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Monitoring Technologies for Multi-Sensor System based on Wireless Data Transmission Modules

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ABSTRACT

The need of energy for sustainable development is evolving at a rapid rate. Hence renewable resources need to be explored efficiently. Solar energy is a promising field for fulfilling the energy requirements of the society which needs to be monitored carefully using sophisticated tool consisting of wireless modules and Internet of Things (IoT). This paper reviews some latest wireless monitoring modules based on multiple sensors utilized for solar PV system. Current issues with regards to several factors are discussed and recommendation are presented based on the study conducted.

Key words: Wireless data, Technologies, Modules, IoT

1. INTRODUCTION

In the recent years, transformation from non-renewable system to renewable system is observed due to issues relating to carbon dioxide emission and fossil fuel depletion. In addition, generation of electrical energy from solar photovoltaics(PV) system is given more emphasis due to energy security and global economics stability. Therefore, solar PV system is now being seen as an attractive option due to clean, abundant and secure source of generation. Factors such as low maintenance cost, zero fuel cost, easy installation and robustness makes solar PV system a promising and popular option for the future.

As the need of solar energy is rising around the globe, there sense a need to develop sophisticated and advanced system for monitoring solar PV parameters. These PV parameters are captured by multiple sensors which are installed in the PV system. Observation and recording of the parameters of solar PV system in real time is termed as monitoring. Monitoring technology improves system efficiency as well as alert user when an unexpected event occurs in the system. Thereby, several monitoring methods employing wireless data transmission module have been presented in recent time.

Earlier wired monitoring system was employed in data transmission from solar panel/string to the centre station. However, asthe solar PV system expands, there is a need to shift the paradigm from wired to wireless monitoring system. The wired monitoring system is prone to several factors such as humidity, temperature, and rain, but in contrast wireless monitoring system have higher mobility, network security, long range, high response time, and low maintenance cost. Thereby, further research is needed to design an efficient solar PV monitoring system.

The paper explores on delivering a review on solar PV monitoring system based on Internet of Things(IoT)/Cloud by utilizing various wireless data transmission modules. Furthermore, the paper explores current issues and challenges relating to wireless data transmission and lastly future recommendations are presented.

2. OUTLINE OF SOLAR PV MONITORING SYSTEM

The overview of solar PV monitoring system is classified in three stages namely data extraction, data processing and data storage and display. In the first stage, data is extracted from different electrical and environmental sensors. The extracted data is moved towards the second stage through wired or wireless method for data processing. Lastly, processed data is stored in storage devices as well as displayed. The data displayed in the third stage is accessible to the user from anywhere in the world by utilizing IoT/Cloud. Moreover, necessary action can be taken to configure the system accordingly.

3. IOT/CLOUD BASED WIRELESS SOLAR PV MONITORING SYSTEM

3.1 ZigBee based monitoring system

IEEE and ZigBee developed ZigBee technology implemented on 802.15.4 standards. ZigBee technology is based on low power consumption and is utilized for small range wireless data transmission and monitoring [1]. The range of ZigBee may vary from 40m indoor to 120m outdoor considering the line of sight [2]. The reliability of the ZigBee technology is enhanced by ready collision prevention mechanism to avoid collision of data with each other. ZigBee network is based on three topologies i.e. star, mesh and tree as shown in figure 1.

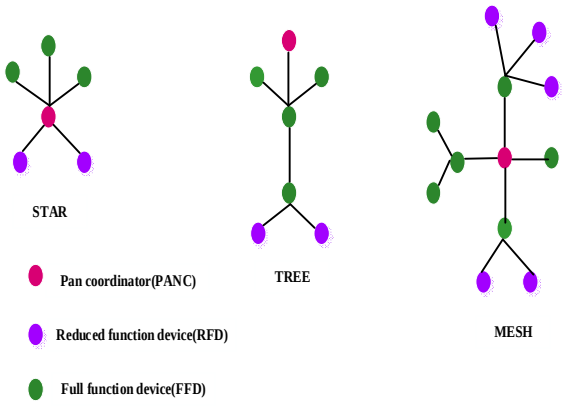

Figure 1: Various topologies of ZigBee network

Shariff et al. [3] presented a ZigBee based wireless system for monitoring solar panel parameters such as panel voltage V_{pv}, panel current V_{pi}, load voltageV_{lv} and load current V_{li}. The test the was conducted to monitor 1.25 kw solar panel as shown in figure 2. Li et al. [4] proposed IoT based real time wireless system for monitoring voltage, current, temperature and irradiance of solar panel. PHP Laravel based website was designed for real time monitoring. Rashidi et al. [5] designed a wireless solar PV monitoring system. The system monitors solar panel parameters as well as detect non ideal operating conditions. Li et al [6] presented IoT based monitoring system based on open source platform. The system monitors as well as manages the solar PV plant in an efficient and economical manner. IoT based Ubidots platform was utilized for displaying the data and realizing PV fault diagnosis.

