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Load Flow Analysis of Grid Disturbance using Newton Raphson Iterative Method on Hypothetical Three Bus System

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Abstract — *The blackout of power system in India in 2012 has indicated that the operation and control of power systems may need to be improved. Even if a lot of data was available, the operators at different control centers did not take the proper actions in time to prevent the blackout. This depends partly on the reorganization of the control centers after the deregulation and partly on the lack of reliable decision support systems when the system is close to instability. Today a large problem for system operators is to identify critical states since there are thousands of parameters which describe and affect the state. Motivated by these facts, in this dissertation, we have consider a hypothetical three bus system and by using Newton –Raphson iterative method we have compare variation in voltage magnitude(V) and bus voltage angle(δ). Due to which, there is significant changes in both active and reactive power (more specifically reactive power).We have verified our results by using MATLAB Program for power flow studies using Newton –Raphson Method. This Paper concludes that FACTS is a technology which provides a methodology for the utilities to effectively utilize their assets, enhance transmission capability by loading lines to their full transmission capability, and therefore, minimize the gap between the stability and the thermal limits, and improve grid reliability.*

Keywords- *Grid disturbance, Newton –Raphson, Three bus system.*

I. INTRODUCTION

In India, Power system for planning and operational purposes is divided into five regional grids. The synchronously connected NEW Grid comprising of the Northern, Western, Eastern, Southern and North-Eastern Grids. The All India demand met is of the order of 110,000 MW currently. There have been major grid disturbances on the 30th and the 31st July 2012 which have affected large parts of the Indian Electricity Grids. Due to high load and failure of monsoon, Northern Region was drawing a large quantum of power from neighboring Western and Eastern Grids whereas due to rains in Western Region demand was less and it was under drawing. This situation led to a much skewed load generation balance among the regions. A large quantum of power was flowing from the Western Grid to the Northern Grid directly as well as through the Eastern Grid and the system was under stress. Even if a lot of data was available, the operators at different control centers did not take the proper actions in time to prevent the blackouts. This depends partly on the reorganization of the control centers after the deregulation and partly on the lack of reliable decision support systems when the system is close to instability. Today a large problem for system operators is to identify critical states since there is thousands of parameter which describe and affect the state. If the power system is close to the stability limit, actions must be taken by system operators to counteract a prospective blackout.The deregulation of the power markets has contributed to the fact that the power systems today are frequently operated close to stability limit. Motivated by these facts, in this dissertation, we have consider a hypothetical three bus system and by using Newton –Raphson iterative method we have compare variation in voltage magnitude(V) and bus voltage angle(δ).we have verified our results by using MATLAB Program for power flow studies using Newton –Raphson Method.

II. POWER SYSTEM CONTROL

This paper provides overview of power system operation and the security limits that are taken to maintain system stability in stressed situations.

2.1 Power System Stability

The stability of power systems is defined as: "The ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact". This means that some faults should not cause any instability problems.

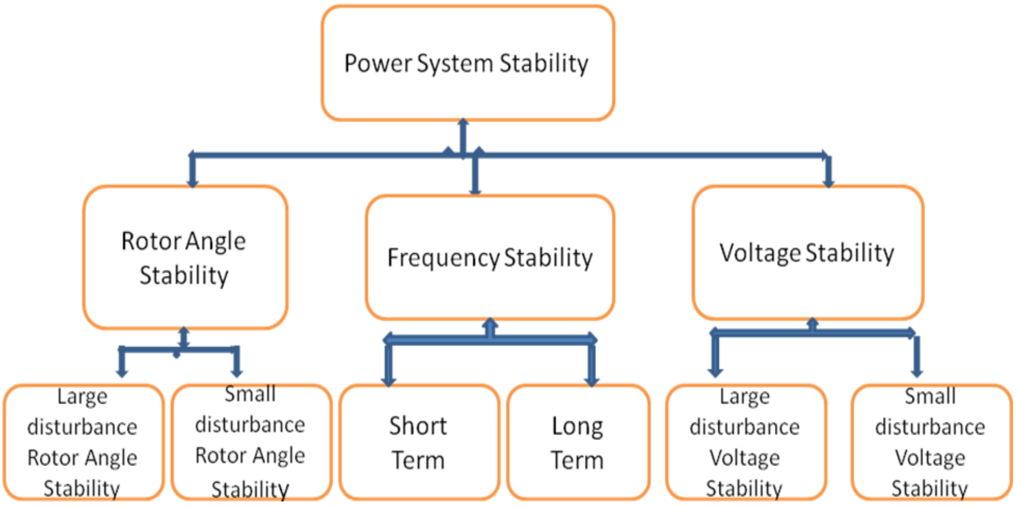

Figure 1. Classification of power system stability

When two or more synchronous machines are interconnected, the stator voltages and currents must have the same frequency and the rotor mechanical speed of each machine is synchronized to this frequency. To change the electrical torque (or power) output of the generator, the mechanical torque input is changed to advance the rotor to a new position relative to the revolving magnetic field of the stator.

