Remote Data Acquisition System for Measurement of Ambient Climatic Conditions and SPV Battery Status

Mahesh B. Gorawar, Veeresh G. Balikai, Vinayak H. Khatawate, and P. P. Revankar

Abstract The cost of solar PV (SPV) systems has reduced drastically over the years on account of efficient PV cell manufacturing technologies. Its suitability and economic viability for the installation site have strong correlation to local climatic resources. The access to data on solar insolation, wind speed and other climatic parameters is hence essential for site selection and SPV installation. The remotely accessible data of ambient temperature and solar irradiance at target location was acquired through Arduino-GSM hardware loaded with compatible software. The study showed that temperature and solar irradiance measured through developed system was within 2.23% and 5.83%, respectively, as compared to conventional measurement techniques. The novelty of the device is envisioned in its application to monitor small-scale as well as large-capacity renewable energy systems that have a strong dependence on climatic factors.

Keywords Insolation · Temperature · Solar PV · Remote data acquisition

1 Introduction

The increasing energy demand globally has turned to be a serious concern on account of fossil fuels largely used in thermal power generation. This has lead to exploration of cleaner options to satisfy electric power needs and other domestic consumption for cooking and transportation applications. The renewable energy offers dual benefit of eco-friendliness and resource abundance to meet energy demand of human society. The renewable energy includes nature-based sources like solar, wind and biomass. The SPV occupies foremost place for its high feasible potential for exploitation and hence subjected to rigorous research and field implementation [1].

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The electrical equipment that operates on SPV either needs backup of standby devices or storage to support load during non-generating spells. Batteries constitute the vital balance of system (BOS) for SPV system especially operating on stand-alone mode for storage and help maintain constant load even with SPV panels delivering fluctuating power. The charge controllers prevent battery overcharge and maintain a uniform system voltage. The storage support includes battery monitors to continuously track changes in battery status and initiate necessary action in case of exigencies. The unregulated battery storage normally needs higher storage compared to regulated system owing to protection sought against being overcharged [2].

2 Literature Survey

The research on wireless sensing, Arduino sensing, SPV monitoring and effect of parameters on solar PV is dealt in this section. Galande et al. (2014) developed wireless data monitoring using LPC2148 ARM 7 processor and GPRS SIM900 wireless module for relative humidity, ambient temperature and solar irradiance. The data was stored in SQL database with Keil software which made the system more interactive, user friendly to give rapid and accurate results [3]. Tobnaghi et al. (2014) studied effect of temperature and solar radiation on electrical performance of SPV system installed at Baku (40.4° N, 49.9° E) on silicon-based SPV system at three combinations of ambient temperature and solar insolation like 15 °C, 25 °C and 50 °C and 1000 W/m^2, 800 W/m^2 and 500 W/m^2, respectively [4]. Vianney et al. (2015) reported on SPV-powered Arduino wireless flood sensing to predict natural disaster on basis of model using water level indicator, Arduino UNO and necessary support system. The model exhibited accurate, reliable and secured information on natural disasters for long-term disaster management [5]. Adilah et al. (2015) used GSM technology to monitor panel efficiency of system on basis of Arduino Mega 2560 Microcontroller. The model communicated through alert signals and helped to improve the long-term performance of SPV system [6]. Haider-e-Karar et al. (2015) proposed an effective and efficient GUI, using Arduino interfaced with NI LabVIEW and Web browser. The hardware part consists of Arduino Mega 2560 Microcontroller, ACS712 current sensor, voltage divider circuit for voltage sensing, a charge controller and a 5 V relay for switching to other alternative available energy source [7]. Joshi et al. (2016) designed a monitoring system for 125 Wp SPV systems, using ATmega328P as core processor of Arduino and Wi-Fi module [8]. Moron et al. (2017) reported on dual-axis SPV tracker with Arduino platform to draw a maximum benefit of an incident radiation [9]. Mansouri et al. (2018) reported on solar tracker with two geared dc servomotors, LDR and ATmega328P microcontroller with Arduino. The system successfully tracked sun orientation for wide range of locations [10]. Laseinde et al. (2019) developed cost-effective microcontroller-based maximum power point tracking algorithm for solar multiple-axis tracking systems using Arduino board. It was observed that the designed system increased electrical efficiency of the solar array up to 23.95% [11].

