Fuzzy Logic Based Fault Detection Mechanism in Power Distribution System

Devesh Vishwakarma[1], Varsha Mehar[2]

[1,2]*Department of Electrical Engineering, RKDF University, Bhopal, India*

Abstract - In this paper a fuzzy logic based fault locating in a radial power distribution system is discussed. Fuzzy logic method basically ease the calculation involved. The history associated with fault occurred in power system can be effectively used as a strong database. This database will act as the trainer to the fuzzy expert system. A rich history of faulty area will enhance the performance of the fuzzy fault identification system. Fault section location aims to identify the faulty area in the power system using the post fault status of protective relays and circuit breakers and diagnose the cause of a fault that has occurred. Restoration cost can be significantly reduced by accurately identifying a fault location and its cause, which also reduces the restoration time of the faulty section. In this paper methodology based on fuzzy expert system is discussed for assistance to the operators for easy fault detection.

Keywords - Fuzzy System, Distribution System, Fault Identification, Trained System.

I. INTRODUCTION

The power distribution is one of the important aspects in Power System when it comes to customer's satisfaction. Keeping in view of this power distribution reliability becomes a very important topic to be looked upon in the power system industry. When customers satisfaction is talked about the basic need for the consumer is continuity of power [1]. Power quality is the desirable trait looked by the consumer. Faults in a complex power system poses challenge to maintain power quality. Faults can only be minimized it cannot be entirely eliminated from the system [2]. To achieve continuity in power supply we can definitely control fault rectification time. Fault clearance time can be minimized once we detect the faulty section quickly. Questions have always been raised on reliability of power distribution, which directly affect the service restoration cost when a fault occurs. In other words power distribution reliability can be mentioned as minimum service restoration time cost [3].

Present power systems embedded with real time monitoring and control make them the most dependable critical infrastructures. In the smart grid systems, the wide area monitoring is achieved by gathering system information in real time using synchrophasors including Phasor Measurement Units (PMUs) and Phasor Data Concentrators (PDCs) [5-6]. The synchrophasors can improve the reliability of power systems integrated with renewable energy sources like the wind power and solar by triggering the corrective actions for accounting the unpredictable power generation. The PMUs measure voltage, current, and frequency and transmit these measurements to PDCs which is then send to Energy Management Systems (EMSs) to perform state estimation and present synchrophasor data to control centres. PMUs communicate to the control centre using network connections. The use of network connections makes the system vulnerable to cyber attacks. Cyber security and intrusion detection of network are important requirements for maintaining the integrity of wide area monitoring and protection schemes [7- 9]. The intrusion detection method analyzes the measurement data to detect any possible cyber attacks on the operation of smart grid systems.

II. CLASSIFICATION OF POWER DISTRIBUTION

Power system stability is an indispensable requirement for protected and reliable operation of power system. An inclusive understanding of power system instability consequences is crucial for reliable power system analysis and operation. Power system stability has been defined and classified by the Institute of Electrical and Electronics Engineers (IEEE) and International Council for Large Electric Systems (CIGRE) as follows [10]: The capability of synchronous machines to stay in synchronism after a disturbance is referred to rotor angle stability. It relies on the ability of each synchronous machine to preserve equilibrium between input mechanical torque and output electromagnetic torque in the interconnected power system. Instability can cause acceleration or deceleration of the rotor of the synchronous machine and result in angular difference. If the angular separation between synchronous machines goes beyond a certain limit, according to power-angle curve the power transfer will be reduced. The output electromagnetic torque of perturbed system can be divided into two parts:

a) Damping torque: In phase with the speed deviation.
b) Synchronizing torque: In phase with rotor angle divergence.

Figure 1 shows the power system stability classification in terms of the aforementioned classes and subclasses The lack of damping and synchronizing torques can cause oscillatory and non-oscillatory instabilities, respectively. Rotor angle stability can be classified into the following categories:

III. LITERATURE REVIEW

There exists a considerable research effort for the development of adaptive power system stability control technique.

