Review of Communication Methods and System Design Structure for Solar Monitoring System

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Abstract. Solar Photovoltaic system as one of the renewable energy sources is known as an important alternative that significantly contributes towards the sustaining energy supply in the world. As it is known solar photovoltaic systems produce electricity from the solar radiation which is available from the sun. Solar photovoltaic systems are seen as one of the most emerging technology because of the technology enhancement and continual improvement on the solar panels efficiency and cost reduction of the battery storages. As the cost is reducing, global energy consumption demand increases while the world population is growing, effective and efficient solar photovoltaic systems performance monitoring and system's stability are considered as a crucial aspect for overall system's performance. In order to continuously monitor the solar photovoltaic system's performances, at present many technological design and development to monitor solar photovoltaic system have been introduced. Therefore, this paper is focusing to review and present the system structural designs and communication methods of recently research conducted by local or international scholars. The objective of this work is to analysis the newly proposed system structural designs and communication methods with the structural designs and communication methods discussed in section III.

INTRODUCTION

Nowadays, as a result of the increasing electricity consumption demand due to the growing world population, many countries around the world are emplacing more and more renewable energy sources plants, especially solar photovoltaic systems [1, 2]. In order to promote the solar photovoltaic system design and development, governments in many countries provides various type of incentives to start their own solar photovoltaic systems. Among many solar photovoltaic system projects in various countries, under the National Development Plan in Ecuador a significant number of solar photovoltaic systems was installed [3]. Among the many solar photovoltaic systems, one of the solar photovoltaic system which consists 4160 solar panels are connected to Ecuadorian grid network. Due to the large solar panels integration into the main grid network, a communication access point is installed to monitor the solar panels. The communication access points have provided beneficiary to the connected solar photovoltaic system community. In order to ensure stability and performance reliability of the installed solar photovoltaic systems, monitoring system is often preferred. In this context, the main goal of this paper is to review and present the communication methods and system structural design used to develop the solar photovoltaic system performances monitoring.

The reminder of this paper is organized as following. In section II, review of latest developed monitoring system for solar photovoltaic system focusing on their communication methods. A review of solar photovoltaic monitoring system which is focusing on their structural designs and communication methods are described in Section III. The

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suitable communication method and system structural design for the newly proposed solar photovoltaic monitoring system is identify and analyze in Section IV. In Section V, a new system structural design and communication method is described for the newly proposed solar photovoltaic monitoring system. Finally, the conclusion are presented in Section VI.

LITERATURE REVIEW

With the short description in the introduction section, this section will review some of the previously developed solar photovoltaic monitoring system. P. Papageorgas et al., presented the finding in [4] which monitors the real-time each solar panel performance and the information can be access through web-based application. In terms of communications for data transferring, wireless sensor network (WSN) technology is adopted at the solar panels to the remote server. The local interface network (LIN) is used as master communicator with the coordinator installed at the groups of solar panels. In another similar research by P. Sunil and D. Sunil, a microcontroller based data acquisition system is proposed [5]. This system adopts Zigbee communication protocol to permit the users to gather information wirelessly and RS232 is used to transmit the collected data to the computer system.

SOLAR PHOTOVOLTAIC MONITORING SYSTEM

Previous Structural Designs and Communication Methods

This section discusses on the structural designs and communication methods of previously developed research work of solar photovoltaic monitoring system. The structural design presented in Fig. 1 shows the solar panels system is connected to the grid tie inverter to improve the system's performance during the low radiation intensity and maximum load demand [6]. Similar research work discussed in [6] is also conducted in [7]. The temperature and humidity is measure using DHT22 while ACS712 5Ampere current sensor and Arduino voltage sensor is used to measure the photovoltaic output current and voltage.

