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Wide Area Monitoring System based on the third generation Universal Mobile Telecommunication System (UMTS) for event identification

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ABSTRACT

Smart grids are one of the most essential infrastructure components in the world today. Power systems have been becoming more and more complex, as a result of a considerable variety of new components being added, such as High Voltage Direct Current (HVDC) and power electronic devices, and numerous recent technologies continually being put into application, such as distributed generation. In recent years, wide-area voltage and frequency measurements are used to identify different events that occur in power systems. One of the most important events is the generator trip identification. This event could be easily identified as a sudden drop in both the system voltage level and frequency. On the other hand, high-speed, reliable and scalable data communication infrastructure is crucial in both construction and operation of wide-area voltage and frequency measurements. Universal Mobile Telecommunication System (UMTS), the 3G standard for mobile communication networks, was developed to provide high speed data transmission with reliable service performance for mobile users. Therefore, UMTS is considered a promising solution for providing a communication infrastructure for WAMS. 3G based EWAMS (Egyptian Wide Area Monitoring System) is designed and implemented in Egypt through deployment a number of Frequency Disturbance Recorders (FDRs) devices on a live 220 kV/500 kV Egyptian grid to identify the location of tripped generator in the power system. WAMS systems are used for both off-line studies and real-time applications. An important feature of these systems is their ability to provide continuous dynamic measurements that are precisely time synchronized across the power system. With real-time WAMS, the continuous measurements feed out as a data stream which can be applied to on-line applications such as monitoring and control. This paper focuses on developing an efficient and reliable wide area voltage and frequency measurements through UMTS mobile communication technology in addition to the analysis these measurements using Principal Component Analysis (PCA) in order to determine a specific signature and properties for each tripped generator in the power system network.

Introduction

Wide Area Measurement Systems (WAMS) can be defined as a system that takes measurements in the power grid at a high granularity, over a wide area, and across traditional control boundaries and then uses those measurements to improve grid stability and events through wide area situational awareness and advanced analysis. Certain power system measurements cannot be meaningfully combined unless they are captured at the same time. Many advanced applications can use advantage of the Measurement capability provided by WAMS as Wide area monitoring, Real-time operations, improved accuracy of models, system protection, and Forensic analysis [1–7]. When a generator trips in a power system creating an imbalance between the mechanical power and the electrical power being supplied to the power system, this imbalance is translated into a change of generator speed. Most oscillations due to generator outage are damped by the system, but un-damped oscillations can lead to system collapse [8]. To manage and control power system correctly when a generator trips, location of tripped generator must be determined based on wide area monitoring. Many researches as in [8,9] use wide area measurement system to monitor and identify only type of low frequency oscillations in power system by using morphology and its mode based on wavelet analysis and Prony analysis. The method in [8] can discriminate between types of oscillation or disturbance as sag, swell, outage and harmonics. But in [9], the proposed

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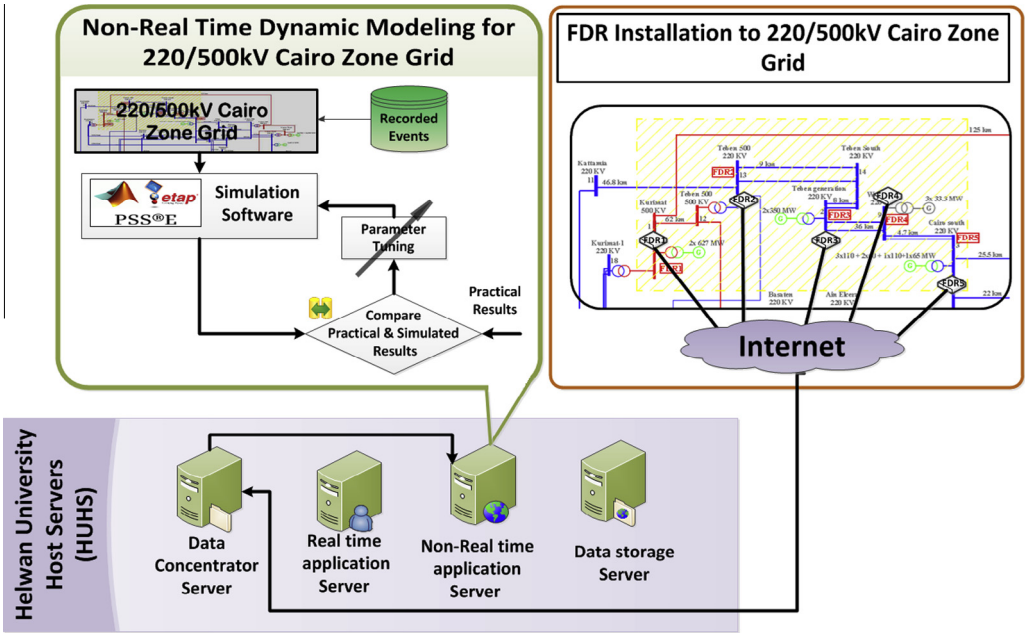