2.2 Concept of Power System Stability

Considering a transmission line of reactance X pu (negligible resistance) connecting two points (stiff buses) in a power system as shown in fig. 2(a).The corresponding phasor diagram is shown in fig.2(b).

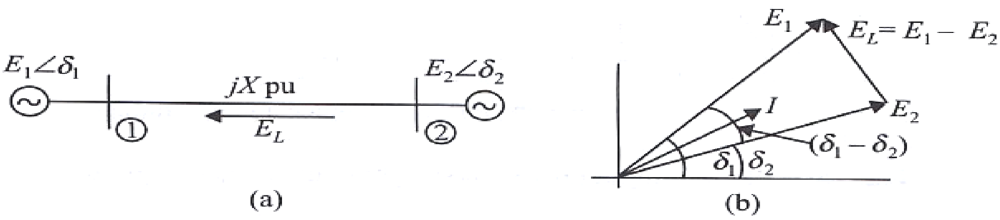

Figure 2. Single line diagram and phasor diagram of a two-machine system

The line current legs the line voltage drop $E_L = (E_1\text{-}E_2)$ by 90º and is given by

$I = E_L/X$

Or

$I = E_1\text{-}E_2/X$ (1)

Active Power flow P along the line is given by

$P = (|E_1|\,|E_2|/X)\,\text{Sin}\,\delta$ (2)

Where $\delta = \delta_1\text{-}\delta_2$. Similarly reactive power flows Q_1 and Q_2 are expressed as

$Q_1 = (1/X)\,(|E_1|^2\text{-}|E_1||E_2|\cos\delta)$ (3)

And $Q_2 = (1/X)\,(|E_2|^2\text{-}|E_1||E_2|\cos\delta)$ (4)

A phasor diagram identifying the relationships between generator and motor voltages is shown in Figure 3. The power transferred from the generator with reactance of XG to the motor with reactance of XM through a transmission line with reactance of XL is given by Equation 1.

$$P = \frac{E_G E_M}{X_T}\sin\delta \qquad (5)$$

where

$$X_T = X_G + X_L + X_M$$

The corresponding power versus angle relationship is plotted in Figure 3. In the equivalent model, an idealized model is used which makes the power varies as a sin of the angle. However, with a more accurate machine models including the effects of automatic voltage regulators, the variation in power with angle would deviate significantly from the sinusoidal relationship, but the general form would be similar. As the angle is increased, the power transfer increases up to a maximum. After a certain angle, normally 90°, a further increase in angle results in a decrease in power. When the angle is zero, no power is transferred.

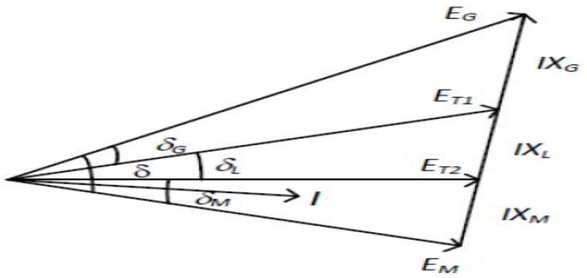

Figure 3. Phasor diagram or power transfer characteristic of a two-machine system