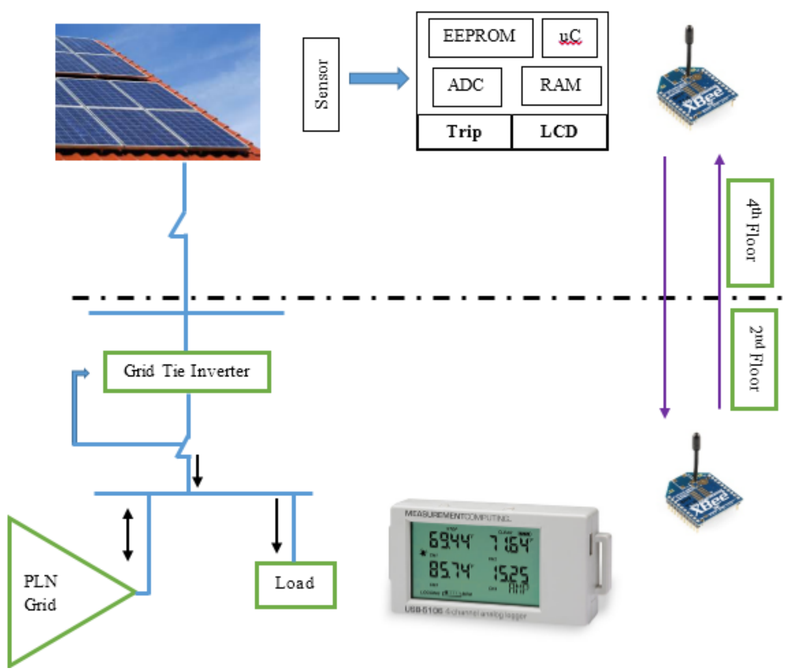

FIGURE 1. Solar photovoltaic system setup-sensors and devices.

Referring to Fig. 1, Zigbee sensors network communication method is adopted to at the solar panels to transfer the measured voltage, current, temperature, humidity, date and time to the data logger storage system before these information can be sent to the web server [6, 7]. The installed Xbee sensors at the remote solar panels are configured as router and Xbee sensor at the receiving station (local station) is configured as coordinator. MySQL database is used to develop the web server system, all the voltage, current, temperature, humidity, date and time is sent to the receiving station (local station). User are allowed to access the information stored on the web through Ethernet or Wi-Fi connections. The information at the remote solar panels can be accessed via the sensor nodes via Zigbee communication protocol, these information can be compared to validate the data received at the web server with the data recorded at the remote solar panels.

Figure 2 shows the designed structure of Grid-Connected Utility-Scale PV Power Plant which consists of data acquisition system, data processing & storage system and client tier [7]. The data acquisition system is performances are monitored using the real-time programmable controller CompactRIO 9075 [7]. The CompactRIO 9075 receive the data via wired and wireless communications. Five CompactRIO 9075 were integrated, four were connected to the inverters to measure the electricity production while one was used to monitor the environmental parameters and electrical parameters in photovoltaic firld using wireless mechanism. Global Positioning System (GPS) as master device is integrated into one CompactRIO 9075 to perform wireless measurements, while remaining CompactRIO 9075 with attached to the inverters are connected to the local Ethernet network as slaves' devices.

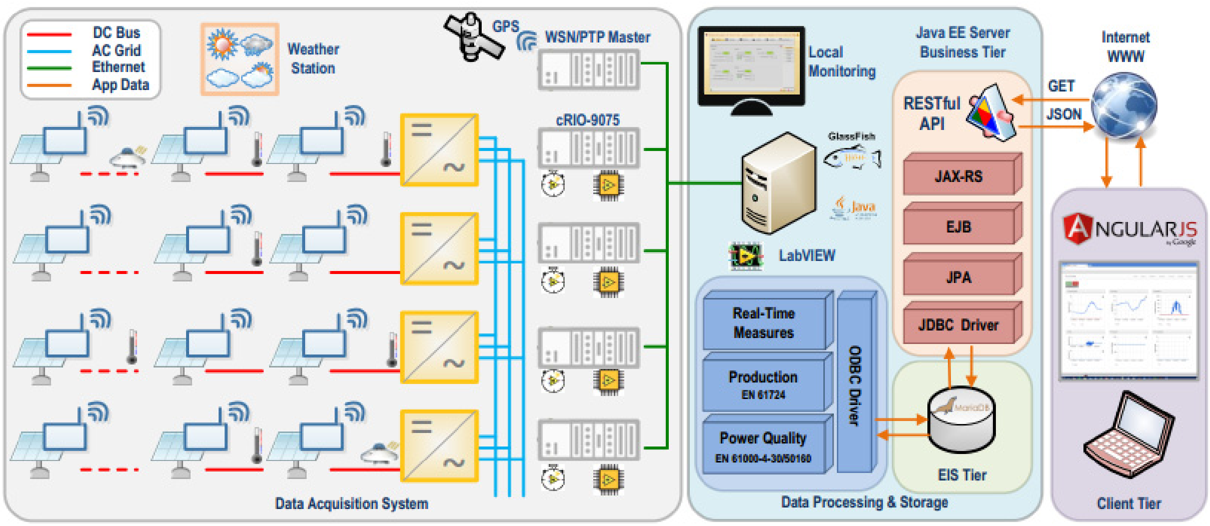

FIGURE 2. Design structure Grid-Connected Utility-Scale PV Power Plant [7].