Chowdhury et al. (2019) reported on stand-alone low-cost, high-precision dual-axis closed-loop sun-tracking system using Astronomical Almanac's (AA) algorithm, implemented in an 8-bit microcontroller. The results revealed that incorporation of the sun position algorithm into a solar tracking system helps in outperforming the fixed system and optical tracking system by 13.9% and 2.1%, respectively [12].

3 Details of Experiment on SPV DAQ System

The details provided in Fig. 1 indicate the programmed Arduino configured as main controlling unit with GSM shield used for communication and sensors collected parameters related to SPV system. The data collected was stored using NetBeans software. The parameters acquired were temperature and irradiance, voltage status of battery charged through solar panel.

LM35 temperature sensor measured ambient temperature while LDR was used for solar irradiance. Voltage divider circuit measured battery voltage status. Figure 2 shows hardware part housed in box with provision made to observing data using LCD display and also for the solar panel and battery connections to the hardware unit.

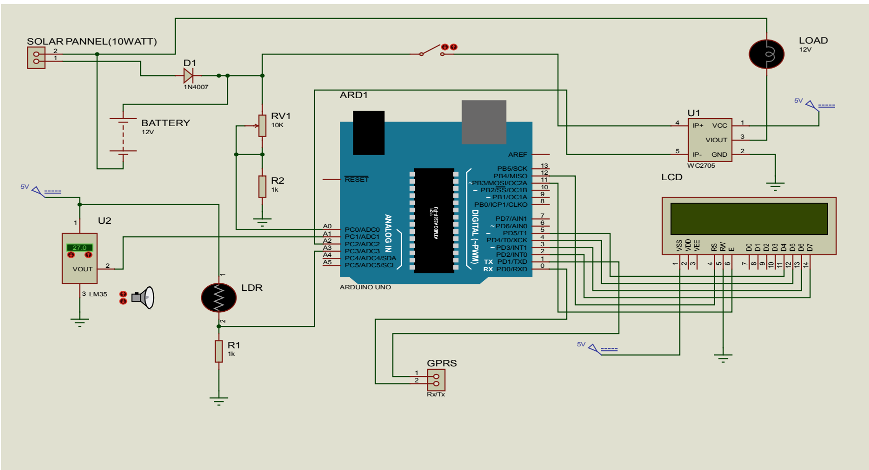

Fig. 1 Circuit diagram of SPV data acquisition system drawn in proteus

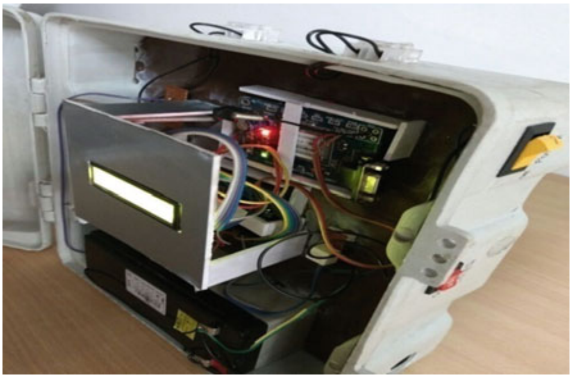

Fig. 2 Hardware implementation of the model developed

4 Experimental Investigations on SPV DAQ System

The authorized user has access to data from anywhere using Internet connection by entering URL and username and password. Figure 3 shows the experimental setup used for the study at the Hubballi location during the month of August. It consists of the hardware unit where all the circuits are housed in a box, a 10 W solar PV panel which is tilted at 15.3°, LDR and LM35 sensors are placed around the panel.

The parameter values which are measured by Arduino and sent to the controlling station are stored in the database created using NetBeans software. Figure 3 shows experimental setup used for the study at the Hubballi location. It consists of the hardware unit, a 10 W solar PV panel which is tilted at 15.3°, LDR and LM35 sensors are placed around the panel.