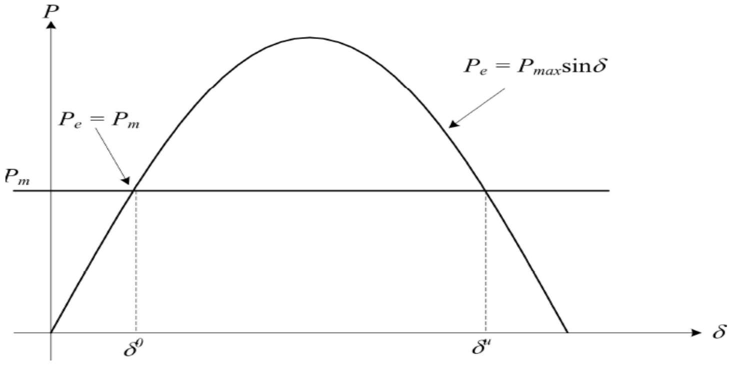

Figure 4. Power-angle characteristic of a two-machine system

From Figure 3, there are two points of interest: stable equilibrium point δ^0 (SEP), and the unstable equilibrium point δ^u (UEP). In the steady-state status, the system rests on the SEP where the mechanical power is equal to the electrical power. However, if the system swings to the UEP, where the mechanical power is equal to the electrical power graphically, the synchronous machine loses synchronism (unstable). Note that the system is assumed to be lossless. When there are more than two machines, their relative angular displacements affect the interchange of power in a similar manner. However, limiting values of power transfers and angular separation are a complex function of generation and load distribution.

Stability is a condition of equilibrium between opposing forces. The mechanism by which interconnected synchronous machines maintain synchronism with one another is through restoring forces, which act whenever there are forces tending to accelerate or decelerate one or more machine with respect to other machines. In steady-state, there is equilibrium between the input mechanical torque and the output electrical power of each machine, and the speed remains constant. However, if the system is perturbed, this equilibrium is disturbed resulting in acceleration or deceleration of the rotors of the machines according to the laws of motion of a rotating body [1]. If one generator runs faster than the other, the rotor angle of the faster machine relative to the rotor angles of the slower machines will change and that particular machine may lose synchronism causing disturbance to the other machines. As previously discussed, beyond a certain limit, an increase in angular separation is accompanied by a decrease in power transfer; this increases the separation further which leads to instability. For any given situation, the stability of the system depends on whether or not the deviations in angular positions of the rotors result in sufficient restoring torque.

Loss of synchronism can occur between one machine and the rest of the system or between groups of machines. In this case, synchronism may be maintained within each group after its separation from the others. The change in electrical torque of a synchronous machine following a perturbation can be resolved into two components:

$$\Delta T_e = T_s \Delta\delta + T_D \Delta\omega \tag{6}$$

where in Equation 2, $T_s\Delta\delta$ is the component of torque change in phase with the rotor angle perturbation $\Delta\delta$ and is referred to as synchronizing torque component; Ts is the synchronizing torque coefficient.

$T_D\Delta\omega$ is the component of torque change in phase with the speed deviation $\Delta\omega$ and is referred to as the damping torque component; TD is the damping torque coefficient.

Lack of sufficient synchronizing torque may result in instability through an aperiodic drift in rotor angle. On the contrary, lack of sufficient damping torque results in oscillatory instability. Variation of magnitudes of voltage E1and /or E2 change the power flow. Fig 5 shows the phasor diagram when the magnitude of E1 is increased to E1'.The phasor diagram shows that with a change in magnitude of E1, the voltage drop E_L does not change significantly but its phase angle varies. It is observed from the current phasor I and I' corresponding to the voltage drops E_L and E_L' that the change in magnitude of E_1 and /or E_2 influences the reactive power flow more than the real power.

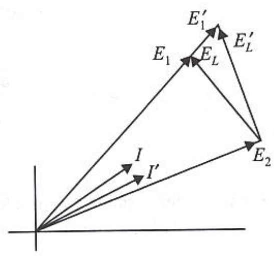

Figure 5. Phasor diagram when voltage magnitude of E_1 is increased

Power flow and current flow over the transmission line can also be varied by injecting voltage in series with the line, that is, by varying the line voltage drop E_L. When voltage is injected in series with the line. Since the injected voltage is in series with the line voltage drop (and approximately in phase quadrature with the line current), it directly affects the line current and a small change in angle influences the reactive power flow considerably.

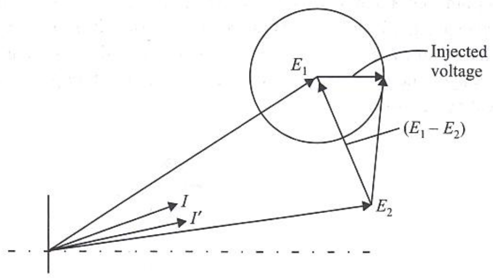

Figure 6. Phasor diagram for variable magnitude and phase angle series voltage injection

In case the magnitude of the voltage being injected in series and its phase angle are varied, there is variation of both the real and reactive components of line current. Fig.6 shows the phasor diagram for the case of series voltage injection with variable magnitude and phase angle. It may be observed that by varying the magnitude and phase angle of the voltage injected in series, both the active and reactive power flow can be changed.