The practical application of ZigBee is countless but complexity, design protocol and constraint in bandwidth are some of its negative points [7]. Furthermore, it lacks strong security of the ZigBee network making it accessible for hackers to steal the data. Other issues are loss of signals, low range and interference in signal.

3.2 Wi-Fi based monitoring system

Wi-Fi technology is implemented in developing Wireless Local Area Network(WLAN) [8]. It is based on 802.11 family standards and utilizes commonly used module like ESP8266 for wireless transmission of the data. The sampling rate of Wi-Fi is higher as compared to other wireless modules

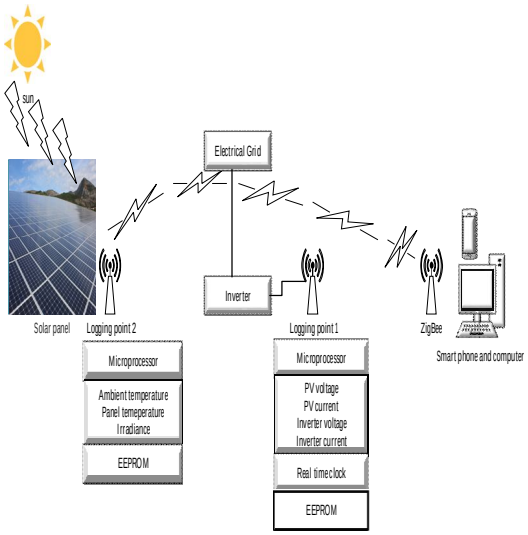

Figure 2: ZigBee based wireless monitoring system for solar PV system

but consumes more power to transmit the data [9]. Allafi and Iqbal [10] designed IoT based wireless solar PV monitoring system. The system monitors electrical parameter of solar panel as well as battery. The data was transmitted by utilizing ESP32 Wi-Fi module and displayed on website application. Pramono et al. [11] proposed solar PV monitoring system as well as overpower trip mechanism by employing IoT as well as relay mechanism. The data extracted from the solar panel is stored in data logger and further sent to web based cloud server. A low cost monitoring system was designed by Rouibah et al. [12] by utilizing Wi-Fi module ESP8266 and cloud server. The system consists of electronic boards, data acquisition sensing(DAS) board and DC-DC boost converter.

Wi-Fi technology contributed to a greater extent in wireless technology such as high sampling rate but is associated with disadvantages such as weak review process of security, bypassing access point and acquisition of frequency by unknown traffic.

3.3 Bluetooth based monitoring system

Bluetooth wireless technology is primarily popular across mobile communication for exchanging the data over short distances. The function of Bluetooth

technology is implemented by IEEE 802.15.4 standards [13]. The power of transmission in Bluetooth wireless network can be increased up to 100m from one node to another. A Bluetooth technology based solar PV monitoring system was presented by Wenxing[14]. The older automation system was combined with proposed monitoring system for developing a new system for monitoring solar PV system. Mohaparta et al. [15] introduced Bluetooth based monitoring system using Bluetooth module HC-05. An IoT based Bluetooth Terminal Application was designed for the user to monitor the data. Furthermore, distribution of power by utilizing relay was also presented.

Although Bluetooth technology comes with many advantages but also consists of several disadvantages such as low data transmission, limited range of operation and high power requirement [16]. Furthermore, concerns relating to the security aspect during the pairing process add to its disadvantages.

3.4 LoRa based monitoring system

LoRa technology was introduced by Semtech with Spread Spectrum Modulation Technique. It is a low power long range technology designed for cloud technology and IoT [17]. In recent times, LoRa technology has attracted both industrial and research community [18]. The method aims for long life in battery powered device where importance is given to the consumption of energy [19]. A LoRa based wireless monitoring system for solar PV application was proposed by Shuda et al. [20] to measure various parameters such as voltage, current, temperature of module as well as irradiance. The system was designed by 250Wp PV module and data was stored in MySQL database through IoT. Moreover, Parades et al. [21] also designed cloud based wireless monitoring system to monitor solar plant located in remote locations. The method was implemented on 5kW solar panel. The data was sent to the remote monitoring centre in packet size of 38 bytes with spreading factor (S.F.) of 10-12.