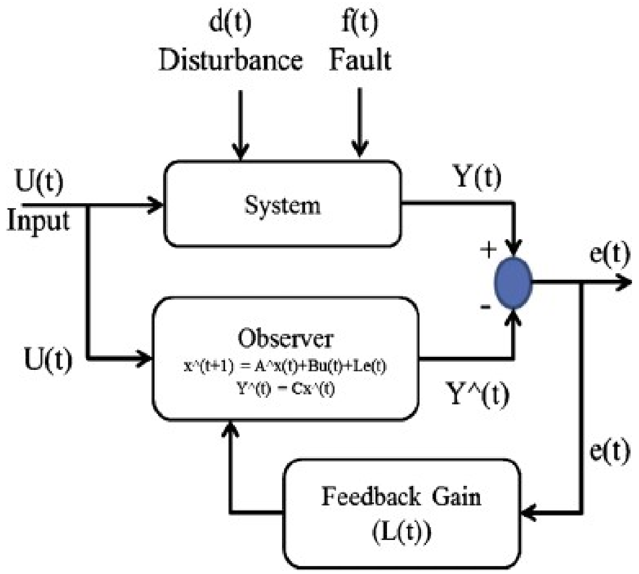

Fig. 1. Power Distribution Mechanism

A. Inter-Area Oscillation of Interconnected Power System

The inter-area oscillation of low frequency modes are essential characteristics of interconnected power system. Inter-area oscillations involve a group of synchronous generators in one area swinging against the ones in other areas. The inter area oscillation modes are identified using the right eigenvectors associated with the synchronous machines rotor speed which is referred to as mode shape. Inadequate damping torque is the main factor of inter area oscillation leading to rotor angle separation and blackouts. Inter area oscillations can limit the electric power transfer between the areas. For example, power transfer capability in it has been restricted by stability considerations for several years. Insufficient damping torque had resulted in tie-line separation. The initial plan was to transfer 2000 MW through ac lines, but stability analysis showed that power flow more than 1300 MW cannot be transferred due to insufficient damping torque. Then, it was discovered that synchronous generators with Power System Stabilizer (PSS) can provide sufficient damping to transfer 1800 MW. Therefore, it is necessary to understand the risks of inter area oscillation, and develop mitigation control techniques to address these issues. The PSS is used to enhance damping to the generator rotor oscillations by controlling its excitation system via an auxiliary control loop [5]. The power system stabilizer produces a damping torque component in phase with the rotor speed deviations. The PSS input signals can be either the rotor speed deviation, Δω, or the synchronous machine acceleration power,

$$P_a = P_m - P_e$$

which is the difference between the mechanical power and the electrical power.

B. Model of Interconnected Power System

For simulation resolves of synchronous and asynchronous machines, the following parameters are defined:

1) Standard parameters: These parameters can be obtained by observing the responses at the machine terminals with suitable test responses.
2) Fundamental parameters: These parameters determine the electrical characteristics of the machine, but they cannot be specified from the machine test responses.

Synchronous machines are parameterized using standard or fundamental parameters and asynchronous machines are parameterized using fundamental parameters.

IV. PROPOSED METHOD AND RESULTS

A. Cyber security of Power System

The generation, transmission, and distribution of electric power systems embedded with real time measurements make the smart grid the most dependable critical infrastructure in the world. The present monitoring systems depends on state estimation, which is based on the Supervisory Control and Data Acquisition (SCADA) systems for the collection of data from field devices such as Remote Terminal Units (RTUs) and sent up to the central control centre. In the future, the wide area monitoring of smart grid systems will be accomplished by collecting system level information in real time by using Phasor Measurement Units (PMUs) and Phasor Data Concentrators (PDCs). The data obtained from PMUs will be used for the state estimation and implementation of control strategies for optimal control of smart grid systems. The PMUs which are also called synchrophasors provide accurate measurements of active power, reactive power, voltage, current along with phasor angles in real-time. The signal f (t) is used to calculate

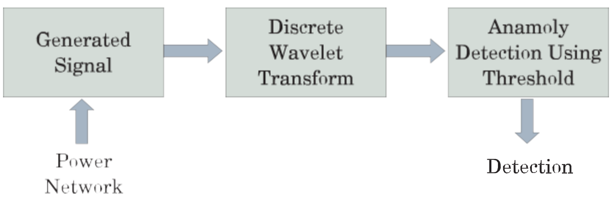

Fig. 2. Malicious Data Detection and Identification using Wavelet Analysis

the approximation and detail coefficients at level one. Then, the calculated approximation coefficients are utilized to obtain the approximation and detail coefficients at level two, and so on. Anomaly detection of malicious data in smart grids consists of three steps as indicated in Figure 2. The first step is to collect the measured data from the PMUs. The second step is the DWT to analyze the signal features. In the final step, the detail coefficient values are compared with predefined threshold values (confidence intervals) for the determination of the anomalies in the signal.

If the data anomalies are considered as a random white noise with Gaussian distribution, for any random variable, choosing $\pm 3\sigma$ confidence interval yields to:

$$P(\mu - 3\sigma < X \leq \mu + 3\sigma) \approx 99.6\%$$

This interval corresponds to 99.6% confidence level, which means that we can detect anomalies with 0.3% error rate.

V. CONCLUSION

The model-based intrusion detection requires high computational effort to obtain the power system dynamic model. However, the signal-based intrusion detection using discrete wavelet transform extract the statistical properties of the signal to detect the anomaly in different resolution levels. The detail coefficients at different levels contain high frequency characteristic of the signal. This method enables us to detect the anomaly faster than model-based method. Also, we can detect the anomaly in different resolution levels. The signal- based method is in real time and it is beneficial and efficient to detect any anomaly activities before damaging the power system.

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