

DEVELOPMENT OF REAL-TIME, EMBEDDED DATA MONITORING WIRELESS NETWORKING SYSTEM TO CHARACTERIZED SOLAR PANEL

V.V.Monica Sindhu and X. Anitha Mary¹

Dept of Electronics and Instrumentation Engineering, Karunya University, Coimbatore, India
vijayamonicasindhu.valle@gmail.com; ¹anithamary@karunya.edu

ABSTRACT

To develop a scalable Measuring and monitoring infrastructure for condition based maintenance of photovoltaic generation system based on wireless sensor networking. An experimental setup for performance investigation under tropical weather conditions of the solar panel are created and a dedicated wireless sensor network is considered and implemented using LabVIEW2014 virtual instrumentation software. Apart from real-time data monitoring and displaying features, it also has the GUI system and diagnostic capabilities that are helpful in acquiring the solar panel performance under test. The environmental parameters such as current, voltage, temperature, and relative humidity of a solar panel is also incorporated. The typical 21W solar panel is used for evaluating data from different sensors connected to it. This experimental setup is mainly aimed to access the performance of the solar panel which is helpful for the homeowners to know the quality of their solar panels from the place where they are.

Keywords—solar panel, ZigBee, Arduino Nano board, sensors network, Lab VIEW.

I. INTRODUCTION

Nowadays, photovoltaic (PV) power system is becoming worldwide-spread due to the ubiquity, abundance, and sustainability of solar energy for electricity generation. Due to the intermittency of sunlight, solar energy is widely available and completely free of cost. In the rising of PV system installation, a performance monitoring system is developed which increases importance to set up for a real-time monitoring function. A data acquisition (DAQ) technology is considered for implementing monitoring system performance. The collected data from the sensors can be further used to evaluate or diagnose output characteristics of the solar panel. By knowing this some micro-controller-based DAQ systems are used for monitoring and evaluating the performance of PV panels [1, 9]. Lab VIEW-based DAQ systems [12,13] have been developed for monitoring PV related power system. The LabVIEW is defined as a graphical programming interface package which informs about the working and appearance of physical instruments by using virtual instruments (VIs) with the advanced system of user-friendly graphic user interface (GUI) and it is also easy-to-use. Vergara and Natangelo [14] have proposed about the PV assessment by analyzing the data in the software's like Lab VIEW and Mat lab environment. They had compared the data of a specific date with the of the same date of the previous year. Basically under the real operating condition, a performance of PV panels has a nonlinear I-V characteristic which depends upon the solar insolation, the temperature of the cell and operating voltage of PV module. This helps us to develop a model-based PV monitoring system including a self-diagnosis function by comparing the estimated ones measurement with the measured data which is based on the simulation of a single-diode PV model. Normally the performance of PV module is evaluated with the standard test condition (STC) respectively. In general, manufacturers only provide some experimental data about thermal and electrical characteristics of PV panels with respect to the STC, like short circuit current, open circuit voltage, maximum power rating, rated

voltage at a maximum power point (MPP), rated current at the MPP, and temperature coefficients of open circuit voltage and short circuit current. Therefore, some references [15,16] contributed for the extraction of parameters of a single diode PV model based on the experimental data provided by the manufacture's datasheets under the STC. Some parameters over a large range of operating conditions are important indices, which can be used to assess, monitor, and diagnose a variety of PV modules.

It is necessary to know and understand the characteristics of the required solar panel under the different light condition to extract the maximum power from a panel. Generally, this extraction is done by tracking V-I characteristics of the panel under different real-world atmospheric conditions. The solution to finding maximum power point of solar panel and to check whether maximum power is produced from the panel, a research work is carried [2,3]. A micro-controller based solar panel monitoring system is reported in [4]. A remote data acquisition system has been developed based on wireless monitoring system [5]. Multiple wireless sensors are monitored using wireless monitoring system is proposed [6]. A proposed work of environmental monitoring framework is characterized by energy harvesting, robustness, and solar-powered has been reported using a wireless sensor network technology [7, 8].

ZigBee is a technological Standard Created for Control and Sensor Networks. It is an IEEE 802.15.4 Standard and it is created by the ZigBee Alliance .normally ZigBee is operated in the frequency of ISM 2.4 GHz Global Band at 250kbps and operates in Personal Area Networks (PAN's) and device-to-device network. Figure 1(b) shows the ZigBee module. It is a communication protocol which is mainly used for a low rate wireless personal area network (LR-WPAN). It is mainly used for applications which are performed under low rate where longer battery life is needed, and due to its small in size and limited in weight makes it use in more applications. The IEEE 802.15.4 standard is allowed to make use of the Physical layer and the sub-

layer of Data link layer. The sub-layer of Data link layer is MAC layer. In OSI model, these two layers are the lowest layers which are showed in figure 1(a).

