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Research paper

Solar remote monitoring unit

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Abstract

In this manuscript, a smart, IoT-enabled, solar-based datalogger, which can measure AC and DC voltage and current of solar panel accurately is presented. Combination of stand-alone current and voltage sensors are used to measure to develop the datalogger. The datalogger can measure the current non-invasively, without introducing disturbance to the circuit under test. The PCB is fabricated, and measurements have been made to evaluate the system's performance. The results demonstrate that sensed values give maximum accuracy compared to manually tested values. The main purpose of the study is to measure the electrical parameters of solar panels to achieve maximum accuracy, reducing the error rate, thus causing a reduction in electricity bills, and accessing the data remotely. The system can send data to the cloud so that a remote user can check the data through a web-application.

Keywords: *Electrical Parameters; IoT; Invasive; Non-Invasive; Real-Time Monitoring.*

1. Introduction

One of the instrumental functional overheads in many commercial edifices and industrial plants is the electricity bill [1]. On one hand, poor maintenance, bad monitoring of the electrical devices, undetected defects, and manual checking is the reason for billing errors. On the other hand, outdated methods of measurement can often be misleading; all these issues collectively can not only cause losses in finance and infrastructure but even in human lives.

Human intervention is involved in all these issues mentioned above, which can cause fatal incidents. Deaths from fatal electric injuries are common because of electricity in homes and industries [2]. In Ireland, there have been 40 electrocutions from the explosive effects of electricity from 2001 to the end of 2020. Of those, 25 deaths have been associated with electrical activity [3]. According to other statistical data, in 2016, a total of 9606 people died in India due to electrocution [4]. So, it is less reliable to depend on human intervention to measure electrical parameters.

Other than the abovementioned errors caused by human intervention, several more human errors are responsible for causing a sudden spike in the electricity bill. These issues are the outcome of poor monitoring of the systems. It includes incorrect meter reading, as it requires manual checking causing human errors, and the other is faulty meter; it can read wrong values due to malfunction behavior.

To overcome the issues mentioned above, it is fundamental to design a system that can monitor the electrical parameters in real-time so that billing systems can gain accuracy in generating bills and the electrical devices can be maintained error-free.

To solve the high billing issue, the solar photovoltaic (PV) system is one of the reliable solutions for the reduction of electricity bills [5]. The obstacle while monitoring such systems is the inaccessibility of the plant, as the majority of them are installed in inaccessible locations and thus unable to be monitored from a dedicated location [6]. Hence, the system needs to be monitored remotely, which demands Internet of Things (IoT) based solutions. Indeed, the future of communications transformed things of the real world into smarter devices [7].

The proposed system is a solar monitoring data logger which can be accessed around the globe for monitoring and analysis of solar setups. It monitors the solar output in real-time, reducing the human intervention; therefore, any interruption in the system can be immediately monitored [8].

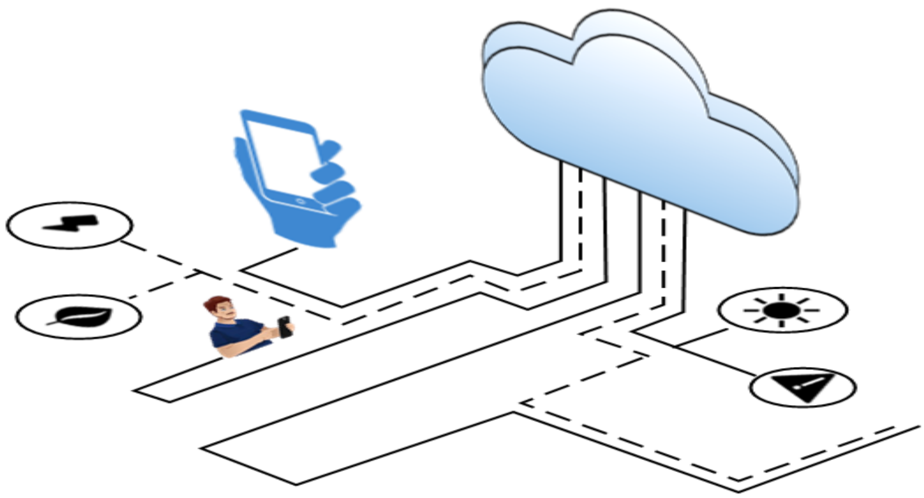

Fig. 1: Overview of the System.

