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CONTINGENCY ANALYSIS IN DEREGULATED POWER MARKET

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ABSTRACT*:* In deregulation power market system security is one of the challenging tasks due to competition and open access network. The security appraisal is an essential task as it gives knowledge about the system state in the event of contingency. In this paper presents contingency analysis of power system is to predict the line outage, generator outage and to keep the system secure and reliable by using full Newton's method. The full Newton's algorithm is more efficient for large power system. This result tends to be significantly more accurate and allow for gauging voltage/VAR effects. Whenever the maximum violation is occur in power system, that line and generator is outage element. So we find the maximum violation in the system network. IEEE-14 bus is the test system for contingency analysis by using power world simulator.

Keywords*:* deregulation, contingency, appraisal, line outage, generator outage.

I. INTRODUCTION

The power system consists of generation, transmission, distribution bundled together. In deregulation unbundling of power system network for efficiency, reliability and least price of power to the customer [1]. Under deregulation minimum price of power transfer to the utility, that time more number of buyers to buy the power from the generation. But all the transmission lines and generators have some limits [2]. Whenever the demand of power is maximum than compared with the transfer limits, the line will be damaged. The power demand is reduced then the generator is reliving from the power system network [3-6]. The system security will be collapsed. So the secured dispatch scheduling of power market is important due to open access and competition. Before security assessment the contingency analysis is needed [7]. The contingency limits are based on system operator experience. But this methodology not predicts the security limits. Before secured dispatch scheduling we have to analysis the contingency under single outage of line, generator and multiple outage of combination of both line and generator [8-10]. Whenever the maximum violation in the element some line and generator get damaged. So the contingency analysis is essential. Various methodologiesare used for contingency analysis such as fast decoupled method, DC power flow, neural network and fuzzy theory [10]. But full Newton's method is high accurate, reliable and better solution.

In this paper presents the contingency analysis of test system by using full Newton's method in power world simulator and two important factor of line outage distribution factor and generation shift factor. In state estimation based contingency analysis more complex. So the student friendly software of power world simulator is used for analysis. The proposed algorithm of Newton's method based contingency selection is presented. The mathematical formulation is in section II. The contingency analysis algorithm is in power world simulator in section III. The description of test system is in section IV. In section V includes simulation results with description and conclusion from the result in section VI.

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II. PROBLEM FORMULATION

The power world simulator can be set to use a full Newton solution or use a DC load flow method to analyse each contingency. The full Newton approach is not as fast as a DC load flow, but the results tend to be significantly more accurate and allow for gauging voltage/VAR effects. The Newton solution method (also called Newton-Rapson method) is more efficient for large power systems. The number of iteration required to obtain a solution is independent of a system size but more functional evaluation are required at each iteration.

Equation for bus Admittance matrix

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \tag{A1}$$

In above equation j includes bus i expressing this equation in polar form, we have

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{A2}$$

The complex power at bus

$$P_i - Q_i = V_i^* I_i \tag{A3}$$

Substituting from (2) for I_i in (3)

$$P_i - Q_i = |V_i| \angle -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{A4}$$

Separating the real and imaginary parts

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_{i+}\delta_j) \tag{A5}$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_{i+}\delta_j) \tag{A6}$$

Equation (5) and (6) constitute of nonlinear algebraic equation in terms of the independent variables, voltage magnitude in per unit and phase angle in radians.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_2}{\partial \delta_n}^{(k)} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_n}{\partial \delta_n}^{(k)} \end{bmatrix} & \begin{bmatrix} \frac{\partial P_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_2}{\partial |V_n|}^{(k)} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_n}{\partial |V_n|}^{(k)} \end{bmatrix} \\ \begin{bmatrix} \frac{\partial Q_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(k)} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_n}{\partial \delta_n}^{(k)} \end{bmatrix} & \begin{bmatrix} \frac{\partial Q_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_2}{\partial |V_2|}^{(k)} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_2}{\partial |V_n|}^{(k)} \end{bmatrix} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix} \tag{A7}$$

In above equation, bus 1 is assumed to be slack bus. The jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta \delta_i^{(k)}$ and voltage magnitude $\Delta |V_i^{(k)}|$ with small changes in real and reactive power $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ elements of jacobian matrix are the partial derivatives of (5) and (6) evaluated at $\Delta \delta_i^{(k)}$ and $\Delta |V_i^{(k)}|$.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \tag{A8}$$

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Accordingly there are (n-1) real power constraints and (n-1-m) reactive power constraints and the jacobian matrix is the order of (2n-2-m) (2n-2-m).

