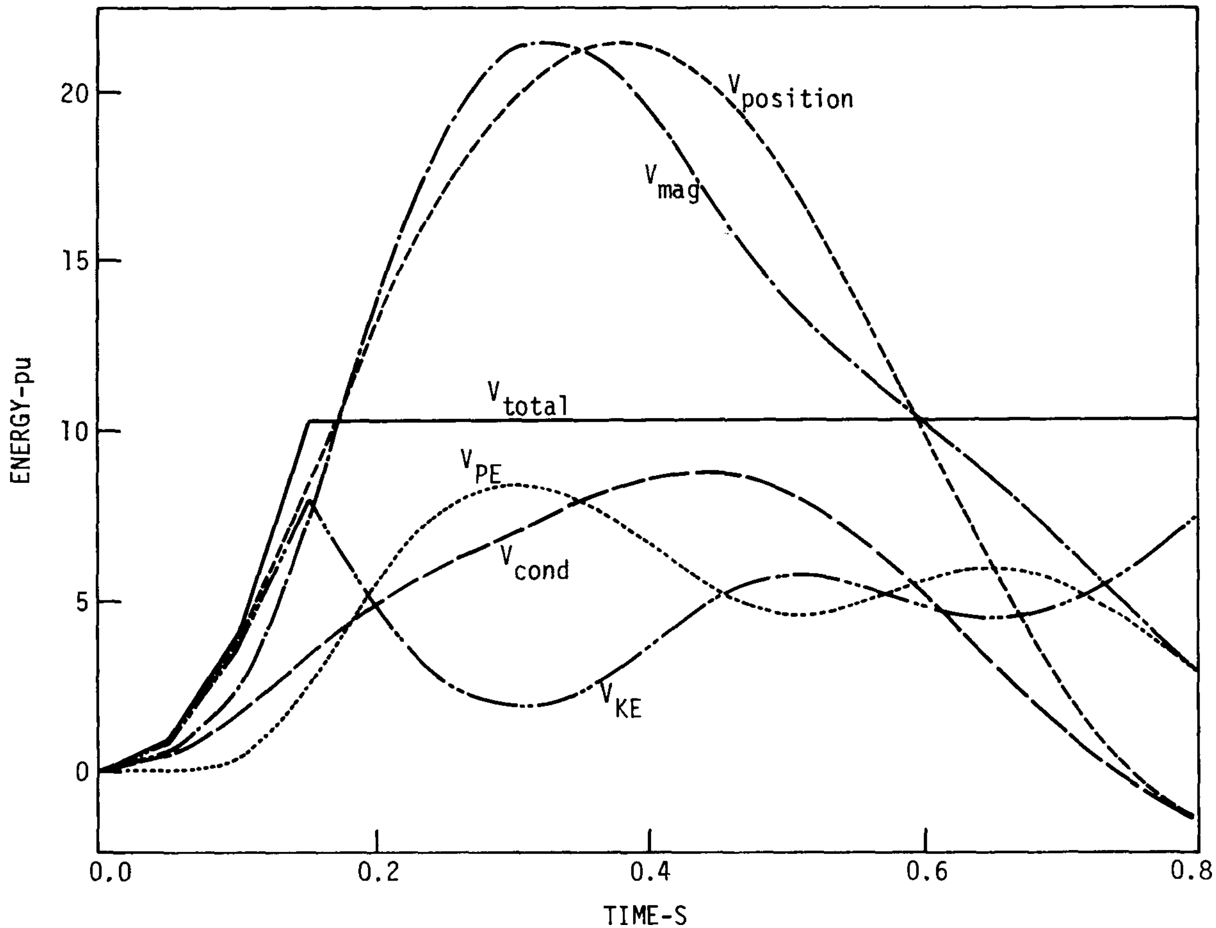


Figure 3-9(b). 17-generator system. Fault at Bus 372 cleared in 0.150s. Energy.

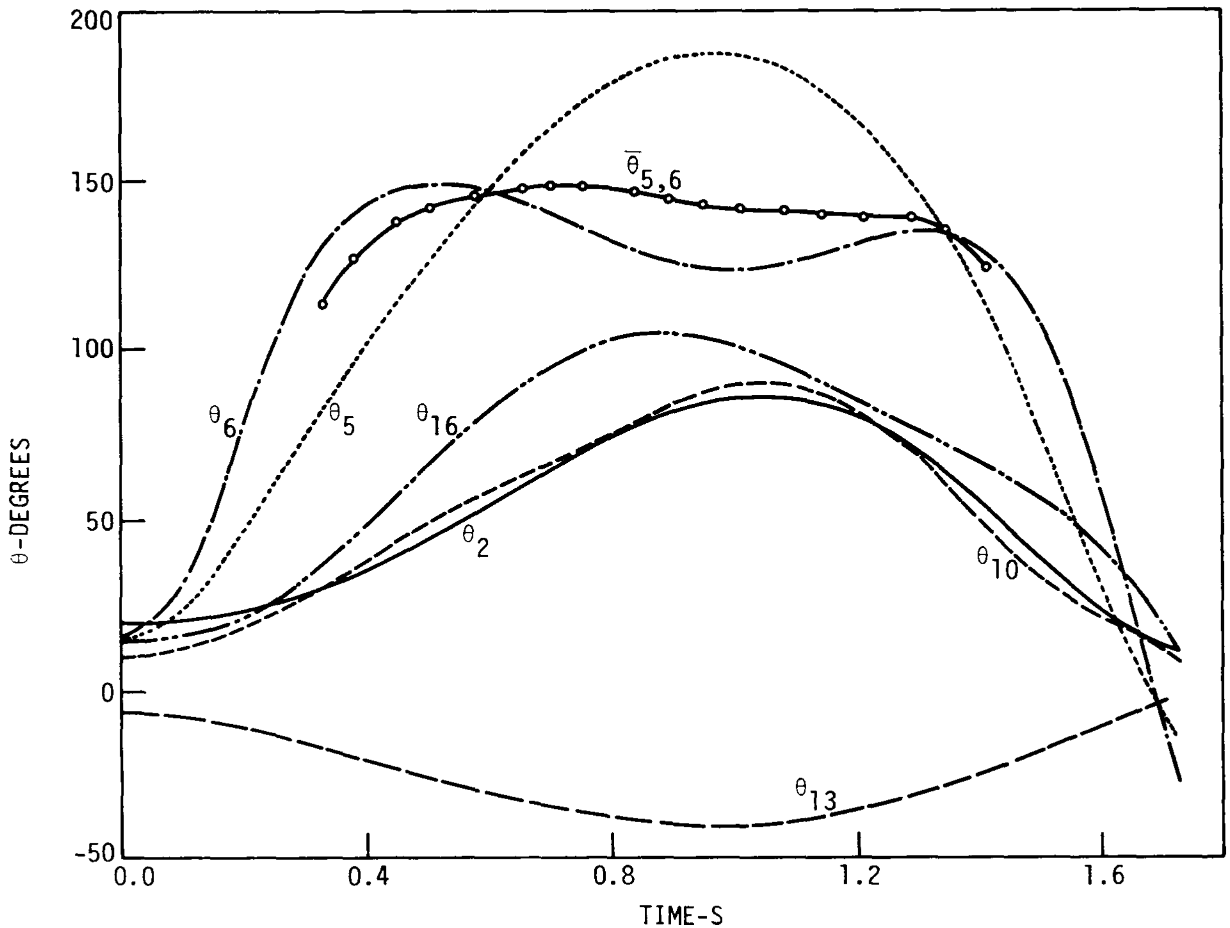


Figure 3-10(a). 17-generator system. Fault at Bus 372 cleared in 0.1923s. Rotor Angles.

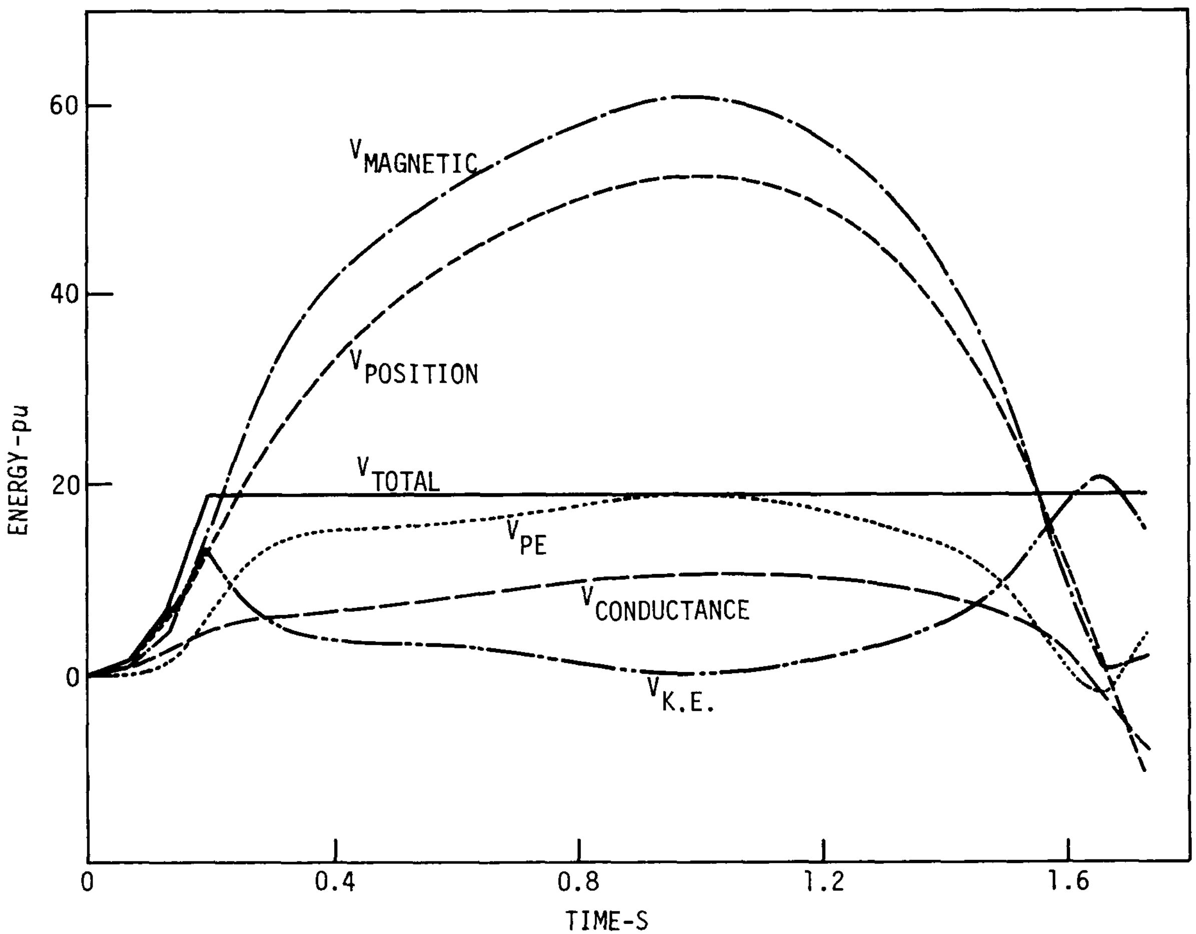


Figure 3-10(b). 17-generator system. Fault at Bus 372 cleared in 0.1923s. Energy.

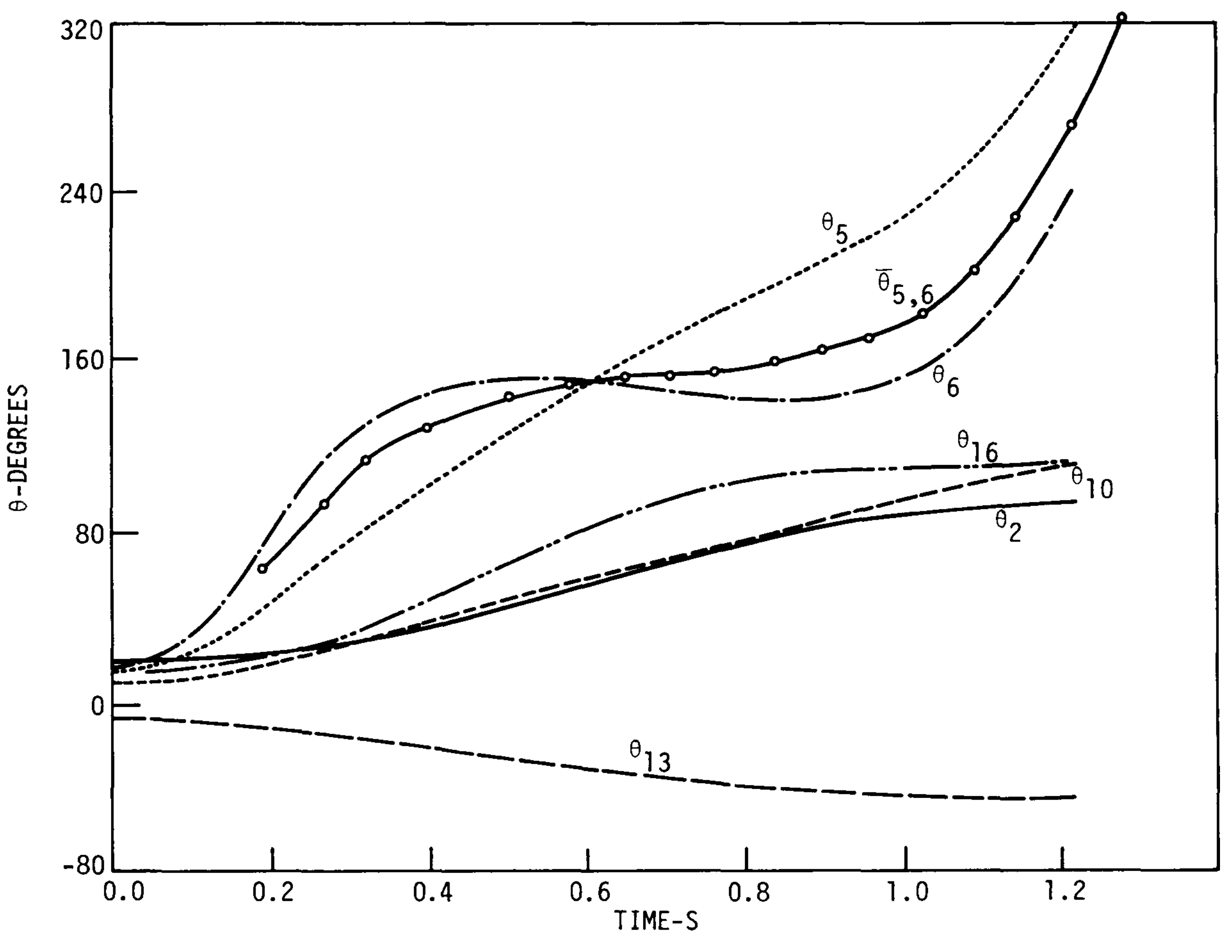


Figure 3-11(a). 17-generator system. Fault at Bus 372 cleared in 0.1926s. Rotor Angles.

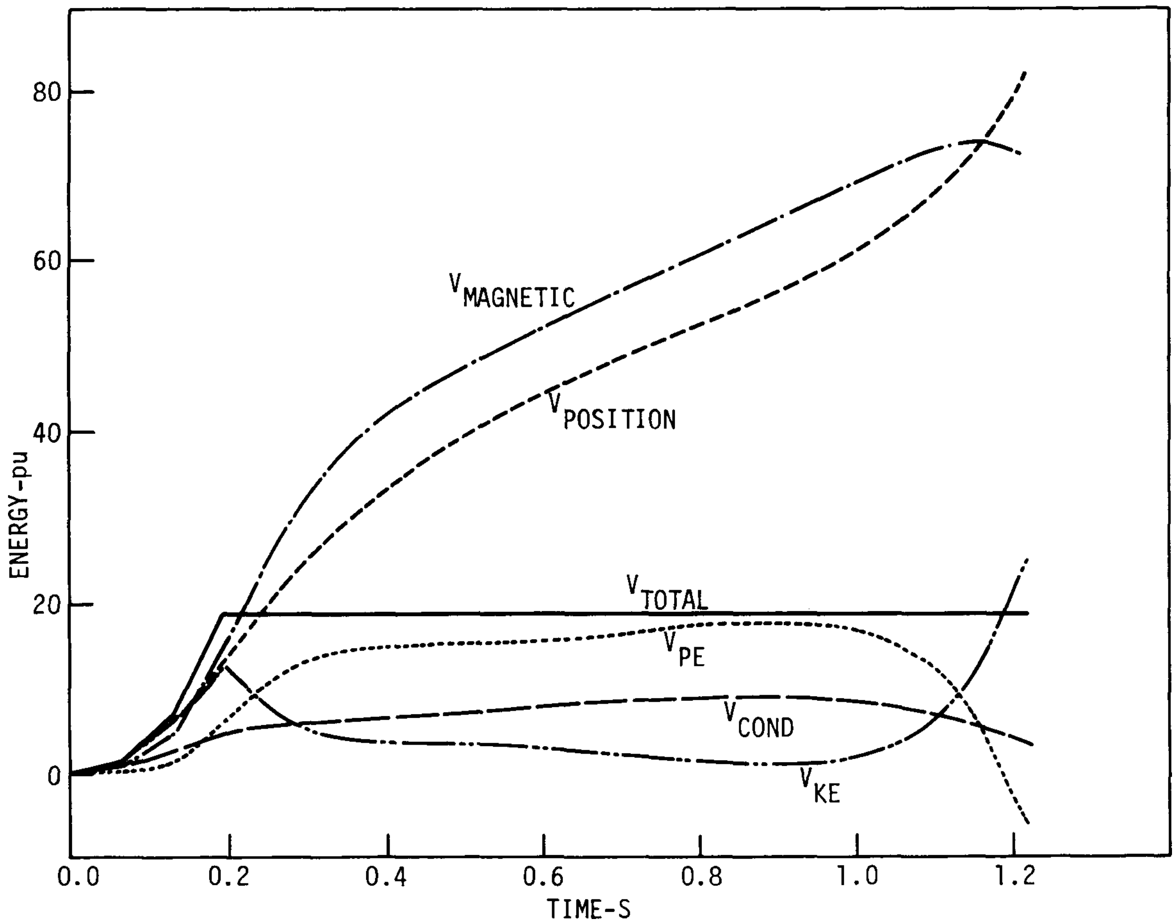


Figure 3-11(b). 17-generator system. Fault at Bus 372 cleared in 0.1926s. Energy.

stable case. Thus, we see clearly that the critical machines coincide with their u.e.p. angles at the peak of the swing of their inertial center. From simple interpolation of the stable trajectory data, the point where $\bar{\theta}_{5,6} = 0$ occurs at t = 0.7 s and V_{PE} = 16.73 pu. For the unstable trajectory, the point is indicated by the point of inflection, which occurs at t = 0.735 s and V_{PE} = 16.97 pu. We conclude from this data that the maximum transient energy that the system can absorb, i.e., the critical energy V_{cr}, must lie between these two values, or

$$16.73 \leq V_{cr} \leq 16.97$$

Figures 3-10(b) and 3-11(b) reveal a very important aspect of the energy distribution along the system trajectory. It is sometimes reported in the literature that the critical energy, which is related to the network's maximum ability to absorb the excess transient energy, is the maximum potential energy along the trajectory. We have already seen that the critical energy V_{cr} is less than 17 units. Figure 3-10(b) shows, however, that the maximum V_{PE} is 18.75 pu and occurs at t = 0.96 s. That the system cannot absorb this amount of excess energy is evident from Figure 3-11(b), where the system becomes unstable when less than this amount of transient energy is injected into the system. Indeed, for that case, when the energy is 17.9 pu (at t = 0.9 s), $\bar{\theta}_{5,6}$ is already accelerating toward instability. An additional observation concerning the kinetic energy is in order. The instant where the trajectory comes close to the u.e.p. and $\bar{\theta}_{5,6}$ reaches its peak, the kinetic energy of the system is not zero; rather, at that instant, V_{KE} = 2.17 pu. In the unstable trajectory, the instant at which $\bar{\theta}_{5,6}$ passes at the inflection point, V_{KE} = 1.967.

This data is of considerable significance to transient stability analysis by direct methods. It clearly indicates that:

- The critical transient energy occurs when the critical machines in the system (i.e., the generators tending to separate from the rest) pass at (or very near to) their value at the u.e.p. This amount of critical transient energy appears to be exactly the same as the value of V at the u.e.p. Our own extensive investigations seem to indicate that for all practical purposes the value of V_u (at θ^u) can be used with sufficient accuracy as V_{cr}.

- A certain amount of kinetic energy, between 1.967 and 2.17 units, is not absorbed by the system at the u.e.p. This indicates that not all excess energy created by the fault contributes to the instability of the system. This component is responsible for much of the intermachine motion, not in separating the critical machines from the others.

DISCUSSION AND CONCLUSIONS

The results of the previous sections merit the following conclusions:

1. The concept of a controlling u.e.p. for a particular system trajectory is a valid concept.

2. From the values of θ_i^u, $i = 1,2,\ldots,n$, the critical machines, i.e., the generators tending to separate from the rest, are identified by $\theta_i > \pi/2$.

3. At critical clearing, the system trajectory is such that only the critical machines need pass at, or very near to, their values at the u.e.p. Other generators may be slightly off from their u.e.p. values.

4. If more than one generator tends to lose synchronism, instability is determined by the gross motion of these machines, i.e., by the motion of their center of inertia.

5. The value of V_u (at the u.e.p.) is, for all practical purposes, equal to the critical energy V_{cr} for the system.

6. Not all the excess kinetic energy (at t_c) contributes directly to the separation of the critical machines from the rest of the system; some of that energy accounts for the other intermachine swings. For stability analysis, that component of kinetic energy should be subtracted from the energy that needs to be absorbed by the system for stability to be maintained.

7. First swing transient stability analysis can be made accurately and directly (without time solutions) if:

   --The transient energy is calculated at the end of the disturbance and corrected for the kinetic energy that does not contribute to system separation.

   --The unstable equilibrium point (θ^u) and its energy are computed.

Section 4

THE TRANSIENT ENERGY MARGIN

DEFINING THE TRANSIENT ENERGY MARGIN

In the previous section, the expressions for the system transient energy, using SCI's energy function method, are given. The values of transient energy at the instant of fault clearing V_{cl}, using the prefault stable equilibrium point θ^{s1} and the postfault network, are given by

$$V_{cl} = V\Big|_{\theta^{s1}}^{\theta^{cl}}$$

$$= \frac{1}{2}\sum_{i=1}^{n} M_i(\omega_i^c)^2 - \sum_{i=1}^{n} P_i(\theta_i^c - \theta_i^{s1}) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} [C_{ij}(\cos\theta_{ij}^c - \cos\theta_{ij}^{s1}) + I_{ij}^c] \quad (4\text{-}1)$$

where the superscript f is used to indicate the parameters of faulted network.

The critical energy is assumed to be the energy at the θ^u with zero velocities and the postfault network. This energy is given by

$$V_{cr} = V\Big|_{\theta^{s2}}^{\theta^{u}} = -\sum_{i=1}^{n} P_i(\theta_i^u - \theta_i^{s2}) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} [C_{ij}(\cos\theta_{ij}^u - \cos\theta_{ij}^{s2}) + I_{ij}^u] \quad (4\text{-}2)$$

The system transient energy margin is obtained from these two expressions. The comparison must be made on the same energy data, which is the postfault θ^{s2}. Thus, the correct transient energy margin is given by

$$\Delta V = V_{cr}\Big|_{\theta^{s2}}^{\theta^{u}} - V_{cl}\Big|_{\theta^{s2}}^{\theta^{c}} \overset{\Delta}{=} \text{transient energy margin} \quad (4\text{-}3)$$

Substituting for V_{cr} and V_{cl} in Eq. 4-3, we can show that the transient energy margin is given by

$$\Delta V = V\Big|_{\theta^c}^{\theta^u} \triangleq \text{transient energy margin} \tag{4-4}$$

Thus, by knowing the values of rotor angles and speeds at clearing and the position of the relevant u.e.p., the transient energy margin can be evaluated using the post disturbance network. In other words, there is no need to compute the value of the energy function at θ^c, and its value at θ^u (with each referred to the same θ^s), and then to compute the difference. This is analogous to the concept of electric potential or voltage (which is defined as the work done per unit charge). The potential difference between two points could be computed directly or could be computed as the difference between the potential of each point with respect to ground. The special computer programs developed at Iowa State for this project used Eq. 4-4 to compute the energy margin.

One point needs some clarification. If V_{cl} and V_{cr} are calculated separately, as in the case in the SCI computer package for example, they are usually given to a different stable equilibrium point: V_{cl} is computed with respect to θ^{s1}, while V_{cr} is computed with respect to θ^{s2}. In this case, a correction term must be used in the calculation of the energy margin, as given in Eq. 4-5.

$$\Delta V = V_{cr} - V_{cl}\Big|_{\theta^{s1}}^{\theta^c} + V_{cl}\Big|_{\theta^{s1}}^{\theta^{s2}} \tag{4-5}$$

We should point out here that if θ^{s1} and θ^{s2} are different, as is the case when the postfault power network differs from that at prefault, the correction in Eq. 4-5 should be used. If this correction is not used, somewhat conservative results in stability analysis will often be obtained.

In addition to the correction cited above, another correction must be made to compute the "true" energy margin for the system, which would be indicative of how much more excess or transient energy can be injected into the power system before instability occurs. This correction is in the component of the system kinetic energy that contributes to the separation of the critical machine(s) from the rest of the system.

In the next section we will deal with the corrections that need to be made so that the transient energy margin may be correctly computed.

TRANSIENT ENERGY MARGIN CORRECTIONS

As previously mentioned, two corrections need to be made in the computation of the transient energy margin:

- Correction to express V_{cr} and V_{cl} to the same reference u.e.p.
- Correction to the transient kinetic energy to remove the kinetic energy components that do not contribute to system separation.

Correction Due to Change in θ^s

The usual manner in which the transient energy is computed at clearing is given by

$$V_{cl} = V\Big|_{\theta^{s1}}^{\theta^c}$$

while at θ^u

$$V_{cr} = V\Big|_{\theta^{s2}}^{\theta^u}$$

Using the same reference for both is equivalent to adding a correction term to the energy at θ^u

$$V_{correction} = V\Big|_{\theta^{s1}}^{\theta^{s2}} \qquad (4\text{-}6)$$

4-Generator System. The pertinent data for a three-phase fault at Bus 10 cleared by opening one of the lines 8-10 is shown in Table 4-1. The potential energy at this particular θ^u is 0.6261 pu. This energy is calculated with respect to θ^{s2}. The correction term, as per Eq. 4-6, is

$$V\Big|_{\theta^{s1}}^{\theta^{s2}} = -0.0558 \text{ pu}$$

This correction term must be either added to the value of V at θ^u or subtracted from the value of V at θ^c. In either case, the effect is to reduce the critical transient energy at clearing by about 9% (for this particular case). In other words,

$$V\Big|_{\theta^{s1}}^{\theta^u} - V\Big|_{\theta^{s1}}^{\theta^{s2}} = V\Big|_{\theta^{s2}}^{\theta^u}$$

Table 4-1

4-GENERATOR SYSTEM
FAULT AT BUS 10, LINE 8-10 CLEARED

Generator Number	θ^{s1} (degrees)	θ^{s2} (degrees)	θ^{u} [a] (degrees)
1	6.95	- 7.42	- 27.72
2	13.48	0.98	- 5.53
3	8.26	- 4.32	- 11.33
4	24.93	28.47	113.24

[a] This is the value of θ^u for this particular transient.

<u>17-Generator System</u>. A three-phase fault at Bus 372 (Raun 345-kV bus) cleared by opening line 372-193 is analyzed. The critical machines are Generators No. 5 and 6 (which are close to the fault) as indicated by their u.e.p. values shown in Table 4-2.

The potential energy at this particular θ^u is 17.16 pu, calculated with respect to θ^{s2}. The correction term is given by

$$V\Big|_{\theta^{s1}}^{\theta^{s2}} = -0.498 \text{ pu}$$

Again, this correction term must be added to the potential energy at the u.e.p. (θ^u) if the critical transient energy at clearing is to be determined.

Table 4-2

17-GENERATOR SYSTEM (REDUCED IOWA SYSTEM)
FAULT AT BUS 372, LINE 372-193 CLEARED

Generator Number	θ^{s1} (degrees) Arbitrary Reference	θ^{s1} (degrees) COI Reference	θ^{s2} (degrees) COI Reference	θ^{u} (degrees) (for this transient) COI Reference
1	-27.92	- 6.26	- 4.92	- 1.41
2	- 1.37	20.28	22.26	46.63
3	-16.28	5.38	5.60	9.68
4	-26.09	- 4.42	- 8.34	- 23.95
5	- 6.24	15.41	18.87	163.55
6	- 4.56	17.10	21.57	144.87
7	-23.02	- 1.35	- 1.53	- 15.96
8	-26.95	- 5.29	- 4.76	- 7.98
9	-12.41	9.25	8.91	- 6.62
10	-11.12	10.53	12.85	47.77
11	-24.30	- 2.64	- 1.17	10.28
12	-10.10	11.55	13.90	49.58
13	-28.10	- 6.44	- 6.61	- 25.80
14	-26.76	- 5.10	- 5.08	- 23.62
15	-21.09	0.56	- 2.12	- 17.61
16	- 6.70	14.95	17.78	63.55
17	- 4.35	17.30	19.43	50.06

Kinetic Energy Correction

The transient kinetic energy which is responsible for the separation of the critical generators from the rest of the system is that associated with the gross motion of the critical generators, i.e., that of their inertial center with regard to the inertial center of the other generators. The remaining portion of the transient kinetic energy need not be absorbed by the network for stability to be maintained. It is identified with the intermachine motion in each of the groups separating from each other.

The kinetic energy associated with the gross motion of a group of k machines having angular speeds $\omega_1, \omega_2, \ldots, \omega_k$ is the same as the kinetic energy of their inertial center. The speed of the inertial center of that group and its kinetic energy are given by

$$\omega = \sum_{i=1}^{k} M_i \omega_i / \sum_{i=1}^{k} M_i \tag{4-7}$$

$$V_{KE} = \frac{1}{2} \left(\sum_{i=1}^{k} M_i \right) (\omega)^2 \tag{4-8}$$

If the system contains very large inertias, i.e., the center of inertia of the whole power system is nearly stationary, the kinetic energy given by Eq. 4-8 tends to separate that group of generators from the rest of the system. If these are the "critical machines," i.e., the generators tending to separate from the system, then the kinetic energy given by Eq. 4-8 is the correct V_{KE} contributing to system separation. The kinetic energy term in V_{cl} should be corrected accordingly.

If the system inertias are finite, i.e., if the system's inertial center is not stationary, the kinetic energy that contributes to system separation is a little more complex. Essentially, the disturbance splits the generators of the system into two groups: the critical machines and the rest of the generators. Their inertial centers have inertia constants and angular speeds M_{cr}, ω_{cr} and M_{sys}, ω_{sys}, respectively. The gross motion of the two groups approximates that of a two-machine system. The kinetic energy causing the separation of the two groups is the same as that of an equivalent one-machine-infinite-bus system having inertia constant M_{eq} and angular speed ω_{eq} given by

$$M_{eq} = \frac{M_{cr} \cdot M_{sys}}{M_{cr} + M_{sys}}$$

(4-9)

$$\omega_{eq} = (\omega_{cr} - \omega_{sys})$$

and the corresponding kinetic energy is given by

$$V_{KE} = \frac{1}{2} M_{eq} (\omega_{eq})^2 \qquad (4\text{-}10)$$

Again the kinetic energy term in V_{cl} should be corrected accordingly. We note that as the ratio (M_{sys}/M_{cr}) gets large, Eqs. 4-8 and 4-10 give nearly the same result.

The kinetic energy contributing to system separation is illustrated by the following examples.

4-Generator System. For a three-phase fault at Bus 10 cleared in 0.1 s by opening one of the lines 8-10, the critical machine is Generator No. 4, which tends to separate from the system. Data for calculating the kinetic energy correction at clearing is shown in Table 4-3.

Table 4-3

4-GENERATOR SYSTEM
FAULT AT BUS 10 CLEARED AT 0.1 s

Generator Number	M_i	ω^c (pu)	V_{KE} (pu)
1	0.1254	-0.0024	0.0507
2	0.034	-0.0005	0.0006
3	0.016	-0.0005	0.0003
4	0.034	0.0095	0.2187

From the data in Table 4-3, we note that the total V_{KE} = 0.2701 pu. The kinetic energy of the critical machine (Generator No. 4) is 0.2187 pu. The inertia of this machine is about 16% of the total system inertia. While the total inertia of the remaining generators is much greater than that of the critical machine, it is evident that the system is split into two groups: Generator No. 4 is accelerating and Generators No. 1, 2, and 3 are decelerating. Converting to an equivalent two-machine system, we get

$M_{cr} = 0.034$ $\omega_{cr} = 0.00951$ pu

$M_{sys} = 0.1754$ $\omega_{sys} = 0.00184$ pu

The one-machine equivalent is given by

$M_{eq} = 0.02848$ $\omega_{eq} = 0.01136$ pu

and

$$V_{KE}\big|_{eq} = 0.2611$$

Comparing this value to the V_{KE} at clearing (0.2703), the kinetic energy correction for this case is -0.009 pu.

17-Generator System. For a three-phase fault at Bus 362 cleared in 0.15 s by opening line 372-193, the critical generators are Generators No. 5 and 6, which tend to separate from the system. Data for calculating the kinetic energy correction at clearing is given in Table 4-4. Although the inertia of the critical machines (Generators No. 5 and 6) is only about 5% of the total inertia of the system, the inertial center of the system is decelerating. To calculate the kinetic energy correction, we compute the data for the equivalent one-machine system as

$M_{eq} = 0.24812$ $\omega_{eq} = 0.0197$ pu

and

$$V_{KE}\big|_{eq} = 6.839$$

From Table 4-2, the total kinetic energy at clearing is 7.97 pu. Thus, the kinetic energy correction at clearing is -1.131 pu.

Finally, we note that the kinetic energy of the inertial center of the critical machines (6.53 pu in Table 4-4) is somewhat less than the actual kinetic energy contributing to system separation of 6.839 pu calculated before, even though the critical machines make up only 5% of the system inertia. The reason for this difference is that there is a significant amount of kinetic energy associated with small retarding motion of the large inertia.

Table 4-4

17-GENERATOR SYSTEM
FAULT AT BUS 372 CLEARED IN 0.15 s

Generator Number	M_i	ω^c (pu)	V_{KE} (pu)
5	0.08907	0.01142	0.83
6	0.17236	0.02252	6.22
Inertial Center of 5,6	0.26143	0.01874	6.53
All Others	4.87442	-0.000954	0.92

PROCEDURE FOR COMPUTING TRANSIENT ENERGY MARGIN

The transient energy margin for a given power system and a specific disturbance is the difference between two values of system energies:

- V_{cr} is the value of the system energy function at the relevant u.e.p.
- V_{cl} is the value of the system transient energy at the end of the disturbance, e.g., at fault clearing when the disturbance is a fault.

As discussed in the previous section both values must be computed to the same reference, and V_{cl} must be corrected for the kinetic energy that does not contribute to system separation.

The procedure for implementing this involves several steps, which are outlined below:

1. Identifying the critical machines, i.e., the generators tending to separate from the rest of the system.

2. Identifying the relevant u.e.p. (θ^u) for the disturbance under investigation and the specific post disturbance network configuration.

3. Computing the angles and speeds of the various generators at fault clearing, i.e., θ^c and ω^c.

4. Computing V_u at θ^u and correcting it for θ^{s1} if necessary.

5. Computing V_{cl} from θ^c and ω^c.

6. Computing the kinetic energy (at clearing) that does not contribute to system separation, and correcting V_{cl} accordingly (see previous section).

7. ΔV = corrected V_u - corrected V_{cl}.

8. If the procedure is repeated (for other post disturbance network configurations) computing changes in the network Y-bus and the corresponding θ^u and V_u.

These steps are identified mainly to bring out the nature of the computational effort involved and to show the possible complexities encountered during implementation. In practice, however, some of the steps are combined.

The computations are actually performed by three separate computer programs (or packages of programs).

Package 1

In this package the following information is obtained:

- During the fault period, generator rotor positions, speeds, and components of their accelerations.
- The postfault Y-bus.
- The transient energy function at clearing V_{cl} (using the postfault Y-bus).

This package is based on programs received from SCI. It has been modified to include the following features:

- Plotting rotor positions of individual generators.
- Computing and plotting the position of the inertial center of a group of generators.

We also mention that this package of computer programs has been used extensively for investigating the system transient energy and the system trajectories discussed in various sections of this report.

Finally, we should point out that much of the information obtained from this program, except for the Y-bus, can be obtained by a simplified procedure, which is discussed later in this section.

Package 2

From the information obtained from Package 1 (specifically, from the accelerations and their derivatives) and the postfault Y-bus, the mode of instability promoted by the fault-on period is determined by a special estimating procedure. This technique "suggests" a u.e.p. that may control the mode of instability for the specified sequence of events. Knowing the controlling u.e.p. (θ^u), the value of V_u can be computed.

For this procedure, we initially used a package of programs received from SCI. We found out, however, that in some cases the method failed to predict the correct u.e.p.; sometimes it even failed to converge. We therefore have developed our own procedure using a technique developed by Davidon-Fletcher-Powell (DFP) and contained in a subroutine in the package received from SCI. In our procedure, we start the DFP process from initial positions obtained from the information available to us from the study of the system trajectory.

Package 3

This package of programs calculates the transient energy margin as well as the additional power perturbations to consume that margin. The information needed is obtained from the previous packages: θ^u, θ^c, ω^c, and Y-bus; also the critical machines are identified. The information obtained is:

- $\Delta V = V\Big|_{\theta^c}^{\theta^u}$ (no correction for θ^s is needed).
- Kinetic energy that does not contribute to system separation and consequently the corrected ΔV.
- When postfault network changes are included, modifies the system Y-bus and recomputes ΔV.
- ΔP to consume this ΔV.

This package was entirely developed for this research project.

SPECIAL ISSUES ADDRESSED IN TRANSIENT MARGIN COMPUTATION

In the procedure for computing the transient energy margin discussed previously, certain problems merit special consideration. They are discussed in this section.

Identification of the Critical Generators

A disturbance creates an unbalance between the mechanical power input and the electrical power output of the various generators. This unbalance forces the generators to accelerate or decelerate, depending upon whether they have excess or deficient power. However, the severity of the impact of the disturbance on the various generators will vary considerably. The net effect is that some of the generators (the ones most severely disturbed) will tend to separate from the rest of the system. When the disturbance is removed (e.g., a fault is cleared), the synchronizing forces tending to hold the generators in synchronism are greatly increased. Again, these forces will depend on the post disturbance network configuration, and their influence on the different generators may vary considerably.

When the system is disturbed, the trajectory of the generators is determined by the continued effects previously described: the disturbance creates a transient energy that tends to cause a group of generators to separate from the rest, and the post disturbance network helps convert this transient energy to potential energy (which includes dissipation), preserving stability. The motion of each generator will depend on how it is affected by the two types of forces.

In most situations encountered in power systems, the group of generators that tends to separate from the rest of the system is clearly identifiable. If the disturbance is large enough these generators will, as a group, lose synchronism with the rest as governed by their gross motion (or the motion of their inertial center), as discussed in Section 3. There are situations, however, where the group of generators initially separating from the system by the disturbance may not lose synchronism as a group, even when the disturbance is large enough to cause loss of synchronism. When the disturbance is removed, the synchronizing forces are such that some generators within this group will remain in synchronism with the rest of the system while the most severely disturbed machines lose synchronism. These situations may be encountered when a number of power plants are concentrated in a small area of the power network.

The correct identification of the critical generators for a particular sequence of events is essential to the determination of the transient energy margin and, hence, for security assessment. The package of computer programs received from SCI, Inc. and adapted for use by the Iowa State University group determines the relevant u.e.p. by a search technique that attempts to account for the two types of forces on the generators discussed: the initial forces tending to separate some generators from the rest, and the forces tending to absorb the transient energy and convert it to potential energy. As pointed out earlier, in most cases this procedure has been successful in identifying the critical machines and, hence, the corresponding relevant u.e.p. In some situations, however, difficulties were encountered. This will be illustrated by investigating faults on the 17-generator test system.