The proposed solution establishes a central data collection point over the cloud to store the data. Different sensors are used to measure and send real-time data to the cloud. To monitor, the mobile application is used to fetch the data. In this way, concerned personnel stays informed regarding the system's functionality. The paper mainly focuses on the solar energy-based smart device embedded with the Wi-Fi module, which helps to build a system that is low-cost, low-power, and remote [9]. A few experiments have been performed to verify the results obtained with the designed system.

2. Proposed system

This system is designed to measure the voltages and currents remotely using invasive and non-invasive techniques. It can measure AC voltage, DC voltage, DC current invasively, and AC current invasively and non-invasively. To measure, it has two modes of operation:

- Mode 1: This mode measures the AC parameters. The ZMPT101B module is used to measure the voltage of the device. The ACS712 current sensor is used to read the current values invasively. The clamp meter is used to measure the AC current non-invasively.
- Mode 2: This is dedicated to measuring DC parameters. The ACS712 current sensor reads the current values, and digital techniques are used to measure the DC voltage.

The proposed system has two modes to measure the AC and DC parameters. Each mode has a specific hardware design to accurately measure the values of voltages and currents.

For real-time monitoring, the ESP32 Wi-Fi module and embedded sensors are used. The Wi-Fi module is purposely used for real-time monitoring; it sends the real-time measured data to the cloud server [10]. A mobile application is designed to access the data of the cloud, and it fetches the real-time data and displays it on the mobile application screen.

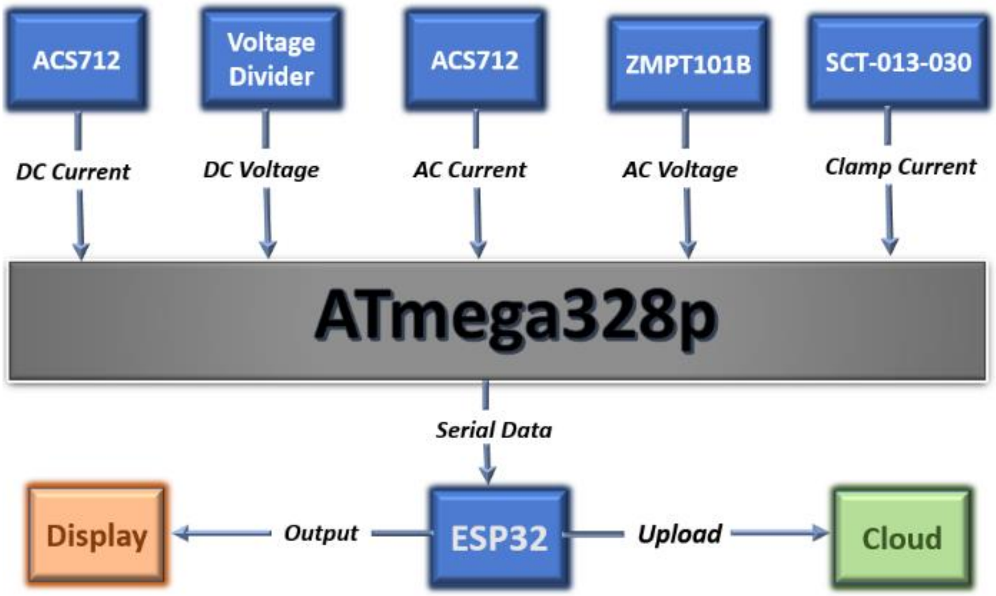

Fig. 2: Hardware Architecture of the System.

The overall block diagram of the system is shown in Fig. 2.

3. A measurement setup

The main focus of this system is to build an accurate and fast real-time monitoring system for electrical parameters. This is achieved by using invasive as well as non-invasive techniques.

Modern methods use surface mount devices and microcontrollers for the fast and accurate measurements of the electrical parameters [11]. Fig. 3 shows the PCB layout, which is designed on Proteus. Microcontrollers that are used for this work are Atmega328p and ESP32. Arduino UNO board has been used for uploading the source code into the Atmega328p microcontroller. The measured values are then sent to ESP32 via serial communication.