Although LoRa technology is considered as low power and long range, it faces some limitations in term of network size which is limited by duty cycle [22]. Moreover, transmission of data over long range requires higher SF which in turn results in low transfer rate and increase in Packet Error Rate(PER).

The performance assessment of different wireless solar PV monitoring technologies is shown below in Table 1.

The performance analysis of various wireless data transmission modules is also summarized as under Table 2.

Table 1: Solar PV monitoring system based on different wireless data transmission modules

Work Done By	Wireless modules	Parameters measured	Software used	Load (in kW)	Achievements
Shariff et al.[3]	ZigBee	V_{pv}, I_{pv}, V_l, I_l, G,T	C & NetBeans	1.25 kW	Monitoring
Cihan[23]	ZigBee	V_{pv}, I_{pv}	C#	5 W	Monitoring, Significance of temperature on panel output
Rouibah et al.[12]	Wi-Fi	V_{pv}, I_{pv}, V_l, I_l, D	C++,HTML	120 W	Monitoring
Allafi[10]	Wi-Fi	V_{pv},I_{pv}	IDE, HTML	1.3 kW	Monitoring
Sarabia et al.[24]	Bluetooth	V_{pv},I_{pv}	LABVIEW	-	Monitoring, Low cost, Implementing 12C protocol
Le at al.[25]	Bluetooth	V_{pv},I_{pv} ,T	MATLAB	87 W	Monitoring, Fault Detection in Panel
Shuda et al.[20]	LoRa	V_{pv},I_{pv} ,G,T	-	250 W & 100 W	Monitoring
Parades et al. [21]	LoRa	V_{pv},I_{pv},G	-	5 kW	Monitoring

V_{pv} is panel voltage; I_{pv} is panel current; V is inverter voltage; I is inverter current; G is irradiance; T is panel temperature; V_{oc} is open circuit voltage of panel; I_{oc} is open circuit current of panel; D is duty cycle

Table 2: Comparison of wireless data transmission modules

Module	Range	Power consumption	Topology	Data Rate
Bluetooth	100m	10-500mW	Point to point	1Mbps
Wi-Fi	150m	1W	Star	11Mbps
ZigBee	300m	1mW	Mesh	250kbps
LoRa	10-30km	100mW	Star, Mesh	5469-293bps

4. ISSUES AND CHALLENGES

The key issue relating to wireless solar PV monitoring system focuses primarily on transmitting the data in an efficient and secured way. In addition, many challenges affect the efficiency and working of wireless technology in the field of monitoring. Factors such as data transmission range, capability of processing data, performance, network safety and rate of sampling affect the performance. Thereby some important issues are discussed below.

4.1 Efficiency

Multiple nodes are required for monitoring solar PV system wirelessly. Efficiency of the node with respect to its lifetime is of prime importance. Failure in the operation of wireless modules due to low life may disturb the working as well as the efficiency of the monitoring system. Furthermore, multiple paths can be utilized for increasing the efficiency of the system.

4.2 Security

An important factor in the IoT based wireless monitoring system is security. The transmitted data from the wireless sensor node needs to be secured against any cyber-attacks. Wireless data transmission modules such as ZigBee, Wi-Fi, Bluetooth and LoRa are prone to external tampering. Unprotected data in ZigBee based network can be transmitted to other devices when an unknown device is included into the network. Moreover, data can be stolen in Wi-Fi based network if the person is in range. Furthermore, data can be accessed in Bluetooth based device by interfering in the network and stealing encryption keys. Lastly, LoRa security is compromised when attackers gain physical access to the module [26].

4.3 Interference

Interference issue results in several complications in wireless systems. Other mode of wireless communication protocols may affect the network by interfering with the frequency band resulting in low data rate, weak signal and improper data transmission.

5.CONCLUSION AND RECOMMENDATION

The paper presents an overview of different wireless modules based solar PV monitoring technologies. An insight summary is provided in the introduction comprising of solar energy, its needs as well asthe importance of monitoring its parameters. Different wireless modules based monitoring system was studied along with current issues and challenges. It is concluded that ZigBee is a low cost module with low power consumption but suffers signal loss. Wi-Fi has high data transfer rate but is limited to low range. Bluetooth exhibits low power characteristics but performance is affected in terms of security issue. LoRa technology is intended for long range transmission with low power consumption but suffers low data transfer rate for long range.

Furthermore, with reference to the above consideration, some recommendation is suggested as,

- To review the security aspect in sending the data from wireless data transmission module.
- More exploration needs to be done for developing wireless module capable of working for long time with interruption in sending the data
- An in depth study is required to reduce the interference of signal in low range of data transmission.

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