Power System Contingency Ranking Adopting Conventional & Fuzzy Based approach

A DISSERTATION

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in

POWER SYSTEMS

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CERTIFICATE

This is to certify that this major project entitled, ” Power System Contingency Ranking Adopting Conventional & Fuzzy Based approach “, submitted by **Manjula B.G. (05/PSY/09),** in partial fulfilment of the requirements for the award of degree of Master of Engineering in Electrical Engineering at Delhi Technological University, Bawana Road, Delhi-42, is true record of work undertaken by her as a part of curriculum under my guidance & supervision.

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MANJULA.B.G.

DEDICATED TO MY SON

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ABSTRACT

The reliability of power system is generally judged in terms of systems adequacy & security. The term adequacy refers to systems capacity to meet the load demand within the component ratings & voltage limits at any time. The term security refers to system's ability to withstand the impact of sudden changes due to equipment outage, such as the loss of a generator, transmission line etc. The security of the system is defined in terms of list of contingencies (i.e. transmission line & generator outages) which may cause insecure operation.

Clearly as the system conditions changes, this list changes. In order to determine the list of contingencies, load flow analysis should be performed to determine the impact of each contingency on the system performance. However since this is not computationally feasible for on line applications, contingency selection algorithms have been developed to identify the set of contingencies which may create problems.

A scalar function called performance index is used in the calculation of the contingency ranking. A real power & voltage performance index is calculated which evaluates the severity of contingency derived from the current overload of lines. The operating state of the power system is a function of time. It keeps on changing due to variation in load level at various buses or due to rescheduling of generation.

To keep the system secure, it is imperative to know the impact of unplanned outages in advance so that suitable preventive / control measures can be taken if necessary. In deregulated operating regime power system security is an issue that needs due consideration from researchers. Real power & voltage contingency ranking is an integral part of security assessment. The objective of contingency screening & ranking is to quickly & accurately short list critical contingencies from a large list of credible contingencies & rank them according to their severity for further rigorous analysis.

A performance index is computed for each single line contingency. To obtain the magnitudes of various parameters a MI power computer aided power system study software which employ iterative methods are used. This document presents an approach using fuzzy logic to evaluate the degree of severity of the considered contingency & to eliminate the masking effect in the Technique.

Contingency Ranking considering transmission line & generator outages are tabulated for five bus & IEEE Fourteen bus systems. Then fuzzy logic is developed to unmask the severity between the two conventionally calculated contingency rankings.

Keywords: System security, Real Power, Voltage, Performance Index, Contingency Ranking, Fuzzy logic approach.

CHAPTER 1: INTRODUCTION

1.1 SYSTEM SECURITY

Until now we are primarily concerned with the economical operation of a power system. An equally important factor in the operation of a power system is the desire to maintain system security. System security involves keeping the system operating when components fail.

An operationally "secure" system is one with low probability of blackout or equipment damage. Since security & economy are normally conflicting requirements, it is inappropriate to treat them separately. The Energy management system is to operate the system at minimum cost, with the guaranteed alleviations of the emergency conditions.

The emergency condition will depend on severity of violations of operating limits (branch flows & bus voltage limits). The most severe violations result from contingencies. Since power system equipment is designed to be operated within certain limits, these are protected by automatic devices that can cause equipment to be switched out of the system.

If these limits are violated, the event may be followed by a series of further actions that switch other equipment out of service. If this process of cascading failure continues, the entire system or large parts of it may completely collapse. This is referred as system blackout.

The type of event sequence that can cause a blackout might start with single line being open due to an insulation failure. The remaining transmission circuits in the system will take up the flow that was flowing on the now opened line.

If one of the remaining lines is now too heavily loaded, it may open due to relay action, thereby causing even more load on the remaining lines. This type of process is termed as cascading outage. In deregulated operating regime power system security is an issue that needs due consideration from researchers.

1.1.1 SYSTEM SECURITY FUNCTIONS

System's security can be broken down into three major functions that are carried out in an operations control center

- System monitoring
- Contingency analysis
- Security constrained optimal power flow

System Monitoring:

It provides the operators of the power system with up-to-date information on the conditions on the power system. It just detects violations in the actual system operating state. Telemetry systems have evolved to schemes that can monitor voltages, currents, power flows and the status of the circuit breakers and switches in every sub-station in a power transmission network. Other critical information such as frequency, generator unit outputs and transformer tap positions can also be telemetered.

With so much information telemetered simultaneously no human operator could hope to check all of it in a reasonable time frame. So, digital computers are installed in operations control centres to gather the telemetered data, process them & place them in a database from which operators can display information on large display monitors. Alarms / warnings may be given if required.

State estimation is normally used in such systems to combine telemetered data to give the best estimate of the current system condition or “state”. The computer can check incoming information against pre-stored limits & alarm the operators in the event of an overload or out-of- limit voltage. Such systems often work with supervisory control systems to help operators control circuit breakers & operate switches as well as taps remotely.

Such systems are combined with SCADA system (Supervisory Control & Data acquisition System). The SCADA system allows a few operators to monitor the generation & high voltage transmission systems & to take actions to correct overloads or out-of-limit voltages.

CONTINGENCY ANALYSIS

Contingency analysis is much more demanding & normally performed in three distinct states i.e. contingency definition, selection & evaluation. Contingency definition gives the list of contingencies to be processed whose probability of occurrence is high. This list, which is usually large, is in terms of network changes, i.e. branch & /or injection outages.

These contingencies are ranked in rough order of severity employing contingency selection algorithms to shorten the list. Limited accuracy results are required & therefore an approximated (linear) system model is utilized for speed. Contingency evaluation is then performed (using AC power flow) on the successive individual cases in decreasing order of severity.

This type of analysis allows systems to be operated defensively. The operator cannot take action fast enough when many of the problems that occur on a power system that causes serious trouble within fraction of time period which causes cascading failures. Because of this aspect of system operation, modern operations computers are equipped with contingency analysis programs that model possible systems troubles before they arise.

They study outage events & alert the operators to any potential overloads or serious voltage violations. For example a simplest form of contingency analysis can be put together with a standard load flow program along with procedures to set up the load flow data for each outage to be studied by the load flow program.

This allows the system operators to locate defensive operating states where no single contingency event will generate overloads &/or voltage violations. Thus this analysis evolves operating constraints which may be employed in the program.

Single contingency:

Whenever a single transmission line, transformer or generator is removed from service, we say an outage has occurred or it is a single contingency.

Outages may be planned for purposes of scheduled maintenance or they may be forced by weather conditions, faults or other contingencies.

A line or transformer is de energized & isolated from the network by tripping the appropriate circuit breakers. Single line contingency will not jeopardize the security of the system.

The ensuing current & voltage transients in the network quickly die away & new steady state operating conditions are established. The system operator & the system planner to be able to evaluate how the line flows & bus voltages will be altered in new steady state.

The large numbers (often hundreds) of possible outages are analyzed by means of "contingency analysis" or "contingency evaluation "program. These programs are based on a model of the power system & are used to study outage events & alarm the apparatus to any potential overloads or out-of-limit voltages. Simplest form of contingency analysis can be put together with the standard power flow program.

Security Constrained Optimal Power Flow:-

Here contingency analysis is combined with an optimal power flow which seeks to make changes to the optimal dispatch of as well as other adjustments so that when a security analysis is run, no contingencies result in violations.

To show this, the power system is divided into four operating states

1) **Optimal dispatch:**

This is the state that the power system is in prior to any contingency .It is optimal with respect to economic operation but it may not be secure.

2) **Post Contingency:**

It is the state of power system after a contingency has occurred. This condition has a security violation (line or transformer beyond its flow limit or a bus voltage outside the limit).

3) **Secure dispatch:**

It is a state of the system with no contingency outages, but with corrections to the operating parameters to account for security violation.

4) **Secure Post- Contingency:**

It is a state of the system when the contingency is applied to the base operating condition with corrections.

There is no loading problem in the base operating condition. If because of failure one of the two circuits making up the transmission line has been opened (in double circuit), there is an overloading on the remaining circuit. So for the secure dispatch necessary controlling action must be taken.

One way to prevent the post contingency operating state from having an overload is to adjust the generator MW, transformer tap etc. This is called as “Security corrections”. Programs which can make control adjustments to the base or pre contingency operation to prevent violations in the post contingency conditions are called “Security–constrained optimal power flow” or SCOPF.

These programs can take account of many contingencies & calculate adjustments to generator MW, generator voltages, transformer taps, interchange etc. The function of system monitoring, contingency analysis & corrective action analysis comprise a very complex set of tools that can aid in the secure operation of a power systems.

1.1.2 Factors affecting power system security

Because of the many widespread blackouts in interconnected power systems the priorities for operation of modern power systems have evolved to the following

- Operate the system in such a way that power is delivered reliably.
- Within the constraints placed on the system operations by reliability considerations, the system will be operated most economically.

The power systems transmission & generation systems are designed keeping reliability in mind that is adequate generation has been installed to meet the load & adequate transmission has been installed to deliver the generated power to the load. If the operation of the system went on without sudden failures or without experiencing unanticipated operating states have no reliability problems.

Any piece of equipment can fail in the system either due to internal causes or due to external causes such as lightening strikes, objects hitting transmission towers or human errors in setting relays. It is impossible to build a power system with so much redundancy that failures never cause load to be dropped on a system. Therefore most power systems are designed to have sufficient redundancy to withstand all major failure events.

Here we will concentrate on the possible consequences & remedial actions required by two major types of failure events

- transmission line outages
- generation unit outages

Transmission line failures cause changes in the flows & voltages on the transmission equipment remaining connected to the system. Therefore the analysis of transmission failure requires methods to predict these flows & voltages so as to be sure they are within their respective limits.

Generation failures can also cause flows & voltages to change in the transmission system with the addition of dynamic problem involving system frequency & generator output.

1.2 CONTINGENCY ANALYSIS: DETECTION OF NETWORK PROBLEMS

The current energy market is involved in an important process of evolution due to the new conditions imposed by circumstances such as deregulation, increasing energy consumption, and economical, social and ecological constraints in the building of new grids. These conditions force the system to work near its security limits, producing less and less conservative operation points, and hindering the action of human operators. Consequently, as a part of a power system security assessment, a continuous system monitoring becomes necessary to detect dangerous situations as soon as possible. In this context, the contingency analysis operation must inform whether the current state is secure, critical or insecure with respect to a possible fault in a particular component of the system.

The operations personnel must know which line or generation outages will cause flows or voltages to fall outside limits. The limit on the line can be expressed in MW or in MVA. To predict the effects of outages, contingency analysis techniques are used.

Contingency analysis procedures model single failure events i.e. one line outage or generator outage. It model multiple equipment failure events i.e. two transmission lines, one transmission line plus one generator etc, one after another in sequence until "all credible outages" have been studied.

For each outage tested, the contingency analysis procedure checks all lines & voltages in the network against their respective limits. The most difficult methodological problem to cope with in contingency analysis is the speed of solution of the model used. The most difficult logical problem is the selection of **all credible outages**.

If each outage case studied were to solve in 1 sec & several thousand outages were of concern, it would take close to 1h before all cases could be reported. This would be useful if the system condition did not change over that period of time.

However, power systems are constantly undergoing changes & the operators usually need to know if the present operation of the system is safe, without waiting too long for the answer. Contingency analysis execution times of less than 1 minute for several thousand outage cases are typical of computer & analytical technology as of 1995.

1.2.1 Modeling for Contingency Analysis:

The power system limits of most interest in contingency analysis are those on line flows & bus voltages. One way to gain speed of solution in a contingency analysis procedure is to use an approximate model of the power system. The most fundamental load flow model is the NR model.

$$\begin{bmatrix} \underline{J}^{P\theta} & \underline{J}^{PV} \\ \underline{J}^{Q\theta} & \underline{J}^{QV} \end{bmatrix} \begin{bmatrix} \Delta\underline{\theta} \\ \Delta|\underline{V}| \end{bmatrix} = -\begin{bmatrix} \Delta\underline{P} \\ \Delta\underline{Q} \end{bmatrix}$$

DC Load Flow:

One of the simplest ways of obtaining a quick calculation of possible overloads is to use network sensitivity factors. The first method has been in use for many years & goes under various names such as “D factor methods”, “linear sensitivity methods”, etc

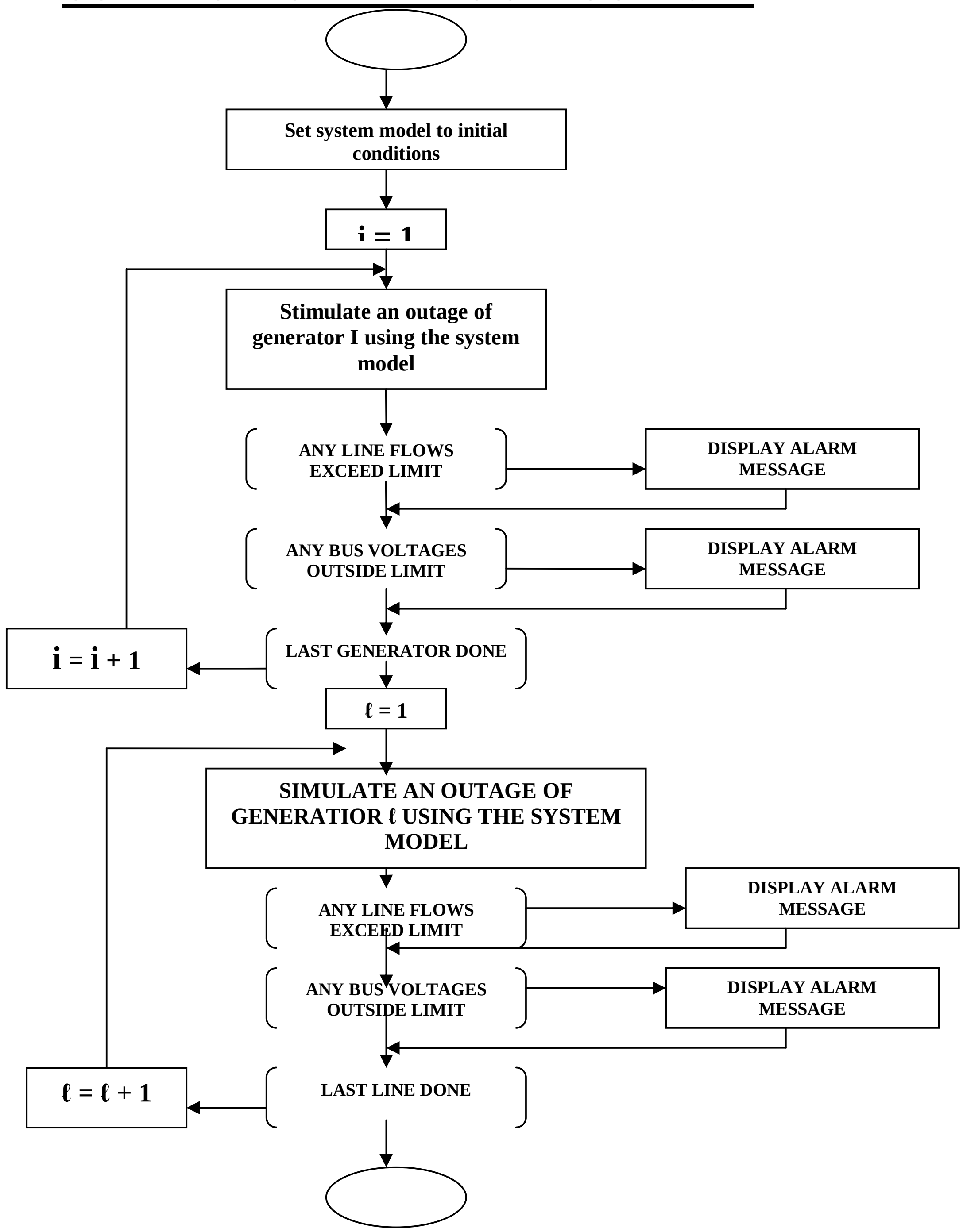
For many systems, the use of DC load flow models provides adequate capability. In such systems the voltage magnitudes may not be of great concern & the DC load flow provides sufficient accuracy with respect to the megawatt flows.

$$[\Delta P]=[B'][\Delta\delta]$$

This model assumes voltages to remain constant after contingencies. This is not true for weak systems. The utility has to be pre specified whether it wants to monitor post-contingency “steady state” conditions immediately after the outage or after the automatic controls (governor, AGC, ED) have responded.

Depending upon this decision, different participation factors are used to allocate the MW generation among the remaining units. The reactive problem tends to be more nonlinear & voltages are strongly influenced by active power flows.

CONTINGENCY ANALYSIS PROCEDURE



1.2.2 Overview of security Analysis:

A security analysis study which is run in an operations center must be executed very quickly in order to be of any use to operators. There are three basic ways to accomplish this.

- Study the power system with approximate but very fast algorithms
- Select only the important cases for detailed analysis.
- Use a computer system made up of multiple processors or vector processors to gain speed.

This approach is useful if one only desires an approximate analysis of the effect of each outage.

It has all the limitations attributed to the DC power flow, i.e. only branch MW flows are calculated & these are only within about 5% accuracy. There is no knowledge of MVAR flows or bus voltage magnitudes. If it is necessary to know a power system's MVA flows & bus voltage magnitudes after a contingency outage, then some form of complete AC power flow must be used.

This presents a great deal of difficulty when thousands of cases must be checked. The needed ways are to eliminate all or most of the non violation cases & only run complete power flows on the "critical" cases. These techniques are named as "contingency selection" or "contingency screening".

Contingency Selection:

There are two main approaches

Direct Methods:

These involve screening & direct ranking of contingency cases. They monitor the appropriate post-contingent quantities (flows, voltages). The severity measure is often a performance index. The ranking is done based on the value of performance index. The higher the performance index more is the severity.

Indirect methods:

These give the values of the contingency case severity indices for ranking, without calculating the monitored contingent quantities directly (use of sensitivity factors).

Simulation of line outage is more complex than a generator outage, since line outage results in a change in system configurations. The inverse matrix modification lemma (IMML) or "compensation" method is used throughout the contingency analysis field.

The IMML helps in calculating the effects of n/w changes due to contingencies, without reconstructing & refactorizing or inverting the base case network matrix.

AC Power Flow Methods

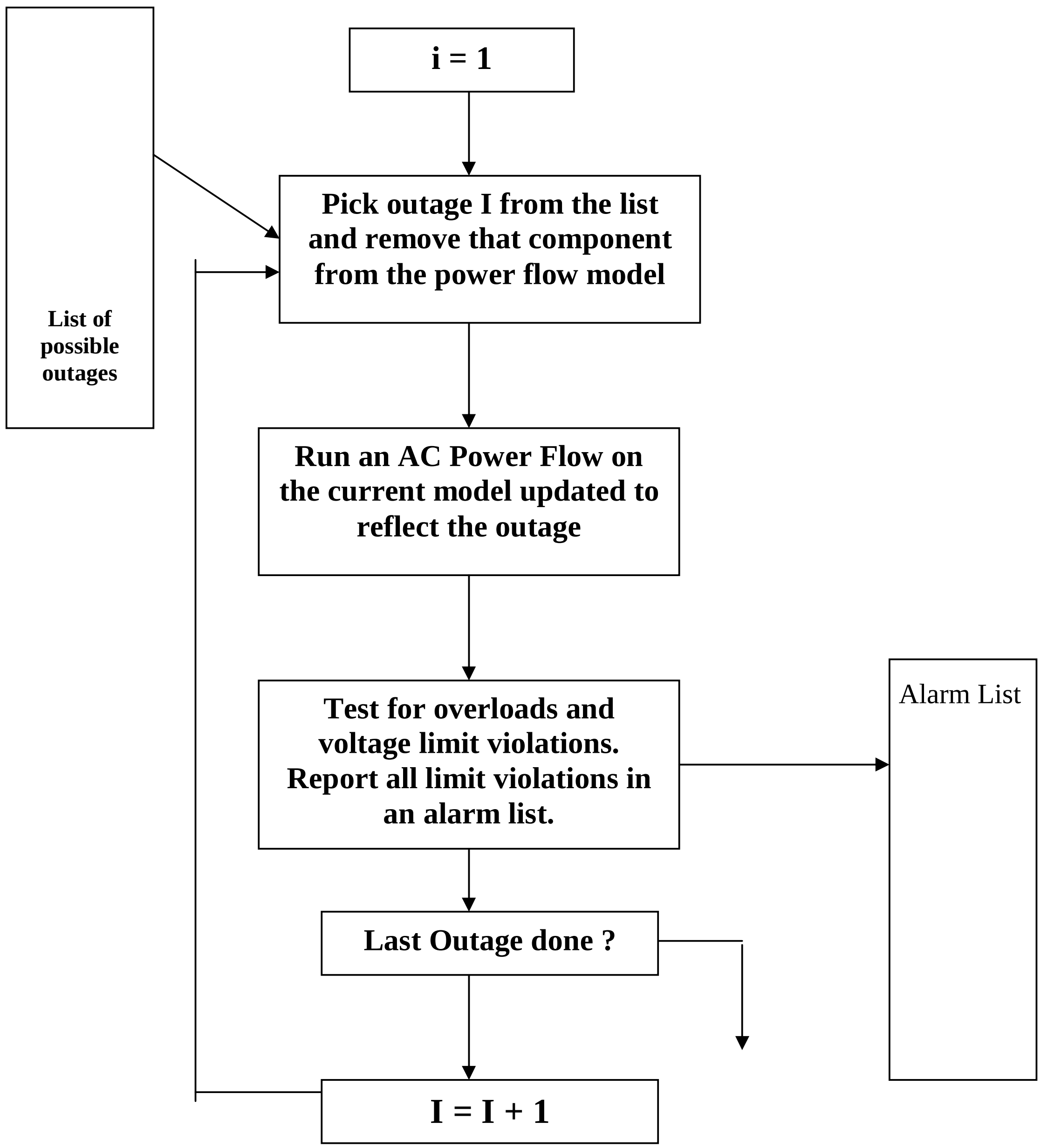
There are many power systems where voltage magnitudes are the critical factor in assessing contingencies. There are some systems where VAR flows predominate on some circuit such as underground cables. An analysis of only the MW flows will not be adequate to indicate overloads.

When an AC power flow is to be used to study each contingency case, the speed of solution & the number of cases to be studied are critical. Most operations control centres' that use an AC power flow program for contingency analysis use either Newton–Raphson or Decoupled power flow or gauss siedal.

These solution algorithms are used because of their speed of solution & the fact that they are reasonably reliable in convergence when solving difficult cases. Decoupled load flow has the advantage that a matrix alteration formula can be incorporated into it to simulate the outage of transmission lines without re inverting the system Jacobian matrix in each iteration.

