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Power System Contingency Analysis Using Artificial Neural Network

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ABSTRACT

Maintaining power system security is one of the challenging tasks for the power system engineers. The security assessment is an essential task as it gives the knowledge about the system state in the event of a contingency. Contingency analysis technique is being widely used to predict the effect of outages like failures of equipment, transmission line etc, and to take necessary actions to keep the power system secure and reliable. The off line analysis to predict the effect of individual contingency is a tedious task as a power system contains large number of components. Practically, only selected contingencies will lead to severe conditions in power system. The process of identifying these severe contingencies is referred as contingency selection and this can be done by calculating performance indices for each contingencies. The main motivation of the work is to carry out the contingency selection by calculating the two kinds of performance indices; active performance index (PIP) and reactive power performance index (PIV) for single transmission line outage. With the help of Fast Decoupled Load Flow (FDLF), the PIP and PIV have been calculated in MI-POWER environment and contingency ranking is made. Further the contingency selection has been done by using Radial Basis Function (RBF) Neural Network in MATLAB environment. This provides an effective mean to rank the contingencies for various loading and generation levels in a power system. The effectiveness of the method has been tested on IEEE-14 Bus test systems.

Keywords—Contingency, Contingency ranking, Performance Indices.

1. INTRODUCTION

The system with generation of power, transmission of power and distribution of power with the control strategies is called electrical power system. It consists of various components namely generator, transformer, circuit breaker, conductor and load. The failure of any one of the component during its normal operating condition leads to the violation of existing state of the system. The power system security plays an important role for the proper operation of the system. In the field of power system planning and co-ordination, the power system engineer's task is to make the system to be secured and reliable.

The power system network is monitored and controlled by the SCADA system. In India the SCADA system is monitored and controlled through regions. There are five regions in India.

They are NR (Northern Region), ER (Eastern Region), WR (western Region), SR (Southern Region), and NER (North Eastern Region). The contingency analysis is carried out by the system operator in the SCADA unit for the pre contingency and post contingency states. It results the possible outages in the network and it helps the system operator to take the remedial actions before the network comes to unsecured state.

When the specified operating limits are violated, the system comes to emergency state. This type of violation (Bus voltages and active power flow) leads to the contingencies. The role of the system operator is to resist the outcome of contingencies. The contingency ranking is sorted according to the severity index or performance index.

Power system security mainly performs three functions. These functions are carried out in SCADA unit.

i. System Monitoring
ii. Contingency Analysis

2. CONTINGENCY ANALYSIS USING LOAD FLOW METHOD

In this paper the detailed study of the contingency analysis and their elements are studied. The contingency elements include contingency definition, contingency ranking, contingency selection and contingency evaluation. In this paper the main discussion is on algorithm and flowchart of Fast Decoupled Load Flow Method. The results of 5 bus and 14 bus system using FDLF method along with the charts are focused.

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Contingency Analysis and Their Elements

Contingency analysis is one of the “Security analysis” application the area of power utility. Its purpose is to identify the bus voltage limits and line power flows in the network that occur due to outage of transmission line, transformer and generator. The contingency elements mainly of four types.

Contingency Definition:

The temporary disruption of operation is called an outage. The contingency analysis is defined as “it is the study of change in bus voltages and power flows in transmission lines due to an outage or condition that is conceivable but it cannot be anticipated”.

Contingency Ranking:

The contingency ranking is calculated according to the severity or performance index (PI). The PI serves two aspects.

- Distinction of real critical outage from non-critical outage.
- Anticipation of relative severity of the critical outage.

The effect of the contingency outages are measured by the PI. There are two types of performance indices.

i. Active Performance Index:

It represents the violation of active line power flow and the mathematical expression is as follows

$$PI_p = \sum_{i=1}^{L}\left[\frac{P_i}{P_{i\max}}\right]^2 \quad \text{................................(1)}$$

Where,

L = Total number of transmission lines present in the system,

Pi = Active power flow in line I,

Pimax = Maximum active power flow in line i.

