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PATTERN RECOGNITION BASED REAL TIME EVENT DETECTION USING WIDE AREA VOLTAGE MEASUREMENTS

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***ABSTRACT*-The wide area measurement system (WAMS) is being installed at several locations for real time monitoring of the power system. Phasor measurements units (PMU) are used to measure voltage, current and frequency in WAMS technology with the sampling rate of 50 / 25 samples per second. Phasor Data Concentrator (PDC) gathers very large volume of Synchrophasor data, which intern transmitted to Power system control center. Many events occur every day in the Power system but identifying events using Synchrophasor data in real time is the big challenge for the power system operator. This paper proposes an intelligent algorithm for event detection and classification using Pattern recognition techniques. Each event in the power system is having a unique feature, KNN based pattern recognition algorithm will extract such features and select features. Real time voltage measurements coming from PMU's compared with the features extracted in order to determine type of event occurred. The developed algorithm is tested for IEEE 14 bus system and results are verified.**

Keywords: Wide Area Monitoring System (WAMS), Phasor Measurement unit (PMU), Phasor Data Concentrator (PDC), Supervisory Control and Data Acquisition (SCADA), Pattern Recognition (PR), Graphical user Interface (GUI) and K-Nearest Neighbor (KNN).

I. 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 dynamic behavior of the power system in real time is 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.

From a research perspective, deployment large number of PMU's is raising several open questions: How to use the massive PMU data in wide-area power systems effectively? Thus analyzing the large amount of Synchrophasor data and taking a decision in few seconds is very difficult for Power system operator, Hence there is a need for 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 situational awareness. This paper presents a multistage intelligent algorithm for event identification using the wide area measurements. The following sections 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.

II. 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.

KNN is amongst the simplest of all classification algorithms in supervised learning. This is a method of classifying patterns based on the class label of the closest training patterns in the feature space. The common algorithms used here are the nearest neighbour (NN) algorithm, the k-nearest neighbour (KNN) algorithm. These are non-parametric methods where no model is fitted using the training patterns. 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.

III. 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. 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.
- PMU data for normal power system operation and fro different events is generated using the model developed in MI POWER software.
- Feature Extraction- Generated data is considered as Input data and required for training the system. Each event is having unique feature.
- Feature Selection-Once System is trained features are selected for different events.
- 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.
- f 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.

IV. FLOWCHART

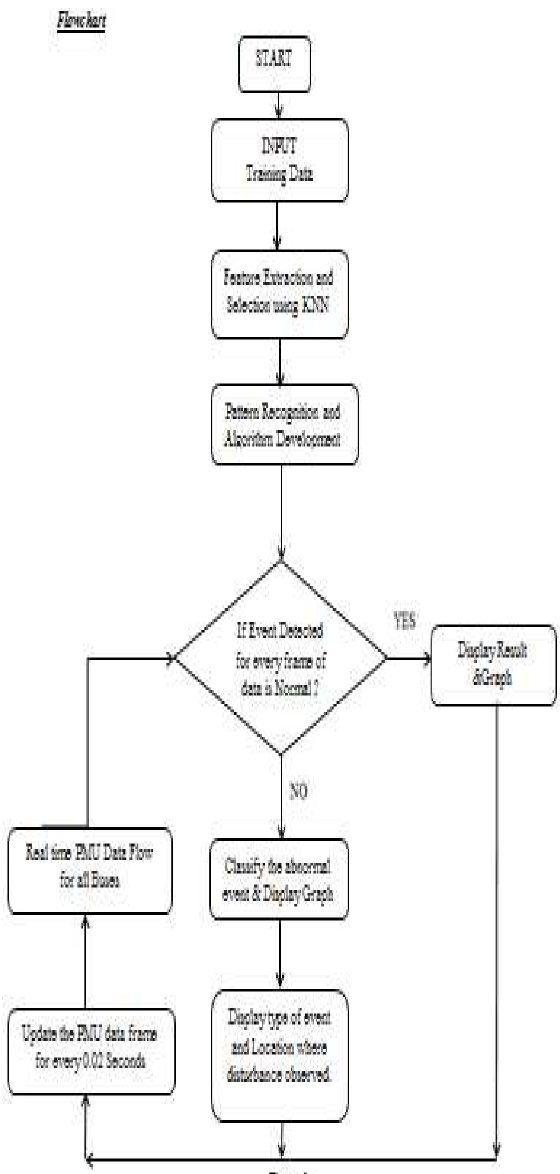

Figure 1

V. RESULTS AND DISCUSSION

Different types of events 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 2 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 3 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 0.002seconds.

Figure 4 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 5 is indicating that an event, 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.