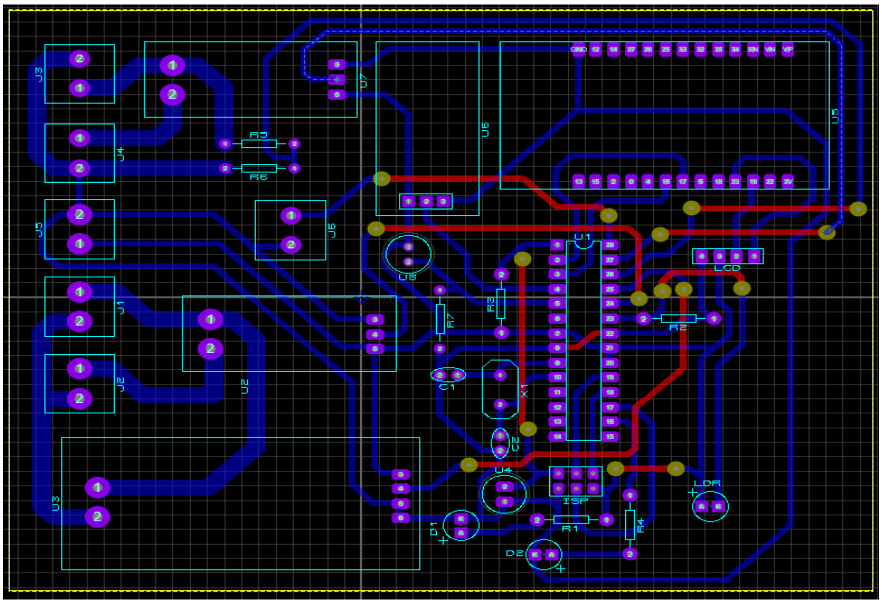

Fig. 3: PCB Layout of Datalogger.

3.1. AC parameters

This mode measures voltages and currents in AC mode.

3.1.1. AC voltage

The proposed design measure AC Voltage with ZMPT101B (a voltage transformer), which can measure voltages up to 240 V [12]. In the case when there is no input connected, then the 5 V supply voltage of the sensor will generate 2.5 V of output. When there is no load connected, the output voltage is half of VCC.

Sensors measure the Root Mean Square (RMS) value of the voltage over 300 cycles of the resulting sinusoidal wavelength [13].

$$V_{RMS} = \frac{1}{\sqrt{2}}\left(\frac{V_{ph} - V_{pl}}{2}\right) \quad (1)$$

Where V_{ph} and V_{pl} are the highest and lowest voltage peaks, respectively. Now, the calculated V_{RMS} is sent to the cloud via the ESP32 module, as shown in Fig. 2. For testing purposes, 220 V_{RMS} has been used.

3.1.2. AC current

In AC current, there are two modes of measurement.

Invasive method

This method uses the ACS712 (a hall-effect-based) sensor to sense the current. For testing purposes, an electronic load of different values was applied; 0.5 A, 1 A, and 1.5 A. The current results lie in the range of 0 – 5 A and produce the tolerance of 1-1.5%, whereas the maximum range it can measure is 30 A [14]. The power P is calculated from the measured voltage and current by the equation P = IV. Then this data is uploaded to the cloud.

Non-Invasive method

This method uses a non-invasive current sensor, SCT-013-030 (a hall-effect-based sensor). The output voltage at 30 A is 1 V, so the microcontroller is programmed to measure the AC current via clamp meter accordingly. As before, the data is sent to the cloud in real-time.

3.2. DC components

This mode measures voltages and currents in DC mode.

3.2.1. DC voltage

The system measures DC voltage by voltage divider technique. As the microcontroller has the upper limit of 5 V, a voltage divider circuit is used to measure high voltages to convert the high voltage into the acceptable range. The microcontroller calculates the output accordingly, which is then uploaded to the cloud. The 40 V power supply is connected to the device for testing purposes. The measurement range for the DC voltage of the system is 0-30 V. The resulted voltage has a tolerance of 1-1.5%.

