Wireless Monitoring Technologies for Renewable Energy Systems

Nisar Memon, Shahzad Memon, Raza Hussain Shah, Asim Tanweri

***Abstract*—In Pakistan, recent surge of energy crises, the government energy policy makers are seriously considering on the development of large scale solar and wind renewable forms for generation of additional power to overcome on the shortage. These large- scale renewable energy forms require the use of data acquisition units for monitoring operations such as wind speed, sunshine, generated energy and humidity. This is one of the important features of renewable energy forms since they are installed in mostly financeable areas. The recent developments in the wireless communication technologies build possibilities to integrate them with renewable energy resources for monitoring purposes. In this paper, authors have presented a review of some wireless technologies and their use for monitoring the renewable energy systems. In addition, some challenges and possible solutions for integrating available wireless technologies for remote monitoring of renewable energy systems in Pakistan has been discussed in this paper.**

***Keywords*— wireless, communication, technology, remote monitoring, renewable energy**

I. INTRODUCTION

With the population growth, the demand for electricity is expected to increase exponentially in Pakistan. It is a big challenge for the government to deal with current and future energy crises of the country. From last few years, government is seriously focused on coordinating, facilitating and promoting the use of alternative/renewable energy technologies at commercial and industrial level [1]. Also, energy policy makers decide to achieve maximum share of power generation form solar and wind by year 2030[2].

Increase in the development of renewable energy power generation at large scale in remote areas such as deserts and costal sites will also increase the challenge of maintenance and monitoring of theses renewable energy power plants. Several power generation monitoring technologies and standardized.

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Wired and Wireless communication systems has been implemented in developed countries and proposed in literature for the remote monitoring of renewable energy systems [3]. These technologies provide economical methods for monitoring the performance and measurements of the field energy farms located at remote areas. However, there is a need to review the other wireless technologies such as Global Service for Mobile Phones (GSM) for remote monitoring purposes for renewable energy farms.

In this paper, the authors review the all major wireless communication technologies which are in use or can be used in future with their technological features and limitations. The rest of paper is divided into three sections. Traditional technologies used for monitoring power generation are explained in section 2 and wireless technologies in use for monitoring power generation reviewed with the latest wireless technologies in section 3. Finally conclusion is drawn in section 4.

II. TRADITIONAL TECHNOLOGIES FOR MONITORING POWER GENERATION

Communication technologies are critical part of remote renewable energy systems which enables a two way communication. To monitor or control the characteristics such as voltage, power, current, temperature in real time is an important part of these systems. SCADA (Supervisory Control and Data Acquisition System) is a control and monitoring system which is in used with power systems. The section discusses the SCADA with its features and limitations [5].

a. *SCADA based Remote Monitoring of Power Generation*

SCADA is a technique that performs PLC (Program Logic Controller) functions. Figure.1. Illustrates architecture of SCADA used in power Systems

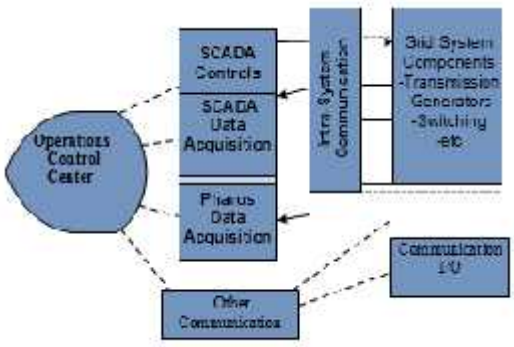

Figure 1(a) Block diagram and b) Architecture of SCADA System

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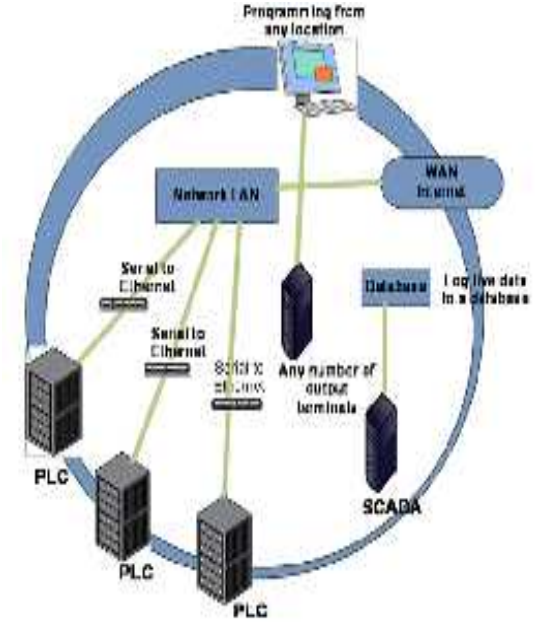