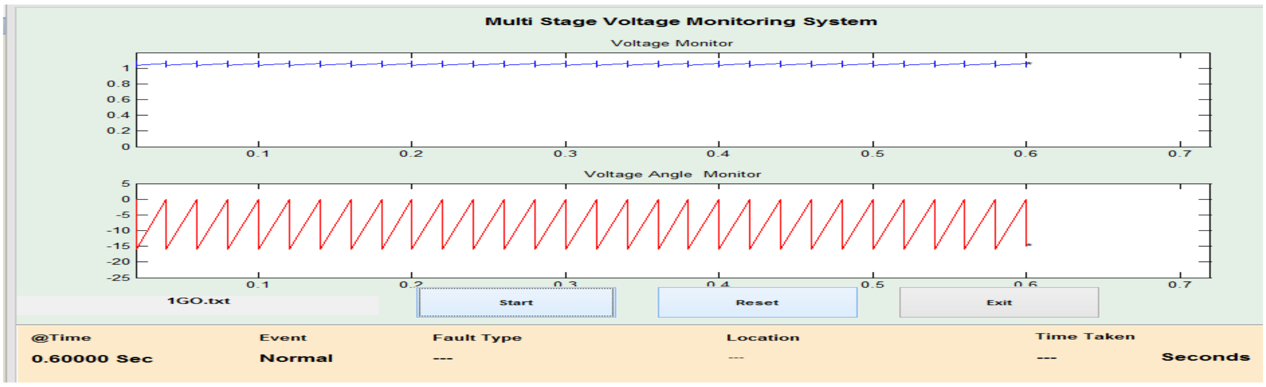

Figure
2

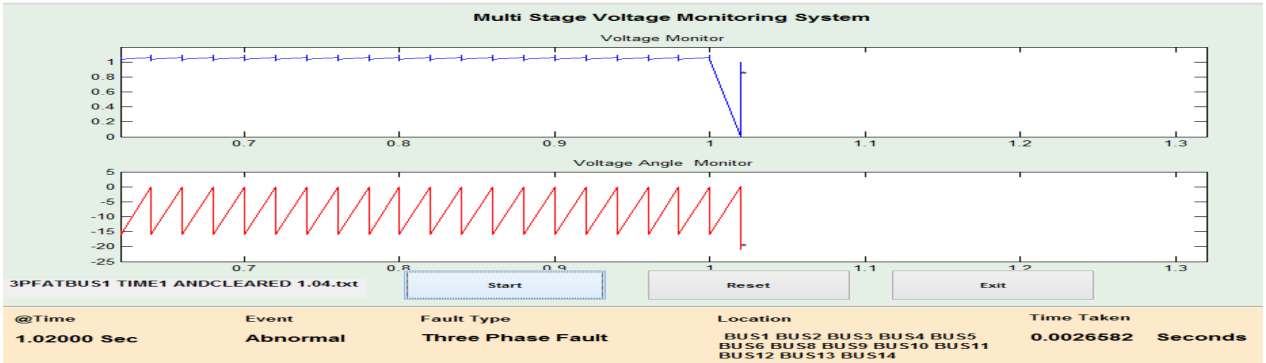

Figure 3

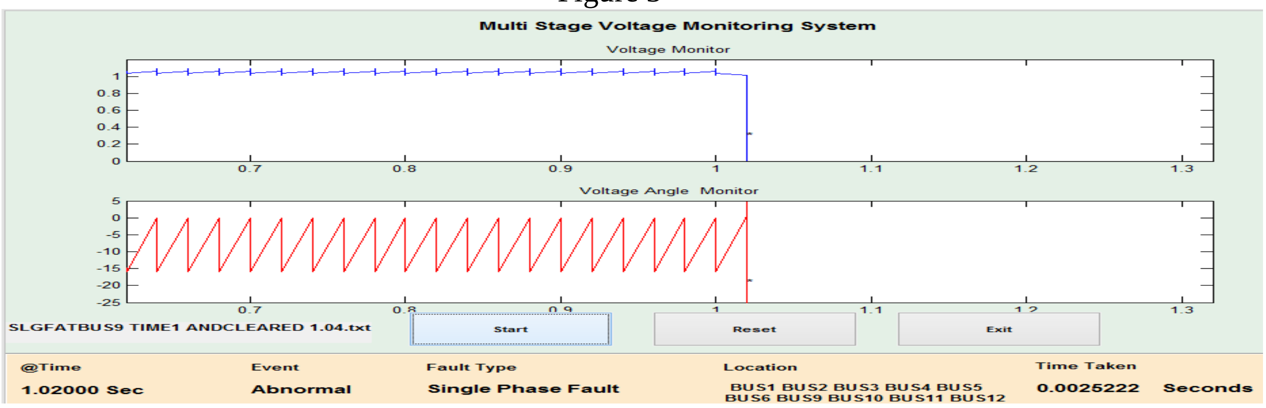

Figure 4

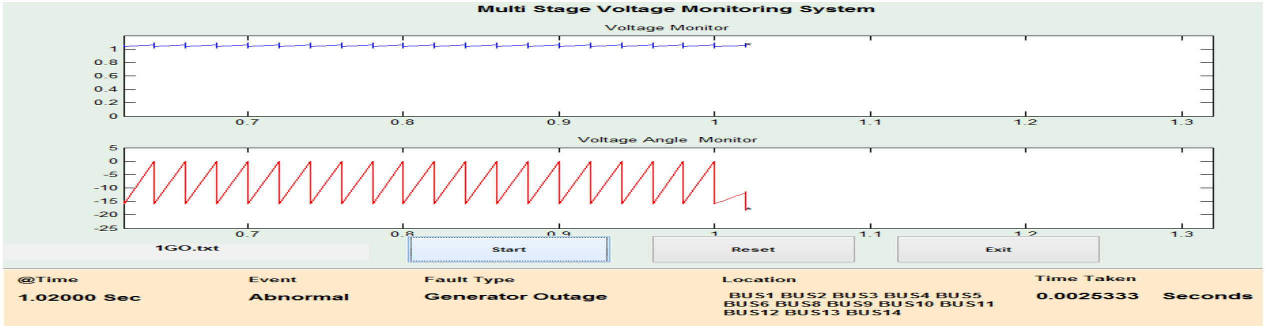

Figure 5

VI. 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. The accuracy using nearest neighbour classifiers is good. KNN based Pattern recognition is observed as the most efficient tool for event detection in power system considering time required for detection. While the nearest neighbour algorithm gives good results and is robust, it is tedious to use when the training data is very large.

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