Figure 3 shows the real-time diagnostic monitoring system design structure for photovoltaic power plant [8]. The designed system comprises of Monitoring Center (MC) which consists of production monitoring tools, multiple communication channels, data analysis system, weather forecast system and surveillance monitoring system [8]. The MC integrates different communication channels for failure notification. The Monitoring Plant Network (MPN) plays a centralize role system which always collect the photovoltaic panels status and update real-time information into the Monitoring Center (MC). Thee MPN also is conceptualized based on the smart photovoltaic modules, sensors and electronic components installed on each panel controls individual panel and a group of panels. The information of sensed voltage, current and temperature and collected and transfer to the MC.

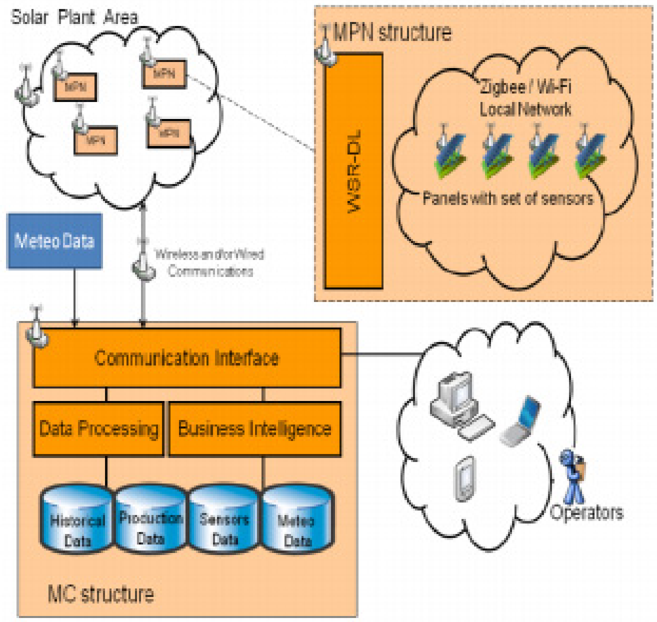

FIGURE 3. Real-time diagnostic monitoring system of photovoltaic power plant [8].

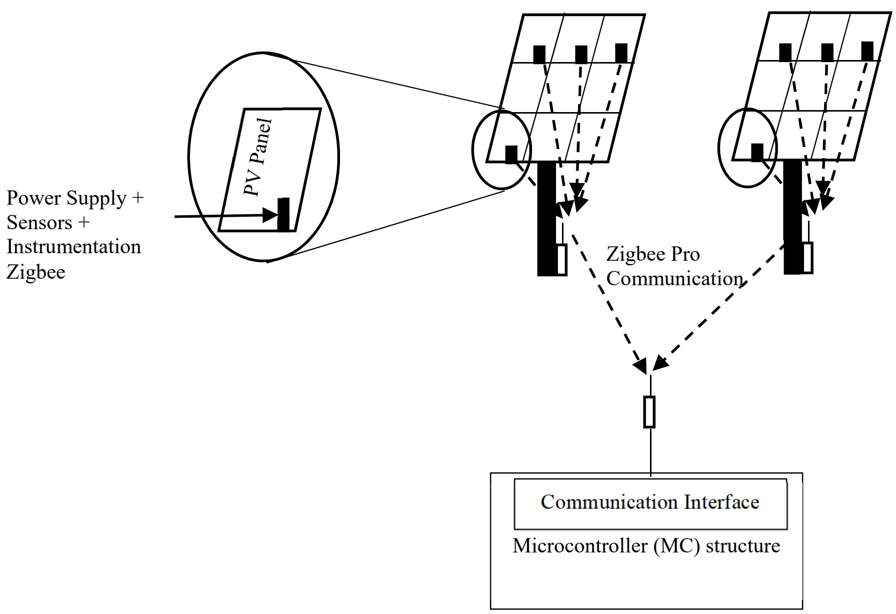

FIGURE 4. Configuration of wireless monitoring system [8].