Fig. 1. EWAMS architecture (FDRs at selected 220 kV/500 kV Cairo zone).

Table 1
FDR locations.

FDR ID	Corresponding station	FDR ID	Corresponding station
1	North Cairo	6	Cairo 500
2	Suez Gulf	7	Kuraymat
3	Zafarana	8	South Cairo
4	East Cairo	9	WadiHof
5	Tebeen Gen.	10	Tebeen 500

technique discriminate between generator trip, load trip or line outage. Another paper [10] tries to define the generator trip location by dividing the grid into *N* numbers of clusters, each cluster has coherent group. Event location is formulated as finding the most likely group from which an event originates.

Depending on the nature of changes due to disturbance propagation in the grid, authors in [11,12], used electromechanical wave signature of a power system perturbation due to generator outage. PARZEN window approach is used in [11] to define the location of the tripped generator. In research [12], the order of the frequency variation due to event is used. The order of frequency changes is six different algorithms were developed to determine FDR detection order from in different areas. If the algorithm possesses these two properties the process of finding an event location involves matching the detection order to the order of a previously observed region.

Principal Component Analysis (PCA) is a well-known and well established technique for dimensionality reduction. Many applications as examples include data compression [13], image processing, visualization, exploratory data analysis, pattern recognition, and time series prediction [14]. The popularity of PCA comes from three basic properties. First, it is a linear scheme for compressing a set of high dimensional vectors into a set of lower dimensional vectors and then reconstructing. Second, the model parameters can be computed directly from the data – for example by diagonalzing the sample covariance matrix. Third, if the model parameters are given, compression and decompression are easy operations to perform – they require only matrix multiplications [15]. PCA develop new variables called "principal components" (PCs), which account for the majority of the variability in the data. This enables us to describe the information with considerably fewer variables than with originally present [15]. PCA derives the direction of a set of orthogonal vectors that point into the direction of the highest variance of the data set. The principal components (PCs) are calculated as the eigenvectors of the covariance matrix of the data set.

The communication infrastructure for WAMS should be carefully developed to provide continuous connectivity between all phasor measurements units in the grid and the control center. Also a huge amount of data from the measurement devices are generated continuously therefore requirements of bandwidth and latency should be met by communication system in order to guarantee the real-time operation. Several wired and wireless communication technologies are identified for smart grids. Recent wireless systems offer the benefits of inexpensive products, rapid deployment, low cost installations, wide area coverage, high speed data, and mobile communications compared to wired technologies [3].

Universal Mobile Telecommunications System (UMTS), the 3rd generation cellular network is designed to provide high-speed wireless Internet access and fulfill high quality of service requirements for rapidly growing Internet applications and services. UMTS can support maximum data transfer rates of up to 21 Mbit/s in downlink and 384 Kbps in uplink [16]. Therefore, UMTS can be considered as a good choice for providing wide area connectivity in WAMS. The voltage/frequency signals give the complete image of that certain generator. Using the voltage and frequency signals based on principal component analysis, the tripped generator can be easily identified.

3G cellular communication based Wide Area Monitoring System (WAMS) for Egyptian power grid

Egyptian WAMS architecture

Egyptian Wide Area Monitoring System (EWAMS) is a power grid situational awareness tool that collects real-time measurements based on Global Positioning System (GPS) with time-stamped and high precision at the distribution and transmission level. It made the synchronized observation of the entire Egyptian