Figure.2: SCADA with multiple communication channels [2]

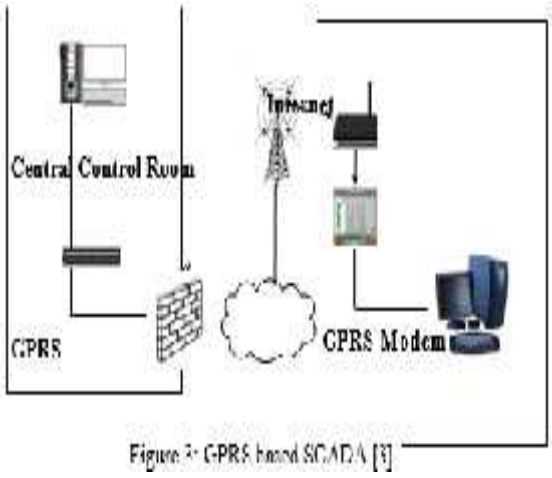

Figure 3: GPRS based SCADA [3]

This technique typically consists of subsystem called RTU (Remote Terminal Unit) also named as IEL (an Intelligent Electronic Device) which supports HTTP protocol [4]. It is a web-based monitoring platform, where the data collected from field with RS-232 medium to the cellular router or modem by using Ethernet connection. The software of SCADA contain web-based application which starts with logon on web browser loads a GUI based HMI (Human Machine Interface) environment on which related operations, data acquisition, supervisory controls, alarms are displayed for monitoring.

Mostly its remote monitoring uses GPRS (General Packet Radio Service) accessed with GSM for transmission and reception of data (shown in Figure). In (S. Joshi, A. et.al, 2014), a supervisory control and data acquisition with use of CDMA (code division multiple access) technique which enables communication between remote terminal unit (RTU) and SCADA server is being discussed. Following are the features of this SCADA system:

- It is featured with a data base in which data is collected from output responses caused by any action
- This platform is used for transmission of generated alarms and warnings through GPRS with particular user
- ID for operator
- It monitors the parameters such as different Alarm zones (critical, warning and normal zone)
- A GUI based display for monitoring, operator guidance and different problem or fault diagnostic blocks.
- Single click interfaces with various parameters and analysis of problems occurs during the monitoring of industrial process control systems of power plant

SCADA system is successfully in used to monitor power plants, however; few issues are still with this technology such as limits of data transmission networks, efficiency, response time and reliability of data transmission during monitoring.

a. *SCADA for monitoring and control of renewable energy systems*

SCADA is the most widely used network system in global society of renewable energy systems and it is more preferable systems compared to other technologies such as ZigBee and WIMAX for remote monitoring [6]. It is used for monitoring purpose either remote or directly with any physical media. Although it has major reputation and widely used technology for DCS (distributed control systems) in power plant technology for and provide an easy interface of plant with operators. Recently a new renewable energy policy in Pakistan designed their 49.6 MW wind power project at Jhimpir, Sindh with SCADA monitoring system. This technology covers a broad range of applications in smart grids monitoring worldwide.

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III. WIRELESS COMMUNICATION TECHNOLOGIES FOR REMOTE MOTORING

In this section, various wireless communication technologies are being discussed with technology and its features. Wireless communication technologies which are implemented, under practice and under research for future implementation has been discussed with their impact on systems and challenges in area of remote monitoring for renewable energy systems. Moreover, each technology has been critically reviewed and summary of limits and features presented zed in tables [8].

