SYNCHROPHASOR DATA BASED INTELLIGENT ALGORITHM FOR REAL TIME EVENT DETECTION IN POWER SYSTEM

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ABSTRACT

The wide area measurement system (WAMS) has been installed at several locations in power system. Phasor measurements units (PMU) are considered as the building blocks of WAMS are being installed at various locations of power system. PMU is sending very large volume of data to Power system control center with the sampling rate of 50 or 25 samples per second. However there are always several events per day occurring in the system but the rate at which data is received and the volume of data to be analyzed is a big challenge for power system engineer. There is a need for developing an intelligent system to handle large volume of Synchrophasor data and identify Power system event in the present context. This paper presents an intelligent algorithm to automatically detect such events using wide area measurements in real time. In this work, Synchrophasor measurements received from PMU are fed to KNN based pattern recognition algorithm which is used to identify the Power system events. The severity and the type of the event can be judged through the change in voltage magnitude and phase angle at various buses. The developed algorithm is tested for IEEE 14 bus system and results are verified.
INTRODUCTION

The challenges in power system operation in India are increasing manifold day by day as a result of enlarged system size; brisk pace of capacity addition; long distance power flows; multiple players; increasing competition in the electricity market; emphasis on pan India optimization; climate change; large scale integration of renewable energy sources in certain pockets; and increasing customer expectations. The ability of the system operators to take decisions in real-time is dependent on their ‘situational awareness’ derived from the data/information available with them in real-time.

The Wide Area Measurement System along with the high speed wideband communication infrastructure from substation to control center has now overcome the limitations of Power system operation and control. The basic building block of WAMS is the Phasor Measurement Unit using which it is possible to visualize the magnitude and angle of each phase of the three phase voltage/current, frequency, rate of change of frequency and angular separation at every few millisecond interval (25-50 samples per second) in the Load Dispatch Centre. This data is time stamped through a common reference and transmitted to the Phasor Data Concentrator (PDC) installed at a nodal point, through high speed wideband communication medium. Thus huge amount of data is collected at the nodal point. Thus analyzing the transient/dynamic behavior of the power system in real time is a challenging job for the operator at control center.

The power system operator has to continuously monitor the system health through observing the measured values and the output of the online tools like state estimators, static and dynamic security assessment. The present model of power system operation is using the data measurement through polling of remote terminal units. Any events like fault or tripping of load or generators is conveyed through binary signals and the final effect of the event on the system is perceived by the operators after the runs of state estimators and security assessment tools. Running State Estimators and other tools require time in terms of few minutes in SCADA systems. Evolution of WAMS technology leads to generation Synchrophasor measurements, binary data as well as the response of the system to the event is quickly communicated to the system control centers. In some cases when an event occurs outside the observable region the binary signal may not be communicated, still its effect can be observed on the phasor measurements.

Thus analyzing the large amount of Synchrophasor data and taking a decision in few seconds is a tedious job for Power system operator, Hence there is a need of developing automatic identification of events from PMU measurements. Using Event detection systems, operators can be alerted earlier about the occurrence of the event as
well as its severity and impact on the power system. Thus having automatic event identification can be useful for better system situation awareness.

This paper presents a multistage intelligent algorithm for event identification using the wide area measurements. The following sections give background about power system events, present method for event detection and method for identifying exact event instant and duration. Few cases studies are given later to highlight the effectiveness of method and discuss the implementation issues encountered.

**PATTERN RECOGNITION AND KNN ALGORITHM**

PR algorithms are essentially a collection of mathematical models that can be used to associate a set of test data with one of several pre-designated categories. Some of these methods are purely statically-based, and others have learning capabilities, however all PR methods have a requirement for training sets to define a “profile” for each category. Three different pattern recognition techniques were investigated during the course of the present research. KNN is a supervised learning algorithm, in which the category of new data set is determined based on its closest neighbor. The simplest version of KNN is where $K=1$, and a data set is assigned to the group of the training set that most closely matches, determined by similarity of features or principal components. As $K$ increases, the data set is assigned to the group of the majority category of $K$-nearest neighbors, as calculated by measuring similarity; here Euclidean distance was used. This is not a true learning algorithm but based on memory where a new instance is determined by input features and training samples. Advantages of KNN include that it is analytically tractable, simple to implement, it uses local information that can yield highly adaptive behavior and it lends itself very easily to parallel implementations.