Investigation of the 17-Generator System

For this system, the following disturbances are investigated:

- A three-phase fault at Raun (Bus 372) cleared by opening line 372-193.
- A three-phase fault at Council Bluffs (C.B.) Generator No. 3 (Bus 436) cleared by opening line 436-771.
- A three-phase fault at Cooper (Bus 6) cleared by opening line 6-439.
- A three-phase fault at Ft. Calhoun (Bus 773) cleared by opening line 773-779.

Using the special computer program packages, the controlling u.e.p. for each disturbance is determined. This particular u.e.p., which assumes a certain mode of instability, identifies the so-called critical machines, i.e., the generators tending to separate from the rest of the system by the disturbance. This information is checked against time solutions to make certain of the identity of the critical generators. In some cases, several modes of instability were found to be possible for the same initial disturbance.

For the Raun fault, the generators tending to separate from the system are Generators No. 5 and 6. This checks with the time solutions shown in Figure 4-1. The critical energy predicted by the special computer program to compute the potential energy at θ^u is comparable to the corrected value of the transient energy at critical clearing, as seen earlier in this section.

For the fault at C.B. No. 3, the critical machines are Generators No. 10 and 12. The swing curves for three clearing times, near $t_{critical}$, are shown in Figure 4-2. While it is possible for Generator No. 12 to lose synchronism alone (t_c = 0.204), the slightest additional transient energy causes both Generators No. 10 and 12 to become unstable. The critical energy for $\theta^u_{12,10}$ is comparable to the corrected value of the transient energy at critical clearing. On the other hand, V_u for θ^u_{12} alone is much lower and would predict a rather conservative critical clearing.

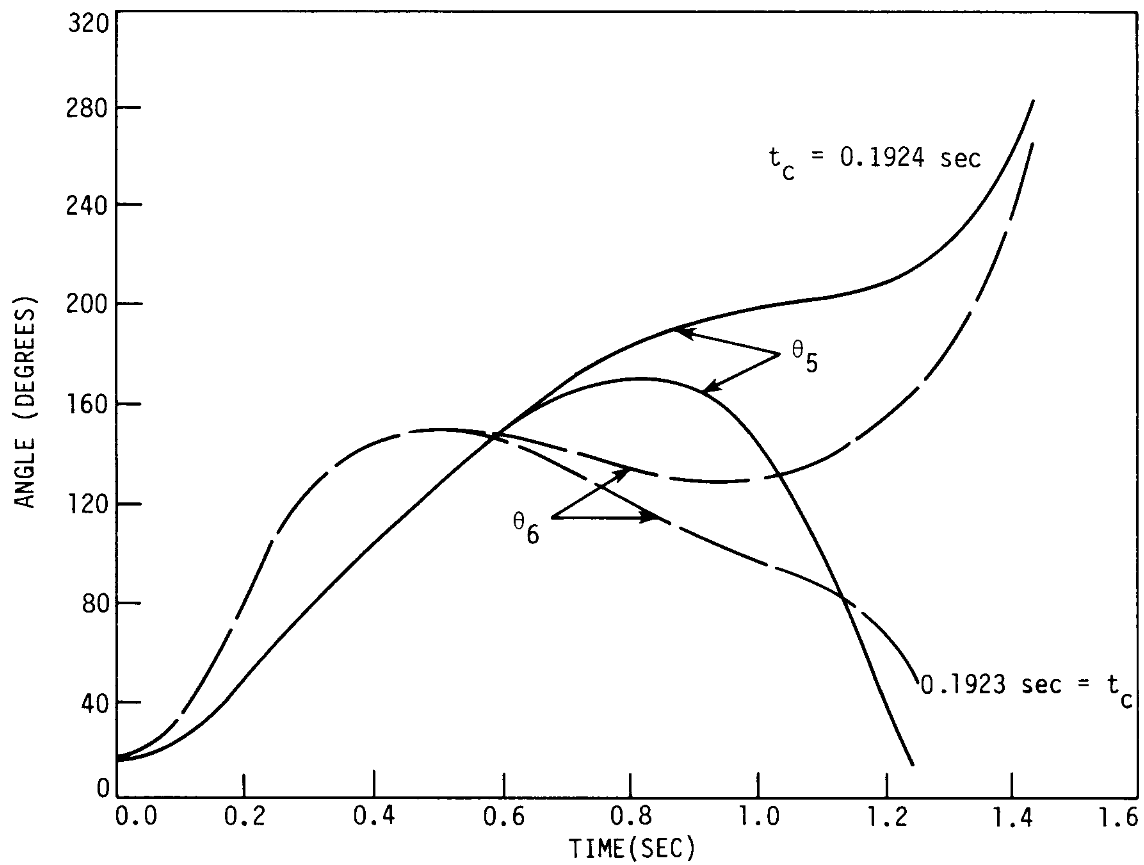


Figure 4-1. 17-generator test system. Swing curves of Generators No. 5 and 6 for RAUN fault; t_c = 0.1923 and 0.1924s.

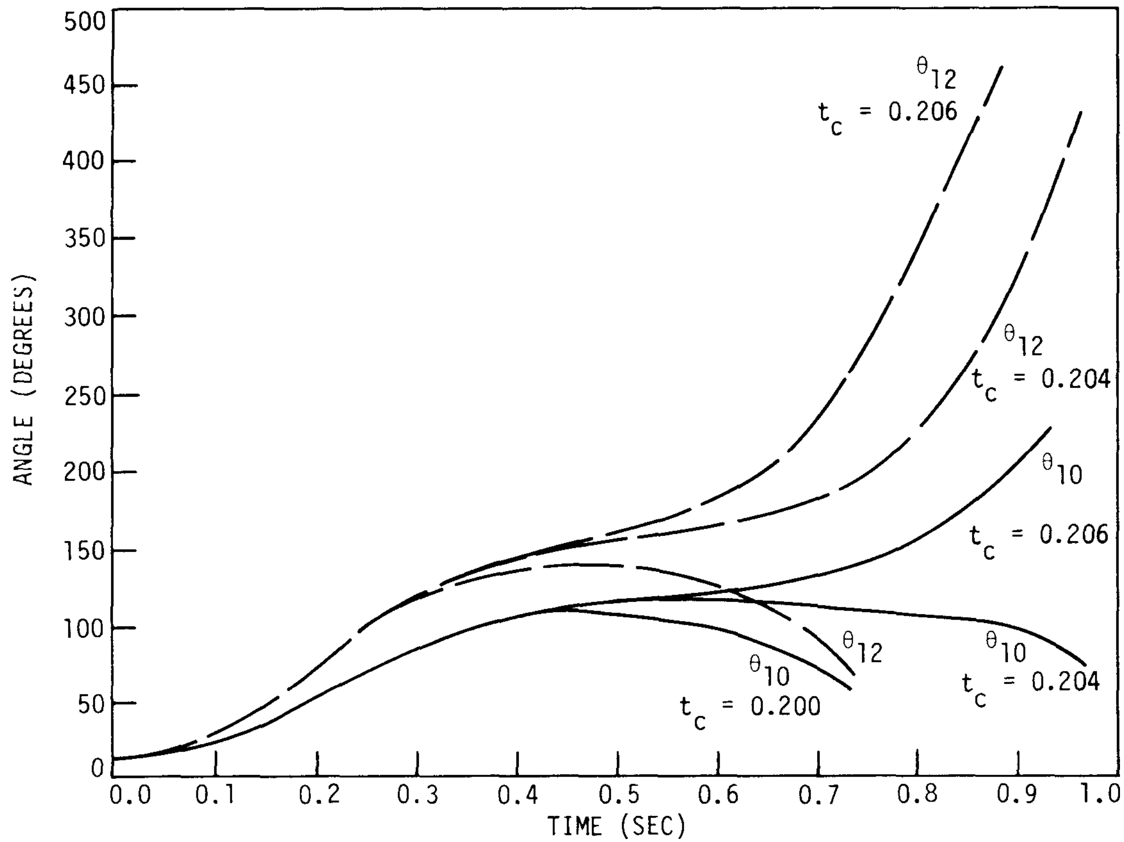


Figure 4-2. 17-generator test system. Swing curves of Generators No. 10 and 12 for fault at Council Bluffs No. 3; t_c = 0.210, 0.204, and 0.206s.

The fault at Cooper (near Generator No. 2) exhibits a similar behavior to that of the fault at C.B. No. 3. Figure 4-3 shows the swing curves for different clearing times. Generator No. 2 loses synchronism alone, unless considerably more transient energy is injected to cause Generator No. 17 to lose synchronism as well (as for $t_c = 0.30$ s). Thus for practical purposes, the mode of instability is that of Generator No. 2 alone. This is confirmed by the fact that the critical energy V_u for θ_2^u alone is comparable to the transient energy at critical clearing.

The situation for the Ft. Calhoun fault is more complex. Figures 4-4(a) and 4-4(b) show the swing curves for six generators for $t_c = 0.357$ s and $t_c = 0.423$ s, respectively. Both are unstable. But in (a), only Generator No. 16 separates from the rest; while in (b), all six generators lose synchronism (plus Generator No. 6, which is not shown in the figure). Detailed investigation of the Ft. Calhoun fault shows that there are several modes of instability possible, with each mode representing a certain group of machines (including Generator No. 16, which is close to the fault) losing synchronism. For each of these modes, a controlling u.e.p. can be identified, each with a corresponding critical energy. These u.e.p.'s have potential energies of similar magnitudes, i.e., in the range of 25.5-28.5 pu, and thus constitute a cluster of u.e.p.'s representing possible modes. Therefore, identification of the controlling u.e.p. is not an easy task. Only the most probable one, i.e., the u.e.p. for which the critical energy most closely matches the energy values along the system trajectory, is selected based on the following reasoning: the disturbance tends to separate the group of Generators No. 2, 5, 6, 10, 12, 16, and 17 from the rest of the system. The energy level needed to separate this group is quite high (about 30 pu). As the system trajectory moves toward the u.e.p. for this group, it encounters the cluster of u.e.p.'s with potential energy levels of 25.5-28.5 pu. This cluster controls the first swing stability of the system for this disturbance. This is confirmed by the fact that the system trajectory in the critically unstable case ($t_c = 0.357$ s) acquires a maximum potential energy of about 25.9 pu.

Data on the critical generators, their associated critical energy (for V_u for the controlling u.e.p.), and the critical transient energy for the four fault locations discussed earlier, are displayed in Table 4-5

Simulation of Disturbances

Computation of the transient energy margin involves the determination of the transient energy at the end of the disturbance, e.g., at fault clearing. For

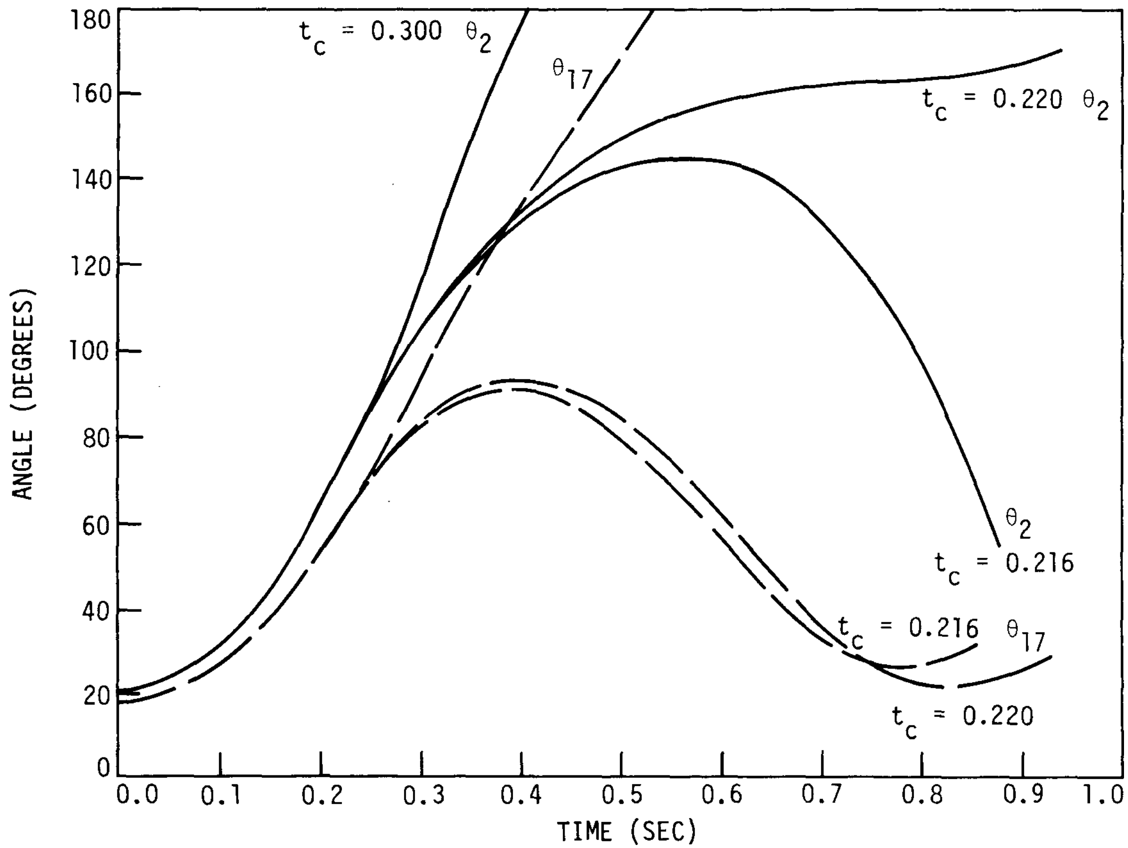


Figure 4-3. 17-generator test system. Swing curves of Generator No. 2 for fault at Cooper; t_c = 0.216, 0.220, 0.30s.

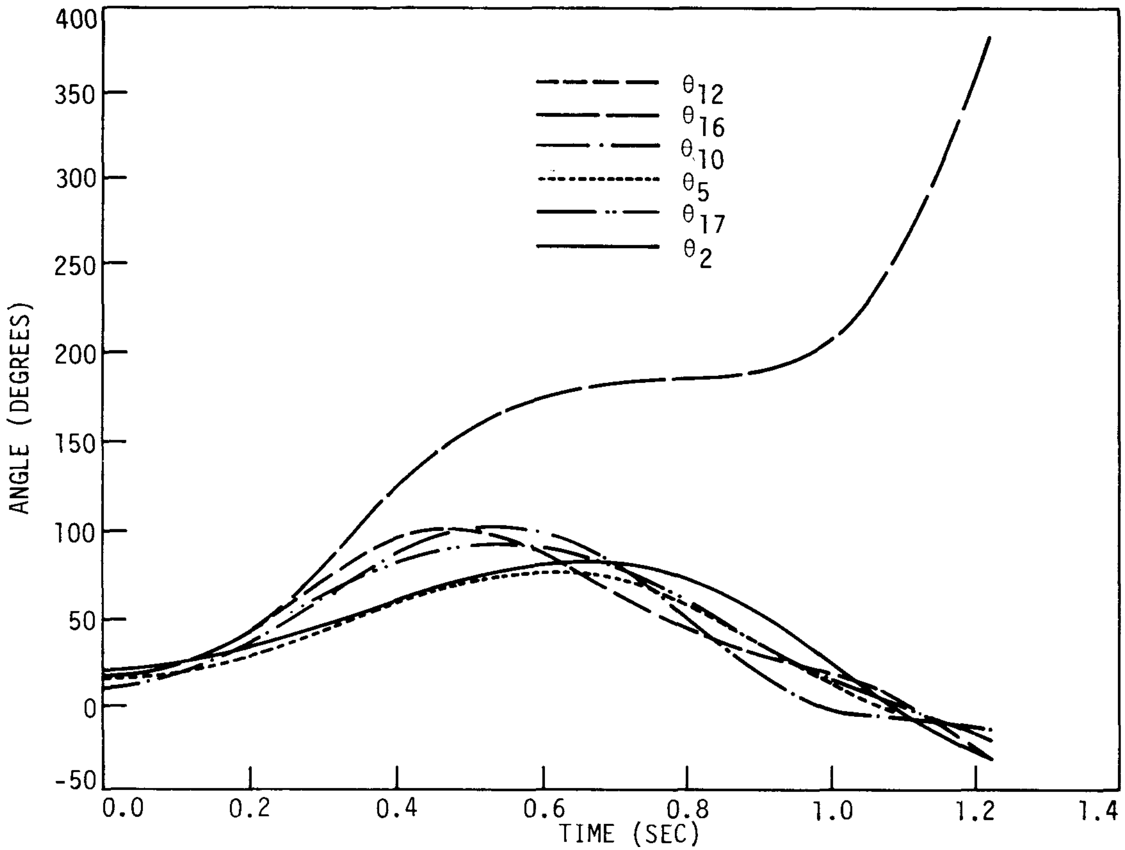


Figure 4-4(a). 17-generator test system. Swing curves of Generators No. 2, 5, 10, 12, 16, and 17 for fault at Ft. Calhoun; t_c = 0.357s.

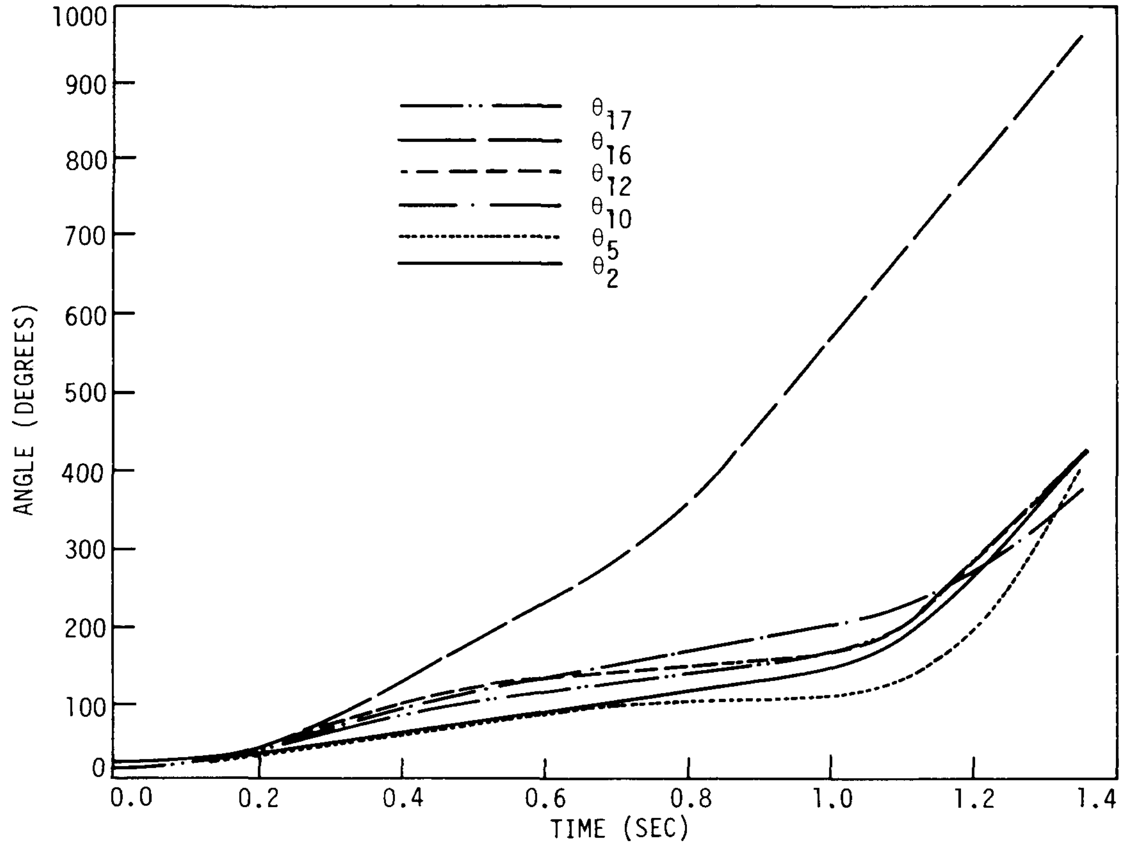


Figure 4-4(b). 17-generator test system. Swing curves of Generators No. 2, 5, 10, 12, 16, and 17 for fault at Ft. Calhoun; t_c = 0.423s.

Table 4-5

DATA FOR CRITICAL GENERATORS
17-GENERATOR SYSTEM

Fault	Critical Generators	Corrected V_u (V_{cr})	Corrected V_{cl}
Raun	5,6	16.66	17.10
C.B. No. 3	10, 12	12.30	13.30
Cooper	2	11.56	13.40
Ft. Calhoun	16, 2, 10, 12, 17	28.25	24.90

on-line security assessment, this must be accomplished without resorting to the use of step-by-step calculation, using a transient stability program. In other words, given an initial set of generator angles and speeds and network conditions, the resulting generator angles and speeds caused by the disturbance must be computed directly. For this to be accomplished, the disturbance itself must be simulated by an initial equivalent change in the angles ($\Delta\delta$'s) and speeds ($\Delta\omega$'s) of the generators and/or equivalent changes in power (ΔP's).

We will consider the effect of the common types of disturbances in an area i:

1. Load change ΔP_i is obviously in one of the appropriate forms.
2. Loss of generation $\Delta P_i = -\Delta$ generation.
3. A fault must be simulated at the instant of clearing. Thus, the generator's angles, speeds, accelerations, and the network condition must be known at that instant. The disturbance is in the form of $-\Delta P(t_o)$, a change in system load or generation due to network switching caused by the fault, and $-\Delta\omega$ and $\Delta\dot{\omega}$, a change of the (equivalent) machine's speed and acceleration due to the fault.

From the observation of the results of many stability studies, we noted that the accelerating power of a synchronous machine is fairly constant during the fault. In this case, the generator speed and angle can be readily estimated at t_c (if t_c is in the order of 0.1 s or less).

For a quick and reliable procedure which can be readily applied on-line, we suggest the following:

1. From the load flow of the faulted network, find $P_e(t_o)$ for each machine. Then, the accelerating power (during the fault) is given by

$$P_a = P_e(o) - P_e(t_o) \quad (4\text{-}11)$$

2. The speed change at fault clearing t_f is given by

$$\Delta\omega = \frac{P_a \; t_f}{2\;H} \text{ pu} \quad (4\text{-}12)$$

3. The angle change at fault clearing is given by

$$\Delta\delta = (377 \times 57.3)\,\frac{P_a \; t_f^2}{4H} \text{ degrees} \quad (4\text{-}13)$$

and

$$\delta(t_o) = \delta_o + \Delta\delta$$

For a long fault duration, e.g., in the case of a stuck breaker, this procedure can be applied in three steps:

1. At time t_1 where $\Delta\omega(t_1)$, $\Delta\delta(t_1)$ and $\delta(t_1)$ are calculated.
2. A new load flow is calculated for the new position of the generator rotors and a new accelerating power $\hat{P}_a$ is calculated.
3. The parameters at the end of the fault time t_2 are

$$\Delta\omega(t_2) = \left[\Delta\omega(t_1) + \frac{\hat{P}_a \; t_2}{2H}\right] \text{pu} \quad (4\text{-}14)$$

$$\Delta\delta(t_2) = (377 \times 57.3)\left[\Delta\omega(t_1) \times t_2 + \frac{\hat{P}_a\left(t_2^2\right)}{4H}\right] \text{degrees}$$

Comparison With System Studies

Calculations were made of the speeds and angles of the generator rotors at the instant of fault clearing for various faults at the Raun bus of the Iowa network. This system is the large network from which the 17-generator system is derived. Three-phase faults which cleared in 0.08, and a single-phase fault which failed

Table 4-6

APPROXIMATED ROTOR SPEEDS AND ANGLES (AT t_c) COMPARED TO DATA OBTAINED BY COMPUTER SIMULATION IOWA NETWORK (NEAL 4 STUDY)

	Three-Phase Fault (T80RURMO) $t_f = 0.08$ s				Single-Phase Fault (S80RMRU3) $t_f = 0.24$ s			
	Approximate Method		Computer Study		Approximate Method		Computer Study	
Station	$\Delta\omega$ (Hz)	$\Delta\delta$ (degrees)	$\Delta\omega$ (Hz)	$\Delta\delta$ (degrees)	$\Delta\omega$ (Hz)	$\delta_{(0.24)}$ (degrees)	$\Delta\omega$ (Hz)	$\delta_{(0.24)}$ (degrees)
Neal 1	0.3914	5.64	0.3919	5.60	0.3896	45.15	0.3920	45.38
Neal 2	0.534	7.67	0.5352	7.70	0.4837	52.82	0.4924	53.89
Neal 3	0.8783	12.65	0.8786	12.70	0.8097	72.81	0.821	74.81
Neal 4	0.7102	10.23	0.7111	10.2	0.6766	63.19	0.6841	64.22
Fort Calhoun	0.1252	1.80	0.1249	1.8	0.1756	31.89	0.1751	31.68
Nebraska City	0.1687	2.43	0.1713	2.5	0.1746	38.67	0.1779	38.96
C.B. No. 3	0.1823	2.66	0.1882	2.7	0.1771	32.48	0.1797	32.96
Cooper	0.1314	1.89	0.1325	1.9	0.1505	34.38	0.1521	34.50

to clear in 0.08 s and then cleared (by back-up protection) in 0.24 s, were analyzed and the results were compared. A summary of the results of two studies is given in Table 4-6.

From these results, we can see that the proposed approximate method predicts the generator angles and speeds at fault clearing with great accuracy for the case of a three-phase fault cleared in 0.08 s. The results for the case of a stuck breaker are still surprisingly good and are within 2% accuracy.

Accounting for Network Changes

The calculation of the transient energy margin involves the use of a complex package of computer programs to perform numerous calculations. For a given disturbance, but for a variety of post disturbance networks, considerable savings in the computational effort can be achieved if the Y-bus of the postfault network can be modified directly instead of reconstructing the Y-bus "from scratch." An efficient method for this has been developed in this project. This method was originally developed to simulate network disturbances (see Interim Report No. 2) and is used here merely to achieve a more efficient computation.

The postfault reduced Y-matrix in which only the internal generator nodes are retained is modified by changes due to (additional) network changes, e.g., sudden opening of a tie line. The approach currently pursued follows the well-known Householder technique. The procedure is illustrated in the following.

Let the full Y-bus matrix be

Y-bus =	IN	TN	LN
IN	$(Y_{IN,IN})$	$(Y_{IN,TN})$	0
TN	$(Y_{TN,IN})$	$(Y_{TN,TN})$	$(Y_{TN,LN})$
LN	0	$(Y_{LN,TN})$	$Y_{LN,LN}$

where IN are the internal nodes, TN are the terminal buses of the machines, and LN are the load buses in the system.

For convenience, this matrix is rewritten in a short form:

$$
\text{Y-bus} = \begin{array}{c|c|c|}
 & \text{IN} & \text{TN} \quad \text{LN} \\ \hline
\text{IN} & Y_A & Y_B \\ \hline
\begin{array}{c}\text{TN}\\ \text{LN}\end{array} & Y_C & Y_D \\ \hline
\end{array}
$$

where

$$
Y_A = \begin{array}{c|c|}
 & \text{IN} \\ \hline
\text{IN} & \begin{matrix} y_{m1} & & \\ & y_{m2} & \\ & & \ddots \end{matrix} \\ \hline
\end{array}
$$

y_{m1}, y_{m2},...are the admittances of the machine impedances (or reactances).

$$
Y_B = Y_C^T = \text{IN} \begin{array}{|c|c|} \hline
\begin{matrix} -y_{m1} & & \\ & -y_{m2} & \\ & & \ddots \end{matrix} & 0 \\ \hline
\end{array}
$$

$$
Y_D = \begin{array}{c|c|}
 & \text{TN} \quad \text{LN} \\ \hline
\begin{array}{c}\text{TN}\\ \text{LN}\end{array} & Y_D \\ \hline
\end{array}
$$

is the bus admittance matrix of the network and the loads and machine reactances.

The Y-bus matrix reduced to the internal nodes is given by

$$
\text{Y-bus (reduced)} = Y_A - Y_B \, Y_D^{-1} \, Y_C \qquad (4\text{-}15)
$$

Any changes in the system configuration can be reflected by changes in the matrix Y_D.

Let a line i-j be considered for outage. Then the change Y_D in the Y_D matrix is given by

$$\Delta Y_D = \begin{array}{c|ccccc} & \cdots & (i) & \cdots & (j) & \cdots \\ \hline \vdots & 0 & | & 0 & | & 0 \\ (i) & - & a & - & b & - \\ \vdots & 0 & | & 0 & | & 0 \\ (j) & - & b & - & a & - \\ \vdots & 0 & | & 0 & | & 0 \end{array}$$

where

$a = -y_{ij} - (c_{ij}/2)$, $b = y_{ij}$

y_{ij} is the line admittance

C_{ij} is the total line charging (susceptance)

ΔY_D can be rewritten as

$$\Delta Y_D = \begin{bmatrix} 0 & 0 \\ \cdot & \cdot \\ 0 & 0 \\ 1 & 1 \\ 0 & 0 \\ \cdot & \cdot \\ 0 & 0 \\ -1 & 1 \\ 0 & 0 \\ \cdot & \cdot \\ 0 & 0 \end{bmatrix} \underset{D}{\begin{bmatrix} \frac{a-b}{2} & \\ & \frac{a+b}{2} \end{bmatrix}} \underset{L}{\begin{bmatrix} 0 \cdot 0 & 1 & 0 \cdot 0 & -1 & 0 \cdot 0 \\ 0 \cdot 0 & 1 & 0 \cdot 0 & 1 & 0 \cdot 0 \end{bmatrix}}$$

$\Delta Y_D = K\ D\ L$ where K, D and L are the matrices as shown in the previous equation. Also $K = L^T$ in these equations.

Now, the reduced Y-bus matrix equation (with this change in the system configuration) is

$$\text{Y-bus (reduced, new)} = Y_A - Y_B(Y_D + K\ D\ L)^{-1}\ Y_C \tag{4-16}$$

By Householder's theorem,

$$(Y_D + K\ D\ L)^{-1} = Y_D^{-1} - Y_D^{-1}\ K\left[D^{-1} + L\ Y_D^{-1}\ K\right]^{-1} L\ Y_D^{-1} \tag{4-17}$$

Substituting in Eq. 3-11 we have

Y-bus (reduced, new)

$$= Y_A - Y_B Y_D^{-1} Y_C + Y_B Y_D^{-1} K \left[D^{-1} + L Y_D^{-1} K \right]^{-1} L Y_D^{-1} Y_C \qquad (4\text{-}18)$$

By comparing Eqs. 4-15 and 4-18, we obtain the modifications to the reduced Y-bus matrix due to the outage of line i-j,

$$\Delta\text{Y-bus (reduced)} = Y_B Y_D^{-1} K \left[D^{-1} + L Y_D^{-1} K \right]^{-1} L Y_D^{-1} Y_C \qquad (4\text{-}19)$$

An efficient way of finding ΔY-bus (reduced) using Eq. 4-19 is developed. A brief outline is given.

- Step 1: from D, L, Y_D and K, find the triangular factors of the matrix $(D^{-1} + L Y_D^{-1} K)$. Note: the order of this matrix is small.
- Step 2: find the matrix $[L Y_D^{-1} Y_C]$.
- Step 3: find $[Y_B Y_D^{-1} K] = [L Y_D^{-1} Y_C]^T$.
- Step 4: find ΔY_{Bus} (reduced).
- Step 5: find Y_{Bus} (reduced).

The method has been successfully applied to the two test systems. The Y-bus obtained by modifying an existing Y-bus (as outlined before) was identical to that obtained by constructing the Y-bus from the complete network.

This procedure is now used to compute the transient energy margin for different postfault networks associated with the same initial disturbance (see transient margin profile).

STATE OF THE COMPUTER PROGRAMS

This section is written for the benefit of colleagues who wish to carry out investigations similar to the ones reported here, using their institution's computer facilities.

The three computer program packages developed in this project were: 1) MARGIN, 2) TSWING, and 3) YMOD (see Appendix A for a description). They are primarily research tools, i.e., in their present form they are useful only to a researcher who is familiar with them and is comfortable with interactive computers. Their advantages are that they are well-tested, versatile, and powerful. Numerous cross-checks were made on the results obtained by these programs. In short, they can reliably dissect the trajectory of a multimachine power system in terms of where the energy resides in the system and investigate in detail the motion of groups of machines. Unstable equilibrium points can be obtained and transient energy margins can be computed with the appropriate corrections made.

The packages are currently dimensioned for a 170-bus, 39-machine system. They require approximately 400 K of core to execute the most core-intensive steps (on an ITEL AS-6 computer). The 170-bus, 39-machine limit can easily be re-dimensioned upward. For example, the 170-bus program is itself a re-dimensioned version of a 120-bus program.

The main disadvantages to these programs are: 1) they are not well-documented, and 2) they are written for use on the interactive facilities at Iowa State University. They represent a mixed collection of routines that are well-tested, but do not represent a production grade research package.

The programs MARGIN and TSWING were written for use in an interactive mode with the researcher directing the program execution from an on-line terminal. Input data files are mixed in an assortment of formats and locations designed to meet the particular need of the researcher, depending on the job performed (and not necessarily in a logical and easily understood form). Output files are created by one program as input to other routines. File management is not automated and is rather cumbersome. In short, inputs and outputs are device dependent and execution options are complicated.

Program YMOD, in contrast to MARGIN and TSWING, was developed in a single development step to accomplish a well-focused result. Thus, it is systematically written and is neither device dependent nor strictly an interactive tool.

Suggestions for Improvement

For other researchers to make use of these programs, the following improvements are suggested:

1. Combine the program packages so that the output files of each program are automatically routed as the input to the next program.

2. Develop a MAIN program to control the various options in the programs in a self-prompting form.

3. Develop a non-interactive version for use in computer facilities without interactive capabilities.

4. Streamline some features in the existing programs. A good example is to use the YMOD program to modify the Y-bus when needed instead of generating a new Y-bus each time the network changes.

These improvements would greatly enhance the potential usefulness of these programs. To implement them (with documentation), a competent programmer who is familiar with the task would take about 3-5 months.

Section 5

SECURITY ASSESSMENT USING TRANSIENT ENERGY MARGIN

The transient energy margin concept has been developed in Section 4. A positive energy margin indicates that the system can absorb additional transient energy before instability occurs. In other words, a more severe <u>initial</u> disturbance could be withstood by the system. Therefore, the energy margin is indicative of the robustness of the power system at a given operating point. As such, it can be used as a tool for dynamic security assessment. In this section, a framework for the use of the transient energy margin for security assessment is presented and is illustrated on the 17-generator test power system.

FRAMEWORK FOR ANALYSIS

Given a system operating condition characterized by the generators' rotor angles, power, etc., security assessment requires the following steps:

1. A classical model for first swing transient studies is developed. The remote areas are represented by suitable equivalents.

2. For a given initial operating condition, a disturbance is simulated so that the generators' angles and speeds and the network configuration (and hence, the admittance matrix) are computed at the end of the disturbance. In this step, the generator's condition at the end of the disturbance is determined. We will denote these as θ^c and ω^c (referred to as the system's inertial center).

3. From the post disturbance system configuration and the conditions at the end of the disturbance, the post disturbance Y-bus and the controlling u.e.p. (θ^u) are determined, as well as the critical machines identified. We note that the critical machines tending to separate from the system can be determined easily by examining the values of θ^u in the computer program output. These are the machines with $\theta_i^u > \pi/2$.

4. From Y-bus, θ^c, ω^c, and θ^u, the transient energy margin ΔV is computed, making the corrections for the kinetic energy components that do not contribute to the separation of the critical machines (see previous section). This gives the value of ΔV for the particular disturbance under investigation and the given initial operating condition, e.g., a three-phase fault at a particular bus cleared in a specified manner.

5. For the same operating conditions and essentially the same disturbance, the margin ΔV can be computed for various possible postfault network configurations, depending on the exact location of the fault and the sequence of breaker operation (or failure). From a computation standpoint, this step is only a variation of the previous step, since the conditions at clearing are the same and only the postfault networks are different. The computational effort is considerably reduced when the program for modifying the previous Y-bus is used.

6. Steps 4 and 5 are repeated for the same operating conditions, but for different disturbances. Thus, different types of disturbances at the same location (when justified) or disturbances at different locations in the power network are investigated.

7. The information compiled in steps 4, 5, and 6 give the desired transient energy margin "profile" of the system for this initial operating condition. This information is then normalized to give relative severity of the impact of the various contingent disturbances on the system. The assessment of security would be based on the ranking or ordering of the disturbances according to their severity.

Potential for On-line Operation

These steps outline a procedure for using the transient energy margin as a tool for dynamic security assessment. We perceive that this procedure can function on-line. The computational effort involved is, in our judgment, well within the capability of computers available in modern control centers. This effort involves the following:

- Deriving a classical model for simulation of first swing transients for the study area within the larger power network. Proper equivalencing can be used for remote areas and in combining machines connected to the same bus, etc. (The Reduced Iowa System is a good example of such a model.) A 20-generator equivalent may be adequate even for a major power system. We note that the state of the art is such that the development of such equivalents (on-line) is realizable, with some development work.

- Simulation of the disturbance and the conditions at the end of the disturbance. The simplified procedure, developed in this project and outlined in Section 4 of this report, can be implemented easily, since it requires information that can be obtained from a load-flow solution.

- Formation of the post disturbance Y-bus. This is perhaps one of the major computational tasks, but it is feasible, especially for a network of 20-generators or less. Furthermore, once a Y-bus is formed, it can be easily modified using the technique outlined in Section 4 of this report.

- Identifying the mode of instability, the critical machines and the controlling u.e.p. As we have pointed out in Section 4, this is often a straightforward task when the disturbance clearly splits a small number of machines from the system. However, it is not a simple task when the disturbance is located at a point in the network where generators are clustered in a small area. While conceptually this leaves an element of uncertainty as to the accuracy of the results, from a practical standpoint it can be readily overcome. For a given system, the critical machines associated with a particular disturbance can be determined in advance (from studies similar to those presented in Section 4).

- Computation of the critical energy and the energy margin with the appropriate corrections. The computational effort is small since it can be accomplished by relatively simple calculations (see Section 4).

TRANSIENT ENERGY MARGIN PROFILE OF THE 17-GENERATOR SYSTEM

As explained in Section 2, the 17-generator test system is a reduced equivalent of the Iowa Network. The study system, which is represented in sufficient detail for transient analysis (using a classical model), is the western area of the network near the Missouri River. Several generating plants are located in that area. They are represented in the study by 7 generators, some of which represent two units on the same bus (e.g., Generator No. 10 represents C.B. units No. 1 and 2). This system, therefore, can yield the desired information for assessment of the security of either the Iowa Power and Light Company or the Iowa Public Service Company.

The initial operating condition is the same used throughout this research project: 1980 Iowa Network, 80% load, with prior outage of line 372-332 (Raun-Hinton). Details of the initial operating conditions are given in Appendix B.

Sequence of Disturbances

Types of Disturbance. The 17-generator system was investigated for faults on the 345-kV network at the following locations: Bus 372 (Raun), Bus 436 (C.B. No. 3), Bus 773 (Ft. Calhoun), and Bus 6 (Cooper). The study covered two types of faults:

- Three-phase faults cleared in 0.15 s by opening one line. While the actual breaker clearing time is 0.08 s, this fault duration was conveniently selected to make use of the data already available, which would have been rather costly to repeat. Breaker failures or breaker reclosings were not pursued in this series.

- Single-line-to-ground faults with stuck breakers, final clearing of the fault accomplished with the back-up protection. The sequence used was as follows:

--Faulted line cleared at remote end in 0.08 s, but with breaker at near end "stuck."

--Back-up protection isolating faulted section in 0.24 s.