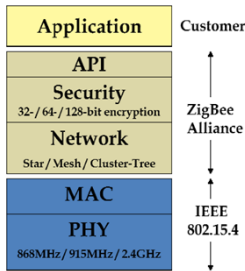


Fig.1 (a) OSI model



Fig.1 (b) Zigbee module.

II. NETWORKING AND HARDWARE

A. Wireless sensor network.

A wireless sensor network is a highly distributed network of lightweight, small wireless nodes which transfer many numbers of data to monitor the environment conditions such as temperature, sound, vibration, pressure, motion or pollutants at different locations. Figure 2 represents working of wireless sensor networking (WSN). Two important operations in sensor networks

1. Data dissemination: Propagation of data/queries throughout the network.
2. Data gathering: Collection of observed data from individual sensor nodes to a sink.

Networks of small, battery-powered, wireless devices.

- Onboard processing.
- Communication.
- Sensing capabilities.

Each node in a sensor network is typically arranged with a small microcontroller, an energy source which usually may be a battery and a radio transceiver.

Basic Network Topologies:

- Ring Topology
- Star Topology
- Bus Topology
- Tree Topology
- Fully Connected Networks
- Mesh Networks

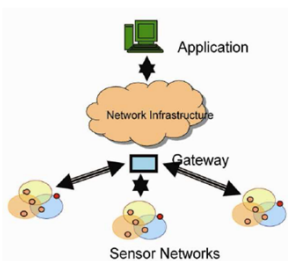


Fig. 2 working of WSN network

B. Microcontroller interface.

To interface all the sensors we make use of Arduino Nano board which contains atmega328 microcontroller in it. Figure 3 shows the Arduino Nano board. It is a small, complete, and breadboard-friendly board which is based on the ATmega328 or ATmega168. It lacks only a DC power jack which works with a Mini-B USB cable

instead of a standard one. It has 8 analog input pins which each has 10-bit resolution since I have used 4 sensors 4 analog input pins are used (A0, A1, A2, A3). The ATmega328 has 32 KB flash memory for storing code, (also with 2 KB used for the bootloader) and ATmega168 has 16 KB of flash memory (of which 2 KB is used for the bootloader). All the 4 sensors are interfaced with the board and Arduino code is dumped onto the board and the transmitter n receiver pins are connected to Dout and Din of the Zigbee coordinate. So that the data is transferred to the Zigbee through Arduino board.



Fig. 3 Arduino Nano board

C. GUI display unit

GUI display is a graphical user interface which mainly used for displaying the values in the graphical format in a user understandable way. Lab VIEW software is used to develop a GUI display this software has multiple collections of drag-and-drop controls and indicators which make the operation quick and easy so that user can create a user interfaces for the application in less time and can also visualize the outputs effectively. The drag-and-drop of controls and indicators is an advantage that improves to develop more applications using it. The power users can customize the built-in controls via the control editor and programmatically can control UI elements to create highly customized user experiences. The main motivation in developing this GUI is for easier user convenience. This GUI is basically to display the various operating and set parameters of the solar panel.

III. THE PERFORMANCE MONITORING SYSTEM

There are many schematic circuit diagrams for measurement of P-I-V characteristics. PV cell is basically a p-n semiconductor which can directly convert the electricity through the photovoltaic effect. To size a PV module, the cells of the module are arranged in series-parallel configuration form. The PV devices generally exhibit nonlinear $I -V$ and $P -V$ characteristics which vary with radiant intensity and cell temperature.

The required setup range and requirements are shown as follows.

- The Voltage range of PV panel is 18V.
- The Current range of PV panel is 5A.
- Maximum power produced by PV panel is 21Wt.
- Adjustable scan time, the scan can be completed under atmospheric condition changes.

Both IV characteristics and a load of a PV module are measured in no of ways from a device and software perspective. The functional block diagram for the wireless monitoring system is shown in the fig. 4.