Maximum active power flow is calculated using the formula

$$P_{i\max} = \frac{|V_i||V_p|}{|Z|} \quad \text{...(2)}$$

Where, L = Total number of transmission lines that present in the system

P_i = active power flow in line i

P_{imax} = Maximum active power flow in line I

ii.Reactive Performance Index:

It expresses the magnitude of the bus voltage violations. The mathematical expression

$$PI_v = \sum_{i=1}^{Npq}\left[2\frac{(V_i - V_{inom})}{V_{i\max} - V_{i\min}}\right]^2 \quad \text{......................................(3)}$$

Where,

Npq = Total number of load buses present in the system,

Vi = Voltage at bus I after the load flow analysis,

Vinom = Average of Vimin and Vimax,

Vimax = Maximum voltage limit,

Vimin = Minimum voltage limit.

Contingency Analysis using Fast Decoupled Load Flow Method

Fast decoupled load Flow is widely used for their speed, good convergence and fast calculation. For the contingency analysis this technique is very effective because it takes least time per iterations and the various contingencies are simulated in a very rapid manner.

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The algorithm steps for the contingency analysis are given as follows:

1. Read the given system bus data and line data.
2. Before simulating the transmission line contingency, set the contingency counter to zero.
3. Simulate the transmission line outage or line contingency.
4. Calculate the MW flows in the remaining transmission lines and the maximum power flow from eq. (3.2).
5. Calculate the active performance index from eq. (3.1). The results indicates the violation of the active power limit.
6. For the particular line outage, calculate the bus voltages.
7. Calculate the reactive performance index from eq. (3.3). The results indicates the violation of bus voltages.
8. Check for the last contingency simulation; if not repeat from no 3 to 7 till the end of the all bus.
9. The contingency ranking is calculated in the decreasing order of reactive performance index.
10. The load flow study is carried out for all the contingency cases. Note down results.

The flowchart for the contingency analysis is shown below.

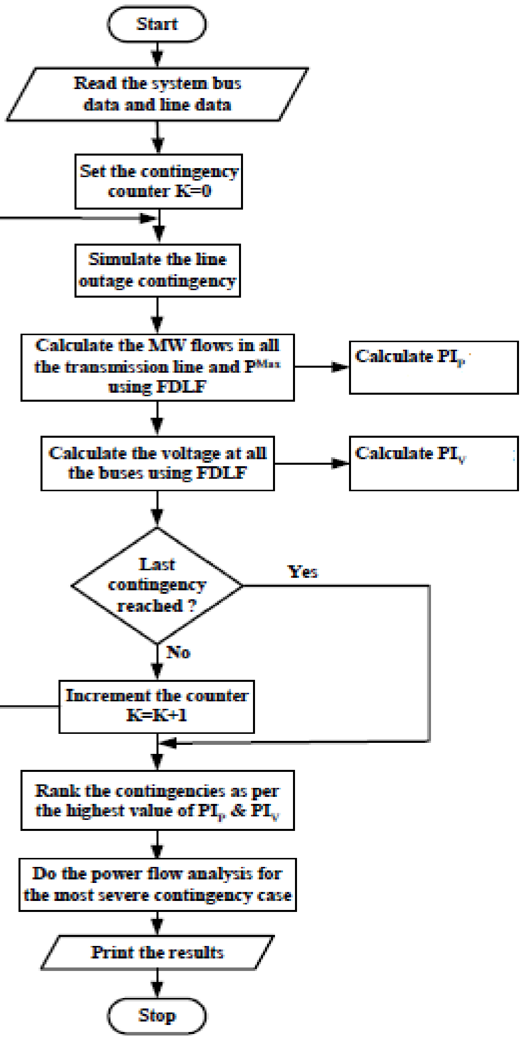

Fig1. Contingency analysis using FDLF flowchart

3. SIMULATION RESULTS AND DISCUSSION

The contingency analysis using Fast Decoupled Load Flow Method is simulated for the 14 bus systems. For these test bus systems the simulated output results are noted down. The results includes the transmission line flows, bus voltages and performance indices. From the values of performance indices the contingency ranking is marked. The complete analysis is carried out in MI-POWER software.