Post Disturbance Network

For each fault, the postfault network is determined by the breaker locations. Schematic diagrams of the breaker positions on the 345-kV stations are shown in Figure 5-1 (for Raun) and Figure 5-2 (for the other stations). The different postfault networks selected for analysis for two types of faults investigated are given below.

Three-phase Faults. For the Raun fault, with prior outage of the 372-332 (Raun-Hinton) line, the following postfault networks are possible:

- Line 372-193 (Lakefield) cleared.
- Line 372-773 (Ft. Calhoun) cleared.
- Line 372-482 (Lehigh) cleared.
- One of the transformers 372-800 (Raun) opened.

For the C.B. No. 3 fault, the following postfault networks are possible:

- Line 436-439 (Booneville) cleared.
- Line 431-771 (Substation 3456) cleared.

For the Ft. Calhoun fault, the following postfault networks are possible:

- Line 773-372 (Raun) cleared.
- Line 773-779 (Wagner) cleared.
- Line 773-775 (Substation 3459) cleared.

For the Cooper fault, the following postfault networks are possible:

- Line 6-774 (Nebraska City) cleared.
- Line 6-439 (Booneville) cleared.
- Line 6-16 (Moore) cleared.
- Line 6-393 (St. Joseph) cleared.

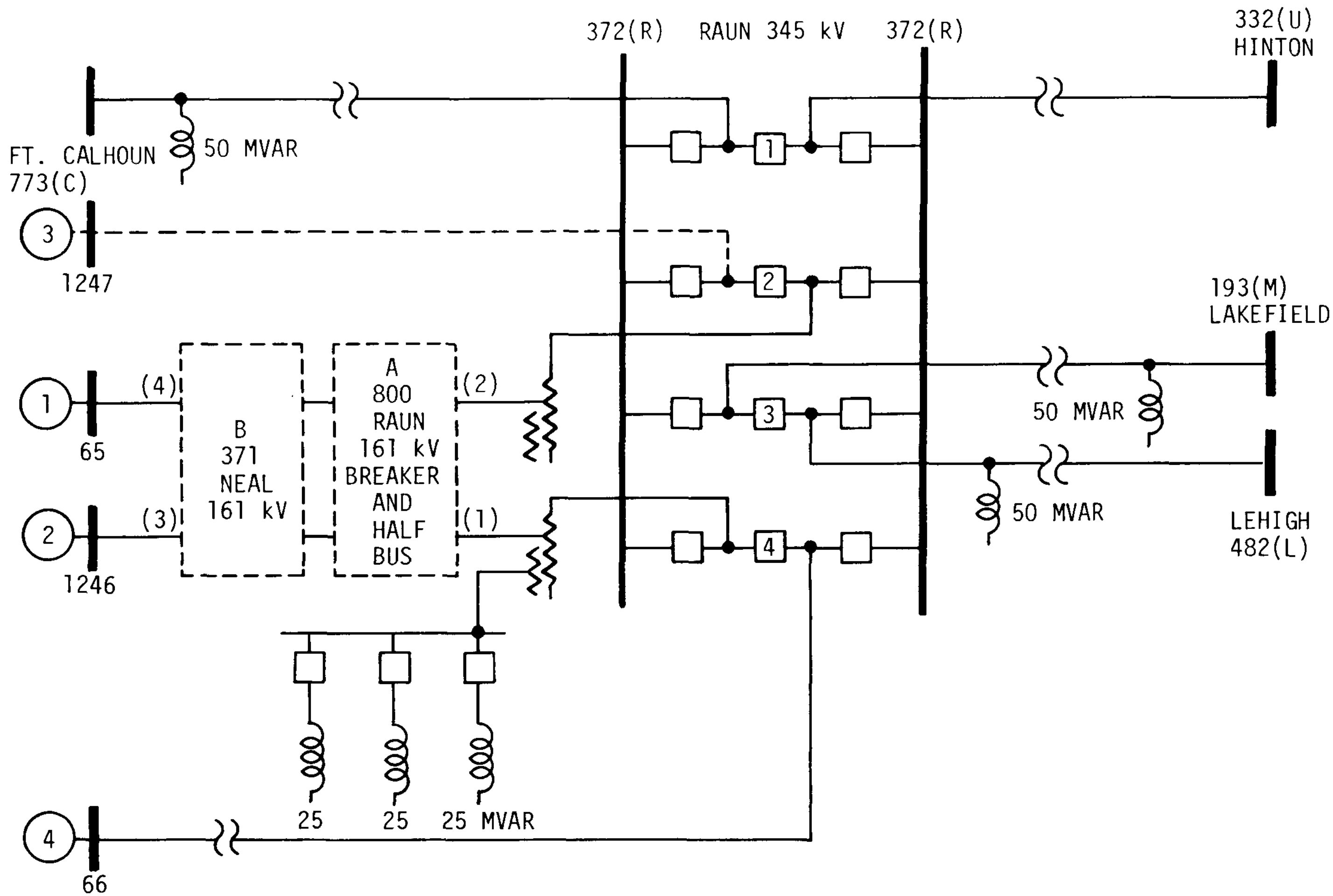


Figure 5-1. Raun 345-kV station.

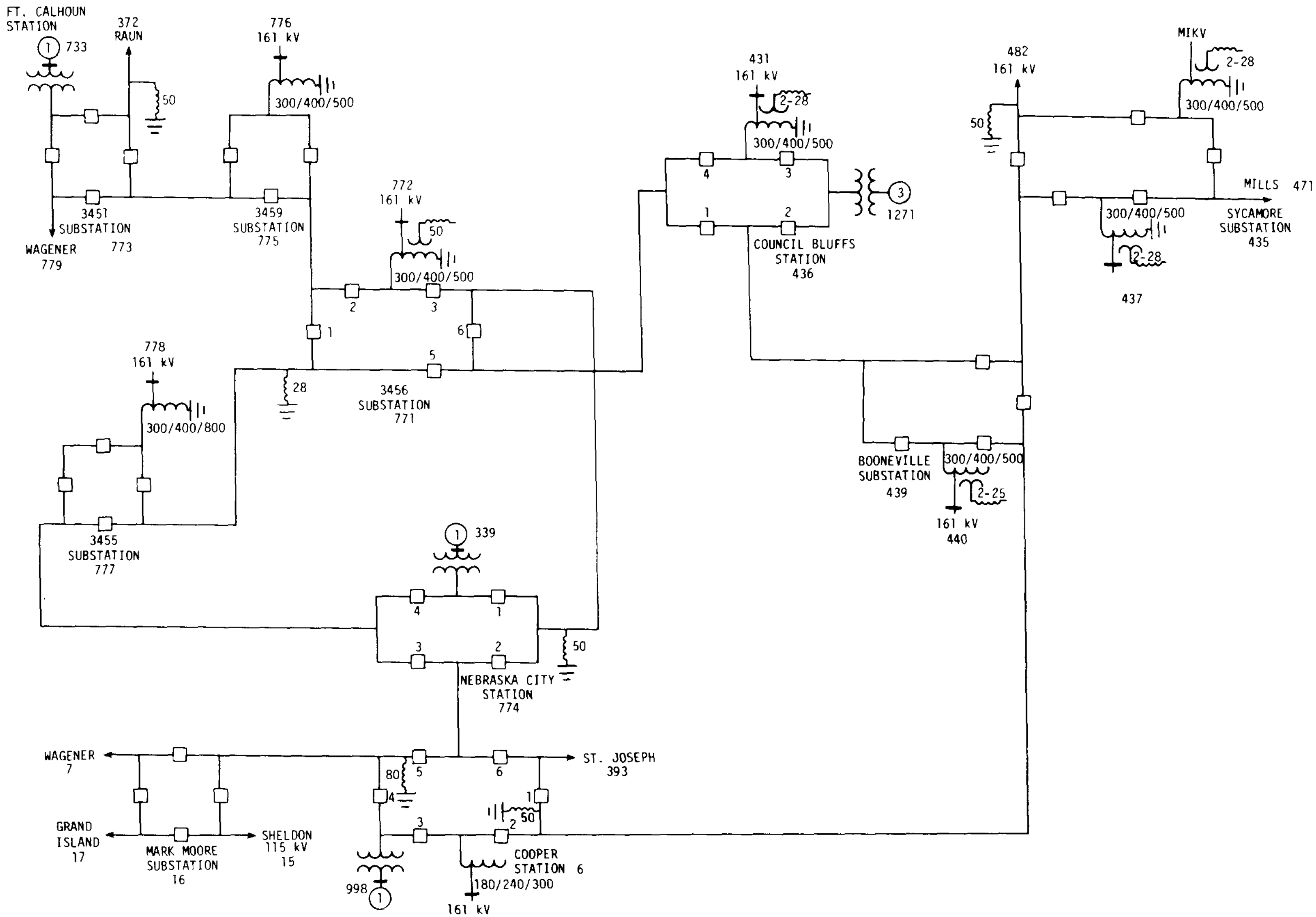


Figure 5-2. Substation breaker diagram.

SLG Faults. As indicated earlier, the postfault network is determined by the sequence of primary clearing and back-up clearing for the given fault. The number of the possible network configurations is quite large (even though this number is considerably reduced since only one prior outage situation is considered). Since our objective is to demonstrate the use of ΔV for security assessment, we have selected only a limited number of possible configurations to analyze for each fault. These selections represent a compromise which we hope combines a realistic selection process while limiting the computational effort to a reasonable size. The resulting postfault networks are given below.

Raun fault:

1. Fault on line 372-193
   --Line 372-193 cleared.
   --Lines 372-193 and 372-482 cleared.
2. Fault on line 372-773
   --Line 372-773 cleared.
3. Fault on line 372-482
   --Line 372-482 cleared.
   --Lines 372-482 and 372-193 cleared.
4. Fault on transformer 372-800
   --One line 372-800 cleared.

C.B. No. 3 fault:

1. Fault on line 436-439
   --Line 436-439 cleared.
   --Lines 436-439 and 436-771 cleared.
2. Fault on line 436-771
   --Line 436-771 cleared.
   --Lines 436-771 and 436-439 cleared.

Ft. Calhoun fault:

1. Fault on line 773-372
   --Line 773-372 cleared.
   --Lines 773-372 and 773-775 cleared.

2. Fault on line 773-779

   --Line 773-779 cleared.

   --Lines 773-779 and 773-775 cleared.

3. Fault on line 773-775

   --Line 773-775 cleared.

   --Lines 773-775 and 773-372 cleared.

   --Lines 773-775 and 773-779 cleared.

Cooper fault:

1. Fault on line 6-774

   --Line 6-774 cleared.

   --Lines 6-774 and 6-393 cleared.

   --Lines 6-774 and 6-16 cleared.

2. Fault on line 6-439

   --Line 6-439 cleared.

   --Lines 6-439 and 6-393 cleared.

3. Fault on line 6-16

   --Line 6-16 cleared.

   --Lines 6-16 and 6-774 cleared.

Sample Calculations

As previously discussed in this section, the corrected transient energy margin ΔV is computed for: a) 12 cases of three-phase faults, and b) 27 cases of SLG faults (with stuck breaker). A sample of the calculations involved is given for the three-phase and the single-line-to-ground faults at Raun, cleared by opening line 372-193.

Table 5-1 shows some of the information needed to compute the margin ΔV, namely, the conditions at clearing and the u.e.p. The latter is the same for both faults since the postfault network is the same for both. Some of the pertinent data for margin computation is displayed in Table 5-2. We note the following:

- The value of ΔV uses the same reference for V_{cl} and V_{cr}, i.e., no correction for the change in θ^s is needed (see earlier discussion in this section).

- A negative value is assigned to the kinetic energy correction to emphasize that it is to be subtracted from the energy at clearing, thus giving a greater value of ΔV.

- The value of ΔV for the SLG fault is greater than that of the three-phase fault only because this happened to be a special case where the postfault network is the same for both cases.

Table 5-1

FAULT AT BUS 372 (RAUN), LINE 372-193 CLEARED
CONDITIONS AT CLEARING AND THE u.e.p.

	Conditions at Clearing				u.e.p.
	Three-Phase Fault		SLG Fault		θ^u (degrees) (same for both cases)
Generator Number	θ^c (degrees)	ω^c (r/s)	θ^c (degrees)	ω^c (r/s)	
1	-27.27	0.226	-8.29	0.754	-1.41
2	3.81	1.169	5.50	1.116	46.63
3	-14.08	0.528	-0.13	0.924	9.68
4	-26.14	0.038	-11.33	0.158	-23.96
5	16.25	5.014	18.51	3.374	163.56
6	34.89	9.199	34.14	4.822	144.87
7	-21.49	0.339	-20.73	0.396	-15.96
8	-22.42	0.943	-21.32	0.803	-7.98
9	-10.92	0.339	-10.39	0.339	-6.62
10	-2.84	1.809	-0.68	1.576	47.78
11	-20.74	0.829	-18.74	0.969	10.29
12	-0.41	2.036	1.49	1.621	49.59
13	-27.87	0.075	-19.23	0.222	-25.80
14	-26.58	0.038	-18.28	0.173	-23.62
15	-20.43	0.151	-3.26	0.426	-17.62
16	0.73	1.697	3.43	1.320	63.56
17	3.12	1.621	4.98	1.414	50.07

Transient Energy Margin Profile

The computed values of ΔV for the disturbance investigated are shown in Table 5-3.

Table 5-2

FAULT AT BUS 372 (RAUN), LINE 372-193 CLEARED
CALCULATION OF TRANSIENT ENERGY MARGIN

Critical Generators: No. 5 and 6

M_{cr} = 0.26143 pu

M_{sys} = 4.8744 pu

M_{eq} = 0.24812 pu

	Three-Phase Fault	SLG Fault
ω^c_{cr}, r/s	7.0650	3.6383
ω^c_{sys}, r/s	-0.3597	-0.1952
ω^c_{eq}, r/s	7.4247	3.8335
KE Correction, pu	-1.131	-0.462
ΔV, pu	6.377	12.075
ΔV (corrected), pu	7.508	12.537

Examining the data in Table 5-3, we note that the transient energy margin ΔV is positive for all three-phase faults investigated. The values of ΔV range from a low value of 4.756 pu for a fault on the line 372-773 at Raun to a value of 27.685 pu for a fault on line 773-775 at Ft. Calhoun.

For the single-line-to-ground faults when there is no additional outage, the value of the transient energy margin ΔV is consistently higher than the corresponding value for a three-phase fault. Therefore, we will not examine these disturbances any further.

For the single-line-to-ground faults with additional line outages due to breaker failure, lower values of ΔV are often obtained. Values of ΔV range from a low of 0.963 pu (predicting transient instability) for a fault on line 6-774 at Cooper cleared by additional outage of line 6-393, to a value of 27.694 pu for a fault at Ft. Calhoun on line 773-775 cleared by additional outage of line 773-779.

Having computed the values of the transient energy margin ΔV for the various disturbances, what inferences can be made from this information? Would a value of ΔV of 6.0 pu indicate a more robust system (farther from instability) than that of a situation where ΔV is 5.0 pu? Intuitively we feel that the answer

Table 5-3

NORMALIZED TRANSIENT ENERGY MARGIN
17-GENERATOR SYSTEM

	Three-Phase Fault			SLG Fault			
Fault Location (Bus and Line Faulted)	ΔV (pu)	Corrected KE (pu)	ΔV / Corrected KE	Additional Line Out	ΔV (pu)	Corrected KE (pu)	ΔV / Corrected KE
Raun Fault							
372-193	7.432	6.878	1.080	372-482	7.879	1.824	4.319
372-773	4.756	6.878	0.691	-	-	-	-
372-482	9.159	6.878	1.332	372-193	7.523	1.791	4.200
Transformer 372-800[a]	12.147[a]	6.878	1.766	-	-	-	-
C.B. No. 3 Fault							
436-439	12.831	3.831	3.283	436-771	4.350	0.998	4.354
436-771	6.208	3.831	1.620	436-439	3.408	1.658	2.057
Ft. Calhoun Fault							
773-372	22.513	1.302	17.291	773-775	21.980	0.643	34.205
773-779	27.512	1.302	21.131	773-775	27.097	0.498	54.379
773-775	27.685	1.302	21.272	773-372	22.660	0.189	119.767
				773-779	27.694	0.189	146.374
Cooper Fault							
6-774	5.200	3.158	1.647	6-16	5.561	1.002	5.53
				6-393	0.963	1.002	0.962
6-439	6.502	3.158	2.059	6-393	3.217	0.969	3.321
6-16	6.278	3.158	1.988	6-774	5.457	0.975	5.596
6-393	6.596	3.158	2.089				

[a]See discussion of Table 5-4.

should be: not necessarily. The magnitude of the transient energy margin ΔV is of significance only in relation to the excess transient energy at the end of the disturbance. For this reason we seek to present the data on the transient energy margin in a normalized form.

Normalizing the Transient Energy Margin

The significance of the transient energy margin is that it represents a "margin of safety" before instability occurs. Thus, a greater disturbance, as indicated by the transient energy at clearing, could be tolerated until the margin is used up. It would be logical, therefore, to relate the margin ΔV to the amount of transient energy directly responsible for instability.

The component of transient energy at clearing that must be converted to other forms of energy for stability to be maintained is the corrected transient kinetic energy (ΔV/Corrected KE). The latter is the transient kinetic energy at clearing corrected for the energy that does not contribute to system separation. The true margin of safety, therefore, is how ΔV compares to Corrected KE. In other words, a true measure of the severity of the fault is the ratio of (ΔV/Corrected KE). This ratio is computed for the three-phase faults and the SLG faults with additional outages due to breaker failure, and is displayed in Table 5-3.

Ranking of Disturbances

We will proceed to rank the various disturbances in the order of severity: the most severe disturbance giving the lowest ratio of (ΔV/Corrected KE), and so on. Ranking of the three-phase faults according to this ratio is presented in Table 5-4, together with the corresponding values of ΔV. This ranking seems to indicate that the Raun fault at line 372-482, which has a transient margin $\Delta V = 9.159$, is more severe than several other faults with considerably smaller values of ΔV.

Critical clearing times for some of these faults were obtained (by time solutions) to test the validity of the ranking of the severity of the faults. This information is also given in Table 5-4.

There is a discrepancy between the value of ΔV in Table 5-4 for the Raun fault at transformer 372-800 with the value given in Table 5-3 for the same fault. The reason for this discrepancy is that ΔV was originally computed assuming that the mode of instability is that of Generators No. 5 and 6 going unstable (this would affect the values of V_{cr} and the correction to the kinetic energy). From the

Table 5-4

RANKING OF THREE-PHASE FAULTS
17-GENERATOR SYSTEM

Rank	ΔV / Corrected KE	ΔV (pu)	Fault Location	Critical Clearing Time s	
				Stable	Unstable
1	0.691	4.756	Raun, line 372-773	0.177	0.180
2	1.080	7.432	Raun, line 372-193	0.1923	0.1924
3	1.332	9.159	Raun, line 372-482	0.192	0.196
4	1.530	9.870	Raun, transformer 372-800	0.196	0.200
5	1.620	6.208	C.B. No. 3, line 436-771	0.200	0.204
6	1.647	5.200	Cooper, line 6-774	0.204	0.212
7	1.988	6.278	Cooper, line 6-16	0.212	0.216
8	2.059	6.502	Cooper, line 6-439	0.216	0.220
9	2.089	6.596	Cooper, line 6-393	---	---
10	3.283	12.579	C.B. No. 3, line 436-439	---	---
11	17.298	22.513	Ft. Calhoun, line 773-372	---	---
12	21.139	27.512	Ft. Calhoun, line 773-779	0.345	0.356
13	21.272	27.685	Ft. Calhoun, line 773-775	---	---

swing curve data and from the critical clearing time, the correct mode of instability for this particular disturbance was found to be for Generator No. 6 alone going unstable, i.e., a different mode of instability from the other Raun faults. When the transient kinetic energy is corrected according to this mode, the following values are obtained: $\Delta V = 9.87$ pu, and (ΔV/Corrected KE) = 1.53. These values are entered in Table 5-4.

Examining the information on critical clearing times t_{cr}, we note that t_{cr} increases consistently with the increased ranking, i.e., with the increased value of (ΔV/Corrected KE).

The severity of the single-line-to-ground faults cleared with back-up protection after a breaker failure is now ranked according to the same criterion, i.e., according to the ratio of (ΔV/Corrected KE). This information is displayed in Table 5-5.

Table 5-5

RANKING OF SLG FAULTS
17-GENERATOR SYSTEM

Rank	ΔV Corrected KE	ΔV (pu)	Disturbance: Faulted Bus	Disturbance: Lines Removed
1	0.962	0.963	Cooper	6-774, 6-393
2	2.057	3.408	C.B. No. 3	436-771, 436-439
3	3.321	3.217	Cooper	6-439, 6-393
4	4.200	7.523	Raun	372-482, 372-193
5	4.319	7.879	Raun	372-193, 372-482
6	4.354	4.350	C.B. No. 3	436-439, 436-771
7	5.550	5.561	Cooper	6-774, 6-16
8	34.205	21.980	Ft. Calhoun	773-372, 773-775
9	54.379	27.097	Ft. Calhoun	773-779, 773-775
10	119.767	22.660	Ft. Calhoun	773-775, 773-372
11	146.374	27.694	Ft. Calhoun	773-775, 773-779

No information is given in Table 5-5 on the time solutions. Since this data was compiled toward the end of the contract period, time did not permit the exhaustive study needed to confirm the mode of instability encountered in each of the SLG faults. The ranking given in Table 5-5 is based on the assumption that the modes of instability are the same as those encountered for the three-phase faults.

DYNAMIC SECURITY ASSESSMENT: THE ALERT STATE

In this section we have seen how the normalized transient energy margin profile of the power system for a given initial operating condition can be used to rank the relative severity of the impact of the various contingent disturbances. This ranking has been substantiated by the time solutions obtained in some of the simulation studies. How can this information be translated into an assessment of the system's robustness? We will now address this question.

One elementary and rather obvious answer is that the energy margin profile gives information on the weak links in the system. To illustrate this, our studies on the 17-generator system show that any combination of two line outages at Raun that includes the line 372-773 (to Ft. Calhoun) stresses the system considerably. A similar situation exists with any combination of two line outages at Cooper that includes the line 6-393 (to St. Joseph). Undoubtedly some of these situations are well known to the system operator. On the other hand, some combinations of conditions and sequences of events may not be familiar to the operator, and hence their consequences may not be evident. On-line computation of the transient energy margin, when feasible, would spot the potentially dangerous situation and reveal it to the operator.

Now we come to the key question: What value of transient energy margin ΔV constitutes an alertable situation? To some extent, the procedure for normalizing the transient energy margin will be helpful in providing the answer, since the important factor is how this margin compares to the energy primarily responsible for system separation. Still, what is an acceptable ratio of (ΔV/Corrected KE)? Obviously, there cannot be a clear-cut answer to this question. Each system will have to develop its own criteria. For example, the investigators, having familiarized themselves with the 17-generator system, would offer the following criteria for this system:

> An alertable situation occurs when the normalized transient energy margin is less than 1.0. The system's "reserve capacity" to convert the excess transient kinetic energy to potential energy is low. Numerous studies have indicated that when the normalized ΔV is less than 1.0, the system would be severely disturbed, even though it would be under the stability limit. The degree of alert, however, can be refined further. For example, a classification that is admittedly arbitrary and judgmental may be as follows:

Situation	Normalized V	Suggested Action
Warning	1.0-2.0	None
Alert	0.5-1.0	Diagnostic
Severe Alert	0.0-0.5	Diagnostic Suggest remedial action and changes
Potential Emergency	<0	Same

Finally, it cannot be overemphasized that this classification is arbitrary and judgmental. The decision should be the system operator's, guided by his experience with the system and adjusted according to operating constraints.

Section 6

SECURITY ASSESSMENT WITH MULTIPLE DISTURBANCES

INTRODUCTION

In this approach, the tool for assessment of power system security is the distribution of additional disturbances that would "consume" the transient energy margin ΔV. Thus the margin of safety, which is indicated by ΔV, is used to assess the relative severity of the impact of additional perturbations to the system during the transient period. In addition to giving substantive information on the system dynamic behavior, which is of intrinsic importance, it would help identify the weak links in the system and their margin.

Given a system operating condition, the first four steps in the analysis would be the same as those described in Section 4. They are outlined here again for convenience.

1. A classical model is developed.
2. A disturbance is simulated so that the generator's condition at the end of the disturbance is computed.
3. The controlling u.e.p. for this disturbance (θ^u) is computed and the critical machines are identified.
4. The transient energy margin ΔV is computed and corrected.

Security assessment by this method would require the following additional steps:

- Additional disturbances that use up the margin ΔV are investigated.
- Dynamic security assessment would be based on the magnitude, location, and timing of these additional disturbances.

Theoretical work and simulation studies were performed to investigate the additional perturbations (or disturbances), following an initial disturbance initiating the transient, that a system could withstand before instability is encountered.

The additional perturbations investigated were:

- Power disturbances (e.g., loss of load, changes in generators' input powers) at various instances in the post (initial) disturbance period.
- Network changes after the termination of the initial disturbance.

This work was pursued until the middle of the second year of the project. Upon consultation with the project manager at EPRI, it was agreed that no further work in this area is needed. The following is a summary of the work performed, the results obtained, and the issues dealt with.

INVESTIGATION OF POWER IMPACTS

Our original thinking (see Section 2.5 of Interim Report No. 1 (36)) was that the controlling u.e.p. (θ^u) for a given faulted system trajectory would not be changed by the additional disturbance. Thus, defining $\Delta\theta_i = \theta_i^u - \theta_i^c$ for machine i, the distribution of power inpacts ΔP_i to use up ΔV are given by

$$\Delta V = -\sum_{i=1}^{n} \Delta P_i \, \Delta\theta_i \tag{6-1}$$

For changes in generator input powers, Eq. 6-1 is used directly. For loss of load disturbances, the portions of the load loss picked up by various generators are determined by distribution factors k_i. The load (loss) power impact is thus given by

$$\Delta P_L = V / \sum_{i=1}^{n} k_i \, \Delta\theta_i \tag{6-2}$$

The initial results reported in Interim Report No. 1 (36) were very encouraging. Equations 6-1 and 6-2 gave very good predictions of the limits of power impacts in some cases, but the power margin predictions were not so accurate in others. This subject received a great deal of attention by the investigators for several months. Theoretical work, supported by extensive simulation studies on the two networks previously given, was conducted. The issues dealt with were:

1. <u>The shift in θ^u due to the additional disturbance.</u>
   The idea is illustrated by the analogy with the equal area criterion for the one-machine-infinite-bus system shown in Figure

6-1. The area A_1 represents the excess kinetic energy at clearing which must be absorbed by the network. With no additional disturbances, the area A_2, which is equal to A_1, gives the maximum rotor swing θ_{max}. Since θ_{max} is less than θ^u, there is a transient margin ΔV. An additional power disturbance ΔP_i is introduced to consume the margin such that the area $\hat{A}_2$ is equal to A_1. Note that $\hat{A}_2$ is confined by the intersection of the line $(P_i + \Delta P_i)$ and the post disturbance power angle curve. That intersection defines the new value of θ^u, marked in the figure as θ^{u1}. In other words, the introducton of ΔP_i shifts the u.e.p. from θ^u to θ^{u1}. The implication of this is that while θ^u is used to calculate ΔP_i, ΔP_i in turn shifts θ^u. The process of calculating ΔP_i must therefore be an iterative process. This has been incorporated in the computer programs developed at Iowa State for this project.

2. <u>How the injected energy is absorbed by the system.</u>
This point has been essentially dealt with in Section 4. We have seen that to compute the correct value of the transient energy margin ΔV, proper accounting must be made for the energy that tends to separate the critical machine(s) from the rest.

3. <u>More than one machine separating from the system.</u>
The faulted trajectory is controlled by a certain θ^u. Care must be exercised so that the additional power disturbance would not change the mode of system separation. If that occurs, a different θ^u must be considered which would have a new value of critical energy and, hence, a different energy margin. To illustrate this point, for a fault at the Raun bus of the 17-generator system, Generators No. 5 and 6 are the critical machines, with Generator No. 6 being closer to the disturbance. However, the nature of the inertias and the electrical forces on these two machines is such that their rotor swings tend to peak at different instants. The mode of system separation is for both Generators No. 5 and 6 to separate from the rest of the system. Additional power disturbances, however, may in some cases change this mode of system separation. For those cases, the predicted values of power perturbations would be greatly in error, unless the new θ^u is recognized and the calculation of ΔP_i is adjusted accordingly.

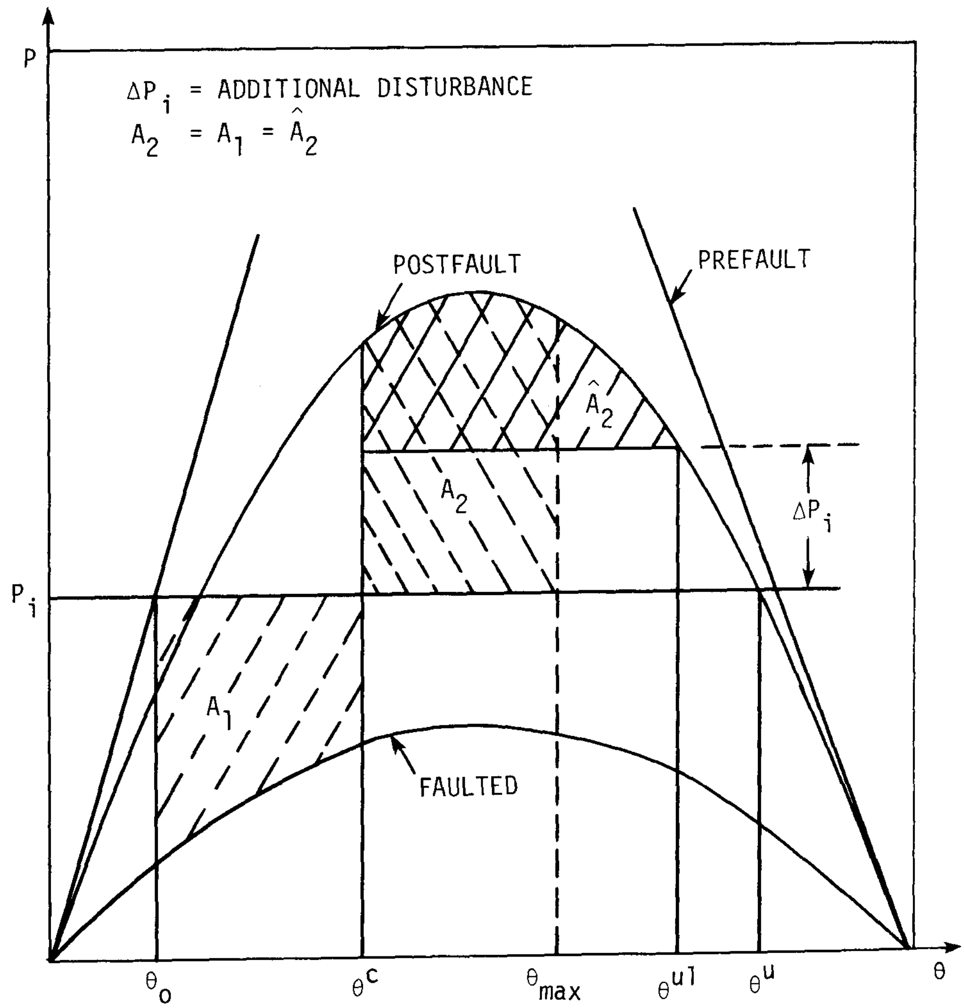


Figure 6-1. Illustration of θ^u shift for one-machine-infinite-bus system.

Simulation Studies

4-Generator System (For A Fault at Bus 10 Cleared in 6 Cycles). The original u.e.p. is given by

$\theta_1^u = -27.7°$ $\theta_2^u = -11.3°$

$\theta_3^u = -5.5°$ $\theta_4^u = 113.2°$

The corrected value of energy margin for this disturbance is given by $\Delta V = 0.4053$.

1. For a change in internal power at Generator No. 4 of $\Delta P_{m4} =$ 22.3 MW, the u.e.p. shifts to

   $\theta_1^{u1} = -26.5°$ $\theta_2^{u1} = -3.74°$

   $\theta_3^{u1} = -9.31°$ $\theta_4^{u1} = 105.83°$

   The new value of energy margin is now $\Delta V = 0.400$. Using this value to calculate the $\Delta P_{m4}|_{max}$, we get $\Delta\theta_4 = 1.425$ rad and $\Delta P_{m4}|_{max} = 28$ MW. In other words, if there is a second disturbance (at clearing) of 28 MW at Generator No. 4, the energy margin is consumed. Actual transient stability run, i.e., time solution on this system, shows that when an additional disturbance at ΔP_{m4} of 28 MW is introduced at clearing, the system barely goes unstable.

2. For a (negative) load change at Bus 11, the load loss is "felt" by the various generators according to the distribution factors $k_1 = 0.0577$, $k_2 = 0.0808$, $k_3 = 0.0615$, and $k_4 = 0.80$. The initial estimate of $\Delta P_{L11} = -29$ MW is used. The new u.e.p. is given by

   $\theta_1^{u1} = -26.71°$ $\theta_2^{u1} = -3.34°$

$\theta_3^{ul} = -8.87°$ $\theta_4^{ul} = 106.18°$

and the new value of energy margin is given by $\Delta V = 0.405$. Using these values to calculate $\Delta P_{L11}|_{max}$, $\Delta\theta_1 = -0.3495$, $\Delta\theta_2 = -0.0935$, $\Delta\theta_3 = -0.0986$, and $\Delta\theta_4 = 1.431$ rad. The predicted maximum load loss at Bus 11 at the instant of fault clearing is then obtained. The computed value is given by

$$\Delta P_{L11}\Big|_{max} = 36.4 \text{ MW}$$

Transient stability runs (i.e., with time solution) showed that when a negative constant impedance load of 35 MW is introduced at Bus 11, the system was found to be stable.

3. For a (negative) load change at Bus 10, the distribution factors for the different generators are $k_1 = 0.0814$, $k_2 = 0.1205$, $k_3 = 0.0879$, and $k_4 = 0.710$. The initial estimate of $\Delta P_{L10} =$ -33 MW is used. The new u.e.p. is given by

$\theta_1^{ul} = -26.9°$ $\theta_2^{ul} = -3.05°$

$\theta_3^{ul} = -8.6°$ $\theta_4^{ul} = 106.4°$

and the new value of the energy margin is given by 0.406 pu. From these values we get $\Delta\theta_1 = -0.353$, $\Delta\theta_2 = -0.088$, $\Delta\theta_3 = -0.093$, and $\Delta\theta_4 = 1.436$ rad. Using these values to calculate the predicted maximum load loss at Bus 10 at the instant of clearing, we get

$$\Delta P_{L10}\Big|_{max} = 41.8 \text{ MW}$$

A transient stability run (with time solution) was made for a negative constant impedance load at Bus 10 of 41 MW at t_c. The system was stable.

17-Generator System (For A Fault at Bus 372 (Raun Bus Near Generator No. 6) Cleared in 0.15 s). The original u.e.p. for the critical machines is given by

$\theta_5^u = 163.56°$ $\theta_6^u = 144.88°$

The corrected value of the energy margin for this disturbance is given by

$\Delta V = 7.832$ pu

1. For a change in internal power at Generator No. 6 of ΔP_{m6} = 395 MW, the new u.e.p. is given by

   $\theta_5^{u1} = 98.3°$ $\theta_6^{u1} = 147.2°$

   and the new value of ΔV is given by

   $\Delta V = 7.20$ pu

   The new value of $\Delta\theta_6$ = 1.634 rad. These values give a predicted maximum change in P_{m6} at the instant of clearing t_c of

   $\Delta P_{m6}\big|_{max} = 441$ MW

   Further iteration over θ^u and ΔP_{m6} is expected to increase this value slightly. Several transient stability runs were made for different values of ΔP_{m6} applied at $t = t_c$. The critical value of ΔP_{m6} was found to be

   $\Delta P_{m6}\big|_{max} \cong 480$ MW

   This type of disturbance merits some further comments. From the new values of θ_u, it appears that the generators separating from the rest are still Generators No. 5 and 6, even though the additional energy is injected at t_c at Generator No. 6 only. Thus, the mode of instability of the system is not changed by the new disturbance. This is confirmed by the data for ΔP_{m6} = 485 MW displayed in Figure 6-2, where plots of θ_5, θ_6, $\bar{\theta}_{5,6}$ and the energies are shown. The instant where the system's potential energy matches that of the u.e.p. is indicated. The following observations on the values of θ are of interest.

calculated: $\theta_5^{u1} = 97°$, $\theta_6^{u1} = 144°$, $\bar{\theta}_{5,6} = 128°$

observed: $\theta_5 = 110°$, $\theta_6 = 141°$, $\bar{\theta}_{5,6} = 130.4°$

2. The case of change in internal power at Generator No. 5 is of considerable interest since the additional disturbance changes the mode of instability. This is shown by the following data. For ΔP_{m5} = 275 MW, the computed value of the u.e.p. (the same u.e.p. but slightly shifted due to ΔP_{m5}) gives

$$\theta_5^{u1} = 164.8°, \quad \theta_6^{u1} = 134.4°$$

The predicted margin calculation for this case, however, is substantially higher than that found by transient stability studies. The reason for this is the fact that the newly injected energy in Generator No. 5 changes the mode of instability. Instead of Generators No. 5 and 6 separating from the system, now Generator No. 5 alone is the critical machine. The data on this case is displayed in Figure 6-3. Examining Figure 6-3 we note that the 17-generator system now has a simple mode of instability, i.e., only Generator No. 5 is going unstable. The instant at which V_{PE} is maximum coincides with the maximum trajectory of θ_5 alone and not $\bar{\theta}_{5,6}$. The kinetic energy is also minimum at that instant. Therefore, the u.e.p. controlling the original trajectory is no longer the controlling u.e.p. when the new disturbance is added. The new relevant θ^u must have only $\theta_5^u < \pi/2$. The new u.e.p. was found by careful search, using the new computer programs developed at Iowa State University. The following observations are pertinent concerning that u.e.p. and the instant at which θ_5 peaks in Figure 6-3, noting that the trajectory in Figure 6-3 is less than critical.

θ^u calculated: $\theta_5^u = 166°$, $\theta_6^u = 46°$

θ observed: $\theta_5 = 153°$, $\theta_6 = 31°$

INVESTIGATION OF NETWORK CHANGES

In this series of investigations the initial disturbance, e.g., a fault cleared by isolating the faulted section, is followed by an additional network disturbance in the form of a sudden opening of another branch of the network. A special computer algorithm was developed for modifying the postfault Y-bus due to these additional changes (see Section 4).

When this phase of the work was terminated, some computations of ΔV were made due to network changes at the instant of fault clearing. Some of these results are given below.

4-Generator System

This system is investigated for a three-phase fault at Bus 10 cleared in 0.1 s by opening line 1-8. The corrected transient energy margin ΔV is obtained for various additional line outages occurring at the instant of clearing. The results are given in Table 6-1, together with the maximum value of the angle θ_{41} obtained from the time solution.

Examining the data in Table 6-1, we note the following:

1. The additional opening of any of the lines 5-7, 7-8, or 8-9 would represent a severe additional disturbance to the system that would bring the system close to instability.
2. The swing curve for case 6 appears to indicate that this is a smaller disturbance than that of cases 5 and 7. Closer examination reveals that this is not so. For case 6, $\theta_{41}^u = 133.6°$ and $\theta_{41}|_{max} = 104.9°$, or $\theta_{41}|_{max}$ is within 28.7° from θ_{41}^u. The same analysis indicates that $\theta_{41}|_{max}$ is within 37° and 71° from θ_{41}^u for cases 7 and 5, respectively. Thus in case 6, Generator No. 4 is actually closer to instability.
3. In cases 2 and 3, the additional opening of the lines 4-5 or 4-6 actually improves stability, since ΔV increases from that of the base case. This is substantiated by the time solution.