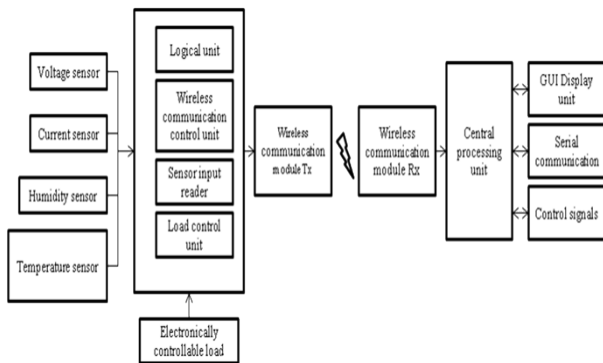


Fig.4. The functional block diagram for wireless data monitoring system

A. Measurement of voltage

Here to measure voltage, a voltage divider circuit is used as a voltage sensor. A simple circuit is referred to be as a voltage divider circuit which is used to compress a large amount of voltage into a smaller one. Voltage divider circuit is designed by just connecting a number of resistors on series here an input voltage and two series resistors are needed to produce an output voltage which will be the fraction of the input given. Voltage divider circuits are known as fundamental circuits in electronics. Here 100k, 10k and 1k resistors and a Zener diode are used for the construction of voltage divider circuit by considering the voltage produced by the panel. In the fig.5 shows the voltage divider circuit which is connected on the breadboard for testing the values. The maximum measurable voltage is 18V.

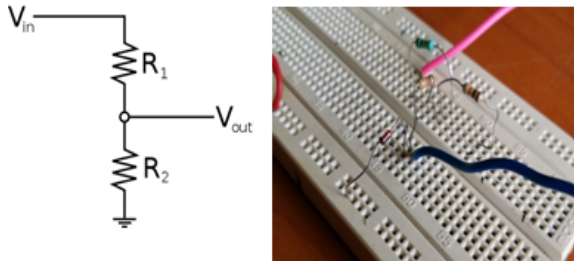


Fig.5 voltage divider circuit designed on bread board

Consider the input voltage is V_{in} , and R_1 and R_2 are two resistors used. We can use the below equation to find out the required output voltage (V_{out}):

$$V_{out} = V_{in} * (R_2 / (R_1 + R_2))$$

The above equation represents that the output voltage V_{out} is directly proportional to the input voltage V_{in} and to the ratio of two resistors R_1 and R_2 . R_1 used is 100k ohms and R_2 used is 10k ohms.

B. Measurement of current

Here current sensor used is ACS712; it provides economical and precise solutions for AC or DC current sensing. Fig 6 shows the current sensor ACS712

The sensor device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near to the surface. The applied current which flows through this copper conduction path generates a magnetic field which is converted into a proportional voltage by Hall IC. It uses a low ohm current sensing resistor to measure the current. The voltage is amplified

which is across the current sensing resistor and fed into the microcontroller which converts analog data into digital data. Sensor positive is connected to the solar panel positive and negative is connected to the load resistor.

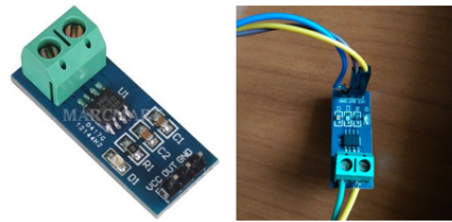


Fig.6 current sensor (ACS712).

C. Measurement of temperature sensor

The LM35 is preferred as a temperature sensing element. Its series are precision integrated-circuit temperature sensors, where its output voltage is linearly proportional to the Celsius (Centigrade) temperature. Figure 7 represents the temperature sensor LM35. The LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin; The LM35 does not need any external trimming or calibration to provide typical accuracies of $\pm 1/4^\circ\text{C}$ at room temperature and $\pm 3/4^\circ\text{C}$ over a -55 to $+150^\circ\text{C}$ temperature range. The temperature sensor is interfaced with Arduino Nano board so that the analog readings from the sensor is converted into the digital form and transmitted to ZigBee router through ZigBee coordinate.

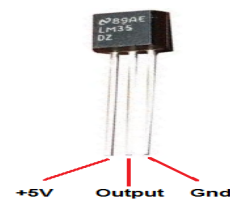


Fig.7 temperature sensor

D. Measurement of humidity sensor

The module of HSM-20G is used as a humidity sensor which is essential for the applications where the relative humidity can be converted to standard voltage output. In figure 8.2 shows the representation of humidity sensor and figure 8.1 represents the schematic diagram of the humidity sensor. Input voltage range of humidity sensor is DC $5.0 \pm 0.2\text{V}$ and output voltage range is DC 1.0-3.0 V, maximum operating current is 2mA.