III. GRID DISTURBANCE

Due to the complexity of power systems, the different instabilities affect each other. A blackout scenario often starts with a single stability problem but after the initial phase other instability problems may occur. Therefore the actions in order to prevent a blackout in stressed situations may be different. Due to mainly economical factors there is a limit of which faults the system should withstand and remain in stability.

3.1 Grid Disturbance on 30th July 2012

A disturbance occurred in the Northern India electricity grid at 0233 hours of 30th July 2012 leading to a blackout in nearly the entire Northern region covering all the 8 States i.e., the States of Delhi, Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Himachal Pradesh and Jammu and Kashmir as well as the Union Territory of Chandigarh. The frequency just before the incident was 49.68 Hz. The All India Demand Met prior to the incident was about 99700 MW and the demand being met in the Northern Region was about 38000 MW. Small pockets of generation and loads in the Northern Region survived the blackout which comprised of 3 generating units at Badarpur thermal power station with approximately 250 MW load in Delhi, Narora Atomic Power Station in UP on house load some parts of Rajasthan system (around Bhinmal) that remained connected to the Western Grid with a load of about 100 MW and some parts of Uttar Pradesh system (around Sahupuri) that remained connected with Eastern region. Some load of Western Region (around Gwalior area) remained connected to NR via 400 kV Gwalior-Agra-I.

Immediately after the disturbance, restoration of the affected areas was taken up. Startup supply was extended to the thermal power stations and essential loads by taking assistance from the neighboring Eastern and the Western Grids. Hydro generation was self started at Uri and Salal in J & K; Chamera-1, Nathpa Jhakri ,Karcham Wangtoo, Bhakra and Pong in Himachal Pradesh; and Chibro/Khodri HEP in Uttarakhand. Supply was extended to all emergency loads such as Railways, Metros and airport mostly by about 0800 hours. By 1000 hours of 30th July 2012, nearly 40% of the antecedent load (more than 15000MW) had been restored covering most of the towns and all thermal power stations were extended start up supply. The Northern Regional System was fully restored by 1600 Hrs.

The power supply position prior to the grid disturbance at 0200 Hrs, in terms of generation, demand met and import from other regions for all Regions, is indicated diagrammatically below in Fig 3.1. Import from Bhutan was about 1127 MW and 1900 MW power was being transmitted to SR from the NEW Grid. A demand of 38322 MW was being met by the Northern Grid at 0200 hrs prior to the disturbance.

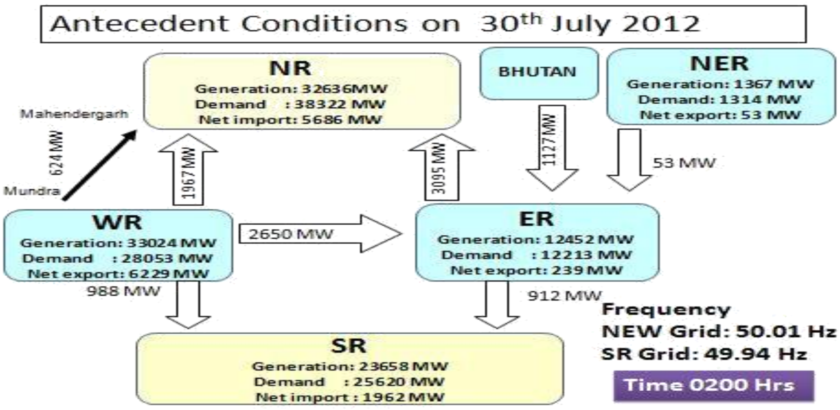

Figure 7. Antecedent Conditions on 30th July 2012 before disturbance

The power supply position prior to the grid disturbance at 0230 Hrs, in terms of import/ export from other regions for all Regions.