14 – Bus System

- **Fourteen - Bus System**

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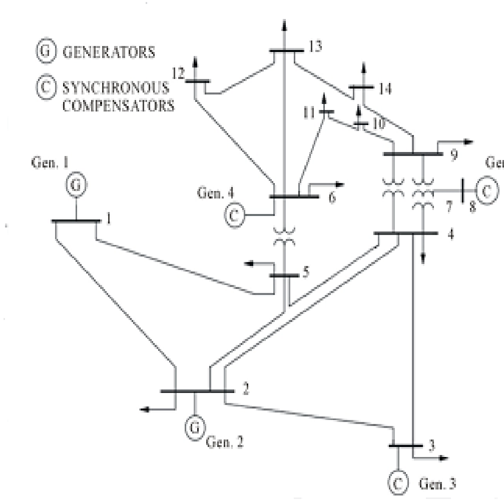
Fourteen bus system includes one slack bus, eleven load buses and four generator buses. The generator bus 3, 4 and 5 act as synchronous condenser. The load flow analysis is simulated for the test bus system. The FDLF method is applied for the same. The bus voltages, line flows and the performance indices are observed. The contingency analysis is carried out for each contingency at a time. There are twenty possible contingency outages or contingency numbers. The pre outage and post outage of fourteen bus system shown below.



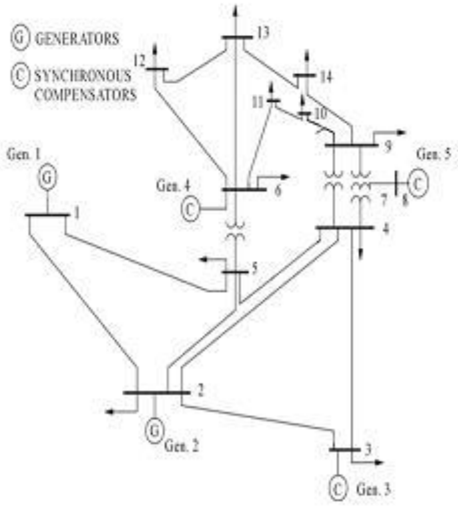
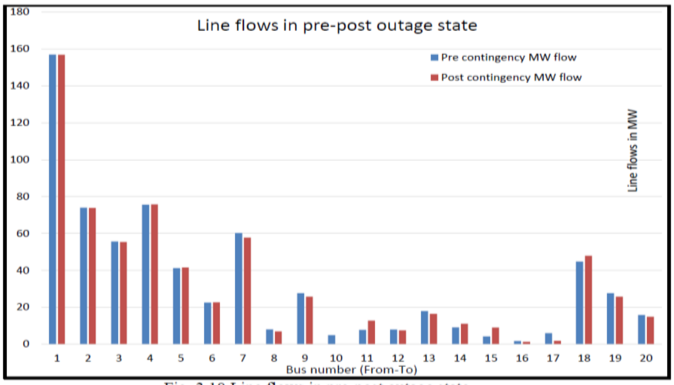


Fig.2 Pre outage state of f14 bus system Fig.3Post outage state of 14 bus system



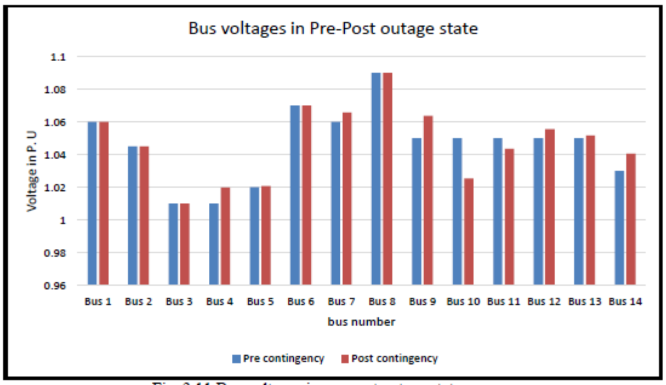


Fig. 4 Line flows in pre-post outage state Fig. 5 Bus voltages in pre-post outage state