3.2.2. DC current

DC current is measured by current sensor ACS712. The measured current is in the range of 0 – 5 A [15]. The DC power is calculated from DC current and DC voltage using the relation P = IV. Then this data is uploaded to the cloud.
So, the designed system efficiently measures electrical parameters using invasive and non-invasive methods. The data can be remotely accessed from the cloud by using a mobile application.

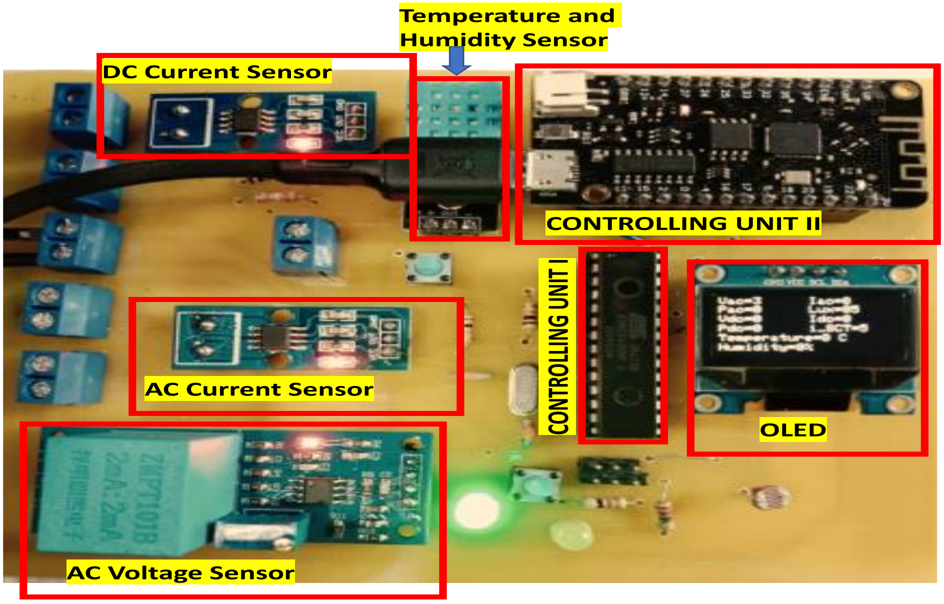

Fig. 4: Proposed Hardware Design of Datalogger.

3.3. Experimental results

The plotted results of sensed AC voltage values and measured AC voltage values are given below:

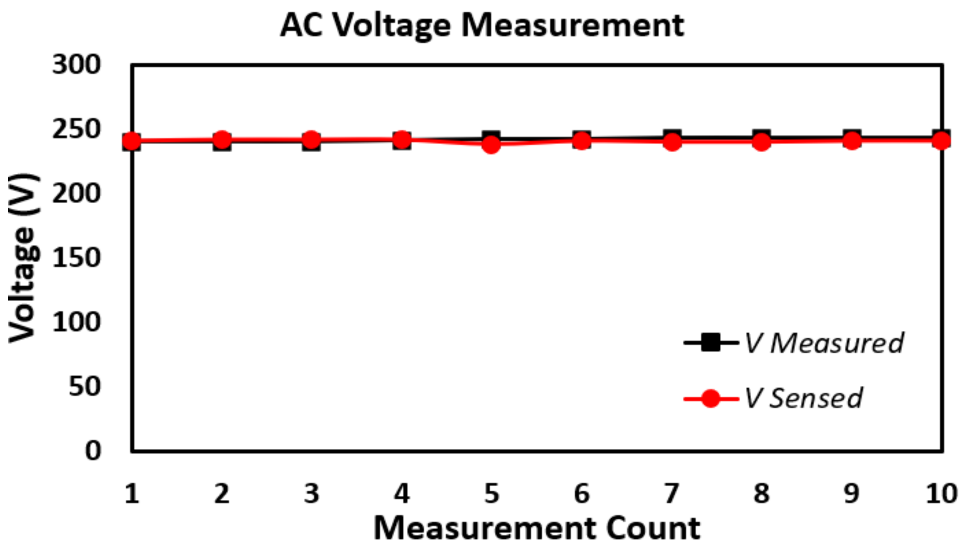

Fig. 5: AC Voltage vs. the Number of Readings.