The simplest AC security analysis procedure consists of running an AC power flow analysis for each possible generator, transmission line & transformer outage as in fig (a).

AC POWER FLOW SECURITY ANALYSIS



This procedure will determine the overloads & voltage limit violations accurately. If the list of outages has several thousand entries, then the total time to test for all of the outages can be too long. Because of the way the power system is designed & operated, very few of the outages will actually cause trouble.

Only few of the power flow solutions will conclude that an overload or voltage violation exists. Selection of contingencies is such a way that only those that are likely to result in overload or voltage limit violation will be considered & other cases will go unanalyzed.

Because of the way the power system is designed & operated, very few of the outages will actually cause trouble. That is, most of the time spent running AC power flows will go for solutions of the power flow model that discover that there are no problems.

Two sources of error can arise

- Placing too many cases on the short list :

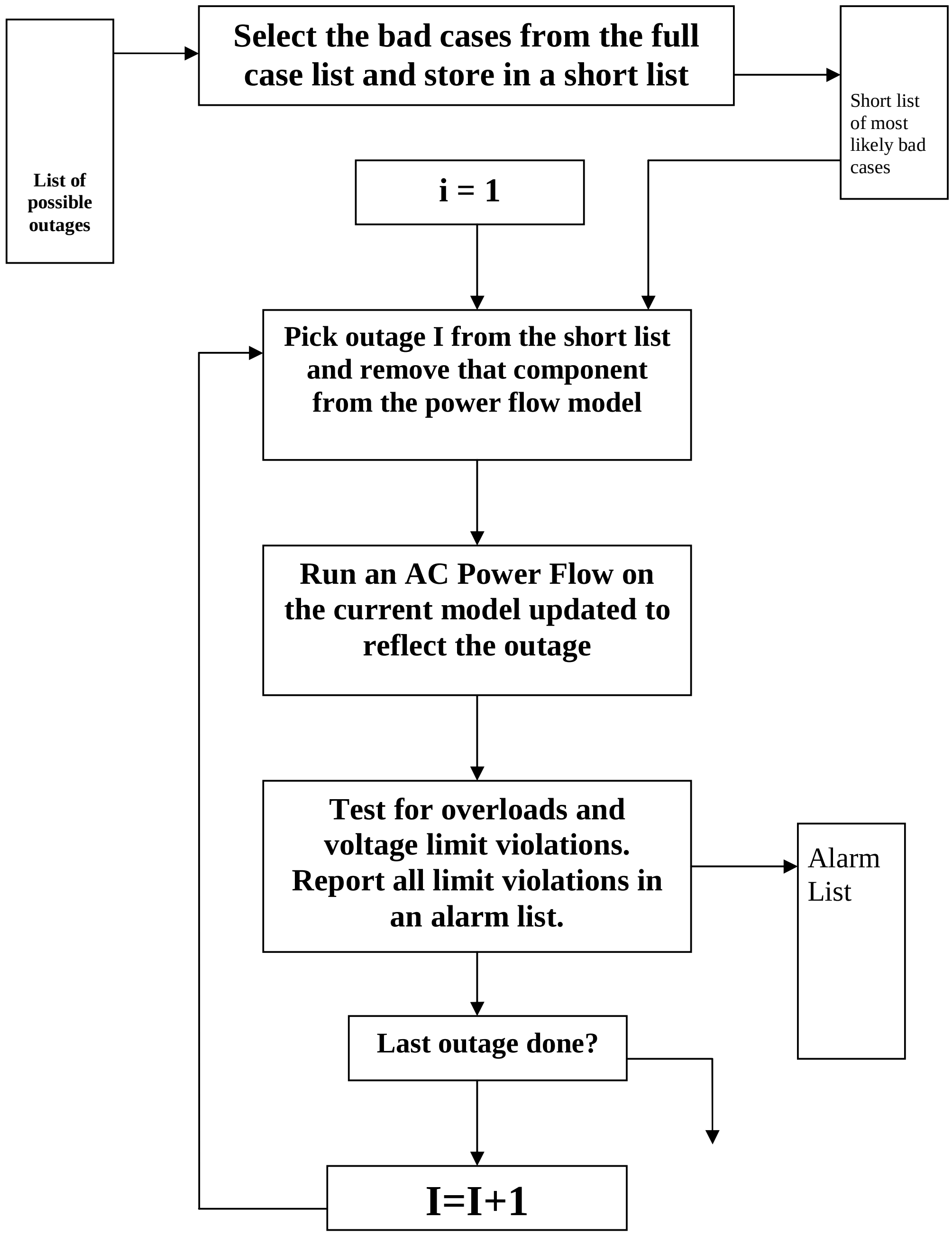
This is the 'conservative' approach & simply leads to longer run times for the security analysis procedure to execute.

- Skipping cases :

  A case that would have shown a problem is not placed on the short list & results in possibly having that outage take place & cause trouble without the operators being warned.

AC power flow security analysis with contingency case selection is as shown in figure. A flow chart for a process like this appears in figure. Selecting bad or troubled cases from the full outage case list is not an exact procedure & has been subject of intense research for the past 15 years. List of most likely bad cases are obtained from possible outages.

AC Power Flow Security Analysis with Contingency Case Selection



Contingency:

The effect of the line outage when the rest of the system is stable is called contingency study. Contingency is termed as the event that occurs in a power system which affects the normal operation of the system. For example when a line is switched on or off of the system through the action of circuit breakers line currents are distributed throughout the network & bus voltage change.

The post contingency state of a power system such as the new steady state bus voltages, line currents & voltage stability condition can be predicted from the contingency analysis program. The result of contingency analysis can be used to save the power system by preventing other cascade accidents.

Here to assess the effects of each contingency, on real power & voltage margin in order to rank the contingencies are considered. Contingency can be so hard where voltage collapse may occur. To maintain security of power system in certain level the impact of each contingency on power system should be estimated.

Determining the security margin of power system is crucial especially if it isn’t sufficient, the type, amount & the location of compensation should be determined. Line outage in a power system could also lead to the event of voltage collapse which implies contingency in the system.

Although the advancement of computer technology has made almost all major aspects in human activities to run smoothly still there are several events which are caused by natural disaster or sometimes unpredictable &

beyond our control. In power system operation unpredictable events is termed as contingency.

The rapid demand of electrical power have made the task of power system engineers becoming more challenging since they have to think on how to ensure an efficient & secure power dispatch to the consumer.

With the existing infrastructure & no development of power generation stations, it is believed that most of the existing systems could not cope with the increasing demand. The values of real power & voltage index are used to perform the contingency ranking in power system based on line outage & generator outage.

The contingency analysis techniques are tested on a 5 bus & IEEE 14 bus systems. Values which approach one imply that the power system approaches its voltage stability limit.

1.3 Contingency Ranking:

Alberta power has been collecting information on generation & transmission equipment outages in a database since late 1970's. Examination of generator, line & transformer failure is provided. The probability of multiple outages is computed & a generalized discussion of the impact of extreme weather on outage is included. The computed contingencies are ranked & a consistent frame work for system reliability performance table is developed based on the groupings.

Line outage contingencies are ranked so that the line which highly affects the system when there is an outage occurring in this line in terms of voltage instability could be identified. The contingency ranking process can be conducted by computing the line contingency index of each line for a particular line outage & sort them in ascending order. The contingency which is ranked the highest implies that it contributed to system instability.

A contingency ranking table was developed from the results obtained from the simulation of each transmission line outage. The outage which resulted in a severe stability condition will be ranked high. From the contingency ranking table the effect of breakdown at a line on voltage stability condition of a system could be determined. The results could be used by the operation engineers as early information so that contingencies which are highly ranked could be avoided & hence a secure system is maintained.

Contingency screening & ranking is one of the most important issues for security assessment in the field of power system operation. The objective of contingency screening & ranking is to quickly & accurately select a shortlist of critical contingencies from a large list of potential contingencies. Then rank them according to their severity.

Then suitable preventive control actions can be implemented considering contingencies that are likely to affect the power system performances.

1.3.1 Contingency Selection:

Contingency analysis can be approached using both functional and graphical methods. The first one characterizes the severity of each contingency with a numerical value, and the second one allows the contingency evaluation in a visual way. In both cases, the majority of methods are based on the evaluation by means of some performance index (PI). These PIs, generally inform on the relative surpassing of the security limit of the grid components with respect to a particular magnitude (voltage or power flow).

PIs have been considered in this project is the real power & voltage performance indexes, which evaluates the severity of a contingency derived from the current overload of lines, and the reactive power performance index, which evaluates the severity of a contingency derived from the voltage violation in buses.

Some measure must be obtained as to how much a particular outage might affect the power system. The idea of a performance index (PI) is as follows

$$PI\ (P) = \sum_{l=1}^{nL} \left[\frac{P_{lBASE} - P_{lNEW}}{P_{lBASE}} \right]_{1}^{2n}$$

$$PI\ (V) = \sum_{l=1}^{nB} \left[\frac{V_{lBASE} - V_{lNEW}}{V_{lBASE}} \right]_{2}^{2n}$$

If 'n' is large number , the performance index will be a small number if all flows are within limit & it will be large If one or more lines are overloaded. The selection procedure then involves ordering the performance index table from largest value to least. The lines corresponding to the top of the list are then the candidates for the short list.

The PIs are calculated by full ac load flow for all the contingencies in the readability list and can be ranked for more comprehensive study based on these PI values. Although this approach offers accurate ranking, but running ac load flow program for each contingency makes it very computation intensive. The other time efficient approach shortlists the critical contingencies on the basis of approximate load flow method such as dc load flow or 1P–1Q method.

No doubt, these methods proved to be more efficient but being approximate in nature at times fail to identify critical contingencies that actually cause problems and also in wasting time to solve contingencies which are not critical otherwise. Another technique uses sensitivity analysis and distribution factor based on linear model to estimate line-flow.

We are considering line outages as the only contingencies. To decide about the security level of the system, every bus voltage and line power flow must be compared to its corresponding maximum and minimum tolerable values.

Thus, each time, the system security level will be a function of both the number of grid elements (buses and lines) the limit values of which are surpassed, and of the percentage of this surpass. In any case, the target of contingency analysis is not to analyze the security of the present state, for which we suppose all voltage and flow variables are known, but to analyze the security of a future state, where the system would evolve after the hypothetic occurrence of a particular contingency.

The complexity of the problem is due to both the difficulty of calculating this future state and the high number of contingencies that can be considered. Contingency analysis can be approached using both the difficulty of calculating this future state and the high number of contingencies that can be considered.

Currently, most of the extended functional contingency analysis techniques are based on the solution of the load flow problem for the system, which may be described as follows

For the current state of the system:

- Solve a load flow problem for each contingency to be evaluated; therefore establishing the next state of the system arrived after the contingency would have occurred.
- Calculate the numerical value of a selected PI indicating the seriousness of each contingency.
- Rank the contingencies from their PI values.

This process, especially the first step, requires a very high computational cost, making real-time response impossible. To reduce this computational time, several techniques have been proposed, such as more efficient algorithms to solve the load flow problem, selection of a reduced set of contingencies to be analyzed, and parallelization or distribution of processes. Thus, efficient load flow algorithms are presented, which are based on gauss siedal load flow.

However in these methods of load flow algorithms, the convergence is not guaranteed in heavily loaded systems. The drawback of this method is that the specific sub network is different for each contingency and its definition is not direct.

The security and operation cost analysis is parallelized by means of a set of Monte Carlo simulations, but very high hardware and design costs are necessary because the parallelization process is specific for each network.

Power performance index:

The operating state of the system is a function of time. It keeps on changing due to variation in load level at various buses or due to rescheduling of generation. To keep the system secure, it is imperative to know the impact of unplanned outages in advance so that suitable preventive/control measures can be taken if necessary.

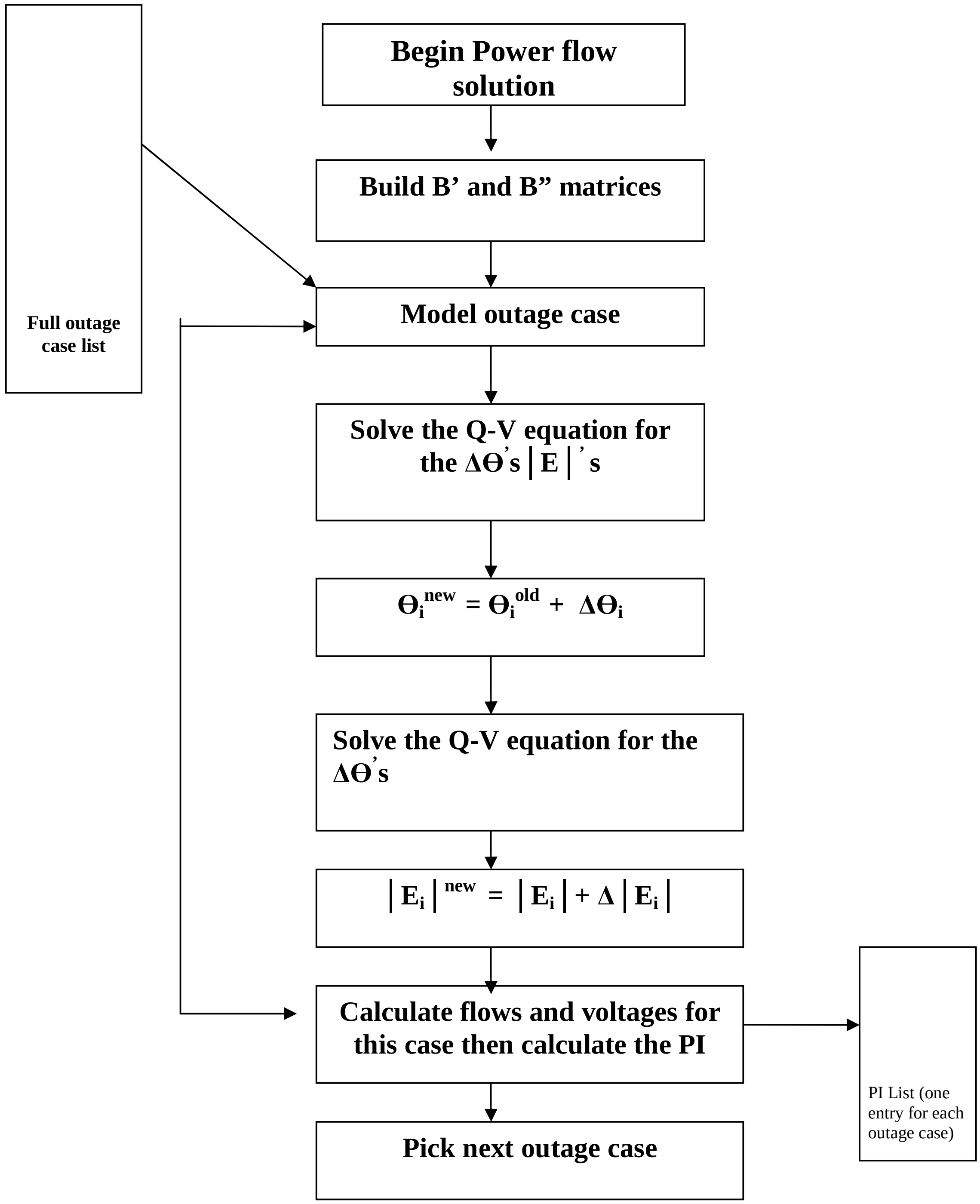
The conceivable contingencies being large in number, their severity ranking is done as per system wide performance index and only critical contingencies are picked up for detailed assessment. Flows on transmission lines are usually constrained by thermal limits and sometimes by stability considerations of long lines. The performance index for quantifying the extent of line overloads is defined in terms of real power performance index.

The electrical power system is continuously expanding in size and growing in complexity all over the word. Extensive system studies on computer; both at off-line planning stage as well as at on line operational stage, are a must. A power system engineer is always concerned with adopting newer and better mathematical model for solving system problem more efficiently and effectively.

To complete the security analysis, the PI list is sorted so that the largest PI appears at the top. The security analysis can then start by executing full power flows with the case which is at the top of the list, then solve the case which is second & so on down the list.

This continues until either a fixed number of cases are solved which do not have any alarms. Flow chart shown below explains the contingency selection procedure.

The 1P1Q Contingency selection procedure



1.4 LOAD FLOW ANALYSIS:

A load flow analysis is carried out prior to the computation of the voltage & active power index. The results obtained from the load flow analysis will be utilized for computing the performance index & ranking of the contingencies.

The contingency ranking is determined by using two methodologies

- Conventional load flow

- Fuzzy logic Approach

1.4.1 Conventional Load Flow:

Load-flow studies are probably the most common of all power system analysis calculations. They are used in planning studies to determine if and when specific elements will become overloaded.

In operating studies, load-flow analysis is used to ensure that each generator runs at the optimum operating point; demand will be met without overloading facilities; and maintenance plans can be preceded without undermining the security of the system.

The main aim of a modern electrical power system is to satisfy continuously the electrical power contracted by all customers. But some problems exists

i.e.

- Nodal voltage magnitudes and system frequency must be kept within narrow boundaries.
- The alternating current (AC) voltage and current wave must remain largely sinusoidal

- Transmission lines must be operated well below their thermal and stability limits
- Even short term interrupt must be kept to minimum

Objective:

The main objective of power flow study is to determine the steady state operating condition of the electrical power network. Steady state may be determined by finding out for a given set of loading conditions, the flow of active and reactive powers throughout the network and the voltage magnitudes and phase angles of all buses of the network.

Power flow studies provide

- Required information regarding bus usage
- Required information regarding power flow theory and transmission lines, transformers and other elements of power system for a specified load demand subject to the regulating capabilities of generators, condensers, tap changing transformers, phase shifting transformers.
- Specified net interchange of power with adjoining power systems.
- Power flow studies help in critically assessing alternate plans for system expansion to meet the ever increasing load demand.
- Power flow studies help the planning and operation engineers to meet contingency conditions such as loss of large generating unit or a major line outage due to thermal over loading of the line.
- Power Flow studies help to determine best size and the most favorable location for the power capacitors for improving the power factor as well as the usage profile of power system

- On line power flow studies are periodically executed for monitoring and controlling of power system.
- Real time results of power flow computation may be used to determine the reactive compensation needed to establish bus voltages.
- If power flow study predicts that the nodal voltage magnitudes, active and reactive power flows in transmission lines and transformers are not within limit, then control action is taken.

In practical system, there may be thousands of buses and transmission links. We shall concentrate mainly on transmission system with the generators and loads modeled by the complex powers. Thus, the load flow study involves extensive calculations.

Before the advent of digital computers, the AC calculating boards was used for carrying out load flow studies. These studies were tedious and time consuming with the availability of fast and large sized digital computers. All kinds of power system studies, including load flow study are conducted by using the "**MI POWER**" computer aided power system study software package.

General Power Flow Concept:

The mathematical formulation of power flow problem, also known as the load flow problem results in a system of non linear algebraic equations. Because cosine & sine terms are included in real & reactive power calculations. These equations are derived by assuming that a perfect symmetry exists between the phases of the 3 phase power system (Arillaga & Arnold 1990)

The coefficients of the equations depend on the selection of the independent variables i.e. voltage & currents. Thus either bus admittance or impedance matrices can be used .The solution of algebraic equations describing the power system is based on iterative techniques because of their non linearity. The solution must satisfy Kirchhoff's laws .The solution must also satisfy the constraints such as the tap setting range of under load tap changing transformers & specified power interchange with adjoining power systems.

Power Flow Problems

In power flow analysis load powers are assumed as constants. A given set of loads on the buses can be served from a given set of generators in an infinite number of power flow configuration.

Aspects of power flow analysis

The sum of real power injected at the generating buses must equal, at each instant of time, the sum of total system load demand plus system losses. The individual generator outputs must be closely maintained at the predetermined set points. As the load demand slowly changes throughout the day, therefore, these set points change slowly with time. Thus load flow results for a certain hour of the day may be quite different from the next hour.

The power transfer capability of a power transmission line is limited to the thermal loading limit & the stability limit. It must be seen that transmission lines do not operate too close to their stability or thermal limits.

It is necessary to keep the voltage levels of certain buses within close tolerances. This can be achieved by proper scheduling of reactive powers.

The power system must fulfill contractual scheduled interchange of power to neighboring systems, if any via its tie lines. Power flow analysis is very important in the planning stages of new networks or addition to existing ones.

SUB PROBLEMS OF LOAD FLOW OR POWER FLOW PROBLEM

- Formulation of mathematical model that describe the relationship between voltages & powers in the interconnected system.
- Specification of the power & voltage constraints that must apply to the various buses of the network
- The computation of voltage magnitude & phase angle of each node or bus in a power system under balanced three phase steady state conditions.

METHODS OF POWER FLOW SOLUTIONS

Power flow solution consists of solving set of non linear algebraic equations that describe electrical power network under steady state conditions.

Several approaches

Early approaches were based on loop equations & numerical methods using Gauss – type solutions. This method was laborious as the network loops had to be specified before hand by the system engineer.

Improved techniques used nodal analysis leading to a considerable reduction in data preparation. Reliability towards convergence was main concern.

Further development (by Ward & Hale in 1956) led to the introduction of Gauss-Seidel method with acceleration factors. This method has minimum storage requirements, easy to comprehend and to code in the form of computer programs and slower convergence.

In 1961 Van-Ness & Griffins suggested Newton's method using Gaussian Elimination that has the advantage of superior convergence characteristic.

Sato & Tinney (1963) introduced the concept of optimally ordered elimination for the solution of large, sparse systems and showed such methods to be very efficient.

Later in 1967, Tinney & Hart showed that by use of optimally ordered Gaussian Elimination and special programming techniques both the storage requirements and computing speed are drastically reduced by Newton's Method.

To overcome such limitations Newton-Raphson Method and derived formulations were developed in early 1970's and firmly established throughout the Power system Industry which has a quadratic convergence characteristic. It provides general purpose power flow study for most electric utilities.

Power Flow solutions based on nodal impedance matrix were briefly experimented (Brown 1975). But there was problem with computer storage and speed.

1.5 **Fuzzy Based Contingency Ranking**

A number of algorithms based on more powerful methods like Gauss siedal, Newton Raphson and Fast Decoupled Load Flow have been proposed. The terminology associated with Fuzzy Inference System i.e. fuzzification, rule, membership function, linguistic variable, defuzzification etc. are well documented by Zadeh Lotfi.

It is a fact that uncertainty is present in each and every real life problem. Sometimes this uncertainty is neglected to simplify the analysis procedures. It is reported that, through fuzzy sets, it is possible to model the imprecise knowledge and perception of human beings into meaningful probability distributions in a natural way. The requirement is that, each uncertain variable must be assigned a degree of membership that represents the degree of participation of the parameter under study.