4. CONTINGENCY ANALYSIS USING RADIAL BASIS FUNCTION NEURAL NETWORK

Introduction to ANN

The contingency analysis using RBF method is described in this chapter. The aim of using the neural network is, it processes the information like brain than a computer. It has very simplex principle and it models linear and nonlinear systems. It predicts the output for an unseen input by repeating the training patterns. ANN finds number applications in the area of load forecasting, security assessment, fault location/diagnosis, solar radiation estimation and prediction of wind speed etc.

Algorithm for Contingency Ranking using Radial Basis Function

The algorithm for active and reactive performance indices is given below.

1. Do the load flow analysis for the test bus systems and apply FDLF method for the same. The results of contingency ranking are the desired output for neural network.

2. Choose the input vector for RBF.

3. Assign the hidden layer neurons and find the bias center.

4. Choose the spread value.

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5. Calculate the output of hidden layer of jth unit.

6. Calculate the first unit output of output layer.

7. Calculate the weight matrix output

8. Select one set of test data to solve the training set.

9. The weight matrix is used get the results from the output unit.

10. Note down the output results and compare with the desired output. If the results are not matched, change the spread and the hidden layer neurons and repeat steps 5-9.

Results of Fourteen Bus System

The performance indices are calculated for fourteen bus system. The contingency ranking is calculated for 10% of the base case loading

