Wireless Sensor Network Based Real-Time Monitoring and Fault Detection for Photovoltaic Systems

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***Abstract*— This paper presents design and implementation of a monitoring and fault detection for photovoltaic renewable energy system. A real-time monitoring unit based on wireless sensor networks is designed to monitor required variables related to each module and unit in the PV system. An intelligent algorithm based on fuzzy logic has been developed to detect and locate faults. A mathematical model together with an experimental prototype is designed to evaluate the performance of the proposed PV system under normal and faulty conditions. The obtained results from both simulated and experimental systems confirm that the implemented monitoring and fault detection system perform the required tasks with acceptable accuracy and cost. Applying real-time remote monitoring is easier to specify faults and observe the overall performance of any solar PV system.**

Keywords: *Photovoltaic system, Renewable energy system, Real-time monitoring, Wireless sensor networks, Fault detection, Fuzzy logic.*

I. INTRODUCTION

Over the last ten years, renewable energy sources have become widespread, especially with problems of environmental pollution and high oil prices. Therefore, several researchers focus their attention on renewable energy resources to replace fossil fuel sources. Renewable energy sources are energy sources that depend on the natural sources, such as sunlight, wind, water, bio-mass, and geothermal [1]. Solar energy is the most popular type of renewable energy resources. It can be used to heat water instead of gas and electricity, or to be used to drive cars instead of petrol. The photovoltaic (PV) cells convert directly the energy of sunlight to electrical energy [2].

Real-time monitoring of PV modules, arrays and units is required to manage and control the generated power. Moreno-Garcia et al. [3] proposed a real-time monitoring PV power that includes embedded acquisition units to continuously measuring current and voltage. A wireless sensor network and a GPS module are installed around the plant to measure wirelessly the magnitude of energy. Moreover, a weather station is installed in plant to monitor the environmental weather. This station provides data about wind direction, wind speed, atmospheric pressure, and temperature. Al-dahoud [4] provided a new graphical simulation technique for monitoring the solar PV system. This technique includes distributing the solar PV system as nodes. Each node has a wireless sensor network and some of appropriate sensors such as temperature, humidity, light, current, and dust sensors. Furthermore, monitoring software provides real-time data concerning the environment following a certain topology of network is used to analyze, examine, and gives an alarm to detect any fault.

Real-time remote monitoring is widely used in enhancing the performance of solar PV system. An Internet of Things (IoT) technology has been proposed for solar PV power station system for monitoring, controlling and supervising of the plant [5]. This technology includes three levels; sensing level, WSN level, and an application level to monitor the performance of plant and discover any fault in the PV system. The weather conditions are one of the important factors that affect the performance of the solar PV systems [6]. Temperature, irradiation, wind speed, humidity sandstorm and cloudy are climate parameters that required to analyze the performance indices like an efficiency of PV array and electrical inverter, system operation, energy losses, and performance rate. Yahyaoui and Segatto [7] proposed a strategy to reduce the energy losses and ensure the optimal energy value during the solar PV system when connected to a single-phase grid operated. The main idea is to determine any damaged PV panel by the voltage and current indicators and comparing them to their thresholds. Experimental results show that the practical strategy enhances the efficiency and reduces the power losses. However, this practical strategy was not considered climate parameter and effect on solar PV system.

A prototype for solar PV system with two plants level monitoring has been implemented [8]. The first level includes weather sensors to monitor the weather parameter, while the second level has solar tracking. Hence, all data and information collected from two levels via ZigBee communicate technology will be analyzed, monitored and processed by a central control station. A WSN-based monitoring system includes all sensors and components required to measure the electrical output and weather forecasting of solar PV system [9]. Furthermore, all images and real-time data that sent from WSN to the monitoring center via ZigBee technology is analyzed to take the suitable decision to detect any fault and get the best performance. The proposed work contributes to reduce faults, wastes, costs and enhance the performance of solar PV system.

Molina-García et al. [10] proposed a solution based on decentralization wireless sensor technology in a PV power plant. Twenty-one sensor nodes and 4 sink nodes are used to collect both weather forecasting and DC electrical variables. The proposed work was focused on the DC electrical variables and did not care about AC part.

Ventura and Tina [11] introduced a monitoring and fault detection system based on comparison between the measured and estimated values depend on statistical approach. Daily performance ratio and DC and AC output power of the solar PV system are considered. The obtained results prove that the proposed fault detection method is effective and suitable for PV