3.2 Grid Disturbance on 31st July 2012

Another disturbance that occurred at 1300 hours of 31st July 2012 affected the Northern, Eastern and North-Eastern electricity grids. The frequency before the incident was 49.84 Hz. The All India Demand Met just prior to the incident was about 100,500 MW and the demand being met in the NEW Grid was 73000 MW approximately. Approximately 48000MW of consumer load across 21 States and 1 Union Territory was affected by the grid disturbance. The areas which survived included Western Region, generating units at Narora Atomic Power Station, Anta GPS, Dadri GPS and Faridabad GPS as well as part of Delhi system in NR and system comprising of Sterlite/IB TPS, Bokaro Steel and CESC Kolkata systems in ER. Immediate steps were initiated for restoration of the areas affected in the incident. Start up supply was extended from the Western Region and the Southern Region which were intact. Several hydro units in the Northern Region, Eastern Region and North-Eastern Region were self started. Supply was extended to emergency loads such as Railways, Metro, Mines and Airports, etc.

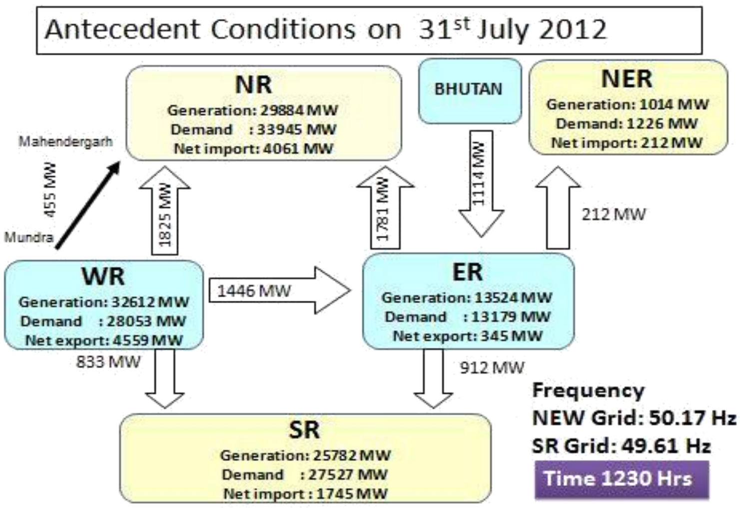

Figure 8. Antecedent Condition on 31th July 2012 before disturbance

All emergency loads such as Railways, Metros and airport were provided with power supply mostly by about 1530 hours approximately. The system was restored fully by about 2130 hrs of 31st July 2012. The power supply position prior to the grid disturbance at 1230 Hrs, in terms of generation, demand met and import from other regions for all Regions. Import from Bhutan was about 1114 MW and 1745 MW power was being transmitted to SR from the NEW Grid. A total demand of 76403 MW was being met by the NEW Grid (North-East-West and North-East Grids) prior to the disturbance. The demand met by the Northern Region was 33945 MW, Western Region was 28053 MW, Eastern Region was 13179 MW and the North-Eastern Region was 1226 MW. The power supply position prior to the grid disturbance at 1257 Hrs, in terms of import / export from other regions for all Regions.

IV. HYPOTHETICAL THREE BUS SYSTEM AND NEWTON –RAPHSON ITERATIVE METHOD

Power flow studies, commonly known as load flow, forms an important part in power system analysis. They are necessary for planning, economic scheduling and control of an existing system as well as planning its future extension. The problem consists of determining magnitude and phase angle of voltages at each bus and active and reactive power flow in each line. In solving a power flow problem, the system is assumed to be operating under in balanced conditions and a single-phase model is used. Four quantities are associated with each bus. These are voltage magnitude $|V|$, phase angle δ, real power P, and reactive power Q. The system buses are generally classified into three into three types:-

4.1 Classification of buses:

4.1.1 Slack bus

One bus, known as slack or swing bus, is taken as reference where the magnitude and phase angle of the voltage are specified. This bus makes up the difference between the scheduled loads and generated power that are caused by the losses in the network.

4.1.2 Load bus

At these buses the active and reactive powers are specified. The magnitude and the phase angle of the bus voltage are unknown. These buses are also called P-Q buses.

4.1.3 Regulated buses

These buses are the generator buses. They are also called voltage-controlled buses. At these buses, the real power and voltage magnitude are specified. The phase angles of the voltages and the reactive power are to be determined. The limits on the value of the reactive power are also specified. These buses are also called P-V buses.

4.2 Newton-Raphson (N-R) Methods

The Newton- Raphson method is the most widely used method for solving simultaneous, non-linear algebraic equations. N-R method is an iterative procedure based on an initial estimate of the unknown variables and the use of Taylor's series expansions. Before extending the method to non-linear algebraic equations, it is helpful to illustrate the solution of a non linear equation in one variable and then generalize it for the n-dimensional case.