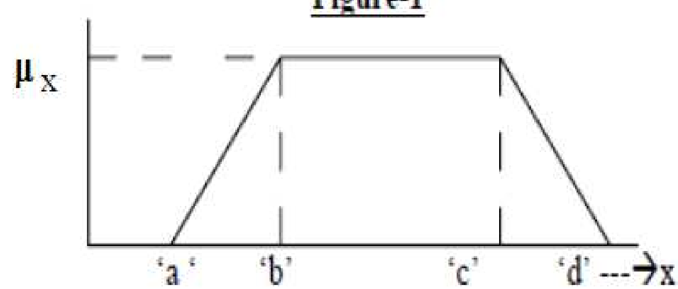
The uncertain variables are modeled as intervals in the real axis and the corresponding imaginary axis shows their degree of participation. A fuzzy set Ā in the universe of discourse 'U' can be defined as a set of ordered pairs, where each subset includes some element 'x' and its membership function μ_x. This membership function denoted by μ_x indicates the degree that 'x' belongs to A.

This relationship is expressed in a mathematical form in equation
$\bar{A} = \{(x, \mu A\ (x)) | x \in U\}$ 1 In fuzzy set theory there exist several forms of distribution functions, (e.g., triangular, trapezoidal, ramp, exponential etc.) to suit to the need and requirement of the problem. In this document, the uncertainties in the contingency ranking are modeled with the help of trapezoidal membership functions.

A trapezoidal fuzzy membership function as indicated in **figure 1** is usually expressed by the characteristic points a, b, c, d such that the fuzzy number under study can assumed any value between a and d, but values within the range b and c are most likely to place. All the values within the range b and c have membership value (μ_x=1) that indicates complete membership for event.

However, the values within ranges (a-b) and (c-d) have membership values ($0 \leq \mu_x \leq 1$), which indicates partial membership values. Any value outside the range of a and d has membership value (μ_x=0) indicating non membership for parameter. Thus the uncertainty of the parameter 'x' is conveniently characterized by a trapezoidal fuzzy distribution with suitable left right slopes. A specific relationship for the element 'x' and its degree of membership, 'μ_x' for the trapezoidal membership function is presented in equation. Trapezoid (x, a, b, c, d)
= max (min (x-a/b-a, 1, d-x/d-c), 0)

Figure-1



Fuzzy Logic (FL) is applied for the power system problems such as application in load forecasting, system control, security assessment, system planning and power system stability. Recently, fuzzy logic based approach has been exploited in different ways in solving power flow problem. In the principle of fuzzy set theory has been exploited and successfully applied to the modeling of the input parameter for the purpose of power flow analysis.

Initially the contingency ranking analysis is done by the conventional load flow data. According to the performance index the ranking is done. The severities of the outage are more for the lowest ranking lines. The line with lowest performance index has the rank one. As the performance index increases the ranking increase & hence the severity.

The lowest ranking contingencies are credible, as the ranking increase the credibility decreases. These credible outages are severe & cannot be neglected. The credibility decreases with the increase in the performance index which is also known as contingency index.
The ranking obtained by the conventional load flow results give the base result. There may be some possibilities that in between the two contingency ranking there exist some more. To observe this possibility fuzzy based analysis is done.

We motivate these ideas by introducing a simple example. We assume that all electrical variables in this document are given in the per-unit system.

1.6 OBJECTIVE & SCOPE OF THESIS

In deregulated operating regime power system security is an issue that needs due consideration from researchers. Real power & voltage contingency ranking is an integral part of security assessment. The objective of contingency screening & ranking is to quickly & accurately shortlist critical contingencies from a large list of credible contingencies

& rank them according to their severity for further rigorous analysis. A performance index PI is computed for each single line contingency. To obtain the magnitudes of various parameters a MI power computer aided power system study software package which employ iterative methods are used. This paper presents an approach using fuzzy logic to evaluate the degree of severity of the normal contingency & to eliminate the masking effect in the technique.

1.7 OUTLINE OF THESIS

Chapter 1: Introduction explains about system security functions that are carried out in operations control center, factors affecting power system security, basics of contingency analysis. Discussion is carried out on contingency ranking using conventional & fuzzy logic approach.

Chapter 2: "Literature Overview" provides list of works of various scholars in the field of contingency ranking in power system is discussed.

Chapter 3: "Analysis of Cases" In this chapter analysis of Five Bus System and 14 Bus System is done.

Chapter 4: "Case Study". In this chapter the Load flow results of Five Bus & IEEE 14 Bus system is done including base case, single line outages and generator outage contingency cases.

Chapter 5: "Results & Discussions ". In this chapter the results & discussions of all single line contingency, generator contingencies are discussed for Five bus & IEEE 14 bus system. The performance index is calculated for each contingency. Based on the scalar value of performance index the Contingency ranking is assigned. The highest valued of performance index indicates the most severe condition. Ranking is calculated using conventional method & later on suggested that fuzzy approach is the accurate method.

Chapter 6: "Recommendations and conclusions**"**

CHAPTER-2: LITERATURE REVIEW

2.1 OVERVIEW OF CONTINGENCY RANKING IN POWER SYSTEM

The performance index is first defined to provide a measure of system stress. Then some technique is used for predicting the change in PI when component is outaged. The contingency ranking is assigned depending on the scalar value of the PI. The outage is severe if the value of the PI is more but the ranking is lower. This is not a foolproof method of ranking contingencies. It is possible that some severe contingencies may be left out & some not so severe contingencies may be ranked. Therefore fuzzy based logic is utilized to reveal the unattended severities in between the conventionally obtained ranking.

2.2 RECENT WORK

SNRK Srinivas Tanniru, K Ramesh Reddy & VKD Devi proposed an approach that can provide the user with those outages that may cause immediate loss of load or islanding at certain bus. The resultant performance index will depend heavily on loading of particular line which is loaded closest to its limit that is 90% to 95% of rated capacity, other lines which are less heavily loaded that is 80%-85% of rated capacity though of large in number, will have relatively small weightage on performance index value. In fuzzy set method the contribution of these lines, which are less heavily loaded, to the severity index are taken into account by using membership functions for the linguistic variables to evaluate the network contingency ranking of a practical IEEE -14 bus system.

C.V. Gopalakrishna Rao , Dr.V. BapiRaju, Dr.G.Ravindranath presented a work on uncertainity of load on power system bus bar is successfully modeled by assuming trapezoidal membership function by using fuzzy technology. The Newton Raphson method is used in obtaining the high voltage low voltage solution of transmission network. The load flow study is carried out on IEEE 14 bus test system.

Majid Poshtan & Shehu Farinwata demonstrated that computing MW margin sensitivities from the nose of the P-V curve can do effective contingency analysis for voltage collapse studies. It is shown that sensitivity of the MW margin to voltage collapse studies w.r.t first & second level contingencies could be computed efficiently & quickly. The paper introduces a ranking scheme to categorize the contingencies into three categories based on their impact on the MW margin. Contingencies are categorized as low contingencies for negative MWM. Those with less than 90% of maximum MWM are categorized as sufficient contingencies. Remaining contingencies are called high contingencies.

Robert Fischl, Thomas F Halpin, Albert Guvenis presented a work on how one must select a performance index in order to correctly rank the contingencies according to their impact on the security constraint violations. The Automatic contingency selection (ACS) problem is concerned with developing efficient computer algorithms which rank the contingencies in terms of their impact on the system performance. Most of the work in ACS has concentrated on developing algorithms for ranking contingencies in terms of their impact on real power flows throughout the network & then extending these algorithms to rank the contingencies according to their impact on bus voltages & reactive power injections. The essential components needed in developing an ACS algorithm are a scalar performance index for ranking the contingencies &

a computationally efficient method for evaluating the performance index for each contingency.

Musirin & T K A Rahman presents a new technique for contingency ranking based on voltage stability condition in power system. A new line stability index was formulated. It is used to identify the critical line outages & sensitive lines in the system. The line outage contingency ranking was performed on several loading condition in order to identify the effect of increase in loading to the critical line outages.

Ismail Musirin & Titik Khawa Abdul Rahman in their paper Simulation technique for voltage collapse prediction & Contingency ranking in power system presents a new voltage stability index referred to a line used to rank the line outage. The information from the contingency ranking indicates the severity of the voltage stability condition in a power system due to line outage. The voltage stability indices are taken as an instrument that will measure the stability condition & used to rank the contingencies in a power system. A Load flow analysis will be utilized for computing the voltage stability index & ranking the contingencies. The outage which resulted in a severe stability condition will be ranked high. The voltage stability & contingency analysis were performed on the standard IEEE 6 bus system. By observing the voltage stability index value i.e. whether close to 1.00 or not the voltage collapse has occurred in a line or not has been found.

M.A. Kamarposhti & H.Lesani in their paper contingencies ranking for voltage stability analysis using continuation power flow method. Here applying continual power flow (CPF) that is based on reformation of load flow equations applying a continuous parameters calculating (MLP) maximum load point & its corresponding Mega Watt margin decrease percent in each contingency ranking of contingencies is done based on the severity of their effect on static voltage collapse. IEEE 14 bus system was used to validate the proposed method. PSAT simulation software is used i.e. power system analysis software which has many features including power flow. Conventional PV curves are used to find the load margin for all possible first level contingencies. Nose of PV curve can do effective contingency analysis for voltage collapse studies. Study revealed that occurrence of contingencies in Power System result in increasing of voltage drop in some of buses, the possibility of change in the weakest bus position decrease of MLP & so its corresponding decrease of MWM.

CHAPTER 3: ANALYSIS OF CASES

3.1 Five Bus System:

Description & figure of Five bus system:

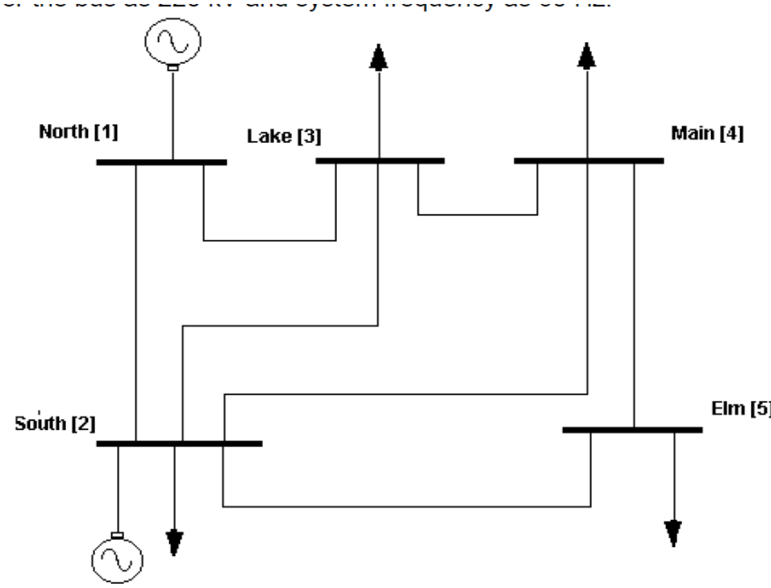


Figure 1: Five bus system

Description

Figure 1 shows the single line diagram of the five bus system. There are two generators connected at the buses 1 and 2. There are four loads in the system totaling 165 MW and 40Mvar. There are seven lines. The detailed data including Impedances, line charging, generation, loads & bus voltages for five bus system are given in Appendix A-1. North [1] is taken as slack bus. Gauss-Siedel method is used in the load flow solution. The results of base case load flow for five bus system are produced in the chapter 4.1. The base voltage is 220kv and base MVA selected is 100 MVA. Further each single line outage & generator outage results are produced in chapter 4.2 and 4.3.

3.2 IEEE 14 Bus System

Description & figure of IEEE 14 bus system:

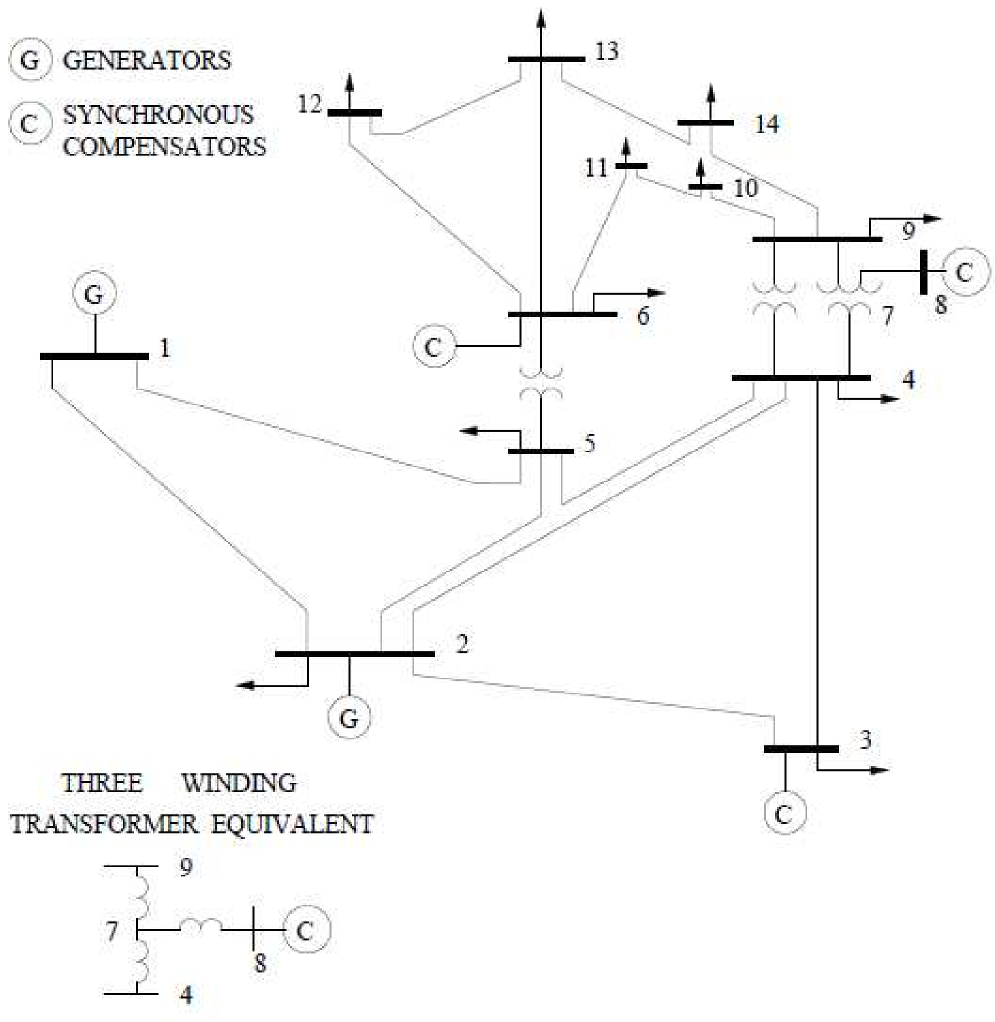


Figure 1.1: IEEE 14-bus test system.

Description

A single line diagram of the IEEE 14- bus standard system is shown in figure 1.1. It consists of five synchronous machines. Among the five synchronous machines, three of which are synchronous compensators used only for reactive power support.

There are 11 loads in the system totalling 259MW and 81.3Mvar. The detailed data of the system including generator data, bus data and line data are given in appendix A-2. The base MVA selected is 100MVA. Here Gauss-siedel method is used in load flow solution. The results of load flow solution for IEEE 14 bus system is given in chapter 4.4 for base case system. Further results of each single line outages and generator outages are presented in chapter 4.5 and 4.6 as contingencies.

CHAPTER 4: CASE STUDY (MI Power Analysis)

Introduction

To obtain the magnitudes of various parameters a computer aided power system study software package which employ iterative methods are used. The analysis and results of five bus and IEEE 14 bus systems are carried out as follows.

(A): FIVE BUS SYSTEM

4.1 Results: Base case

LOAD FLOW BY GAUSS-SIEDEL METHOD
CASE NO : 1 CONTINGENCY : 0 SCHEDULE NO : 0
CONTINGENCY NAME : Base Case RATING CONSIDERED : NOMINAL

VERSION NUMBER	**:**	**6.1**
LARGEST BUS NUMBER USED	**:**	**5**
ACTUAL NUMBER OF BUSES	**:**	**5**
NUMBER OF 2 WIND. TRANSFORMERS	**:**	**0**
NUMBER OF 3 WIND. TRANSFORMERS	**:**	**0**
NUMBER OF TRANSMISSION LINES	**:**	**7**
NUMBER OF SERIES REACTORS	**:**	**0**
NUMBER OF SERIES CAPACITORS	**:**	**0**
NUMBER OF CIRCUIT BREAKERS	**:**	**0**
NUMBER OF SHUNT REACTORS	**:**	**0**
NUMBER OF SHUNT CAPACITORS	**:**	**0**
NUMBER OF SHUNT IMPEDANCES	**:**	**0**
NUMBER OF GENERATORS	**:**	**2**
NUMBER OF LOADS	**:**	**4**

NUMBER OF LOAD CHARACTERISTICS : 0
NUMBER OF UNDER FREQUENCY RELAY : 0
NUMBER OF GEN CAPABILITY CURVES : 0
NUMBER OF FILTERS : 0
NUMBER OF TIE LINE SCHEDULES : 0
NUMBER OF CONVERTORS : 0
NUMBER OF DC LINKS : 0

LOAD FLOW WITH GAUSS-SEIDEL METHOD : 5
NUMBER OF ZONES : 1
PRINT OPTION : 3 - BOTH DATA AND RESULTS
PRINT PLOT OPTION : 1 - PLOTTING WITH PU VOLTAGE
NO FREQUENCY DEPENDENT LOAD FLOW, CONTROL OPTION: 0
BASE MVA : 100.000000
NOMINAL SYSTEM FREQUENCY (Hzs) : 50.000000
FREQUENCY DEVIATION (Hzs) : 0.000000
FLOWS IN MW AND MVAR, OPTION : 0
SLACK BUS : 0 (MAX GENERATION BUS)
TRANSFORMER TAP CONTROL OPTION : 0
Q CHECKING LIMIT (ENABLED) : 4
REAL POWER TOLERANCE (PU) : 0.00100
REACTIVE POWER TOLERANCE (PU) : 0.00100
MAXIMUM NUMBER OF ITERATIONS : 15
BUS VOLTAGE BELOW WHICH LOAD MODEL IS CHANGED : 0.75000
CIRCUIT BREAKER RESISTANCE (PU) : 0.00000
CIRCUIT BREAKER REACTANCE (PU) : 0.00010
TRANSFORMER R/X RATIO : 0.05000

ANNUAL PERCENTAGE INTEREST CHARGES : 15.000
ANNUAL PERCENT OPERATION & MAINTENANCE CHARGES : 4.000
LIFE OF EQUIPMENT IN YEARS : 20.000
ENERGY UNIT CHARGE (KWHOUR) : 2.500 Rs
LOSS LOAD FACTOR : 0.300
COST PER MVAR IN LAKHS : 5.000 Rs

ZONE WISE MULTIPLICATION FACTORS

ZONE	P LOAD	Q LOAD	P GEN	Q GEN	SH REACT	SH CAP	C LOAD
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000

BUS DATA

BUS NO.	AREA	ZONE	BUS KV	VMIN-PU	VMAX-PU	NAME
1	1	1	220.000	0.950	1.050	north
2	1	1	220.000	0.950	1.050	south
3	1	1	220.000	0.950	1.050	lake
4	1	1	220.000	0.950	1.050	main
5	1	1	220.000	0.950	1.050	elm

TRANSMISSION LINE DATA

STA	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	LINE PARAMETER R(P.U)	X(P.U.)	B/2(P.U.)	RATING MVA	KMS
3	1	1	north	2	south	0.02000	0.06000	0.03000	100	1.0
3	1	1	north	3	lake	0.08000	0.24000	0.02500	100	1.0
3	1	2	south	3	lake	0.06000	0.18000	0.02000	100	1.0
3	1	2	south	4	main	0.06000	0.18000	0.02000	100	1.0
3	1	2	south	5	elm	0.04000	0.12000	0.01500	100	1.0
3	1	3	lake	4	main	0.01000	0.03000	0.01000	100	1.0
3	1	4	main	5	elm	0.08000	0.24000	0.02500	100	1.0

TOTAL LINE CHARGING SUSCEPTANCE : 0.29000
TOTAL LINE CHARGING MVAR AT 1 PU VOLTAGE : 29.000

TOTAL CAPACITIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR
TOTAL INDUCTIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR

GENERATOR DATA

SL.NO*	FROM NODE	FROM NAME*	REAL POWER(MW)	Q-MIN MVAR	Q-MAX MVAR	V-SPEC P.U.	CAP. CURV	MVA	STAT RATING
1	1	north	80.0000	0.0000	60.0000	1.0600	0	100.00	3
2	2	south	40.0000	30.0000	30.0000	1.0000	0	50.00	3

LOAD DATA

SLNO *	FROM NODE	FROM NAME*	REAL MW	REACTIVE MVAR	COMP MVAR	COMPENSATING MIN	MAX	STEP	MVAR NO	VALUE NO	CHAR STAT	F/V
1	2	south	20.000	10.000	0.000	0.000	0.000	0.000	0	0	3	0
2	5	elm	60.000	10.000	0.000	0.000	0.000	0.000	0	0	3	0
3	3	lake	45.000	15.000	0.000	0.000	0.000	0.000	0	0	3	0
4	4	main	40.000	5.000	0.000	0.000	0.000	0.000	0	0	3	0

TOTAL SPECIFIED MW GENERATION : 120.00000
TOTAL MIN MVAR LIMIT OF GENERATOR : 30.00000
TOTAL MAX MVAR LIMIT OF GENERATOR : 90.00000
TOTAL SPECIFIED MW LOAD : 165.00000 reduced 165.00000
TOTAL SPECIFIED MVAR LOAD : 40.00000 reduced 40.00000
TOTAL SPECIFIED MVAR COMPENSATION : 0.00000 reduced 0.00000

GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD FLOW

SLNO*	FROM NODE	FROM NAME*	P-RATE MW	P-MIN MW	P-MAX MW	%DROOP	PARTICI FACTOR	BIAS SETTING	C0	C1	C2
1	1	north	80.000	0.0000	80.0000	4.0000	0.0000	0.0000	0.0000	0.1000	0.0100
2	2	south	40.000	0.0000	40.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Acceleration factor : 1.40

