Contingency ranking of power systems using a performance index

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Abstract - *Power system security and contingency analysis are important tasks in modern energy management systems. Contingency ranking using the performance index is a method for the line outages in a power system, which ranks the highest performance index line first and proceeds in a descending manner based on the calculated PI for all the line outages. This helps to take the prior action to keep the system secure. In the present work the Newton Raphson load flow method is used for the power system contingency ranking for the line outage based on the Active power and Voltage performance index.*

Key Words: Active Power performance index (PIP), Voltage performance index (PIV).

1. Introduction

Power system steady-state security analysis is one of the most important issues in power system. Contingency evaluation is one aspect of power system security assessment. Some cases in the contingency set may lead to transmission line overloads or bus voltage limit violations during power system operations. Such critical contingencies should be quickly identified for further detailed evaluation. The process of identifying these critical contingencies is referred to as contingency selection which uses the complete AC load flow program considering outage of each line or generator[1].

The application of AC power flow methods in outage cases have been discussed by [2]. [3],[4] presented how the line flows is influenced for generator and line outages using distribution factors. For contingency evaluation the authors in [5] introduced the method of concentric relaxation. For quick power flow solutions, the zero mismatch method is proposed in [6]. The selection of weighting coefficients for performance indices for contingency ranking has been presented in [7]. The use of an iterative method to calculate Eigen values under outage condition for contingency ranking is proposed in [8]. In [9] the authors used decoupled load flow and compensation method to obtain Post outage voltages and ranking is given based on performance index

2. Contingency ranking approach

The use of AC power flow solution in contingency analysis is that it gives active, reactive power flows and magnitudes of bus voltage. In power system contingency ranking approach, line outage case has been considered and the ranking is given based on the severity measured using the performance index. These indices are computed using the load flow (Newton Raphson Method) for each contingency. Based on the performance index obtained the contingencies are ranked starting with the highest value of PI.

2.1 Active Power performance index (PI_P)

This index is used to measure the degree of line over loads[10].

$$PI_P = \sum_{i=1}^{N_L} (W/2n)\left(P_i / P_i^{\max}\right)^{2n} \qquad (1)$$

where,
P_i and P_{ima} is the MW flow and MW capacity of line *i*
N_L - Number of lines of the system
W - Real non-negative weighting factor = 1
n - Penalty function =1

$$P_i^{\max} = \frac{V_i V_j}{X} \qquad (2)$$

where,
V_i is the Voltage at bus i by NR load flow
V_j - Voltage at bus j by NR load flow
X -Reactance of the line connecting bus

2.2 Voltage performance index (PI_V)

This is the index which determines the out of limit bus voltages [10].

$$PI_V = \sum_{i=1}^{N_B} (W/2n)\left\{\left(|V_i| - |V_i^{sp}|\right)/\Delta V_i^{\lim}\right\}^{2n} \qquad (3)$$

where,
V_i is theVoltage magnitude corresponding to bus i
V_i^{sp} -Specified voltage magnitude corresponding to bus i
ΔV_i^{lim} -Voltage deviation limit

n -Penalty function =1
N_B - Number of buses in the system
W - Real non-negative weighting factor = 1

The bus voltages are influenced by the reactive power produced by the generating units and PI_V gives the severity of abnormal voltages until the reactive power lie in the limits. Under contingency case the reactive power may approach the limits, and in this scenario the AC load flow computes the bus voltages by considering the reactive power limits and thus voltage violation is observed from their actual voltage at the generator buses. In this case the voltage study during contingency involves the generators reactive power constraints[20].

The established formula is:

$$PI_{VQ} = \sum_{i=1}^{N_B} (W/2n)\left\{\left(|V_i| - |V_i^{sp}|\right)/\Delta V_i^{\lim}\right\}^{2n} + \sum_{i=1}^{N_G} (W/2n)\left\{Q_i/Q_i^{\max}\right\}^{2n} \quad (4)$$

where,
Q_i istheReactive power at bus i
Q_i^{max} -Reactive power limit at bus i
N_G -number of generating units
W -Real non-negative weighting factor=1

2.3 Algorithm for contingency analysis using Newton Raphson mothod

The algorithm for contingency analysis using Newton Raphson load flow solution is as follows:

Step 1: Read the given system's line data and bus data.
Step 2: Without considering the line contingency perform the load flow analysis for base case.
Step 3: Simulating a line outage or line contingency, i.e. removing a line and proceeding to the next step.
Step 4: Load flow analysis is done for this particular outage, then calculation of the active power flow is done in the remaining lines and value Pmax is found out .
Step 5: The active power performance index (PIP) is found, which indicates the active power limit violation of the system model taken.
Step 6: subsequently for the particular line contingency; voltages of all the load buses are calculated.
Step 7: Then voltage performance index (PIV) is being calculated which indicates the voltage limit violation at all the load buses due to the line contingencies.
Step 8: Computation of overall performance index is done by adding PIP and PIV for each line outage of the system.
Step 9: Steps 3 to 8 for all line outages is repeated to obtain the PIP and PIV. for all line outages.
Step10: Then contingencies is ranked based on the overall performance index (OPI) which is calculated according to the values of the performance indices obtained.
Step11: Do the power flow analysis for the most severe contingency case and obtain the results.