Fig. 5 shows the AC voltage measurements. It can be seen that the designed system sensed the AC voltage with 100% accuracy when compared to manually measured values.
The plotted results of sensed AC current values and measured AC current values are given below:

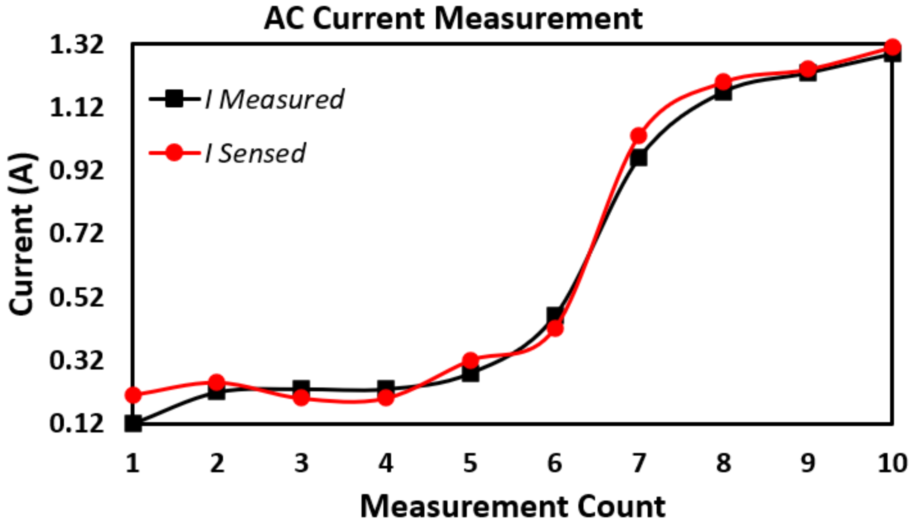

Fig. 6: AC Current vs. the Number of Readings.

Fig. 6 shows the AC current measurements. The designed system sensed the AC current, and compared to manually measured values; the system gave realistic results.

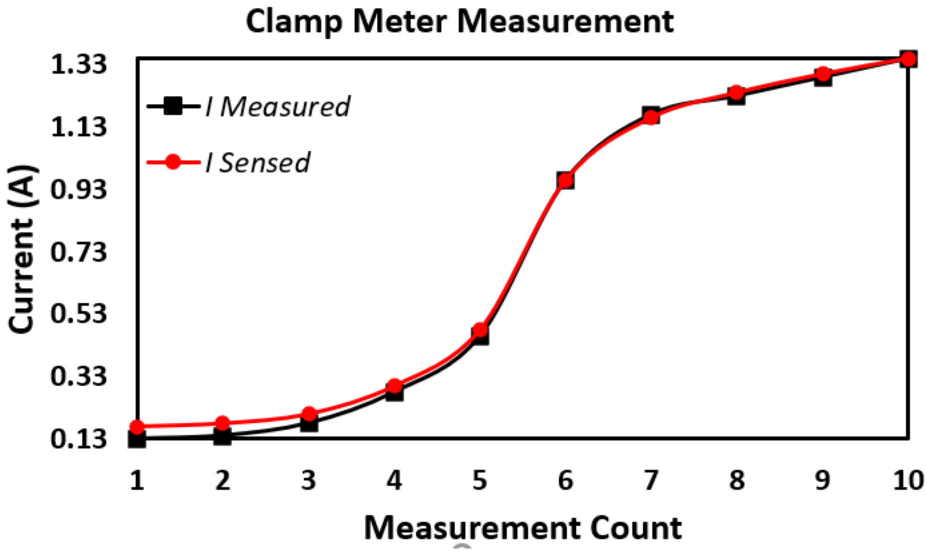

Fig. 7: Clamp Current vs. Number of Readings.

Fig.7 shows the clamp current (AC) measurements. The designed system sensed the AC current, and on comparing to manually measured values, the system gave realistic results.