Slack bus angle (degrees) : 0.00

TOTAL NUMBER OF ISLANDS IN THE GIVEN SYSTEM : 1
TOTAL NUMBER OF ISLANDS HAVING ATLEAST ONE GENERATOR : 1

SLACK BUSES CONSIDERED FOR THE STUDY

ISLAND NO.	SLACK BUS	NAME	SPECIFIED MW
1	1	north	80.000

Iteration count = 1 Error = 0.029411 Bus = 5
Iteration count = 2 Error = 0.005769 Bus = 4
Iteration count = 3 Error = 0.003904 Bus = 3
Iteration count = 4 Error = 0.001101 Bus = 5
Iteration count = 5 Error = 0.034595 Bus = 5
Iteration count = 6 Error = 0.013569 Bus = 3
Iteration count = 7 Error = 0.008711 Bus = 5
Iteration count = 8 Error = 0.004668 Bus = 2
Iteration count = 9 Error = 0.001942 Bus = 3
Iteration count = 10 Error = 0.001082 Bus = 5
Iteration count = 11 Error = 0.000356 Bus = 2

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	129.729	-10.585	0.000	0.000	0.000 #<
2	south	1.0468	-3.01	40.000	30.000	20.000	10.000	0.000
3	lake	1.0336	-4.28	0.000	0.000	45.000	15.000	0.000
4	main	1.0312	-4.79	0.000	0.000	40.000	5.000	0.000
5	elm	1.0202	-6.10	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 1

NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	FROM NODE	TO NAME	TO MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	95.183	-9.186	1.6186	-1.8021	90.2#
2	1	1	north	3	lake	34.546	-1.399	0.8511	-2.9265	32.6^
3	1	2	south	3	lake	43.001	5.780	0.3525	-5.4348	42.7^
4	1	2	south	4	main	19.581	0.645	0.2144	-3.6750	19.2&
5	1	2	south	5	elm	50.480	5.986	0.9515	-0.3504	48.6^
6	1	3	lake	4	main	31.058	-2.858	0.0906	-1.8599	30.2^
7	1	4	main	5	elm	10.443	-1.320	0.0834	-5.0102	10.8&

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 0
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 4
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

NEW SYSTEM FREQUENCY FOR ISLAND 1 : 50.000000 Hzs

Summary of results

TOTAL REAL POWER GENERATION : 169.729 MW
TOTAL REACT. POWER GENERATION : 19.415 MVAR
GENERATION pf : 0.994
TOTAL SHUNT REACTOR INJECTION : 0.000 MW
TOTAL SHUNT REACTOR INJECTION : 0.000 MVAR

TOTAL SHUNT CAPACIT.INJECTION	:	0.000 MW
TOTAL SHUNT CAPACIT.INJECTION	:	0.000 MVAR
TOTAL REAL POWER LOAD	:	165.000 MW
TOTAL REACTIVE POWER LOAD	:	40.000 MVAR
LOAD pf	:	0.972
TOTAL COMPENSATION AT LOADS	:	0.000 MVAR
TOTAL HVDC REACTIVE POWER	:	0.000 MVAR
TOTAL REAL POWER LOSS (AC+DC)	:	4.162143 MW (4.162143+ 0.000000)
PERCENTAGE REAL LOSS (AC+DC)	:	2.452
TOTAL REACTIVE POWER LOSS	:	-21.058951 MVAR

Zone wise distribution

Description	Zone # 1
MW generation	169.7289
MVAR generation	19.4154
MW load	165.0000
MVAR load	40.0000
MVAR compensation	0.0000
MW loss	4.1621
MVAR loss	-21.0590
MVAR - inductive	0.0000
MVAR - capacitive	0.0000

Zone wise export(+ve)/import(-ve)

Zone #	1 MW & MVAR
1	-----

Area wise distribution

Description Area # 1

MW generation	169.7289
MVAR generation	19.4154
MW load	165.0000
MVAR load	40.0000
MVAR compensation	0.0000
MW loss	4.1621
MVAR loss	-21.0590
MVAR - inductive	0.0000
MVAR - capacitive	0.0000

4.2 LINE OUTAGE

Line 1-3 open

Date and Time : Wed Feb 02 10:41:23 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	130.960	0.867	0.000	0.000	0.000 #
2	south	1.0355	-4.06	40.000	30.000	20.000	10.000	0.000
3	lake	1.0161	-6.14	0.000	0.000	45.000	15.000	0.000
4	main	1.0148	-6.51	0.000	0.000	40.000	5.000	0.000
5	elm	1.0069	-7.44	0.00	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	130.960	0.867	3.0560	2.5804	123.5@
2	1	1	north	3	lake	LINE IS OPEN				
3	1	2	south	3	lake	67.578	8.849	0.8790	-3.6772	65.8$
4	1	2	south	4	main	26.184	1.540	0.3912	-3.0306	25.3^
5	1	2	south	5	elm	53.891	6.622	1.1087	0.1970	52.4$
6	1	3	lake	4	main	21.451	-3.801	0.0453	-1.9265	21.4&
7	1	4	main	5	elm	7.212	-1.557	0.0412	-4.9857	7.9&

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 1
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 0
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 2
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 1
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Line 1-2 open

Date and Time : Wed Feb 02 10:48:45 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	133.991	28.326	0.000	0.000	0.000 #

2	south	0.9371	-18.49	40.000	30.000	20.000	10.000	0.000 @
3	lake	0.9314	-17.49	0.000	0.000	45.000	15.000	0.000 @
4	main	0.9248	-18.69	0.000	0.000	40.000	5.000	0.000 @
5	elm	0.9065	-21.76	0.000	0.000	60.000	10.000	0.000 @

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 4
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM	FROM	TO	TO	FORWARD	LOSS	%		
		NODE	NAME	NODE	NAME	MW	MVAR	MW	MVAR	LOADING
1	1	1	north	2	south	LINE IS OPEN				
2	1	1	north	3	lake	133.991	28.326	13.4732	35.4416	129.2!
3	1	2	south	3	lake	-20.134	13.159	0.1491	-4.7897	29.1^
4	1	2	south	4	main	3.435	3.480	0.0268	-3.3866	8.3&
5	1	2	south	5	elm	43.914	9.086	0.9277	0.2333	47.9^
6	1	3	lake	4	main	60.499	0.023	0.4220	-0.4569	65.0$
7	1	4	main	5	elm	19.132	-0.948	0.3437	-3.1617	20.7&

! NUMBER OF LINES LOADED BEYOND 125% : 1
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 0
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 1
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Line 2-4 open

Date and Time : Wed Feb 02 28 11:31:23 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	129.973	-5.800	0.000	0.000	0.000 #<
2	south	1.0455	-2.91	40.000	30.000	20.000	10.000	0.000
3	lake	1.0279	-4.57	0.000	0.000	45.000	15.000	0.000
4	main	1.0227	-5.33	0.000	0.000	40.000	5.000	0.000
5	elm	1.0166	-6.24	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	92.710	-6.194	1.5313	-2.0557	87.7#
2	1	1	north	3	lake	37.263	0.394	0.9959	-2.4627	35.2^
3	1	2	south	3	lake	56.278	9.303	0.6085	-4.6230	55.8$
4	1	2	south	4	main	LINE IS OPEN				
5	1	2	south	5	elm	54.298	6.850	1.1054	0.1263	52.3$
6	1	3	lake	4	main	47.211	1.394	0.2115	-1.4679	45.9^

7	1	4	main	5	elm	6.954	-2.309	0.0371	-5.0874	7.3&

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 2
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 1
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Line 2-5 open

Date and Time : Wed Feb 02 12:03:17 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	135.065	5.653	0.000	0.000	0.000 #
2	south	1.0412	-2.87	40.000	30.000	20.000	10.000	0.000
3	lake	1.0157	-5.00	0.000	0.000	45.000	15.000	0.000
4	main	1.0057	-6.11	0.000	0.000	40.000	5.000	0.000
5	elm	0.9217	-14.61	0.000	0.000	60.000	10.000	0.000 @

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 1
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	93.494	1.028	1.5594	-1.9448	88.2#
2	1	1	north	3	lake	41.571	4.625	1.2698	-1.5785	39.5^
3	1	2	south	3	lake	72.653	18.029	1.0574	-3.1746	71.9$
4	1	2	south	4	main	36.041	7.243	0.7680	-1.8871	35.3^
5	1	2	south	5	elm	LINE IS OPEN				
6	1	3	lake	4	main	69.660	9.951	0.4821	-0.5968	69.3$
7	1	4	main	5	elm	63.225	15.871	3.4292	5.6352	64.8$

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 3
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 0
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Line 3-4 open

Date and Time : Thu Feb 03 10:39:36 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	130.331	-7.849	0.000	0.000	0.000 #<
2	south	1.0445	-3.18	40.000	30.000	20.000	10.000	0.000
3	lake	1.0360	-3.59	0.000	0.000	45.000	15.000	0.000

4	main	1.0155	-6.99	0.000	0.000	40.000	5.000	0.000
5	elm	1.0126	-6.95	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	101.067	-6.785	1.8202	-1.1828	95.6#
2	1	1	north	3	lake	29.265	-1.064	0.6119	-3.6564	27.6^
3	1	2	south	3	lake	16.301	6.081	0.0648	-6.2983	19.7&
4	1	2	south	4	main	40.743	2.368	0.9244	-1.4710	39.1^
5	1	2	south	5	elm	61.070	7.636	1.3990	1.0226	58.9$
6	1	3	lake	4	main	LINE IS OPEN				
7	1	4	main	5	elm	0.057	-1.389	0.0011	-5.1382	3.7&

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 1
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Contingency 6: Line 4-5 open

Date and Time : Thu Feb 03 10:45:21 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	129.904	-5.175	0.000	0.000	0.000 #<
2	south	1.0440	-3.02	40.000	30.000	20.000	10.000	0.000
3	lake	1.0321	-4.09	0.000	0.000	45.000	15.000	0.000
4	main	1.0301	-4.49	0.000	0.000	40.000	5.000	0.000
5	elm	1.0079	-6.74	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	96.605	-4.750	1.6615	-1.6561	91.2#
2	1	1	north	3	lake	33.299	-0.426	0.7935	-3.0915	31.4^
3	1	2	south	3	lake	36.555	5.567	0.2595	-5.6869	36.8^
4	1	2	south	4	main	16.258	0.655	0.1499	-3.8523	16.2&
5	1	2	south	5	elm	61.294	11.213	1.4394	1.1595	59.7$
6	1	3	lake	4	main	24.141	-2.175	0.0548	-1.9619	23.5&
7	1	4	main	5	elm	LINE IS OPEN				

! NUMBER OF LINES LOADED BEYOND 125%	:	0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%	:	0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100%	:	1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75%	:	1
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50%	:	2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25%	:	2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1%	:	0

Line 2-3 open

Date and Time : Thu Feb 03 11:03:16 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	130.626	-0.928	0.000	0.000	0.000 #<
2	south	1.0476	-2.55	40.000	30.000	20.000	10.000	0.000
3	lake	1.0089	-5.98	0.000	0.000	45.000	15.000	0.000
4	main	1.0111	-6.07	0.000	0.000	40.000	5.000	0.000
5	elm	1.0139	-6.25	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark)	:	0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark)	:	1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark)	:	1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark)	:	0

LINE FLOWS AND LINE LOSSES

SLNO CS FROM FROM TO TO FORWARD LOSS %

		NODE	NAME	NODE	NAME	MW	MVAR	MW	MVAR	LOADING
1	1	1	north	2	south	81.345	-6.696	1.1798	-3.1237	77.0#
2	1	1	north	3	lake	49.281	5.768	1.7816	-0.0089	46.8^
3	1	2	south	3	lake	LINE IS OPEN				
4	1	2	south	4	main	39.185	7.096	0.8867	-1.5792	38.0^
5	1	2	south	5	elm	60.748	9.346	1.3892	0.9794	58.7$
6	1	3	lake	4	main	2.575	-9.241	0.0073	-2.0182	9.5&
7	1	4	main	5	elm	0.862	-4.032	0.0023	-5.1188	4.1&

! NUMBER OF LINES LOADED BEYOND 125%	:	0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%	:	0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100%	:	1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75%	:	1
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50%	:	2
& NUMBER OF LINES LOADED BETWEEN 1% AND 25%	:	2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1%	:	0

4.3 Generator outage

Generator 1 outage

Date and Time : Thu Feb 03 11:25:18 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	0.9993	-0.44	0.000	0.000	0.000	0.000	0.000
2	south	1.0000	0.00	167.469	17.058	20.000	10.000	0.000 <
3	lake	0.9838	-1.96	0.000	0.000	45.000	15.000	0.000

4	main	0.9814	-2.41	0.000	0.000	40.000	5.000	0.000
5	elm	0.9709	-3.55	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 0
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	-11.797	-0.157	0.0295	-5.9074	13.2&
2	1	1	north	3	lake	11.798	0.157	0.1171	-4.5650	12.8&
3	1	2	south	3	lake	58.966	5.232	0.7090	-3.7770	59.2$
4	1	2	south	4	main	23.879	0.838	0.3470	-2.8855	23.9&
5	1	2	south	5	elm	52.797	6.737	1.1422	0.5126	53.2$
6	1	3	lake	4	main	24.938	-1.268	0.0643	-1.7384	25.4^
7	1	4	main	5	elm	8.406	-0.807	0.0608	-4.5820	9.4&

! NUMBER OF LINES LOADED BEYOND 125% : 0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% : 0
# NUMBER OF LINES LOADED BETWEEN 75% AND 100% : 0
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75% : 2
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50% : 1
& NUMBER OF LINES LOADED BETWEEN 1% AND 25% : 4
* NUMBER OF LINES LOADED BETWEEN 0% AND 1% : 0

Generator 2 outage

Date and Time : Thu Feb 03 11:45:42 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	north	1.0600	0.00	170.991	25.652	0.000	0.000	0.000 #
2	south	1.0244	-3.84	0.000	0.000	20.000	10.000	0.000
3	lake	1.0142	-5.03	0.000	0.000	45.000	15.000	0.000
4	main	1.0109	-5.59	0.000	0.000	40.000	5.000	0.000
5	elm	0.9979	-7.02	0.000	0.000	60.000	10.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	1	north	2	south	129.051	20.475	3.0657	2.6777	123.3@
2	1	1	north	3	lake	41.940	5.176	1.2978	-1.4870	39.9^
3	1	2	south	3	lake	37.850	2.155	0.2784	-5.3990	37.8^
4	1	2	south	4	main	18.233	-0.195	0.1921	-3.5664	18.2&
5	1	2	south	5	elm	49.826	5.841	0.9672	-0.1662	49.0^
6	1	3	lake	4	main	33.370	-0.916	0.1083	-1.7257	32.9^
7	1	4	main	5	elm	11.153	-0.645	0.1002	-4.7433	11.8&

! NUMBER OF LINES LOADED BEYOND 125% : 0

@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%	:	1
# NUMBER OF LINES LOADED BETWEEN 75% AND 100%	:	0
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75%	:	0
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50%	:	4
& NUMBER OF LINES LOADED BETWEEN 1% AND 25%	:	2
* NUMBER OF LINES LOADED BETWEEN 0% AND 1%	:	0

CASE STUDY

(B): IEEE 14 BUS SYSTEM

4.4 **RESULT**: Base Case

Date and Time : Mon Feb 14 13:41:18 2011

LOAD FLOW BY GAUSS-SIEDEL METHOD

CASE NO : 1 CONTINGENCY : 0 SCHEDULE NO : 0

CONTINGENCY NAME : Base Case RATING CONSIDERED : NOMINAL

VERSION NUMBER : 6.1

LARGEST BUS NUMBER USED	:	15
ACTUAL NUMBER OF BUSES	:	14
NUMBER OF 2 WIND. TRANSFORMERS	:	2
NUMBER OF 3 WIND. TRANSFORMERS	:	1
NUMBER OF TRANSMISSION LINES	:	15
NUMBER OF SERIES REACTORS	:	0
NUMBER OF SERIES CAPACITORS	:	0
NUMBER OF CIRCUIT BREAKERS	:	0

NUMBER OF SHUNT REACTORS	:	0
NUMBER OF SHUNT CAPACITORS	:	0
NUMBER OF SHUNT IMPEDANCES	:	0
NUMBER OF GENERATORS	:	5
NUMBER OF LOADS	:	11
NUMBER OF LOAD CHARACTERISTICS	:	0
NUMBER OF UNDER FREQUENCY RELAY	:	0
NUMBER OF GEN CAPABILITY CURVES	:	0
NUMBER OF FILTERS	:	0
NUMBER OF TIE LINE SCHEDULES	:	0
NUMBER OF CONVERTORS	:	0
NUMBER OF DC LINKS	:	0

LOAD FLOW WITH GAUSS-SEIDEL METHOD	:	5
NUMBER OF ZONES	:	1
PRINT OPTION	:	3 - BOTH DATA AND RESULTS PRINT
PLOT OPTION	:	1 - PLOTTING WITH PU VOLTAGE
NO FREQUENCY DEPENDENT LOAD FLOW, CONTROL OPTION	:	0
BASE MVA	:	100.000000
NOMINAL SYSTEM FREQUENCY (Hzs)	:	50.000000
FREQUENCY DEVIATION (Hzs)	:	0.000000
FLOWS IN MW AND MVAR, OPTION	:	0
SLACK BUS	:	2
TRANSFORMER TAP CONTROL OPTION	:	0
Q CHECKING LIMIT (ENABLED)	:	4
REAL POWER TOLERANCE (PU)	:	0.00100
REACTIVE POWER TOLERANCE (PU)	:	0.00100
MAXIMUM NUMBER OF ITERATIONS	:	15
BUS VOLTAGE BELOW WHICH LOAD MODEL IS CHANGED	:	0.75000
CIRCUIT BREAKER RESISTANCE (PU)	:	0.00000

CIRCUIT BREAKER REACTANCE (PU)	:	0.00010
TRANSFORMER R/X RATIO	:	0.05000

ANNUAL PERCENTAGE INTEREST CHARGES	:	15.000
ANNUAL PERCENT OPERATION & MAINTENANCE CHARGES	:	4.000
LIFE OF EQUIPMENT IN YEARS	:	20.000
ENERGY UNIT CHARGE (KWHOUR)	:	2.500 Rs
LOSS LOAD FACTOR	:	0.300
COST PER MVAR IN LAKHS	:	5.000 Rs

ZONE WISE MULTIPLICATION FACTORS

ZONE	P LOAD	Q LOAD	P GEN	Q GEN	SH REACT	SH CAP	C LOAD
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000

BUS DATA

BUS NO.	AREA	ZONE	BUS KV	VMIN-PU	VMAX-PU	NAME
1	1	1	220.000	0.950	1.050	Bus1
2	1	1	220.000	0.950	1.050	Bus2
3	1	1	220.000	0.950	1.050	Bus3
4	1	1	220.000	0.950	1.050	Bus4
5	1	1	220.000	0.950	1.050	Bus5
6	1	1	132.000	0.950	1.050	Bus6
8	1	1	3.300	0.950	1.050	Bus8
9	1	1	132.000	0.950	1.050	Bus9
10	1	1	132.000	0.950	1.050	Bus10
11	1	1	132.000	0.950	1.050	Bus11
12	1	1	132.000	0.950	1.050	Bus12

13	1	1	132.000	0.950	1.050	Bus13
14	1	1	132.000	0.950	1.050	Bus14
15	1	1	220.000	0.950	1.050	DUM0001

TRANSFORMER DATA

STATUS	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	IMPEDANCE R(P.U)	X(P.U.)	NOMINAL TAP	RATING MVA	CTR	MINTAP	MAXTAP	TAPSTEP	SHIFT-DE
3	1	5	Bus5	6	Bus6	0.00003	0.25202	1.00000	25.00	6	0.93200	1.06800	0.01700	0.000
3	1	4	Bus4	9	Bus9	0.00006	0.55618	0.98450	60.00	9	0.96900	1.03100	0.00775	0.000
3	1	4	Bus4	15	DUM0001	0.00001	0.20912	1.02200	100.00	8	0.97800	1.02200	0.00550	0.000
3	1	9	Bus9	15	DUM0001	0.00001	0.11001	1.00000	50.00	8	1.00000	1.00000	0.00000	0.000
3	1	8	Bus8	15	DUM0001	0.00000	0.17615	1.00000	25.00	8	1.00000	1.00000	0.00000	0.000

TRANSMISSION LINE DATA

STA	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	LINE PARAMETER R(P.U)	X(P.U.)	B/2(P.U.)	RATING MVA	KMS
3	1	1	Bus1	2	Bus2	0.01938	0.05917	0.02640	100	1.0
3	1	1	Bus1	5	Bus5	0.05403	0.22304	0.02460	100	1.0
3	1	2	Bus2	3	Bus3	0.04699	0.19797	0.02190	100	1.0
3	1	2	Bus2	4	Bus4	0.05811	0.17632	0.01870	100	1.0
3	1	2	Bus2	5	Bus5	0.05695	0.17388	0.01700	100	1.0
3	1	3	Bus3	4	Bus4	0.06701	0.17103	0.01730	100	1.0
3	1	4	Bus4	5	Bus5	0.01335	0.04211	0.00640	100	1.0
3	1	6	Bus6	11	Bus11	0.09498	0.19890	0.00000	100	1.0
3	1	6	Bus6	12	Bus12	0.12291	0.25581	0.00000	100	1.0
3	1	6	Bus6	13	Bus13	0.06615	0.13027	0.00000	100	1.0
3	1	9	Bus9	10	Bus10	0.03181	0.08450	0.00000	100	1.0
3	1	9	Bus9	14	Bus14	0.12711	0.27038	0.00000	100	1.0
3	1	10	Bus10	11	Bus11	0.08205	0.19207	0.00000	100	1.0

3	1	12	Bus12	13	Bus13	0.22092	0.19988	0.00000	100	1.0
3	1	13	Bus13	14	Bus14	0.17093	0.34802	0.00000	100	1.0

TOTAL LINE CHARGING SUSCEPTANCE : 0.26460
TOTAL LINE CHARGING MVAR AT 1 PU VOLTAGE : 26.460

TOTAL CAPACITIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR
TOTAL INDUCTIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR

GENERATOR DATA

SL.NO*	FROM NODE	FROM NAME*	REAL POWER(MW)	Q-MIN MVAR	Q-MAX MVAR	V-SPEC P.U.	CAP. CURV	MVA	STAT RATING
1	1	Bus1	232.0000	-1000.0000	569.5620	1.0600	0	615.00	3
2	2	Bus2	40.0000	-40.0000	50.0000	1.0400	0	60.00	3
3	3	Bus3	0.0000	0.0000	40.0000	1.0100	0	60.00	3
4	6	Bus6	0.0000	-6.0000	25.0000	1.0000	0	25.00	3
5	8	Bus8	0.0000	-6.0000	25.0000	1.0900	0	25.00	3