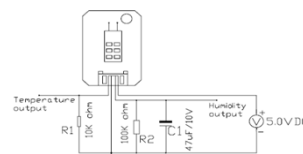


Fig. 8.1 schematic diagram of humidity sensor



Fig. 8.2 humidity sensor

IV. SETUP AND RESULT

All the sensors are calibrated separately and each sensor is interfaced to the microcontroller to separate ports. The temperature sensor is connected to A0 port,

the current sensor to A1 port, the voltage divider to A2 port and humidity sensor to A3 port of Arduino board. This interface setup is attached near the solar panel. All the data from the sensors is collected by the microcontroller and this data is formed in a format to send wirelessly to the coordinator using ZigBee communication. The data that is received by the Zigbee receiver is read into the Lab VIEW program by using VISA ports and displayed on the monitor and also stored in a File. The communication between the coordinate and computer is done through USB to serial cable.

The data is saved in a database and also in text files. The performance data is communicated using ZigBee protocol, ZigBee used here is Xbee series2 for the purpose of low cost. Because of it matches in data rate, distance and power consumption ZigBee protocol is used. The reliability and efficiency of the communications are tested during the experiment for various conditions.

Due to various factors like reflections, noise caused by household appliances, the sensor nodes are reliably tested and the satisfactory result is obtained. The range of Xbee is sufficient for the normal household application, if need to change to the high range then simply Xbee can be replaced with Xbee-Pro without changing the entire circuit.

As soon as the performance data is stored in the file, depending upon the stored data different performance characteristics of the solar panel can be plotted. Fig 9 shows the temperature readings of the solar panel, Fig 10 shows the current-voltage readings according to the power produced by the solar panel and Fig 11 shows the humidity of solar panel. Fig 12 represents the parameter readings displayed in a tabular Colum in LabVIEW software.

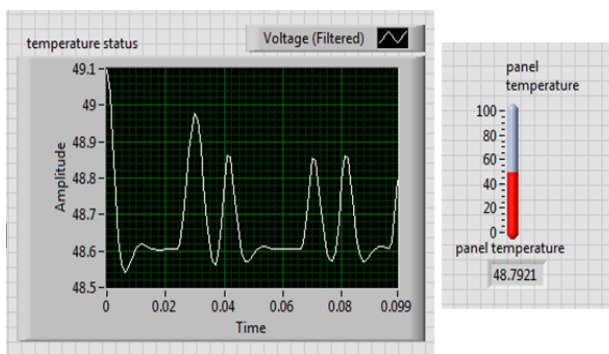


Fig.9 measurement of the temperature of a solar panel.

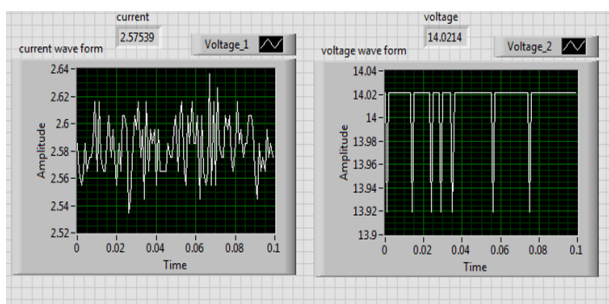


Figure 10 Current and Voltage readings from solar cell

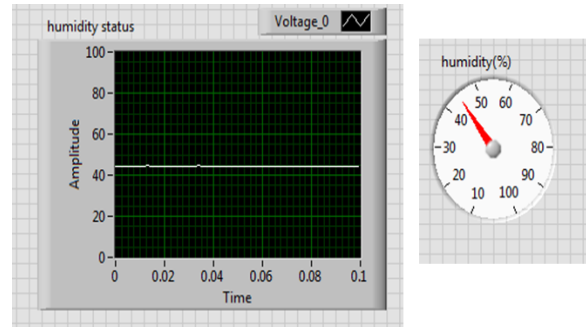


Figure 11 Humidity sensor readings

date and time	temp	humidity	current	voltage
10/30/2015 11:00:18 AM	48.642550	30.436641	2.585579	14.021363
10/30/2015 11:00:18 AM	48.594540	30.436641	2.585579	14.021363
10/30/2015 11:00:18 AM	48.572622	30.436641	2.605962	14.021363
10/30/2015 11:00:18 AM	48.570868	30.436641	2.605962	14.021363
10/30/2015 11:00:18 AM	48.580359	30.436641	2.595770	14.021363
10/30/2015 11:00:18 AM	48.593043	30.436641	2.565195	14.021363
10/30/2015 11:00:18 AM	48.603653	30.359275	2.544811	14.021363
10/30/2015 11:00:18 AM	48.609962	30.436641	2.585579	14.021363
10/30/2015 11:00:18 AM	48.612043	30.436641	2.565195	14.021363
10/30/2015 11:00:18 AM	48.611193	30.436641	2.575387	14.021363
10/30/2015 11:00:18 AM	48.608989	30.436641	2.565195	14.021363
10/30/2015 11:00:18 AM	48.606695	30.436641	2.595770	14.021363
10/30/2015 11:00:18 AM	48.623474	30.436641	2.575387	14.021363
10/30/2015 11:00:18 AM	48.691998	30.436641	2.585579	14.021363
10/30/2015 11:00:18 AM	48.792119	30.436641	2.575387	14.021363