Fig. 3 Experimental setup for the study

5 Results and Discussions

The experiments were conducted, and all data obtained was sent wirelessly using Arduino to database created using NetBeans that was accessed through Internet connection from anywhere in the world and at any time. The experiments were conducted, and all recorded data were sent wireless medium using Arduino to database created using NetBeans and stored in database. The recorded data were accessed remotely through internet.

5.1 Comparison of Instruments

This section is about the comparison of the obtained data of temperature and irradiance from experiment with that of standard instruments, i.e., mercury thermometer and handheld pyranometer. The accuracy of the devices used in the experiment, such as LM35 and LDR sensors used for temperature sensing and solar radiation measurement are assessed using mercury thermometer, and pyranometer respectively. LM35 temperature sensor is compared with the mercury thermometer, and LDR is compared with the handheld pyranometer. From Fig. 4, we can observe that temperature value measured using LM35 sensor showed better accuracy with those of mercury thermometer readings. An accuracy of 1 °C was acceptable as per standards. The measurement of temperature using the developed system and a mercury thermometer indicated a maximum percentage error of 2.23% and a minimum error of 0.86%. From Fig. 5, we can observe that the irradiance value measured using LDR is nearly

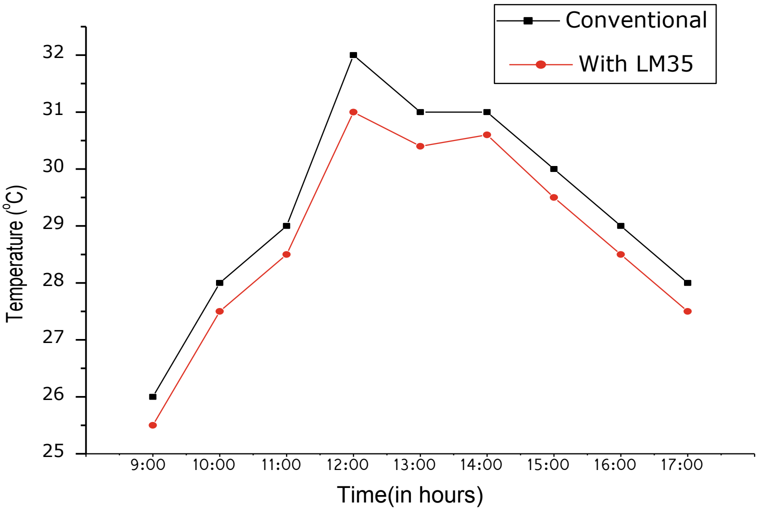

Fig. 4 Comparison of temperature measurement using thermometer and LM35

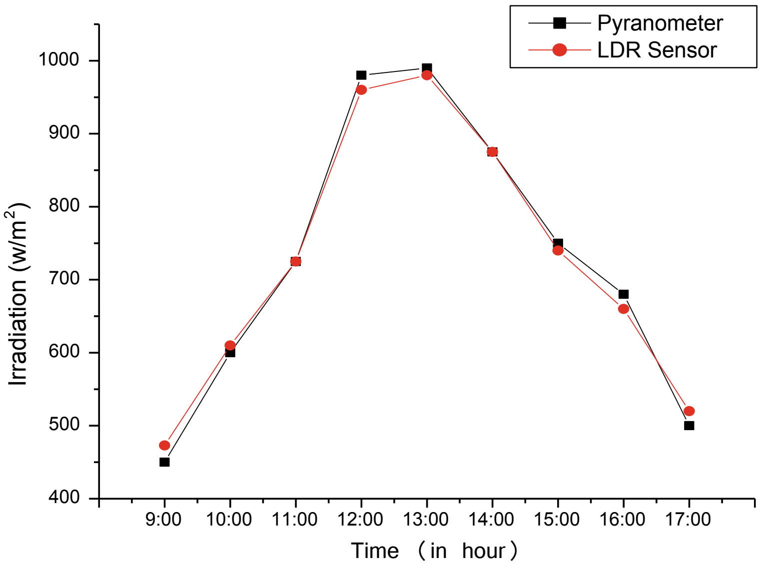

Fig. 5 Comparison of temperature measurement using pyranometer and LDR sensor

accurate at higher insolation level, but at lower insolation level, the difference is high when compared with the handheld pyranometer. The inaccuracy in measurement of solar irradiance is attributed to rapid changes in the intensity of solar energy available at the site on account of climatic variations. The measurement of irradiance using the developed system and a handheld pyranometer indicated a maximum percentage error of 5.83% and a minimum error of 0.99%.