LOAD DATA

SLNO *	FROM NODE	FROM NAME*	REAL MW	REACTIVE MVAR	COMP MVAR	COMPENSATING MIN	MAX	MVAR STEP	VALUE NO		CHAR NO	F/V STAT
1	2	Bus2	21.700	12.700	0.000	0.000	0.000	0.000	0	0	3	0
2	3	Bus3	94.200	19.000	0.000	0.000	0.000	0.000	0	0	3	0
3	4	Bus4	47.800	3.900	0.000	0.000	0.000	0.000	0	0	3	0
4	5	Bus5	7.600	1.600	0.000	0.000	0.000	0.000	0	0	3	0
5	6	Bus6	11.200	7.500	0.000	0.000	0.000	0.000	0	0	3	0
6	9	Bus9	29.500	16.600	0.000	0.000	0.000	0.000	0	0	3	0
7	10	Bus10	9.000	5.800	0.000	0.000	0.000	0.000	0	0	3	0

8	11	Bus11	3.500	1.800	0.000	0.000	0.000	0.000	0	0	3	0
9	12	Bus12	6.100	1.600	0.000	0.000	0.000	0.000	0	0	3	0
10	13	Bus13	13.500	5.800	0.000	0.000	0.000	0.000	0	0	3	0
11	14	Bus14	14.900	5.000	0.000	0.000	0.000	0.000	0	0	3	0

TOTAL SPECIFIED MW GENERATION : 272.00000
TOTAL MIN MVAR LIMIT OF GENERATOR : -1052.00000
TOTAL MAX MVAR LIMIT OF GENERATOR : 709.56201
TOTAL SPECIFIED MW LOAD : 259.00000 reduced 259.00000
TOTAL SPECIFIED MVAR LOAD : 81.30001 reduced 81.30001
TOTAL SPECIFIED MVAR COMPENSATION : 0.00000 reduced 0.00000

GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD FLOW

SLNO*	FROM NODE	FROM NAME*	P-RATE MW	P-MIN MW	P-MAX MW	%DROOP FACTOR	PARTICI SETTING	BIAS	C0	C1	C2
1	1	Bus1	232.000	0.0000	232.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	2	Bus2	40.000	0.0000	40.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	3	Bus3	0.000	0.0000	0.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	6	Bus6	0.000	0.0000	0.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	8	Bus8	0.000	0.0000	0.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Acceleration factor : 1.60

Slack bus angle (degrees) : 0.00

Iteration count = 1 Error = 0.072265 Bus = 14
Iteration count = 2 Error = 0.064388 Bus = 13
Iteration count = 3 Error = 0.030893 Bus = 10
Iteration count = 4 Error = 0.020389 Bus = 11

Iteration count = 5 Error = 0.032778 Bus = 7
Iteration count = 6 Error = 0.028402 Bus = 7
Iteration count = 7 Error = 0.022169 Bus = 1
Iteration count = 8 Error = 0.015118 Bus = 6
Iteration count = 9 Error = 0.010275 Bus = 11
Iteration count = 10 Error = 0.006042 Bus = 8
Iteration count = 11 Error = 0.003765 Bus = 7
Iteration count = 12 Error = 0.002633 Bus = 7
Iteration count = 13 Error = 0.001365 Bus = 9
Iteration count = 14 Error = 0.001117 Bus = 11
Iteration count = 15 Error = 0.000592 Bus = 7

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	0.953	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.824	50.821	21.700	12.700	0.000 >
3	Bus3	1.0100	-8.00	0.000	39.819	94.200	19.000	0.000
4	Bus4	0.9953	-5.19	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0001	-3.54	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9421	-9.35	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9832	-8.17	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9560	-9.77	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9454	-10.07	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9400	-9.90	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9273	-10.40	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9241	-10.50	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9218	-11.36	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9733	-8.19	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 6
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	37.848	24.942	0.0005	5.1771	181.3!
2	1	4	Bus4	9	Bus9	13.870	10.539	0.0002	1.6512	29.2^
3	1	4	Bus4	15	DUM0001	35.999	1.365	0.0002	1.8833	36.2^
4	1	9	Bus9	15	DUM0001	-35.917	-22.554	0.0001	1.4069	88.7#
5	1	8	Bus8	15	DUM0001	0.876	25.396	0.0000	0.2573	103.4@
6	1	1	Bus1	2	Bus2	158.023	-11.929	4.3209	7.3707	149.5!
7	1	1	Bus1	5	Bus5	74.013	12.995	2.7536	6.1426	70.9$
8	1	2	Bus2	3	Bus3	74.646	0.843	2.4252	5.6148	71.8$
9	1	2	Bus2	4	Bus4	56.453	8.141	1.7677	1.4887	54.8$
10	1	2	Bus2	5	Bus5	40.727	9.837	0.9451	-0.6534	40.3^
11	1	3	Bus3	4	Bus4	-21.832	16.176	0.5245	-2.1398	29.0^
12	1	4	Bus4	5	Bus5	-64.922	9.640	0.5822	0.5624	66.1$
13	1	6	Bus6	11	Bus11	3.911	-0.867	0.0172	0.0360	4.3&
14	1	6	Bus6	12	Bus12	7.224	2.033	0.0780	0.1624	8.0&
15	1	6	Bus6	13	Bus13	16.025	4.993	0.2100	0.4135	17.8&
16	1	9	Bus9	10	Bus10	8.926	8.691	0.0540	0.1435	13.0&
17	1	9	Bus9	14	Bus14	12.120	6.520	0.2634	0.5603	14.4&
18	1	10	Bus10	11	Bus11	-0.173	2.738	0.0069	0.0162	2.9&
19	1	12	Bus12	13	Bus13	1.099	0.260	0.0033	0.0030	1.2&
20	1	13	Bus13	14	Bus14	3.190	-0.942	0.0222	0.0451	3.6&

! NUMBER OF LINES LOADED BEYOND 125%	:	2
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%	:	1
# NUMBER OF LINES LOADED BETWEEN 75% AND 100%	:	1
$ NUMBER OF LINES LOADED BETWEEN 50% AND 75%	:	4
^ NUMBER OF LINES LOADED BETWEEN 25% AND 50%	:	4
& NUMBER OF LINES LOADED BETWEEN 1% AND 25%	:	8
* NUMBER OF LINES LOADED BETWEEN 0% AND 1%	:	0

NEW SYSTEM FREQUENCY FOR ISLAND 1 : 50.000000 Hzs

Summary of results

TOTAL REAL POWER GENERATION	:	271.824 MW
TOTAL REACT. POWER GENERATION	:	110.593 MVAR
GENERATION pf	:	0.926
TOTAL SHUNT REACTOR INJECTION	:	0.000 MW
TOTAL SHUNT REACTOR INJECTION	:	0.000 MVAR
TOTAL SHUNT CAPACIT.INJECTION	:	0.000 MW
TOTAL SHUNT CAPACIT.INJECTION	:	0.000 MVAR
TOTAL REAL POWER LOAD	:	259.000 MW
TOTAL REACTIVE POWER LOAD	:	81.300 MVAR
LOAD pf	:	0.954
TOTAL COMPENSATION AT LOADS	:	0.000 MVAR
TOTAL HVDC REACTIVE POWER	:	0.000 MVAR
TOTAL REAL POWER LOSS (AC+DC)	:	13.975368 MW (13.975368+ 0.000000)
PERCENTAGE REAL LOSS (AC+DC)	:	5.141
TOTAL REACTIVE POWER LOSS	:	30.141729 MVAR

Zone wise distribution

Description	Zone # 1
MW generation	271.8238
MVAR generation	110.5932
MW load	259.0000
MVAR load	81.3000
MVAR compensation	0.0000
MW loss	13.9754
MVAR loss	30.1417
MVAR - inductive	0.0000
MVAR - capacitive	0.0000

Zone wise export(+ve)/import(-ve)

Zone #	1 MW & MVAR
1	-----

Area wise distribution

Description	Area # 1
MW generation	271.8238
MVAR generation	110.5932
MW load	259.0000
MVAR load	81.3000
MVAR compensation	0.0000
MW loss	13.9754
MVAR loss	30.1417
MVAR - inductive	0.0000
MVAR - capacitive	0.0000

Date and Time : Mon Feb 14 13:41:18 2011

4.5 Line Outage

Line 1-2 open

Date and Time : Mon Feb 14 13:55:47 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP	
1	Bus1	1.0600	31.87	232.000	31.283	0.000	0.000	0.000	#
2	Bus2	1.0400	0.00	59.744	79.944	21.700	12.700	0.000	>
3	Bus3	1.0052	-5.41	0.000	40.000	94.200	19.000	0.000	
4	Bus4	0.9905	-0.05	0.000	0.000	47.800	3.900	0.000	
5	Bus5	0.9892	3.45	0.000	0.000	7.600	1.600	0.000	
6	Bus6	0.9879	-3.18	0.000	25.000	11.200	7.500	0.000	
8	Bus8	0.9883	-2.63	0.000	25.000	0.000	0.000	0.000	
9	Bus9	0.9664	-3.97	0.000	0.000	29.500	16.600	0.000	
10	Bus10	0.9618	-4.17	0.000	0.000	9.000	5.800	0.000	
11	Bus11	0.9710	-3.85	0.000	0.000	3.500	1.800	0.000	
12	Bus12	0.9716	-4.19	0.000	0.000	6.100	1.600	0.000	
13	Bus13	0.9659	-4.29	0.000	0.000	13.500	5.800	0.000	
14	Bus14	0.9464	-5.31	0.000	0.000	14.900	5.000	0.000	@
15	DUM0001	0.9787	-2.64	0.000	0.000	0.000	0.000	0.000	

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 1
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1

NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	44.791	3.081	0.0005	5.1916	181.5!
2	1	4	Bus4	9	Bus9	11.977	7.586	0.0001	1.1044	23.9&
3	1	4	Bus4	15	DUM0001	31.233	-5.980	0.0001	1.4817	32.8^
4	1	9	Bus9	15	DUM0001	-30.728	-16.195	0.0001	0.9235	71.9$
5	1	8	Bus8	15	DUM0001	0.749	24.748	0.0000	0.2417	100.2@
6	1	1	Bus1	2	Bus2	LINE IS OPEN				
7	1	1	Bus1	5	Bus5	231.995	31.341	26.4402	103.9760	220.9!
8	1	2	Bus2	3	Bus3	51.795	5.970	1.1957	0.4560	50.1$
9	1	2	Bus2	4	Bus4	9.097	24.167	0.4130	-2.6043	28.4^
10	1	2	Bus2	5	Bus5	-22.848	37.107	1.0735	-0.2246	44.8^
11	1	3	Bus3	4	Bus4	-43.410	26.447	1.7769	1.0898	52.3$
12	1	4	Bus4	5	Bus5	-126.766	47.007	2.4953	6.6168	136.9!
13	1	6	Bus6	11	Bus11	7.849	4.705	0.0815	0.1707	9.3&
14	1	6	Bus6	12	Bus12	7.848	2.595	0.0860	0.1791	8.4&
15	1	6	Bus6	13	Bus13	17.997	7.693	0.2596	0.5113	19.8&
16	1	9	Bus9	10	Bus10	5.099	3.337	0.0126	0.0336	6.3&
17	1	9	Bus9	14	Bus14	9.253	2.890	0.1279	0.2720	10.0&
18	1	10	Bus10	11	Bus11	-3.986	-2.866	0.0214	0.0500	5.1&
19	1	12	Bus12	13	Bus13	1.722	0.860	0.0087	0.0078	2.0&
20	1	13	Bus13	14	Bus14	5.946	2.530	0.0765	0.1557	6.7&

Line 1-5 open

Date and Time : Mon Feb 14 14:08:07 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP	
1	Bus1	1.0600	7.40	232.000	-27.592	0.000	0.000	0.000	#
2	Bus2	1.0400	0.00	44.852	102.481	21.700	12.700	0.000	>
3	Bus3	0.9987	-9.39	0.000	40.000	94.200	19.000	0.000	
4	Bus4	0.9732	-7.68	0.000	0.000	47.800	3.900	0.000	
5	Bus5	0.9715	-6.83	0.000	0.000	7.600	1.600	0.000	
6	Bus6	0.9145	-12.56	0.000	-6.000	11.200	7.500	0.000	@
8	Bus8	0.9621	-10.88	0.000	25.000	0.000	0.000	0.000	
9	Bus9	0.9337	-12.63	0.000	0.000	29.500	16.600	0.000	@
10	Bus10	0.9218	-13.02	0.000	0.000	9.000	5.800	0.000	@
11	Bus11	0.9140	-13.01	0.000	0.000	3.500	1.800	0.000	@
12	Bus12	0.8994	-13.64	0.000	0.000	6.100	1.600	0.000	@
13	Bus13	0.8963	-13.75	0.000	0.000	13.500	5.800	0.000	@
14	Bus14	0.8962	-14.47	0.000	0.000	14.900	5.000	0.000	@
15	DUM0001	0.9512	-10.92	0.000	0.000	0.000	0.000	0.000	

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING

1	1	5	Bus5	6	Bus6	35.181	23.749	0.0005	4.8108	174.8!
2	1	4	Bus4	9	Bus9	14.313	10.358	0.0002	1.7766	30.3^
3	1	4	Bus4	15	DUM0001	37.180	1.778	0.0002	2.1028	38.2^
4	1	9	Bus9	15	DUM0001	-37.051	-22.270	0.0002	1.5322	92.6#
5	1	8	Bus8	15	DUM0001	1.618	27.085	0.0000	0.3064	112.8@
6	1	1	Bus1	2	Bus2	232.002	-27.594	9.3884	22.8425	220.4!
7	1	1	Bus1	5	Bus5	LINE IS OPEN				
8	1	2	Bus2	3	Bus3	87.524	5.574	3.3555	9.5835	84.3#
9	1	2	Bus2	4	Bus4	82.473	15.333	3.8162	7.7854	80.7#
10	1	2	Bus2	5	Bus5	75.769	18.437	3.2393	6.4469	75.0$
11	1	3	Bus3	4	Bus4	-9.562	17.164	0.3011	-2.5956	22.7&
12	1	4	Bus4	5	Bus5	-29.094	12.848	0.1448	-0.7535	33.2^
13	1	6	Bus6	11	Bus11	2.765	-1.085	0.0100	0.0210	3.2&
14	1	6	Bus6	12	Bus12	7.033	2.072	0.0790	0.1644	8.0&
15	1	6	Bus6	13	Bus13	15.550	4.964	0.2108	0.4151	17.9&
16	1	9	Bus9	10	Bus10	10.473	9.291	0.0715	0.1900	15.0&
17	1	9	Bus9	14	Bus14	13.191	6.929	0.3237	0.6885	16.0&
18	1	10	Bus10	11	Bus11	1.253	3.219	0.0115	0.0270	3.7&
19	1	12	Bus12	13	Bus13	1.031	0.228	0.0030	0.0028	1.2&
20	1	13	Bus13	14	Bus14	2.371	-1.110	0.0146	0.0297	2.9&

Line 2-3 open

Date and Time : Mon Feb 14 14:22:32 2011

BUS VOLTAGES AND POWERS

NODE	FROM	V-MAG	ANGLE	MW	MVAR	MW	MVAR	MVAR

NO.	NAME	P.U.	DEGREE	GEN	GEN	LOAD	LOAD	COMP
1	Bus1	1.0600	4.39	232.000	16.747	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	48.176	68.325	21.700	12.700	0.000 >
3	Bus3	0.9100	-20.37	0.000	40.000	94.200	19.000	0.000 @
4	Bus4	0.9566	-8.84	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9702	-6.11	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9092	-12.59	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9480	-11.82	0.000	25.000	0.000	0.000	0.000 @
9	Bus9	0.9197	-13.47	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9090	-13.74	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9045	-13.39	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.8935	-13.74	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.8894	-13.91	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.8847	-15.06	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9367	-11.88	0.000	0.000	0.000	0.000	0.000 @

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 10
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	39.502	25.722	0.0006	5.9489	194.3!
2	1	4	Bus4	9	Bus9	12.949	9.603	0.0002	1.5309	28.1^
3	1	4	Bus4	15	DUM0001	33.721	0.452	0.0002	1.7865	36.0^
4	1	9	Bus9	15	DUM0001	-33.389	-21.368	0.0001	1.3281	86.2#

5	1	8	Bus8	15	DUM0001	2.199	27.909	0.0000	0.3359	118.1@
6	1	1	Bus1	2	Bus2	140.893	-7.828	3.4280	4.6445	133.1!
7	1	1	Bus1	5	Bus5	90.844	25.606	4.3554	12.8997	89.0#
8	1	2	Bus2	3	Bus3	LINE IS OPEN				
9	1	2	Bus2	4	Bus4	94.871	22.587	5.1610	11.9259	93.8#
10	1	2	Bus2	5	Bus5	69.070	20.566	2.7762	5.0374	69.3$
11	1	3	Bus3	4	Bus4	-93.092	20.492	7.4014	15.8747	105.2@
12	1	4	Bus4	5	Bus5	-103.845	4.002	1.5761	3.7835	108.7@
13	1	6	Bus6	11	Bus11	5.612	-0.472	0.0364	0.0763	6.2&
14	1	6	Bus6	12	Bus12	7.385	2.105	0.0877	0.1825	8.4&
15	1	6	Bus6	13	Bus13	17.069	5.333	0.2559	0.5040	19.7&
16	1	9	Bus9	10	Bus10	8.016	8.701	0.0526	0.1398	12.9&
17	1	9	Bus9	14	Bus14	11.464	6.638	0.2637	0.5609	14.4&
18	1	10	Bus10	11	Bus11	-1.415	2.742	0.0095	0.0221	3.4&
19	1	12	Bus12	13	Bus13	1.460	0.219	0.0060	0.0055	1.7&
20	1	13	Bus13	14	Bus14	4.127	-0.786	0.0381	0.0776	4.7&

Line 2-4 open

Date and Time : Mon Feb 14 14:35:43 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.47	232.000	12.473	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	37.899	49.119	21.700	12.700	0.000
3	Bus3	0.9962	-9.76	0.000	40.000	94.200	19.000	0.000
4	Bus4	0.9682	-8.38	0.000	0.000	47.800	3.900	0.000

5	Bus5	0.9790	-5.80	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9197	-12.07	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9594	-11.28	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9314	-12.90	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9205	-13.17	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9155	-12.85	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9042	-13.20	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9003	-13.37	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.8964	-14.47	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9481	-11.35	0.000	0.000	0.000	0.000	0.000 @

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 8
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	39.026	25.156	0.0006	5.6692	189.7!
2	1	4	Bus4	9	Bus9	12.955	9.705	0.0002	1.5068	27.9^
3	1	4	Bus4	15	DUM0001	33.715	0.336	0.0002	1.7434	35.6^
4	1	9	Bus9	15	DUM0001	-33.417	-21.298	0.0001	1.2940	85.1#
5	1	8	Bus8	15	DUM0001	2.562	28.122	0.0000	0.3337	117.7@
6	1	1	Bus1	2	Bus2	143.393	-8.438	3.5517	5.0220	135.5!
7	1	1	Bus1	5	Bus5	88.889	21.674	4.0866	11.7484	86.3#
8	1	2	Bus2	3	Bus3	90.886	6.630	3.6238	10.7251	87.6#
9	1	2	Bus2	4	Bus4	LINE IS OPEN				
10	1	2	Bus2	5	Bus5	65.155	16.330	2.4090	3.8873	64.6$

11	1	3	Bus3	4	Bus4	-6.165	17.202	0.2673	-2.6563	21.6&
12	1	4	Bus4	5	Bus5	-98.569	8.145	1.3946	3.1857	102.2@
13	1	6	Bus6	11	Bus11	5.460	-0.624	0.0339	0.0710	6.0&
14	1	6	Bus6	12	Bus12	7.369	2.088	0.0852	0.1774	8.3&
15	1	6	Bus6	13	Bus13	17.002	5.241	0.2476	0.4875	19.3&
16	1	9	Bus9	10	Bus10	8.179	8.965	0.0540	0.1434	13.0&
17	1	9	Bus9	14	Bus14	11.667	6.710	0.2654	0.5645	14.4&
18	1	10	Bus10	11	Bus11	-1.157	2.901	0.0094	0.0221	3.4&
19	1	12	Bus12	13	Bus13	1.435	0.199	0.0057	0.0051	1.6&
20	1	13	Bus13	14	Bus14	4.029	-0.923	0.0360	0.0734	4.6&

Line 2-5 open

Date and Time : Mon Feb 14 14:49:16 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.50	232.000	13.008	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	37.762	44.836	21.700	12.700	0.000
3	Bus3	1.0017	-8.91	0.000	40.000	94.200	19.000	0.000
4	Bus4	0.9786	-6.80	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9778	-5.67	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9211	-11.41	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9677	-9.90	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9396	-11.60	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9278	-11.97	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9203	-11.91	0.000	0.000	3.500	1.800	0.000 @

12	Bus12	0.9061	-12.47	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9030	-12.60	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9025	-13.38	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9568	-9.94	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	MVAR	LOSS MW	MVAR	% LOADING
1	1	5	Bus5	6	Bus6	35.717	23.747	0.0005	4.8496	175.5!
2	1	4	Bus4	9	Bus9	14.065	10.328	0.0002	1.7139	29.7^
3	1	4	Bus4	15	DUM0001	36.566	1.512	0.0002	2.0103	37.4^
4	1	9	Bus9	15	DUM0001	-36.338	-22.189	0.0001	1.4681	90.6#
5	1	8	Bus8	15	DUM0001	2.034	27.286	0.0000	0.3080	113.1@
6	1	1	Bus1	2	Bus2	144.186	-8.630	3.5913	5.1431	136.3!
7	1	1	Bus1	5	Bus5	88.086	22.280	4.0327	11.5316	85.7#
8	1	2	Bus2	3	Bus3	83.080	4.385	3.0185	8.1510	80.0#
9	1	2	Bus2	4	Bus4	73.576	13.977	3.0460	5.4287	72.0$
10	1	2	Bus2	5	Bus5	LINE IS OPEN				
11	1	3	Bus3	4	Bus4	-13.592	17.476	0.3699	-2.4487	24.9&
12	1	4	Bus4	5	Bus5	-39.822	14.501	0.2529	-0.4271	43.7^
13	1	6	Bus6	11	Bus11	3.218	-1.118	0.0130	0.0272	3.7&
14	1	6	Bus6	12	Bus12	7.076	2.060	0.0787	0.1638	8.0&
15	1	6	Bus6	13	Bus13	15.789	4.952	0.2135	0.4204	18.0&

16	1	9	Bus9	10	Bus10	10.194	9.279	0.0685	0.1819	14.7&
17	1	9	Bus9	14	Bus14	12.990	6.924	0.3120	0.6637	15.7&
18	1	10	Bus10	11	Bus11	0.903	3.236	0.0108	0.0252	3.6&
19	1	12	Bus12	13	Bus13	1.103	0.207	0.0034	0.0031	1.2&
20	1	13	Bus13	14	Bus14	2.634	-1.139	0.0173	0.0351	3.2&