Figure 12 Temperature, Humidity, Current, Voltage readings displayed in tabular form

V. CONCLUSION

A simple wireless sensor networking based performance monitoring system is developed for a solar panel and performed as a standalone current and a voltage measuring transducer. An adjustment in scan speed will reduce or eliminate 50 Hz AC interface from a solar simulator. Filters are used to allow DC values from AC signals that are acquired from the controllers. It also acts as a small portable standalone microprocessor based system.

For maintaining the regularly based performance monitoring of solar panel this development system will give a solution. It is so flexible that can be used for any other monitoring system using wireless sensor networking system and Zigbee communication.

REFERENCES

- [1] Santos, A., C.L.Barrio and A.G.Guerra, Automatic data acquisition system for PV solar plant. *Solar and Wind Technology* 3(4): 259-265 (1986).
- [2] "PC print port controls I-V curve tracer (an253)." [online]. Available:www.maxim-ic/an235 (2004).
- [3] Arustizabad, A.J., C. A. Arredondo, J. Hernandez and G. Gordillo, Development of equipment for monitoring PV power plants, using virtual instrumentation. *Proc. 4th IEEE World Conf. Photovoltaic Energy Conversion* 2: 2367-2370 (2006) DOI:10.1109/WCEPEC.2006.279667.
- [4] Azim,M.A., S. M. Ariful Huda, H.Mohammad and N. Amin, Microcontroller based standalone PV system for wireless sensor node. *Proc. Int. Conf. Comput. Commun. Eng., Kuala Lumpur, Malaysia*, Pp. 1136-1139 (2008).
- [5] Karunanithi, S., N. M. Din, H. Hakinie, C.K.Hua, R. C. Omar and T. C. Yee, Performance of lab scale solar powered wireless landfill monitoring system. *Proc. 3rd Int. Conf. Energy and Environ., ICEE, Malacca, Malaysia*, Pp. 443-448 (2009).
- [6] Masuda, S. and T. Hattpri, Development of a wireless remote monitoring system utilizing multiple wireless sensors. *Electron. Commun. Japan* 91(6): 61-0-617

- (2008), (Transland from Denki Gakkai Ronbunshi, vol. 127-D, No. 6, 207, pp.610-617).
- [7] Alippi, C., R. Camplani, C. Galperti and M. Reveri, A robust, adaptive, solar-powered WSN framework for aquatic environmental monitoring. *IEEE Sensor J.* **11**(1): 45-55 (2011).
- [8] Alippi, C. and C. Galperti, An adaptive system for optimal solar energy harvesting in wireless sensor network nodes. *IEEE-Trans. Circuits Syst. I: Regular Papers* **55**(6): 1742-1750 (2008).
- [9] Mukaro, R. and X. F. Carelse, A microcontroller-based data acquisition for solar radiation and environmental monitoring. *IEEE Transactions Instrumentation and Measurement* **48**(6): 1232-1238 (1999).
- [10] Kim, M. and E Hwang, Monitoring the battery status for photovoltaic system. *Journal of Power Sources* **64**(1-2): 193-196 (1997).
- [11] Benghanem, M., A. H. Arab and K. Mukadam, Data acquisition system for photovoltaic water pump. *Renewable Energy* **17**(3): 385-396 (1999).
- [12] Wichert, B., M. Dymond, W. Lawrance and T. Friese, Development of a test facility for photovoltaic-diesel hybrid energy system **22**(1-3): 313-319 (2001).
- [13] Aristizabal, A.J. and G. Gordillo, Performance monitoring result of the first grid-connected BIPV system in Colombia. *Renewable Energy* **33**(11): 2475-2484 (2008).
- [14] Vergara, S. and E. Natangelo, Labview interface for data analysis of PV plants. *Proceedings of International Conference on Clean Electrical Power*, Pp. 236-241 (2009).
- [15] De Blas, M.A., J. L. Torres, E. Prieto and A. Garcia, Selecting a suitable model for characterizing photovoltaic devices. *Renewable Energy* **25**(3): 317-180 (2002).
- [16] Villalva, M.G., J. R. Gazoli and E. R. Filho, Comprehensive approach to modeling and simulation of photovoltaic arrays. *IEEE Transaction on Power Electronics* **24**(5): 1198-1208 (2009).