TELKOMNIKA Telecommunication Computing Electronics and Control
Vol. 20, No. 4, August 2022, pp. 914~921
ISSN: 1693-6930, DOI: 10.12928/TELKOMNIKA.v20i4.23302

Design visual studio based GUI applications on-grid connected rooftop photovoltaic measurement

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Article Info

Article history:

Received Jun 15, 2021
Revised May 19, 2022
Accepted Jun 01, 2022

Keywords:

Data logger
Microcontroller Arduino Uno
Photovoltaic
Visual studio

ABSTRACT

This article describes the design of a data system to integrate energy conversion from photovoltaic measurements connected to the power grid. The software used is visual studio, while the hardware uses polycrystalline photovoltaic (PV) with a capacity of 2.08 kW and several sensors that have been integrated into Arduino. Parameter data in measuring the performance of this PV system consists of temperature and humidity sensors to measure the panel surface, direct current (DC) current sensor, DC voltage sensor. To measure the current and voltage sourced from the electricity network, the module (PZEM-004T) is used. Measurements are designed using a graphical user interface (GUI) on a Visual Studio application that has been interfaced through Arduino programming. The data output on the sensor measurement will simultaneously record the circuit that has been connected to the solar panel and then display it visually in the form of tables and graphs in real time with a delay of 1 minute. The results of PV on grid measurements in sunny weather conditions obtained the maximum value of all measurements with a DC voltage of 221 V, while for an alternating current (AC) voltage of 231.60 V, the DC value reached 1827.17 W while the AC power was 1681 W.

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1. INTRODUCTION

The trend of using renewable energy continues to experience a significant increase, one of which is the use of solar energy sources. Many benefits can be obtained from the use of solar energy when converted into electrical energy, among others, it can be an alternative energy solution in compensating the cost of electricity bills from grid, then as an alternative energy solution backup the occurrence of rotating blackouts and can also be a solution to the national economic [1], [2]. In addition, this renewable energy is the best energy source and is friendly to the surrounding environment [3], [4]. The strategic geographical position makes the territory of Indonesia very potential in exploiting development, and the development of energy from solar sources is supported by a very high tropical climate [5]. The main equipment for converting energy from the sun to electrical energy is photovoltaic (PV) or better known as solar panels [6], [7]. PV technology has advantages in environmental factors such as being free of carbon dioxide (CO_2) emissions and as sustainable energy for future generations [8]-[10]. Work system photovoltaic itself uses materials made of semiconductors or solar cells to produce electrical energy [11]. In the PV installation technique, it can be done by utilizing the PV system off-grid and system on grid. On-system off-grid solar panels are installed without being connected to the grid network while the solar system on-grid solar panels are installed by being connected to a power source from grid [12], [13]. The West Sumatra region has the potential for large-scale solar panel development as well as for household scale. This is influenced by the high potential for solar radiation with an average capacity of 4.8 kWh/m2 per day [14]. However, the frequent occurrence of rotating power outages have a significant impact on activities that occur in the local community such as the Bonjol area where this area does not yet have a main substation and is only supplied by the Bukit Tinggi and West Pasaman substations, even though the weather conditions in the Bonjol area are almost at sunlight reaches 12 hours with hot weather conditions [15]. For this reason, favorable conditions in the utilization of new and renewable energy must be optimized as quickly as possible and also the layout of PV installation in solar energy absorption must be reviewed in depth before installing PV. The technique that concentrates on the direction of movement of the sun is the most optimal efficiency in the absorption of energy conversion from PV installations [16]. In designing and building systems data logger on PV on-grid reliable, it takes some hardware and also software so that the data obtained has a good reading accuracy [17], [18]. Data logger built aims to store data from the parameters to be measured so that the PV performance can be analyzed [19], [20]. Software operation data logger using the visual studio-based programming language. Advantage software visual studio facilitated graphical user interface (GUI) display which later output PV on-grid generated in tabular and graphical data views with real time [21], [22]. The results of the data that have been recorded on software visual studio controlled by Arduino Uno microcontroller and then transmitted into a my structured query language (MySQL) database with a web display with a delay of 1 minute. The information displayed on the web includes, among others, value (temperature and humidity), value (alternating current (AC) and direct current (DC) voltage), value (AC and DC), power rating (AC and DC). During the process of capturing system performance, metadata loggers continue to be monitored so that it doesn't happen data loss and sensor readings remain stable [23], [24]. Design and monitoring data recorded in the database will help the community to install PV installations on a small scale or on a larger scale.

2. DEVELOPED SYSTEM MODEL

The research was carried out with system design techniques data logger in the form of hardware development and software applications. Device hardware used is PV on the grid with a capacity of 2.08 kW is connected directly to the grid network using a grid-tie inverter. To control the integration between PV on grid with several sensors connected, the Arduino Uno microcontroller is used as the control. The block diagram of the PV system connected to the grid is shown in Figure 1.