Line 3-4 open

Date and Time : Mon Feb 14 15:02:36 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	5.14	232.000	1.802	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.270	62.006	21.700	12.700	0.000 >
3	Bus3	1.0100	-10.65	0.000	32.956	94.200	19.000	0.000
4	Bus4	0.9893	-3.94	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9962	-2.64	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9375	-8.35	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9785	-6.96	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9514	-8.60	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9406	-8.94	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9350	-8.85	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9225	-9.39	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9192	-9.50	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9167	-10.28	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9681	-6.99	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 6
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	36.879	25.061	0.0005	5.0484	179.0!
2	1	4	Bus4	9	Bus9	13.968	10.231	0.0002	1.6512	29.2^
3	1	4	Bus4	15	DUM0001	36.255	0.856	0.0002	1.9318	37.5^
4	1	9	Bus9	15	DUM0001	-36.170	-21.803	0.0001	1.4089	88.8#
5	1	8	Bus8	15	DUM0001	1.201	26.378	0.0000	0.2805	107.9@
6	1	1	Bus1	2	Bus2	163.630	-13.232	4.6363	8.3336	154.9!
7	1	1	Bus1	5	Bus5	68.460	15.321	2.4110	4.7473	66.2$
8	1	2	Bus2	3	Bus3	98.409	-0.830	4.2084	13.1274	94.6#
9	1	2	Bus2	4	Bus4	45.472	14.295	1.2539	-0.0479	45.8^
10	1	2	Bus2	5	Bus5	32.682	14.274	0.6991	-1.3914	34.3^
11	1	3	Bus3	4	Bus4	LINE IS OPEN				
12	1	4	Bus4	5	Bus5	-52.922	0.425	0.3822	-0.0559	53.5$
13	1	6	Bus6	11	Bus11	3.568	-0.549	0.0141	0.0295	3.9&
14	1	6	Bus6	12	Bus12	7.166	2.089	0.0779	0.1622	8.0&
15	1	6	Bus6	13	Bus13	15.891	5.195	0.2104	0.4143	17.8&
16	1	9	Bus9	10	Bus10	9.501	8.600	0.0577	0.1533	13.5&
17	1	9	Bus9	14	Bus14	12.489	6.445	0.2774	0.5900	14.8&
18	1	10	Bus10	11	Bus11	0.334	2.554	0.0062	0.0144	2.7&
19	1	12	Bus12	13	Bus13	1.105	0.305	0.0034	0.0031	1.2&
20	1	13	Bus13	14	Bus14	2.944	-0.770	0.0187	0.0382	3.3&

Line 4-5 open

Date and Time : Mon Feb 14 15:18:44 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP	
1	Bus1	1.0600	5.63	232.000	-4.437	0.000	0.000	0.000	#
2	Bus2	1.0400	0.00	42.439	67.226	21.700	12.700	0.000	>
3	Bus3	1.0033	-9.93	0.000	40.000	94.200	19.000	0.000	
4	Bus4	0.9818	-8.79	0.000	0.000	47.800	3.900	0.000	
5	Bus5	1.0064	-0.36	0.000	0.000	7.600	1.600	0.000	
6	Bus6	0.9455	-8.54	0.000	-6.000	11.200	7.500	0.000	@
8	Bus8	0.9702	-10.89	0.000	25.000	0.000	0.000	0.000	
9	Bus9	0.9418	-12.02	0.000	0.000	29.500	16.600	0.000	@
10	Bus10	0.9334	-11.80	0.000	0.000	9.000	5.800	0.000	@
11	Bus11	0.9346	-10.38	0.000	0.000	3.500	1.800	0.000	@
12	Bus12	0.9298	-9.80	0.000	0.000	6.100	1.600	0.000	@
13	Bus13	0.9241	-10.12	0.000	0.000	13.500	5.800	0.000	@
14	Bus14	0.9132	-12.51	0.000	0.000	14.900	5.000	0.000	@
15	DUM0001	0.9599	-10.91	0.000	0.000	0.000	0.000	0.000	

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM	FROM	TO	TO	FORWARD	LOSS	%		
		NODE	NAME	NODE	NAME	MW	MVAR	MW	MVAR	LOADING
1	1	5	Bus5	6	Bus6	53.750	28.191	0.0009	9.1654	241.2!
2	1	4	Bus4	9	Bus9	9.520	10.200	0.0001	1.0887	23.7&
3	1	4	Bus4	15	DUM0001	24.734	0.959	0.0001	0.9138	25.2^
4	1	9	Bus9	15	DUM0001	-24.629	-23.577	0.0001	0.9368	72.4$
5	1	8	Bus8	15	DUM0001	0.964	25.992	0.0000	0.2768	107.2@
6	1	1	Bus1	2	Bus2	178.374	-16.568	5.5198	11.0311	169.0!
7	1	1	Bus1	5	Bus5	53.565	12.325	1.4892	0.8917	51.9$
8	1	2	Bus2	3	Bus3	92.175	2.955	3.7035	11.0300	88.7#
9	1	2	Bus2	4	Bus4	92.082	8.784	4.6182	10.1877	88.9#
10	1	2	Bus2	5	Bus5	9.337	15.187	0.1985	-2.9545	20.2&
11	1	3	Bus3	4	Bus4	-5.612	13.178	0.1691	-2.9771	17.5&
12	1	4	Bus4	5	Bus5	LINE IS OPEN				
13	1	6	Bus6	11	Bus11	13.723	-1.169	0.2016	0.4221	14.6&
14	1	6	Bus6	12	Bus12	8.441	1.831	0.1026	0.2135	9.1&
15	1	6	Bus6	13	Bus13	21.039	5.091	0.3467	0.6828	22.9&
16	1	9	Bus9	10	Bus10	-0.449	9.544	0.0327	0.0870	10.1&
17	1	9	Bus9	14	Bus14	6.041	7.151	0.1256	0.2671	9.9&
18	1	10	Bus10	11	Bus11	-9.664	3.687	0.1007	0.2358	11.1&
19	1	12	Bus12	13	Bus13	2.385	0.013	0.0145	0.0132	2.6&
20	1	13	Bus13	14	Bus14	9.370	-1.498	0.1802	0.3669	10.3&

Line 4-15 open

Date and Time : Fri Feb 18 11:30:40 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.99	232.000	-6.526	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	24.382	36.274	21.700	12.700	0.000
3	Bus3	1.0100	-7.52	0.000	30.907	94.200	19.000	0.000
4	Bus4	1.0103	-4.64	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0158	-3.46	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0132	-10.53	0.000	25.000	11.200	7.500	0.000
7	Bus7	1.0072	-11.35	0.000	0.000	0.000	0.000	0.000
8	Bus8	1.0424	-10.12	13.200	21.231	0.000	0.000	0.000
9	Bus9	0.9847	-12.26	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9813	-12.29	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9929	-11.58	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9964	-11.55	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9900	-11.72	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9674	-13.19	0.000	0.000	14.900	5.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	MVAR	LOSS MW	MVAR	% LOADING
1	1	5	Bus5	6	Bus6	50.223	4.149	0.0006	6.2031	198.4!

2	1	4	Bus4	9	Bus9	23.701	6.233	0.0003	3.2723	97.0#
3	1	4	Bus4	15	LINE IS OPEN					
4	1	9	Bus9	15	DUM0001	-14.21	-20.758	0.0000	-0.6862	25.0&
5	1	8	Bus8	15	DUM0001	0.954	-19.990	0.0001	0.9796	94.3#
6	1	1	Bus1	2	Bus2	159.087	-12.178	4.3799	7.5507	150.5!
7	1	1	Bus1	5	Bus5	73.054	5.807	2.6016	5.4375	69.1$
8	1	2	Bus2	3	Bus3	70.344	1.264	2.1555	4.4785	67.6$
9	1	2	Bus2	4	Bus4	49.283	1.185	1.3104	0.0447	47.4^
10	1	2	Bus2	5	Bus5	37.761	1.397	0.7563	-1.2836	36.3^
11	1	3	Bus3	4	Bus4	-25.827	8.909	0.5130	-2.2214	28.3^
12	1	4	Bus4	5	Bus5	-49.148	2.419	0.3171	-0.3133	48.8^
13	1	6	Bus6	11	Bus11	11.588	4.885	0.1463	0.3065	12.4&
14	1	6	Bus6	12	Bus12	8.340	2.691	0.0920	0.1914	8.6&
15	1	6	Bus6	13	Bus13	20.074	7.975	0.3007	0.5921	21.3&
16	1	9	Bus9	10	Bus10	1.920	3.271	0.0047	0.0125	3.9&
17	1	9	Bus9	14	Bus14	7.143	2.986	0.0786	0.1671	7.9&
18	1	10	Bus10	11	Bus11	-7.467	-2.695	0.0537	0.1257	8.1&
19	1	12	Bus12	13	Bus13	2.243	0.710	0.0123	0.0111	2.4&
20	1	13	Bus13	14	Bus14	8.261	2.462	0.1296	0.2639	8.7&

Line 4-9 Open

Date and Time : Mon Feb 14 15:30:03 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	1.337	0.000	0.000	0.000 #

2	Bus2	1.0400	0.00	38.769	51.461	21.700	12.700	0.000	>
3	Bus3	1.0100	-7.96	0.000	39.537	94.200	19.000	0.000	
4	Bus4	0.9956	-5.11	0.000	0.000	47.800	3.900	0.000	
5	Bus5	0.9991	-3.54	0.000	0.000	7.600	1.600	0.000	
6	Bus6	0.9348	-9.98	0.000	-6.000	11.200	7.500	0.000	@
8	Bus8	0.9717	-8.92	0.000	25.000	0.000	0.000	0.000	
9	Bus9	0.9385	-11.01	0.000	0.000	29.500	16.600	0.000	@
10	Bus10	0.9293	-11.22	0.000	0.000	9.000	5.800	0.000	@
11	Bus11	0.9279	-10.81	0.000	0.000	3.500	1.800	0.000	@
12	Bus12	0.9191	-11.10	0.000	0.000	6.100	1.600	0.000	@
13	Bus13	0.9149	-11.25	0.000	0.000	13.500	5.800	0.000	@
14	Bus14	0.9075	-12.44	0.000	0.000	14.900	5.000	0.000	@
15	DUM0001	0.9614	-8.95	0.000	0.000	0.000	0.000	0.000	

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	LOSS MVAR	% MW	MVAR	LOADING
1	1	5	Bus5	6	Bus6	41.617	27.819	0.0006	6.3270	200.4!
2	1	4	Bus4	9	Bus9	LINE IS OPEN				
3	1	4	Bus4	15	DUM0001	45.526	10.499	0.0003	3.1660	46.9^
4	1	9	Bus9	15	DUM0001	-45.331	-29.280	0.0002	2.3637	115.0@
5	1	8	Bus8	15	DUM0001	1.403	25.905	0.0000	0.2746	106.8@
6	1	1	Bus1	2	Bus2	158.044	-11.934	4.3221	7.3742	149.5!
7	1	1	Bus1	5	Bus5	74.050	13.461	2.7634	6.1880	71.0$

8	1	2	Bus2	3	Bus3	74.226	0.882	2.3982	5.5008	71.4$
9	1	2	Bus2	4	Bus4	55.706	8.173	1.7231	1.3522	54.1$
10	1	2	Bus2	5	Bus5	40.859	10.397	0.9579	-0.6110	40.5^
11	1	3	Bus3	4	Bus4	-22.138	16.165	0.5331	-2.1188	29.3^
12	1	4	Bus4	5	Bus5	-61.263	11.368	0.5249	0.3827	62.8$
13	1	6	Bus6	11	Bus11	6.395	0.255	0.0445	0.0932	6.8&
14	1	6	Bus6	12	Bus12	7.578	2.144	0.0872	0.1816	8.4&
15	1	6	Bus6	13	Bus13	17.390	5.606	0.2527	0.4977	19.5&
16	1	9	Bus9	10	Bus10	6.677	7.729	0.0377	0.1001	10.9&
17	1	9	Bus9	14	Bus14	10.622	5.883	0.2128	0.4526	12.9&
18	1	10	Bus10	11	Bus11	-2.461	1.759	0.0087	0.0203	3.3&
19	1	12	Bus12	13	Bus13	1.473	0.321	0.0059	0.0054	1.6&
20	1	13	Bus13	14	Bus14	4.769	-0.333	0.0467	0.0950	5.2&

Line 5-6 Open

Date and Time : Mon Feb 14 15:45:44 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	5.03	232.000	-7.231	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	35.884	37.781	21.700	12.700	0.000
3	Bus3	1.0100	-8.06	0.000	33.985	94.200	19.000	0.000
4	Bus4	1.0039	-5.55	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0165	-3.29	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9393	-20.28	0.000	25.000	11.200	7.500	0.000 @
8	Bus8	0.9960	-10.47	0.000	25.000	0.000	0.000	0.000

9	Bus9	0.9726	-13.16	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9586	-14.77	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9447	-17.69	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9239	-20.78	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9236	-20.42	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9291	-17.56	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9854	-10.56	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 5
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	MVAR	LOSS MW	MVAR	% LOADING
1	1	5	Bus5	6	Bus6	LINE IS OPEN				
2	1	4	Bus4	9	Bus9	23.598	10.192	0.0004	3.5344	42.7^
3	1	4	Bus4	15	DUM0001	61.355	0.403	0.0005	5.3700	62.5$
4	1	9	Bus9	15	DUM0001	-60.812	-16.054	0.0003	2.9895	129.3!
5	1	8	Bus8	15	DUM0001	3.925	27.337	0.0000	0.2961	110.9@
6	1	1	Bus1	2	Bus2	160.246	-12.448	4.4446	7.7483	151.6!
7	1	1	Bus1	5	Bus5	71.957	5.558	2.5231	5.1096	68.1$
8	1	2	Bus2	3	Bus3	75.134	0.797	2.4568	5.7480	72.2$
9	1	2	Bus2	4	Bus4	58.848	2.671	1.8724	1.7743	56.6$
10	1	2	Bus2	5	Bus5	36.004	1.417	0.6881	-1.4944	34.6^
11	1	3	Bus3	4	Bus4	-21.044	10.665	0.3924	-2.5067	25.1^
12	1	4	Bus4	5	Bus5	-94.945	1.187	1.1946	2.4619	94.6#
13	1	6	Bus6	11	Bus11	-17.193	6.121	0.3586	0.7509	19.4&

14	1	6	Bus6	12	Bus12	4.641	3.430	0.0464	0.0966	6.1&
15	1	6	Bus6	13	Bus13	5.868	8.308	0.0776	0.1528	10.8&
16	1	9	Bus9	10	Bus10	32.599	4.344	0.3637	0.9661	33.8^
17	1	9	Bus9	14	Bus14	27.417	3.746	1.0289	2.1886	28.5^
18	1	10	Bus10	11	Bus11	23.093	-2.310	0.4810	1.1259	24.2&
19	1	12	Bus12	13	Bus13	-1.152	1.408	0.0086	0.0078	2.0&
20	1	13	Bus13	14	Bus14	-10.367	3.940	0.2464	0.5018	12.0&

Line 6-11 Open

Date and Time : Tue Feb 15 10:05:21 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.94	232.000	-4.652	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	38.864	37.933	21.700	12.700	0.000
3	Bus3	1.0100	-7.92	0.000	34.153	94.200	19.000	0.000
4	Bus4	1.0051	-5.28	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0125	-3.68	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-8.98	0.000	15.441	11.200	7.500	0.000
8	Bus8	0.9968	-8.16	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9727	-9.74	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9619	-10.26	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9552	-10.60	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9831	-9.99	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9772	-10.07	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9551	-11.07	0.000	0.000	14.900	5.000	0.000

15	DUM0001	0.9873	-8.21	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM	FROM	TO	TO	FORWARD	LOSS	%		
		NODE	NAME	NODE	NAME	MW	MVAR	MW	MVAR	LOADING
1	1	5	Bus5	6	Bus6	37.097	6.729	0.0004	3.4945	148.9!
2	1	4	Bus4	9	Bus9	13.888	9.390	0.0002	1.4996	27.8^
3	1	4	Bus4	15	DUM0001	36.087	-1.819	0.0002	1.8578	36.7^
4	1	9	Bus9	15	DUM0001	-35.836	-19.366	0.0001	1.2537	83.8#
5	1	8	Bus8	15	DUM0001	2.024	24.549	0.0000	0.2352	98.8#
6	1	1	Bus1	2	Bus2	157.428	-11.790	4.2882	7.2706	148.9!
7	1	1	Bus1	5	Bus5	74.510	7.199	2.7174	5.9318	70.6$
8	1	2	Bus2	3	Bus3	73.903	0.913	2.3775	5.4137	71.1$
9	1	2	Bus2	4	Bus4	56.053	2.608	1.6995	1.2452	54.0$
10	1	2	Bus2	5	Bus5	40.348	2.651	0.8678	-0.9319	38.9^
11	1	3	Bus3	4	Bus4	-22.540	10.598	0.4341	-2.4044	26.3^
12	1	4	Bus4	5	Bus5	-65.993	3.558	0.5778	0.5201	65.8$
13	1	6	Bus6	11	Bus11	LINE IS OPEN				
14	1	6	Bus6	12	Bus12	8.101	2.759	0.0900	0.1873	8.6&
15	1	6	Bus6	13	Bus13	18.439	8.244	0.2699	0.5315	20.2&
16	1	9	Bus9	10	Bus10	12.957	7.638	0.0761	0.2020	15.5&
17	1	9	Bus9	14	Bus14	9.027	2.181	0.1159	0.2465	9.5&
18	1	10	Bus10	11	Bus11	3.615	1.784	0.0144	0.0337	4.2&
19	1	12	Bus12	13	Bus13	1.741	0.979	0.0091	0.0082	2.0&

20	1	13	Bus13	14	Bus14	6.265	3.180	0.0884	0.1799	7.2&

Line 6-12 Open

Date and Time : Tue Feb 15 10:20:09 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG **P.U.**	ANGLE **DEGREE**	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.95	232.000	1.129	0.000	0.000	0.000 >
3	Bus3	1.0097	-8.02	0.000	40.000	94.200	19.000	0.000
4	Bus4	0.9947	-5.21	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9997	-3.54	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9418	-9.32	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9822	-8.23	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9546	-9.86	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9442	-10.14	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9392	-9.92	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.8982	-11.53	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9168	-10.95	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9178	-11.61	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9722	-8.25	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 6
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	37.584	24.850	0.0005	5.1195	180.3!
2	1	4	Bus4	9	Bus9	14.070	10.703	0.0002	1.7026	29.6^
3	1	4	Bus4	15	DUM0001	36.507	1.763	0.0002	1.9407	36.7^
4	1	9	Bus9	15	DUM0001	-36.468	-22.953	0.0001	1.4566	90.3#
5	1	8	Bus8	15	DUM0001	0.734	25.487	0.0000	0.2596	103.8@
6	1	1	Bus1	2	Bus2	157.972	-11.917	4.3181	7.3622	149.5!
7	1	1	Bus1	5	Bus5	74.077	13.177	2.7609	6.1747	71.0$
8	1	2	Bus2	3	Bus3	74.773	0.983	2.4339	5.6526	71.9$
9	1	2	Bus2	4	Bus4	56.673	8.417	1.7841	1.5405	55.1$
10	1	2	Bus2	5	Bus5	40.857	10.041	0.9532	-0.6272	40.5^
11	1	3	Bus3	4	Bus4	-21.732	16.293	0.5247	-2.1363	29.0^
12	1	4	Bus4	5	Bus5	-65.269	9.382	0.5883	0.5828	66.5$
13	1	6	Bus6	11	Bus11	4.307	-0.822	0.0206	0.0431	4.7&
14	1	6	Bus6	12	Bus12	LINE IS OPEN				
15	1	6	Bus6	13	Bus13	22.370	6.991	0.4097	0.8068	24.9&
16	1	9	Bus9	10	Bus10	8.555	8.596	0.0513	0.1364	12.7&
17	1	9	Bus9	14	Bus14	13.181	6.966	0.3100	0.6595	15.6&
18	1	10	Bus10	11	Bus11	-0.628	2.696	0.0071	0.0165	2.9&
19	1	12	Bus12	13	Bus13	-6.030	-1.651	0.1070	0.0968	7.0&
20	1	13	Bus13	14	Bus14	2.166	-1.306	0.0130	0.0265	2.8&

Line 6-13 Open

Date and Time : Tue Feb 15 10:35:43 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	1.010	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	40.053	52.521	21.700	12.700	0.000 >
3	Bus3	1.0092	-8.01	0.000	40.000	94.200	19.000	0.000
4	Bus4	0.9936	-5.21	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9996	-3.52	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9457	-8.95	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9788	-8.41	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9498	-10.12	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9405	-10.29	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9390	-9.82	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9099	-11.58	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.8777	-12.83	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.8974	-12.60	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9686	-8.42	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	35.470	23.047	0.0005	4.5131	169.3!

