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Application of WiMAX for Load Monitoring in Smart Grid Infrastructure

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ABSTRCT

The WiMAX uses OFDM technique, so as to have better redundancy among the signals and enable to achieve the orthogonality. This paper gives an insight in to the use the WiMAX protocol to enable bidirectional communication between various sections of the power system (generation, transmission and distribution). WiMAX is communicating through WAM (Wide Area Manager) and LAM (Local Area Manager). The WAM and LAM arrangement ensure coordinated operation for three cases defined for effective monitoring of load. The collected data in the Wide Area Manager is used to make suitable decision like tripping and re-closure of the relays that connect or disconnect the load or the generator from the grid. The protocol is simulated and the results prove its suitability in power system applications.

KEYWORDS: WiMAX, OFDM, QPSK, LTE, ISI

I.INTRODUCTION

Present day network infrastructure which is based on synchronous digital hierarchy and synchronous optical network technology is not efficient enough to support ever changing demands both physically as well as economically. The change in the demands is mainly due to irresistible increase in bandwidth, transport of IP traffic, need of automated network, high resiliency and more flexible connectivity. Due to these factors existing communication technologies are unable to respond to the delay requirements of smart grid. In order to mitigate this issue, there is a requirement for building next generation networks which suits all the applications of the deregulated power system. In deregulated environment, consumer actively participates as a small scale energy supplier to grid with the utilization of renewable sources. Hence, there is a requirement of effective communication between consumers and utility over long distance. With this objective, IEEE introduced series of wireless broadband standards called IEEE 802.16 Wireless MAN. This workgroup belong to a unit of IEEE 802 local area network and metropolitan area network standards committee. Officially the IEEE 802.16 standard is called Wireless MAN (Metropolitan Area Network) and commercially it is called WiMAX (Worldwide Interoperability for Microwave Access). IEEE 802.16 effectively covers a frequency range of 2 to 66 GHz which is standard of fixed wireless broadband along with mobile broadband application. This paper presents the study and validation of mobile WiMAX. It is proposed to effectively monitor the load against certain predefined cases in a simulated smart grid infrastructure.

II. LITERATURE REVIEW

Quite a good number of papers have been referred and few turning out to be highly relevant to this work are cited here below. The importance of TOU (Time of Use) pricing method is one in which energy consumption is charged more during peak hours and is charged less during off-peak hours. Thus, a TOU-aware energy management technique is developed with wireless sensor network which found to be effective in reducing the peak hour's demand by consumers. The technique was found

satisfactory in decreasing number of appliances used by consumers during peak hours and thereby reduce their energy bills [1]. A priority based load shedding system is proposed in [2] with an objective to make it compatible to smart cities emerging in near future. The system introduced here consists of two basic controllers viz Central Load Manager (CLM) and Local Load Manager (LLM). Sensors are deployed in both CLM and LLM for receiving the real time data and take necessary decisions on a prior check against certain threshold values. Related control signals are then communicated to LLM via TCP/IP protocol. The results are obtained and tested by developing a MATLAB/Simulink model under various conditions so as to analyze the performance and practicability of the system. The use of information technology to obtain more flexibility and smartness for protecting load in the wide area power system is available [3].The design of a communication channel using WiMAX help communicating between the LAM (Local Area Manager) and clients, then with WAM (Wide Area Manager) vice-versa. WAM takes necessary control action based on load data sent to it by LAM via WiMAX. Further, the results of islanding operation through WAM for the areas which become intensive faulty are also available. All these results are studied in MATLAB/Simulink. Energy efficient buildings are those where energy consumption of all the appliances is recorded and at the same time this data need to be transmitted to control system for necessary control actions so as to achieve energy saving. Thus, there is a requirement of two way communication network that collects all information from sensors and also sends necessary control actions. Hence, the paper [4] introduces a modern energy sensing and monitoring system involving a communication infrastructure to study the objectives of coordination, energy efficiency and that of integration in an intelligent building. At another paper [5] documents the importance of WiMAX networks since they include many Quality of Service (QoS) mechanisms at the Medium Access Control (MAC) level for guaranteed service of data, video and voice. There is a document [6] provides information about WiMAX technology, its validation through advanced test beds, pricing of WiMAX networks and advanced WiMAX architectures, its role in distributed wide area monitoring applications. This paper [7] introduces a model that helps in performance evaluation of the WiMAX under different data rate, channel status and coding methods. This is an important resource to conduct their study on WiMAX. The presented model is processed in physical layer including convolutional encoding rate of 5/6 along with QPSK (Quadrature Phase Shift Keying) modulation. The data is transmitted with 256 carrier OFDM (Orthogonal Frequency Division Multiplexing) symbols.