Figure 6 depicts the average temperature data recorded for five days between 9:00 and 17:00 h. It was observed that the variation in temperature was between 25 °C and 32 °C in the month of August for the Hubballi location. The temperature variation indicated that day four had higher temperature while day one recorded lower levels of temperature distribution among the observations made.

The variations in ambient temperature are important with respect to performance characteristics of SPV module. A lower temperature of the SPV module generates higher voltage and results in more energy gain from the panel. The observations of ambient temperature made during the test period have indicated that operating efficiency of the module is influenced by the ambient temperature conditions as well as the solar irradiance.

Figure 7 depicts the average irradiance data recorded between 9:00 and 17:00 h during test period. It was observed that variation in irradiance was between 450 and 1018 W/m^2 in the month of August for Hubballi location. The irradiance variation indicated that day two had higher insolation while day five recorded lower levels of insolation distribution among the observations made. The variations in irradiance with time were between 450 and 1018 W/m^2. Initially, at the start of the day, insolation

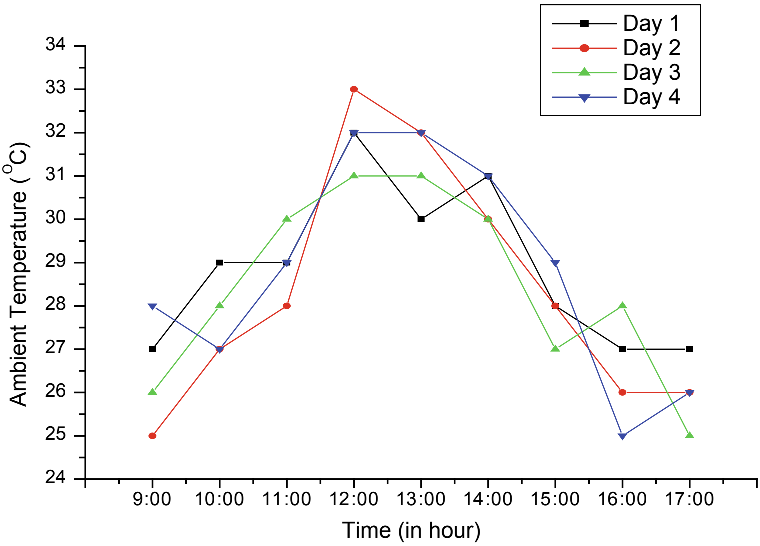

Fig. 6 Variation of temperature with time at the location measured using LM35

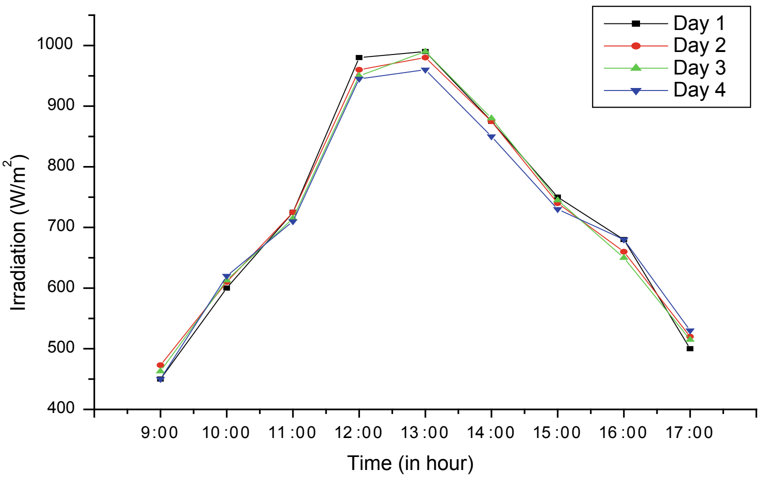

Fig. 7 Variation of temperature with time at the location measured using LDR sensor

