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Wireless Sensor Network Tools for Power Quality Applications: A Survey

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***Abstract*—This paper surveys the literature for modern application of Wireless Sensor Networks (WSN) in Power Quality. A considerable collection of literature covering application of Zigbee, M2M and IEEE802.154 model for cyber physical power monitoring grid in power quality has been included. It also includes comparison of these communication infrastructures in the power quality monitoring.**

***Index Terms*— IEEE802.154, M2M, WSN, Zigbee.**

I. INTRODUCTION

Power quality can be defined as the ability of the electrical network's or the grid's to provide a pure and stable power supply. In other words, power quality perfectly creates a flawless power supply which is accessible, as a pure noise-free sinusoidal wave shape, as well as it is always within voltage and frequency tolerances. But, with growing and changing energy demands from different industrial processes, many loads regularly impose disturbances on the grid and causes deflections from these perfect conditions.
[1] Presently, greater attention is paid to the electrical power quality. Any deviation from its quality standards leads to rupture or impairment of electrical devices and electrical apparatus coupled to the power system. For both suppliers and consumers the power quality is important thus, more and more systems for its monitoring have been introducing .
Wireless sensor networks (WSN) have been identified as a connected and smart monitoring structure policy for smart grid systems. For example, low-priced wireless sensor nodes can be assigned over wild fields where the power plants are located and can upgrade efficiency service monitoring capabilities. [2] The information from remote wireless sensors will be collected by the control center to detect the behavior of the power equipment and maintain balance in the power grid. WSNs will play a significant role in automatic meter reading, remote system monitoring, remote home/customer site monitoring, equipment fault diagnosing etc .[3] Wireless Sensor Networks (WSNs) with its economical low cost and various features enable utilities to monitor its remote facilities any time with applications such as SCADA . This paper presents survey of real – time monitoring system in power quality assessment using WSNs.

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II.WSN- BASED SMART GRID APPLICATIONS

[4] Generally, WSN-based smart grid applications can be classified into three functional units: consumer WSN –based smart side, transmission and distribution side and generation side WSN-based smart grid applications.

[5] The necessary condition for communication and network plays a significant role in accomplishing the WSN technologies for power quality monitoring in smart grid . Different communication Standards for WSNs based PQ monitoring systems can be used like Zigbee, 6LOWPAN, RPL, ZWave, Wireless HART, ISA-100, Wavenis and so on.

A. Design of Communication Infrastructure

Zigbee

[6] Implementation of Zigbee in designing the communication infrastructure is used to substitute conventional wired mode in PQ real-time monitoring system. Zigbee is one of the global standards of communication protocol, builds on the IEEE 802.15.4 standard that defines the physical and MAC layers economical and low rate personal area networks.

WSNs comprises of data acquisition node and sink node through Zigbee technology. Wireless data transmission is achieved by sink node and remote monitoring center through Internet or satellite. It is primarily responsible for two tasks: transfer power grid parameters from transformer to local aggregation node through Zigbee technology, and set proper operating mode pursuant to those received commands.

Sensor node links the sensor network and the external network and accomplishes communication protocol transfiguration between various protocol stacks. The primary objective of sink node is to process the power quality data and compute various technical indices.

Primary task of remote monitoring center encompasses data analysis, results display, and data storage and so on. Remote monitoring center can communicate concurrently with numerous WSNs to obtain the power quality parameters in various monitoring areas. Zigbee-based WSNs consists of two steps, the network initialization and the network access.

The collection and storage of the electrical parameters are accomplished by the sink node. It also identifies and exhibits the nature of power quality disturbance (PQD). The monitoring system can exactly asses a variety of power quality indices, such as harmonic voltage and waveform distortion, three-phase voltage unbalance, voltage fluctuation and flicker, and so on.

Owing to the use of Zigbee wireless transmission module in the real-time power quality monitoring system, it expels the need for complicated wiring link and reduces the human and materials costs. On the whole, the features of the system are low cost, high reliability, high capacity and speedy networking process .

M2M Communications in the Smart Grid:

[7] M2M is undoubtedly a consolidation of numerous heterogeneous electronic, communication, and software technologies. In order to accomplish the intelligent electricity network, machine-to-machine (M2M) communication is treated as a elementary block for SG as a means to extend a large-scale monitoring and control infrastructure, thus providing great opportunities for the information and communication technology (ICT) industry.

[8] A wireless sensor and actuator networks (WSAN) based wide area network (WAN) electric energy substation monitoring system plays an essential role in assuring the health of the power subsystems (transformers, circuit breakers, etc.) and transmission lines, and enhancing the observability and reliability of power systems.

WSN furnish the patentability for wireless automatic meter reading (WAMR) for electric power distribution systems with the advantage of reduced operational expense, online pricing, and remote monitoring for resource protection. The reliable two-way communications between the electric utilities and customer’s smart metering devices is the major demand in WAMR.

[9] One of the crucial roles of the WSAN in a power distribution system is voltage quality management (VQM). With the increase of nonlinear time variant loads due to numerous current and new applications, the distortion and disturbances on the voltage signal have turned into progressively a significant issue. In a VQM WSAN, evaluation of performance of the monitored site is done ideally by each node, by employing local information for computation, also the global performance of the monitored grid section by employing local

information exchanges between its neighbour nodes. With these features, the node can identify local voltage quality anomalies.