III.PROPOSED METHOD

From the literature review it is noted that considerable work has been reported in transmission sector regarding the smart operation with the reconfiguration of power system. However, little work is reported in distribution sector, thus, opening the avenues for research in this area. Thus, the problem is undertaken to give the consumer to participate and there is a need for effective bidirectional communication between the consumers and utility. In order to achieve this objective and to develop reliable smart grid applications, the condition of reclosure and tripping of relays to protect the parts of the power system is to be introduced. This process would be more efficiently achieved, if the tripping and reclosure is guided by some standards. Care is taken to ensure maximum and efficient use of renewable energy. Thus, a centralized control technique along with an effective communication protocol which would satisfy the above factors is developed.

III. METHODOLOGY

This study proposes a centralized controller that would control both the load side and source side dynamics in the power grid and the centralized controller (WAM-Wide Area Manager) is always available for both the load and the generator side. In this paper an attempt is made to use the WiMAX to facilitate the load and the generator data transfer from the LAM (Local Area Manager) to the WAM. The collected data received in the WAM is used to make related decision like tripping and re-closure of the relays that connect or disconnect the load or the generator from the grid. The measured voltage, current and angle data are compared against pre defined standards as per IEEE standard requirements for secondary network protection i.e. IEEE Std C57.12.44TM-2014. Load is monitored by centralized controller for following two cases:

- Protection of load against any faults: In this case, when fault occurs at the load side then that part of the load is tripped by the WAM so as to protect it from fault quantity. The information regarding fault existing in the system is sensed by the relays of LAM and the same information is sent by the LAM to WAM for necessary action through WiMAX.
- Load Prioritization: Here, for a small demand, the centralized controller sends trip signals such that load is not supplied from utility instead it is supplied by renewable energy. In the case of higher demand then trip signal is not sent by WAM such that partly the load is supplied by utility and other part is supplied by renewable energy.

The proposed model of partial smart grid involving load monitoring system with WiMAX is simulated using MATLAB/Simulink. For the above mentioned cases WAM or centralized control is achieved with commands in MATLAB editor (code) and LAM is measurement blocks of Simulink library. LAM sends information to WAM and relays act accordingly.

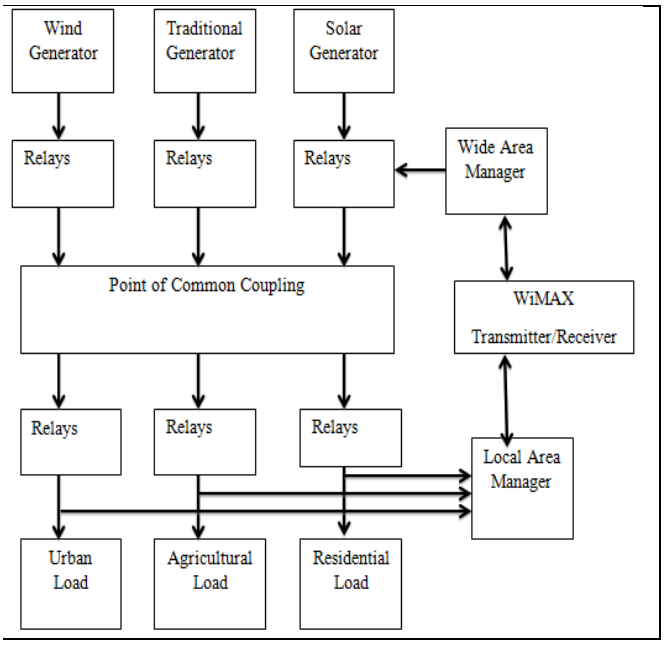


Figure.1 Block diagram of proposed model

The Figure.1 depicts the proposed model involving smart grid infrastructure with WAM and LAM along with WiMAX communication channel and relays having bidirectional information flow.