J_1 is the order of (n-1) x (n-1)

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{j\neq 1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_{i+}\delta_j) \quad (A9)$$

$$\frac{\partial P_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_{i+}\delta_j) \qquad j\neq 1 \quad (A10)$$

J_2 is the order of (n-1) x (n-1-m)

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}|cos\theta_{ii} + \sum_{j\neq 1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_{i+}\delta_j) \quad (A11)$$

$$\frac{\partial P_i}{\partial |V_j|} = |V_i||Y_{ij}|c\,os(\theta_{ij} - \delta_{i+}\delta_j) \qquad j\neq i \quad (A12)$$

J_3 is the order of (n-1-m) x (n-1)

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{j\neq 1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_{i+}\delta_j) \quad (A13)$$

$$\frac{\partial Q_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_{i+}\delta_j) j\neq i \quad (A14)$$

J_4 is the order of (n-1-m) x (n-1-m)

$$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}|sin\theta_{ii} - \sum_{j\neq 1}^{n} |V_j||Y_{ij}| \sin(\theta_{ij} - \delta_{i+}\delta_j) \quad (A15)$$

$$\frac{\partial Q_i}{\partial |V_j|} = -|V_i||Y_{ij}|sin(\theta_{ij} - \delta_{i+}\delta_j) j\neq i \quad (A16)$$

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are difference between the schedule and calculated values, known as the power residuals, given by

$$\Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)} \quad (A17)$$

$$\Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)} \quad (A18)$$

The new estimated for bus voltage is

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \quad (A19)$$

$$|V_i^{(k+1)}| = |V_i^{(k)}| + \Delta|V_i^{(k)}| \quad (A20)$$

Another solution method in simulator is DC load flow. These factors can be derived in a variety of ways and basically come down to two types.

a) Generation shift factors

b) Line outage distribution factor

The generation shift factors are designated A_{li} and have the following definition

$$A_{li} = \frac{\Delta f1}{\Delta pi} \quad (A21)$$

The line outage distribution factors are used in a similar manner, only they apply to the testing for overloads when transmission circuits are lost. By defining the line outage distribution factor has the following meanings.

$$D_{lk} = \frac{\Delta fl}{fk0} \quad (A22)$$

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III. PROPOSED APPROACH

Before the secured dispatch scheduling the contingency analysis is the important one for selection of contingency element in the maximum violation of the system network. The following steps to involve in the contingency analysis.

A. CONTINGENCY ANALYSIS ALGORITHM

Step 1: Draw the Simulink one line diagram in new case window of power world simulator for the given power System in edit mode.

Step 2:Save the case with apt name.

Step 3:Select run mode.

Step 4:Play or Run the one line diagram in tool menu.

Step 5:Select CONTINGENCY ANALYSIS in tool menu, then the contingency analysis dialogue box is open.

Step 6:Right click on label and select auto insert contingencies through insert special option.

Step 7:Verify that single transmission line or transformer is selected.

Step 8:If can limit the contingencies inserted to only those meeting a definedfilter.

Step 9:We want to insert contingencies for all branches and generators so nofiltering is desired.

Step 10: To check the following conditions

a) Remove the checkmark in use area/ zone filters.

b) Verify no other options are selected.

Step 11: Click do insert contingencies button to accept the all contingencies.

Step 12: Click YES to get the contingencies.

Step 13: Now the contingency analysis dialog shows contingencies.

a) Right click on the list display on the contingency tap and select insert special and click auto insert to the local menu

b) Select single generating unit then click the do insert contingencies button. Click YES to complete.

Step 14:The auto insert tool did not insert a contingency for the generator connected to the slack bus.

Step 15:Click ‘start run’ on the contingencies tab click start on summary tab or Run contingency.

Step 16:Select the maximum violation of contingency analysis taken for account in the secured dispatch of deregulation of power market.

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IV. TEST SYSTEM

The contingency analysis of 14-bus test system is shown below when the power flow is running on the power world simulator. The percentage of power flow is mentioned in power flow diagram. It consists of five generators for dispatch of power.