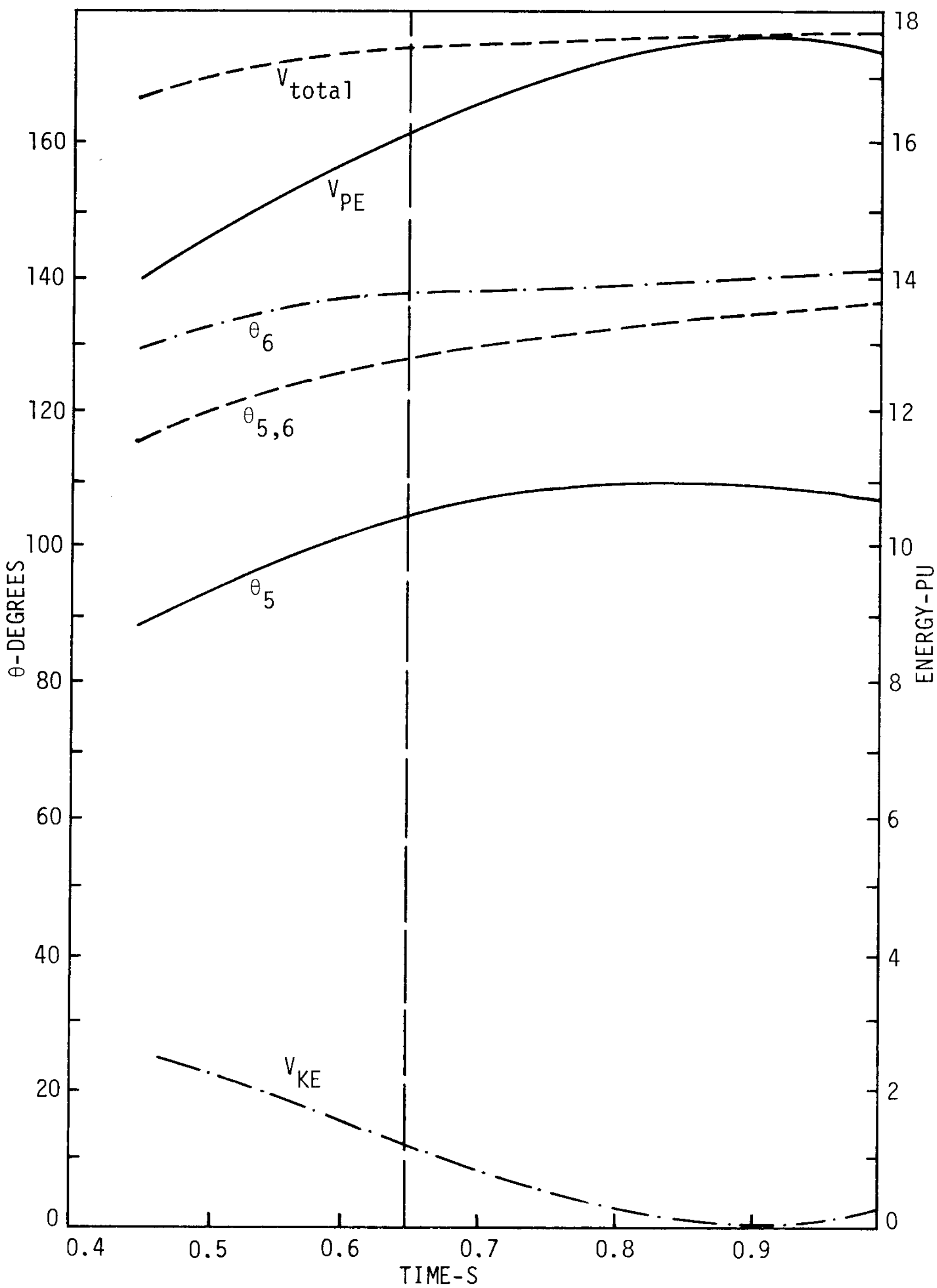


Figure 6-2. 17-generator system. Fault at Bus 372 cleared in 0.15s. Additional disturbance ΔP_{m6} = 485 MW.

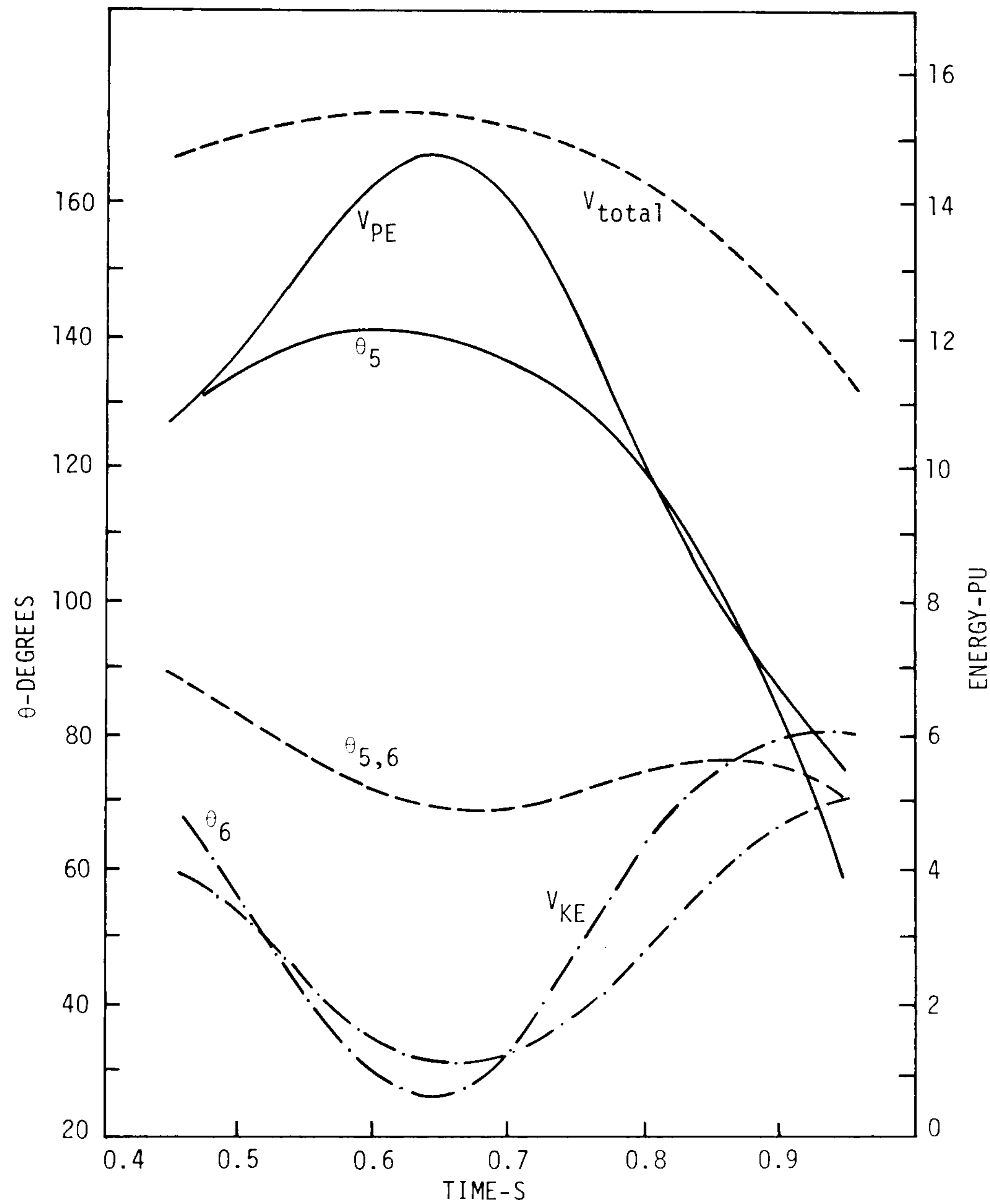


Figure 6-3. 17-generator system. Fault at Bus 372 cleared in 0.15s. Additional disturbance ΔP_{m5} = 275 MW.

17-Generator System

This system is investigated for a three-phase fault at Raun (Bus 372) cleared in 0.15 s by opening line 372-193. The corrected transient energy margin ΔV is computed for several additional line outages at the instant of fault clearing. The results are given in Table 6-2. Some information on the trajectories of the critical machines (Generators No. 5 and 6) obtained from the time solutions is also given.

Table 6-1

ΔV FOR ADDITIONAL NETWORK CHANGES[a]
4-GENERATOR SYSTEM

Case Number	Lines Cleared	ΔV (pu)	$\theta_{41}\|_{max}$[b] (degrees)
1	10-8 alone (base Case)	0.363	84.8
2	10-8, 4-5	0.462	80.7
3	10-8, 4-6	0.500	76.0
4	10-8, 5-7	0.005	140.0 (critically stable)
5	10-8, 6-9	0.180	114.7
6	10-8, 7-8	0.056	104.9
7	10-8, 8-9	0.083	111.3

[a]Fault at Bus 10.
[b]Data taken from swing curves.

Before this work was terminated, substantiation of some of this data was made by obtaining time solutions (swing curves). To judge the severity of the fault, the position of the inertial center of the critical machines (Generators No. 5 and 6) with respect to the position of one of the large equivalents in the eastern part of the system (Generator No. 13 - Davenport) was computed; this is designated as $\bar{\theta}_{5,6-13}$. In Table 6-2, the peak value of this angle is given together with the corresponding value at the u.e.p. for three cases. The peaks that are

Table 6-2

ΔV FOR ADDITIONAL NETWORK CHANGES[a]
17-GENERATOR SYSTEM

Case Number	Lines Cleared	ΔV (pu)	Swing Curves: $\bar{\theta}_{5,6-13}\big\|_{max}$	Swing Curves: $\bar{\theta}^{u}_{5,6-13}$
1	372-193 alone (base case)	7.44	98.0	176.3
2	372-193, 372-482	3.17	103.3	176.7
3	372-193, 372-773	- 1.74	Unstable	
4	372-193, 371-800	7.37		
5	372-193, 436-771	7.04		
6	372-193, 436-439	6.84		
7	372-193, 439-435	6.97		
8	372-193, 482-435	11.86		
9	372-193, 771-775	6.34		
10	372-193, 773-775	3.03	94.5	162.1
11	372-193, 435-471	6.84		
12	372-193, 6-439	6.74		
13	372-193, 774-771	7.18		

[a]Fault at Bus 372.

closer to the value of the u.e.p. angle are judged to indicate more severe disturbances. This criterion checks with the relative magnitudes of the transient energy margin ΔV.

The data in Table 6-2 indicates that for a fault at the Raun bus, the most severe additional network change is when line 372-773 is lost, since the system becomes unstable. Therefore, for this disturbance, this line represents the weakest link in the system. The next most severe network changes are the loss of either lines 771-775 or 372-482.

This work was not pursued further.

Section 7

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Appendix A

SUPPORTING EFFORTS

To carry out the investigations pursued in this research project, numerous supporting efforts were needed. Most of these efforts have been mentioned in the previous sections. For convenience, and to emphasize the scope and complexity of the research project, they are outlined here.

COMPUTER PROGRAMS

Several computer programs were used in the different tasks of this project. A brief summary is given here.

Computer Programs in Library

Two computer program packages were used as obtained from outside sources:

1. The Philadelphia Electric Transient Stability Program and its companion load flow program were available from the Power System Computer Service at Iowa State University. This package was used to simulate disturbances by time solution of the network.

2. Transient Energy Stability Analysis (TESA) was provided by Systems Control, Inc. The TESA programs estimate the unstable equilibrium angles θ^u, the critical energy, and the energy at the time of the fault clearing.

Computer Programs Adapted or Developed

In addition to the program packages obtained from outside sources, three rather extensive programs were developed in the course of this research. The first two, TSWING and MARGIN, borrowed several of the subroutines from the TESA package. The third program, YMOD, is a new method of generating the modified Y-bus matrices required in this work.

TSWING

The program TSWING simulates the disturbance by time simulation. At each time step it computes and plots various parameters. The basic features are:

1. Computes and plots rotor angles, $\theta_i(t)$, with respect to the system inertial center.

2. Computes and plots the rms deviation between $\theta_i(t)$ and θ_i^u.

3. Computes and plots kinetic energy, position energy, magnetic energy, dissipation energy, potential energy, and total energy.

4. Injects additional disturbances in the form of additional generation or load in any distribution and at any instant.

5. Generates the reduced Y-bus matrix used in program MARGIN.

The basic network reduction and swing simulation are accomplished by subroutines borrowed from TESA. The TSWING program provides a means of inspecting energy shifts and the resulting trajectories for a wide range of disturbances.

MARGIN

The program MARGIN computes the energy function between any two system states, a and b, i.e., calculates $V\Big|_a^b$. When a is the system states (angles and velocities) at the instant of clearing and b is the system states at the u.e.p., then the result is the energy margin. This margin is then corrected for the kinetic energy that does not contribute to instability. The program also implements the algorithm that computes the additional disturbance ΔP (see Section 6) and iterates to adjust the u.e.p. to account for the injection of ΔP.

The basic features of MARGIN are:

1. Computation of θ^{s2} and θ^u for a given system condition and initial estimate of θ^s and θ^u. This utilizes a Davidon-Fletcher-Powell subroutine from TESA.

2. Computation of the energy, broken down in line-by-line and node-by-node fashion. This provides a complete dissecting of where the energy resides in the system.

3. Predicts an additional disturbance ΔP (see Section 6) that will consume the margin obtained in step 2 for any distribution desired.

4. Computes new values of θ^u for any ΔP injection and any distribution.

5. Provides iteration of steps 2, 3, and 4 to obtain a margin and ΔP prediction that includes the effect of the ΔP injection on the u.e.p.

6. Computes the kinetic energy correction and adjusts the margin accordingly.

YMOD

The YMOD program performs reduction of the full Y-bus matrix to the reduced Y-bus corresponding to the internal nodes. The method stores all the necessary steps in the process of reduction, namely, in the form of triangular matrix factors of the Y-bus matrix. Then it uses these triangular matrix factors to efficiently compute the changes to the reduced Y-bus matrix due to various network disturbances such as tripping or closing of lines.

The program uses an efficient technique to find the changes to the reduced Y-bus matrix. However, the program is not in its most efficient form in the sense that it does not exploit sparsity to the fullest extent, both for storing and operations.

The YMOD program can eventually replace the network reduction subroutine now used to generate the reduced Y-bus matrices for both TSWING and MARGIN and be useful in assessment of network changes.

The TSWING, MARGIN and YMOD programs have been adapted for use in an interactive mode so that an operator dictates the course of program execution by manipulating keyboard controls. This interactive control makes these three programs very powerful tools for system study.

SIMPLIFIED DISTURBANCE SIMULATION

Keeping in mind that the goal of the project is to develop tools for dynamic security assessment, we felt that we needed to be able to simulate a disturbance without using step-by-step calculation. Disturbances in the form of load changes ΔP_L (or a distribution of load changes), loss of generation, and faults were investigated. The resulting changes in machine angles, speeds, and equivalent internal powers were computed. The results obtained by the approximate methods developed in this project were very encouraging and compared favorably with results obtained by time solutions. This work is documented in Section 4 (see also Interim Report No. 1).

THEORETICAL INVESTIGATIONS

The following areas of investigation were pursued in the various stages of this research project.

1. The "shift" in the unstable equilibrium point due to additional power disturbances (see Section 6).
2. How the transient energy is absorbed by the various generators in the system (see Sections 3 and 4).

3. The mechanism by which critical generators tend to separate from the system, and hence, the modes of instability in a multimachine system (see Sections 3 and 4).

4. The concept of the Principal Energy Boundary Surface (PEBS). It has received much attention in the recent Japanese literature and in SCI's final report on the energy function method. This concept has been mentioned in several sections of this report (but was not the focus of any section).

5. Investigation of other direct methods of stability analysis. We devoted considerable time and effort to the method used by Professor M. Ribbens-Pavella at the University of Liege. Some fundamental discrepancies were encountered, and we opted not to devote additional efforts to it.

6. Corrections to expressions for transient energy and transient energy margin (see Sectons 4 and 5).

   -- Correcton due to change of θ^s.

   -- Correction for the kinetic energy not contributing to separation of the critical machines.

7. Analogy with equal area criterion for one-machine-infinite-bus system. This has improved our understanding of the transient process. It has been mentioned in several places in this report (e.g., see Sections 3 and 6).

8. Investigation of network disturbances (see Sections 4 and 6).

9. Normalization of the transient energy margin (see Section 5).

Appendix B

TEST SYSTEMS DATA

4-GENERATOR TEST SYSTEM

The line data, bus data, and load flow of the 11-bus test system are given on the following pages. A diagram of the system is given in Figure 2-1.

This system is a modified version of a 9-bus test system often referred to in the literature as the WSCC test system. The modifications include the following:

1. Bus loads and generation were increased.
2. Two lines, a transformer and a fourth generator were added to the system.
3. Transmission line capacitance was changed to represent a 161-kV system.
4. Bus capacitors were added to the three load buses.

The four generators modeled in the system are identified in Table B-1. The bus and generator numbers correspond to the numbers in Table 2-1 and Figure 2-1.

Table B-1

4 GENERATORS MODELED IN THE 4-GENERATOR SYSTEM

Generator Number	Load Flow Bus Number	Bus Name
1	1	Gen 1
2	2	Gen 2
3	3	Gen 3
4	11	Gen 11

****

IOWA STATE UNIVERSITY VERSION OF 360 LOADFLOW PROGRAM

TITLE-LOADFLOW OF THE 4 GENERATOR, 11 BUS TEST POWER SYSTEM

==

TRANSMISSION LINE AND TRANSFORMER DATA ASSEMBLY

	INPUT BASE	CONVERTED BASE
GROUP 1		
	0.0 KV	0.0 KV
LINE	0. MVA	100. MVA

LINE P	LINE Q	NO.	ACTUAL R(PCT)	ACTUAL X(PCT)	ACTUAL KVAC	CONVERTED NO TAP EFFECT BC/2(PU)	G(PU)	B(PU)	MVA RATING	TAP/PH RATIO	TAP/PH LIM TMIN	TAP/PH LIM TMAX	SCHEDULE VALUE	MAP DATA FLOW PG	FLOW LOC	FLOW Q	TAP LOC	REV FLOW PG	REV FLOW LOC	REV FLOW Q
1	4	0	0.0	5.76	0.0	0.0	0.0	-17.3611	0.	1.000				0	0		0	0	0	
2	7	0	0.0	6.25	0.0	0.0	0.0	-16.0000	0.	1.000				0	0		0	0	0	
3	9	0	0.0	5.86	0.0	0.0	0.0	-17.0648	0.	1.000				0	0		0	0	0	
4	6	0	1.70	9.20	3793.58	0.0190	1.9422	-10.5107	0.					0	0			0	0	
5	4	0	1.00	8.50	4225.76	0.0211	1.3652	-11.6041	0.					0	0			0	0	
6	9	0	3.90	17.00	8595.58	0.0430	1.2820	-5.5882	0.					0	0			0	0	
7	5	0	3.20	16.10	7347.06	0.0367	1.1876	-5.9751	0.					0	0			0	0	
7	8	0	0.85	7.20	3577.49	0.0179	1.6171	-13.6980	0.					0	0			0	0	
8	10	0	3.57	30.24	15054.27	0.0753	0.3850	-3.2614	0.					0	0			0	0	
8	10	1	3.57	30.24	15054.27	0.0753	0.3850	-3.2614	0.					0	0			0	0	
9	5	0	1.19	10.09	5018.09	0.0251	1.1551	-9.7843	0.					0	0			0	0	
11	10	0	0.0	6.00	0.0	0.0	0.0	-16.6667	0.	1.000				0	0		0	0	0	

==

BASE CASE BUS DATA ENTERED

BUS NO.	BUS NAME	AREA	REG	VOLTAGE MAG(PU)	VOLTAGE ANG(DEG)	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	QMIN MVAR	QMAX MVAR	REACTOR MVAR	MAP DATA PAGE	VOLT LOC A	LOAD LOC Q	GEN LOC Q	REACTOR LOC QS
1	GEN 1	64	2	1.040	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0
2	GEN 2	64	1	1.035	0.0	0.0	0.0	160.0	0.0	-30.0	100.0	0.	0	0	0	0	0
3	GEN 3	64	1	1.035	0.0	0.0	0.0	100.0	0.0	-30.0	60.0	0.	0	0	0	0	0
4	BUS 4	64	0	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0
5	STA 'A'	64	0	1.000	0.0	200.0	80.0	0.0	0.0	0.0	0.0	60.	0	0	0	0	0
6	STA 'B'	64	0	1.000	0.0	230.0	77.0	0.0	0.0	0.0	0.0	70.	0	0	0	0	0
7	BUS 7	64	0	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0
8	STA 'C'	64	0	1.000	0.0	200.0	70.0	0.0	0.0	0.0	0.0	30.	0	0	0	0	0
9	BUS 9	64	0	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0
10	BUS 10	64	0	1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0
11	GEN 11	64	1	1.035	0.0	0.0	0.0	160.0	0.0	-30.0	100.0	0.	0	0	0	0	0

TITLE-LOADFLOW OF THE 4 GENERATOR, 11 BUS TEST POWER SYSTEM

RECORD OF CONVERGENCE

ITERATION COUNT	LARGEST BUS NO.	LARGEST MW MISMATCH	NUMBER ABOVE TOL.	MW SYSTEM MISMATCH	LARGEST BUS NO.	LARGEST MVAR MISMATCH	NUMBER ABOVE TOL.	MVAR SYSTEM MISMATCH	JACOBIAN SIZE IN FOUR BYTE WORDS ORIGINAL	SOLVED
0	6	2.3000E 02	6	-2.1000E 02	8	1.6619E 01	7	1.3708E 01	176	83
1	6	1.3166E 01	10	-1.7531E 01	10	2.5176E 01	7	-1.2002E 02	176	83
2	6	1.3694E 00	7	-7.7727E-01	4	9.8501E-01	7	-3.7111E 00	176	83
3	4	6.9123E-03	0	-2.9284E-03	4	5.1528E-03	0	-9.5190E-03	176	83

SUMMARY

LINE AND BUS TOTALS	ACTUAL	MAX
TRANSMISSION LINES	8	1050
TRANSFORMERS - FIXED	4	350
- LTC	0	350
FLOW TRANS - PHASE	0	350
- VARS	0	350
TOTAL LINES ---------	12	1050
BUSES - NON REG (INCLUDING SWING)	8	700
- GENERATOR	3	266
TOTAL BUSES ---------	11	700
CAPACITORS OR REACTORS	3	120

	MW	MVAR
TOTAL LOAD	630.000	227.000
TOTAL LOSSES	16.880	170.714
LINE CHARGING		-62.935
FIXED CAP/REACT		-151.091
SYSTEM MISMATCH	-0.001	0.012
TOTAL GENERATION	646.879	183.700

MISCELLANEOUS CONSTANTS	
ACTUAL ITERATIONS	3
MAXIMUM ITERATIONS	10
TOLERANCE - REAL	0.10 MW
- IMAG	0.10 MVAR
STUDY BASE ---	100.00 MVA

THERE ARE NO VOLTAGES UNDER 0.950

THERE ARE NO VOLTAGES OVER 1.050

TITLE-LOADFLOW OF THE 4 GENERATOR, 11 BUS TEST POWER SYSTEM

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1 GEN 1 , AREA 64

AREA NO.	FROM BUS	FROM NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	TO NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
64	1	GEN 1	1.040	0.0	0.0	0.0	226.9	93.2									
										4-	BUS 4	64	0	226.88	93.21		1.000
64	2	GEN 2	1.035	3.8	0.0	0.0	160.0	44.3R									
										7-	BUS 7	64	0	160.00	44.27		1.000
64	3	GEN 3	1.035	-0.8	0.0	0.0	100.0	36.3R									
										9-	BUS 9	64	0	100.00	36.33		1.000
64	4	BUS 4	1.002	-7.2	0.0	0.0	0.0	0.0									
										1-	GEN 1	64	0	-226.88	-52.11		
										5-	STA 'A'	64	0	94.70	28.81		
										6-	STA 'B'	64	0	132.17	23.30		
64	5	STA 'A'	0.969	-11.8	200.0	80.0	0.0	0.0	-56.363								
										4-	BUS 4	64	0	-93.71	-24.51		
										7-	BUS 7	64	0	-106.29	0.87		
64	6	STA 'B'	0.963	-14.2	230.0	77.0	0.0	0.0	-64.959								
										4-	BUS 4	64	0	-129.11	-10.37		
										9-	BUS 9	64	0	-100.89	-1.66		
64	7	BUS 7	1.013	-1.7	0.0	0.0	0.0	0.0									
										2-	GEN 2	64	0	-160.00	-28.19		
										5-	STA 'A'	64	0	110.14	11.30		
										8-	STA 'C'	64	0	49.86	16.88		
64	8	STA 'C'	0.996	-3.6	200.0	70.0	0.0	0.0	-29.759								
										7-	BUS 7	64	0	-49.62	-18.50		
										9-	BUS 9	64	0	5.22	-22.87		
										10-	BUS 10	64	0	-77.80	0.57		
										10-	BUS 10	64	1	-77.80	0.57		
64	9	BUS 9	1.016	-4.0	0.0	0.0	0.0	0.0									
										3-	GEN 3	64	0	-100.00	-30.13		
										6-	STA 'B'	64	0	105.17	11.89		
										8-	STA 'C'	64	0	-5.17	18.24		
64	10	BUS 10	1.028	9.8	0.0	0.0	0.0	0.0									
										8-	STA 'C'	64	0	80.00	2.66		
										8-	STA 'C'	64	1	80.00	2.66		
										11-	GEN 11	64	0	-160.00	-5.33		
64	11	GEN 11	1.035	15.0	0.0	0.0	160.0	19.9R									
										10-	BUS 10	64	0	160.00	19.89		1.000

END OF REPORT FOR THIS CASE

TITLE-LOADFLOW OF THE 4 GENERATOR, 11 BUS TEST POWER SYSTEM

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
1	GEN 1	64	4	BUS 4	64	0	0.0	5.76	0.0	0.	1.000				0	0	0	0				YES
2	GEN 2	64	7	BUS 7	64	0	0.0	6.25	0.0	0.	1.000				0	0	0	0				YES
3	GEN 3	64	9	BUS 9	64	0	0.0	5.86	0.0	0.	1.000				0	0	0	0				YES
4	BUS 4	64	1	GEN 1	64	0	0.0	5.76	0.0	0.									0	0	0	NO
4	BUS 4	64	5	STA 'A'	64	0	1.00	8.50	-4225.75	0.					0	0	0					YES
4	BUS 4	64	6	STA 'B'	64	0	1.70	9.20	-3793.58	0.					0	0	0					YES
5	STA 'A'	64	4	BUS 4	64	0	1.00	8.50	-4225.75	0.									0	0	0	NO
5	STA 'A'	64	7	BUS 7	64	0	3.20	16.10	-7347.05	0.					0	0	0					YES
6	STA 'B'	64	4	BUS 4	64	0	1.70	9.20	-3793.58	0.									0	0	0	NO
6	STA 'B'	64	9	BUS 9	64	0	3.90	17.00	-8595.57	0.					0	0	0					YES
7	BUS 7	64	2	GEN 2	64	0	0.0	6.25	0.0	0.									0	0	0	NO
7	BUS 7	64	5	STA 'A'	64	0	3.20	16.10	-7347.05	0.									0	0	0	NO
7	BUS 7	64	8	STA 'C'	64	0	0.85	7.20	-3577.49	0.					0	0	0					YES
8	STA 'C'	64	7	BUS 7	64	0	0.85	7.20	-3577.49	0.									0	0	0	NO
8	STA 'C'	64	9	BUS 9	64	0	1.19	10.08	-5018.09	0.					0	0	0					YES
8	STA 'C'	64	10	BUS 10	64	0	3.57	30.24	-15054.26	0.					0	0	0					YES
8	STA 'C'	64	10	BUS 10	64	1	3.57	30.24	-15054.26	0.					0	0	0					YES
9	BUS 9	64	3	GEN 3	64	0	0.0	5.86	0.0	0.									0	0	0	NO
9	BUS 9	64	6	STA 'B'	64	0	3.90	17.00	-8595.57	0.									0	0	0	NO
9	BUS 9	64	8	STA 'C'	64	0	1.19	10.08	-5018.09	0.									0	0	0	NO
10	BUS 10	64	8	STA 'C'	64	0	3.57	30.24	-15054.26	0.									0	0	0	NO
10	BUS 10	64	8	STA 'C'	64	1	3.57	30.24	-15054.26	0.									0	0	0	NO
10	BUS 10	64	11	GEN 11	64	0	0.0	6.00	0.0	0.									0	0	0	NO
11	GEN 11	64	10	BUS 10	64	0	0.0	6.00	0.0	0.	1.000				0	0	0	0				YES

LOADFLOW DATA CURRENTLY IN STORAGE FOR BUSES

BUS NO.	NAME	AREA	REG	VOLTAGE MAG(PU)	ANG(DEG)	LOAD MW	MVAR	GENERATION MW	MVAR	QMIN MVAR	QMAX MVAR	REACTOR KVAR	MAP DATA PAGE	VOLT LOC	A	LOAD LOC	Q	GEN LOC	Q	REACTOR LOC	QS
1	GEN 1	64	2	1.010	0.0	0.0	0.0	225.9	83.2	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
2	GEN 2	64	1	1.035	3.8	0.0	0.0	160.0	44.3	-30.0	100.0	0.	0	0	0	0	0	0	0	0	0
3	GEN 3	64	1	1.035	-0.8	0.0	0.0	100.0	36.3	-30.0	60.0	0.	0	0	0	0	0	0	0	0	0
4	BUS 4	64	0	1.002	-7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
5	STA 'A'	64	0	0.969	-11.8	200.0	80.0	0.0	0.0	0.0	0.0	-60000.	0	0	0	0	0	0	0	0	0
6	STA 'B'	64	0	0.963	-14.2	230.0	77.0	0.0	0.0	0.0	0.0	-70000.	0	0	0	0	0	0	0	0	0
7	BUS 7	64	0	1.013	-1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
8	STA 'C'	64	0	0.996	-3.6	200.0	70.0	0.0	0.0	0.0	0.0	-30000.	0	0	0	0	0	0	0	0	0
9	BUS 9	64	0	1.016	-4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
10	BUS 10	64	0	1.023	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
11	GEN 11	64	1	1.035	15.0	0.0	0.0	160.0	19.9	-30.0	100.0	0.	0	0	0	0	0	0	0	0	0

TITLE-LOADFLOW OF THE 4 GENERATOR, 11 BUS TEST POWER SYSTEM

SCHEDULED VOLTAGE FOR BUSES REGULATED BY REACTIVE GENERATION

B U S NO.	NAME	AREA	SCHEDULED VOLTAGE
2	GEN 2	64	1.035
3	GEN 3	64	1.035
11	GEN 11	64	1.035

==

NO BUSES ARE REGULATED BY LTC CONTROL

==

MISCELLANEOUS DATA CONSTANTS CURRENTLY IN STORAGE

REAL POWER MISMATCH TOLERANCE PER UNIT = 0.001000

IMAG POWER MISMATCH TOLERANCE PER UNIT = 0.001000

SYSTEM BASE MVA = 100.000

INPUT DEVICE UNIT NUMBER = 5

OUTPUT DEVICE UNIT NUMBER = 3

==

THERE IS NO AREA INTERCHANGE DATA IN STORAGE

==

END OF LISTING FOR DATA TABLES IN STORAGE

==

THERE ARE NO OUTAGES IN EFFECT

17-GENERATOR TEST SYSTEM (MODIFIED IOWA SYSTEM)

The system data and load flow of a 284-line, 162-bus, 17-generator system are given on the following pages. The data was obtained by a network reduction of the load flow data actually used by the Iowa Public Service Company in a stability study of their NEAL 4 unit. The data represents 1980 load, generation and transmission conditions in Iowa and the surrounding areas.

In the load flow data, transmission lines with a parallel line number (circuit number) of 31 are equivalent lines from the reduction process. Buses with an area code of 31 are terminal buses of the reduction. The terminal buses have an equivalent load or generation and are "terminals" for the equivalent lines.

The 17 generators modeled in the system are identified in Table B-2. The generator numbers correspond to the numbers given in Table 2-1 and Figure 2-4. Bus numbers and names are those shown in Figures 2-3 and 2-4. All other generations given in the following load flow data were converted to equivalent loads and modeled as constant impedance loads in the stability analysis. This generation was not modeled in the stability analyses because it represented either:

- A relatively small generator.
- A generator located far from the region of interest.
- An equivalent generation created by the network reduction program and not representing an actual generator.

Table B-2

17 GENERATORS MODELED IN THE 17-GENERATOR IOWA SYSTEM

Generator Number	Load Flow Bus Number	Load Flow Bus Name	Name
1	393	STJO712	St. Joseph
2	998	COOPR1G	Cooper
3	268	FTRAD4	Ft. Randall
4	635	WILMRT3	Wilmarth
5	1246	NEAL12G	Neal 1 and 2
6	1247	NEAL34G	Neal 3 and 4
7	1252	PRARK4G	Prairie Creek
8	1254	MTOW3G	Marshalltown
9	1265	AROL1G	Duane Arnold
10	1267	C.BL12G	Council Bluffs 1 and 2
11	1270	DPS57G	Des Moines
12	1271	C.BL3G	Council Bluffs 3
13	480	DVNPT3	Davenport
14	1201	PALM710	Palmyra
15	539	PRILD3	Prairie Island
16	733	FT.CL1G	Ft. Calhoun
17	339	NEBCY1G	Nebraska City

IOWA STATE UNIVERSITY VERSION OF 360 LOADFLOW PROGRAM

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

RECORD NUMBER 3 HAS BEEN LOADED FROM REEL- 0 ON DRIVE 20 WITH A TITLE AND DATE AS FOLLOWS

TITLE-NEAL 4 LOADFLOW CASE LF-080-8-00

DATE= 4/26/79 TIME= 2:10 PM

COMPANY-EPRI PROJECT

NEW CHANGES TO LINE OR TRANSFORMER DATA

TYPE	P	TK	Q	NO.	R(PCT)	X(PCT)	KVAC	RATING	TAP	TMIN	TMAX	SKD VAL	BSOLD	BSNEW	BSMVA	PG	FLO	NV	TAP	PG	RFLO	NV
X	XXXX	X	XXXX	XX	XXX.XX	XXX.XX	XXXXX.XX	XXX.	.XXX	.XXX	.XXX	X.XXX	XX.X	XX.X	XXX.	XX	XXX	X	XXX	XX	XXX	X
2	372		332																			

RECORD OF CONVERGENCE

ITERATION COUNT	LARGEST BUS NO.	LARGEST MW MISMATCH	NUMBER ABOVE TOL.	MW SYSTEM MISMATCH	LARGEST BUS NO.	LARGEST MVAR MISMATCH	NUMBER ABOVE TOL.	MVAR SYSTEM MISMATCH	JACOBIAN SIZE IN FOUR BYTE WORDS ORIGINAL	SOLVED
0	372	3.0072E 02	2	1.1853E 00	332	3.1131E 01	4	-8.8488E 00	7287	3563
1	372	8.8768E 00	16	-3.5401E 00	258	6.0356E 00	35	-3.8365E 01	7287	3563
2	332	1.5064E-01	2	-6.3348E-02	376	2.2155E 00	1	-2.6720E 00	7327	3583
3	371	3.7818E-03	0	-3.0961E-02	371	4.7967E-02	0	-2.2246E-01	7327	3583

AREA INTERCHANGE TOTALS SUMMARY

AREA NO. NAME	AREA FLOW(NEGATIVE INTO AREA) ACTUAL MW	DESIRED MW	TOL. MW	AREA SWING BUS NO.	NAME	GEN MW	AREA TOTALS GEN MW	LOAD MW	LOSS MW	NUMBER OF BUSES IN AREA
31-EQUIVAL	-1211.59	0.0	0.0	0-		0.0	44951.38	46113.40	49.57	30
195-NPPD	785.85	0.0	0.1	0-		0.0	794.00	0.0	8.15	4
200-ISP	-332.00	0.0	0.1	0-		0.0	0.00	317.61	14.40	10
201-USBR-6	-301.10	0.0	0.1	0-		0.0	83.70	375.43	9.37	11

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

AREA INTERCHANGE TOTALS SUMMARY

AREA NO. NAME	AREA FLOW(NEGATIVE INTO AREA) ACTUAL MW	DESIRED MW	TOL. MW	AREA SWING BUS NO.	NAME	GEN MW	AREA TOTALS GEN MW	LOAD MW	LOSS MW	NUMBER OF BUSES IN AREA
209-CBPC	-88.94	0.0	0.1	0-		0.0	0.00	88.24	0.70	3
210-IPS	831.83	0.0	0.1	0-		0.0	1502.00	638.14	32.03	31
211-IELP	-195.13	0.0	0.1	0-		0.0	764.61	948.13	11.60	26
212-IPL	-161.09	0.0	0.1	0-		0.0	924.00	1066.79	18.30	30
213-ISU	-98.85	0.0	0.1	0-		0.0	0.00	96.01	2.85	3
214-IIGE	-250.65	0.0	0.1	0-		0.0	0.00	243.10	7.54	5
216-NSP	-1.05	0.0	0.1	0-		0.0	0.0	0.0	1.05	1
233-OPPD	1022.75	0.0	0.1	0-		0.0	1030.00	0.0	7.25	8

SUMMARY OF AREA INTERCHANGE (NEGATIVE FLOW DENOTES POWER RECEIVED BY AREA)

AREA NO.	AREA NAME	LINE FROM NO. NAME	LINE TO NO. NAME	LINE NO.	AREA NO.	FLOW	DESIRED FLOW	TOL	SLACK BUS NO.	NAME	GEN	AREA GENERATION	LOAD	LOSSES
31	EQUIVAL	14-TWINCH4	258-SX CY 4	0	201	-178.52								
		15-SHELON7	16-MOOR 3	0	195	-176.01								
		17-GR ILD3	16-MOOR 3	0	195	-31.16								
		53-WAGEER7	7-LINCLN3	0	195	-343.51								
		146-HARMNY5	198-ADAM 5	0	200	79.87								
		152-ROCHTR5	198-ADAM 5	0	200	61.85								
		175-POSTIL5	201-HAZLON5	0	200	75.45								
		192-HRN K 5	204-LAKFD 5	0	200	-58.77								
		200-DUBUUE5	414-DUNDE 5	0	211	-1.61								
		203-CLINON5	410-CALUS 5	0	211	13.11								
		259-SX FLL7	260-SIOXLS4	0	201	-66.25								
		259-SX FLL7	260-SIOXLS4	1	201	-110.32								
		268-FTRAD 4	258-SX CY 4	0	201	72.87								
		268-FTRAD 4	262-UTICJC4	0	201	102.23								
		274-FTTHMP4	260-SIOXLS4	0	201	101.32								
		326-HANLN 4	260-SIOXLS4	0	201	67.45								
		333-WTRTWN3	648-SIOXLS	0	201	106.96								
		340-MARY 12	224-CRESN 5	0	201	10.59								
		340-MARY 12	432-CLRNA 5	0	212	-20.21								
		393-STJO712	6-CCOPR 3	0	195	-398.21								
		454-WAPELO5	441-OSKLOS5	0	212	-4.41								
		474-DAVNRT5	410-CALUS 5	0	211	52.67								
		474-DAVNRT5	472-HILL 5	0	214	28.58								
		480-DVNPT 3	471-HILL 3	0	214	160.05								
		539-GR ILO3	515-ADAM 3	0	216	187.37								
		635-WILMRT3	193-LAKFD 3	0	200	-43.57								
		636-RAPIAN5	195-WINRGO5	0	200	17.28								
		651-LACRSS3	515-ADAM 3	0	216	42.65								
		772-S1206 5	771-S3456 3	0	233	-368.75								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

SUMMARY OF AREA INTERCHANGE (NEGATIVE FLOW DENOTES POWER RECEIVED BY AREA)