IV. DETAILS OF WiMAX

The IEEE 802.16e is an amendment of 802.16d standard. Mobile WiMAX uses OFDMA (Orthogonal Frequency Division Multiple Access) technique. The OFDMA system divides signals into sub channels so that resistance to multipath interference gets enlarged. Thus, the problem of Inter Symbol Interference (ISE) vanishes and supports Long Term Evaluation (LTE) leading to the path of 4G.

A. WiMAX Physical and MAC Layer Architecture:

It utilizes two layers of OSI (Open System Interconnection) reference model viz. physical and MAC (Medium Access Control) of data link layer. Two types of transmission techniques are adopted by the physical layer; which are OFDM and OFDMA. A frequency band below 11GHz is supported by these techniques.

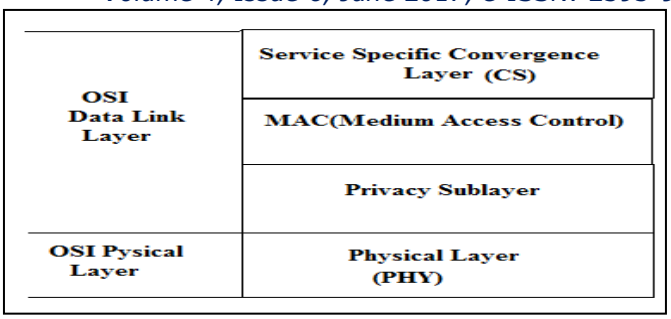
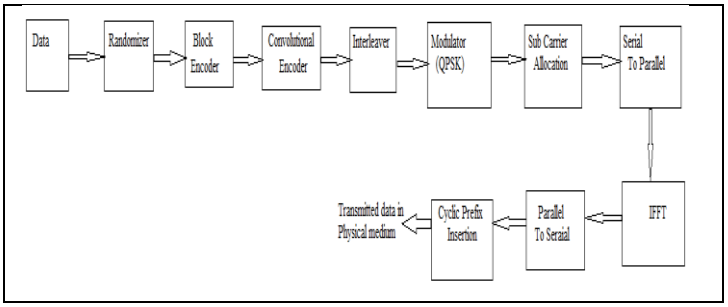


Figure.2 WiMAX Architecture.

B. Simulation of Mobile WiMAX Performance:

The performance of mobile WiMAX is studied with WiMAX transmitter and WiMAX receiver module which are designed separately in MATLAB/Simulink software.

B.1.WiMAX Transmitter Module



The following section describes the components used in the transmitter module.

- Randomizer: This block is concerned with generation of random numbers. Deterministic and non-deterministic are two types of random numbers.
- Encoder: Figure 3 shows steps involved in encoding.

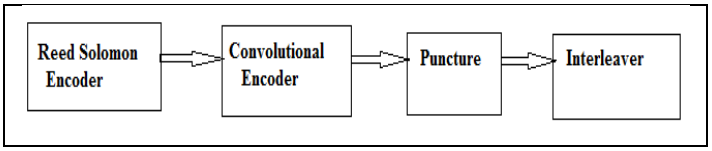


Figure.3 Encoding process in WiMAX

1. Reed Solomon Encoder: In this a polynomial is generated from the data symbols to be transmitted. Then the generated polynomial is over sampled to send instead of sending original symbols.

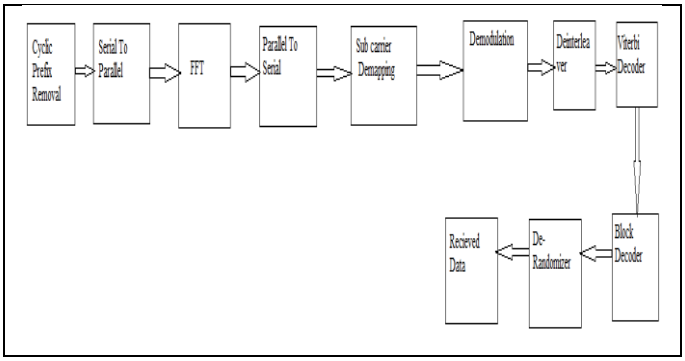
2. Convolutional Encoder: After Rs-Encoding step, the convolutional encoder is used to combine (multiply) the generator polynomial and primitive polynomial sampled data.

3. Puncturing Process: It systematically removes bits from the output of an encoder of low rate. It is with a view to minimize amount of data transmitted. This convolution and encoding is directly supported by Simulink and the same is implemented in single block.