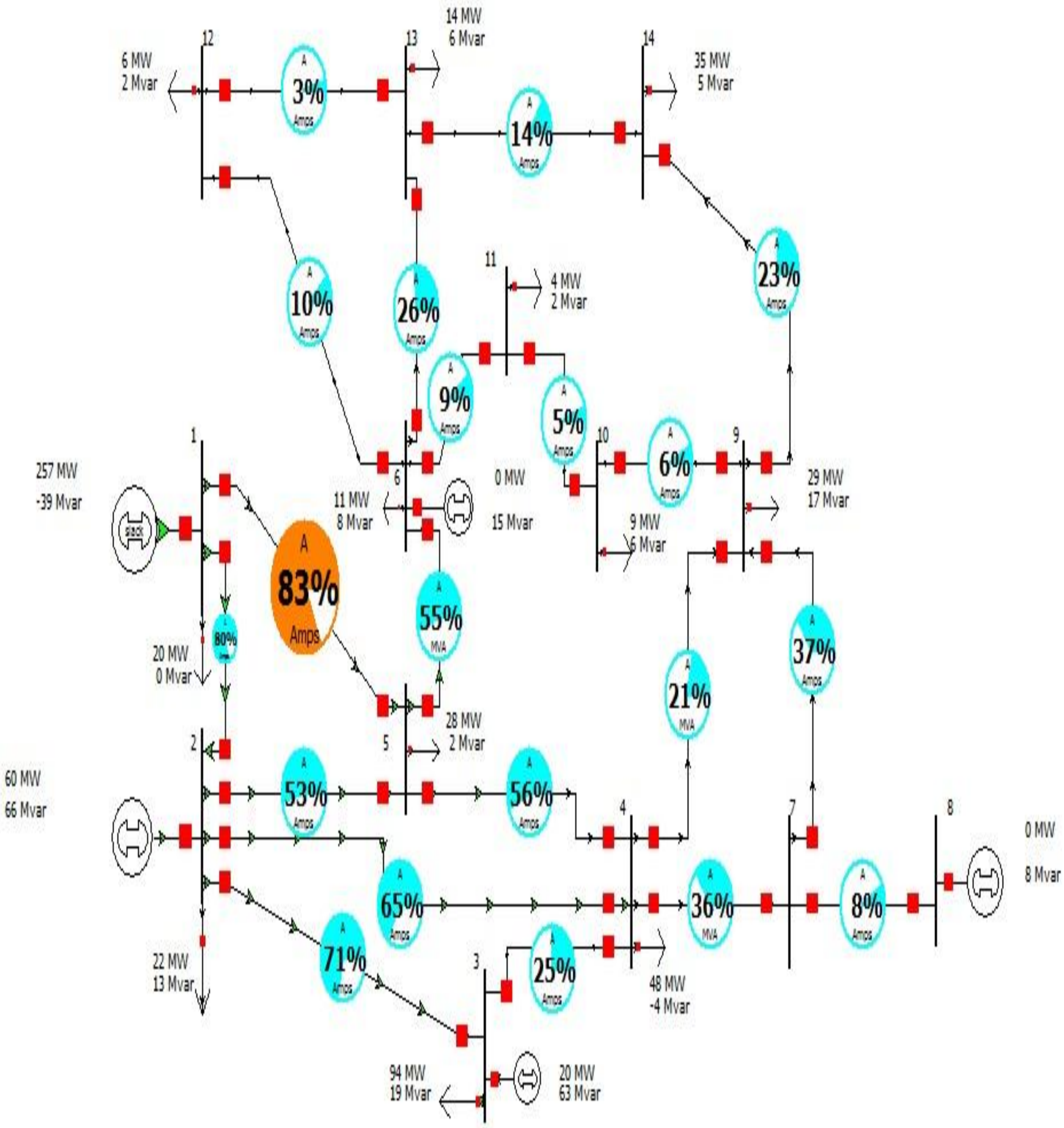

Fig.1 Test system

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V. SIMULATION RESULTS

The contingency analysis is classified as single contingency, multiple contingency. In IEEE test system having 110 contingency. But in maximum violation of single contingency of line and generator is taken in account in table1.which depends on maximum branch percentage and minimum voltage the contingency element is taken in account for security dispatch of power.

LABEL	VIOLATIONS	MAXIMUM BRANCH %	MINIMUM VOLTAGE
L_0000011-0000022C1	2	276.5	-
L_0000011-0000055C1	1	127.5	-
L_0000022-0000033C1	2	102.0	-
L_0000022-0000044C1	1	102.0	-
L_0000022-0000055C1	1	103.0	-
L_0000066-00001313C1	2	-	0.898
L_0000099-00001414C1	1	-	0.848
G_0000022U1	1	103.6	-

Table.1 Single contingency of line and generator

The combination of both generator and line contingency is also in security analysis. The maximum violation only taken in account in table 2. The L_ indicates line and G_ indicates generator.

LABEL	VIOLATIONS	MAXIMUM BRANCH	MINIMUM VOLTAGE
G_0000022U1&L_0000022-0000033C1	3	115.7	-
G_0000022U1&L_0000066-00001313C1	3	104.6	0.894
G_0000033U1&L_0000011-0000022C1	4	325.3	0.891
G_0000033U1&L_0000011-0000055C1	3	140.2	-
G_0000033U1&L_0000022-0000033C1	6	118.0	0.739
G_0000066U1&L_0000011-0000022C1	3	283.4	0.883
G_0000066U1&L_0000077-0000099C1	5	-	0.842
G_0000066U1&L_0000099-000001414C1	3	-	0.733

Table.2 Multiple contingency of both line and generator

The generation shift factor describe a generator power sensitivity under the contingency condition is shown in table 3. It consists of 5 generators and their sensitivity.