AREA NO.	AREA NAME	LINE FROM NO. NAME	LINE TO NO. NAME	LINE NO.	AREA NO.	FLOW	DESIRED FLOW	DESIRED TOL	SLACK BUS NO.	SLACK BUS NAME	GEN	AREA GENERATION	AREA LOAD	AREA LOSSES
		776-S1209 5	775-S3459 3	0	233	-355.34								
		778-S1255 5	777-S3455 3	0	233	-264.24								
		780-S1211 5	987-S701 5	0	212	-20.31								
		1201-PALM710	471-HILL 3	0	214	107.94								
		1302-TEKAMA5	800-RAUN 5	0	210	-45.61								
			TIE LINE LOSSES			-13.06								
						-1211.59	0.0	0.0	0-		0.0	44951.38	46113.40	49.57
195	NPPD	6-COOPR 3	393-STJ0712	0	31	403.64								
		6-COOPR 3	439-BOONIL3	0	212	249.50								
		6-COOPR 3	774-NEBCY 3	0	233	-128.43								
		7-LINCLN3	53-WAGEER7	0	31	343.96								
		7-LINCLN3	779-S3454 3	0	233	-284.57								
		16-MOOR 3	15-SHELON7	0	31	176.25								
		16-MOOR 3	17-GR ILO3	0	31	31.21								
			TIE LINE LOSSES			-5.71								
						785.85	0.0	0.1	0-		0.0	794.00	0.0	8.15
200	ISP	193-LAKFD 3	372-RAUN 3	0	210	-244.17								
		193-LAKFD 3	635-WILMRT3	0	31	43.65								
		195-WINBGO5	636-RAPIAN5	0	31	-17.22								
		197-MASNTY5	377-FRANKN5	0	210	-0.26								
		197-MASNTY5	382-FLOY 5	0	210	23.77								
		197-MASNTY5	423-GARNR 5	0	211	5.50								
		198-ADAM 5	146-HARMNY5	0	31	-78.16								
		198-ADAM 5	152-ROCHTR5	0	31	-60.40								
		198-ADAM 5	515-ADAM 3	0	216	-110.97								
		201-HAZLON5	175-POSTIL5	0	31	-73.51								
		201-HAZLON5	379-BLKHK 5	0	210	117.15								
		201-HAZLON5	380-WSHRN 5	0	210	59.37								
		201-HAZLON5	414-DUNDE 5	0	211	23.40								
		202-HAZLON3	422-ARNOD 3	0	211	-26.85								
		202-HAZLON3	515-ADAM 3	0	216	-116.95								
		204-LAKFD 5	192-HRN K 5	0	31	59.46								
		204-LAKFD 5	416-TRI9JI5	0	211	71.32								
			TIE LINE LOSSES			-7.13								
						-332.00	0.0	0.1	0-		0.0	0.00	317.61	14.40
201	USBR-6	221-DENIN 5	223-ANITTP5	0	211	33.89								
		224-CRESN 5	223-ANITTP5	0	211	17.78								
		224-CRESN 5	340-MARY 12	0	31	-10.54								
		224-CRESN 5	432-CLRNA 5	0	212	-26.36								
		224-CRESN 5	434-D.MON 5	0	212	-14.63								
		226-SX CY 5	375-PLYMH 5	0	210	-191.99								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

SUMMARY OF AREA INTERCHANGE (NEGATIVE FLOW DENOTES POWER RECEIVED BY AREA)

AREA NO.	AREA NAME	LINE FROM NO. NAME	LINE TO NO. NAME	LINE NO.	AREA NO.	FLOW	DESIRED FLOW	DESIRED TOL	SLACK BUS NO.	SLACK BUS NAME	AREA GEN	AREA GENERATION	AREA LOAD	AREA LOSSES
		227-WISDM 5	361-OSGOD 5	0	209	47.26								
		227-WISDM 5	376-SAC 5	0	210	-5.76								
		227-WISDM 5	416-TRIBJI5	0	211	-50.33								
		258-SX CY 4	14-TWINCH4	0	31	180.18								
		258-SX CY 4	268-FTRAD 4	0	31	-71.41								
		260-SIOXLS4	259-SX FLL7	0	31	66.39								
		260-SIOXLS4	259-SX FLL7	1	31	110.60								
		260-SIOXLS4	274-FTTHMP4	0	31	-98.35								
		260-SIOXLS4	326-HANLN 4	0	31	-67.25								
		262-UTICJC4	268-FTRAD 4	0	31	-101.07								
		336-HINTON8	880-PLYMTH8	0	210	-7.98								
		648-SIOXLS	333-WTRTWN3	0	31	-106.31								
			TIE LINE LOSSES			-5.21								
						-301.10	0.0	0.1	0-		0.0	83.70	375.43	9.37
209	CBPC	361-OSGOD 5	227-WISDM 5	0	201	-46.84								
		362-HOPE 5	373-HOPET 5	0	210	-68.26								
		363-BURT 5	423-GARNR 5	0	211	26.59								
			TIE LINE LOSSES			-0.43								
						-88.94	0.0	0.1	0-		0.0	0.00	88.24	0.70
210	IPS	372-RAUN 3	193-LAKFD 3	0	200	247.69								
		372-RAUN 3	482-LEHIH 3	0	214	363.70								
		372-RAUN 3	773-FT.CL 3	0	233	226.58								
		373-HOPET 5	362-HOPE 5	0	209	68.57								
		373-HOPET 5	477-FT.DDG5	0	214	-28.34								
		373-HOPET 5	481-LEHIH 5	0	214	-117.04								
		375-PLYMH 5	226-SX CY 5	0	201	192.18								
		376-SAC 5	227-WISDM 5	0	201	5.77								
		377-FRANKN5	197-MASNTY5	0	200	0.26								
		377-FRANKN5	412-IA FS 7	0	211	45.11								
		379-BLKHK 5	201-HAZLON5	0	200	-114.66								
		380-WSHBN 5	201-HAZLON5	0	200	-58.73								
		380-WSHBN 5	419-OYSAT 5	0	211	-74.19								
		382-FLOY 5	197-MASNTY5	0	200	-23.64								
		383-POMEOY5	477-FT.DDG5	0	214	-5.71								
		387-CARRLL5	401-GR JT 5	0	211	59.78								
		800-RAUN 5	1302-TEKAMA5	0	31	46.13								
		880-PLYMTH8	336-HINTON8	0	201	7.99								
			TIE LINE LOSSES			-9.63								
						831.83	0.0	0.1	0-		0.0	1502.00	638.14	32.03
211	IELP	223-ANITTP5	221-DENIN 5	0	201	-33.53								
		223-ANITTP5	224-CRESN 5	0	201	-17.69								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

SUMMARY OF AREA INTERCHANGE (NEGATIVE FLOW DENOTES POWER RECEIVED BY AREA)

AREA NO.	AREA NAME	LINE FROM NO. NAME	LINE TO NO. NAME	LINE NO.	AREA NO.	FLOW	DESIRED FLOW	DESIRED TOL	SLACK BUS NO.	SLACK BUS NAME	GEN	AREA GENERATION	AREA LOAD	AREA LOSSES
		401-GR JT 5	387-CARRLL5	0	210	-58.96								
		401-GR JT 5	451-JASPR 8	0	213	-3.14								
		404-CDRPS 5	472-HILL 5	0	214	5.07								
		406-MTOW 7	451-JASPR 8	0	213	-0.60								
		410-CALUS 5	203-CLINON5	0	31	-13.08								
		410-CALUS 5	474-DAVNRT5	0	31	-52.33								
		412-IA FS 7	377-FRANKN5	0	210	-44.95								
		414-DUNDE 5	200-DUBUUE5	0	31	1.66								
		414-DUNDE 5	201-HAZLON5	0	200	-23.26								
		416-TRIBJI5	204-LAKFD 5	0	200	-70.63								
		416-TRIBJI5	227-WISDM 5	0	201	50.61								
		419-DYSAT 5	380-WSHBN 5	0	210	74.50								
		422-ARNOD 3	202-HAZLON3	0	200	27.01								
		422-ARNOD 3	471-HILL 3	0	214	-2.00								
		423-GARNR 5	197-MASNTY5	0	200	-5.49								
		423-GARNR 5	363-BURT 5	0	209	-26.47								
			TIE LINE LOSSES			-1.84								
						-195.13	0.0	0.1	0-		0.0	764.61	948.13	11.60
212	IPL	432-CLRNA 5	224-CRESN 5	0	201	26.75								
		432-CLRNA 5	340-MARY 12	0	31	20.37								
		434-D.MON 5	224-CRESN 5	0	201	14.76								
		434-D.MON 5	417-MONRE 5	0	213	90.95								
		434-D.MON 5	481-LEHIH 5	0	214	-26.86								
		435-SYCAOR3	471-HILL 3	0	214	-68.00								
		435-SYCAOR3	482-LEHIH 3	0	214	-96.56								
		436-CBLUFS3	771-S3456 3	0	233	154.14								
		439-BOONIL3	6-COOPR 3	0	195	-245.76								
		441-OSKLOS5	454-WAPELO5	0	31	4.45								
		441-OSKLOS5	457-POWAHK5	0	213	-51.74								
		987-S701 5	780-S1211 5	0	31	20.32								
			TIE LINE LOSSES			-3.91								
						-161.09	0.0	0.1	0-		0.0	924.00	1066.79	18.30
213	ISU	417-MONRE 5	434-D.MON 5	0	212	-89.09								
		451-JASPR 8	401-GR JT 5	0	211	3.18								
		451-JASPR 8	406-MTOW 7	0	211	0.61								
		457-POWAHK5	441-OSKLOS5	0	212	52.10								
		457-POWAHK5	472-HILL 5	0	214	-63.26								
			TIE LINE LOSSES			-2.39								
						-98.85	0.0	0.1	0-		0.0	0.00	96.01	2.85
214	IIGE	471-HILL 3	422-ARNOD 3	0	211	2.05								
		471-HILL 3	435-SYCAOR3	0	212	68.28								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

SUMMARY OF AREA INTERCHANGE (NEGATIVE FLOW DENOTES POWER RECEIVED BY AREA)

AREA NO.	AREA NAME	LINE FROM NO. NAME	LINE TO NO. NAME	LINE NO.	AREA NO.	FLOW	DESIRED FLOW	DESIRED TOL	SLACK BUS NO.	SLACK BUS NAME	AREA GEN	AREA GENERATION	AREA LOAD	AREA LOSSES
		471-HILL 3	480-DVNPT 3	0	31	-159.53								
		471-HILL 3	1201-PALM710	0	31	-107.16								
		472-HILL 5	404-CORPS 5	0	211	-5.03								
		472-HILL 5	457-POWAHK5	0	213	65.78								
		472-HILL 5	474-DAVNRT5	0	31	-28.37								
		477-FT.DDG5	373-HOPET 5	0	210	28.43								
		477-FT.DDG5	383-POMEOY5	0	210	5.76								
		481-LEHIH 5	373-HOPET 5	0	210	117.73								
		481-LEHIH 5	434-O.MON 5	0	212	27.30								
		482-LEHIH 3	372-RAUN 3	0	210	-355.81								
		482-LEHIH 3	435-SYCAOR3	0	212	96.85								
			TIE LINE LOSSES			-6.91								
						-250.65	0.0	0.1	0-		0.0	0.00	243.10	7.54
216	NSP	515-ADAM 3	198-ADAM 5	0	200	110.97								
		515-ADAM 3	202-HAZLON3	0	200	117.50								
		515-ADAM 3	539-PR ILD3	0	31	-185.90								
		515-ADAM 3	651-LACRSS3	0	31	-42.57								
			TIE LINE LOSSES			-1.05								
						-1.05	0.0	0.1	0-		0.0	0.0	0.0	1.05
233	OPPD	771-S3456 3	436-CBLUFS3	0	212	-154.01								
		771-S3456 3	772-S1206 5	0	31	369.17								
		773-FT.CL 3	372-RAUN 3	0	210	-225.14								
		774-NEBCY 3	6-COOPR 3	0	195	128.60								
		775-S3459 3	776-S1209 5	0	31	355.83								
		777-S3455 3	778-S1255 5	0	31	264.51								
		779-S3454 3	7-LINCLN3	0	195	285.90								
			TIE LINE LOSSES			-2.12								
						1022.75	0.0	0.1	0-		0.0	1030.00	0.0	7.25

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

SUMMARY

LINE AND BUS TOTALS	ACTUAL	MAX
TRANSMISSION LINES	238	1050
TRANSFORMERS - FIXED	46	350
- LTC	0	350
FLOW TRANS - PHASE	0	350
- VARS	0	350
TOTAL LINES ---------	284	1050
BUSES - NON REG (INCLUDING SWING)	146	700
- GENERATOR	16	266
TOTAL BUSES ---------	162	700
CAPACITORS OR REACTORS	34	120

	MW	MVAR
TOTAL LOAD	49886.852	1174.635
TOTAL LOSSES	162.790	1834.747
LINE CHARGING		-2288.621
FIXED CAP/REACT		193.956
SYSTEM MISMATCH	0.060	0.588
TOTAL GENERATION	50049.703	915.306

MISCELLANEOUS CONSTANTS	
ACTUAL ITERATIONS	3
MAXIMUM ITERATIONS	10
TOLERANCE - REAL	0.10 MW
- IMAG	0.10 MVAR
STUDY BASE ---	100.00 MVA

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THE FOLLOWING BUSES ARE CONTROLLED BY REACTIVE GENERATION ACTION AT OR BEYOND QMIN-QMAX LIMITS

NO.	BUS NAME	AREA	ACTUAL VOLTAGE	QG MVAR	QMIN MVAR	QMAX MVAR
376	SAC	5 210	0.998	20.0	-0.1	20.0

THERE ARE NO VOLTAGES UNDER 0.950

THERE ARE NC VCLTAGES OVER 1.050

NO LINES OVERLOADED

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G. AREA 211

AREA NO.	FROM BUS	FROM NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	TO NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
195	6	COOPR 3	1.033	-25.3	0.0	0.0	0.0	0.0	106.652								
										16	MOOR 3	195	0	269.29	-14.89	27.0	
										393	STJO712	31	0	403.64	47.56	37.8	
										439	BOONIL3	212	0	249.50	-37.68	25.2	
										774	NEBCY 3	233	0	-128.43	-9.27	11.1	
										998	COOPR1G	195	0	-794.00	-92.40	88.8	1.052
195	7	LINCLN3	1.019	-30.4	0.0	0.0	0.0	0.0									
										16	MOOR 3	195	0	-59.38	-34.88	6.4	
										53	WAGEER7	31	0	343.96	60.31	52.0	0.975
										779	S3454 3	233	0	-284.57	-25.45	39.8	
31	14	TWINCH4	0.993	-35.7	0.0	0.0	-226.0	11.5									
										17	GR ILD3	31	31	-14.11	0.11		
										53	WAGEER7	31	31	-4.00	-2.07		
										258	SX CY 4	201	0	-178.52	8.93	55.9	
										259	SX FLL7	31	31	-2.26	0.53		
										268	FTRAD 4	31	31	-27.12	4.00		
31	15	SHELON7	1.038	-33.7	0.0	0.0	-193.3	5.9									
										16	MOOR 3	195	0	-176.01	-17.30	52.6	1.025
										17	GR ILD3	31	31	-13.36	12.50		
										53	WAGEER7	31	31	6.10	5.04		
										772	S1206 5	31	31	-6.78	3.44		
										778	S1255 5	31	31	-3.24	2.21		
195	16	MOOR 3	1.023	-30.0	0.0	0.0	0.0	0.0									
										6	COOPR 3	195	0	-266.90	-20.65	26.8	
										7	LINCLN3	195	0	59.44	13.27	5.7	
										15	SHELON7	31	0	176.25	28.80	53.2	
										17	GR ILD3	31	0	31.21	-21.43	3.8	
31	17	GR ILD3	1.015	-30.7	0.0	0.0	-204.2	-37.3									
										14	TWINCH4	31	31	14.37	1.15		
										15	SHELON7	31	31	13.69	-11.53		
										16	MOOR 3	195	0	-31.16	-51.35	6.0	
										53	WAGEER7	31	31	10.29	-6.58		
										268	FTRAD 4	31	31	-33.64	5.14		
										274	FTTHMP4	31	31	-177.75	25.86		
31	53	WAGEER7	1.035	-33.8	0.0	0.0	-398.3	-19.2									
										7	LINCLN3	195	0	-343.51	-39.21	51.4	
										14	TWINCH4	31	31	4.09	2.29		
										15	SHELON7	31	31	-6.09	-5.00		
										17	GR ILD3	31	31	-10.11	7.27		
										268	FTRAD 4	31	31	-8.56	4.19		
										772	S1206 5	31	31	-12.67	3.50		
										778	S1255 5	31	31	-21.46	7.77		
212	57	SYCAOR8	1.014	-40.0	120.0	24.0	0.0	0.0									
										437	SYCAOR5	212	0	-120.00	-24.00	76.5	1.000
31	146	HARMNY5	1.007	-28.8	0.0	0.0	116.5	-44.7									
										152	ROCHTR5	31	31	0.61	-0.82		
										175	POSTIL5	31	31	10.33	-2.49		
										198	ADAM 5	200	0	79.87	-45.38	41.0	
										200	DUBUUE5	31	31	20.01	-3.46		

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										651-LACRSS3	31	31	5.67	7.45		
31	152	ROCHTR5	1.015	-29.6	0.0	0.0	54.2	-26.7								
										146-HARMNY5	31	31	-0.61	0.84		
										198-ADAM 5	200	0	61.85	-37.48	43.3	
										539-PR ILD3	31	31	-9.81	2.94		
										635-WILMRT3	31	31	1.89	1.55		
										651-LACRSS3	31	31	0.88	5.46		
31	175	POSTIL5	1.009	-30.4	0.0	0.0	69.8	-23.2								
										146-HARMNY5	31	31	-10.28	2.79		
										200-DUBUUE5	31	31	6.94	-0.48		
										201-HAZLON5	200	0	75.45	-29.22	33.7	
										651-LACRSS3	31	31	-2.32	3.71		
31	192	HRN K 5	0.989	-34.9	0.0	0.0	-63.5	-21.4								
										204-LAKFD 5	200	0	-58.77	-21.12	27.9	
										259-SX FLL7	31	31	-4.73	-0.28		
200	193	LAKFD 3	1.002	-29.4	0.0	0.0	0.0	0.0	50.156							
										204-LAKFD 5	200	0	200.52	46.64	91.5	
										372-RAUN 3	210	0	-244.17	-58.25	21.1	
										635-WILMRT3	31	0	43.65	-38.54	5.1	
200	194	FOX K 5	0.989	-36.1	38.5	13.2	0.0	0.0								
										195-WINBGO5	200	0	30.07	-8.87	18.8	
										204-LAKFD 5	200	0	-68.54	-4.31	30.7	
200	195	WINBGO5	0.989	-37.9	28.3	9.0	0.0	0.0								
										194-FOX K 5	200	0	-29.84	5.46	18.2	
										196-HAYWD 5	200	0	18.75	-14.40	21.5	
										636-RAPIAN5	31	0	-17.22	-0.09	10.3	
200	196	HAYWD 5	0.999	-39.8	101.2	32.5	0.0	0.0	-14.959							
										195-WINBGO5	200	0	-18.57	8.25	18.5	
										198-ADAM 5	200	0	-101.97	-12.16	45.6	
										208-LIMECK5	200	0	19.37	-13.65	11.7	
200	197	MASNTY5	0.999	-43.0	45.2	15.1	0.0	-0.1	-19.957							
										208-LIMECK5	200	0	-74.17	4.46	36.8	
										377-FRANKN5	210	0	-0.26	-2.95	2.6	
										382-FLOY 5	210	0	23.77	1.25	9.9	
										423-GARNR 5	211	0	5.50	2.04	2.7	
200	198	ADAM 5	1.036	-33.8	34.4	11.7	0.0	0.0								
										146-HARMNY5	31	0	-78.16	46.84	40.7	
										152-ROCHTR5	31	0	-60.40	36.97	42.4	
										196-HAYWD 5	200	0	104.15	18.22	47.0	
										208-LIMECK5	200	0	110.97	8.41	49.7	
										515-ADAM 3	216	0	-110.97	-122.12	73.3	1.119
31	200	DUBUUE5	1.000	-38.1	0.0	0.0	-64.4	-3.8R								
										146-HARMNY5	31	31	-19.07	6.59		
										175-POSTIL5	31	31	-6.76	1.38		
										203-CLINON5	31	31	-16.65	-0.57		
										414-DUNOE 5	211	0	-1.61	-18.10	8.3	
										651-LACRSS3	31	31	-20.31	6.91		
200	201	HAZLON5	1.034	-37.6	17.4	5.3	0.0	0.0								
										175-POSTIL5	31	0	-73.51	31.23	33.3	

IOWA STATE UNIVERSITY VERSION OF 360 LOADFLOW PROGRAM

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										202-HAZLON3	200	0	-143.80	-97.59	77.2	1.108
										379-BLKHK 5	210	0	117.15	20.59	52.9	
										380-WSHBN 5	210	0	59.37	18.86	28.6	
										414-DUNDE 5	211	0	23.40	21.63	14.2	
200	202	HAZLON3	0.988	-33.2	0.0	0.0	0.0	0.0								
										201-HAZLON5	200	0	143.80	114.67	81.7	
										422-ARNOD 3	211	0	-26.85	-98.23	21.2	
										515-ADAM 3	216	0	-116.95	-16.45	24.6	
31	203	CLINON5	1.012	-35.7	0.0	0.0	-41.5	17.2								
										200-DUBUUE5	31	31	16.82	1.29		
										410-CALUS 5	211	0	13.11	1.18	7.9	
										474-DAVNRT5	31	31	-10.11	0.19		
										480-DVNPT 3	31	31	-44.70	11.06		
										1201-PALM710	31	31	-16.62	3.47		
200	204	LAKFD 5	1.010	-33.3	0.0	0.0	0.0	0.0								
										192-HRN K 5	31	0	59.46	20.84	28.1	
										193-LAKFD 3	200	0	-200.52	-32.27	90.3	1.022
										194-FOX K 5	200	0	69.74	5.78	31.2	
										416-TRIBJI5	211	0	71.32	5.64	32.1	
200	208	LIMECK5	1.006	-41.1	52.7	15.1	0.0	0.0	-20.221							
										196-HAYWD 5	200	0	-19.24	9.56	10.6	
										197-MASNTY5	200	0	74.80	-4.06	37.1	
										198-ADAM 5	200	0	-108.26	-0.34	48.3	
201	221	DENIN 5	0.999	-39.0	65.3	22.3	0.0	0.0	-26.166							
										223-ANITTP5	211	0	33.89	-3.95	31.0	
										258-SX CY 4	201	0	-99.20	7.82	49.8	
211	223	ANITTP5	0.991	-41.7	4.8	1.6	0.0	0.0								
										221-DENIN 5	201	0	-33.53	-0.63	30.5	
										224-CRESN 5	201	0	-17.69	-6.23	17.1	
										429-ANIT 5	211	0	46.40	5.30		
201	224	CRESN 5	1.000	-40.6	93.8	22.9	60.0	29.9R								
										223-ANITTP5	211	0	17.78	1.62	16.2	
										340-MARY 12	31	0	-10.54	0.58		
										432-CLRNA 5	212	0	-26.36	12.68		
										434-D.MON 5	212	0	-14.63	-7.85	10.3	
201	226	SX CY 5	0.996	-30.7	0.0	0.0	0.0	0.0								
										227-WISOM 5	201	0	62.60	-6.19	57.2	
										258-SX CY 4	201	0	99.47	-22.63	27.2	1.000
										336-HINTON8	201	0	29.92	14.56	44.4	
										375-PLYMH 5	210	0	-191.99	14.24	57.6	
201	227	WISOM 5	0.989	-37.9	94.0	29.6	23.7	9.0								
										226-SX CY 5	201	0	-61.52	4.53	56.1	
										361-OSGOD 5	209	0	47.26	-13.24	22.3	
										376-SAC 5	210	0	-5.76	-8.79	4.4	
										416-TRIBJI5	211	0	-50.33	-3.08	22.9	
201	259	SX CY 4	1.000	-31.8	0.0	0.0	0.0	0.0								
										14-TWINCH4	31	0	180.18	-4.03	56.3	
										221-DENIN 5	201	0	100.64	-14.13	50.8	
										226-SX CY 5	201	0	-99.41	24.73	27.3	

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										262-UTICJC4	201	0	-51.50	-9.26		
										268-FTRAD 4	31	0	-71.41	-12.05		
										330-EAGL 4	201	0	47.42	21.33		
										332-SX CY 3	201	0	-105.91	-6.60	21.2	
31	259	SX FLL7	0.993	-34.0	0.0	0.0	-243.7	-26.0								
										14-TWINCH4	31	31	2.27	-0.47		
										192-HRN K 5	31	31	4.74	0.35		
										260-SIOXLS4	201	0	-66.25	-18.83	68.9	1.025
										260-SIOXLS4	201	1	-110.32	-30.05	57.2	1.025
										268-FTRAD 4	31	31	-9.59	1.51		
										274-FTTHMP4	31	31	-24.43	9.94		
										333-WTRTWN3	31	31	-33.47	10.15		
										539-PR ILD3	31	31	-6.66	1.41		
201	260	SIOXLS4	0.984	-31.4	0.0	0.0	0.0	0.0								
										259-SX FLL7	31	0	66.39	21.92	69.9	
										259-SX FLL7	31	1	110.60	35.53	58.1	
										262-UTICJC4	201	0	-48.75	-25.64	45.9	
										274-FTTHMP4	31	0	-98.35	-12.59	41.3	
										326-HANLN 4	31	0	-67.25	-7.24	45.1	
										330-EAGL 4	201	0	37.37	-11.98		
201	262	UTICJC4	1.009	-28.7	0.0	0.0	0.0	0.0								
										258-SX CY 4	201	0	51.95	-8.84		
										260-SIOXLS4	201	0	49.12	10.13	41.8	
										268-FTRAD 4	31	0	-101.07	-1.29		
31	268	FTRAD 4	1.019	-24.5	3420.2	0.0	3500.0	5.9								
										14-TWINCH4	31	31	28.09	1.36		
										17-GR ILD3	31	31	34.14	-1.51		
										53-WAGEER7	31	31	8.99	-2.71		
										258-SX CY 4	201	0	72.87	-14.28		
										259-SX FLL7	31	31	9.96	0.09		
										262-UTICJC4	201	0	102.23	-5.95		
										274-FTTHMP4	31	31	-182.98	27.26		
										326-HANLN 4	31	31	6.51	1.63		
31	274	FTTHMP4	1.024	-18.5	0.0	0.0	865.6	70.8								
										17-GR ILD3	31	31	180.82	12.38		
										259-SX FLL7	31	31	27.02	-3.14		
										260-SIOXLS4	201	0	101.32	-4.89	42.3	
										268-FTRAD 4	31	31	185.75	-7.88		
										326-HANLN 4	31	31	118.43	21.63		
										333-WTRTWN3	31	31	166.46	38.34		
										539-PR ILD3	31	31	49.30	7.12		
										635-WILMRT3	31	31	36.50	7.24		
31	326	HANLN 4	0.989	-29.8	0.0	0.0	-59.1	2.9								
										260-SIOXLS4	201	0	67.45	1.78	45.0	
										268-FTRAD 4	31	31	-6.44	-1.00		
										274-FTTHMP4	31	31	-116.24	1.89		
										333-WTRTWN3	31	31	-3.87	0.22		
201	330	EAGL 4	0.985	-33.0	84.4	27.1	0.0	0.0								
										258-SX CY 4	201	0	-47.22	-28.35		

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										260	SIOXLS4	201	0	-37.21	1.30		
201	332	SX CY 3	1.001	-31.1	0.0	0.0	0.0	0.0	50.096								
										258	SX CY 4	201	0	105.91	7.93	21.2	1.000
										648	SIOXLS	201	0	-105.91	-58.02	10.1	
31	333	WTRTWN3	0.997	-25.3	0.0	0.0	26.3	-116.3									
										259	SX FLL7	31	31	34.76	-5.01		
										274	FTTHMP4	31	31	-165.34	-17.75		
										326	HANLN 4	31	31	3.90	0.08		
										539	PR ILD3	31	31	14.29	-9.51		
										635	WILMRT3	31	31	31.73	-0.29		
										648	SIOXLS	201	0	106.96	-83.82	11.3	
201	336	HINTON8	0.980	-32.7	37.9	12.5	0.0	0.0									
										226	SX CY 5	201	0	-29.92	-13.28	43.7	1.000
										880	PLYMTH8	210	0	-7.98	0.78	12.5	
233	339	NEBCY1G	1.018	-20.4	0.0	0.0	575.0	94.1R									
										774	NEBCY 3	233	0	575.00	94.12	82.1	
31	340	MARY 12	0.996	-39.5	0.0	0.0	-99.7	23.4									
										224	CRESN 5	201	0	10.59	-8.14		
										393	STJ0712	31	31	-67.51	17.63		
										432	CLRNA 5	212	0	-20.21	10.01		
										454	WAPELO5	31	31	6.00	-1.15		
										1201	PALM710	31	31	-28.57	5.05		
209	361	OSGOD 5	0.992	-40.5	25.3	7.3	0.0	0.0	-3.150								
										227	WISOM 5	201	0	-46.84	11.21	21.9	
										363	BURT 5	209	0	21.55	-15.31	12.2	
209	362	HOPE 5	1.014	-40.2	40.4	12.7	0.0	0.0	-12.340								
										363	BURT 5	209	0	27.85	6.05	13.1	
										373	HOPET 5	210	0	-68.26	-6.39	31.4	
209	363	BURT 5	1.001	-41.7	22.5	7.0	0.0	0.0	-6.007								
										361	OSGOD 5	209	0	-21.44	11.67	11.3	
										362	HOPE 5	209	0	-27.69	-10.10	13.6	
										423	GARNR 5	211	0	26.59	-2.60	12.3	
210	371	NEAL 5	1.027	-23.6	0.0	0.0	0.0	0.0									
										800	RAUN 5	210	0	179.32	11.95	53.8	
										800	RAUN 5	210	1	179.32	11.95	53.8	
										873	NEAL 8	210	0	44.18	10.57	48.8	
										873	NEAL 8	210	1	44.18	10.57	48.8	
										1246	NEAL12G	210	0	-447.00	-45.00	90.8	1.040
210	372	RAUN 3	1.032	-21.5	0.0	0.0	0.0	0.0	53.296								
										193	LAKFD 3	200	0	247.69	-3.24	20.8	
										482	LEHIH 3	214	0	363.70	-14.33	50.6	
										773	FT.CL 3	233	0	226.58	-32.60	21.3	
										800	RAUN 5	210	0	108.51	19.46	36.7	
										800	RAUN 5	210	1	108.51	19.46	36.7	
										1247	NEAL34G	210	0	-1055.00	-42.06	84.5	1.040
210	373	HOPET 5	1.021	-38.9	0.0	0.0	0.0	0.0									
										362	HOPE 5	209	0	68.57	6.25	31.6	
										384	WRIGT 5	210	0	76.81	4.46	46.1	
										477	FT.DOG5	214	0	-28.34	0.44	25.3	

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3. SWING BUS = 1265 AROL 1G. AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										481-LEHIH 5	214	0	-117.04	-11.16	36.3	
210	375	PLYMH 5	0.996	-30.4	0.0	0.0	0.0	0.0								
										226-SX CY 5	201	0	192.18	-13.50	57.7	
										376-SAC 5	210	0	66.53	-17.93	29.6	
										800-RAUN 5	210	0	-174.50	4.62	78.6	
										803-LEEDS 5	210	0	-128.69	6.71	38.6	
										880-PLYMTH8	210	0	44.48	20.09	32.5	
210	376	SAC 5	0.998	-37.5	48.5	15.6	0.0	20.0H								
										227-WISDM 5	201	0	5.77	3.07	2.7	
										375-PLYMH 5	210	0	-64.38	18.17	28.7	
										383-POMEOY5	210	0	10.13	-16.84	17.5	
210	377	FRANKN5	0.999	-43.0	14.2	5.3	0.0	0.0	-3.196							
										197-MASNTY5	200	0	0.26	-2.24	2.0	
										379-BLKHK 5	210	0	-10.29	-1.44	5.1	
										384-WRIGT 5	210	0	-49.27	-1.95	29.5	
										412-IA FS 7	211	0	45.11	3.58	42.7	
210	378	WATELO8	1.002	-46.4	50.9	16.8	0.0	0.0	-22.183							
										379-BLKHK 5	210	0	-21.81	2.91	44.0	
										380-WSHBN 5	210	0	-29.07	2.47	58.4	
210	379	BLKHK 5	1.001	-42.1	52.9	17.6	0.0	0.0								
										201-HAZLON5	200	0	-114.66	-14.46	51.4	
										377-FRANKN5	210	0	10.34	-5.29	5.7	
										378-WATELO8	210	0	21.95	-1.64	44.0	
										381-WATELO5	210	0	-1.61	4.74	2.3	
										382-FLOY 5	210	0	31.10	-0.96	28.0	
210	380	WSHBN 5	1.008	-40.2	39.2	12.8	0.0	0.0								
										201-HAZLON5	200	0	-58.73	-19.93	28.4	
										378-WATELO8	210	0	29.39	0.10	58.8	
										388-WTR OGT	210	0	64.33	3.57		
										419-DYSAT 5	211	0	-74.19	3.45	29.5	
210	381	WATELO5	1.000	-42.0	62.3	20.3	0.0	0.0	-10.393							
										379-BLKHK 5	210	0	1.62	-5.82	2.8	
										388-WTR OGT	210	0	-63.90	-4.05		
210	382	FLOY 5	0.990	-44.4	54.5	14.6	0.0	0.0	-4.901							
										197-MASNTY5	200	0	-23.64	-5.67	10.1	
										379-BLKHK 5	210	0	-30.84	-4.06	28.0	
210	383	POMEOY5	1.010	-38.4	15.8	5.3	0.0	0.0	-2.859							
										376-SAC 5	210	0	-10.05	12.41	14.3	
										477-FT.DDG5	214	0	-5.71	-14.80	14.2	
210	384	WRIGT 5	1.012	-40.5	26.4	8.8	0.0	-0.1	-4.812							
										373-HOPET 5	210	0	-76.25	-4.09	45.7	
										377-FRANKN5	210	0	49.84	0.01	29.8	
210	386	MONDA 5	0.993	-31.8	29.9	11.9	0.0	0.0	-11.823							
										387-CARRLL5	210	0	103.61	-1.87	47.5	
										801-NEAL4 5	210	0	-133.48	1.76	59.6	
210	387	CARRLL5	0.971	-41.1	40.5	11.3	0.0	-0.1	-11.316							
										386-MONDA 5	210	0	-100.30	11.37	46.3	
										401-GR JT 5	211	0	59.78	-11.41	25.4	
210	388	WTR OGT	1.004	-41.1	0.0	0.0	0.0	0.0								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3. SWING BUS = 1265 AROL 1G. AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										380	WSHBN 5	210	0	-64.11	-3.77		
										381	WATELO5	210	0	64.11	3.77		
31	393	STJ0712	1.000	-32.5	9369.7	96.9	9000.0	0.0									
										6	COOPR 3	195	0	-398.21	-70.14	37.6	
										340	MARY 12	31	31	69.42	-9.29		
										454	WAPELO5	31	31	14.04	-0.72		
										474	DAVNRT5	31	31	2.10	-0.94		
										480	DVNPT 3	31	31	-4.00	-1.29		
										772	S1206 5	31	31	-3.05	-2.04		
										1201	PALM710	31	31	-49.99	-12.48		
211	401	GR JT 5	0.970	-45.0	50.7	13.3	0.0	0.0	-11.293								
										387	CARRLL5	210	0	-58.96	10.78	25.0	
										402	GR JT 7	211	0	33.60	5.42	37.8	
										403	GUTHIE7	211	0	-22.23	-5.54	11.3	
										451	JASPR 8	213	0	-3.14	-12.72	11.7	
211	402	GR JT 7	0.991	-46.2	0.0	0.0	0.0	0.0									
										401	GR JT 5	211	0	-33.60	-4.72	37.7	1.025
										407	BOON 7	211	0	33.60	4.72	56.6	
211	403	GUTHIE7	0.980	-43.5	16.9	4.2	0.0	0.0									
										401	GR JT 5	211	0	22.38	1.03	11.1	
										429	ANIT 5	211	0	-39.28	-5.26		
211	404	CDRPS 5	1.013	-36.6	51.2	12.8	0.0	0.0									
										405	PRARCK7	211	0	0.78	4.90	2.0	
										409	WYOMG 5	211	0	22.53	6.13	13.9	
										421	ARNOD 5	211	0	-79.63	-5.95	24.6	
										472	HILL 5	214	0	5.07	-17.91	7.4	
211	405	PRARCK7	1.031	-36.6	117.2	39.0	0.0	0.0									
										404	CDRPS 5	211	0	-0.78	-5.27	2.1	1.020
										406	MTOW 7	211	0	68.57	-13.22	59.2	
										411	CALUS 7	211	0	4.14	-2.37	9.6	
										418	SIX T 7	211	0	-58.20	-25.12	15.8	
										1252	PRARK4G	211	0	-130.90	6.96	87.4	1.030
211	406	MTOW 7	1.002	-45.1	119.2	0.0	0.0	0.0									
										405	PRARCK7	211	0	-64.66	13.87	56.0	
										407	BOON 7	211	0	18.02	0.66	22.5	
										413	WELSRG7	211	0	9.98	3.39	17.6	
										451	JASPR 8	213	0	-0.60	4.41	6.4	
										1254	MTOW 3G	211	0	-82.00	-22.32	88.5	1.030
211	407	BOON 7	0.962	-48.6	50.2	16.8	0.0	0.0	-9.245								
										402	GR JT 7	211	0	-32.79	-4.47	55.2	
										406	MTOW 7	211	0	-17.42	-3.04	22.1	
211	408	MOOKTA5	1.004	-37.0	16.5	4.1	0.0	0.0									
										409	WYOMG 5	211	0	13.70	-3.27	8.4	
										410	CALUS 5	211	0	-30.24	-0.81	27.0	
211	409	WYOMG 5	1.003	-37.5	36.1	9.0	0.0	0.0									
										404	CDRPS 5	211	0	-22.44	-9.49	14.5	
										408	MOOKTA5	211	0	-13.67	0.44	8.1	
211	410	CALUS 5	1.008	-36.2	16.3	3.7	0.0	0.0									
										203	CLINON5	31	0	-13.08	-4.61	8.3	

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										408-HOOKTA5	211	0	30.36	-1.13	27.1	
										411-CALUS 7	211	0	18.74	4.69	23.0	
										474-DAVNRT5	31	0	-52.33	-2.66	46.8	
211	411	CALUS 7	1.027	-37.2	22.8	5.7	0.0	0.0								
										405-PRARCK7	211	0	-4.12	-1.13	8.5	
										410-CALUS 5	211	0	-18.72	-4.58	22.9	1.025
211	412	IA FS 7	0.994	-44.6	31.5	10.5	0.0	-0.1	-5.531							
										377-FRANKN5	210	0	-44.95	-2.60	42.5	1.000
										413-WELSRG7	211	0	13.43	-2.42	22.7	
211	413	WELSRG7	0.988	-45.8	23.2	6.9	0.0	0.0	-2.928							
										406-MTOW 7	211	0	-9.90	-5.03	18.5	
										412-IA FS 7	211	0	-13.31	1.06	22.3	
211	414	DUNDE 5	1.019	-38.1	14.8	4.1	0.0	0.0	-1.558							
										200-DUBUUE5	31	0	1.66	12.31	5.6	
										201-HAZLON5	200	0	-23.26	-23.73	14.8	
										415-DUNDE 7	211	0	6.84	8.89	24.9	
211	415	DUNDE 7	1.034	-38.6	24.8	6.2	0.0	0.0	-1.819							
										414-DUNDE 5	211	0	-6.84	-8.75	24.7	1.025
										418-SIX T 7	211	0	-18.01	4.34	30.9	
211	416	TRIBJI5	0.996	-36.2	20.0	5.4	0.0	0.0	-1.885							
										204-LAKFD 5	200	0	-70.63	-5.41	31.8	
										227-WISDM 5	201	0	50.61	1.88	23.0	
213	417	MONRE 5	0.995	-43.0	0.0	0.0	0.0	0.0								
										434-D.MON 5	212	0	-89.09	2.08	53.4	
										451-JASPR 8	213	0	64.72	0.81	25.8	
										457-POWAHK5	213	0	24.37	-2.89	14.7	
211	418	SIX T 7	1.045	-35.3	151.1	50.4	0.0	29.1R								
										405-PRARCK7	211	0	58.47	24.30	15.8	
										415-DUNDE 7	211	0	18.51	-6.70	32.8	
										421-ARNOD 5	211	0	-228.12	-38.88	45.9	1.025
211	419	DYSAT 5	1.011	-37.8	37.9	9.5	0.0	0.0	-2.655							
										380-WSHBN 5	210	0	74.50	-3.26	29.6	
										421-ARNOD 5	211	0	-112.39	-3.58	44.6	
211	421	ARNOD 5	1.030	-32.7	103.8	34.6	0.0	0.0								
										404-CORPS 5	211	0	80.52	6.80	24.9	
										418-SIX T 7	211	0	228.42	46.21	46.2	
										419-DYSAT 5	211	0	113.94	9.48	45.4	
										422-ARNOD 3	211	0	25.00	1.93	6.3	1.025
										1265-AROL 1G	211	0	-551.71	-98.99	93.4	1.050
211	422	ARNOD 3	1.004	-33.0	0.0	0.0	0.0	0.0								
										202-HAZLON3	200	0	27.01	67.91	15.2	
										421-ARNOD 5	211	0	-25.00	-1.77	6.3	
										471-HILL 3	214	0	-2.00	-66.15	6.0	
211	423	GARNR 5	0.997	-43.2	32.0	8.7	0.0	0.0	-2.980							
										197-MASNTY5	200	0	-5.49	-4.56	3.3	
										363-BURT 5	209	0	-26.47	-1.14	12.2	
211	429	ANIT 5	0.989	-42.0	6.8	1.8	0.0	0.0								
										223-ANITTP5	211	0	-46.34	-5.56		
										403-GUTHIE7	211	0	39.51	3.78		