4. Inter-leaver: It is used to combine available bits using 12 interleaving levels. The effect of this is similar to spreading the bits with different symbols where they are then combined to get new symbols. These new symbols are of the same size but are having rearranged bits

- Modulation**:** The data is modulated depending on their size with use of different schemes like BPSK (Binary Phase Shift Keying), QPSK (Quadrature Phase Shift Keying). Here QPSK modulation is used.
- IFFT: The source symbols are converted from frequency domain to time domain.
- CP (Cyclic Prefix): A CP is to be inserted before a transmitted symbol so as to avoid Inter Symbol Interference (ISI).

B.2 WiMAX Receiver Module:



- CP Removal**:** After synchronization, the data received contains CP of each of OFDM signal which is removed.
- FFT (Fast Fourier Transform): This converts time domain signal to frequency domain.
- Denormalizer: This deals with separating the signal either in time or frequency domain. By this data, pilots, training are obtained.
- Decoder: In this process the data transmits over four blocks is as shown in figure 4.

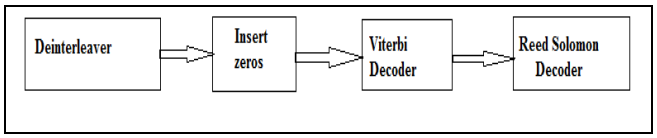


Figure 4.Decoding process in WiMAX

1. Deinterleaver: This rearranges the bits from each group correctly and places them in consecutive order.

2. Inserting Zeros: Here zeros are inserted in the gaps of sequence of bits.

3. Viterbi decoder: It is a type of decoder which is very efficient since it uses trellis structures.

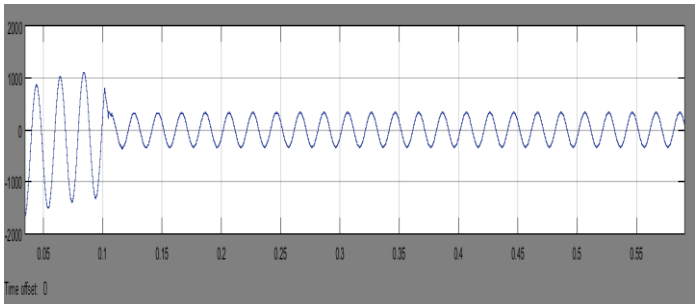
4. Reed- Solomon Decoder: It performs all the necessary steps in reverse to that performed in encoder so that transmitted data is recovered.

V.RESULTS AND DISCUSSIONS

This section describes MATLAB/Simulink models developed for two different cases where in load is monitored by centralized controller with WiMAX.

A. Protection of Loads against unsymmetrical faults:

In this section a Simulink model has been developed to detect the faults at the load side and then send this information to protective device (circuit breaker) so as to trip that part of the load via WiMAX. A SLG (Single Line to Ground) is considered at one of the load side and the WAM works such that when current exceeds a preset value of 150 ampere then the circuit breaker trips such that fault is removed from the system. The LG fault and the waveform for isolated fault is shown in Figure.5. The values of the current observed for some interval is noted in the Table.1



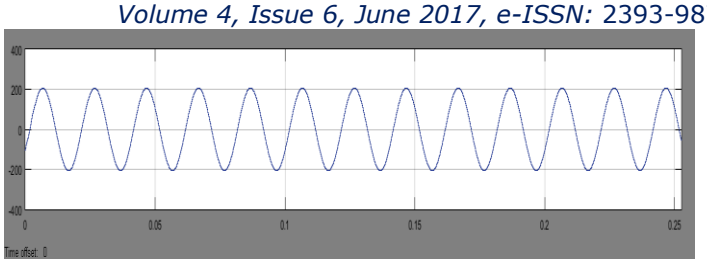


Figure.5 SLG Fault at Load side (Top), Fault Cleared with Circuit Breaker (Bottom)

Table.1 SLG Fault

Iteration No.	Current(ampere) Without CB	Current(Ampere) With CB
106035	198.6822	109.2671
106075	200.7690	100.6388
106100	224.7340	126.5424

B. Load Prioritization:

A Simulink model is developed for this case which involves a load, utility and renewable sources of energy (Solar and Wind power).The load prioritization is achieved for high and low load conditions. When the power system encounters a low load condition then the decision is made by WAM such that the load is only supplied by the renewable energy. If a higher load exists, then WAM decide to supply the load with utility as well as renewable energy. Centralized controller (WAM) is achieved with MATLAB code such that a higher load is taken as any load with value above the 20 KW and that load below this value is considered as low load.