levels were lower and increased to a peak value in the duration between 11:00 a.m. and 3:00 p.m. The insolation level was observed to decrease beyond 3:00 p.m. due to the transition of sun downwards the horizon. The variations in insolation levels are important with respect to performance characteristics of SPV module. A higher insolation on the SPV module generates higher load current and results in more energy gain from the panel.

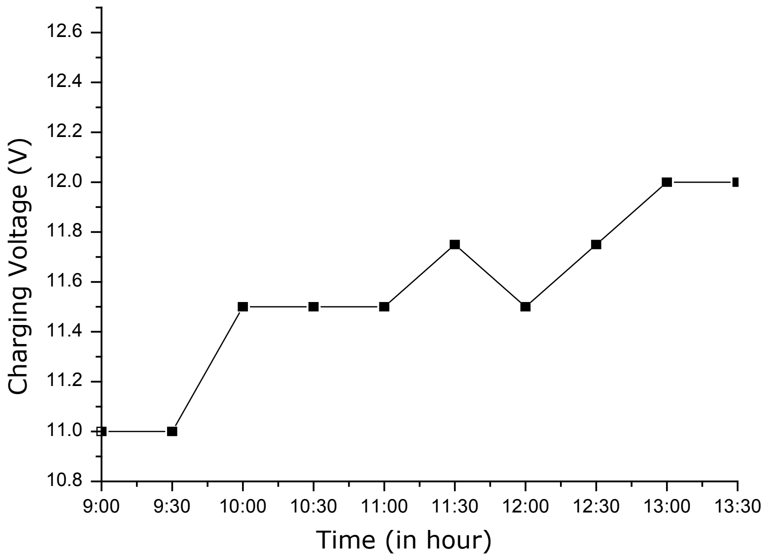

Fig. 8 Variation of battery charging voltage with time

This section is about the charging characteristics of 12 V 7.2 Ah battery charged through 18 V 10 W solar panel and discharging characteristics of the same battery discharged using 5 W incandescent bulb.

The battery storage system forms an important part of the renewable energy system and functions to match between the source side and demand side. The charging and discharging characteristics of the battery storage are hence important in the transient behavior of the renewable energy based on battery storage system. The charging and discharging characteristics of lead–acid battery of 7.2 Ah, 12 V were observed by connecting with 10 W solar PV system for charging and 5 W incandescent lamp for discharging respectively.

Figure 8 indicates the charge cycle of 12 V battery using 10 W solar panel which took a time span of seven and half hours to develop a voltage gain of 2.8 V. The data was taken when there is good amount of sunlight throughout the day with readings recorded by voltage sensor connected to the battery. The charge cycle takes a shorter charge time in the initial part that reaches a saturation limit in the later part of the cycle.

6 Conclusion

The following conclusions were drawn from the study:

- The prototype of a simple wireless solar photovoltaic data acquisition system based on Arduino and GSM communication was developed and successfully tested. The developed system offers the advantage of remote monitoring of SPV-based system.
- The LM35 and LDR-based measuring systems performed satisfactorily for wide range of temperature and irradiance measurement. The errors in measurement of ambient temperature and irradiance lie within a margin of 2.23% and 5.83%, respectively.
- The charging and discharging cycle of the battery storage connected to PV panel and load indicated that charge duration is greater than the discharge duration on account of variations in solar PV panel output. The ratio of charging duration to the discharging duration of the battery was as high as 7.5 owing to direct connection between panel and battery without use of charge controller.

The NetBeans IDE was developed to create a cloud-linked database for long-term storage of climatic information at the location obtained from the developed DAQ system. The memory space of 10 GB available on this platform is adequate for continuous storage and retrieval of the recorded climate data.

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