Health Monitoring System of Solar Photovoltaic Panel: An Internet of Things Application

Prutha M. Badave, B. Karthikeyan, S. M. Badave, S.B. Mahajan, P. Sanjeevikumar and Gurjit Singh Gill

Abstract A wireless remote monitoring system for solar photovoltaic (PV) plant is proposed in this paper. It is an Internet of Things (IoT) application implemented with an objective to offer a cost-effective solution of monitoring system, which continuously presents remote energy yields and its performance either on computer or on handheld gadgets such as smart phones. A system for proof of concept is developed with eight solar panels to monitor string voltage, string current, temperature and humidity. System is controlled by CC3200 microcontroller with ARM Cortex-M4 as core. On board Wi-Fi, wireless communication enhances the system performance with reduced area and facilitates to monitor system parameters after every 30 s.

Keywords Remote monitoring system · Data acquisition system Internet of Things · Parameter measurement · Solar photovoltaic

---

P.M. Badave (✉) · B. Karthikeyan
School of Electronics Engineering, Vellore Institute of Technology, Vellore, India
e-mail: pruthabadave11@gmail.com

B. Karthikeyan
e-mail: bkarthikeyan@vit.ac.in

S.M. Badave · S.B. Mahajan
Department of Electrical and Electronics Engineering,
Marathwada Institute of Technology, Aurangabad, India
e-mail: smb.eed@gmail.com

S.B. Mahajan
e-mail: sagar25.mahajan@gmail.com

P. Sanjeevikumar
Department of Electrical & Electronics Engineering,
University of Johannesburg, Auckland Park, South Africa
e-mail: sanjeevi_12@yahoo.co.in

G.S. Gill
Gill Instruments Private Limited, Bengaluru, India
e-mail: contact@gill-instruments.com

S. SenGupta et al. (eds.), *Advances in Smart Grid and Renewable Energy*,
Lecture Notes in Electrical Engineering 435, https://doi.org/10.1007/978-981-10-4286-7_34

1 Introduction

In last few years, the development of sustainable energy has strongly constrained due to the depletion of fossil fuel and contamination of environmental issues. The demands of sustainable energy generation systems can progressively replace conventional supply system. Nowadays, solar photovoltaic (PV) generation is gaining importance because of foremost advantages is that, it is clean and free energy source. Apart from that, it also offers the benefit includes ease of installation, low economic viability, noise-free generation, more resilient and more affordable to grid connected systems. Furthermore, efficiency of PV panels is increasing day-by-day due to technological advancement.

Solar systems are essentially installed over the wide range of capacity from less than kW as roof top installation to few tens of MW as solar farming system. For better performance and ease of maintenance, the performances of the solar PV systems need to be monitored continuously, especially when installations are in rural areas or spread over huge land, at reduced operational cost. Remote monitoring system mainly divided in three parts (i) a sensing unit, (ii) processing unit and (iii) display unit. Sensing unit basically includes various sensors and signal conditioning units. Obviously, this unit is located in close proximity with PV system. Information given by sensing unit is conveyed to processing unit either with wired or wireless network, which further given to display unit. Many times, sensing unit is equipped with smart sensors, to handle the PV system signals effectively before transmitting it to central processing unit. A case study of solar PV plant in UiTM Pulau Pinang, Malaysia is an automated data acquisition systems used to monitor small-scale solar PV plant by collecting all the data regarding the installed system [1]. National Instruments (NI) software LabView along with its data acquisition modules is used for real-time data collection of PV plant parameters on regular intervals. In this case sensing system, processing and monitoring system are in close proximity. PV voltage and current connect are mainly monitored as measure of performance parameters [2, 3]. GSM voice channel is used as communication media. Analog transmission is preferred for communication by work on various communication protocols is also carried out thoroughly in [4]. An improved wireless remote monitoring and control system of a solar photovoltaic distributed generator (PV-DG) for micro-grids applications is implemented with full-duplex wireless communication using the ZigBee protocol [4, 5]. The supervisory control system is implemented on a digital signal processor (DSP) and a Human–Machine Interface (HMI) software is developed to measure PV parameters such as current, voltage and humidity along with solar tracking. Sensing unit is operated with intelligence of digital signal processor; however, ARM-based microcontroller LPC2148 is used for central control system. Though this kind of systems is offering efficient monitoring and control appeared to be costly solution due to smart sensors at each node. The electrical and physical parameters such as voltage, current, temperature and humidity [6, 7] are monitored with Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) system. It is a system implemented with basic programming and with relevant peripherals, which offers operational simplicity; however, it is suitable for industrial environment where existing infrastructure of PLC and SCADA is readily available.

