Wireless Sensor System for Photovoltaic Panel Efficiency Monitoring Using Wi-Fi Network

by Suryono Suryono

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Abstract **- Photovoltaic (PV) panel is an instrument that serves as a source of electric energy with many advantages. There is a need for a monitoring system for external disturbances on PV panels as to ensure its optimum function. This research developed a wireless sensor system to monitor the condition of PV panels. This system consists of a light illumination sensor as the input, a current sensor, and a voltage divider to measure electric power as the output parameter mounted on the Remote Terminal Unit (RTU) in the field. Data from these sensors are acquired by a micro controller via an ADC and an Inter-Integrated Circuit (I2C) protocol specified for the sensors used. These data are then sent to the network via an Ethernet board using the TCP/IP protocol. Then, a radio is used to communicate these data to a Control Terminal Unit (CTU) computer. These data are saved in a database for further computations on PV panel efficiency. Results of output graphic analyses will indicate whether the PV panels are normal and or not normal. Hence, the system serves to diagnose disturbances on the PV panel by comparing the input variable (light illumination) against the resulting PV panel efficiency.**

Keywords — photovoltaic; monitoring; wireless sensor; electric power; diagnosis

I. Introduction

Energy crisis is an actual problem all countries in the world try to anticipate. Less and less fossil fuels available affect economic growth that in turn has an impact on energy crisis. The search for alternative energies that will replace fossil fuels is on its hike in order to anticipate that crisis. Solar energy is both new and renewable and is available in its abundance, especially in the tropical regions. This source of energy serves as an important alternative for the development of new and renewable energy. Solar energy can be turned into electrical energy using silicon semiconductors embedded in photovoltaic (PV) panels.

Solar power plant has its own efficiency in its electric power transmission system. Solar power plant can be built in the vicinity of settlements that it will reduce transmission cost. On the other, building a power plant for solar energy requires a massive investment. Therefore, efficiency improvement for solar powers plant is a must. Solar energy is categorized as environmentally friendly as it does not come with environmental pollution in its conversion. Conversion of solar energy to electrical energy does not release any carbon compound that is both harmful to health and causes greenhouse effect [1].

One of the ways to improve the efficiency of solar power plant using PV panels is by monitoring the conditions of PV panels in the field, so that any disturbance can be handled in a timely manner. Simply put, diagnose for disturbance is carried out by measuring the PV input performance against electric power output [2]. Sunlight intensity is another variable that significantly contributes to the power efficiency PV panels produce. The other variables include dust [3], snow [4], and other external effects that prevent PV panels from producing optimum power.

Solar panel monitoring is done by integrating a special sensor chip into the panel. The chip in this case uses the CMOS 0.35 um technology. This technology enables it to measure values of light intensity and temperature when it is connected to a microcontroller [5]. This paper proposed the use of measuring solar panel efficiency using embedded sensors of light intensity, current, and voltage that can be easily found in the market. This allows quick maintenance measures whenever damage occurs.

Communication protocol is handled with a microcontroller connected to a Wi-Fi network that allows long distance communication. This takes care of spatial issues concerning wide coverage areas and also the requirement for continuous data history. Wireless Sensor System (WSS) solar panel monitoring can acquire data in real-time up to hundreds of years without being affected by rain, heat, wind, location, and the likes. WWS is proposed here as it allows monitoring efficiency with only sensors being put in the field to send data and control parameters automatically to the monitoring station [6]. The use of Wi-Fi radio based on TCP/IP protocol using ad hoc communication for the WSN communication system results in high efficiency and low cost.

II. System Realization

Solar PV panel works by converting solar radiation energy into direct current (DC) electric energy. Sunlight intensity is turned into electric current by semiconductor materials of monocrystalline silicon, polycrystalline silicon, amorphous silicon, telluride cadmium, and indium gallium copper via photoelectric effect. PV panel performance depends on efficiency value η by comparing output electric power (P_{max}) with sun radiation input energy (E) on the panel area (A) and is formulated as:

$$\eta = \frac{P_{max}}{E.A} \tag{1}$$

PV panel efficiency monitoring system consists of two parts; the Remote Terminal Unit (RTU) mounted on the PV panel, and the Control Terminal Unit (CTU), which is a computer in the monitoring room. The RTU consists of sensors of light intensity and power, and a microcontroller, an Ethernet board, and a Wi-Fi radio to send data to the CTU. This research takes P in Watt as power, which is gained by measuring panel current (I) in amperes, and PV panel voltage in Volt (V). The unit for sun radiation is Watt/m^2. In the visible light spectrum, the unit Watt/m^2, can be converted in Lux; 1 Watt/cm^2 = 6.83 x 10^6 lux [7].