4.3 Algorithm for Power flow solution by Newton-Raphson (N-R) Methods

Step1 Initialize the N-R iterative process by setting the iteration count k=0and set the voltage magnitude $|V_i|^0$ equal to slack bus voltage or equal to 1.0.Set the bus voltage angle δ_i^0 equal to zero for the P-Q or load buses. Set the voltage angles δ_i^0 equal to zero for the P-V or voltage-controlled buses.

Step2 For the load buses, compute the real and reactive powers by using below (7) and (8) equations respectively.

$$P_i=|V_i|\sum_{k=1}^{n}|Y_{im}||V_m|\cos(\theta_{im}-\delta_i+\delta_m)$$

For i= 1, 2, 3 …n (7)

$$Q_i=|V_i|\sum_{m=1}^{n}|Y_{im}||V_m|\sin(\theta_{im}-\delta_i+\delta_m)$$

For i= 1, 2, 3 …n (8)

Then compute power residuals using equations (9) and (10) respectively.

$$\Delta P_i^k=P_i^{sp}-P_i^k$$

For i= 1, 2, 3 …n (9)

$$\Delta Q_i^k=Q_i^{sp}-Q_i^k$$

For i= 1, 2, 3 …n (10)

For voltage-controlled buses, real power at the buses is calculated by equation (1) then compute $[\Delta P_i^k]$ using equation (9).

Step3 Compute the elements of Jacobian matrix by computing the sub-matrices $[J_1^k]$, $[J_2^k]$, $[J_3^k]$ and $[J_4^k]$, using equations (11) to (18).

$$\partial P_i/\partial\delta_i=\sum_{m\neq i}|V_i||V_m||Y_m|\sin(\theta_{im}-\delta_i+\delta_m) \quad (11)$$

$$\partial P_i/\partial\delta_m=-|V_i||V_m||Y_m|\sin(\theta_{im}-\delta_i+\delta_m) \quad (12)$$

The diagonal and off- diagonal elements of $[J_2]$ are

$$\partial P_i/\partial|V_i|=2|V_i||Y_{im}|\cos\theta_{ii}+\sum_{m\neq i}|Y_{im}||V_m|\cos(\theta_{im}-\delta_i+\delta_m) \quad (13)$$

$$\partial P_i/\partial|V_m|=|V_i||V_m|\cos(\theta_{im}-\delta_i+\delta_m) \quad \text{for } m\neq i \quad (14)$$

The diagonal and off-diagonal elements of $[J_3]$ are

$$\partial Q_i/\partial\delta_i=\sum_{m\neq i}|V_i||V_m||Y_{im}|\cos(\theta_{im}-\delta_i+\delta_m) \quad (15)$$

$$\partial Q_i/\partial\delta_m=-|V_i||V_m||Y_m|\cos(\theta_{im}-\delta_i+\delta_m) \quad \text{for } m\neq i \quad (16)$$

The diagonal and off-diagonal elements of $[J_4]$ are

$$\partial Q_i/\partial|V_i|=-2|V_i||Y_{im}|\sin\theta_{ii}-\sum_{m\neq i}|Y_{im}||V_m|\sin(\theta_{im}-\delta_i+\delta_m) \quad (17)$$

$$\partial Q_i/\partial|V_m|=|V_i||V_m|\sin(\theta_{im}-\delta_i+\delta_m) \quad \text{for } m\neq i \quad (18)$$

Step 4 Solve equations (13), by either forward or backward substitution (Gauss elimination or the MATLAB function (\) for computing the inverse of a matrix, to obtain $\Delta\delta_i^k$ and ΔV_i^k.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\partial P_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_2}{\partial \delta_n}^{(k)} & \frac{\partial P_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_2}{\partial |V_n|}^{(k)} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_n}{\partial \delta_n}^{(k)} & \frac{\partial P_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_n}{\partial |V_n|}^{(k)} \\ \hline \frac{\partial Q_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(k)} & \frac{\partial Q_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_2}{\partial |V_n|}^{(k)} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_n}{\partial \delta_n}^{(k)} & \frac{\partial Q_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_n}{\partial |V_n|}^{(k)} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix} \tag{19}$$

Step5 Compute the new estimates of bus voltage magnitudes and voltage angles by using equation (20).

$$\begin{aligned} \delta_i^{(k+1)} &= \delta_i^{(k)} + \Delta \delta_i^{(k)} \\ |V_i^{(k+1)}| &= |V_i^{(k)}| + \Delta |V_i^{(k)}| \end{aligned} \tag{20}$$

Step 6 Apply the following test for convergence.