Referring to Fig. 4, two types of communications mode is identified to transfer the relevant information:

1. The smart photovoltaic modules to the central node which is within the MPN communication is established using the Xbee 802.15.4 low power.
2. The communication between the central nodes to the MC is established using the XBee-PRO 802.15.4 which communication is extended to communication to the MC.

PROPOSED DESIGN OF SOLAR PHOTOVOLTAIC MONITORING SYSTEM

Referring to Fig. 5, a solar photovoltaic monitoring system have been proposed after reviewing some latest research work presented in section solar photovoltaic monitoring system. This review considers the solar monitoring system's structural design and communication methods. After reviewing both of these aspect, this paper tends to proposed a new structural design and communication method for the solar photovoltaic monitoring system proposed in Fig. 5.

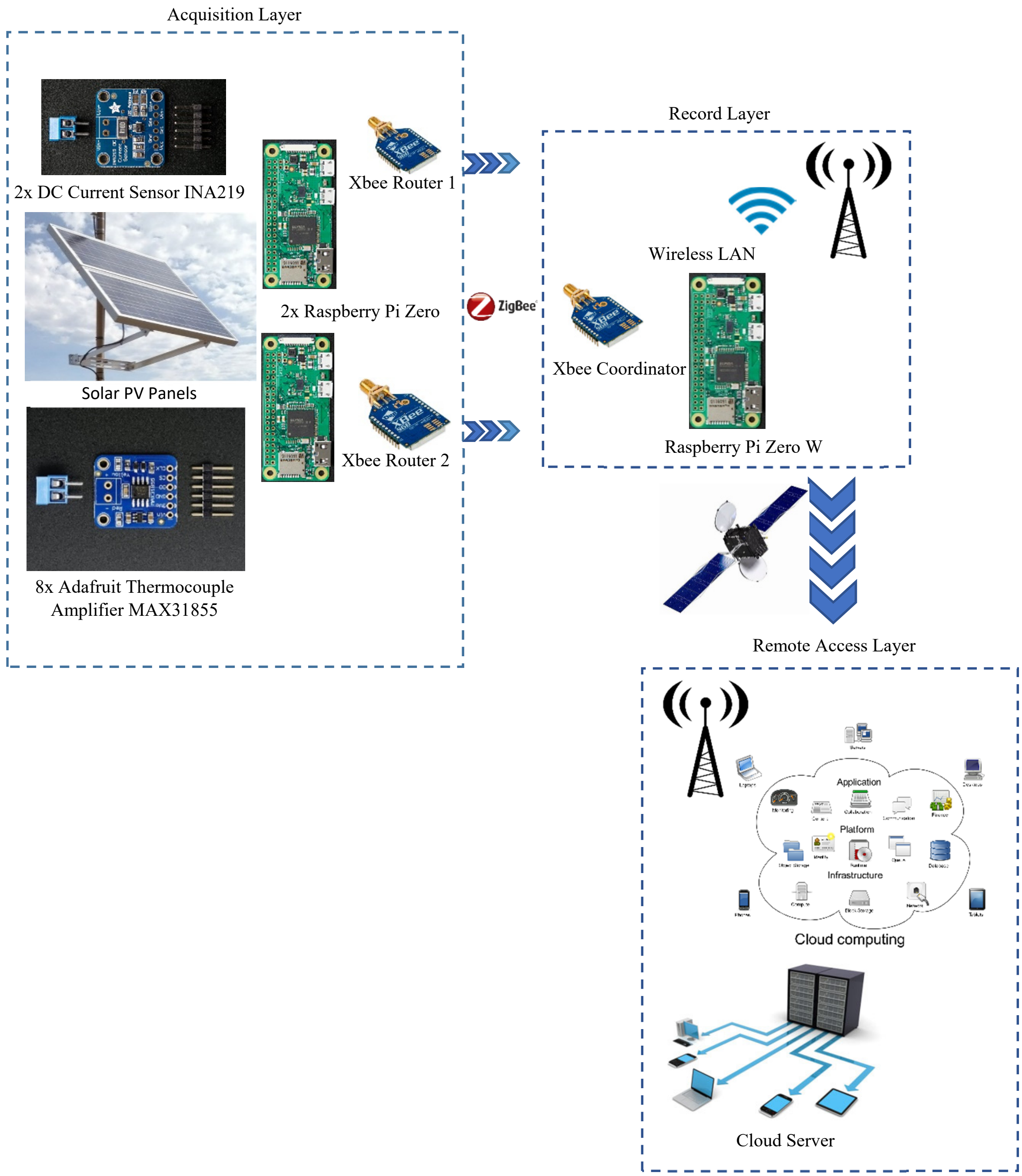

FIGURE 5. Proposed solar photovoltaic monitoring system.