A cost-effective, Internet of Things (IoT)-based health monitoring system is proposed here for solar PV plant, where sensors are embedded in solar PV system and are linked to the Internet through wireless networks, using the Internet Protocol, MQ Telemetry Transport (MQTT).

2 Proposed Solar Photovoltaic System

The proposed solar photovoltaic PV monitoring system, shown in Fig. 1, consists of PV array, storage battery banks, operational control unit of battery and an electrical load.

2.1 Photovoltaic Array

A prototype photovoltaic (PV) system of 2.5 kW is implemented using an assembly of polycrystalline PV modules, each is capable of yielding short-circuit current (I_{SC}) of 8.7 A and open-circuit voltage (V_{OC}) of 37.25 V. PV array is of such eight panels, arranged in form of two strings. Charge controller is a vital part of a system, which controls the power flow of battery thereby maximizing the battery life. Inverter is also essential to power AC load. In proposed work, instead of using charge controller and inverter as a separate entity, a power conditioning unit is installed to serve the purpose. Sensors placed at different locations are used to monitor system operation.

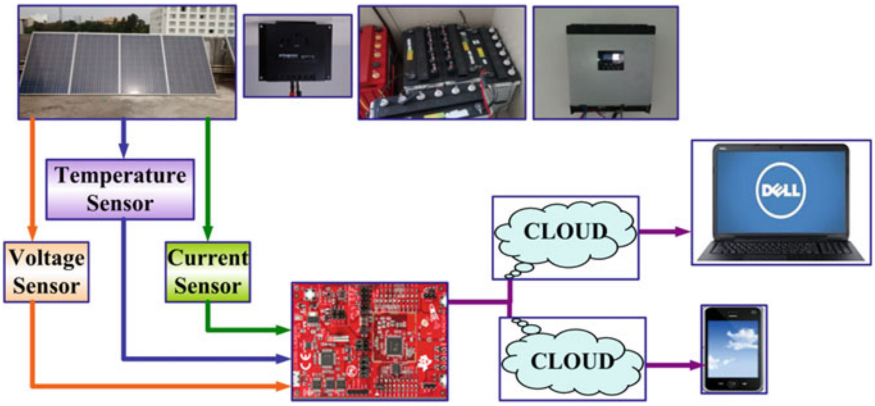

Fig. 1 Proposed solar photovoltaic system

	P1		P3	
Ref	Signal	Dev Pin#	Dev Pin#	Signal
1	3.3V			5V
2	ADC_CH1	58		GND
3	UART0_RX	4	57	ADC_CH0
4	UART0_TX	3	60	ADC_CH3
5	GPIO	61	58*	ADC_CH1
6	ADC_CH2	59	59*	ADC_CH2
7	SPI_CLK	5	63	AUD_SYNC
8	GPIO	62	53	AUD_CLK
9	I2C_SCL	1	64	AUD_DOUT
10	I2C_SDA	2	50	AUD_DIN

P4		P2		
Signal	Dev Pin#	Dev Pin#	Signal	Ref
PWM	2*		GND	1
PWM	1*	18	GPIO	2
PWM	17*	8	SPI_CS	3
PWM	64*	45	GPIO	4
CCAP/GPIO	21*		RESET_OUT	5
CCAP/GPIO	18*	7	SPI_DOUT	6
GPIO	62*	6	SPI_DIN	7
GPIO	60*	21	GPIO	8
GPIO	16	55	GPIO	9
GPIO	17	15	GPIO	10

Fig. 2 CC3200 launch pad

2.2 *Processing Unit*

Processing unit comprised with CC3200 launch pad (shown in Fig. 2) used to control complete solar PV panel health monitoring system. It is a low-cost evaluation platform integrated with high-performance ARM® Cortex®-M4 and built-in Wi-Fi connectivity. It is also featured with ADC operating on 1.5 V.

2.3 *Battery Storage*

Another essential element of solar array photovoltaic system (SAPV) is the storage battery. These batteries are necessary in order to avoid fluctuating nature of the output delivered by PV array. Batteries are designed to capture surplus electricity generated by solar PV system by permitting to store solar electricity for use later in the day. The energy obtained during day time directly feeds to load and unutilized energy can be stored in a battery to meet the demand during lack of solar energy. During the night, or during a period with low solar irradiation, energy is supplied to the load from the battery.