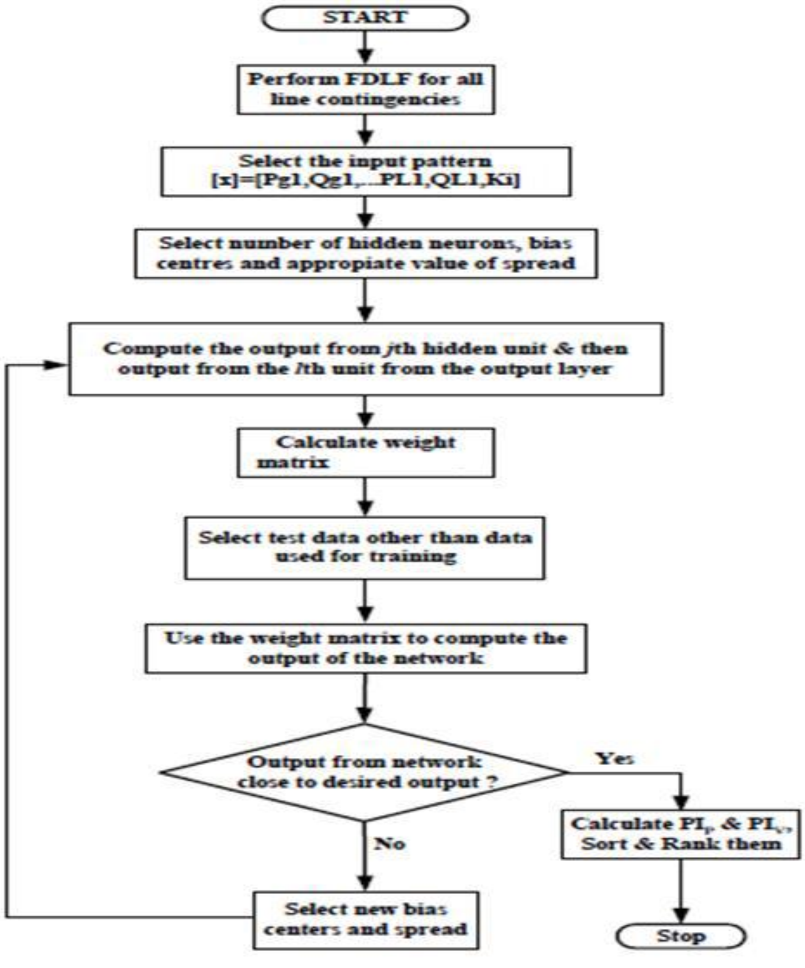

Fig. 6 Flowchart for contingency ranking using RBF

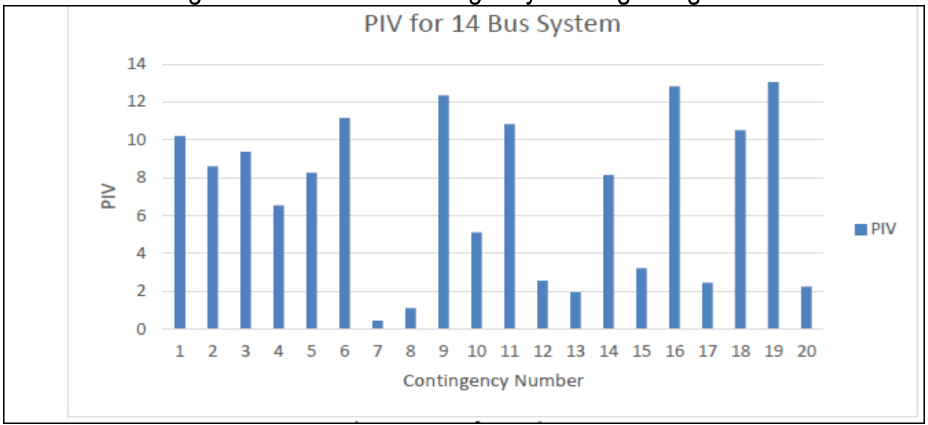

Fig. 7 PIV for 14 bus system

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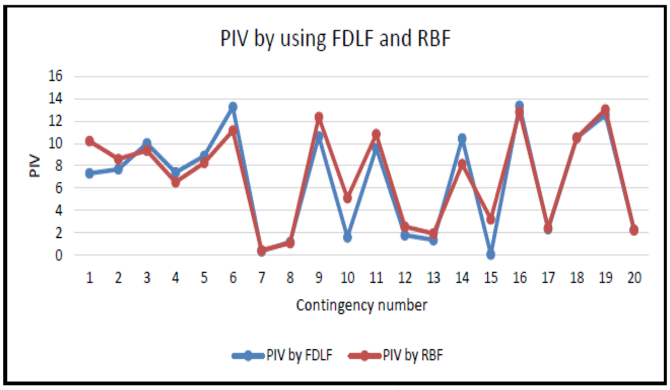

Fig. 8 PIV using FDLF and RBF for 14 bus system

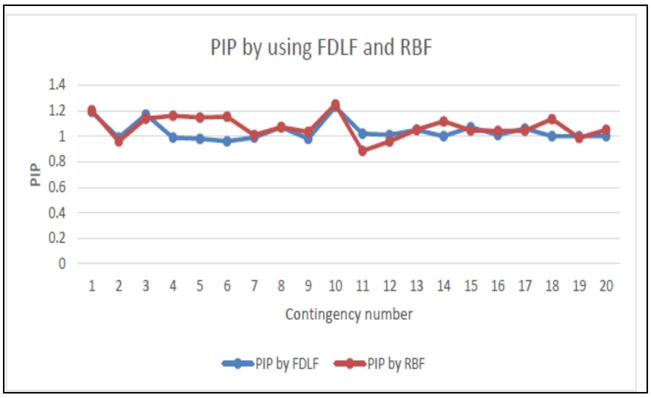

Fig. 9 PIP using FDLF and RBF for 14 bus system

5. CONCLUSION

In this work, the power system contingency analysis and ranking is done by using two types of performance indices. i.e. active performance index and reactive performance index. These indices are calculated for 14 bus system using FDLF method using MI-POWER software. The improvement in the analysis is carried out by using RBF for 14 bus system in MATLAB software.

- The contingency ranking using performance indices indicates the severity of the power system transmission line outage.
- The contingency analysis using FDLF method for base case loading condition indicates more simulation time. The indices are predicted in off line manner for a single loading condition.
- The RBF neural network for the contingency analysis yields the accurate values of performance indices. The simulation time for the analysis is less.

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