GENERATOR	GENERATOR MW	MIN MW	MAX MW	$P_{SENSITIVITY}$
1	256.7	0	1000	0.648910
2	60	0	1000	- 0.241716
3	20	0	1000	-0.217109
6	0	0	1000	-0.072487
8	0	0	1000	-0.117599

Table.3 sensitivity analysis of generation shift factor

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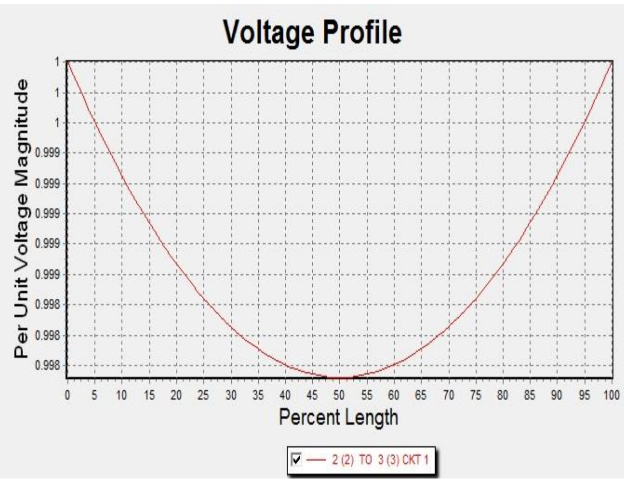
Line outage distribution factor (LODF) is used to approximate the change in the flow on one line caused by the outage of a second line. It is a real time operation. The percentage of LODF is tabulated in each line in table 4.

LINE FROM THE BUS NUMBER	LINE TO THE BUS NUMBER	MW FROM	MW TO	CTG MW FROM	CTG MW TO	%LODF
1	2	-154	-144.1	0.0	4.9	-100
1	5	82.7	-78.9	236.7	-232.9	100
2	3	70.2	-67.8	44.2	-41.8	-16.9
2	4	64.5	-62.1	10.1	-7.7	-35.3
2	5	52.6	-51.0	-21.0	22.6	-47.8
3	4	-6.4	-6.8	-32.4	32.8	-16.9
4	5	-49.2	49.6	-125.3	125.7	-49.4
4	7	36.0	-36.0	33.2	-33.2	-1.8
4	9	20.7	-20.7	19.1	-19.1	-1.0
5	6	52.7	-52.7	57.1	-57.1	2.8
6	11	7.7	-7.6	10.3	-10.3	1.7
6	12	9.5	-9.4	9.9	-9.8	0.2
6	13	24.3	-23.9	25.6	-25.2	0.9
7	8	0.0	-0.0	0.0	-0.0	0.0
7	9	36.0	-36.0	33.2	-33.2	-1.8
9	10	4.9	-4.9	2.3	-2.3	-1.7
9	14	22.3	-21.6	20.6	-19.9	-1.1
10	11	-4.1	4.1	-6.7	6.8	-1.7
12	13	3.3	-3.3	3.7	-3.6	0.2
13	14	13.6	-13.3	15.3	-15.0	1.1

Table.4 percentage of line outage distribution factor



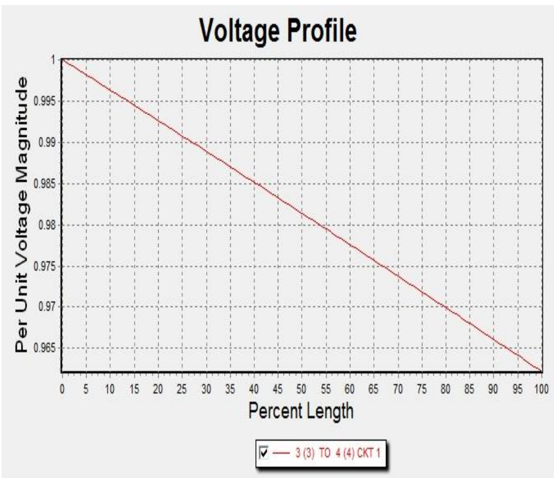


Fig.2 violated line voltageprofile (L_22 to L_33)

Fig.3 unviolated line voltageprofile (L_33 toL_4 4)

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VI. CONCLUSIONS

The Full Newton's method based contingency analysis algorithm is high accuracy and better efficiency. The contingency analysis in power world simulator is easy to run the power system and more reliable than compared with state estimation based contingency analysis. The security limits described from maximum violation of the element of test system and sensitivity analysis of both line outage distribution factor and generation shift factor. In feature power world simulator based contingency analysis is widely used for secured dispatch scheduling and the demand response improvement of deregulated power market. Voltage profile is varied which depends on violated and unviolated line is shown in Figure 2 and 3.

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BIOGRAPHY

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