2.4 Monitoring System

Solar PV panel monitoring system comprises with three major units, sensing unit, processing unit and display unit. An Internet of Things (IoT)-based system is developed to monitor system parameters such as solar panel voltage, current, temperature and humidity.

2.5 Display Unit

Continuous monitoring is facilitated by display unit, which includes smart phones and remote terminal on Internet connected by MQTT protocol. ThingSpeak is an open source Internet of Things (IoT) application. It is an application programming interface (API) to store and retrieve data from sensors. ThingSpeak enables the creation of sensor logging applications, location tracking applications and a social network of things with status updates. It allows user to collect, store, analyze, visualize and act on data from sensors. Sensor unit comprised with voltage and current sensor is connected to analog inputs of 12 bit ADC section of controller CC3200; however, humidity and temperature sensor to Inter-Integrated circuit I^2C bus section. The Wi-Fi network processor subsystem features a Wi-Fi Internet-on-a-chip and contains an additional dedicated ARM MCU that completely offloads the applications MCU. An 802.11 protocol is used for system with a powerful crypto engine for fast, secure Internet connections with 256-bit encryption. CC32XX network processor and MCU Block arrangement is shown in Fig. 3.

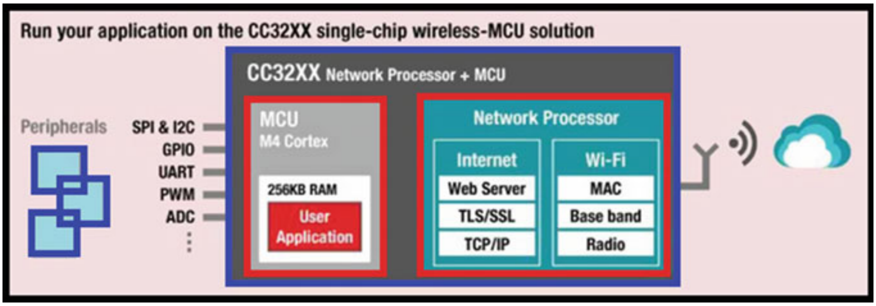

Fig. 3 CC32XX network processor and MCU

3 Sensing Units of Proposed System

Function of sensing unit is to sense system parameters and to act as an interface to processing unit. In proposed work, system operation is controlled by CC3200 launch pad, which is equipped with inbuilt ADC and accepts analog as well as digital inputs within the range of 0–1.5 V.

3.1 Voltage and Current Sensor

A desired level of string voltage is obtained from voltage divider circuitry, comprised with linear resistive elements and is as shown in Fig. 4. Commonly available linear potentiometer also can serve the purpose. A Hall effect sensor, 9350 CSLA2CD, is an inductive analog current sensor (shown in Fig. 5), works on AC or DC current up to 72 A and operating temperature is from −25 to 85 °C, which varies its output voltage in response to a magnetic field. Desired level of voltage is obtained by adjusting input number of terms.