Figure1 shows the flow chart for the overall performance index based power system contingency ranking

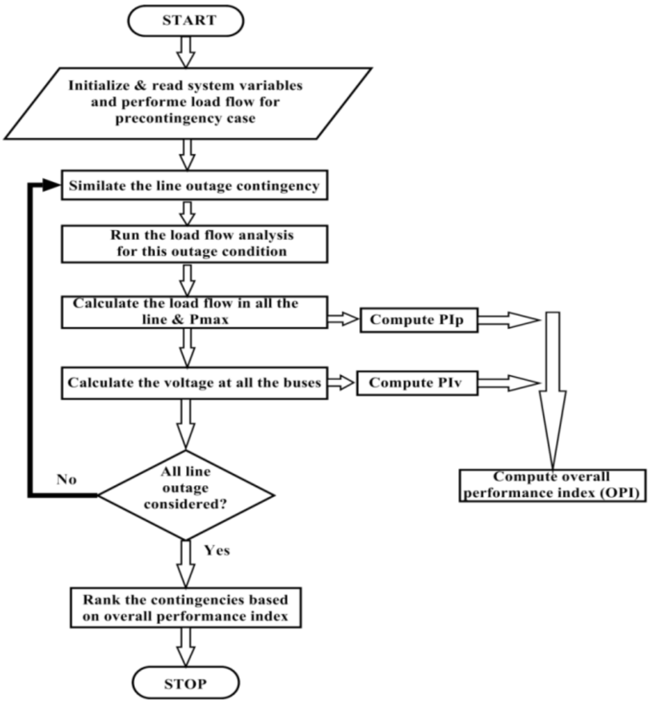

Fig -1: Flow chart for contingency ranking

3. Case studies

The simulation was performed on the test network called IEEE 30 bus Figure 2, which consists of 30 buses, 41 transmission lines, bus 2, 5, 8, 11 and 13 are generator bus and all other buses are load bus. The slack bus is associated with bus 1.

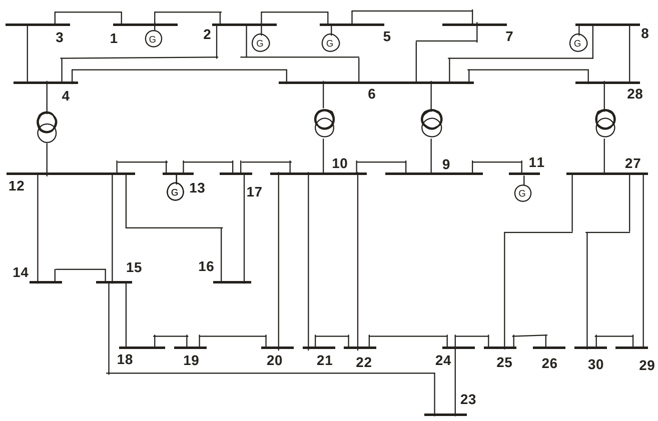

Fig -2: Single line diagram of the IEEE 30-bus test system

From the simulation we get the value of Voltage profile in the base case and the load flow calculation (Newton Raphson method) to the base case (no line outage) for the test system IEEE 30-bus.

Figure3 , shows the Voltage profile (to the base case for the test system IEEE 30-bus .

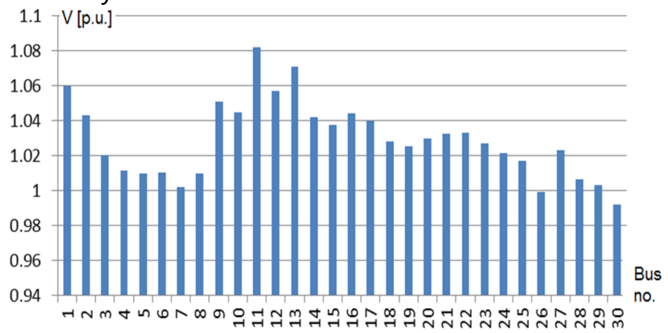

Fig -3: Voltage profile in the base case of(IEEE 30-bus)

Equation (1), (4) use to find the contingencies ranking in terms of performance index calculated for power flows (Newton Raphsen method)

Figure 4, shows the ranking of branch contingencies in term of the Performance Index calculated based on the branches overload. It can be seen that the most dangerous contingency is the disconnection of the line 4-12 which leads to overloading of the line 9-10.