a. GSM (Global system for Mobile Communication

GSM technology operates with a device called GSM modem which supported a licensed frequency spectrum about 900/1800MHz [9]. It is TDMA (Time Division multiple access) based technology for transmission and receiving of data and it provides high speed outdoor mobility which makes it suitable for remote monitoring applications. The 3G (Third generation) and 4G (fourth generation) has frequency spectrum about 824 -894\1900MHz with a specific data rate up to 240 kbps. The distance covering capability is proportional to the availability of cellular communication and it uses cell to cell or cell splitting topology with low power transmitters and it allows users to monitor or accessing service at different points in a cell location [10-11] However, from remote monitoring perspective operations can be control through SMS (short messaging service) using attention commands. GSM technology widely uses RTUs for transmission of data between client and server in the SCADA monitoring system [12]. In addition, it is considered as standard choice for remote communication and used for smart metering, smart grids and remote monitoring of renewable energy sources [13], and allows operators to monitor the remote renewable energy plant anywhere and at any time.

The advantage of using this technology is developments in its generations, rapid increase in data rates and improves QoS (Quality of services). Although it has some limitations such as typically the unavailability of signals and dropout of communication may create interference and may victims the heavy data transmissions.

Table 1: Features and Limitations of GSM/cellular technology

Features of GSM Technology	Limitations of GSM
▪ Global roaming: ▪ Allow mobility to the user when working with remote monitoring system for point to point communication ▪ Multimedia messaging services ▪ High speed integrated data data transmission flow is from cell to cell to overcome the mobility device monitoring system which prevents any data communication interferences to the users or any loss of signals ▪ TDMA (Time Division multiple access): ▪ Transmission and receiving of data from one Ethernet interface to the other Ethernet interface that manage maximum data handling capability and also economic at costs and fully maintained network	▪ Availability of network or weak signal ▪ May create interferences during high rate data transmission

Table 2: Features and Limit of WLAN

Features of WLAN	Limitations of Wireless (LAN)
▪ Ad hoc infrastructure ▪ Using different IEEE standards increases data rates and frequencies makes possible to collect frequently larger number of variations or parameters data at once from the field ▪ Easy in deployment ▪ Provides a mobile control to devices ▪ Feasible and economical solution	▪ Insufficient availability of wireless LAN ▪ hardware equipments ▪ Data Transmission may influenced by Electromagnetic interferences or power Interrupts ▪ Coverage area

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Table 3.Features and Limitations of ZigBee

Features of ZigBee technology	Limitations of ZigBee technology
▪ Useful approach for portable power monitoring systems ▪ It uses the mobile phone communication and email function for monitoring the warnings and alarms and status report deliveries to the operators ▪ low data rates and low power consumption in remote locations for radio communications	▪ Limited bandwidth and coverage ▪ Cost ▪ Installation of system ▪ limited size of device leads to limited battery life and internal memory and processing capacity

b. WLAN (Wireless local Area Network)

WLAN infrastructure depends on various IEEE standards and commonly it is based on IEEE 802.11 standard. It allows more than one users to control or monitor the field by utilizing the same frequency spectrum band which does not provides any communication interferences between the users in the field plant. IEEE 802.11 facilitates high speed single and multipoint communication and currently in used with small micro grid stations, SCADA and distributed control systems. However, losing or unavailability of service, weak signals, interferences, power losses and coverage area needs further research in implementation of WLAN for remote monitoring of renewable energy systems.

c. ZigBee Technology

ZigBee is a WSN (Wireless sensor network) based technology and one of the most significant technologies of present century. The main purpose of this technology is to provide support in remotely controlled applications and devices. Its architecture builds on IEEE802.15.4 standard operating on unlicensed frequency spectrum of 868MHz, 915MHz, and 2.4GHz with DSSS technique and different network topologies supported which directly effects the battery life of ZigBee devices and coverage areas and also featured with AES 128-bit security encryption The data rate of ZigBee is throughout low about 250 kbps which is enough requirement to be utilized for remote monitoring [14]. ZigBee covers wide area of applications like

d. Wi-MAX (Worldwide Interoperability for Microwave Access)