The proposed solar photovoltaic monitoring system shown in Fig. 5 is integrated with sensors and electronic components at the acquisition layer, the raspberry pi zero w is integrated as central controller at the record layer and wirelessly the information at the central controller is send to the cloud for user's to monitor the system's performances.

At the acquisition layer, eight adafruit thermocouple sensors for temperature sensing is installed, amplifier MAX31855 is integrated with the adafruit thermocouple sensors to amplify the sensed temperature values. The INA219 current and voltage sensors are installed to sense the current and voltage values from solar panels. The temperature, current and voltage values are stored into the raspberry pi zero which is send to the central controller via the Zigbee communication protocol. These values are stored at the Raspberry Pi Zero before it is uploaded into the cloud system.

PRELIMINARY RESULT OF PROPOSED SOLAR PHOTOVOLTAIC MONITORING SYSTEM

This section presents the preliminary results for acquisition layer section. In this section, the adafruit thermocouple sensors and INA 219 current/voltage sensor integrated to the Raspberry Pi Zero to sense and measure required parameters. Figure 6 shows the placement of FOUR (4) adafruit thermocouple sensors, the adafruit thermocouple sensors are used to sense and measure the solar panel temperature when it is installed. The sensed and measured temperature is used to validate the current, voltage and power produced when the solar photovoltaic panel is generating and producing energy.

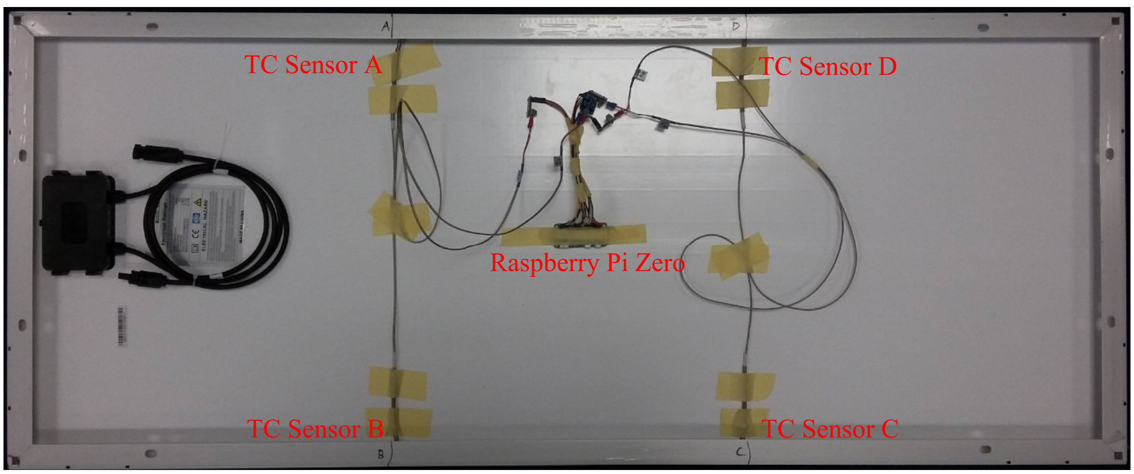

FIGURE 6. Integration of thermocouple sensors.

Figure 7 presents the measured temperature from all the FOUR (4) thermocouple sensors installed at the back of the solar photovoltaic panel. The temperature reading is taken before and after 11am. According to the recorded temperature data, the temperature increases when the sun starts to rise higher which indicates the solar photovoltaic panel temperature is increasing.

Figure 8 presents the sensed and measured current, voltage and calculated power generated from the solar photovoltaic panel. Looking at the current and voltage trend, a small increment before and after 11am. The output power indicates small increment but eventually remain constant because of the increase in environment temperature which affects the generated output power.