**PROBLEM FORMULATION**

It is clearly deducible that most of the blackout events occur due to lack of situational awareness. Legible visualizations need to be developed in order to make the operator aware of the situations. Different types of visualizations which help the operator to understand the data are to be developed. Online voltage security monitoring tools are also essential. Efforts are still going on to provide better easily understandable visualizations for the operators regarding the condition of the power system.

With such fast rate of data the operator may not be able to notice the events, while if the large amount of data is displayed then also it will not be helpful to the operator. The application of PMU data for real time power system monitoring in order to make the operator to take preventive actions is the necessity of present situation. This paper investigates the feasibility of utilizing synchronized phasor measurements to determine the real-time event detection.

**ALGORITHM**

- MI POWER software is used to run the power system transient model for PMU data which is considered as Input data and required for training the system for Feature Extraction.
- A Multistage intelligent algorithm using K Nearest Neighbor pattern recognition to perform Event classification is developed.
- A Multistage intelligent algorithm using KNN will provide the current operating condition of the System as represented by the PMU measurements. Large numbers of
offline power flow simulations were used to generate the database required to build and test the decision KNN.

- The algorithm will classify the observed events into Normal and Abnormal in first stage.
- If the event is abnormal, type of abnormality and location is identified in second stage.
- Event based alarms in real time for operator with complete observability of the system is notified by the developed system.

FLOWCHART

![Flowchart Image]
Synchrophasor Data Based Intelligent Algorithm For Real Time Event Detection In Power System

RESULTS AND DISCUSSION

Figure 2

Figure 3

Figure 4

Figure 5
Different types of disturbance samples are created for IEEE 14 bus system using Mi Power software and system is trained for feature extraction. Once features are extracted then feature selection and reduction steps are carried out to develop Pattern Recognition algorithm. The Developed algorithm is implemented and tested for IEEE 14 bus system and results are discussed as follows.

Figure 2, 3, 4 & 5 are (Graphical user Interface) GUI’s of the algorithm developed in Matlab Software for Event detection using Pattern Recognition. The GUI consists of two graphs and Event details at the below. First graph is Voltage magnitude versus time and second graph is Voltage phase angle versus time of all buses. Voltage magnitude and phase angle are the two states of power systems which are directly measured for PMU at all buses and patterns are identified for normal or abnormal operation using the MATLAB Software. Developed algorithm is tested for different events at various time intervals as discussed below.

Figure 1 is a GUI that is indicating the system is in Normal mode of operation. To carry out this analysis the algorithm is taking a time of 0.002 second which is very fast and accurate. Analysis of PMU data with such a fast rate is very much useful to take decision by the operator before next set of data is available.

Figure 2 depicts that an abnormal event occurred at 1.02 seconds is a three phase fault at bus no 1 is successfully identified within the time frame of 0.002 seconds.

Figure 3 is showing that single line to ground fault occurred at Bus 9 and disturbance is observed at many buses with a detection time of 0.002522 seconds.

Figure 4 GUI is displaying that an event like generator outage has occurred at Bus no1 and disturbance is observed at many buses with the event detection tone of 0.002633 seconds.

The above discussion depicts that Pattern recognition Algorithm developed using KNN is successfully identifying different events in 0.002 second which very quick and helpful in taking decision for power system operator. The algorithm is using Patterns of Voltage magnitude and phase angle of all buses to classify events directly instead any time consuming procedure. The data updation rate is 50 samples per second which means that data is updated for every 0.02 seconds and event is identified around 0.002 seconds which is one – tenth of the time of the data updation rate. Every data set is analyzed and event is detected before the next data set arrives to the control center which helps for taking control action for power system operator.

**CONCLUSION**

In this paper, a novel intelligent algorithm is presented that is able to rapidly detect and locate power system events in 0.002 seconds which is significantly shorter than critical fault clearing time. This paper lays out the fundamental concept of KNN based pattern-recognition approach for power system operation and control. The developed event detection algorithm has successfully identified the beginning of the event and the location of the event for the IEEE 14 bus system. KNN based Pattern recognition is observed as the most efficient tool for event detection in power system considering time required for detection.
REFERENCES