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3. SWING BUS = 1265 AROL 1G. AREA 211

BUS - DATA										LINE - DATA							
AREA NO.	FROM BUS	FROM NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	TO NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
212	431	CBLUFS5	1.027	-29.5	0.0	0.0	0.0	0.0									
										433	AVOC 5	212	0	81.83	4.36	73.2	
										436	CBLUFS3	212	0	-249.44	5.98	49.9	1.000
										987	S701 5	212	0	96.57	5.33	29.9	
										1082	HSTNGS5	212	0	122.81	2.46	74.9	
										1256	CBLUFS8	212	0	79.23	-9.33	49.9	
										1267	C.BL12G	212	0	-131.00	-8.80	87.5	1.040
212	432	CLRNA 5	0.992	-38.2	0.0	0.0	0.0	0.0									
										224	CRESN 5	201	0	26.75	-17.12		
										340	MARY 12	31	0	20.37	-13.56		
										1082	HSTNGS5	212	0	-70.19	12.32	43.5	
										1497	CLRNDA8	212	0	23.07	18.36	35.5	
212	433	AVOC 5	1.006	-33.9	65.4	16.7	0.0	0.0									
										431	CBLUFS5	212	0	-80.36	-2.79	71.8	
										440	BOONIL5	212	0	14.95	-13.93	9.8	
212	434	D.MON 5	1.015	-39.3	218.2	42.8	0.0	0.0									
										224	CRESN 5	201	0	14.76	0.73	9.1	
										417	MONRE 5	213	0	90.95	0.49	54.5	
										437	SYCAOR5	212	0	-77.06	-9.85	24.3	
										438	ASHAA 5	212	0	-47.02	12.21	23.2	
										481	LEHIH 5	214	0	-26.86	-4.40	16.3	
										1270	DPS 57G	212	0	-173.00	-42.00	89.0	1.043
212	435	SYCAOR3	1.010	-35.3	0.0	0.0	0.0	0.0									
										437	SYCAOR5	212	0	398.17	124.76	41.7	
										439	BOONIL3	212	0	-233.60	-58.99	24.1	
										471	HILL 3	214	0	-68.00	-45.80	8.2	
										482	LEHIH 3	214	0	-96.56	-19.98	9.9	
212	436	CBLUFS3	1.027	-27.0	0.0	0.0	0.0	0.0	52.776								
										431	CBLUFS5	212	0	249.44	4.93	49.9	
										439	BOONIL3	212	0	216.42	-43.87	22.1	
										771	S3456 3	233	0	154.14	59.63	16.5	
										1271	C.BL 3G	212	0	-620.00	-73.46	86.7	1.050
212	437	SYCAOR5	1.024	-37.3	56.1	11.2	0.0	0.0									
										57	SYCAOR8	212	0	120.00	29.98	77.3	
										434	D.MON 5	212	0	77.41	10.02	24.4	
										435	SYCAOR3	212	0	-398.17	-109.40	41.3	1.025
										438	ASHAA 5	212	0	33.50	21.37	12.3	
										959	WABASH5	212	0	111.18	36.82	36.3	
212	438	ASHAA 5	1.014	-38.0	101.9	20.1	0.0	0.0									
										434	D.MON 5	212	0	47.29	-13.44	23.5	
										437	SYCAOR5	212	0	-33.42	-22.99	12.6	
										440	BOONIL5	212	0	-221.73	7.33	34.7	
										959	WABASH5	212	0	105.94	9.02	32.9	
212	439	BOONIL3	1.019	-33.8	0.0	0.0	0.0	0.0									
										6	COOPR 3	195	0	-245.76	-29.85	24.8	
										435	SYCAOR3	212	0	234.38	44.53	23.9	
										436	CBLUFS3	212	0	-213.80	-27.78	21.6	
										440	BOONIL5	212	0	225.17	13.09	45.1	1.000
212	440	BOONIL5	1.018	-36.1	17.3	3.3	0.0	0.0									

TITLE-LF-080-8-PU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

BUS - DATA: AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	LINE - DATA: TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										433-AVOC 5	212	0	-14.79	4.05	7.3	
										438-ASHAA 5	212	0	222.64	-3.36	34.8	
										439-BOONIL3	212	0	-225.17	-4.03	45.0	
212	441	OSKLOSS	0.989	-45.8	47.3	9.4	0.0	0.0								
										454-WAPELOS	31	0	4.45	-15.95	7.6	
										457-POWAHKS	213	0	-51.74	6.59	23.0	
213	451	JASPR 8	0.989	-44.8	60.6	4.4	0.0	0.0								
										401-GR JT 5	211	0	3.18	2.42	3.6	
										406-MTOW 7	211	0	0.61	-5.76	8.4	
										417-MONRE 5	213	0	-64.39	-1.11	25.7	
31	454	WAPELOS	1.000	-46.2	0.0	0.0	-164.9	54.7R								
										340-MARY 12	31	31	-5.85	1.85		
										393-STJO712	31	31	-13.47	4.02		
										441-OSKLOSS	212	0	-4.41	12.21	6.0	
										474-DAVNRTS	31	31	-25.32	6.79		
										1201-PALM710	31	31	-115.85	29.79		
213	457	POWAHKS	0.991	-43.9	35.4	5.4	0.0	0.0								
										417-MONRE 5	213	0	-24.25	0.61	14.5	
										441-OSKLOSS	212	0	52.10	-7.75	23.2	
										472-HILL 5	214	0	-63.26	1.73	37.9	
214	471	HILL 3	1.014	-33.1	0.0	0.0	0.0	0.0								
										422-ARNOD 3	211	0	2.05	32.73	3.0	
										435-SYCAOR3	212	0	68.28	-46.70	8.3	
										472-HILL 5	214	0	196.36	41.58	66.9	
										480-DVNPT 3	31	0	-159.53	18.30	15.3	
										1201-PALM710	31	0	-107.16	-45.93	11.7	
214	472	HILL 5	1.027	-36.9	164.0	6.5	0.0	0.0								
										404-CORPS 5	211	0	-5.03	13.17	5.6	
										457-POWAHKS	213	0	65.78	-2.48	39.4	
										471-HILL 3	214	0	-196.36	-27.87	66.1	1.025
										474-DAVNRTS	31	0	-28.37	10.68	13.6	
31	474	DAVNRTS	1.015	-34.7	0.0	0.0	-322.1	45.8								
										203-CLINONS	31	31	10.14	-0.02		
										393-STJO712	31	31	-2.09	1.03		
										410-CALUS 5	211	0	52.67	1.53	47.0	
										454-WAPELOS	31	31	26.57	-1.63		
										472-HILL 5	214	0	28.58	-16.29	14.8	
										480-DVNPT 3	31	31	-390.14	54.47		
										1201-PALM710	31	31	-47.84	6.70		
214	477	FT.DDGS	1.023	-38.2	79.1	0.0	0.0	0.0								
										373-HOPET 5	210	0	28.43	-2.16	25.5	
										383-POMEOYS	210	0	5.76	10.60	10.8	
										481-LEHIH 5	214	0	-113.31	-8.45	40.1	
31	480	DVNPT 3	1.009	-31.0	9000.0	90.9	9570.9	0.0								
										203-CLINONS	31	31	45.31	-7.41		
										393-STJO712	31	31	4.00	1.41		
										471-HILL 3	214	0	160.05	-51.20	16.0	
										474-DAVNRTS	31	31	390.44	-29.34		
										539-PR ILD3	31	31	-9.51	0.77		

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS

TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										1201-PALM710	31	31	-19.40	-5.14		
214	481	LEHIH 5	1.032	-36.2	0.0	0.0	0.0	0.0								
										373-HOPET 5	210	0	117.73	14.57	36.6	
										434-O.MON 5	212	0	27.30	-3.96	16.5	
										477-FT.DDGS	214	0	113.94	10.66	40.4	
										482-LEHIH 3	214	0	-258.96	-21.26	52.0	1.025
214	482	LEHIH 3	1.012	-33.6	0.0	0.0	0.0	0.0								
										372-RAUN 3	210	0	-355.81	-6.81	49.4	
										435-SYCAOR3	212	0	96.85	-26.45	10.0	
										481-LEHIH 5	214	0	258.96	33.25	52.2	
216	515	ADAM 3	0.987	-30.6	0.0	0.0	0.0	0.0								
										198-ADAM 5	200	0	110.97	136.60	78.2	
										202-HAZLON3	200	0	117.50	-43.51	26.1	
										539-PR ILD3	31	0	-185.90	-69.05	27.5	
										651-LACRSS3	31	0	-42.57	-24.05	5.1	
31	539	PR ILD3	1.011	-26.6	9000.0	0.0	9467.0	63.8								
										152-ROCHTR5	31	31	9.92	-2.41		
										259-SX FLL7	31	31	6.92	-0.54		
										274-FTTHMP4	31	31	-49.20	-0.10		
										333-WTRTWN3	31	31	-14.28	9.96		
										480-DVNPT 3	31	31	9.56	-0.03		
										515-ADAM 3	216	0	187.37	16.13	26.1	
										635-WILMRT3	31	31	300.73	39.37		
										651-LACRSS3	31	31	7.65	2.95		
										1201-PALM710	31	31	8.34	-1.54		
31	635	WILMRT3	0.998	-30.4	6323.5	57.9	6000.0	0.0								
										152-ROCHTR5	31	31	-1.88	-1.50		
										193-LAKFD 3	200	0	-43.57	-44.51	8.6	
										274-FTTHMP4	31	31	-36.27	0.43		
										333-WTRTWN3	31	31	-31.63	3.09		
										539-PR ILD3	31	31	-298.75	-19.14		
										636-RAPIANS	31	31	90.62	3.99		
										651-LACRSS3	31	31	-0.90	0.99		
										1201-PALM710	31	31	-1.12	-1.25		
31	636	RAPIANS	0.991	-37.1	0.0	0.0	-72.5	3.1								
										195-WINBGOS	200	0	17.28	-3.42	10.5	
										635-WILMRT3	31	31	-89.78	6.52		
201	648	SIOXLS	1.016	-28.9	0.0	0.0	0.0	0.0								
										332-SX CY 3	201	0	106.31	0.90	8.9	
										333-WTRTWN3	31	0	-106.31	-0.91	8.9	
31	651	LACRSS3	0.986	-29.6	0.0	0.0	52.6	-65.0								
										146-HARMNYS	31	31	-5.64	-7.22		
										152-ROCHTR5	31	31	-0.85	-5.30		
										175-POSTILS	31	31	2.32	-3.59		
										200-DUBUUES	31	31	20.81	-3.78		
										515-ADAM 3	216	0	42.65	-41.66	6.2	
										539-PR ILD3	31	31	-7.59	-2.49		
										635-WILMRT3	31	31	0.91	-0.97		
233	733	FT.CLIG	1.030	-19.4	0.0	0.0	455.0	123.1R								

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

BUS-DATA: AREA NO.	FROM BUS	FROM NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	LINE-DATA: TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										773-FT.CL 3	233	0	455.00	123.13	81.6	
233	771	S3456 3	1.024	-27.4	0.0	0.0	0.0	0.0								
										436-CBLUFS3	212	0	-154.01	-66.05	16.8	
										772-S1206 5	31	0	369.17	128.48	78.2	0.975
										774-NEBCY 3	233	0	-237.48	-36.81	20.7	
										775-S3459 3	233	0	-35.39	-4.30	5.0	
										777-S3455 3	233	0	57.70	-21.35	8.6	
31	772	S1206 5	1.028	-31.0	0.0	0.0	-381.0	-56.3								
										15-SHELON7	31	31	6.87	-3.10		
										53-WAGEER7	31	31	12.74	-2.86		
										393-STJ0712	31	31	3.08	2.18		
										771-S3456 3	233	0	-368.75	-102.43	76.5	
										776-S1209 5	31	31	-3.54	14.62		
										778-S1255 5	31	31	-28.88	27.07		
										780-S1211 5	31	31	-2.52	8.21		
233	773	FT.CL 3	1.030	-25.4	0.0	0.0	0.0	0.0	53.053							
										372-RAUN 3	210	0	-225.14	-5.46	20.9	
										733-FT.CL1G	233	0	-454.16	-72.45	79.6	1.025
										775-S3459 3	233	0	392.39	32.95	54.9	
										779-S3454 3	233	0	286.91	-8.12	40.0	
233	774	NEBCY 3	1.034	-24.5	0.0	0.0	0.0	0.0	53.461							
										6-COOPR 3	195	0	128.60	-10.38	11.1	
										339-NEBCY1G	233	0	-575.00	-52.52	81.3	1.025
										771-S3456 3	233	0	238.67	8.76	20.6	
										777-S3455 3	233	0	207.73	0.67	29.0	
233	775	S3459 3	1.024	-27.3	0.0	0.0	0.0	0.0								
										771-S3456 3	233	0	35.39	-6.14	5.0	
										773-FT.CL 3	233	0	-391.22	-37.69	54.8	
										776-S1209 5	31	0	355.83	43.85	71.7	1.000
31	776	S1209 5	1.017	-30.8	0.0	0.0	-427.1	-109.9								
										772-S1206 5	31	31	3.57	-14.44		
										775-S3459 3	233	0	-355.34	-21.78	71.2	
										778-S1255 5	31	31	-47.98	-11.30		
										780-S1211 5	31	31	11.68	-68.40		
										1302-TEKAMA5	31	31	-39.03	6.02		
233	777	S3455 3	1.024	-27.5	0.0	0.0	0.0	0.0								
										771-S3456 3	233	0	-57.69	14.64	8.3	
										774-NEBCY 3	233	0	-206.83	-38.55	29.3	
										778-S1255 5	31	0	264.51	23.88	53.1	1.000
31	778	S1255 5	1.020	-30.4	0.0	0.0	-159.0	-36.1								
										15-SHELON7	31	31	3.30	-1.99		
										53-WAGEER7	31	31	21.58	-6.37		
										772-S1206 5	31	31	28.96	-26.52		
										776-S1209 5	31	31	48.04	11.70		
										777-S3455 3	233	0	-264.24	-10.58	52.9	
										780-S1211 5	31	31	3.35	-2.36		
233	779	S3454 3	1.026	-27.8	0.0	0.0	0.0	0.0								
										7-LINCLN3	195	0	285.90	8.61	39.9	
										773-FT.CL 3	233	0	-285.90	-8.61	39.9	

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G. AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
31	780	S1211 5	1.025	-31.0	0.0	0.0	-32.7	95.2								
										772-S1206 5	31	31	2.52	-8.19		
										776-S1209 5	31	31	-11.58	69.01		
										778-S1255 5	31	31	-3.34	2.41		
										987-S701 5	212	0	-20.31	31.97	11.7	
210	800	RAUN 5	1.026	-23.8	0.0	0.0	0.0	0.0								
										371-NEAL 5	210	0	-179.26	-11.50	53.8	
										371-NEAL 5	210	1	-179.26	-11.50	53.8	
										372-RAUN 3	210	0	-108.51	-15.06	36.5	1.000
										372-RAUN 3	210	1	-108.51	-15.06	36.5	1.000
										375-PLYMH 5	210	0	179.20	12.79	80.9	
										801-NEAL4 5	210	0	142.02	14.13	42.7	
										802-INTRCG5	210	0	208.20	35.53	63.2	
										1302-TEKAMA5	31	0	46.13	-9.41	23.1	
210	801	NEAL4 5	1.023	-24.4	4.8	1.6	0.0	0.0								
										386-MONOA 5	210	0	137.02	11.10	61.4	
										800-RAUN 5	210	0	-141.82	-12.69	42.6	
210	802	INTRCG5	1.010	-26.7	24.0	8.0	0.0	0.0								
										800-RAUN 5	210	0	-206.54	-25.85	62.3	
										804-KELOG 5	210	0	182.54	17.83	54.9	
210	803	LEEDS 5	1.001	-29.0	20.0	6.4	0.0	0.0								
										375-PLYMH 5	210	0	129.36	-4.52	38.8	
										804-KELOG 5	210	0	-149.36	-1.88	44.7	
210	804	KELOG 5	1.004	-28.1	32.0	10.4	0.0	0.0								
										802-INTRCG5	210	0	-181.85	-14.04	54.6	
										803-LEEDS 5	210	0	149.85	3.64	44.9	
210	873	NEAL 8	1.018	-25.8	4.0	1.6	0.0	0.0								
										371-NEAL 5	210	0	-44.18	-8.77	48.4	1.000
										371-NEAL 5	210	1	-44.18	-8.77	48.4	1.000
										877-KELLOG8	210	0	40.14	7.05	56.6	
										878-M SIDE8	210	0	44.21	8.89	47.0	
210	874	LOGANP8	0.968	-33.5	16.0	5.6	0.0	0.0	-2.814							
										875-MCCOOK8	210	0	-3.52	1.19	5.2	
										880-PLYMTH8	210	0	-12.48	-3.98	18.2	
210	875	MCCOOK8	0.969	-33.3	8.0	2.4	0.0	0.0								
										874-LOGANP8	210	0	3.52	-1.30	5.2	
										876-SC WST8	210	0	-11.52	-1.10	16.1	
210	876	SC WST8	0.972	-32.8	14.4	4.8	0.0	0.0	-2.832							
										875-MCCOOK8	210	0	11.55	0.09	16.0	
										877-KELLOG8	210	0	-25.95	-2.06	36.2	
210	877	KELLOG8	0.975	-32.1	28.0	9.6	0.0	0.0	-5.707							
										873-NEAL 8	210	0	-39.00	-3.02	54.3	
										876-SC WST8	210	0	26.02	2.27	36.3	
										879-E SIDE8	210	0	-15.03	-3.16	21.3	
210	878	M SIDE8	0.986	-30.3	12.0	4.0	0.0	0.0								
										873-NEAL 8	210	0	-43.37	-5.63	45.6	
										879-E SIDE8	210	0	31.37	1.63	32.7	
210	879	E SIDE8	0.979	-31.8	8.0	2.4	0.0	0.0								
										877-KELLOG8	210	0	15.06	3.18	21.4	

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL 1G, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
										878-M SIDE8	210	0	-31.19	-0.94	32.5	
										880-PLYMTH8	210	0	8.12	-4.64	19.5	
210	880	PLYMTH8	0.980	-32.6	32.0	10.4	0.0	0.0								
										336-HINTON8	201	0	7.99	-0.81	12.5	
										375-PLYMH 5	210	0	-44.48	-18.10	32.0	1.000
										874-LOGANP8	210	0	12.57	3.97	18.3	
										879-E SIDE8	210	0	-8.08	4.54	19.3	
212	959	WABASH5	1.011	-39.0	216.4	42.8	0.0	0.0								
										437-SYCAOR5	212	0	-110.72	-34.68	35.9	
										438-ASHAA 5	212	0	-105.70	-8.13	32.8	
212	987	S701 5	1.023	-30.9	17.5	3.3	0.0	0.0								
										431-CBLUFS5	212	0	-96.28	-4.48	29.8	
										780-S1211 5	31	0	20.32	-32.27	11.8	
										1014-S701 8	212	0	58.51	33.39	42.1	
195	998	COOPR1G	1.000	-19.2	0.0	0.0	794.0	180.6R								
										6-COOPR 3	195	0	794.00	180.58	90.5	
212	1014	S701 8	1.035	-32.2	30.1	6.0	0.0	0.0								
										987-S701 5	212	0	-58.51	-31.61	41.6	1.025
										1075-S702 8	212	0	7.28	9.55	19.1	
										1088-S703 8	212	0	8.58	6.80	19.2	
										1100-S704 8	212	0	12.56	9.24	17.9	
212	1075	S702 8	1.032	-32.2	20.1	4.0	0.0	0.0								
										1014-S701 8	212	0	-7.26	-9.56	19.1	
										1256-CBLUFS8	212	0	-12.80	5.55	24.5	
212	1082	HSTNGS5	1.003	-33.9	0.0	0.0	0.0	0.0								
										431-CBLUFS5	212	0	-119.81	3.86	73.1	
										432-CLRNA 5	212	0	71.88	-11.50	44.4	
										1189-HSTNGS8	212	0	47.93	7.64	60.7	
212	1088	S703 8	1.026	-32.5	20.1	4.0	0.0	0.0								
										1014-S701 8	212	0	-8.53	-6.87	19.2	
										1390-S706 8	212	0	-11.53	2.85	20.8	
212	1100	S704 8	1.029	-32.5	20.1	4.0	0.0	0.0								
										1014-S701 8	212	0	-12.53	-9.23	17.9	
										1257-S705 8	212	0	-7.54	5.21	10.5	
212	1189	HSTNGS8	1.022	-36.2	12.4	2.0	0.0	-0.0								
										1082-HSTNGS5	212	0	-47.93	-5.72	60.3	1.025
										1391-GWOOD 8	212	0	-11.87	6.29	23.6	
										1494-R.OAK 8	212	0	24.44	-1.93	38.9	
										1498-SHENDO8	212	0	22.99	-0.64	26.4	
31	1201	PALM710	1.020	-29.4	9000.0	0.0	9387.5	-24.7R								
										203-CLINON5	31	31	17.02	-1.64		
										340-MARY 12	31	31	29.70	0.06		
										393-STJO712	31	31	50.21	15.50		
										454-WAPELO5	31	31	121.90	5.14		
										471-HILL 3	214	0	107.94	-50.54	11.9	
										474-DAVNRT5	31	31	48.47	-2.24		
										480-DVNPT 3	31	31	19.44	5.76		
										539-PR ILD3	31	31	-8.32	1.95		
										635-WILMRT3	31	31	1.12	1.30		

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

REPORT OF LOADFLOW CALCULATIONS TOTAL ITERATIONS = 3, SWING BUS = 1265 AROL IG, AREA 211

AREA NO.	FROM BUS	NAME	VOLTS PU	ANGLE DEG	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	CAP/REACT MVAR	TO BUS	NAME	AREA NO.	PAR NO.	LINE FLOW MW	LINE FLOW MVAR	PCT CAP	TAP RATIO
210	1246	NEAL12G	1.000	-18.5	0.0	0.0	447.0	85.8R		371	NEAL 5	210	0	447.00	85.82	92.0	
210	1247	NEAL34G	1.000	-16.5	0.0	0.0	1055.0	134.8R		372	RAUN 3	210	0	1055.00	134.81	85.1	
211	1252	PRARK4G	1.000	-31.4	0.0	0.0	130.9	4.8R		405	PRARCK7	211	0	130.90	4.79	87.3	
211	1254	MTOW 3G	1.000	-40.1	0.0	0.0	82.0	30.2R		406	MTOW 7	211	0	82.00	30.20	91.0	
212	1256	CBLUFS8	1.032	-31.3	0.0	0.0	0.0	0.0		431	CBLUFS5	212	0	-79.23	11.80	50.1	1.000
										1075	S702 8	212	0	12.89	-5.54	24.6	
										1257	S705 8	212	0	21.23	-2.35	24.5	
										1390	S706 8	212	0	21.78	-0.70	38.2	
										1391	GWOOD 8	212	0	23.34	-3.21	41.3	
212	1257	S705 8	1.029	-32.4	13.6	2.7	0.0	0.0		1100	S704 8	212	0	7.54	-5.23	10.5	
										1256	CBLUFS8	212	0	-21.12	2.55	24.5	
211	1265	AROL IG	1.000	-27.7	0.0	0.0	551.7	149.3R		421	ARNCD 5	211	0	551.71	149.30	95.3	
212	1267	C.BL12G	1.000	-23.7	0.0	0.0	131.0	22.4R		431	CBLUFS5	212	0	131.00	22.36	88.6	
212	1270	DPS S7G	1.000	-34.0	0.0	0.0	173.0	59.4R		434	D.MON 5	212	0	173.00	59.40	91.5	
212	1271	C.BL 3G	1.000	-20.1	0.0	0.0	620.0	150.8R		436	CBLUFS3	212	0	620.00	150.81	88.6	
31	1302	TEKAMA5	1.023	-26.8	0.0	0.0	-6.0	2.8		776	S1209 5	31	31	39.61	-3.30		
										800	RAUN 5	210	0	-45.61	6.10	22.6	
212	1390	S706 8	1.027	-32.1	10.1	2.0	0.0	-0.0		1088	S703 8	212	0	11.56	-2.88	20.9	
										1256	CBLUFS8	212	0	-21.66	0.88	38.0	
212	1391	GWOOD 8	1.019	-34.4	10.8	2.2	0.0	0.0		1189	HSTNGS8	212	0	12.03	-6.23	23.8	
										1256	CBLUFS8	212	0	-22.86	4.02	40.7	
212	1494	R.OAK 8	1.006	-39.4	21.1	4.0	0.0	0.0		1189	HSTNGS8	212	0	-23.91	3.05	38.3	
										1497	CLRNDA8	212	0	2.84	-7.06	12.1	
212	1497	CLRNDA8	1.028	-40.6	27.1	5.4	-0.0	0.0		432	CLRNA 5	212	0	-23.07	-16.83	34.4	1.070
										1494	R.OAK 8	212	0	-2.76	6.57	11.3	
										1498	SHENDO8	212	0	-1.27	4.91	8.0	
212	1498	SHENDO8	1.010	-39.9	21.3	4.0	0.0	0.0		1189	HSTNGS8	212	0	-22.65	1.51	26.1	
										1497	CLRNDA8	212	0	1.31	-5.52	9.0	

END OF REPORT FOR THIS CASE

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	FROM BUS NAME	FROM BUS AREA	TO BUS NO.	TO BUS NAME	TO BUS AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TAP LIMITS TMAX	SCHED VALUE	MAP DATA FLOW PG	MAP DATA FLOW LOC	MAP DATA FLOW Q	MAP DATA TAP LOC	MAP DATA REV FLOW PG	MAP DATA REV FLOW LOC	MAP DATA REV FLOW Q	FWRD ENTRY
6	COOPR 3	195	16	MOOR 3	195	0	0.35	3.21	-54371.90	1000.					1	917	0					YES
6	COOPR 3	195	393	STJO712	31	0	0.34	3.26	-72239.50	1075.					1	952	0					YES
6	COOPR 3	195	439	BCONIL3	212	0	0.64	6.21	-98699.63	1000.					1	889	0					YES
6	COOPR 3	195	774	NEBCY 3	233	0	0.11	1.19	-20119.99	1160.					0	0	0					YES
6	COOPR 3	195	998	COOPR1G	195	0	0.0	1.33	0.0	900.	1.052				0	0	0	0				YES
7	LINCLN3	195	16	MOOR 3	195	0	0.14	1.25	-21209.93	1075.					0	0	0					YES
7	LINCLN3	195	53	WAGEER7	31	0	0.04	1.89	0.0	672.	0.975				0	0	0	0				YES
7	LINCLN3	195	779	S3454 3	233	0	0.17	1.69	-28725.97	717.					0	0	0					YES
14	TWINCH4	31	17	GR ILD3	31	31	12.99	62.20	0.0	0.					0	0	0					YES
14	TWINCH4	31	53	WAGEER7	31	31	45.91	107.03	0.0	0.					0	0	0					YES
14	TWINCH4	31	258	SX CY 4	201	0	0.51	3.70	-7160.00	320.					0	0	0					YES
14	TWINCH4	31	259	SX FLL7	31	31	25.25	122.42	0.0	0.					0	0	0					YES
14	TWINCH4	31	268	FTRAD 4	31	31	12.75	70.33	0.0	0.					0	0	0					YES
15	SHELON7	31	16	MOOR 3	195	0	0.08	3.77	0.0	336.	1.025				0	0	0	0				YES
15	SHELON7	31	17	GR ILD3	31	31	10.38	31.37	0.0	0.					0	0	0					YES
15	SHELON7	31	53	WAGEER7	31	31	1.06	5.74	0.0	0.					0	0	0					YES
15	SHELON7	31	772	S1206 5	31	31	15.98	64.15	0.0	0.					0	0	0					YES
15	SHELON7	31	778	S1255 5	31	31	44.86	157.73	0.0	0.					0	0	0					YES
16	MOOR 3	195	6	COOPR 3	195	0	0.35	3.21	-54371.90	1000.									0	0	0	NO
16	MOOR 3	195	7	LINCLN3	195	0	0.14	1.25	-21209.93	1075.									0	0	0	NO
16	MOOR 3	195	15	SHELON7	31	0	0.08	3.77	0.0	336.									0	0	0	NO
16	MOOR 3	195	17	GR ILD3	31	0	0.46	4.17	-70584.63	1000.					1	931	0					YES
17	GR ILD3	31	14	TWINCH4	31	31	12.99	62.20	0.0	0.									0	0	0	NO
17	GR ILD3	31	15	SHELON7	31	31	10.38	31.37	0.0	0.									0	0	0	NO
17	GR ILD3	31	16	MOOR 3	195	0	0.46	4.17	-70584.63	1000.									0	0	0	NO
17	GR ILD3	31	53	WAGEER7	31	31	12.74	47.84	0.0	0.					0	0	0					YES
17	GR ILD3	31	268	FTRAD 4	31	31	4.40	32.27	0.0	0.					0	0	0					YES
17	GR ILD3	31	274	FTTHMP4	31	31	0.98	12.21	0.0	0.					0	0	0					YES
53	WAGEER7	31	7	LINCLN3	195	0	0.04	1.89	0.0	672.									0	0	0	NO
53	WAGEER7	31	14	TWINCH4	31	31	45.91	107.03	0.0	0.									0	0	0	NO
53	WAGEER7	31	15	SHELON7	31	31	1.06	5.74	0.0	0.									0	0	0	NO
53	WAGEER7	31	17	GR ILD3	31	31	12.74	47.84	0.0	0.									0	0	0	NO
53	WAGEER7	31	268	FTRAD 4	31	31	50.35	174.33	0.0	0.					0	0	0					YES
53	WAGEER7	31	772	S1206 5	31	31	4.73	39.56	0.0	0.					0	0	0					YES
53	WAGEER7	31	778	S1255 5	31	31	2.52	28.80	0.0	0.					0	0	0					YES
57	SYCAOR8	212	437	SYCAOR5	212	0	0.0	4.10	0.0	160.	1.000				0	0	0	0				YES
146	HARMNY5	31	152	ROCHTR5	31	31	60.17	143.73	0.0	0.					0	0	0					YES
146	HARMNY5	31	175	POSTIL5	31	31	4.71	26.65	0.0	0.					0	0	0					YES
146	HARMNY5	31	198	ADAM 5	200	0	2.13	10.13	-6410.00	224.					0	0	0					YES
146	HARMNY5	31	200	DUBUUE5	31	31	23.14	76.78	0.0	0.					0	0	0					YES
146	HARMNY5	31	651	LACRSS3	31	31	2.87	26.37	0.0	0.					0	0	0					YES
152	ROCHTR5	31	146	HARMNY5	31	31	60.17	143.73	0.0	0.									0	0	0	NO
152	ROCHTR5	31	198	ADAM 5	200	0	2.97	10.70	-5460.00	167.					0	0	0					YES
152	ROCHTR5	31	539	PR ILD3	31	31	10.53	51.32	0.0	0.					0	0	0					YES
152	ROCHTR5	31	635	WILMRT3	31	31	15.74	88.71	0.0	0.					0	0	0					YES
152	ROCHTR5	31	651	LACRSS3	31	31	9.58	52.76	0.0	0.					0	0	0					YES
175	POSTIL5	31	146	HARMNY5	31	31	4.71	26.65	0.0	0.									0	0	0	NO
175	POSTIL5	31	200	DUBUUE5	31	31	38.67	190.05	0.0	0.					0	0	0					YES