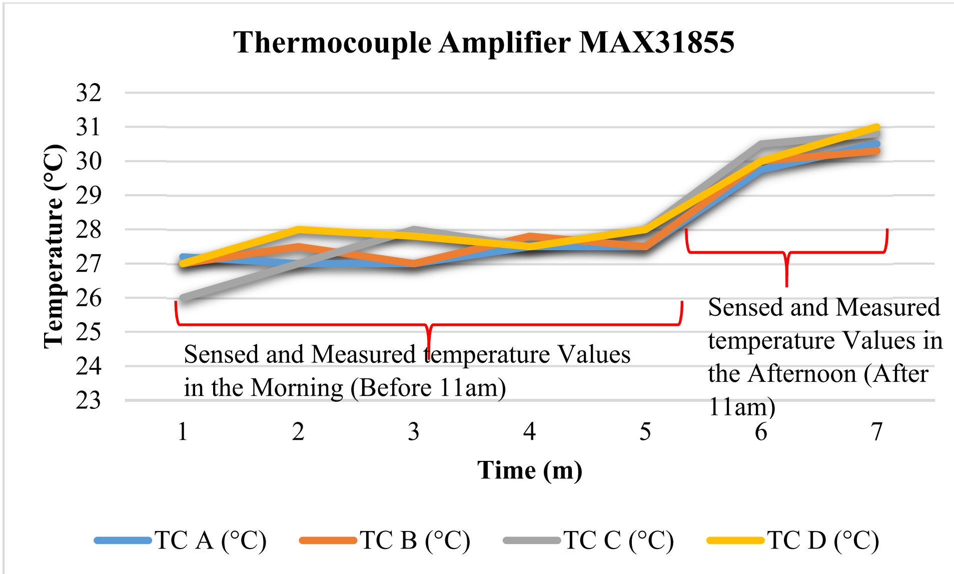

FIGURE 7. Sensed and measured temperature of integrated thermocouple sensors.

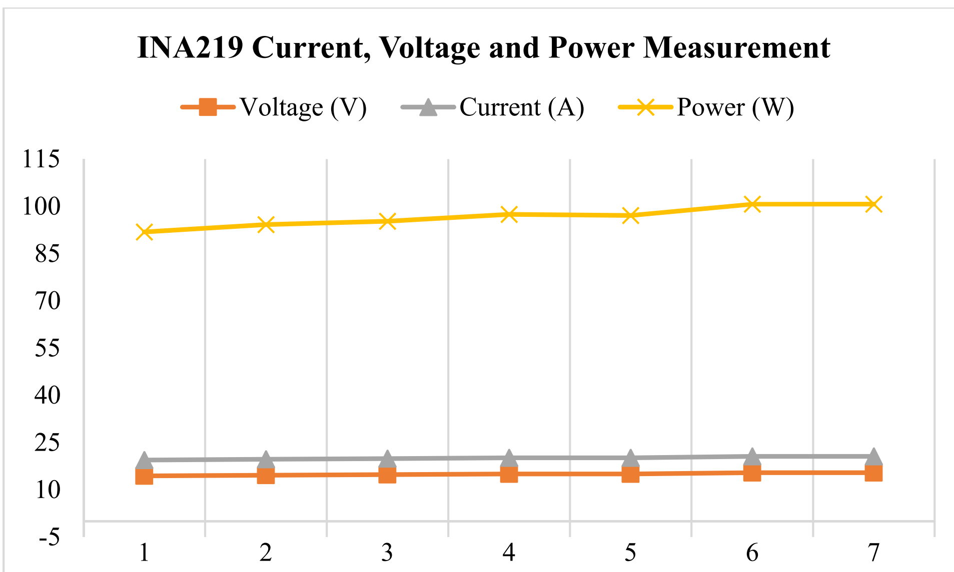

FIGURE 8. Sensed and measured current, voltage and power.

CONCLUSION

This paper adopts the adafruit thermocouple sensors and INA 219 sensor to sense and measure the temperature, current and voltage of each respective solar photovoltaic panel. The value of temperature, current and voltage are recorded into the Raspberry Pi W. The overall system is fully tested and the presented results in Fig. 7 and 8 validate the initial finding of our proposed design concept. In the nutshell, the presented system also provides accurate and real time information about the temperature, current and voltage of a solar photovoltaic panel installed. In another word, any incorrect information recorded and retrieved from the Raspberry PI Zero could immediately indicate the system's inconsistency.

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