This research develops a system to measure PV panel efficiency using an electronic circuit made up of sensors of light intensity, current, and voltage embedded on PV panels. Measurement of PV panel performance parameters is carried out automatically using a microcontroller and the data acquired are sent to the monitoring station using a Wi-Fi network. A block diagram of this measurement system is shown in Figure 1.

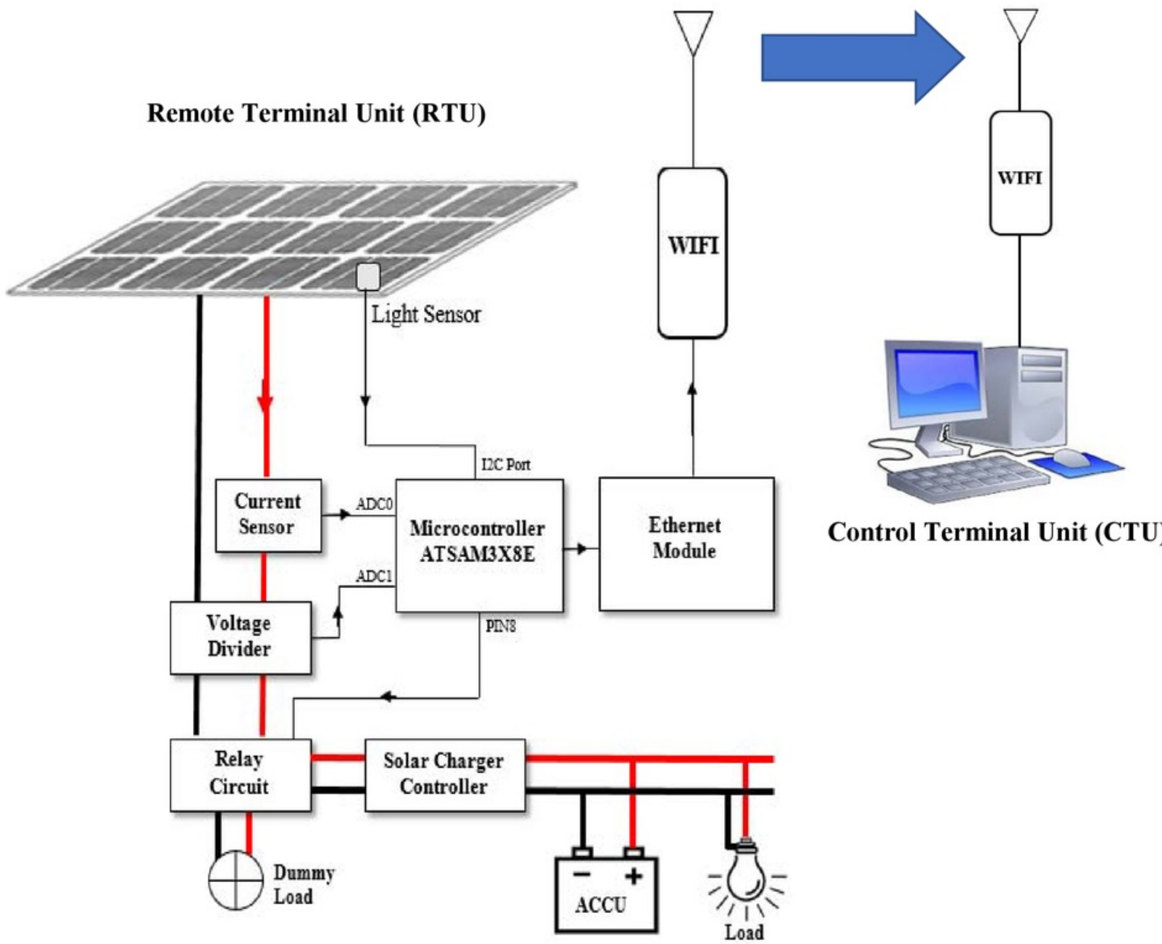

Figure 1. Wireless sensor system for PV panel monitoring

The PV panel used in this research has a maximum power output of 100 Watt. A light sensor of BH1750 type is mounted on top of the panel to measure light intensity falling on the PV surface. Data gained by this sensor is read by a 32-bit microcontroller of ATSAM3X8E type with the help of I2C (Inter-integrated Circuit) protocol. Meanwhile, the output electric power sensor consists of an ACS712 current sensor, and a circuit of voltage dividing resistors of 1KΩ : 10KΩ ratio. Both of these are connected to a 12-bit ADC0 and ADC1 port respectively, on the ATSAM3X8E microcontroller.