$|\Delta P_i^k| = |P_i^{sp} - P_i^k| \leq$ tolerance

$|\Delta Q_i^k| = |Q_i^{sp} - Q_i^k| \leq$ tolerance

The power mismatch at each bus is used to specify the tolerance which is usually of 0.01 Pu for real and active powers. If the tolerance condition for each bus is satisfied, the solution of the power flow equation has been obtained, if not, put k=k+1, and go to Step 2.

4.4 Hypothetical three bus system and its solution by analytical method

For the Three bus power system network shown below, compute the bus voltage using the Newton-Raphson iterative technique. Line reactance and loads are shown in the figure. Bus 1 is the slack bus and bus 2 and bus3 are the load and voltage-control buses, respectively. Assume tolerance equal to 0.00001, P_{G3}=1.0pu, P_{L2}=1.0pu, Q_{L2}=0.8pu, V_1=1.04

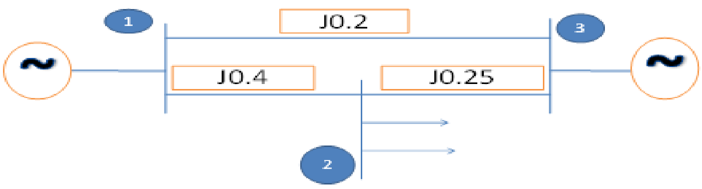

Figure 9. Hypothetical three bus system

The Y_{bus} matrix in polar of the system is calculated and given as follows:

Y_{bus}=

$$\begin{vmatrix} 7.5000 & 2.5000 & 5.000 \\ 2.5000 & 6.5000 & 4.000 \\ 5.0000 & 4.0000 & 9.000 \end{vmatrix}$$

And

$[\theta]$=

$$\begin{vmatrix} -1.5708 & 1.5708 & 1.5708 \\ 1.5708 & -1.5708 & 1.5708 \\ 1.5708 & 1.5708 & -1.5708 \end{vmatrix}$$

Step1: Assume V_2^0=1.04 and δ_2^0=0 radians; for the voltage-controlled bus, take δ_3^0=0 radians.

Step2: Employing equation (1) and (2), the real and reactive powers for bus2 and the real power for bus3are computed as follows:

P_2= 1.04*[2.5*1.04* cos (-1.5708) + 6.5*1.04*cos (1.5708) +4.0*1.005*cos (-1.5708)] =0

Similarly, P_3=0

Q_2=1.04*[2.5*1.04*sin (-1.5708) +6.5*1.04*sin (1.5708) + 4.0*1.005*sin (-1.5708)] =0.1456

$\Delta P_2=P_2^{sp}-P_2=-1.0-0 = -1.0$
$\Delta P_3=P_3^{sp}-P_3=-1.0-0 = -1.0$
$\Delta Q_3=Q_3^{sp}-Q_3=-0.8-0.1456 = -0.9456$

Use equation (5) to (12) to compute the element of [J1], [J2], [J3] and [J4].Thus
$\partial P_2/\partial \delta_2=6.8848$,
$\partial P_2/\partial \delta_3=-4.1808$,
$\partial P_3/\partial \delta_2=-4.1808$ and
$\partial P_3/\partial \delta_3=9.4068$.
[J1]=

$$\begin{vmatrix} 6.8848 & -4.1808 \\ -4.1808 & 9.4608 \end{vmatrix}$$

$\partial P_2/\partial V_2=0$, $\partial P_3/\partial V_2=0$
[J2]=

$$\begin{vmatrix} 0 \\ 0 \end{vmatrix}$$

$\partial Q_2/\partial \delta_2=0$
$\partial Q_2/\partial \delta_3=0$
[J3]= [0 0]
$\partial Q_2/\partial V_2= 6.9$

Therefore, the Jacobian matrix is formulated as follows:
[J]=

$$\begin{vmatrix} 6.8848 & -4.1808 & 0.0000 \\ -4.1808 & 9.4068 & 0.0000 \\ 0.0000 & -0.0000 & 6.9000 \end{vmatrix}$$

Step 3:

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = [J]^{-1} \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_2 \end{bmatrix} = \begin{matrix} -0.1105 \\ 0.0572 \\ -0.1370 \end{matrix}$$