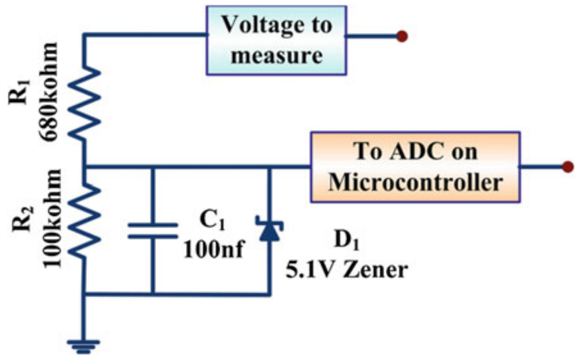

Fig. 4 Voltage sensing unit

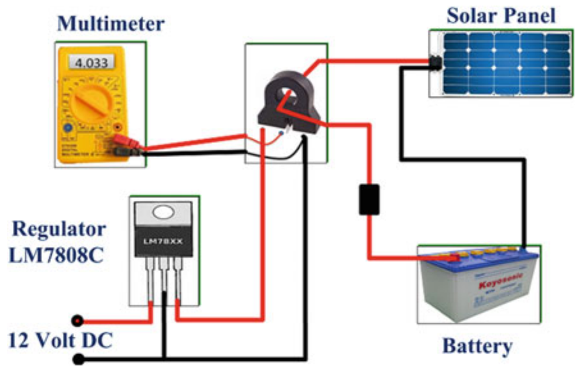

Fig. 5 Current sensing unit

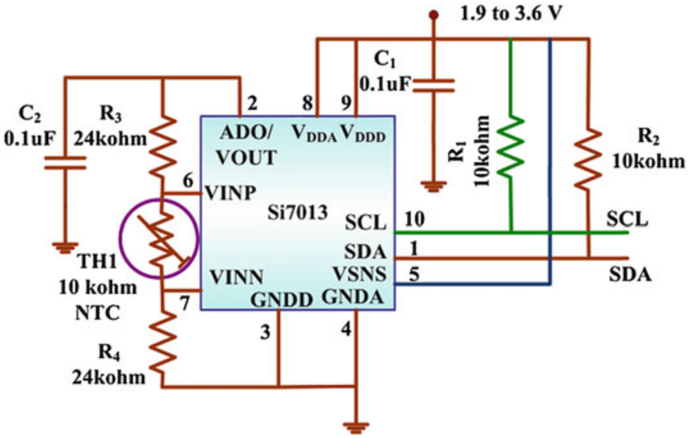

Fig. 6 Humidity and temperature sensor

3.2 Humidity and Temperature Sensor

For an Internet of Things (IoT) application, the humidity measurement using large footprint is no longer suitable. A Single-Chip Relative Humidity and Temperature Sensors, SI7013, with fully calibrated sensing elements, on chip analog to digital converter with signal conditioning circuitry is used in proposed system. It also provides an Inter-Integrated circuit (I^2C) interface with processing unit for operating range from 0 to 80% relative humidity (RH) of humidity sensor and from −10 to 85 °C temperature range for temperature sensor. A thermistor is used to measure the temperature at remote location with the help of the auxiliary analog pins as shown in Fig. 6.

4 Performance Evaluation

Remote monitoring of PV panel is achieved through machine-to-machine 'Internet of Things' connectivity protocol MQTT, which is used to transport message at remote location. Launch Pad has two analog inputs, which are used to capture solar system performance parameters directly connected to sensor. On chip 10 bit ADC convert these inputs in digital form for further processing. During normal operating conditions, system sends the message to smart phone as well as publishes on cloud as shown in Fig. 7. Input received from temperature and humidity sensor is directly logged to memory, as it is I^2C compatible and further it is sent on Internet.

Fig. 7 Performance result (received by smart phone and cloud)

5 Conclusions

In this work, a wireless remote monitoring system for solar photovoltaic (PV) plant is proposed. Proposed wireless remote monitoring system is offering an automated cost-effective solution for measurement of solar PV parameters on real time. It is flexible system and can easily be expanded with more number of stings at ultra-low-power consumption. On chip facilities, such as ADC of high resolution and Wi-Fi connectivity reduces system size to a great extent.

References

1. Othman, N.A., Damanhuri, N.S., Ibrahim, I.R., Radzali, R., Mohd, M.N.: Automated monitoring system for small scale dual-tariff solar PV plant in UiTM Pulau Pinang. In: Proceedings of the World Congress on Engineering, Vol. II, London, UK (2010)
2. Zahran, M., Atia, Y., Abdullah A., El-Sayed I.: Wired and wireless remote control of PV system. WSEAS Trans. Syst. Control **5**(8), 656–666 (2010)
3. López, M.E.A., Mantiñan, F.J.G., Molina, M.G.: Implementation of wireless remote monitoring and control of solar photovoltaic (PV) system. Transmission and Distribution: Latin America Conference and Exposition, pp. 1–6 (2012)
4. Tejwani, R., Kumar, G., Solanki, C.: Remote monitoring for solar photovoltaic systems in rural application using GSM voice channel. ISES Sol. World Congr. 1526–1535 (2013)

5. Al-Dahoud, A., Fezari, M., Belhouchet, F.Z.: Remote monitoring system using WSN for solar power panels. First International Conference on Systems Informatics, Modelling and Simulation, pp. 120–125 (2014)
6. Nagalakshmi, R., Babu, B.K., Prashanth, D.: Design and development of a remote monitoring and maintenance of solar plant supervisory system. Int. J. Eng. and Comput. Sci. **3**(12), 9382–9385 (2014)
7. Narayan L.P., Anshika: Data acquisition of solar power plant using scada system. Int. J. Eng. Trends and Technol., **23**(4), 189–194 (2015)