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	FROM BUS NAME	FROM BUS AREA	TO BUS NO.	TO BUS NAME	TO BUS AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TAP LIMITS TMAX	SCHED VALUE	MAP DATA FLOW PG	MAP DATA FLOW LOC	MAP DATA FLOW Q	MAP DATA TAP LOC	MAP DATA REV FLOW PG	MAP DATA REV FLOW LOC	MAP DATA REV FLOW Q	FWRD ENTRY
175	POSTILS	31	201	HAZLONS	200	0	3.12	16.29	-7780.00	240.					0	0	0					YES
175	POSTILS	31	651	LACRSS3	31	31	1.05	64.14	0.0	0.					0	0	0					YES
192	HRN K 5	31	204	LAKFD 5	200	0	1.74	5.11	-2300.00	224.					0	0	0					YES
192	HRN K 5	31	259	SX FLL7	31	31	6.60	30.93	0.0	0.					0	0	0					YES
193	LAKFD 3	200	204	LAKFD 5	200	0	0.0	3.40	0.0	225.									1	145	1	NO
193	LAKFD 3	200	372	RAUN 3	210	0	0.59	5.83	-93015.69	1190.					0	0	0					YES
193	LAKFD 3	200	635	WILMRT3	31	0	0.44	4.10	-83839.94	720.					1	44	0					YES
194	FOX K 5	200	195	WINBGO5	200	0	2.40	9.65	-4440.00	167.					0	0	0					YES
194	FOX K 5	200	204	LAKFD 5	200	0	2.49	7.25	-2020.00	224.					0	0	0					YES
195	WINBGO5	200	194	FOX K 5	200	0	2.40	9.65	-4440.00	167.									0	0	0	NO
195	WINBGO5	200	196	HAYWD 5	200	0	3.80	15.00	-6960.00	110.					0	0	0					YES
195	WINBGO5	200	636	RAPIAN5	31	0	2.06	8.33	-3850.00	167.					0	0	0					YES
196	HAYWD 5	200	195	WINBGO5	200	0	3.80	15.00	-6960.00	110.									0	0	0	NO
196	HAYWD 5	200	198	ADAM 5	200	0	2.07	10.88	-5200.00	225.					0	0	0					YES
196	HAYWD 5	200	208	LIMECK5	200	0	2.49	10.05	-4580.00	202.					0	0	0					YES
197	MASNTY5	200	208	LIMECK5	200	0	1.14	4.48	-2078.00	202.					0	0	0					YES
197	MASNTY5	200	377	FRANKN5	210	0	2.80	11.40	-5200.00	112.					0	0	0					YES
197	MASNTY5	200	382	FLOY 5	210	0	2.16	10.70	-5100.00	240.					0	0	0					YES
197	MASNTY5	200	423	GARNR 5	211	0	1.02	5.36	-2550.00	217.					0	0	0					YES
198	ADAM 5	200	146	HARMNY5	31	0	2.13	10.13	-6410.00	224.									0	0	0	NO
198	ADAM 5	200	152	ROCHTR5	31	0	2.97	10.70	-5460.00	167.									0	0	0	NO
198	ADAM 5	200	196	HAYWD 5	200	0	2.07	10.88	-5200.00	225.									0	0	0	NO
198	ADAM 5	200	208	LIMECK5	200	0	2.34	12.20	-5830.00	224.					0	0	0					YES
198	ADAM 5	200	515	ADAM 3	216	0	0.0	4.56	0.0	225.	1.119				0	0	0	0				YES
200	DUBUUE5	31	146	HARMNY5	31	31	23.14	76.78	0.0	0.									0	0	0	NO
200	DUBUUE5	31	175	POSTILS	31	31	38.67	190.05	0.0	0.									0	0	0	NO
200	DUBUUE5	31	203	CLINON5	31	31	6.03	25.72	0.0	0.					0	0	0					YES
200	DUBUUE5	31	414	DUNDE 5	211	0	2.39	12.50	-5960.00	220.					0	0	0					YES
200	DUBUUE5	31	651	LACRSS3	31	31	10.74	68.09	0.0	0.					0	0	0					YES
201	HAZLON5	200	175	POSTILS	31	0	3.12	16.29	-7780.00	240.									0	0	0	NO
201	HAZLON5	200	202	HAZLON3	200	0	0.0	4.93	0.0	225.	1.108				0	0	0	0				YES
201	HAZLON5	200	379	BLKHK 5	210	0	1.88	7.17	-3280.00	225.					0	0	0					YES
201	HAZLON5	200	380	WSHBN 5	210	0	1.72	8.50	-4046.00	218.					0	0	0					YES
201	HAZLON5	200	414	DUNDE 5	211	0	1.40	5.40	-2500.00	225.					0	0	0					YES
202	HAZLON3	200	201	HAZLON5	200	0	0.0	4.93	0.0	225.									1	65	1	NO
202	HAZLON3	200	422	ARNOD 3	211	0	0.20	1.86	-31999.97	480.					0	0	0					YES
202	HAZLON3	200	515	ADAM 3	216	0	0.39	3.79	-66999.63	480.					0	0	0					YES
203	CLINON5	31	200	DUBUUE5	31	31	6.03	25.72	0.0	0.									0	0	0	NO
203	CLINON5	31	410	CALUS 5	211	0	1.88	7.51	-3490.00	167.					0	0	0					YES
203	CLINON5	31	474	DAVNRT5	31	31	3.24	17.02	0.0	0.					0	0	0					YES
203	CLINON5	31	480	DVNPT 3	31	31	2.93	17.66	0.0	0.					0	0	0					YES
203	CLINON5	31	1201	PALM710	31	31	14.49	65.09	0.0	0.					0	0	0					YES
204	LAKFD 5	200	192	HRN K 5	31	0	1.74	5.11	-2300.00	224.									1	107	0	NO
204	LAKFD 5	200	193	LAKFD 3	200	0	0.0	3.40	0.0	225.	1.022				0	0	0	0				YES
204	LAKFD 5	200	194	FOX K 5	200	0	2.49	7.25	-2020.00	224.									1	94	0	NO
204	LAKFD 5	200	416	TRIBJI5	211	0	1.37	7.25	-3400.00	223.					1	124	0					YES
208	LIMECK5	200	196	HAYWD 5	200	0	2.49	10.05	-4580.00	202.									0	0	0	NO
208	LIMECK5	200	197	MASNTY5	200	0	1.14	4.48	-2078.00	202.									0	0	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
208	LIMECK5	200	198	ADAM 5	200	0	2.34	12.20	-5830.00	224.									0	0	0	NO
221	DENIN 5	201	223	ANITTP5	211	0	3.10	13.78	-6220.00	110.					1	698	0					YES
221	DENIN 5	201	258	SX CY 4	201	0	1.42	12.25	-18759.92	200.					0	0	0					YES
223	ANITTP5	211	221	DENIN 5	201	0	3.10	13.78	-6220.00	110.									0	0	0	NO
223	ANITTP5	211	224	CRESN 5	201	0	2.51	11.14	-5020.00	110.					0	0	0					YES
223	ANITTP5	211	429	ANIT 5	211	0	0.30	1.20	-540.00	0.					0	0	0					YES
224	CRESN 5	201	223	ANITTP5	211	0	2.51	11.14	-5020.00	110.									0	0	0	NO
224	CRESN 5	201	340	MARY 12	31	0	3.36	16.60	-7799.98	0.					0	0	0					YES
224	CRESN 5	201	432	CLRNA 5	212	0	4.20	13.00	-5700.00	0.					0	0	0					YES
224	CRESN 5	201	434	D.MON 5	212	0	5.40	16.80	-7400.00	162.					0	0	0					YES
226	SX CY 5	201	227	WISDM 5	201	0	2.75	19.61	-9560.00	110.					1	217	0					YES
226	SX CY 5	201	258	SX CY 4	201	0	0.05	2.00	0.0	375.	1.000				0	0	0	0				YES
226	SX CY 5	201	336	HINTON8	201	0	0.0	11.40	0.0	75.									1	113	1	NO
226	SX CY 5	201	375	PLYMH 5	210	0	0.05	0.26	-230.00	334.					0	0	0					YES
227	WISDM 5	201	226	SX CY 5	201	0	2.75	19.61	-9560.00	110.									0	0	0	NO
227	WISDM 5	201	361	OSGOD 5	209	0	1.74	9.10	-4300.00	220.					1	189	0					YES
227	WISDM 5	201	376	SAC 5	210	0	2.50	12.37	-5886.00	240.					0	0	0					YES
227	WISDM 5	201	416	TRIBJI5	211	0	1.08	5.70	-2720.00	220.					0	0	0					YES
258	SX CY 4	201	14	TWINCH4	31	0	0.51	3.70	-7160.00	320.									1	293	0	NO
258	SX CY 4	201	221	DENIN 5	201	0	1.42	12.25	-18759.92	200.									1	375	0	NO
258	SX CY 4	201	226	SX CY 5	201	0	0.05	2.00	0.0	375.									1	97	1	NO
258	SX CY 4	201	262	UTICJC4	201	0	1.70	10.70	-20739.93	0.					0	0	0					YES
258	SX CY 4	201	268	FTRAD 4	31	0	2.85	17.93	-34839.90	0.					0	0	0					YES
258	SX CY 4	201	330	EAGL 4	201	0	0.71	4.71	-8520.00	0.					1	214	0					YES
258	SX CY 4	201	332	SX CY 3	201	0	0.0	1.18	0.0	500.									0	0	0	NO
259	SX FLL7	31	14	TWINCH4	31	31	25.25	122.42	0.0	0.									0	0	0	NO
259	SX FLL7	31	192	HRN K 5	31	31	6.60	30.93	0.0	0.									0	0	0	NO
259	SX FLL7	31	260	SIOXLS4	201	0	0.27	6.53	-220.00	100.	1.025				0	0	0	0				YES
259	SX FLL7	31	260	SIOXLS4	201	1	0.20	3.93	0.0	200.	1.025				0	0	0	0				YES
259	SX FLL7	31	268	FTRAD 4	31	31	39.07	167.53	0.0	0.					0	0	0					YES
259	SX FLL7	31	274	FTTHMP4	31	31	36.74	96.40	0.0	0.					0	0	0					YES
259	SX FLL7	31	333	WTRTWN3	31	31	10.41	41.44	0.0	0.					0	0	0					YES
259	SX FLL7	31	539	PR ILD3	31	31	53.67	182.95	0.0	0.					0	0	0					YES
260	SIOXLS4	201	259	SX FLL7	31	0	0.27	6.53	-220.00	100.									1	257	1	NO
260	SIOXLS4	201	259	SX FLL7	31	1	0.20	3.93	0.0	200.									1	257	1	NO
260	SIOXLS4	201	262	UTICJC4	201	0	1.33	10.18	-18419.92	120.					0	0	0					YES
260	SIOXLS4	201	274	FTTHMP4	31	0	2.96	22.75	-39959.96	240.					0	0	0					YES
260	SIOXLS4	201	326	HANLN 4	31	0	0.43	4.22	-7640.00	150.					0	0	0					YES
260	SIOXLS4	201	330	EAGL 4	201	0	1.06	7.06	-12099.95	0.					1	150	0					YES
262	UTICJC4	201	258	SX CY 4	201	0	1.70	10.70	-20739.93	0.									1	196	0	NO
262	UTICJC4	201	260	SIOXLS4	201	0	1.33	10.18	-18419.92	120.									1	164	0	NO
262	UTICJC4	201	268	FTRAD 4	31	0	1.15	7.32	-14199.93	0.					0	0	0					YES
268	FTRAD 4	31	14	TWINCH4	31	31	12.75	70.33	0.0	0.									0	0	0	NO
268	FTRAD 4	31	17	GR ILD3	31	31	4.40	32.27	0.0	0.									0	0	0	NO
268	FTRAD 4	31	53	WAGEER7	31	31	50.35	174.33	0.0	0.									0	0	0	NO
268	FTRAD 4	31	258	SX CY 4	201	0	2.85	17.93	-34839.90	0.									1	228	0	NO
268	FTRAD 4	31	259	SX FLL7	31	31	39.07	167.53	0.0	0.									0	0	0	NO
268	FTRAD 4	31	262	UTICJC4	201	0	1.15	7.32	-14199.93	0.									0	0	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80X CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
268	FTRAD 4	31	274	FTTHMP4	31	31	0.84	5.88	0.0	0.					0	0	0					YES
268	FTRAD 4	31	326	HANLN 4	31	31	17.04	145.55	0.0	0.					0	0	0					YES
274	FTTHMP4	31	17	GR ILD3	31	31	0.98	12.21	0.0	0.									0	0	0	NO
274	FTTHMP4	31	259	SX FLL7	31	31	36.74	96.40	0.0	0.									0	0	0	NO
274	FTTHMP4	31	260	SIOXLS4	201	0	2.96	22.75	-39959.96	240.									1	132	0	NO
274	FTTHMP4	31	268	FTRAD 4	31	31	0.84	5.88	0.0	0.									0	0	0	NO
274	FTTHMP4	31	326	HANLN 4	31	31	1.58	17.02	0.0	0.					0	0	0					YES
274	FTTHMP4	31	333	WTRTWN3	31	31	0.40	7.40	0.0	0.					0	0	0					YES
274	FTTHMP4	31	539	PR ILD3	31	31	0.44	29.69	0.0	0.					0	0	0					YES
274	FTTHMP4	31	635	WILMRT3	31	31	1.73	58.10	0.0	0.					0	0	0					YES
326	HANLN 4	31	260	SIOXLS4	201	0	0.43	4.22	-7640.00	150.									1	100	0	NO
326	HANLN 4	31	268	FTRAD 4	31	31	17.04	145.55	0.0	0.									0	0	0	NO
326	HANLN 4	31	274	FTTHMP4	31	31	1.58	17.02	0.0	0.									0	0	0	NO
326	HANLN 4	31	333	WTRTWN3	31	31	24.09	196.00	0.0	0.					0	0	0					YES
330	EAGL 4	201	258	SX CY 4	201	0	0.71	4.71	-8520.00	0.									0	0	0	NO
330	EAGL 4	201	260	SIOXLS4	201	0	1.06	7.06	-12099.95	0.									0	0	0	NO
332	SX CY 3	201	258	SX CY 4	201	0	0.0	1.18	0.0	500.	1.000				1	81	1	0				YES
332	SX CY 3	201	648	SIOXLS	201	0	0.33	3.81	-60655.96	1200.					0	0	0					YES
333	WTRTWN3	31	259	SX FLL7	31	31	10.41	41.44	0.0	0.									0	0	0	NO
333	WTRTWN3	31	274	FTTHMP4	31	31	0.40	7.40	0.0	0.									0	0	0	NO
333	WTRTWN3	31	326	HANLN 4	31	31	24.09	196.00	0.0	0.									0	0	0	NO
333	WTRTWN3	31	539	PR ILD3	31	31	0.31	15.36	0.0	0.					0	0	0					YES
333	WTRTWN3	31	635	WILMRT3	31	31	1.05	27.64	0.0	0.					0	0	0					YES
333	WTRTWN3	31	648	SIOXLS	201	0	0.50	5.71	-90983.81	1200.					1	86	0					YES
336	HINTON8	201	226	SX CY 5	201	0	0.0	11.40	0.0	75.	1.000				0	0	0	0				YES
336	HINTON8	201	880	PLYMTH8	210	0	1.13	2.79	-49.00	64.					1	261	0					YES
339	NEBCY1G	233	774	NEBCY 3	233	0	0.0	1.27	0.0	710.									0	0	0	NO
340	MARY 12	31	224	CRESN 5	201	0	3.36	16.60	-7799.98	0.									0	0	0	NO
340	MARY 12	31	393	STJO712	31	31	3.89	16.99	0.0	0.					0	0	0					YES
340	MARY 12	31	432	CLRNA 5	212	0	3.00	9.00	-4100.00	0.					0	0	0					YES
340	MARY 12	31	454	WAPELO5	31	31	40.71	185.43	0.0	0.					0	0	0					YES
340	MARY 12	31	1201	PALM710	31	31	13.37	60.31	0.0	0.					0	0	0					YES
361	OSGOD 5	209	227	WISDM 5	201	0	1.74	9.10	-4300.00	220.									0	0	0	NO
361	OSGOD 5	209	363	BURT 5	209	0	1.70	8.94	-4250.00	217.					0	0	0					YES
362	HOPE 5	209	363	BURT 5	209	0	1.93	10.13	-4820.00	217.					1	238	0					YES
362	HOPE 5	209	373	HOPET 5	210	0	0.68	3.53	-1690.00	218.					0	0	0					YES
363	BURT 5	209	361	OSGOD 5	209	0	1.70	8.94	-4250.00	217.									0	0	0	NO
363	BURT 5	209	362	HOPE 5	209	0	1.93	10.13	-4820.00	217.									0	0	0	NO
363	BURT 5	209	423	GARNR 5	211	0	1.76	9.24	-4400.00	217.					1	159	0					YES
371	NEAL 5	210	800	RAUN 5	210	0	0.02	0.18	-91.20	334.					1	467	0					YES
371	NEAL 5	210	800	RAUN 5	210	1	0.02	0.18	-91.20	334.					1	499	0					YES
371	NEAL 5	210	873	NEAL 8	210	0	0.0	9.16	0.0	93.									1	177	1	NO
371	NEAL 5	210	873	NEAL 8	210	1	0.0	9.16	0.0	93.									1	177	1	NO
371	NEAL 5	210	1246	NEAL12G	210	0	0.0	1.97	0.0	495.	1.040				0	0	0	0				YES
372	RAUN 3	210	193	LAKFD 3	200	0	0.59	5.83	-93015.69	1190.									1	394	0	NO
372	RAUN 3	210	482	LEHIH 3	214	0	0.63	6.07	-92999.81	720.					1	455	0					YES
372	RAUN 3	210	773	FT.CL 3	233	0	0.30	3.22	-50387.93	1075.					1	502	0					YES
372	RAUN 3	210	800	RAUN 5	210	0	0.0	3.86	0.0	300.									1	369	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
372	RAUN 3	210	800	RAUN 5	210	1	0.0	3.86	0.0	300.									1	401	0	NO
372	RAUN 3	210	1247	NEAL34G	210	0	0.0	0.82	0.0	1250.	1.040				0	0	0	0				YES
373	HOPET 5	210	362	HOPE 5	209	0	0.68	3.53	-1690.00	218.									1	303	0	NO
373	HOPET 5	210	384	WRIGT 5	210	0	0.98	3.74	-1698.00	167.					1	320	0					YES
373	HOPET 5	210	477	FT.DDG5	214	0	1.14	4.34	-1970.00	112.					0	0	0					YES
373	HOPET 5	210	481	LEHIH 5	214	0	0.52	4.33	-2206.00	324.					0	0	0					YES
375	PLYMH 5	210	226	SX CY 5	201	0	0.05	0.26	-230.00	334.									1	265	0	NO
375	PLYMH 5	210	376	SAC 5	210	0	4.62	17.63	-8013.00	233.					1	328	0					YES
375	PLYMH 5	210	800	RAUN 5	210	0	1.53	6.71	-3127.40	222.					0	0	0					YES
375	PLYMH 5	210	803	LEEDS 5	210	0	0.40	1.89	-976.80	334.					1	357	0					YES
375	PLYMH 5	210	880	PLYMTH8	210	0	0.0	8.27	0.0	150.									1	209	1	NO
376	SAC 5	210	227	WISOM 5	201	0	2.50	12.37	-5886.00	240.									1	300	0	NO
376	SAC 5	210	375	PLYMH 5	210	0	4.62	17.63	-8013.00	233.									0	0	0	NO
376	SAC 5	210	383	POMEOY5	210	0	2.72	10.37	-4713.79	112.					1	349	0					YES
377	FRANKN5	210	197	MASNTY5	200	0	2.80	11.40	-5200.00	112.									0	0	0	NO
377	FRANKN5	210	379	BLKHK 5	210	0	3.97	15.17	-6899.00	202.					0	0	0					YES
377	FRANKN5	210	384	WRIGT 5	210	0	2.35	8.96	-4071.70	167.					0	0	0					YES
377	FRANKN5	210	412	IA FS 7	211	0	0.80	6.37	-330.00	106.									0	0	0	NO
378	WATELO8	210	379	BLKHK 5	210	0	3.00	34.50	-390.00	50.					0	0	0					YES
378	WATELO8	210	380	WSHBN 5	210	0	3.70	37.20	-580.00	50.					0	0	0					YES
379	BLKHK 5	210	201	HAZLON5	200	0	1.88	7.17	-3280.00	225.									0	0	0	NO
379	BLKHK 5	210	377	FRANKN5	210	0	3.97	15.17	-6899.00	202.									0	0	0	NO
379	BLKHK 5	210	378	WATELO8	210	0	3.00	34.50	-390.00	50.									0	0	0	NO
379	BLKHK 5	210	381	WATELO5	210	0	0.40	1.90	-1080.00	218.					0	0	0					YES
379	BLKHK 5	210	382	FLOY 5	210	0	2.71	13.41	-6382.00	111.					0	0	0					YES
380	WSHBN 5	210	201	HAZLON5	200	0	1.72	8.50	-4046.00	218.									0	0	0	NO
380	WSHBN 5	210	378	WATELO8	210	0	3.70	37.20	-580.00	50.									0	0	0	NO
380	WSHBN 5	210	388	WTR OGT	210	0	0.52	2.56	-1234.00	0.					0	0	0					YES
380	WSHBN 5	210	419	DYSAT 5	211	0	0.57	5.80	-2910.00	252.					0	0	0					YES
381	WATELO5	210	379	BLKHK 5	210	0	0.40	1.90	-1080.00	218.									0	0	0	NO
381	WATELO5	210	388	WTR OGT	210	0	0.53	2.49	-1301.00	0.					0	0	0					YES
382	FLOY 5	210	197	MASNTY5	200	0	2.16	10.70	-5100.00	240.									0	0	0	NO
382	FLOY 5	210	379	BLKHK 5	210	0	2.71	13.41	-6382.00	111.									0	0	0	NO
383	POMEOY5	210	376	SAC 5	210	0	2.72	10.37	-4713.79	112.									0	0	0	NO
383	POMEOY5	210	477	FT.DDG5	214	0	2.44	9.30	-4228.50	112.					0	0	0					YES
384	WRIGT 5	210	373	HOPET 5	210	0	0.98	3.74	-1698.00	167.									0	0	0	NO
384	WRIGT 5	210	377	FRANKN5	210	0	2.35	8.96	-4071.70	167.									0	0	0	NO
386	MONOA 5	210	387	CARRLL5	210	0	3.04	15.06	-7166.59	218.					1	570	0					YES
386	MONOA 5	210	801	NEAL4 5	210	0	1.96	9.70	-4617.50	224.					0	0	0					YES
387	CARRLL5	210	386	MONOA 5	210	0	3.04	15.06	-7166.59	218.									0	0	0	NO
387	CARRLL5	210	401	GR JT 5	211	0	2.11	10.46	-4978.00	240.					1	572	0					YES
388	WTR OGT	210	380	WSHBN 5	210	0	0.52	2.56	-1234.00	0.									0	0	0	NO
388	WTR OGT	210	381	WATELO5	210	0	0.53	2.49	-1301.00	0.									0	0	0	NO
393	STJO712	31	6	COOPR 3	195	0	0.34	3.26	-72239.50	1075.									0	0	0	NO
393	STJO712	31	340	MARY 12	31	31	3.89	16.99	0.0	0.									0	0	0	NO
393	STJO712	31	454	WAPELO5	31	31	28.83	167.19	0.0	0.					0	0	0					YES
393	STJO712	31	474	DAVNRT5	31	31	10.74	180.23	0.0	0.					0	0	0					YES
393	STJO712	31	480	DVNPT 3	31	31	1.40	64.83	0.0	0.					0	0	0					YES

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
393	STJ0712	31	772	SI206 5	31	31	23.61	101.22	0.0	0.					0	0	0					YES
393	STJ0712	31	1201	PALM710	31	31	0.84	11.39	0.0	0.					0	0	0					YES
401	GR JT 5	211	387	CARRLL5	210	0	2.11	10.46	-4978.00	240.									0	0	0	NO
401	GR JT 5	211	402	GR JT 7	211	0	0.0	5.70	0.0	90.									0	0	0	NO
401	GR JT 5	211	403	GUTHIE7	211	0	2.80	11.20	-5370.00	202.					0	0	0					YES
401	GR JT 5	211	451	JASPR 8	213	0	4.40	22.80	-10901.97	112.					1	542	0					YES
402	GR JT 7	211	401	GR JT 5	211	0	0.0	5.70	0.0	90.	1.025				0	0	0	0				YES
402	GR JT 7	211	407	BOON 7	211	0	6.90	13.40	-1400.00	60.					0	0	0					YES
403	GUTHIE7	211	401	GR JT 5	211	0	2.80	11.20	-5370.00	202.									0	0	0	NO
403	GUTHIE7	211	429	ANIT 5	211	0	1.40	6.80	-2660.00	0.					0	0	0					YES
404	CDRPS 5	211	405	PRARCK7	211	0	0.54	4.58	-360.00	250.									0	0	0	NO
404	CDRPS 5	211	409	WYOMG 5	211	0	1.56	8.19	-3760.00	168.					0	0	0					YES
404	CDRPS 5	211	421	ARNOD 5	211	0	1.43	8.95	-4495.00	325.					0	0	0					YES
404	CDRPS 5	211	472	HILL 5	214	0	1.45	9.57	-4800.00	252.					0	0	0					YES
405	PRARCK7	211	404	CDRPS 5	211	0	0.54	4.58	-360.00	250.	1.020				0	0	0	0				YES
405	PRARCK7	211	406	MTOW 7	211	0	8.70	21.20	-8600.00	118.					0	0	0					YES
405	PRARCK7	211	411	CALUS 7	211	0	12.89	28.09	-3349.00	50.					0	0	0					YES
405	PRARCK7	211	418	SIX T 7	211	0	0.71	4.30	-2247.00	400.					0	0	0					YES
405	PRARCK7	211	1252	PRARK4G	211	0	0.0	6.85	0.0	150.	1.030				0	0	0	0				YES
406	MTOW 7	211	405	PRARCK7	211	0	8.70	21.20	-8600.00	118.									0	0	0	NO
406	MTOW 7	211	407	BOON 7	211	0	18.37	35.90	-3700.00	80.					0	0	0					YES
406	MTOW 7	211	413	WELSRG7	211	0	6.90	16.10	-1850.00	60.					0	0	0					YES
406	MTOW 7	211	451	JASPR 8	213	0	7.40	25.00	-1428.00	69.					0	0	0					YES
406	MTOW 7	211	1254	MTOW 3G	211	0	0.0	10.31	0.0	96.	1.030				0	0	0	0				YES
407	BOON 7	211	402	GR JT 7	211	0	6.90	13.40	-1400.00	60.									0	0	0	NO
407	BOON 7	211	406	MTOW 7	211	0	18.37	35.90	-3700.00	80.									0	0	0	NO
408	MOOKTA5	211	409	WYOMG 5	211	0	1.50	6.10	-2920.00	168.					0	0	0					YES
408	MOOKTA5	211	410	CALUS 5	211	0	1.30	5.00	-2370.00	112.					0	0	0					YES
409	WYOMG 5	211	404	CDRPS 5	211	0	1.56	8.19	-3760.00	168.									0	0	0	NO
409	WYOMG 5	211	408	MOOKTA5	211	0	1.50	6.10	-2920.00	168.									0	0	0	NO
410	CALUS 5	211	203	CLINON5	31	0	1.88	7.51	-3490.00	167.									0	0	0	NO
410	CALUS 5	211	408	MOOKTA5	211	0	1.30	5.00	-2370.00	112.									0	0	0	NO
410	CALUS 5	211	411	CALUS 7	211	0	0.51	10.07	-251.00	84.									0	0	0	NO
410	CALUS 5	211	474	DAVNRT5	31	0	1.27	5.10	-2450.00	112.					0	0	0					YES
411	CALUS 7	211	405	PRARCK7	211	0	12.89	28.09	-3349.00	50.									0	0	0	NO
411	CALUS 7	211	410	CALUS 5	211	0	0.51	10.07	-251.00	84.	1.025				0	0	0	0				YES
412	IA FS 7	211	377	FRANKN5	210	0	0.80	6.37	-330.00	106.	1.000				0	0	0	0				YES
412	IA FS 7	211	413	WELSRG7	211	0	6.20	14.50	-1660.00	60.					0	0	0					YES
413	WELSRG7	211	406	MTOW 7	211	0	6.90	16.10	-1850.00	60.									0	0	0	NO
413	WELSRG7	211	412	IA FS 7	211	0	6.20	14.50	-1660.00	60.									0	0	0	NO
414	DUNDE 5	211	200	DUBUUE5	31	0	2.39	12.50	-5960.00	220.									0	0	0	NO
414	DUNDE 5	211	201	HAZLON5	200	0	1.40	5.40	-2500.00	225.									0	0	0	NO
414	DUNDE 5	211	415	DUNDE 7	211	0	0.0	11.60	0.0	45.									0	0	0	NO
415	DUNDE 7	211	414	DUNDE 5	211	0	0.0	11.60	0.0	45.	1.025				0	0	0	0				YES
415	DUNDE 7	211	418	SIX T 7	211	0	14.85	29.30	-3100.00	60.					0	0	0					YES
416	TRIBJI5	211	204	LAKFD 5	200	0	1.37	7.25	-3400.00	223.									0	0	0	NO
416	TRIBJI5	211	227	WISDM 5	201	0	1.08	5.70	-2720.00	220.									0	0	0	NO
417	MONRE 5	213	434	D.MON 5	212	0	2.31	7.17	-3150.00	167.					0	0	0					YES

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 37? - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
417	MONRE 5	213	451	JASPR 8	213	0	0.79	4.68	-2315.00	251.					0	0	0					YES
417	MONRE 5	213	457	POWAHKS	213	0	1.96	6.11	-2684.00	167.					0	0	0					YES
418	SIX T 7	211	405	PRARCK7	211	0	0.71	4.30	-2247.00	400.									0	0	0	NO
418	SIX T 7	211	415	DUNDE 7	211	0	14.85	29.30	-3100.00	60.									0	0	0	NO
418	SIX T 7	211	421	ARNOD 5	211	0	0.06	2.14	-3406.50	504.	1.025				0	0	0	0				YES
419	DYSAT 5	211	380	WSHBN 5	210	0	0.57	5.80	-2910.00	252.									0	0	0	NO
419	DYSAT 5	211	421	ARNOD 5	211	0	1.25	8.26	-4150.00	252.					0	0	0					YES
421	ARNOD 5	211	404	CORPS 5	211	0	1.43	8.95	-4495.00	325.									0	0	0	NO
421	ARNOD 5	211	418	SIX T 7	211	0	0.06	2.14	-3406.50	504.									0	0	0	NO
421	ARNOD 5	211	419	DYSAT 5	211	0	1.25	8.26	-4150.00	252.									0	0	0	NO
421	ARNOD 5	211	422	ARNOD 3	211	0	0.0	2.60	0.0	400.	1.025				0	0	0	0				YES
421	ARNOD 5	211	1265	AROL 1G	211	0	0.0	1.54	0.0	600.	1.050				0	0	0	0				YES
422	ARNOD 3	211	202	HAZLON3	200	0	0.20	1.86	-31999.97	480.									0	0	0	NO
422	ARNOD 3	211	421	ARNOD 5	211	0	0.0	2.60	0.0	400.									0	0	0	NO
422	ARNOD 3	211	471	HILL 3	214	0	0.19	1.96	-33299.93	1100.					0	0	0					YES
423	GARNR 5	211	197	MASNTY5	200	0	1.02	5.36	-2550.00	217.									0	0	0	NO
423	GARNR 5	211	363	BURT 5	209	0	1.76	9.24	-4400.00	217.									0	0	0	NO
429	ANIT 5	211	223	ANITTP5	211	0	0.30	1.20	-540.00	0.									0	0	0	NO
429	ANIT 5	211	403	GUTHIE7	211	0	1.40	6.80	-2660.00	0.									1	700	0	NO
431	CBLUFS5	212	433	AVOC 5	212	0	2.30	9.90	-4600.00	112.					0	0	0					YES
431	CBLUFS5	212	436	CBLUFS3	212	0	0.0	1.85	0.0	500.	1.000				0	0	0	0				YES
431	CBLUFS5	212	987	S701 5	212	0	0.32	2.56	-1346.00	323.					0	0	0					YES
431	CBLUFS5	212	1082	HSTNGS5	212	0	2.10	6.49	-2873.00	164.					0	0	0					YES
431	CBLUFS5	212	1256	CBLUFS8	212	0	0.0	4.10	0.0	160.									0	0	0	NO
431	CBLUFS5	212	1267	C.BL12G	212	0	0.0	7.68	0.0	150.	1.040				0	0	0	0				YES
432	CLRNA 5	212	224	CRESN 5	201	0	4.20	13.00	-5700.00	0.									0	0	0	NO
432	CLRNA 5	212	340	MARY 12	31	0	3.00	9.00	-4100.00	0.									0	0	0	NO
432	CLRNA 5	212	1082	HSTNGS5	212	0	3.23	10.00	-4427.00	164.					0	0	0					YES
432	CLRNA 5	212	1497	CLRNDA8	212	0	0.0	17.28	0.0	83.									0	0	0	NO
433	AVOC 5	212	431	CBLUFS5	212	0	2.30	9.90	-4600.00	112.									0	0	0	NO
433	AVOC 5	212	440	BOONIL5	212	0	5.27	22.15	-10300.00	209.					0	0	0					YES
434	D.MON 5	212	224	CRESN 5	201	0	5.40	16.80	-7400.00	162.									0	0	0	NO
434	D.MON 5	212	417	MONRE 5	213	0	2.31	7.17	-3150.00	167.									0	0	0	NO
434	D.MON 5	212	437	SYCAOR5	212	0	0.60	4.87	-2570.00	320.					0	0	0					YES
434	D.MON 5	212	438	ASHAA 5	212	0	1.17	4.93	-2300.00	209.					0	0	0					YES
434	D.MON 5	212	481	LEHIH 5	214	0	6.23	21.26	-9400.00	167.					0	0	0					YES
434	D.MON 5	212	1270	DPS 57G	212	0	0.0	5.20	0.0	200.	1.043				0	0	0	0				YES
435	SYCAOR3	212	437	SYCAOR5	212	0	0.0	0.90	0.0	1000.									1	289	1	NO
435	SYCAOR3	212	439	BOONIL3	212	0	0.14	1.19	-20499.93	1000.					0	0	0					YES
435	SYCAOR3	212	471	HILL 3	214	0	0.60	5.77	-92899.63	1000.					1	672	0					YES
435	SYCAOR3	212	482	LEHIH 3	214	0	0.31	3.10	-48209.90	1000.					0	0	0					YES
436	CBLUFS3	212	431	CBLUFS5	212	0	0.0	1.85	0.0	500.									0	0	0	NO
436	CBLUFS3	212	439	BOONIL3	212	0	0.59	5.68	-92499.63	1000.					1	793	0					YES
436	CBLUFS3	212	771	S3456 3	233	0	0.05	0.44	-7200.00	1000.					1	791	0					YES
436	CBLUFS3	212	1271	C.BL 3G	212	0	0.0	1.90	0.0	720.	1.050				0	0	0	0				YES
437	SYCAOR5	212	57	SYCAOR8	212	0	0.0	4.10	0.0	160.									0	0	0	NO
437	SYCAOR5	212	434	D.MON 5	212	0	0.60	4.87	-2570.00	320.									1	576	0	NO
437	SYCAOR5	212	435	SYCAOR3	212	0	0.0	0.90	0.0	1000.	1.025				0	0	0	0				YES

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE															X----- MAP DATA -----X							
FROM BUS			TO BUS							MVA	TAP	TAP LIMITS		SCHED	FLOW			TAP	REV FLOW			FWRD
NO.	NAME	AREA	NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	RATING	RATIO	TMIN	TMAX	VALUE	PG	LOC	Q	LOC	PG	LOC	Q	ENTRY
437	SYCAORS	212	438	ASHAA 5	212	0	0.48	3.91	-2143.00	323.					0	0	0					YES
437	SYCAORS	212	959	WABASHS	212	0	0.35	2.86	-1558.00	323.					0	0	0					YES
438	ASHAA 5	212	434	D.MON 5	212	0	1.17	4.93	-2300.00	209.									0	0	0	NO
438	ASHAA 5	212	437	SYCAORS	212	0	0.48	3.91	-2143.00	323.									0	0	0	NO
438	ASHAA 5	212	440	BOONILS	212	0	0.19	1.54	-3300.00	640.					0	0	0					YES
438	ASHAA 5	212	959	WABASHS	212	0	0.22	1.75	-1007.00	323.					0	0	0					YES
439	BOONIL3	212	6	COOPR 3	195	0	0.64	6.21	-98699.63	1000.									0	0	0	NO
439	BOONIL3	212	435	SYCAOR3	212	0	0.14	1.19	-20499.93	1000.									1	671	0	NO
439	BOONIL3	212	436	CBLUFS3	212	0	0.59	5.68	-92499.63	1000.									1	734	0	NO
439	BOONIL3	212	440	BOONILS	212	0	0.0	1.85	0.0	500.	1.000				0	0	0	0				YES
440	BOONILS	212	433	AVOC 5	212	0	5.27	22.15	-10300.00	209.									0	0	0	NO
440	BOONILS	212	438	ASHAA 5	212	0	0.19	1.54	-3300.00	640.									0	0	0	NO
440	BOONILS	212	439	BOONIL3	212	0	0.0	1.85	0.0	500.									0	0	0	NO
441	OSKLOSS	212	454	WAPELOS	31	0	1.75	8.35	-3970.00	217.					0	0	0					YES
441	OSKLOSS	212	457	POWAHKS	213	0	1.30	6.21	-2960.00	227.					0	0	0					YES
451	JASPR 8	213	401	GR JT 5	211	0	4.40	22.80	-10901.97	112.									0	0	0	NO
451	JASPR 8	213	406	MTOW 7	211	0	7.40	25.00	-1428.00	69.									0	0	0	NO
451	JASPR 8	213	417	MONRE 5	213	0	0.79	4.68	-2315.00	251.									0	0	0	NO
454	WAPELOS	31	340	MARY 12	31	31	40.71	185.43	0.0	0.									0	0	0	NO
454	WAPELOS	31	393	STJO712	31	31	28.83	167.19	0.0	0.									0	0	0	NO
454	WAPELOS	31	441	OSKLOSS	212	0	1.75	8.35	-3970.00	217.									0	0	0	NO
454	WAPELOS	31	474	DAVNRTS	31	31	18.20	75.10	0.0	0.					0	0	0					YES
454	WAPELOS	31	1201	PALM710	31	31	4.23	24.41	0.0	0.					0	0	0					YES
457	POWAHKS	213	417	MONRE 5	213	0	1.96	6.11	-2684.00	167.									0	0	0	NO
457	POWAHKS	213	441	OSKLOSS	212	0	1.30	6.21	-2960.00	227.									0	0	0	NO
457	POWAHKS	213	472	HILL 5	214	0	6.13	18.91	-8366.00	167.					0	0	0					YES
471	HILL 3	214	422	ARNOD 3	211	0	0.19	1.96	-33299.93	1100.									0	0	0	NO
471	HILL 3	214	435	SYCAOR3	212	0	0.60	5.77	-92899.63	1000.									0	0	0	NO
471	HILL 3	214	472	HILL 5	214	0	0.0	3.50	0.0	300.									0	0	0	NO
471	HILL 3	214	480	DVNPT 3	31	0	0.20	2.22	-37819.92	1048.					0	0	0					YES
471	HILL 3	214	1201	PALM710	31	0	0.70	6.20	-99999.94	1000.					0	0	0					YES
472	HILL 5	214	404	CORPS 5	211	0	1.45	9.57	-4800.00	252.									0	0	0	NO
472	HILL 5	214	457	POWAHKS	213	0	6.13	18.91	-8366.00	167.									0	0	0	NO
472	HILL 5	214	471	HILL 3	214	0	0.0	3.50	0.0	300.	1.025				0	0	0	0				YES
472	HILL 5	214	474	DAVNRTS	31	0	2.27	13.33	-6600.00	223.					0	0	0					YES
474	DAVNRTS	31	203	CLINONS	31	31	3.24	17.02	0.0	0.									0	0	0	NO
474	DAVNRTS	31	393	STJO712	31	31	10.74	180.23	0.0	0.									0	0	0	NO
474	DAVNRTS	31	410	CALUS 5	211	0	1.27	5.10	-2450.00	112.									0	0	0	NO
474	DAVNRTS	31	454	WAPELOS	31	31	18.20	75.10	0.0	0.									0	0	0	NO
474	DAVNRTS	31	472	HILL 5	214	0	2.27	13.33	-6600.00	223.									0	0	0	NO
474	DAVNRTS	31	480	DVNPT 3	31	31	0.02	1.67	0.0	0.					0	0	0					YES
474	DAVNRTS	31	1201	PALM710	31	31	2.79	19.72	0.0	0.					0	0	0					YES
477	FT.DDGS	214	373	HOPET 5	210	0	1.14	4.34	-1970.00	112.									0	0	0	NO
477	FT.DDGS	214	383	POMEOYS	210	0	2.44	9.30	-4228.50	112.									0	0	0	NO
477	FT.DDGS	214	481	LEHIH 5	214	0	0.51	3.36	-1825.00	283.					0	0	0					YES
480	DVNPT 3	31	203	CLINONS	31	31	2.93	17.66	0.0	0.									0	0	0	NO
480	DVNPT 3	31	393	STJO712	31	31	1.40	64.83	0.0	0.									0	0	0	NO
480	DVNPT 3	31	471	HILL 3	214	0	0.20	2.22	-37819.92	1048.									0	0	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
480	DVNPT 3	31	474	DAVNRT5	31	31	0.02	1.67	0.0	0.									0	0	0	NO
480	DVNPT 3	31	539	PR ILD3	31	31	5.77	82.56	0.0	0.					0	0	0					YES
480	DVNPT 3	31	1201	PALM710	31	31	1.13	15.85	0.0	0.					0	0	0					YES
481	LEHIH 5	214	373	HOPET 5	210	0	0.52	4.33	-2206.00	324.									1	415	0	NO
481	LEHIH 5	214	434	D.MON 5	212	0	6.23	21.26	-9400.00	167.									1	495	0	NO
481	LEHIH 5	214	477	FT.DDG5	214	0	0.51	3.36	-1825.00	283.									1	398	0	NO
481	LEHIH 5	214	482	LEHIH 3	214	0	0.0	1.80	0.0	500.	1.025				0	0	0	0				YES
482	LEHIH 3	214	372	RAUN 3	210	0	0.63	6.07	-92999.81	720.									1	461	0	NO
482	LEHIH 3	214	435	SYCAOR3	212	0	0.31	3.10	-48209.90	1000.									1	559	0	NO
482	LEHIH 3	214	481	LEHIH 5	214	0	0.0	1.80	0.0	500.									1	161	1	NO
515	ADAM 3	216	198	ADAM 5	200	0	0.0	4.56	0.0	225.									1	49	1	NO
515	ADAM 3	216	202	HAZLON3	200	0	0.39	3.79	-66999.63	480.									0	0	0	NO
515	ADAM 3	216	539	PR ILD3	31	0	0.40	3.81	-66999.63	720.					0	0	0					YES
515	ADAM 3	216	651	LACRSS3	31	0	0.40	4.03	-68319.81	960.					0	0	0					YES
539	PR ILD3	31	152	ROCHTR5	31	31	10.53	51.32	0.0	0.									0	0	0	NO
539	PR ILD3	31	259	SX FLL7	31	31	53.67	182.95	0.0	0.									0	0	0	NO
539	PR ILD3	31	274	FTTHMP4	31	31	0.44	29.69	0.0	0.									0	0	0	NO
539	PR ILD3	31	333	WTRTWN3	31	31	0.31	15.36	0.0	0.									0	0	0	NO
539	PR ILD3	31	480	DVNPT 3	31	31	5.77	82.56	0.0	0.									0	0	0	NO
539	PR ILD3	31	515	ADAM 3	216	0	0.40	3.81	-66999.63	720.									0	0	0	NO
539	PR ILD3	31	635	WILMRT3	31	31	0.22	2.25	0.0	0.					0	0	0					YES
539	PR ILD3	31	651	LACRSS3	31	31	8.77	70.49	0.0	0.					0	0	0					YES
539	PR ILD3	31	1201	PALM710	31	31	2.01	59.15	0.0	0.					0	0	0					YES
635	WILMRT3	31	152	ROCHTR5	31	31	15.74	88.71	0.0	0.									0	0	0	NO
635	WILMRT3	31	193	LAKFD 3	200	0	0.44	4.10	-83839.94	720.									0	0	0	NO
635	WILMRT3	31	274	FTTHMP4	31	31	1.73	58.10	0.0	0.									0	0	0	NO
635	WILMRT3	31	333	WTRTWN3	31	31	1.05	27.64	0.0	0.									0	0	0	NO
635	WILMRT3	31	539	PR ILD3	31	31	0.22	2.25	0.0	0.									0	0	0	NO
635	WILMRT3	31	636	RAPIANS	31	31	1.01	12.73	0.0	0.					0	0	0					YES
635	WILMRT3	31	651	LACRSS3	31	31	15.06	143.55	0.0	0.					0	0	0					YES
635	WILMRT3	31	1201	PALM710	31	31	3.50	168.45	0.0	0.					0	0	0					YES
636	RAPIANS	31	195	WINBGOS	200	0	2.06	8.33	-3850.00	167.									0	0	0	NO
636	RAPIANS	31	635	WILMRT3	31	31	1.01	12.73	0.0	0.									0	0	0	NO
648	SIOXLS	201	332	SX CY 3	201	0	0.33	3.81	-60655.96	1200.									1	184	0	NO
648	SIOXLS	201	333	WTRTWN3	31	0	0.50	5.71	-90983.81	1200.									0	0	0	NO
651	LACRSS3	31	146	HARMNYS	31	31	2.87	26.37	0.0	0.									0	0	0	NO
651	LACRSS3	31	152	ROCHTR5	31	31	9.58	52.76	0.0	0.									0	0	0	NO
651	LACRSS3	31	175	POSTILS	31	31	1.05	64.14	0.0	0.									0	0	0	NO
651	LACRSS3	31	200	DUBUUES	31	31	10.74	68.09	0.0	0.									0	0	0	NO
651	LACRSS3	31	515	ADAM 3	216	0	0.40	4.03	-68319.81	960.									0	0	0	NO
651	LACRSS3	31	539	PR ILD3	31	31	8.77	70.49	0.0	0.									0	0	0	NO
651	LACRSS3	31	635	WILMRT3	31	31	15.06	143.55	0.0	0.									0	0	0	NO
733	FT.CLIG	233	773	FT.CL 3	233	0	0.04	2.42	0.0	578.									0	0	0	NO
771	S3456 3	233	436	CBLUFS3	212	0	0.05	0.44	-7200.00	1000.									0	0	0	NO
771	S3456 3	233	772	S1206 5	31	0	0.03	1.88	0.0	500.	0.975				0	0	0	0				YES
771	S3456 3	233	774	NEBCY 3	233	0	0.22	2.24	-37929.98	1160.					0	0	0					YES
771	S3456 3	233	775	S3459 3	233	0	0.04	0.51	-10008.00	717.					0	0	0					YES
771	S3456 3	233	777	S3455 3	233	0	0.03	0.38	-6518.50	717.					0	0	0					YES