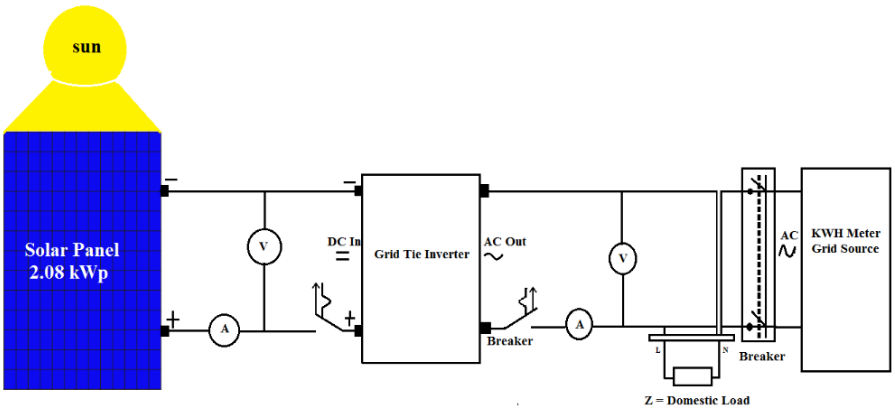

Figure 1. Block PV integration system with grid

The components of the tools used in monitoring the conversion of solar energy to electrical energy include PV with a capacity of 2.08 kW with type polycrystalline, grid electricity network, grid-tie inverter, Arduino Uno microcontroller, Arduino current sensor (ACS712) current sensor to measure DC value, and ZMPT101B sensor to measure DC voltage value, PZEM-004 module to measure AC voltage and AC current value and digital humidity and temperature (DHT11) sensor to measure temperature and humidity. For module (PZEM-004) reading, it is not necessary to support communication in reading current, voltage, and power values. Unlike the voltage sensor (ZMPT101B), the sensor (ACS712) must be calibrated by comparing the analog bit readings and reading the root mean square (RMS) using a manual multimeter.

2.1. Humidity and temperature measurement

The weather which is very decisive in the performance of on-grid PV can be measured using a DHT11 sensor. For the parameters issued by this sensor are a combination of temperature and humidity values. The advantage of this sensor is that there is also a library on the Arduino Uno itself without having to do the initial calibration with a good accuracy data reading, responsive and not easily interfered with.

2.2. Sensor measurement and calibration for on-grid solar panel systems

Photovoltaic is a solar cell made of silicon semiconductor material with its working principle when photon energy generated from sunlight in large quantities penetrates the surface of the solar cell which is located at the confluence of two N-type and P-type semiconductor materials, an electric current will flow [24]. Development data logger as a data monitoring system from output PV on-grid functions as data storage SD card and Arduino as the controller. The results of data storage consist of several variables such as temperature/humidity sensor output, DC/AC voltage, DC/AC, DC/AC power, and all of them will be recorded directly and real time on PC and also the Web on a MySQL database. Design and build a PV system that is connected to the grid electricity network using a tool in the form of a (PZEM-004) module in monitoring the electricity source from grid. This sensor will monitor such as AC current, AC voltage, and AC power. The PZEM-004 module has been completely arranged with the advantage that the module has been equipped with an integrated voltage sensor and current sensor (CT). The use of this tool, specifically for indoor and the installed load is not allowed to exceed the specified power. Display the physical form and wiring diagram of the PZEM-module-004T can be seen in Figure 2.

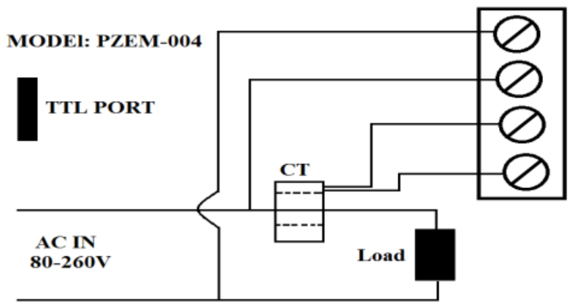

Figure 2. PZEM-004T wiring diagram

The ZMPT101B module is a sensor that is used to measure the DC voltage value and this study uses the ZMPT10B sensor to obtain the voltage value. For the value of the DC voltage to be obtained with an accuracy corresponding to the capacity output PV then the capacity of the resistor value is modified and added to 370 k. It is intended that the voltage rating capacity on the ZMPT101B sensor will be maximized with a total voltage of 250 V. The equivalent circuit is formulated in (1).

$$Vout = \frac{R1}{(R1+R2)} Vin \quad (1)$$

The standard voltage at Vout as the limit of the input voltage on the Arduino is 5 V, so it can read voltage on PV on the grid with a capacity of up to 250 volts direct current (VDC). The ZMPT101B sensor is only able to read 0 to 1023 in binary form. To do a reading output on PV on-grid then the (2) can be done as follows.