Combination of wired and wireless communication:
[10] This kind of communication infrastructure has been employed in KEPCO. The communication infrastructure consists of two parts; wired for the relay subsystem and wireless for the collection subsystem. The relay subsystem sends data from substations to the monitoring subsystem through wired infrastructure due to the long distances between the relay subsystems and the monitoring subsystems. Authors make use of a WSN to construct the collection subsystem, in order to restrict the deployment and operational cost. Since substations in the relay subsystem are connected to the monitoring center through a high-speed wired network, the communication between them is immensely reliable. Thus the complication of data delivery in electrical distribution system (EDS) is the synonymous to the data delivery problem at the collection subsystem.
[12] The group of subsystem can be accomplished by employing the IEEE 802.15.4 [11] or IEEE 802.11b standards . A wireless personal area network (WPAN) based on the IEEE 802.15.4 standard is used due to the short communication range (e.g., dozens of meters) and the extra low power consumption of a communication devices, despite of its low data rates. Authors use Wi-Fi (IEEE 802.11b) radio modules. The advantages of particular modules are high data throughput (e.g., 11 Mbps) and the ability to abstract wireless communication technicalities including collision detection and avoidance and error detection. The wireless sensor node design on a pole transformer. Through the 3-phase transformer part, power quality is measured periodically. Measurements are carried out once every second, which is sufficient to provide the power quality monitoring service. In EDS, all pole transformers can be data sources, while the monitoring center alone is a data sink. In supplement, the network topology in EDS is immobile. Authors design the data forwarding protocol for the collection subsystem. Since multi-hop and many-to-one nature of data flows, authors come up with a new tree-based data forwarding protocol for delivery of the power quality information from each pole transformer to a monitoring center.
[13] To calculate the performance of the recommended data forwarding protocol quantitatively, authors use NS-2 network simulator . Authors use the shadowing model in [14] to model a radio propagation environment.

A Reliable IEEE 802.15.4 Model for Cyber Physical Power Grid Monitoring Systems:
[15] Cyber physical systems (CPSs) can significantly improve the flexibility of the smart grid. In CPSs, real time and reliable monitoring require an accurate and stable model of the wireless sensor network (WSN)-based monitoring system.
[16], [17] Cyber-physical systems (CPSs) integrate communication and information technology functions to the physical elements of a system for monitoring and supervising purposes. As the power grid is evolving into a Smart Grid with the usage of Information and Communications Technology (ICT), it is becoming one of the largest CPSs, where physical grid components are monitored and controlled based on the interactions on the cyber space. With respect to this, Wireless Sensor Network (WSN) will be extensively adopted in Smart Grid monitoring applications.
[18] [19] WSNs have been considered for use in different parts of the Smart Grid and QoS is relevant for most of those WSN-based applications. Authors presented an analytical model for the MAC sub-layer of the IEEE 802.15.4 standard that can pro-vide QoS to certain Smart Grid applications such as PD detection. The model can present QoS by reducing the fluctuations of the WSN parameters as the traffic rates and the number of nodes varies. The model considers a star topology and two cluster-tree based WSN topologies.

III. Comparision of Communication Infrastructure

In the first communication infrastructure described above i.e., by using Zigbee, the sink node used is S3C2440A which is developed with ARM920T core. It employs a new bus architecture known as Advanced Micro Controller Bus Architecture (AMBA). By assuring a complete set of common system peripherals, the S3C2440A reduces overall system price and removes the necessity of configuring extra components. Using the ARM9 S3C2440A microcontroller, the local monitoring center was effectively designed and realized.
WSAN has a significant role to play in the area of PQ monitoring due to its low cost, adaptability, and collaborative nature for total intelligence. They are capable of monitoring the crucial parameters of the

apparatus in SG and supply a timely feedback to operate the SG system to respond to the varying conditions. This enables SG to function in a reliable way with self-healing capability.
The next two communication infrastructure as been compared and tabulated in TABLE I and II. In third communication infrastructure the power quality data is measured every one second and the measured data is transmitted to the monitoring center at every transmission interval. Here authors have deployed the system at the area which is covered by a residential distribution. The usage of the current off-the-shelf radio interfaces is preferred.
In the forth communication infrastructure Markov-based model for cluster-tree have been employed in power grids as they are appropriate for wide scale deployments. Authors are able to achieve high reliability and lower power consumption for all traffic generation rates.

TABLE I: COMPARISON OF SIMULATORS AND TOPOLOGIES USED IN THE COMMUNICATION INFRASTRUCTURE

SL. No. ***SL.No.***	**Comparison of Simulators and Topologies employed**		
	Communication Infrastructure	***Network Topologies***	***Simulator Employed***
1	Combination of wired and wireless communication	Tree-based data forwarding protocol	NS-2 simulator
2	A Reliable IEEE 802.15.4 Model for Cyber Physical Power Grid Monitoring Systems	Star and Cluster tree topologies	QualNet Network Simulator

TABLE II: COMPARISON OF THE COMMUNICATION PARAMETERS

SL. No. ***SL.No.***	**Comparison of communication parameters**			
	Communication Infrastructure	***Maximum Bit Rate***	***Channel Access***	***Distance between nodes or area***
1	Combination of wired and wireless communication	11 Mbps (When Wi-Fi is used)	CSMA	200-300 meters and 500 meters radius
2	A Reliable IEEE 802.15.4 Model for Cyber Physical Power Grid Monitoring Systems	250 Kbps	Beacon	(30m *30m) area

IV. CONCLUSION

WSNs have become essential to the analysis of power quality. In this paper, PQ monitoring in energy grid and its necessity was discussed. The paper also presents the literature for application of Zigbee, M2M and IEEE802.154 model for cyber physical power monitoring grid .The comparison of communication parameters in these infrastructures has been discussed indicating inferring that WSN plays a significant role in Smart Grid in the future by replacing the conventional wired distribution system.

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