B.1 For 10 KW load:

For a light load (less than 20MW) renewable energy is used to feed it completely. This is shown in figure.6.To support this statement, positive power symbolizes power fed by renewable sources and that negative power is from utility. The figure.6 depicts only positive power in both renewable and utility side i.e for a load of 10KW, renewable sources are sufficient enough to provide power to load, and excess power from renewable is fed to the utility. This decision of supplying load by renewable sources is taken by WAM and is conveyed through WiMAX.

B.2 For 100 KW load:

The considered real power of the load is more than the defined value of 20 KW hence; this load is considered as higher load. Thus, the part of the load is being fed by the renewable sources and the other part of the load is being fed by utility. The result is shown in figure 7 where negative power on utility side proves that utility is supplying power to the load.

Power supplied by utility and renewable sources in both cases are tabulated in Table 2.

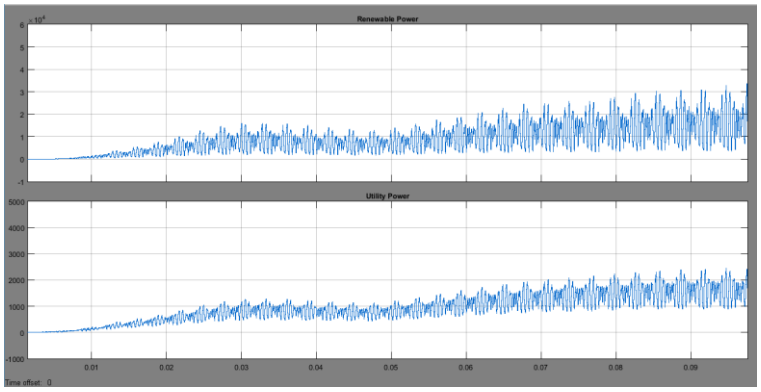


Figure.6 .For a Load with real power=10KW

Table.2 Load Prioritization

SL. No	Load (in KW)	Renewable Real Power(KW)	Utility Real Power(KW)	Status of Relay
1.	10	5.636	2.872	On
2.	100	39.90	-61.03	Off

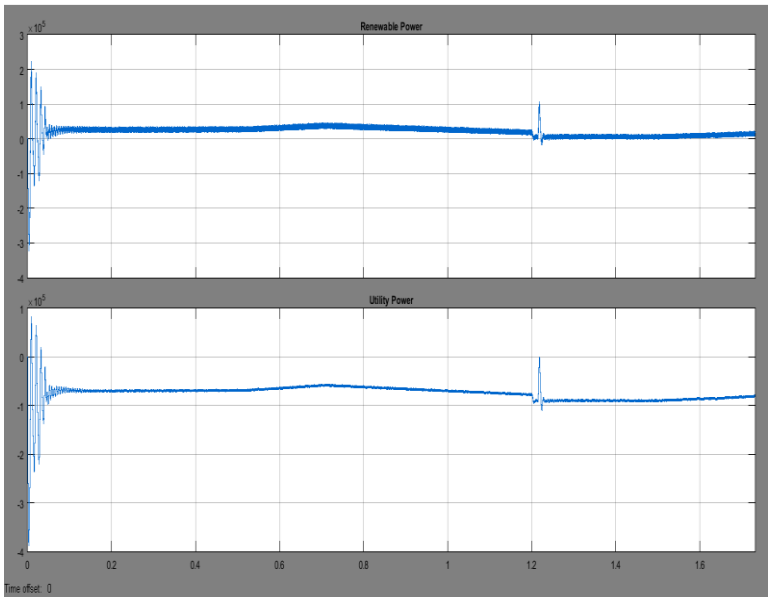


Figure.7 For Load with real power=100KW

VI.CONCLUSION

The work carried out in this paper demonstrates the importance of WiMAX protocol in effective monitoring of a load in a smart grid environment. For two cases defined for a load, the WiMAX transmits the related information to the WAM (Wide Area Manager) where necessary action is taken. Thus, objective of the work is met and the need for a centralized controller in the power system using wireless communication is achieved.

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