A Microwave Access based on WMAN (Wireless Metropolitan Area Network) with IEEE 802.16 standards. In this, the use of 5.8 GHz band is allowed without license and it offers a data rate about 70Mbps up to48km. Whereas, the frequency spectrum ranges 2.3, 2.5 and 3.5GHz are licensed and facilitate to work with higher power for longer distance communication [15]. The communication transfer rate and speed depends on the distance of the network. High data rates supports to use of this technology in WMAR (Wireless Automatic meter reading) and it's implemented in many developed countries. It provides higher bandwidths and allows us to use as a replacement of copper/fiber optic cables for long range communications. However, hardware for radio communication is expensive. The cost of hardware can be reduced with the use of low frequencies spectrum and installation of hardware which deliver optimal performance.

e.Bluetooth technology

ZigBee technology based wireless power monitoring system is demonstrated in. A direct load controlling and power monitoring module with advanced digital signal processing techniques is being developed for calculation of real time monitoring of system parameters. The features of this system are:

Bluetooth technology is built on IEEE802.15.1 standard with an unlicensed operation frequency spectrum about 2.4835GHz. It offers data rate about 720Kbps and provide coverage area about 1m to 100m [16]. Bluetooth interfaced devices can form a point to point to point and multipoint infrastructure communication topologies. The use of Bluetooth technology is not well documented for industrial monitoring applications because of its limited coverage area, however; it could be used for local online monitoring for substation generation systems [17].

f. *Mobile Fi-Technology*

It is based on IEEE802.20 standard for mobile broadband access wireless access with licensed Frequency spectrum less than 3.5GHz [17-18]. It

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provides about 1Mbps for real time and 20Mbps for high speed data rate [19]. This technology provides full mobility and maximum bandwidth up to 1.15 MB/s. It is a recent standard and no any Remote monitoring applications reported yet. However, it is an expensive solution at the moment as compared to cellular technology.

It can access by any unauthorized communication link and can be interfaced with IEEE802.11based wireless LAN and this technology is considered as weak in security compared to other standards.

There is a background for wireless communication technologies that used as the remote monitoring of power plants. A traditional monitoring system for PV (photovoltaic) was introduced based on GSM (Global system for mobile) communication technology for remote monitoring supported on PDU (protocol description unit) and text mode it was a feasible to the user for monitoring the PV plant that are placed at remote areas GSM monitoring improved the reliability and efficiency of data transmission and covers miscellaneous deficiencies of the wireless transmission. A low cost hardware for data acquisition from remote PV solar plants is being discussed in [20]. The system was based on Lab View environment and data acquisition cards (NI-FP-1000 and NI-6024e board) which were used as communication link between user PC display and I/O modules. This system receives input signals from various sensors and transducer, analyzes and creates VI characteristics. An experimental model has been proposed in for remote data monitoring via 3G (Third generation) cellular networks for small wind turbines [21-22].In addition, it also focused on the advancements in cellular technology and possibilities to use it for remote monitoring of any renewable energy farms.

Independently accessing any RAT (radio access technology) each terminal have IP link [28-29].

g. State-of-the-art wireless Services

Many technologies of previous generations 2G, 3G, 4G proven themselves with satisfactory results with their emerging features in the world of wireless technology in many aspects like increased data rates , distance coverage, frequency spectrums , portability, security and in QoS (quality of service). Currently the researchers are moving towards a new robust wireless technology that is 5th Generation known as 4G LTE [26-27]. In Fig.5, the functional architecture shows that combining all networks together it is interoperability with wireless and mobile networks terminal each consisting different IP addressed. However the user terminal which is capable of

This technology offers a high data rate up to 1Gbps with the frequency Bandwidth rages about 3 to 300GHz [23-24]. Functionality of the 4G LTE could be very useful for future implementation in various aspects including remote monitoring of renewable energy systems [25].

The independent multi-access of the user terminal from other radio terminal may bring advancement in remote monitoring and with this plant supervisor can simultaneously monitor more than one plant using a single device only. Summary and comparison of 3G, 4G and 4GLTE is illustrated in table 7.

IV. CONCLUSION

In this paper, the authors presents a literature review of various aspects such as, technology, features and limits of wireless technologies which are in used/ could be used for real-time remote monitoring for renewable energy plants. The development of these wireless technologies increased the possibilities of installation of renewable energy plants in deserts, coastal areas and offshore in Pakistan where sometimes human capabilities cannot sustain longer due to severe or unpredictable environments. Moreover, wireless monitoring of renewable energy systems reduces the risks and barriers of geographic limits. However, there are many limits still exist which required vast amount of research has been discussed in this paper. This literature review could be beneficial for the researchers that are working on the various aspects of wireless remote monitoring for renewable energy systems.