Figure 5 shows the branch contingencies ranking based on the performance index calculated in terms of the bus voltage. It is easy to observe that the most dangerous contingencies from the voltage point of view are the disconnections of lines 27-28 and 2-5.

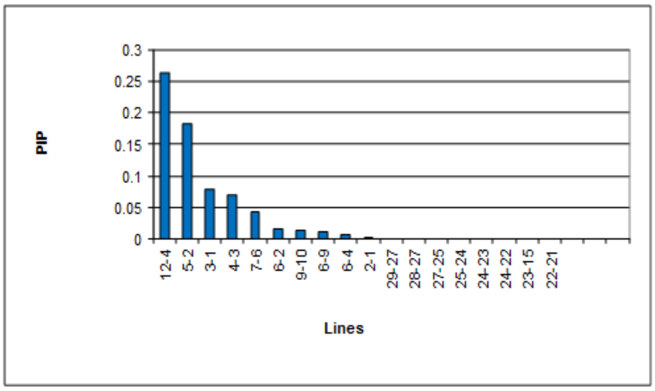

Fig -4: Contingencies ranking in terms of performance index calculated for power flows

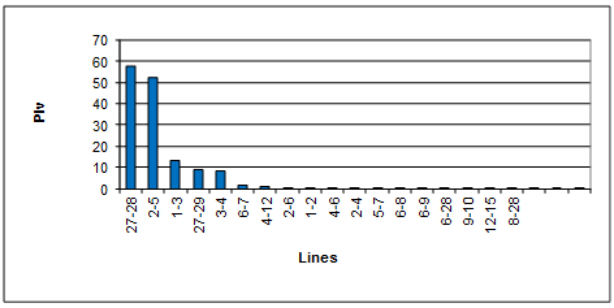

Fig -5: Contingencies ranking in terms of performance index calculated for voltages

Figure 6 shows the single-line diagram of the IEEE 30 bus network emphasizing the lines, and the region, sensitive to contingencies; branch overloads are observed in the higher voltage network.
Figure 7 shows the single-line diagram of the IEEE 30 bus network emphasizing the buses that are sensitive to voltage violations when a first contingency occurs.

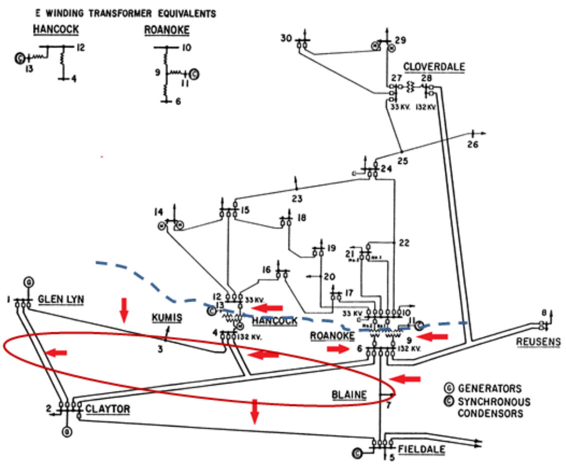

Fig -5: Emphasizing of line contingencies in the IEEE 30 bus network.

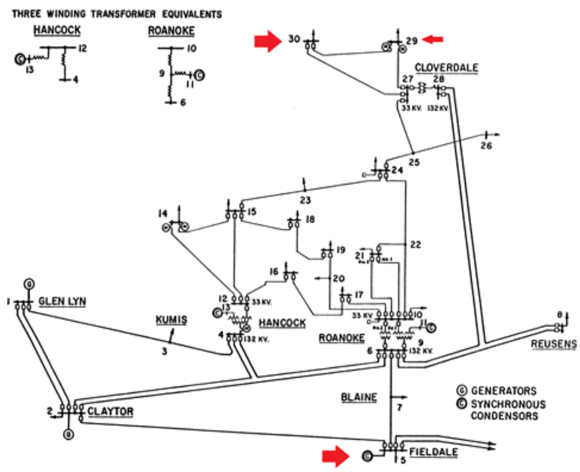

Fig -6: Emphasizing of bus contingencies in the IEEE 30 bus network.

3. CONCLUSIONS

The simulations have revealed that:

- The most dangerous contingency is the disconnection of the line 4-12 which leads to overloading of the line 9-10, in term of the Performance index calculated based on the branches overload.
- The most dangerous contingencies from the voltage point of view are the disconnections of lines 27-28

and 2-5 , in term of the Performance index calculated of the bus voltage.

- Load flow calculations (Newton Raphson method) are succeesfully used to ranking the contangensy happened to the power system in term of the Performance index calculated of the bus voltage (PI_{VQ})or the branches overload (PI_P).

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