This diagnosis system requires a constant dummy load of a 100 Watt light bulb to measure the peak power of the PV panel. Measurements are managed by an Oleg relay that transfers wiring from the regular load to the dummy load. PV panel power is a measure of multiplication of current and voltage division readings. The microcontroller read power reading of the PV panel by ordering the Oleg relay to transfer regular load to dummy load in order to ensure consistent measurement of load from the same circuit.

The microcontroller in the RTU acquires data of light intensity and electric power. These data are then sent to the RTU computer using a Wi-Fi radio. Data are sent using the TCP/IP protocol connected with the Wi-Fi radio by an Ethernet board. These data are accessed using a client server socket programming and are kept in a database. IP address configuration for the microcontroller and the Wi-Fi is made to be in one class of that for the RTU as to allow data transfer.

III. Result And Discussion

Wireless sensor system for online and real-time monitoring of PV panel efficiency makes use of Wi-Fi network and uses sensors of light illumination as the input parameter and electric power measured from its current and voltage variables as the output parameter. The first system testing to do is sensor validation. Sensor validation is carried out by comparing measured field data at the RTU against computer readings at the RTU. Validation for the light illumination sensor in Lux is done using a standard Lux meter at the RTU and is the compared with the computer readings at the RTU. Validation results are shown in Figure 2.

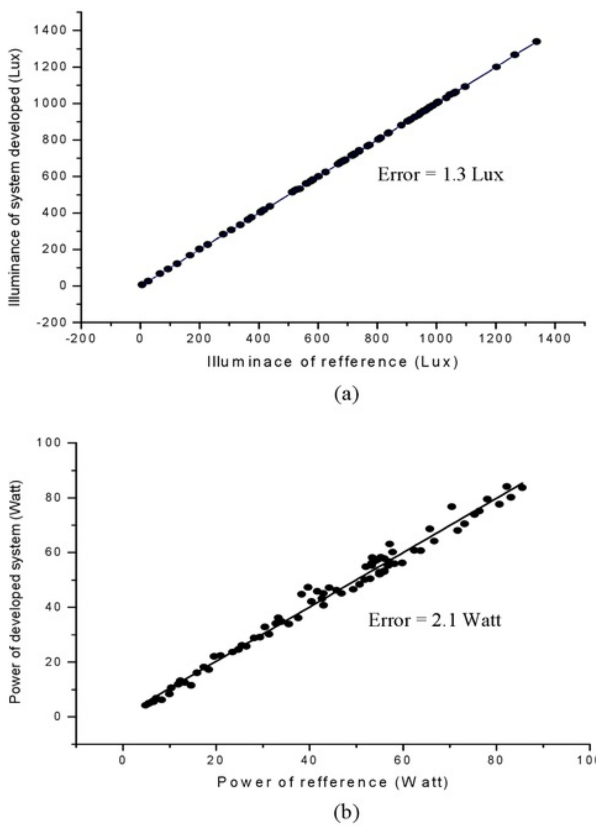

Figure 2. Validation results for illumination sensor (a), and power sensor (b) on the PV panel

This graph shows that the illumination measurement system has an error of 1.3 Lux. The same comparison technique also applies to the validation of electric power sensor (current and voltage sensors). The results for this are given in Figure 2.b.

Data gained from readings for light illumination and electric power output of the PV panel is kept in the database of the computer at the CTU. These data are then computed to calculate the values of input (illumination and PV area) in watt/cm^2 against the electric power output. These calculations are carried out by the computer using Equation (1). Results are then shown in graphs, as shown in Figure 3.

Figure 3 shows graphs of illumination and efficiency of the PV panel. Label-A is when the PV runs normally without any disturbances. This is known from fluctuating intensities in line with changes in efficiency. Meanwhile, Label-B is an example of diagnosis when the PV panel does not run normally. Disturbances in this case are the presence of leaves that block lights coming into the panel. This is known from the abnormality in the panel, as when illumination rises, efficiency falls. This indicates that the panel is disturbed and that there needs to be a fixing and or maintenance to do.