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Table 4: Comparison of Various Wireless Technologies

Wireless technology	**Distance Coverage**	**Data Rates**	**Application Areas**
Cellular/GSM	10 to 50 km	60 to240Kbps	SCADA and monitoring for remote distribution
ZigBee	10 to 100m	20 to250Kbps	Remote monitoring for ,power, Smart grid ,home appliances
Wi-Max	48 km	70Mbps	Smart metering or WMAR (Wireless automatic meter reading)
Wireless LAN	100m	1 to 54Mbps	Distributed energy sources and local remote monitoring
MobileFi	Varies with vehicle motion	20Mbps	Vehicular remote monitoring
Bluetooth	1 to 100m	720Kbps	Local online monitoring

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Table .5: Comparison of 3G, 4G and 4G LTE Services [29]

Technology/features	3G	4G	4G (LTE)
Start from	2001	2010	2015?
Definition	Digital broadband, data packet	Digital broadband, packet data all IP	Digital broadband, packet data all IP, very high throughput
Technology	Broad bandwidth CDMA,IP technology	Unified IP and seamless combination of broadband LAN/WAN/ PAN and WLAN	Unified IP and seamless combination of broadband, LAN/WAN/ PAN/WLAN and technologies for 5G new development (could be OFDM etc)
Services	Integrated high quality audio, video and data	Dynamic information access wear-able devices, HD streaming, global roaming;	Dynamic information access wear-able devices, HD streaming; any demand of users; upcoming all technologies global roaming smoothly;
Data Bandwidth	2Mbps	2Mbps – 1Gbps	1Gbps & Higher (as demand)
Frequency Band	1.8-2.5 GHz	2-8 GHz	3-300 GHz
Standards	WCDMA CDMA-200 TD-SCDMA	All access convergence including : OFMDA,MC-CDMA Network-LMPS	CDMA & BDMA
Multiple Access	CDMA	CDMA	CDMA & BDMA
Core Network	Packet Network	All IP Network	Flatter IP Network &5G Network Interfacing(5G-NI)
Hand off	Horizontal	Horizontal & Vertical	Horizontal & Vertical

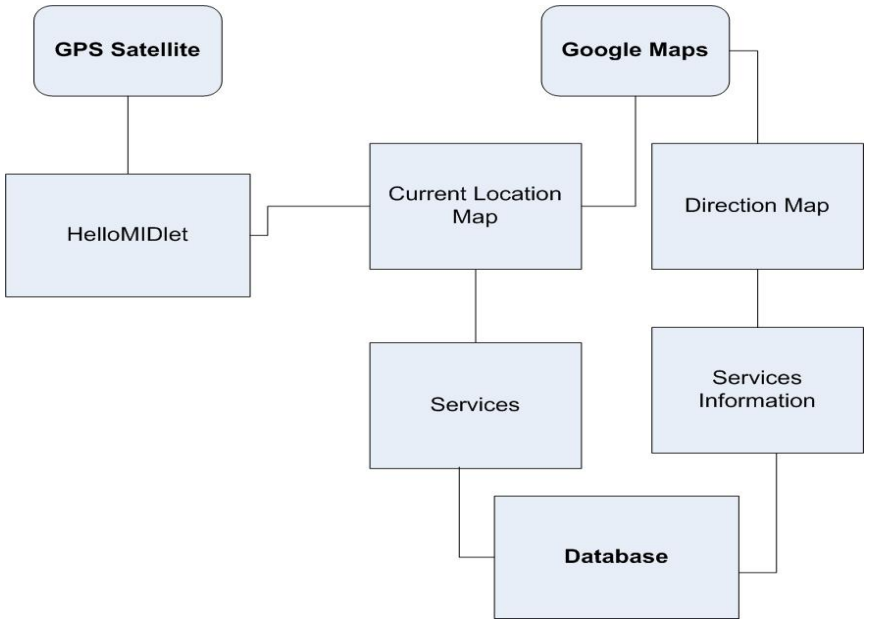

Figure.5: Location service Architecture

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