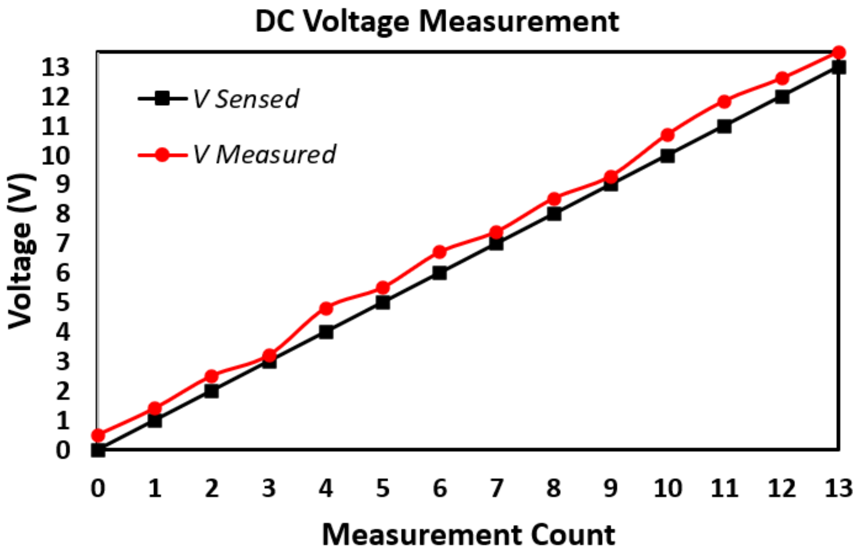

Fig. 6: DC Voltage vs. the Number of Readings.

Fig. 8 shows the DC voltage measurements. The proposed system measures the voltage with the embedded sensors and gives satisfactory results.

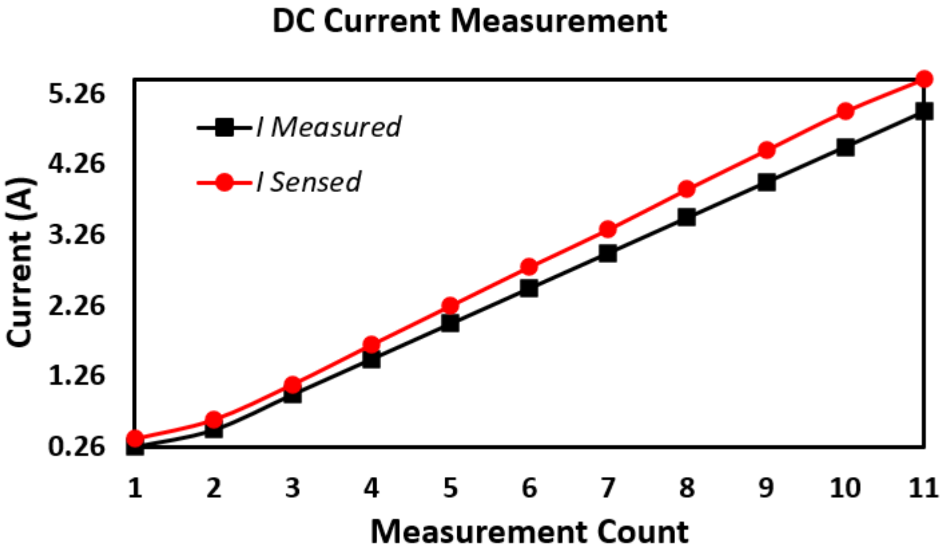

Fig. 7: DC Current vs. the Number of Readings.

Fig. 9 shows the DC current measurements. The system measured the DC current, and the comparison was made with the manually measured values. The comparison analytics show that the system gives satisfactory performance.
The experimental results give us good analytics. The technical methods used for measurement purposes proved to be efficient and reliable. Results fetched from the cloud server can be displayed on the mobile screen to the technical staff, causing ease in real-time monitoring of the solar energy-based systems.

4. Conclusion

In this paper, a detailed solution for measuring the electrical parameters of the solar device has been proposed. This paper in-depth discusses the performance of the solar-energy-based device, which is opted for measuring electrical parameters so that accuracy in calculating electricity bills can be achieved. The designed system is IoT-enabled which helps to monitor the data autonomously and sends it promptly. A mobile application is designed to display real-time data to the user. The developed system is efficient, accurate, and easy to use. The hit and trial method has achieved the experimental results to obtain maximum accuracy.

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