Step 4: the new δ_2, δ_3, and V_2 are estimated, that is,
$\delta_2 =0-0.1105 =-0.1105$, $\delta_3 =0+0.0572=0.0572$,
$V_2=1.04-0.1370=0.9030$.
The results of subsequent iteration are as follow:

Table 1 Result of subsequent iteration

Iteration	V_2	δ_2	δ_3	ΔP_2	ΔP_3	ΔQ_2	$\Delta\delta_2$	$\Delta\delta_3$	ΔV_2
2	0.9030	-0.1105	0.0572	0.1352	0.0954	-0.1873	-0.0279	0.0026	-0.0410
3	0.8619	-0.1384	0.0598	-0.008	0.0053	-0.0122	-0.0021	0.0001	-0.0031
4	0.8589	-0.1405	0.0599	<<0.01	<<0.01	<<0.01	<<0.0001	<<0.0001	<<0.0001

We have verified our results by using MATLAB Program for power flow studies using Newton –Raphson Method. Results and MATLAB Program are mentioned in appendices. As we have seen line reactance X Pu (negligible resistance), system voltage magnitudes in per unit |V| and Phase angle δ, are three factors which effect power system stability. Out of which, |V| and δ has major effect on power system stability.
As we have discussed above, when the magnitude of E1 is increased to E1'.The phasor diagram shows that with a change in magnitude of E1, the voltage drop E_L does not change significantly but its phase angle varies. It is observed from the current phasor I and I' corresponding to the voltage drops E_L and E_L' that the change in magnitude of E_1 and /or E_2 influences the reactive power flow more than the real power. We have concluded same in Table 4.1 (Result of subsequent iteration) with the change in voltage magnitude V_2 phase angle δ_2 and δ_3 changes, due to this, there is significant changes in both active and reactive power (more specifically reactive power).
FACTS (Flexible alternative current transmission systems) technology utilizes thyristor-controlled fast acting controllers to control the following: line reactance X, magnitude of terminal voltages, magnitude of line voltage drop and the phase difference angle δ to control the transmission line loading.
FACTS is a technology which provides a methodology for the utilities to effectively utilize their assets, enhance transmission capability by loading lines to their full transmission capability, and therefore, minimize the gap between the

stability and the thermal limits, and improve grid reliability. The FACTS technology is based on the use of reliable high-speed power electronics, advanced control technology, advanced microcomputers, and powerful analytical tools. The key feature is the availability of power electronic switching devices at high kV and KA levels.

V. CONCLUSION

Ensuring integrated operation is a collective responsibility. The strengthening of Load Dispatch Centers in terms of adequacy and competence of manpower as well as availability of suitable tools would enhance the effectiveness and efficiency of Load Dispatch Centers. While several initiatives are being taken for empowerment of the Load Dispatch Centers, the grid disturbance has emphasized the need for a greater thrust at institutional capacity building of the Load Dispatch Centers in India. It is seen that both real (active) and reactive power on transmission line are dependent on line reactance X, voltage magnitude |V|, line voltage drop, and the phase angle (δ). As we have seen in our results two deciding factors which were more responsible for grid disturbance on 30th and 31st of July 2012 were voltage magnitude and Phase angle (δ).These quantities are both interrelated, so it is quite important to control these quantities form stability point of view. It is also important to use new techniques like FACTS more, which enables the power utilities to load their transmission lines to their full thermal capability and in addition has the ability to control power compromising on the security of supply.

On the other hand, it may also be clarified that since FACTS technology increases the power transmission capability of lines it may not be understood that it precludes either the need for enhancing the transmission capacity of lines, when thermal limits permits, or the need to set up new transmission line.

The factor which decides between the use of FACTS technology and the need to upgrade existing lines or add new lines is determined from an economical evaluation of the cost of losses on an existing transmission line plus the cost of FACTS technology against the cost of a new transmission line.

Following action has to be taken to ensure secure operation:

1. Special protection schemes to shed load in case of loss of injection should be implemented.
2. Transfer capability of inter-regional links and other critical links should be reviewed in consultation with CEA and CTU.
3. Extensive audit of protection system should be initiated.
4. Utilities/generators are being asked not to deviate from schedule irrespective of system frequency.
5. All states should ascertain preparedness of power system defense plans and cooperate at the regional level for coordinating their protection systems.
6. States should prepare plans in long term, medium term and short term horizons for procurement of power, network and demand management in accordance with Indian Electricity Grid Code (IEDC).

States Should carries out periodically power system studies for operation planning and transfer capability determination.

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