2	1	4	Bus4	9	Bus9	14.760	11.422	0.0002	1.9019	31.3^
3	1	4	Bus4	15	DUM0001	38.370	3.639	0.0002	2.1629	38.8^
4	1	9	Bus9	15	DUM0001	-38.128	-24.403	0.0002	1.6240	95.3#
5	1	8	Bus8	15	DUM0001	0.770	25.889	0.0000	0.2697	105.8@
6	1	1	Bus1	2	Bus2	158.241	-11.980	4.3330	7.4075	149.7!
7	1	1	Bus1	5	Bus5	73.961	13.227	2.7534	6.1441	70.9$
8	1	2	Bus2	3	Bus3	74.774	1.264	2.4348	5.6589	71.9$
9	1	2	Bus2	4	Bus4	56.847	9.021	1.8017	1.5981	55.3$
10	1	2	Bus2	5	Bus5	40.640	10.147	0.9453	-0.6512	40.3^
11	1	3	Bus3	4	Bus4	-21.522	16.542	0.5252	-2.1292	29.1^
12	1	4	Bus4	5	Bus5	-66.907	7.503	0.6143	0.6662	67.9$
13	1	6	Bus6	11	Bus11	6.832	-0.022	0.0496	0.1038	7.2&
14	1	6	Bus6	12	Bus12	17.849	5.023	0.4725	0.9834	19.6&
15	1	6	Bus6	13	Bus13	LINE IS OPEN				
16	1	9	Bus9	10	Bus10	6.161	8.119	0.0366	0.0973	10.7&
17	1	9	Bus9	14	Bus14	18.394	10.072	0.6197	1.3181	22.1&
18	1	10	Bus10	11	Bus11	-2.883	1.985	0.0114	0.0266	3.7&
19	1	12	Bus12	13	Bus13	11.261	2.299	0.3525	0.3189	12.6&
20	1	13	Bus13	14	Bus14	-2.668	-3.643	0.0452	0.0921	5.1&

Line 8-15 Open

Date and Time : Fri Feb 18 11:51:08 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.91	232.000	-5.323	0.000	0.000	0.000 #

2	Bus2	1.0400	0.00	40.270	33.815	21.700	12.700	0.000
3	Bus3	1.0100	-7.88	0.000	31.387	94.200	19.000	0.000
4	Bus4	1.0095	-5.31	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0142	-3.84	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-10.30	0.000	23.463	11.200	7.500	0.000
8	Bus8	1.0111	-7.79	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9916	-9.08	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9519	-12.13	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9715	-11.35	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9841	-11.11	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9800	-11.08	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9674	-11.10	0.000	0.000	14.900	5.000	0.000
15	DUM0001	1.0015	-7.80	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	44.582	8.426	0.0005	5.1378	180.6!
2	1	4	Bus4	9	Bus9	15.945	8.333	0.0002	1.8138	72.2$
3	1	4	Bus4	15	DUM0001	27.661	14.434	0.0002	2.0511	125.3!
4	1	9	Bus9	15	DUM0001	-28.033	-12.611	0.0000	-1.1101	31.8^
5	1	8	Bus8	15	DUM0001	LINE IS OPEN				
6	1	1	Bus1	2	Bus2	157.376	-11.777	4.2853	7.2618	148.9!
7	1	1	Bus1	5	Bus5	74.694	10.718	2.7703	6.1878	71.2$

8	1	2	Bus2	3	Bus3	74.137	0.891	2.3925	5.4769	71.3$
9	1	2	Bus2	4	Bus4	55.474	7.826	1.7054	1.2961	53.9$
10	1	2	Bus2	5	Bus5	41.300	6.881	0.9381	-0.6910	40.3^
11	1	3	Bus3	4	Bus4	-22.341	15.835	0.5314	-2.1256	29.2^
12	1	4	Bus4	5	Bus5	-59.634	-1.363	0.4784	0.2276	59.8$
13	1	6	Bus6	11	Bus11	7.632	7.773	0.1150	0.2408	11.0&
14	1	6	Bus6	12	Bus12	7.977	3.092	0.0918	0.1910	8.6&
15	1	6	Bus6	13	Bus13	18.128	9.287	0.2800	0.5514	20.6&
16	1	9	Bus9	10	Bus10	5.646	0.114	0.0111	0.0296	5.9&
17	1	9	Bus9	14	Bus14	9.359	0.923	0.1235	0.2628	9.9&
18	1	10	Bus10	11	Bus11	-3.675	-5.979	0.0446	0.1044	7.4&
19	1	12	Bus12	13	Bus13	1.771	1.168	0.0105	0.0095	2.2&
20	1	13	Bus1	14	Bus14	5.873	4.563	0.1014	0.2064	7.7&

Line 9-15 Open

Date and Time : Fri Feb 18 12:12:28 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.91	232.000	-5.323	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	40.270	33.815	21.700	12.700	0.000
3	Bus3	1.0100	-7.88	0.000	31.387	94.200	19.000	0.000
4	Bus4	1.0095	-5.31	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0142	-3.84	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-10.30	0.000	23.463	11.200	7.500	0.000
8	Bus8	1.0111	-7.79	0.000	25.000	0.000	0.000	0.000

9	Bus9	0.9916	-9.08	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9519	-12.13	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9715	-11.35	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9841	-11.11	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9800	-11.08	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9674	-11.10	0.000	0.000	14.900	5.000	0.000
15	DUM0001	1.0015	-7.80	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	59.273	17.920	0.0009	9.4914	245.5!
2	1	4	Bus4	9	Bus9	29.473	21.185	0.0007	7.2168	144.1!
3	1	4	Bus4	15	DUM0001	13.207	19.138	-0.0001	-1.1137	92.3 #
4	1	9	Bus9	15	DUM0001	LINE IS OPEN				
5	1	8	Bus8	15	DUM0001	0.436	0.6748	0.0001	0.9330	92.1 #
6	1	1	Bus1	2	Bus2	158.524	-12.046	4.3486	7.4553	150.0!
7	1	1	Bus1	5	Bus5	73.569	8.884	2.6679	5.7445	69.9$
8	1	2	Bus2	3	Bus3	70.405	1.257	2.1592	4.4942	67.7$
9	1	2	Bus2	4	Bus4	49.098	2.793	1.3076	0.0464	47.3^
10	1	2	Bus2	5	Bus5	39.194	4.980	0.8333	-1.0253	38.0^
11	1	3	Bus3	4	Bus4	-25.773	10.521	0.5355	-2.1545	29.0^
12	1	4	Bus4	5	Bus5	-41.971	9.718	0.2458	-0.5262	43.1^
13	1	6	Bus6	11	Bus11	16.716	11.113	0.4021	0.8421	20.6&

14	1	6	Bus6	12	Bus12	9.226	3.461	0.1254	0.2610	10.1&
15	1	6	Bus6	13	Bus13	22.936	11.436	0.4566	0.8991	26.3^
16	1	9	Bus9	10	Bus10	-3.016	-2.247	0.0055	0.0146	4.2&
17	1	9	Bus9	14	Bus14	3.701	-0.470	0.0216	0.0459	4.1&
18	1	10	Bus10	11	Bus11	-12.305	-8.063	0.2151	0.5036	16.2&
19	1	12	Bus12	13	Bus13	3.090	1.390	0.0278	0.0252	3.5&
20	1	13	Bus13	14	Bus14	11.784	6.132	0.3378	0.6877	14.1&

Line 9-10 Open

Date and Time : Tue Feb 15 11:05:17 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.91	232.000	-5.323	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	40.270	33.815	21.700	12.700	0.000
3	Bus3	1.0100	-7.88	0.000	31.387	94.200	19.000	0.000
4	Bus4	1.0095	-5.31	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0142	-3.84	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-10.30	0.000	23.463	11.200	7.500	0.000
8	Bus8	1.0111	-7.79	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9916	-9.08	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9519	-12.13	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9715	-11.35	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9841	-11.11	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9800	-11.08	0.000	0.000	13.500	.800	0.000
14	Bus14	0.9674	-11.10	0.000	0.000	14.900	5.000	0.000

15	DUM0001	1.0015	-7.80	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	45.288	8.266	0.0005	5.1926	181.6!
2	1	4	Bus4	9	Bus9	12.041	6.634	0.0001	0.9996	22.7&
3	1	4	Bus4	15	DUM0001	31.229	-9.154	0.0002	1.4938	32.9^
4	1	9	Bus9	15	DUM0001	-31.177	-13.386	0.0001	0.8370	68.4$
5	1	8	Bus8	15	DUM0001	0.426	25.068	0.0000	0.2369	99.2#
6	1	1	Bus1	2	Bus2	156.619	-11.600	4.2437	7.1350	148.2!
7	1	1	Bus1	5	Bus5	75.501	6.319	2.7808	6.1850	71.5$
8	1	2	Bus2	3	Bus3	73.530	0.948	2.3537	5.3136	70.7$
9	1	2	Bus2	4	Bus4	55.779	0.115	1.6741	1.1511	53.6$
10	1	2	Bus2	5	Bus5	41.635	1.317	0.9180	-0.7845	40.1^
11	1	3	Bus3	4	Bus4	-22.906	8.085	0.4084	-2.4856	25.4^
12	1	4	Bus4	5	Bus5	-59.633	7.874	0.4753	0.1888	59.7$
13	1	6	Bus6	11	Bus11	12.893	8.275	0.2229	0.4669	15.3&
14	1	6	Bus6	12	Bus12	6.855	2.968	0.0686	0.1428	7.5&
15	1	6	Bus6	13	Bus13	14.373	8.146	0.1805	0.3556	16.5&
16	1	9	Bus9	10	Bus10	LINE IS OPEN				
17	1	9	Bus9	14	Bus14	13.708	2.659	0.2521	0.5362	14.1&
18	1	10	Bus10	11	Bus11	-9.054	-5.761	0.1043	0.2441	11.3&
19	1	12	Bus12	13	Bus13	0.897	1.032	0.0043	0.0039	1.4&

20	1	13	Bus13	14	Bus14	1.467	2.828	0.0181 0.0368	3.3&

Line 9-14 Open

Date and Time : Tue Feb 15 11:05:17 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.92	232.000	-5.104	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.022	34.239	21.700	12.700	0.000
3	Bus3	1.0100	-7.84	0.000	31.554	94.200	19.000	0.000
4	Bus4	1.0092	-5.25	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0143	-3.83	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-10.45	0.000	24.589	11.200	7.500	0.000
8	Bus8	1.0100	-7.60	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9902	-8.87	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9846	-9.51	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9891	-10.14	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9796	-11.71	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9684	-12.01	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9207	-14.82	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	1.0006	-7.64	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 1
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0

NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	MVAR	LOSS MW	MVAR	% LOADING
1	1	5	Bus5	6	Bus6	46.430	8.427	0.0005	5.4551	186.1!
2	1	4	Bus4	9	Bus9	11.530	6.799	0.0001	0.9483	22.1&
3	1	4	Bus4	15	DUM0001	29.920	-8.781	0.0001	1.3723	31.6^
4	1	9	Bus9	15	DUM0001	-29.830	-14.090	0.0001	0.7936	66.6$
5	1	8	Bus8	15	DUM0001	1.825	24.685	0.0000	0.2313	98.0#
6	1	1	Bus1	2	Bus2	156.869	-11.658	4.2574	7.1769	148.4!
7	1	1	Bus1	5	Bus5	75.495	6.285	2.7801	6.1815	71.5$
8	1	2	Bus2	3	Bus3	73.131	0.987	2.3284	5.2067	70.3$
9	1	2	Bus2	4	Bus4	55.264	0.420	1.6440	1.0612	53.1$
10	1	2	Bus2	5	Bus5	41.540	1.297	0.9137	-0.7978	40.0^
11	1	3	Bus3	4	Bus4	-22.951	8.300	0.4126	-2.4738	25.5^
12	1	4	Bus4	5	Bus5	-58.015	6.355	0.4476	0.1016	58.0$
13	1	6	Bus6	11	Bus11	-0.108	5.524	0.0290	0.0607	5.5&
14	1	6	Bus6	12	Bus12	9.964	3.288	0.1353	0.2816	10.5&
15	1	6	Bus6	13	Bus13	25.921	11.376	0.5301	1.0438	28.3^
16	1	9	Bus9	10	Bus10	13.441	1.546	0.0594	0.1578	13.7&
17	1	9	Bus9	14	Bus14	LINE IS OPEN				
18	1	10	Bus10	11	Bus11	3.872	-3.942	0.0258	0.0605	5.6&
19	1	12	Bus12	13	Bus13	3.843	1.242	0.0376	0.0340	4.1&
20	1	13	Bus13	14	Bus14	15.517	5.972	0.5039	1.0259	17.2&

Line 10-11 Open

Date and Time : Tue Feb 15 11:45:51 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	1.161	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.787	51.071	21.700	12.700	0.000 >
3	Bus3	1.0100	-8.01	0.000	39.643	94.200	19.000	0.000
4	Bus4	0.9954	-5.20	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9996	-3.53	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9370	-9.28	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9852	-8.20	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9589	-9.82	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9507	-10.20	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9295	-9.64	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9228	-10.34	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9201	-10.46	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9217	-11.37	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9752	-8.23	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 5
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING

1	1	5	Bus5	6	Bus6	37.283	26.691	0.0005	5.3026	183.5!
2	1	4	Bus4	9	Bus9	14.045	10.042	0.0002	1.6219	28.9^
3	1	4	Bus4	15	DUM0001	36.455	0.094	0.0002	1.9282	37.4^
4	1	9	Bus9	15	DUM0001	-36.363	-21.300	0.0001	1.3807	87.9#
5	1	8	Bus8	15	DUM0001	1.102	25.652	0.0000	0.2616	104.2@
6	1	1	Bus1	2	Bus2	158.109	-11.949	4.3257	7.3852	149.6!
7	1	1	Bus1	5	Bus5	73.982	13.212	2.7547	6.1493	70.9$
8	1	2	Bus2	3	Bus3	74.652	0.842	2.4256	5.6164	71.8$
9	1	2	Bus2	4	Bus4	56.513	8.080	1.7707	1.4974	54.9$
10	1	2	Bus2	5	Bus5	40.705	10.114	0.9476	-0.6441	40.3^
11	1	3	Bus3	4	Bus4	-21.792	16.108	0.5218	-2.1471	29.0^
12	1	4	Bus4	5	Bus5	-65.143	11.018	0.5901	0.5877	66.6$
13	1	6	Bus6	11	Bus11	3.569	1.853	0.0175	0.0366	4.3&
14	1	6	Bus6	12	Bus12	7.099	1.875	0.0755	0.1570	7.8&
15	1	6	Bus6	13	Bus13	15.724	4.321	0.2003	0.3945	17.4&
16	1	9	Bus9	10	Bus10	9.412	5.812	0.0423	0.1124	11.5&
17	1	9	Bus9	14	Bus14	12.381	7.498	0.2896	0.6161	15.1&
18	1	10	Bus10	11	Bus11	LINE IS OPEN				
19	1	12	Bus12	13	Bus13	1.010	0.104	0.0027	0.0024	1.1&
20	1	13	Bus13	14	Bus14	2.981	-1.851	0.0249	0.0506	3.8&

Line 12-13 Open

Date and Time : Thu Feb 17 10:10:53 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP

1	Bus1	1.0600	4.93	232.000	-5.133	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.431	35.800	21.700	12.700	0.000
3	Bus3	1.0100	-7.91	0.000	32.595	94.200	19.000	0.000
4	Bus4	1.0075	-5.30	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0134	-3.75	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-9.48	0.000	19.396	11.200	7.500	0.000
8	Bus8	1.0051	-8.08	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9835	-9.52	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9786	-9.85	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9856	-9.82	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9882	-10.28	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9771	-10.50	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9614	-11.12	0.000	0.000	14.900	5.000	0.000
15	DUM0001	0.9956	-8.09	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	40.180	7.402	0.0004	4.0961	161.3!
2	1	4	Bus4	9	Bus9	13.312	7.818	0.0001	1.2657	25.5^
3	1	4	Bus4	15	DUM0001	34.710	-6.208	0.0002	1.7608	35.8^
4	1	9	Bus9	15	DUM0001	-34.150	-16.250	0.0001	1.0571	76.9#
5	1	8	Bus8	15	DUM0001	0.465	24.778	0.0000	0.2342	98.6#
6	1	1	Bus1	2	Bus2	157.177	-11.731	4.2743	7.2285	148.7!

7	1	1	Bus1	5	Bus5	74.939	6.732	2.7438	6.0361	71.0$
8	1	2	Bus2	3	Bus3	73.769	0.925	2.3689	5.3777	70.9$
9	1	2	Bus2	4	Bus4	56.010	1.238	1.6911	1.2106	53.9$
10	1	2	Bus2	5	Bus5	40.855	1.978	0.8865	-0.8779	39.3^
11	1	3	Bus3	4	Bus4	-22.708	9.227	0.4181	-2.4537	25.7^
12	1	4	Bus4	5	Bus5	-63.719	6.280	0.5403	0.3974	63.7$
13	1	6	Bus6	11	Bus11	5.239	4.767	0.0477	0.0998	7.1&
14	1	6	Bus6	12	Bus12	6.174	1.694	0.0504	0.1048	6.4&
15	1	6	Bus6	13	Bus13	17.801	8.696	0.2596	0.5113	19.8&
16	1	9	Bus9	10	Bus10	7.675	2.841	0.0220	0.0585	8.3&
17	1	9	Bus9	14	Bus14	11.133	2.959	0.1744	0.3709	11.7&
18	1	10	Bus10	11	Bus11	-1.511	-2.893	0.0091	0.0214	3.3&
19	1	12	Bus12	13	Bus13	LINE IS OPEN				
20	1	13	Bus13	14	Bus14	4.083	2.412	0.0403	0.0820	4.9&

Line 13-14 Open

Date and Time : Thu Feb 17 10:25:12 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.93	232.000	-4.774	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.515	37.072	21.700	12.700	0.000
3	Bus3	1.0100	-7.93	0.000	33.782	94.200	19.000	0.000
4	Bus4	1.0059	-5.30	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0128	-3.71	0.000	0.000	7.600	1.600	0.000
6	Bus6	1.0000	-9.16	0.000	16.916	11.200	7.500	0.000

8	Bus8	0.9994	-8.17	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9767	-9.70	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9731	-9.94	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9827	-9.70	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9863	-9.98	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9842	-9.96	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9416	-11.82	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9903	-8.20	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 1
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	38.129	6.969	0.0004	3.6910	153.1!
2	1	4	Bus4	9	Bus9	13.756	8.804	0.0001	1.4211	27.1^
3	1	4	Bus4	15	DUM0001	35.851	-3.405	0.0002	1.8425	36.6^
4	1	9	Bus9	15	DUM0001	-35.296	-18.108	0.0001	1.1794	81.2#
5	1	8	Bus8	15	DUM0001	1.544	23.613	0.0000	0.2160	94.7#
6	1	1	Bus1	2	Bus2	157.250	-11.748	4.2784	7.2407	148.8!
7	1	1	Bus1	5	Bus5	74.704	7.019	2.7296	5.9802	70.8$
8	1	2	Bus2	3	Bus3	73.995	0.904	2.3834	5.4384	71.2$
9	1	2	Bus2	4	Bus4	56.188	2.100	1.7053	1.2595	54.1$
10	1	2	Bus2	5	Bus5	40.604	2.379	0.8775	-0.9036	39.1^
11	1	3	Bus3	4	Bus4	-22.596	10.123	0.4282	-2.4223	26.1^
12	1	4	Bus4	5	Bus5	-65.492	4.520	0.5694	0.4920	65.3$

13	1	6	Bus6	11	Bus11	7.240	5.266	0.0761	0.1594	9.0&
14	1	6	Bus6	12	Bus12	6.614	2.198	0.0597	0.1243	7.0&
15	1	6	Bus6	13	Bus13	13.348	5.442	0.1375	0.2707	14.4&
16	1	9	Bus9	10	Bus10	5.587	2.053	0.0118	0.0314	6.1&
17	1	9	Bus9	14	Bus14	15.266	5.718	0.3541	0.7532	16.7&
18	1	10	Bus10	11	Bus11	-3.513	-3.350	0.0204	0.0478	5.0&
19	1	12	Bus12	13	Bus13	0.445	0.580	0.0012	0.0011	0.7*
20	1	13	Bus13	14	Bus14	LINE IS OPEN				

4.6 Generator Outage

Generator 1 Outage

Date and Time : Thu Feb 17 11:30:52 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0302	-1.08	0.000	0.000	0.000	0.000	0.000
2	Bus2	1.0400	0.00	267.270	37.234	21.700	12.700	0.000
3	Bus3	1.0067	-8.72	0.000	40.000	94.200	19.000	0.000
4	Bus4	0.9884	-6.50	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9914	-5.27	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9335	-11.01	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9767	-9.58	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9492	-11.24	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9382	-11.58	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9320	-11.49	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9186	-12.06	0.000	0.000	6.100	1.600	0.000 @

13	Bus13	0.9155	-12.16	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9140	-12.93	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9665	-9.60	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 0
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	36.676	24.629	0.0005	5.0039	178.2!
2	1	4	Bus4	9	Bus9	14.151	10.476	0.0002	1.7105	29.7^
3	1	4	Bus4	15	DUM0001	36.726	1.476	0.0002	1.9878	37.2^
4	1	9	Bus9	15	DUM0001	-36.666	-22.397	0.0001	1.4648	90.5#
5	1	8	Bus8	15	DUM0001	0.966	25.832	0.0000	0.2699	105.9@
6	1	1	Bus1	2	Bus2	-35.876	-7.816	0.2396	-4.9256	35.6^
7	1	1	Bus1	5	Bus5	35.986	7.789	0.7143	-2.0800	35.7^
8	1	2	Bus2	3	Bus3	81.201	1.940	2.8727	7.5143	78.1#
9	1	2	Bus2	4	Bus4	69.692	9.172	2.6768	4.2724	67.6$
10	1	2	Bus2	5	Bus5	58.562	10.532	1.8863	2.2496	57.2$
11	1	3	Bus3	4	Bus4	-15.725	15.622	0.3631	-2.5169	24.5&
12	1	4	Bus4	5	Bus5	-47.130	7.781	0.3132	-0.2666	48.5^
13	1	6	Bus6	11	Bus11	3.285	-0.862	0.0126	0.0263	3.6&
14	1	6	Bus6	12	Bus12	7.132	2.062	0.0777	0.1618	8.0&
15	1	6	Bus6	13	Bus13	15.731	5.027	0.2070	0.4077	17.7&
16	1	9	Bus9	10	Bus10	9.602	8.794	0.0599	0.1590	13.7&
17	1	9	Bus9	14	Bus14	12.580	6.585	0.2844	0.6051	15.0&

18	1	10	Bus10	1	Bus11	0.482	2.796	0.0075	0.0176	3.0&
19	1	12	Bus12	13	Bus13	1.042	0.270	0.0030	0.0027	1.2&
20	1	13	Bus13	14	Bus14	2.787	-0.946	0.0177	0.0360	3.2&

Generator 2 outage

Date and Time : Thu Feb 17 12:05:10 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	0.953	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.824	50.821	21.700	12.700	0.000
3	Bus3	1.0100	-8.00	0.000	39.819	94.200	19.000	0.000
4	Bus4	0.9953	-5.19	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0001	-3.54	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9421	-9.35	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9832	-8.17	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9560	-9.77	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9454	-10.07	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9400	-9.90	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9273	-10.40	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9241	-10.50	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9218	-11.36	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9733	-8.19	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 6
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1

NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	37.848	24.942	0.0005	5.1771	181.3!
2	1	4	Bus4	9	Bus9	13.870	10.539	0.0002	1.6512	29.2^
3	1	4	Bus4	15	DUM0001	35.999	1.365	0.0002	1.8833	36.2^
4	1	9	Bus9	15	DUM0001	-35.917	-22.554	0.0001	1.4069	88.7#
5	1	8	Bus8	15	DUM0001	0.876	25.396	0.0000	0.2573	103.4@
6	1	1	Bus1	2	Bus2	158.023	-11.929	4.3209	7.3707	149.5!
7	1	1	Bus1	5	Bus5	74.013	12.995	2.7536	6.1426	70.9$
8	1	2	Bus2	3	Bus3	74.646	0.843	2.4252	5.6148	71.8$
9	1	2	Bus2	4	Bus4	56.453	8.141	1.7677	1.4887	54.8$
10	1	2	Bus2	5	Bus5	40.727	9.837	0.9451	-0.6534	40.3^
11	1	3	Bus3	4	Bus4	-21.832	16.176	0.5245	-2.1398	29.0^
12	1	4	Bus4	5	Bus5	-64.922	9.640	0.5822	0.5624	66.1$
13	1	6	Bus6	11	Bus11	3.911	-0.867	0.0172	0.0360	4.3&
14	1	6	Bus6	12	Bus12	7.224	2.033	0.0780	0.1624	8.0&
15	1	6	Bus6	13	Bus13	16.025	4.993	0.2100	0.4135	17.8&
16	1	9	Bus9	10	Bus10	8.926	8.691	0.0540	0.1435	13.0&
17	1	9	Bus9	14	Bus14	12.120	6.520	0.2634	0.5603	14.4&
18	1	10	Bus10	11	Bus11	-0.173	2.738	0.0069	0.0162	2.9&
19	1	12	Bus12	13	Bus13	1.099	0.260	0.0033	0.0030	1.2&
20	1	13	Bus13	14	Bus14	3.190	-0.942	0.0222	0.0451	3.6&