TITLE-LF-090-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
772	S1206 5	31	15	SHELON7	31	31	15.98	64.15	0.0	0.									0	0	0	NO
772	S1206 5	31	53	WAGEER7	31	31	4.73	39.56	0.0	0.									0	0	0	NO
772	S1206 5	31	393	STJ0712	31	31	23.61	101.22	0.0	0.									0	0	0	NO
772	S1206 5	31	771	S3456 3	233	0	0.03	1.88	0.0	500.									0	0	0	NO
772	S1206 5	31	776	S1209 5	31	31	1.07	8.28	0.0	0.					0	0	0					YES
772	S1206 5	31	778	S1255 5	31	31	0.57	3.74	0.0	0.					0	0	0					YES
772	S1206 5	31	780	S1211 5	31	31	0.63	3.82	0.0	0.					0	0	0					YES
773	FT.CL 3	233	372	RAUN 3	210	0	0.30	3.22	-50387.93	1075.									0	0	0	NO
773	FT.CL 3	233	733	FT.CL1G	233	0	0.04	2.42	0.0	578.	1.025				0	0	0	0				YES
773	FT.CL 3	233	775	S3459 3	233	0	0.08	0.87	-16592.96	717.					1	742	0					YES
773	FT.CL 3	233	779	S3454 3	233	0	0.13	1.50	-26828.96	717.					1	740	0					YES
774	NEBCY 3	233	6	COOPR 3	195	0	0.11	1.19	-20119.99	1160.									1	918	0	NO
774	NEBCY 3	233	339	NEBCY1G	233	0	0.0	1.27	0.0	710.	1.025				0	0	0	0				YES
774	NEBCY 3	233	771	S3456 3	233	0	0.22	2.24	-37929.98	1160.									1	855	0	NO
774	NEBCY 3	233	777	S3455 3	233	0	0.22	2.68	-46119.98	717.					1	854	0					YES
775	S3459 3	233	771	S3456 3	233	0	0.04	0.51	-10008.00	717.									0	0	0	NO
775	S3459 3	233	773	FT.CL 3	233	0	0.08	0.87	-16592.96	717.									0	0	0	NO
775	S3459 3	233	776	S1209 5	31	0	0.04	1.80	0.0	500.	1.000				0	0	0	0				YES
776	S1209 5	31	772	S1206 5	31	31	1.07	8.28	0.0	0.									0	0	0	NO
776	S1209 5	31	775	S3459 3	233	0	0.04	1.80	0.0	500.									0	0	0	NO
776	S1209 5	31	778	S1255 5	31	31	0.28	1.68	0.0	0.					0	0	0					YES
776	S1209 5	31	780	S1211 5	31	31	0.22	1.30	0.0	0.					0	0	0					YES
776	S1209 5	31	1302	TEKAMA5	31	31	3.85	18.00	0.0	0.					0	0	0					YES
777	S3455 3	233	771	S3456 3	233	0	0.03	0.38	-6518.50	717.									0	0	0	NO
777	S3455 3	233	774	NEBCY 3	233	0	0.22	2.68	-46119.98	717.									0	0	0	NO
777	S3455 3	233	778	S1255 5	31	0	0.04	1.98	0.0	500.	1.000				0	0	0	0				YES
778	S1255 5	31	15	SHELON7	31	31	44.86	157.73	0.0	0.									0	0	0	NO
778	S1255 5	31	53	WAGEER7	31	31	2.52	28.80	0.0	0.									0	0	0	NO
778	S1255 5	31	772	S1206 5	31	31	0.57	3.74	0.0	0.									0	0	0	NO
778	S1255 5	31	776	S1209 5	31	31	0.28	1.68	0.0	0.									0	0	0	NO
778	S1255 5	31	777	S3455 3	233	0	0.04	1.98	0.0	500.									0	0	0	NO
778	S1255 5	31	780	S1211 5	31	31	4.59	29.11	0.0	0.					0	0	0					YES
779	S3454 3	233	7	LINCLN3	195	0	0.17	1.69	-28725.97	717.									0	0	0	NO
779	S3454 3	233	773	FT.CL 3	233	0	0.13	1.50	-26828.96	717.									0	0	0	NO
780	S1211 5	31	772	S1206 5	31	31	0.63	3.82	0.0	0.									0	0	0	NO
780	S1211 5	31	776	S1209 5	31	31	0.22	1.30	0.0	0.									0	0	0	NO
780	S1211 5	31	778	S1255 5	31	31	4.59	29.11	0.0	0.									0	0	0	NO
780	S1211 5	31	987	S701 5	212	0	0.08	0.72	-380.00	323.					0	0	0					YES
800	RAUN 5	210	371	NEAL 5	210	0	0.02	0.18	-91.20	334.									0	0	0	NO
800	RAUN 5	210	371	NEAL 5	210	1	0.02	0.18	-91.20	334.									0	0	0	NO
800	RAUN 5	210	372	RAUN 3	210	0	0.0	3.86	0.0	300.	1.000				0	0	0	0				YES
800	RAUN 5	210	372	RAUN 3	210	1	0.0	3.86	0.0	300.	1.000				0	0	0	0				YES
800	RAUN 5	210	375	PLYMH 5	210	0	1.53	6.71	-3127.40	222.									1	406	0	NO
800	RAUN 5	210	801	NEAL4 5	210	0	0.10	0.85	-197.60	334.					1	487	0					YES
800	RAUN 5	210	802	INTRCG5	210	0	0.39	2.62	-1383.60	334.					1	437	0					YES
800	RAUN 5	210	1302	TEKAMA5	31	0	2.53	11.68	-5445.00	204.					1	533	0					YES
801	NEAL4 5	210	386	MONOA 5	210	0	1.96	9.70	-4617.50	224.									1	536	0	NO
801	NEAL4 5	210	800	RAUN 5	210	0	0.10	0.85	-197.60	334.									0	0	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	X----- MAP DATA -----X FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
802	INTRCG5	210	800	RAUN 5	210	0	0.39	2.62	-1383.60	334.									0	0	0	NO
802	INTRCG5	210	804	KELOG 5	210	0	0.21	1.38	-748.90	334.					1	435	0					YES
803	LEEDS 5	210	375	PLYMH 5	210	0	0.40	1.89	-976.80	334.									0	0	0	NO
803	LEEDS 5	210	804	KELOG 5	210	0	0.22	1.03	-532.70	334.					1	355	0					YES
804	KELOG 5	210	802	INTRCG5	210	0	0.21	1.38	-748.90	334.									0	0	0	NO
804	KELOG 5	210	803	LEEDS 5	210	0	0.22	1.03	-532.70	334.									0	0	0	NO
873	NEAL 8	210	371	NEAL 5	210	0	0.0	9.16	0.0	93.	1.000				0	0	0	0				YES
873	NEAL 8	210	371	NEAL 5	210	1	0.0	9.16	0.0	93.	1.000				0	0	0	0				YES
873	NEAL 8	210	877	KELLOG8	210	0	7.10	28.41	-536.50	72.					0	0	0					YES
873	NEAL 8	210	878	M SIDE8	210	0	4.30	18.56	-388.90	96.					0	0	0					YES
874	LOGANP8	210	875	MCCOOK8	210	0	3.39	6.64	-120.90	72.					0	0	0					YES
874	LOGANP8	210	880	PLYMTH8	210	0	4.89	14.04	-283.50	72.					0	0	0					YES
875	MCCOOK8	210	874	LOGANP8	210	0	3.39	6.64	-120.90	72.									0	0	0	NO
875	MCCOOK8	210	876	SC WST8	210	0	1.90	8.11	-1199.70	72.					0	0	0					YES
876	SC WST8	210	875	MCCOOK8	210	0	1.90	8.11	-1199.70	72.									0	0	0	NO
876	SC WST8	210	877	KELLOG8	210	0	1.02	4.29	-94.90	72.					0	0	0					YES
877	KELLOG8	210	873	NEAL 8	210	0	7.10	28.41	-536.50	72.									0	0	0	NO
877	KELLOG8	210	876	SC WST8	210	0	1.02	4.29	-94.90	72.									0	0	0	NO
877	KELLOG8	210	879	E SIDE8	210	0	1.55	3.79	-72.60	72.					0	0	0					YES
878	M SIDE8	210	873	NEAL 8	210	0	4.30	18.56	-388.90	96.									0	0	0	NO
878	M SIDE8	210	879	E SIDE8	210	0	1.76	8.22	-150.00	96.					0	0	0					YES
879	E SIDE8	210	877	KELLOG8	210	0	1.55	3.79	-72.60	72.									0	0	0	NO
879	E SIDE8	210	878	M SIDE8	210	0	1.76	8.22	-150.00	96.									0	0	0	NO
879	E SIDE8	210	880	PLYMTH8	210	0	5.30	12.73	-218.50	48.					0	0	0					YES
880	PLYMTH8	210	336	HINTON8	201	0	1.13	2.79	-49.00	64.									0	0	0	NO
880	PLYMTH8	210	375	PLYMH 5	210	0	0.0	8.27	0.0	150.	1.000				0	0	0	0				YES
880	PLYMTH8	210	874	LOGANP8	210	0	4.89	14.04	-283.50	72.									0	0	0	NO
880	PLYMTH8	210	879	E SIDE8	210	0	5.30	12.73	-218.50	48.									0	0	0	NO
959	WABASH5	212	437	SYCAOR5	212	0	0.35	2.86	-1558.00	323.									0	0	0	NO
959	WABASH5	212	438	ASHAA 5	212	0	0.22	1.75	-1007.00	323.									0	0	0	NO
987	S701 5	212	431	CBLUFS5	212	0	0.32	2.56	-1346.00	323.									0	0	0	NO
987	S701 5	212	780	S1211 5	31	0	0.08	0.72	-380.00	323.									0	0	0	NO
987	S701 5	212	1014	S701 8	212	0	0.0	4.10	0.0	160.									0	0	0	NO
998	COOPR1G	195	6	COOPR 3	195	0	0.0	1.33	0.0	900.									0	0	0	NO
1014	S701 8	212	987	S701 5	212	0	0.0	4.10	0.0	160.	1.025				0	0	0	0				YES
1014	S701 8	212	1075	S702 8	212	0	1.09	2.59	-47.00	63.					0	0	0					YES
1014	S701 8	212	1088	S703 8	212	0	3.90	9.90	-164.00	57.					0	0	0					YES
1014	S701 8	212	1100	S704 8	212	0	1.34	5.04	-99.00	87.					0	0	0					YES
1075	S702 8	212	1014	S701 8	212	0	1.09	2.59	-47.00	63.									0	0	0	NO
1075	S702 8	212	1256	CBLUFS8	212	0	4.66	11.82	-196.00	57.					0	0	0					YES
1082	HSTNGS5	212	431	CBLUFS5	212	0	2.10	6.49	-2873.00	164.									0	0	0	NO
1082	HSTNGS5	212	432	CLRNA 5	212	0	3.23	10.00	-4427.00	164.									0	0	0	NO
1082	HSTNGS5	212	1189	HSTNGS8	212	0	0.0	8.20	0.0	80.									0	0	0	NO
1088	S703 8	212	1014	S701 8	212	0	3.90	9.90	-164.00	57.									0	0	0	NO
1088	S703 8	212	1390	S706 8	212	0	2.60	6.50	-110.00	57.					0	0	0					YES
1100	S704 8	212	1014	S701 8	212	0	1.34	5.04	-99.00	87.									0	0	0	NO
1100	S704 8	212	1257	S705 8	212	0	0.41	1.56	-31.00	87.					0	0	0					YES
1189	HSTNGS8	212	1082	HSTNGS5	212	0	0.0	8.20	0.0	80.	1.025				0	0	0	0				YES

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE IN TERMS OF PERCENT LINE IMPEDANCE AND KVAR LINE CHARGING. SYSTEM BASE MVA = 100.0 MVA

LINE FROM BUS NO.	NAME	AREA	TO BUS NO.	NAME	AREA	CKT	R(PCT)	X(PCT)	KVAC	MVA RATING	TAP RATIO	TAP LIMITS TMIN	TMAX	SCHED VALUE	MAP DATA FLOW PG	LOC	Q	TAP LOC	REV FLOW PG	LOC	Q	FWRD ENTRY
1189	HSTNGS8	212	1391	GWOOD 8	212	0	8.90	22.10	-313.00	57.					0	0	0					YES
1189	HSTNGS8	212	1494	R.OAK 8	212	0	9.27	23.22	-210.00	63.					0	0	0					YES
1189	HSTNGS8	212	1498	SHENDO8	212	0	6.80	29.06	-583.00	87.					0	0	0					YES
1201	PALM710	31	203	CLINCN5	31	31	14.49	65.09	0.0	0.									0	0	0	NO
1201	PALM710	31	340	MARY 12	31	31	13.37	60.31	0.0	0.									0	0	0	NO
1201	PALM710	31	393	STJO712	31	31	0.84	11.39	0.0	0.									0	0	0	NO
1201	PALM710	31	454	WAPELO5	31	31	4.23	24.41	0.0	0.									0	0	0	NO
1201	PALM710	31	471	HILL 3	214	0	0.70	6.20	-99999.94	1000.									0	0	0	NO
1201	PALM710	31	474	DAVNRT5	31	31	2.79	19.72	0.0	0.									0	0	0	NO
1201	PALM710	31	480	DVNPT 3	31	31	1.13	15.85	0.0	0.									0	0	0	NO
1201	PALM710	31	539	PR ILD3	31	31	2.01	59.15	0.0	0.									0	0	0	NO
1201	PALM710	31	635	WILMRT3	31	31	3.50	168.45	0.0	0.									0	0	0	NO
1246	NEAL12G	210	371	NEAL 5	210	0	0.0	1.97	0.0	495.									0	0	0	NO
1247	NEAL34G	210	372	RAUN 3	210	0	0.0	0.82	0.0	1250.									0	0	0	NO
1252	PRARK4G	211	405	PRARCK7	211	0	0.0	6.85	0.0	150.									0	0	0	NO
1254	MTOW 3G	211	406	MTOW 7	211	0	0.0	10.31	0.0	96.									0	0	0	NO
1256	CBLUFS8	212	431	CBLUFS5	212	0	0.0	4.10	0.0	160.	1.000				0	0	0	0				YES
1256	CBLUFS8	212	1075	S702 8	212	0	4.66	11.82	-196.00	57.									0	0	0	NO
1256	CBLUFS8	212	1257	S705 8	212	0	2.51	9.41	-185.00	87.					0	0	0					YES
1256	CBLUFS8	212	1390	S706 8	212	0	2.60	6.50	-110.00	57.					0	0	0					YES
1256	CBLUFS8	212	1391	GWOOD 8	212	0	9.23	23.38	-387.00	57.					0	0	0					YES
1257	S705 8	212	1100	S704 8	212	0	0.41	1.56	-31.00	87.									0	0	0	NO
1257	S705 8	212	1256	CBLUFS8	212	0	2.51	9.41	-185.00	87.									0	0	0	NO
1265	AROL 1G	211	421	ARNOD 5	211	0	0.0	1.54	0.0	600.									0	0	0	NO
1267	C.BL12G	212	431	CBLUFS5	212	0	0.0	7.68	0.0	150.									0	0	0	NO
1270	DPS 57G	212	434	D.MON 5	212	0	0.0	5.20	0.0	200.									0	0	0	NO
1271	C.BL 3G	212	436	CBLUFS3	212	0	0.0	1.90	0.0	720.									0	0	0	NO
1302	TEKAMAS	31	776	S1209 5	31	31	3.85	18.00	0.0	0.									0	0	0	NO
1302	TEKAMAS	31	800	RAUN 5	210	0	2.53	11.68	-5445.00	204.									0	0	0	NO
1390	S706 8	212	1088	S703 8	212	0	2.60	6.50	-110.00	57.									0	0	0	NO
1390	S706 8	212	1256	CBLUFS8	212	0	2.60	6.50	-110.00	57.									0	0	0	NO
1391	GWOOD 8	212	1189	HSTNGS8	212	0	8.90	22.10	-313.00	57.									0	0	0	NO
1391	GWOOD 8	212	1256	CBLUFS8	212	0	9.23	23.38	-387.00	57.									0	0	0	NO
1494	R.OAK 8	212	1189	HSTNGS8	212	0	9.27	23.22	-210.00	63.									0	0	0	NO
1494	R.OAK 8	212	1497	CLRNDA8	212	0	15.82	39.19	-673.00	63.					0	0	0					YES
1497	CLRNDA8	212	432	CLRNA 5	212	0	0.0	17.28	0.0	83.	1.070				0	0	0	0				YES
1497	CLRNDA8	212	1494	R.OAK 8	212	0	15.82	39.19	-673.00	63.									0	0	0	NO
1497	CLRNDA8	212	1498	SHENDO8	212	0	16.18	38.61	-697.00	63.					0	0	0					YES
1498	SHENDO8	212	1189	HSTNGS8	212	0	6.80	29.06	-583.00	87.									0	0	0	NO
1498	SHENDO8	212	1497	CLRNDA8	212	0	16.18	38.61	-697.00	63.									0	0	0	NO

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE FOR BUSES

BUS NO.	BUS NAME	BUS AREA	BUS REG	VOLTAGE MAG(PU)	VOLTAGE ANG(DEG)	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	QMIN MVAR	QMAX MVAR	REACTOR MVAR	MAP DATA PAGE	MAP DATA VOLT LOC	MAP DATA VOLT A	MAP DATA LOAD LOC	MAP DATA LOAD Q	MAP DATA GEN LOC	MAP DATA GEN Q	MAP DATA REACTOR LOC	MAP DATA REACTOR QS
6	COOPR 3	195	0	1.033	-25.3	0.0	0.0	0.0	0.0	0.0	0.0	100.	1	513	1	0	0	0	0	0	0
7	LINCLN3	195	0	1.019	-30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
14	TWINCH4	31	0	0.993	-35.7	0.0	0.0	-226.0	11.5	0.0	0.0	0.	1	817	1	0	0	0	0	0	0
15	SHELON7	31	0	1.038	-33.7	0.0	0.0	-193.3	5.9	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
16	MOOR 3	195	0	1.023	-30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	883	0	0	0	0	0	0	0
17	GR ILD3	31	0	1.015	-30.7	0.0	0.0	-204.2	-37.3	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
53	WAGEER7	31	0	1.035	-33.8	0.0	0.0	-398.3	-19.2	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
57	SYCAOR8	212	0	1.014	-40.0	120.0	24.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
146	HARMNYS	31	0	1.007	-28.8	0.0	0.0	116.5	-44.7	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
152	ROCHTR5	31	0	1.015	-29.6	0.0	0.0	54.2	-26.7	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
175	POSTIL5	31	0	1.009	-30.4	0.0	0.0	69.8	-23.2	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
192	HRN K 5	31	0	0.989	-34.9	0.0	0.0	-63.5	-21.4	0.0	0.0	0.	1	121	0	0	0	0	0	0	0
193	LAKFD 3	200	0	1.002	-29.4	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	641	1	0	0	0	0	0	0
194	FOX K 5	200	0	0.989	-36.1	38.5	13.2	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
195	WINBGO5	200	0	0.989	-37.9	28.3	9.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
196	HAYWD 5	200	0	0.999	-39.8	101.2	32.5	0.0	0.0	0.0	0.0	-15.	0	0	0	0	0	0	0	0	0
197	MASNTY5	200	0	0.999	-43.0	45.2	15.1	0.0	-0.1	0.0	0.0	-20.	0	0	0	0	0	0	0	0	0
198	ADAM 5	200	0	1.036	-33.8	34.4	11.7	0.0	0.0	0.0	0.0	0.	1	465	1	0	0	0	0	0	0
200	DUBUUE5	31	1	1.000	-38.1	0.0	0.0	-64.4	-3.8	-66.2	9.8	0.	0	0	0	0	0	0	0	0	0
201	HAZLON5	200	0	1.034	-37.6	17.4	5.3	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
202	HAZLON3	200	0	0.988	-33.2	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
203	CLINON5	31	0	1.012	-35.7	0.0	0.0	-41.5	17.2	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
204	LAKFD 5	200	0	1.010	-33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
208	LIMECK5	200	0	1.006	-41.1	52.7	15.1	0.0	0.0	0.0	0.0	-20.	0	0	0	0	0	0	0	0	0
221	DENIN 5	201	0	0.999	-39.0	65.3	22.3	0.0	0.0	0.0	0.0	-26.	1	529	1	0	0	0	0	0	0
223	ANITTP5	211	0	0.991	-41.7	4.8	1.6	0.0	0.0	0.0	0.0	0.	1	731	0	0	0	0	0	0	0
224	CRESN 5	201	1	1.000	-40.6	93.8	22.9	60.0	29.9	-20.0	40.0	0.	0	0	0	0	0	0	0	0	0
226	SX CY 5	201	0	0.996	-30.7	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	625	1	0	0	0	0	0	0
227	WISDM 5	201	0	0.989	-37.9	94.0	29.6	23.7	9.0	0.0	0.0	0.	1	237	0	0	0	0	0	0	0
258	SX CY 4	201	0	1.000	-31.8	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	609	1	0	0	0	0	0	0
259	SX FLL7	31	0	0.993	-34.0	0.0	0.0	-243.7	-26.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
260	SIOXLS4	201	0	0.984	-31.4	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	753	1	0	0	0	0	0	0
262	UTICJC4	201	0	1.009	-28.7	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
268	FTRAD 4	31	0	1.019	-24.5	3420.2	0.0	3500.0	5.9	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
274	FTTHMP4	31	0	1.024	-18.5	0.0	0.0	865.6	70.8	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
326	HANLN 4	31	0	0.989	-29.8	0.0	0.0	-59.1	2.9	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
330	EAGL 4	201	0	0.985	-33.0	84.4	27.1	0.0	0.0	0.0	0.0	0.	1	545	1	0	0	0	0	0	0
332	SX CY 3	201	0	1.001	-31.1	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	593	1	0	0	0	0	0	0
333	WTRTWN3	31	0	0.997	-25.3	0.0	0.0	26.3	-116.3	0.0	0.0	0.	1	785	1	0	0	0	0	0	0
336	HINTON8	201	0	0.980	-32.7	37.9	12.5	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
339	NEBCY1G	233	1	1.018	-20.4	0.0	0.0	575.0	94.1	-265.0	320.0	0.	0	0	0	0	0	0	0	0	0
340	MARY 12	31	0	0.996	-39.5	0.0	0.0	-99.7	23.4	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
361	OSGOD 5	209	0	0.992	-40.5	25.3	7.3	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
362	HOPE 5	209	0	1.014	-40.2	40.4	12.7	0.0	0.0	0.0	0.0	-12.	0	0	0	0	0	0	0	0	0
363	BURT 5	209	0	1.001	-41.7	22.5	7.0	0.0	0.0	0.0	0.0	-6.	1	497	1	0	0	0	0	0	0
371	NEAL 5	210	0	1.027	-23.6	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	673	1	0	0	0	0	0	0
372	RAUN 3	210	0	1.032	-21.5	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	721	1	0	0	0	0	0	0
373	HOPET 5	210	0	1.021	-38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	368	0	0	0	0	0	0	0

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE FOR BUSES

X------ BUS	------X		X---- VOLTAGE	-----X	X--- LOAD	----X	X- GENERATION	-X	QMIN	QMAX	REACTOR	X---------- MAP DATA								----------X
NO.	NAME	AREA	REG	MAG(PU)	ANG(DEG)	MW	MVAR	MW	MVAR	MVAR	MVAR	MVAR	PAGE	VOLT LOC	A	LOAD LOC	Q	GEN LOC	Q	REACTOR LOC	QS
375	PLYMH 5	210	0	0.996	-30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	705	1	0	0	0	0	0	0
376	SAC 5	210	1	0.998	-37.5	48.5	15.6	0.0	20.0	-0.1	20.0	0.	1	364	0	0	0	0	0	0	0
377	FRANKN5	210	0	0.999	-43.0	14.2	5.3	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
378	WATELO8	210	0	1.002	-46.4	50.9	16.8	0.0	0.0	0.0	0.0	-22.	0	0	0	0	0	0	0	0	0
379	BLKHK 5	210	0	1.001	-42.1	52.9	17.6	0.0	0.0	0.0	0.0	0.	1	481	1	0	0	0	0	0	0
380	WSHBN 5	210	0	1.008	-40.2	39.2	12.8	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
381	WATELO5	210	0	1.000	-42.0	62.3	20.3	0.0	0.0	0.0	0.0	-10.	0	0	0	0	0	0	0	0	0
382	FLOY 5	210	0	0.990	-44.4	54.5	14.6	0.0	0.0	0.0	0.0	-5.	0	0	0	0	0	0	0	0	0
383	POMEOY5	210	0	1.010	-38.4	15.8	5.3	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
384	WRIGT 5	210	0	1.012	-40.5	26.4	8.8	0.0	-0.1	0.0	0.0	-5.	0	0	0	0	0	0	0	0	0
386	MONOA 5	210	0	0.993	-31.8	29.9	11.9	0.0	0.0	0.0	0.0	-12.	1	585	0	0	0	0	0	0	0
387	CARRLL5	210	0	0.971	-41.1	40.5	11.3	0.0	-0.1	0.0	0.0	-12.	1	587	0	0	0	0	0	0	0
388	WTR OGT	210	0	1.004	-41.1	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
393	STJO712	31	0	1.000	-32.5	9369.7	96.9	9000.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
401	GR JT 5	211	0	0.970	-45.0	50.7	13.3	0.0	0.0	0.0	0.0	-12.	1	577	1	0	0	0	0	0	0
402	GR JT 7	211	0	0.991	-46.2	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
403	GUTHIE7	211	0	0.980	-43.5	16.9	4.2	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
404	CDRPS 5	211	0	1.013	-36.6	51.2	12.8	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
405	PRARCK7	211	0	1.031	-36.6	117.2	39.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
406	MTOW 7	211	0	1.002	-45.1	119.2	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
407	BOON 7	211	0	0.962	-48.6	50.2	16.8	0.0	0.0	0.0	0.0	-10.	0	0	0	0	0	0	0	0	0
408	MOOKTA5	211	0	1.004	-37.0	16.5	4.1	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
409	WYOMG 5	211	0	1.003	-37.5	36.1	9.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
410	CALUS 5	211	0	1.008	-36.2	16.3	3.7	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
411	CALUS 7	211	0	1.027	-37.2	22.8	5.7	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
412	IA FS 7	211	0	0.994	-44.6	31.5	10.5	0.0	-0.1	0.0	0.0	-6.	0	0	0	0	0	0	0	0	0
413	WELSRG7	211	0	0.988	-45.8	23.2	6.9	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
414	DUNDE 5	211	0	1.019	-38.1	14.8	4.1	0.0	0.0	0.0	0.0	-1.	0	0	0	0	0	0	0	0	0
415	DUNDE 7	211	0	1.034	-38.6	24.8	6.2	0.0	0.0	0.0	0.0	-2.	0	0	0	0	0	0	0	0	0
416	TRIBJI5	211	0	0.996	-36.2	20.0	5.4	0.0	0.0	0.0	0.0	-2.	0	0	0	0	0	0	0	0	0
417	MONRE 5	213	0	0.995	-43.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
418	SIX T 7	211	1	1.045	-35.3	151.1	50.4	0.0	29.1	-0.1	30.0	0.	0	0	0	0	0	0	0	0	0
419	DYSAT 5	211	0	1.011	-37.8	37.9	9.5	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
421	ARNOD 5	211	0	1.030	-32.7	103.8	34.6	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
422	ARNOD 3	211	0	1.004	-33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
423	GARNR 5	211	0	0.997	-43.2	32.0	8.7	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
429	ANIT 5	211	0	0.989	-42.0	6.8	1.8	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
431	CBLUFS5	212	0	1.027	-29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
432	CLRNA 5	212	0	0.992	-38.2	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
433	AVOC 5	212	0	1.006	-33.9	65.4	16.7	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
434	D.MON 5	212	0	1.015	-39.3	218.2	42.8	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
435	SYCAOR3	212	0	1.010	-35.3	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	769	1	0	0	0	0	0	0
436	CBLUFS3	212	0	1.027	-27.0	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	760	0	0	0	0	0	0	0
437	SYCAOR5	212	0	1.024	-37.3	56.1	11.2	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
438	ASHAA 5	212	0	1.014	-38.0	101.9	20.1	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
439	BOONIL3	212	0	1.019	-33.8	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	702	0	0	0	0	0	0	0
440	BOONIL5	212	0	1.018	-36.1	17.3	3.3	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
441	OSKLOS5	212	0	0.989	-45.8	47.3	9.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE FOR BUSES

X------ BUS	------X			X---- VOLTAGE	-----X	--- LOAD	----X	X- GENERATION	-X	QMIN	QMAX	REACTOR	X---------- MAP DATA	VOLT		LOAD		GEN		REACTOR	-----------X
NO.	NAME	AREA	REG	MAG(PU)	ANG(DEG)	MW	MVAR	MW	MVAR	MVAR	MVAR	MVAR	PAGE	LOC	A	LOC	Q	LOC	Q	LOC	QS
451	JASPR 8	213	0	0.989	-44.8	60.6	4.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
454	WAPELO5	31	1	1.000	-46.2	0.0	0.0	-164.9	54.7	6.5	66.6	0.	0	0	0	0	0	0	0	0	0
457	POWAHK5	213	0	0.991	-43.9	35.4	5.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
471	HILL 3	214	0	1.014	-33.1	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
472	HILL 5	214	0	1.027	-36.9	164.0	6.5	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
474	DAVNRT5	31	0	1.015	-34.7	0.0	0.0	-322.1	45.8	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
477	FT.DDG5	214	0	1.023	-38.2	79.1	0.0	0.0	0.0	0.0	0.0	0.	1	561	1	0	0	0	0	0	0
480	DVNPT 3	31	0	1.009	-31.0	9000.0	90.9	9570.9	0.0	'0.0	0.0	0.	0	0	0	0	0	0	0	0	0
481	LEHIH 5	214	0	1.032	-36.2	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
482	LEHIH 3	214	0	1.012	-33.6	0.0	0.0	0.0	0.0	0.0	0.0	0.	1	657	1	0	0	0	0	0	0
515	ADAM 3	216	0	0.987	-30.6	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
539	PR ILD3	31	0	1.011	-26.6	9000.0	0.0	9467.0	63.8	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
635	WILMRT3	31	0	0.998	-30.4	6323.5	57.9	6000.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
636	RAPIAN5	31	0	0.991	-37.1	0.0	0.0	-72.5	3.1	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
648	SIOXLS	201	0	1.016	-28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
651	LACRSS3	31	0	0.986	-29.6	0.0	0.0	52.6	-65.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
733	FT.CLIG	233	1	1.030	-19.4	0.0	0.0	455.0	123.1	-144.0	288.0	0.	0	0	0	0	0	0	0	0	0
771	S3456 3	233	0	1.024	-27.4	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
772	S1206 5	31	0	1.028	-31.0	0.0	0.0	-381.0	-56.3	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
773	FT.CL 3	233	0	1.030	-25.4	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	711	0	0	0	0	0	0	0
774	NEBCY 3	233	0	1.034	-24.5	0.0	0.0	0.0	0.0	0.0	0.0	50.	1	885	0	0	0	0	0	0	0
775	S3459 3	233	0	1.024	-27.3	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
776	S1209 5	31	0	1.017	-30.8	0.0	0.0	-427.1	-109.9	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
777	S3455 3	233	0	1.024	+27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
778	S1255 5	31	0	1.020	-30.4	0.0	0.0	-159.0	-36.1	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
779	S3454 3	233	0	1.026	-27.8	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
780	S1211 5	31	0	1.025	-31.0	0.0	0.0	-32.7	95.2	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
800	RAUN 5	210	0	1.026	-23.8	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
801	NEAL4 5	210	0	1.023	-24.4	4.8	1.6	0.0	0.0	0.0	0.0	0.	1	689	1	0	0	0	0	0	0
802	INTRCG5	210	0	1.010	-26.7	24.0	8.0	0.0	0.0	0.0	0.0	0.	1	404	0	0	0	0	0	0	0
803	LEEDS 5	210	0	1.001	-29.0	20.0	6.4	0.0	0.0	0.0	0.0	0.	1	372	0	0	0	0	0	0	0
804	KELOG 5	210	0	1.004	-28.1	32.0	10.4	0.0	0.0	0.0	0.0	0.	1	737	1	0	0	0	0	0	0
873	NEAL 8	210	0	1.018	-25.8	4.0	1.6	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
874	LOGANP8	210	0	0.968	-33.5	16.0	5.6	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
875	MCCOOK8	210	0	0.969	-33.3	8.0	2.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
876	SC WST8	210	0	0.972	-32.8	14.4	4.8	0.0	0.0	0.0	0.0	-3.	0	0	0	0	0	0	0	0	0
877	KELLOG8	210	0	0.975	-32.1	28.0	9.6	0.0	0.0	0.0	0.0	-6.	0	0	0	0	0	0	0	0	0
878	N SIDE8	210	0	0.986	-30.3	12.0	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
879	E SIDE8	210	0	0.979	-31.8	8.0	2.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
880	PLYMTH8	210	0	0.980	-32.6	32.0	10.4	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
959	WABASH5	212	0	1.011	-39.0	216.4	42.8	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
987	S701 5	212	0	1.023	-30.9	17.5	3.3	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
998	COOPR1G	195	1	1.000	-19.2	0.0	0.0	794.0	180.6	-200.0	400.0	0.	0	0	0	0	0	0	0	0	0
1014	S701 8	212	0	1.035	-32.2	30.1	6.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1075	S702 8	212	0	1.032	-32.2	20.1	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1082	HSTNGS5	212	0	1.003	-33.9	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1088	S703 8	212	0	1.026	-32.5	20.1	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1100	S704 8	212	0	1.029	-32.5	20.1	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LOADFLOW DATA CURRENTLY IN STORAGE FOR BUSES

BUS NO.	BUS NAME	BUS AREA	BUS REG	VOLTAGE MAG(PU)	VOLTAGE ANG(DEG)	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	QMIN MVAR	QMAX MVAR	REACTOR MVAR	MAP DATA PAGE	MAP DATA VOLT LOC	MAP DATA VOLT A	MAP DATA LOAD LOC	MAP DATA LOAD Q	MAP DATA GEN LOC	MAP DATA GEN Q	MAP DATA REACTOR LOC	MAP DATA REACTOR CS
1189	HSTNGS8	212	0	1.022	-36.2	12.4	2.0	0.0	-0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1201	PALM710	31	1	1.020	-29.4	9000.0	0.0	9387.5	-24.7	-1099.4	9900.4	0.	0	0	0	0	0	0	0	0	0
1246	NEAL12G	210	1	1.000	-18.5	0.0	0.0	447.0	85.8	-72.0	267.0	0.	1	0	0	0	0	882	0	0	0
1247	NEAL34G	210	1	1.000	-16.5	0.0	0.0	1055.0	134.8	-170.0	605.0	0.	1	0	0	0	0	913	0	0	0
1252	PRARK4G	211	1	1.000	-31.4	0.0	0.0	130.9	4.8	-60.6	75.6	0.	0	0	0	0	0	0	0	0	0
1254	MTOW 3G	211	1	1.000	-40.1	0.0	0.0	82.0	30.2	-24.4	38.6	0.	0	0	0	0	0	0	0	0	0
1256	CBLUFS8	212	0	1.032	-31.3	0.0	0.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1257	S705 8	212	0	1.029	-32.4	13.6	2.7	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1265	AROL 1G	211	2	1.000	-27.7	0.0	0.0	551.7	149.3	-310.0	204.0	0.	0	0	0	0	0	0	0	0	0
1267	C.BL12G	212	1	1.000	-23.7	0.0	0.0	131.0	22.4	-25.0	33.0	0.	0	0	0	0	0	0	0	0	0
1270	DPS 57G	212	1	1.000	-34.0	0.0	0.0	173.0	59.4	-44.0	100.0	0.	0	0	0	0	0	0	0	0	0
1271	C.BL 3G	212	1	1.000	-20.1	0.0	0.0	620.0	150.8	-120.0	250.0	0.	0	0	0	0	0	0	0	0	0
1302	TEKAMAS	31	0	1.023	-26.8	0.0	0.0	-6.0	2.8	0.0	0.0	0.	1	612	0	0	0	0	0	0	0
1390	S706 8	212	0	1.027	-32.1	10.1	2.0	0.0	-0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1391	GWOOD 8	212	0	1.019	-34.4	10.8	2.2	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1494	R.OAK 8	212	0	1.006	-39.4	21.1	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1497	CLRNDA8	212	0	1.028	-40.6	27.1	5.4	-0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0
1498	SHENDO8	212	0	1.010	-39.9	21.3	4.0	0.0	0.0	0.0	0.0	0.	0	0	0	0	0	0	0	0	0

SCHEDULED VOLTAGE FOR BUSES REGULATED BY REACTIVE GENERATION

BUS NO.	BUS NAME	AREA	SCHEDULED VOLTAGE
200	DUBUUES	31	1.000
224	CRESN 5	201	1.000
339	NEBCY1G	233	1.018
376	SAC 5	210	1.000
418	SIX T 7	211	1.045
454	WAPELOS	31	1.000
733	FT.CL1G	233	1.030
998	COOPR1G	195	1.000
1201	PALM710	31	1.020
1246	NEAL12G	210	1.000
1247	NEAL34G	210	1.000
1252	PRARK4G	211	1.000
1254	MTOW 3G	211	1.000
1265	AROL 1G	211	1.000
1267	C.BL12G	212	1.000
1270	DPS 57G	212	1.000
1271	C.BL 3G	212	1.000

TITLE-LF-080-8-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
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NO BUSES ARE REGULATED BY LTC CONTROL

MISCELLANEOUS DATA CONSTANTS CURRENTLY IN STORAGE

REAL POWER MISMATCH TOLERANCE PER UNIT = 0.001000

IMAG POWER MISMATCH TOLERANCE PER UNIT = 0.001000

SYSTEM BASE MVA = 100.000

INPUT DEVICE UNIT NUMBER = 5

OUTPUT DEVICE UNIT NUMBER = 3

DATA CURRENTLY IN STORAGE FOR AREA INTERCHANGE

SLACK BUS	AREA NAME	AREA NO.	NET MW FLOW DESIRED OUT POS	MW TOLERANCE ACTUAL NET-DESIRED NET
0	EQUIVAL	31	0.0	0.0
0	NPPD	195	0.0	0.10
0	ISP	200	0.0	0.10
0	USBR-6	201	0.0	0.10
0	CBPC	209	0.0	0.10
0	IPS	210	0.0	0.10
0	IELP	211	0.0	0.10
0	IPL	212	0.0	0.10
0	ISU	213	0.0	0.10
0	IIGE	214	0.0	0.10
0	NSP	216	0.0	0.10
0	OPPD	233	0.0	0.10

END OF LISTING FOR DATA TABLES IN STORAGE

TITLE-LF-080-B-RU NEAL-4 STABILITY STUDY 80% CONTINGENCY CASE
OUTAGE RAUN - HINTON 372 - 332

LINE AND TRANSFORMER OUTAGES CURRENTLY IN EFFECT

FROM NO.	FROM NAME	AREA	TO NO.	TO NAME	AREA	CKT	G(PU)	B(PU)	BC/2(PU)	MVA RATING	TAP	TMIN	TMAX	ELTC	FLOW PG	FLOW LOC	FLOW Q	TAP LOC	REV FLOW PG	REV FLOW LOC	REV FLOW Q
372	RAUN	3 210	332	SX CY	3 201	0	7.0406	-76.2733	0.1008	1190.	0.0	0.0	0.0	0.0	1	392	0	0	0	0	0