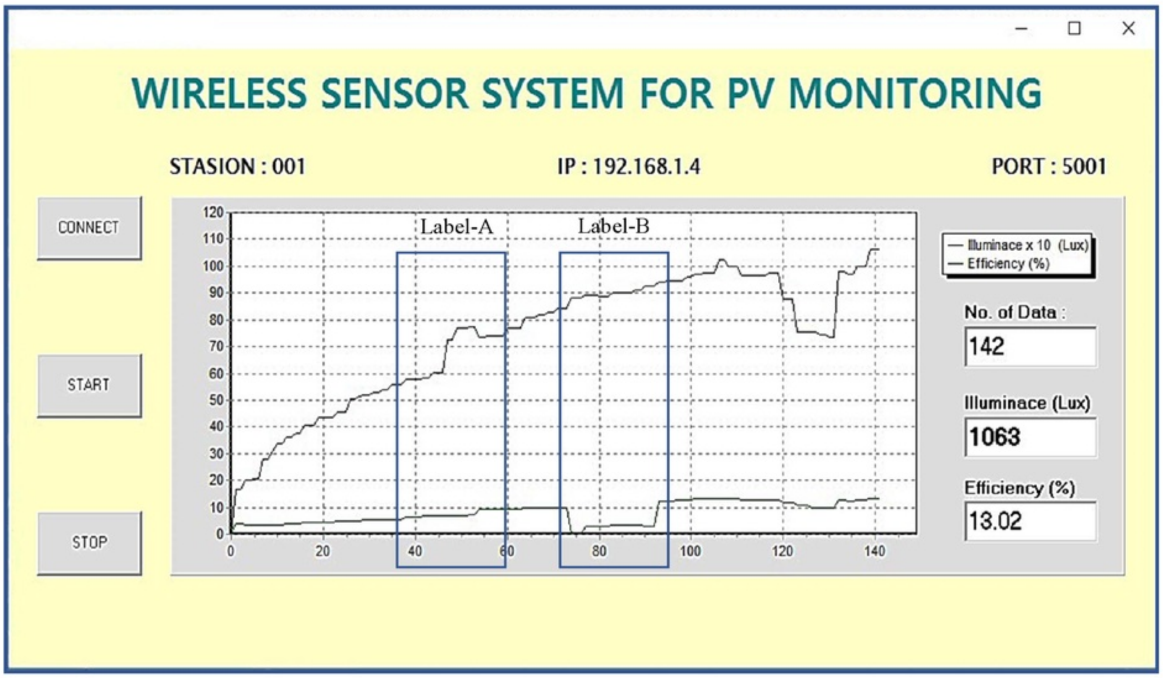

Figure 3. Display of computer program from WSN for monitoring PV panel

IV. Conclusion

Values of light illumination and electric power output of a PV panel can be acquired using a wireless sensor system embedded in the RTU placed in the field and read both online and in real-time at the CTU. The RTU system built here makes use of a microcontroller that acquires data from sensors via an ADC and an Inter-Integrated Circuit (I2C) protocol. Results of these measurements are sent to the database computer with the help of the TCP/IP protocol using an Ethernet board and via a Wi-Fi radio. These data are then computed to compare values of light illumination input and electric power output. Results of graphical analyses show that the system is capable of explaining whether the PV panel is in normal or abnormal state. A normal PV panel is indicated by comparative changes of illumination and panel efficiency represented in the graph, whereas an abnormal PV panel is known from inconsistent changes of efficiency against the corresponding light illumination. Therefore, it is proven that the system developed here is capable of diagnosing disturbances on the PV panel that serves to gather solar power.

References

[1] T. N. Ngoc, Q. N. Phung, L. N. Tung, E.R. Sanseverino, P. Romano, and F. Viola, "Increasing efficiency of

photovoltaic systems under non-homogeneous solar irradiation using improved Dynamic Programming methods', Solar Energy, Vol. 150, pp. 325–334.

[2] T. Sueyoshi, and D. Wang, "Measuring scale e ciency and returns to scale on large commercial rooftop photovoltaic systems in California", Energy Economics, Vol. 65, pp. 389–398, 2017.

[3] M. Mani, and R. Pillai, "Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations", Renew. Sustain. Energy Rev., Vol. 14, pp. 3124–3131, 2010.

[4] R.W. Andrews, A. Pollard, and J.M. Pearce, "The effects of snowfall on solar photovoltaic Performance", Solar Energy, Vol. 92, pp. 84–97, 2013.

[5] F.G. D. Corte, G. Cocorullo, P. Corsonello, C. Felini, M. Merenda, S. Perri, G. Borelli, M. Carpanelli, dan D. Verdilio, "A microchip integrated sensor for the monitoring of high concentration photo-voltaic solar modules", Procedia Engineering: 30th Eurosensors Conference 2016, Vol. 168, pp. 1601 – 1604, 2016.

[6] C. Jun, Y.U. Sun-Zheng, and L. Jing-li, "The design of a wireless data acquisition and transmission system", Journal of Networks, Vol. 4. No. 10, pp. 1042-1049, 2009.

[7] A. Ryer, "Light measurement handbook", International Light 17 Graf Road Newburyport MA 01950, 2008.

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