Generator 3 outage

Date and Time : Fri Feb 18 10:20:02 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.96	232.000	5.536	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.703	88.144	21.700	12.700	0.000 >
3	Bus3	0.9645	-7.56	0.000	0.000	94.200	19.000	0.000
4	Bus4	0.9811	-5.10	0.000	0.000	47.800	3.900	0.000
5	Bus5	0.9899	-3.46	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9300	-9.39	0.000	-6.000	11.200	7.500	0.000 @
8	Bus8	0.9702	-8.14	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9428	-9.79	0.000	0.000	29.500	16.600	0.000 @
10	Bus10	0.9322	-10.11	0.000	0.000	9.000	5.800	0.000 @
11	Bus11	0.9272	-9.95	0.000	0.000	3.500	1.800	0.000 @
12	Bus12	0.9149	-10.46	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9115	-10.58	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9085	-11.44	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9599	-8.17	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 7
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 1

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING

1	1	5	Bus5	6	Bus6	37.725	25.466	0.0005	5.3282	183.9!
2	1	4	Bus4	9	Bus9	13.817	10.194	0.0002	1.6511	29.2^
3	1	4	Bus4	15	DUM0001	35.867	1.018	0.0002	1.9227	36.6^
4	1	9	Bus9	15	DUM0001	-35.802	-22.028	0.0001	1.4211	89.2#
5	1	8	Bus8	15	DUM0001	1.067	26.012	0.0000	0.2773	107.3@
6	1	1	Bus1	2	Bus2	158.198	-11.970	4.3306	7.4002	149.7!
7	1	1	Bus1	5	Bus5	73.903	17.732	2.8283	6.5011	71.7$
8	1	2	Bus2	3	Bus3	72.992	24.364	2.6251	6.6537	74.0$
9	1	2	Bus2	4	Bus4	57.381	16.085	1.9452	2.0795	57.3$
10	1	2	Bus2	5	Bus5	41.497	15.624	1.0673	-0.2459	42.6^
11	1	3	Bus3	4	Bus4	-23.605	-1.215	0.4015	-2.2500	24.5&
12	1	4	Bus4	5	Bus5	-65.326	0.596	0.5921	0.6243	66.6$
13	1	6	Bus6	11	Bus11	3.970	-0.548	0.0176	0.0369	4.3&
14	1	6	Bus6	12	Bus12	7.233	2.095	0.0806	0.1677	8.1&
15	1	6	Bus6	13	Bus13	16.112	5.208	0.2193	0.4318	18.2&
16	1	9	Bus9	10	Bus10	8.985	8.477	0.0546	0.1451	13.1&
17	1	9	Bus9	14	Bus14	12.161	6.398	0.2700	0.5744	14.6&
18	1	10	Bus10	1	Bus11	-0.156	2.509	0.0060	0.0140	2.7&
19	1	12	Bus12	13	Bus13	1.145	0.290	0.0037	0.0033	1.3&
20	1	13	Bus13	14	Bus14	3.220	-0.769	0.0225	0.0459	3.6&

Generator 4 outage

Date and Time : Fri Feb 18 10:50:51 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP

1	Bus1	1.0600	4.95	232.000	-0.539	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	39.791	47.065	21.700	12.700	0.000
3	Bus3	1.0100	-7.98	0.000	38.051	94.200	19.000	0.000
4	Bus4	0.9983	-5.22	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0034	-3.59	0.000	0.000	7.600	1.600	0.000
6	Bus6	0.9562	-9.38	0.000	0.000	11.200	7.500	0.000
8	Bus8	0.9886	-8.14	0.000	25.000	0.000	0.000	0.000
9	Bus9	0.9628	-9.71	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9536	-10.01	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9512	-9.88	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9411	-10.40	0.000	0.000	6.100	1.600	0.000 @
13	Bus13	0.9375	-10.49	0.000	0.000	13.500	5.800	0.000 @
14	Bus14	0.9317	-11.29	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9787	-8.16	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 3
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	38.431	20.734	0.0005	4.7730	174.1!
2	1	4	Bus4	9	Bus9	13.727	9.874	0.0002	1.5466	28.2^
3	1	4	Bus4	15	DUM0001	35.607	-0.444	0.0002	1.8289	36.5^
4	1	9	Bus9	15	DUM0001	-35.579	-20.951	0.0001	1.3147	85.8#
5	1	8	Bus8	15	DUM0001	0.743	25.361	0.0000	0.2537	102.7@

6	1	1	Bus1	2	Bus2	157.788	-11.874	4.3080	7.3311	149.3!
7	1	1	Bus1	5	Bus5	74.241	11.433	2.7473	6.1003	70.9$
8	1	2	Bus2	3	Bus3	74.446	0.861	2.4123	5.5604	71.6$
9	1	2	Bus2	4	Bus4	56.364	6.422	1.7452	1.4089	54.5$
10	1	2	Bus2	5	Bus5	40.762	7.876	0.9245	-0.7275	39.9^
11	1	3	Bus3	4	Bus4	-22.050	14.450	0.4921	-2.2331	28.1^
12	1	4	Bus4	5	Bus5	-64.699	8.807	0.5726	0.5241	65.6$
13	1	6	Bus6	11	Bus11	4.195	0.438	0.0185	0.0387	4.4&
14	1	6	Bus6	12	Bus12	7.306	2.193	0.0782	0.1628	8.0&
15	1	6	Bus6	13	Bus13	16.208	5.640	0.2131	0.4196	17.9&
16	1	9	Bus9	10	Bus10	8.590	7.313	0.0437	0.1160	11.7&
17	1	9	Bus9	14	Bus14	11.833	5.634	0.2355	0.5009	13.6&
18	1	10	Bus10	11	Bus11	-0.473	1.408	0.0020	0.0047	1.6&
19	1	12	Bus12	13	Bus13	1.168	0.411	0.0038	0.0035	1.3&
20	1	13	Bus13	14	Bus14	3.434	-0.117	0.0230	0.0467	3.7&

Generator 5 outage

Date and Time : Fri Feb 18 11:15:40 2011

BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0600	4.94	232.000	-1.616	0.000	0.000	0.000 #
2	Bus2	1.0400	0.00	40.191	46.230	21.700	12.700	0.000
3	Bus3	1.0100	-7.98	0.000	38.782	94.200	19.000	0.000
4	Bus4	0.9970	-5.17	0.000	0.000	47.800	3.900	0.000
5	Bus5	1.0058	-3.67	0.000	0.000	7.600	1.600	0.000

6	Bus6	0.9908	-9.69	0.000	25.000	11.200	7.500	0.000
8	Bus8	0.9627	-7.98	0.000	0.000	0.000	0.000	0.000
9	Bus9	0.9563	-9.47	0.000	0.000	29.500	16.600	0.000
10	Bus10	0.9542	-9.86	0.000	0.000	9.000	5.800	0.000
11	Bus11	0.9685	-9.92	0.000	0.000	3.500	1.800	0.000
12	Bus12	0.9731	-10.63	0.000	0.000	6.100	1.600	0.000
13	Bus13	0.9666	-10.64	0.000	0.000	13.500	5.800	0.000
14	Bus14	0.9408	-11.19	0.000	0.000	14.900	5.000	0.000 @
15	DUM0001	0.9623	-7.98	0.000	0.000	0.000	0.000	0.000

NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) : 1
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# mark) : 1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< mark) : 0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> mark) : 0

LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	6	Bus6	41.515	8.185	0.0004	4.4602	168.3!
2	1	4	Bus4	9	Bus9	13.052	10.765	0.0002	1.5523	28.3^
3	1	4	Bus4	15	DUM0001	33.474	10.190	0.0002	1.7706	35.1^
4	1	9	Bus9	15	DUM0001	-33.377	-7.666	0.0001	0.9169	71.6$
5	1	8	Bus8	15	DUM0001	0.003	0.869	0.0000	0.0003	3.6&
6	1	1	Bus1	2	Bus2	157.390	-11.781	4.2860	7.2641	148.9!
7	1	1	Bus1	5	Bus5	74.644	10.274	2.7610	6.1447	71.1$
8	1	2	Bus2	3	Bus3	74.425	0.863	2.4110	5.5549	71.6$
9	1	2	Bus2	4	Bus4	56.025	7.267	1.7327	1.3761	54.3$
10	1	2	Bus2	5	Bus5	41.144	6.354	0.9267	-0.7293	40.0^
11	1	3	Bus3	4	Bus4	-22.196	15.319	0.5154	-2.1691	28.8^

12	1	4	Bus4	5	Bus5	-62.501	-0.912	0.5247	0.3713	62.7$
13	1	6	Bus6	11	Bus11	5.896	8.313	0.1005	0.2105	10.3&
14	1	6	Bus6	12	Bus12	7.707	3.194	0.0871	0.1814	8.4&
15	1	6	Bus6	13	Bus13	17.175	9.770	0.2631	0.5181	19.9&
16	1	9	Bus9	10	Bus10	7.206	-0.345	0.0181	0.0481	7.5&
17	1	9	Bus9	14	Bus14	10.377	0.755	0.1505	0.3201	10.9&
18	1	10	Bus10	11	Bus11	-2.096	-6.191	0.0385	0.0901	6.8&
19	1	12	Bus12	13	Bus13	1.626	1.369	0.0105	0.0095	2.2&
20	1	13	Bus13	14	Bus14	4.860	4.805	0.0854	0.1740	7.1&

CHAPTER 5: RESULTS & DISCUSSIONS

Results of Five bus & IEEE 14 bus Test systems are discussed below.

Fuzzy Representation of contingency ranking

The four characteristic points a, b, c, d are selected between each two rankings represents performance indices. Membership functions used to evaluate the severity of contingency ranking is divided into five categories using fuzzy set notation. Here the inputs are real power & voltage indices whereas the outputs are severity indices.

Fuzzy set notations are

Very small	**0 - 0.2**	**(VS)**
Small	**0.2 - 0.4**	**(S)**
Medium	**0.4 - 0.6**	**(M)**
Large	**0.6 - 0.8**	**(L)**
Very Large	**0.8 - 1.0**	**(VL)**

Test case-1: Five bus system

CONTINGENCY RANKING: ON REAL POWER BASE

Table 1 explains the contingency ranking for five bus system when real power flow in a line is considered. Both the conventional & fuzzy ranking are indicated in the table. The line with highest performance index is most severe outage. In five bus system the line 3-4 has highest PI so is more severe & line 2-5 is less severe with least PI. Here the normal method stands for conventional method. Being the contingency index an absolute value N stands for the negative PI.

TABLE 1: Line Outage

Sl No	Line	Contingency Index	Rank	
			Normal	Fuzzy
1	2-5	N8.01298	1	L
2	1-2	N2.23573	2	M
3	1-3	N0.73349	3	S
4	2-4	N0.62305	4	L
5	2-3	0.348816	5	M
6	4-5	0.349255	6	M
7	3-4	0.415981	7	M

TABLE 2: Generator Outage

Sl No	Generator	Contingency Index	Rank	
			Normal	Fuzzy
1	2	N0.5107	1	M
2	1	1.537866	2	

In table 2 generator contingencies are considered for ranking the contingencies. The highest performance index has highest ranking. The severity is more with the highest ranked contingency. Generator 1 has large PI compared to generator 1 so is more severe.

Test case-2: Fourteen bus system

CONTINGENCY RANKING - ON REAL POWER BASE

Table 3 explains the contingency ranking for IEEE 14 bus single line contingency ranking.

TABLE 3: Line Outage

Sl No	Line	Contingency Index	Rank	
			Normal	Fuzzy
1	15-9	N76.7379	1	M
2	4-5	N58.1966	2	M
3	9-10	N52.1457	3	VS
4	4-15	N45.4315	4	L
5	6-13	N25.5319	5	S
6	1-2	N25.0169	6	S
7	15-8	N22.1002	7	M
8	13-14	N19.9686	8	L
9	4-9	N15.6251	9	L
10	2-3	N14.8806	10	M
11	2-4	N9.09582	11	VS
12	12-13	N7.57699	12	L
13	10-11	N0.08901	13	M
14	3-4	2.942988	14	M
15	6-12	3.7427	15	S
16	2-5	5.326897	16	M
17	1-5	6.9278	17	VL
18	9-14	14.77855	18	M
19	6-11	18.56171	19	L
20	5-6	137.3323	20	L

Table 4 presents generator contingency ranking. Here the generator 1 has highest contingency index & hence more severe. Whereas the generator 5 has least contingency index value therefore is less severe.

TABLE 4: Generator Outage

Sl No	Generator	Contingency Index	Rank	
			Normal	Fuzzy
1	5	N11.8692	1	M
2	4	N1.74516	2	M
3	3	N0.28909	3	VL
4	2	REF/SLACK	4	-
5	1	5.443052	5	M

Test case-1: Five bus system

CONTINGENCY RANKING: ON VOLTAGE BASE

TABLE 5: Line Outage

Sl No	Bus	Contingency Index	Rank	
			Normal	Fuzzy
1	North	REF/SLACK	1	L
2	South	0.125334	2	M
3	Lake	0.161668	3	S
4	Main	0.187839	4	L
5	Elm	0.250245	5	M

Table 6 reveals the generator contingency ranking for five bus system on voltage base. The node Elm has the largest contingency index value and hence more severe than the other following with node Main. The table gives the increasing severity order.

TABLE 6: Generator Outage

Sl No	Bus	Contingency Index	Rank	
			Normal	Fuzzy
1	North	0.057264	1	L
2	South	0.066106	2	M
3	Lake	0.06695	3	S
4	Main	0.067979	4	L
5	Elm	0.070182	5	M

Test case-2: Fourteen bus system

CONTINGENCY RANKING - ON VOLTAGE BASE

Similarly Table 7 & 8 represents the line & generator contingency ranking for IEEE 14 bus system. Table 7 indicates that node 3 has a highest performance index and hence most severe. Similarly node 6 has least performance index & hence less severe. Table 8 reveals that node 2 has largest performance index with highest severity. Here the severity is in increasing order. Table 7 indicates the single line outage & table 8 shows contingency ranking for generator outage. The fuzzy approach justify that normal method has masking effect & can be unmasked by this method. The original conventional ranking changes when fuzzy approach is used.

Sl No	Bus	Contingency Index	Rank	
			Nor mal	Fuzzy
1	6	N0.4301	1	VL
2	12	N0.36763	2	M
3	13	N0.33135	3	M
4	11	N0.20766	4	VL
5	14	N0.15405	5	S
6	9	N0.12657	6	M
7	8	N0.113	7	L
8	7	N0.08404	8	L
9	10	N0.06918	9	S
10	4	N0.018185	10	L
11	5	N0.0142	11	VS
12	1	N0.0012	12	M
13	2	REF/SLACK	13	-
14	3	0.144554	14	M

Table 7

Table 8

Sl No	Bus	Contingency Index	Rank	
			Normal	Fuzzy
1	6	N0.04469	1	M
2	12	N0.04152	2	S
3	13	N0.03755	3	M
4	11	N0.02011	4	VS
5	3	N0.01109	5	S
6	14	N0.00846	6	L
7	2	REF/SLACK	7	-
8	10	0.003596	8	M
9	5	0.009899	9	S
10	9	0.013494	10	M
11	4	0.016477	11	M
12	15	0.026508	12	VL
13	1	0.028113	13	L
14	8	0.035191	14	M

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

The proposed approach can provide the user with those outages that may cause immediate loss of load or islanding at a certain bus. This is a kind of information in which is very helpful to system operators. An overall severity index is given for which outage case. These severity indices can be used as a guideline for deciding whether corrective control actions should be taken or not.

A performance index (PI) is computed for each contingency. The PI is defined in terms of a branch based active power index & voltage index. They are used to calculate the post-contingent quantities to evaluate the network contingency ranking. The fuzzy contingency ranking method eliminates the masking effect of other methods of contingency ranking effectively.

Conventional Power flow analysis is carried out for computing bus voltage magnitude, voltage angle, real & reactive power of the system. The fuzzy system has many advantageous features such as optimized system complexity, control of power flow, control of non-linear system etc. The composition of the input variable for the proposed fuzzy logic based contingency ranking has been selected to emulate the solution process of a conventional power flow. The effectiveness of the fuzzy based contingency ranking is demonstrated for single line outage contingencies in 5- bus and 14- bus systems.

Several simulations show that the most critical contingencies can be identified correctly by using fuzzy based contingency ranking system than conventional system. Contingency ranking analysis is compulsorily employed in almost every power system of the world.

Suggestions for further work

1. Contingency ranking for a given system can be calculated by using
    - combinational line outage
    - Combined line & generator outage.
2. Preparedness for contingency can be done.
3. Fuzzy logic toolbox can be utilized for ranking the contingency.

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APPENDICES

Appendix A-1

BASE CASE 1 : FIVE BUS SYSTEM

Figure shows single line diagram of 5 bus system with 2 generating units, seven lines, p.u. transmission line series impedances & shunt susceptances are given on 100MVA base in table 1.1. Real power generation, real & reactive power loads in MW & MVAR are given in table 1.2.With bus 1 as slack, use the following methods to obtain a load solution.

Gauss –Siedal using y-bus with acceleration factors of 1.4 tolerances of 0.0001 & 0.0001 p.u for the real & imaginary components of voltage. Assume the base voltage for the bus as 220kv & system frequency as 60Hz. Impedances & line charging for the sample system

Table:1.1

Bus code From To	Impedance R+JX	Line charging B/2
1-2	0.02+j0.06	0.0+j0.030
1-3	0.08+j0.24	0.0+j0.025
2-3	0.05+j0.18	0.0+j0.02
2-4	0.06+j0.18	0.0+j0.02
2-5	0.04+j0.12	0.0+j0.015
3-4	0.01+j0.03	0.0+j0.010
4-5	0.08+j0.24	0.0+j0.025

Generation, loads & bus voltages for sample system

Bus no	Bus voltage	Generation MW	Generation MVAR	Load MW	Load MVAR
1	1.06+J0.0	0	0	0	0
2	1.00+J0.0	40	30	20	10
3	1.00+J0.0	0	0	45	15
4	1.00+J0.0	0	0	40	5
5	1.00+J0.0	0	0	60	10

Table 1.2

APPENDIX A IEEE 14 BUS TEST SYSTEM

Table A.4: Line Data

From Bus	To Bus	Resistance (p.u.)	Reactance (p.u)	Line charging (p.u.)	tap ratio
1	2	0.01938	0.05917	0.0528	1
1	5	0.05403	0.22304	0.0492	1
2	3	0.04699	0.19797	0.0438	1
2	4	0.05811	0.17632	0.0374	1
2	5	0.05695	0.17388	0.034	1
3	4	0.06701	0.17103	0.0346	1
4	5	0.01335	0.04211	0.0128	1
4	7	0.00	0.20912	0.00	0.978
4	9	0.00	0.55618	0.00	0.969
5	6	0.00	0.25202	0.00	0.932
6	11	0.09498	0.1989	0.00	1
6	12	0.12291	0.25581	0.00	1
6	13	0.06615	0.13027	0.00	1
7	8	0.00	0.17615	0.00	1
7	9	0.00	0.11001	0.00	1
9	10	0.03181	0.08450	0.00	1
9	14	0.12711	0.27038	0.00	1
10	11	0.08205	0.19207	0.00	1
12	13	0.22092	0.19988	0.00	1
13	14	0.17093	0.34802	0.00	1

APPENDIX A IEEE 14 BUS TEST SYSTEM

Table A.2: Generator data

Generator bus no.	1	2	3	4	5
MVA	615	60	60	25	25
x_l (p.u.)	0.2396	0.00	0.00	0.134	0.134
r_a (p.u.)	0.00	0.0031	0.0031	0.0014	0.0041
x_d (p.u.)	0.8979	1.05	1.05	1.25	1.25
x'_d (p.u.)	0.2995	0.1850	0.1850	0.232	0.232
x''_d (p.u.)	0.23	0.13	0.13	0.12	0.12
T'_{do}	7.4	6.1	6.1	4.75	4.75
T''_{do}	0.03	0.04	0.04	0.06	0.06
x_q (p.u.)	0.646	0.98	0.98	1.22	1.22
x'_q (p.u.)	0.646	0.36	0.36	0.715	0.715
x''_q (p.u.)	0.4	0.13	0.13	0.12	0.12
T'_{qo}	0.00	0.3	0.3	1.5	1.5
T''_{qo}	0.033	0.099	0.099	0.21	0.21
H	5.148	6.54	6.54	5.06	5.06
D	2	2	2	2	2

APPENDIX A IEEE 14 BUS TEST SYSTEM

Table A.3: Bus data

Bus No.	P Generated (p.u.)	Q Generated (p.u.)	P Load (p.u.)	Q Load (p.u.)	Bus Type*	Q Generated max.(p.u.)	Q Generated min.(p.u.)
1	2.32	0.00	0.00	0.00	2	10.0	-10.0
2	0.4	-0.424	0.2170	0.1270	1	0.5	-0.4
3	0.00	0.00	0.9420	0.1900	2	0.4	0.00
4	0.00	0.00	0.4780	0.00	3	0.00	0.00
5	0.00	0.00	0.0760	0.0160	3	0.00	0.00
6	0.00	0.00	0.1120	0.0750	2	0.24	-0.06
7	0.00	0.00	0.00	0.00	3	0.00	0.00
8	0.00	0.00	0.00	0.00	2	0.24	-0.06
9	0.00	0.00	0.2950	0.1660	3	0.00	0.00
10	0.00	0.00	0.0900	0.0580	3	0.00	0.00
11	0.00	0.00	0.0350	0.0180	3	0.00	0.00
12	0.00	0.00	0.0610	0.0160	3	0.00	0.00
13	0.00	0.00	0.1350	0.0580	3	0.00	0.00
14	0.00	0.00	0.1490	0.0500	3	0.00	0.00

*Bus Type: (1) swing bus, (2) generator bus (PV bus), and (3) load bus (PQ bus)