$$Volt=(DC\ Volt \times 0.244) \quad (2)$$

The current sensor is used in determining the output PV on the grid for DC using a type. sensor ACS712. The ACS712 current sensor functions in reading the DC current rating capacity with a working system photovoltaic which has been given a load. The working principle of this sensor is that the sensor is only able to measure the maximum current rating capacity of -30 A to 30 A (positive and negative current) with a power supply capacity of 5 V. In addition, the ACS17 sensor has a voltage value (zero amperage) and when there is no load at all, the sensor value is read at 507 The reading of the current value measurement on the analog is seen in (3).

$$I = \frac{(507 - DC\ current\ sensor)}{(12.9)} \quad (3)$$

The combination between photovoltaic with the Arduino Uno microcontroller has been connected to all sensor components then an initial calibration is carried out before data collection is carried out so that the measurement results monitored are obtained accurately. The sensors that are calibrated are voltage and current sensors which will be compared with a multimeter measuring instrument to obtain a margin of error smaller. The load used in the calibration is sourced from the Universitas Andalas (UNAND) electrical engineering building where the capacity value is unknown. Module PZEM-004 sensor and the DHT11 sensor, it is not done calibration because this module has been equipped library integrated with Arduino. The results of sensor measurement calibration can be seen in Table 1 and Table 2.

Table 1. Voltage sensor calibration results (DC and AC) on-grid photovoltaic on the load of the UNAND electrical engineering building

No	Measurament results		Margin of error (%)	No	Measurament results		Margin of error (%)
	Voltmeter	Sensor ZMPT101B (DC Volt)			Voltmeter	Sensor PZEM (AC Volt)	
1	224.7 V	226 V	0.58	1	228.3 V	229.6 V	0.57
2	232.8 V	235 V	0.93	2	229.5 V	230.9 V	0.52
3	226.7 V	228 V	0.57	3	229.1 V	230.4 V	0.57
4	228.5 V	230 V	0.65	4	228.2 V	229.6 V	0.61
5	225.3 V	227 V	0.75	5	229.0 V	230.3 V	0.56

Table 2. Current sensor calibration results (AC and DC) on photovoltaic on grid with the load of the UNAND electrical engineering building

No	Measurament results		Margin of error (%)	No	Measurament results		Margin of error (%)
	Measuring instrument ampermeter (A)	Sensor ACS712 (DC current)			Measuring instrument ampermeter (A)	Sensor PZEM (AC current)	
1	3.35 A	3.41 A	1.75	1	3.61 A	3.67 A	1.36
2	2.24 A	3.35 A	3.28	2	3.81 A	3.91 A	2.55
3	3.27 A	3.34 A	2.09	3	3.44 A	3.51 A	1.99
4	3.56 A	3.68 A	3.26	4	4.21 A	4.29 A	1.86
5	3.18 A	3.26 A	2.45	5	4.12 A	4.18 A	1.43

The results of the calibration using a ZMPT101B DC voltage sensor and ACS712 DC current sensor with a manual comparison reference using a voltmeter and ammeter. The load capacity in calibration uses the UNAND Electrical Engineering building with an unknown load capacity. The DC voltage value sensor calibration value margin of error of 0.69% and the value of the AC voltage of 0.57% then the DC sensor calibration has a margin of error of 2.56% and AC sensor by 1.86%. The high heat when the current sensor operates makes the performance of the current sensor greater. However, the tolerance value of the measurement standard International Electrotechnical Commission around ± 3.2% (still in the normal limit category) and the most ideal operating ACS712 sensor value is 25 ˚C [25].

2.3. Arduino connected sonsor test design schematic

Whole sensor circuit testing connected to Arduino Uno microcontroller there are differences in the system. For PZEM-004 devices can be connected directly so that in the reading it is not nee support communication that others forget the value of current, voltage, and power. Unlike the voltage sensor (ZMPT101B), the current sensor (ACS712) where the sensor is not provided manufacturer so that it must be calibrated by comparing the results of analog readings of the sensor output bits with RMS readings using a manual multimeter, while the DHT11 sensor (temperature and humidity) has library itself so that the measurement results have a smaller error. Circuit schematic PV on-grid which is connected to the Arduino Uno microcontroller, then it is connected automatically parallel to all sensors with a given supply voltage of 5 V (VCC). In the circuit DC voltage sensor is connected to analog pin A1, DC sensor is connected to analog pin A3, real time clock (RTC) is connected to Arduino using 2 analog read pins at once serial clock (SCL) is connected to analog pin A5, and serial data (SDA) is connected to analog pin A4, for DHT11 sensor the output is connected to analog pin A0 and for on the PZEM-004 module reading output recived (RX) is connected to pin 6 and transmitter (TX) is connected to pin 5 on the Arduino digital read.

2.4. Visual studio design connected to Arduino

Visual Studio software the results of the performance of the data stored on the Arduino Uno microcontroller are then displayed in an interface on the visual studio software to display all incoming data in the form of tables and graphs on a windows form before being sent to the web display. The desktop visual display designed using visual studio consists of a toolbox, control tabs, labels, buttons, curves, and picture boxes. The output of the data on the sensor that has been integrated into the solar panel then the data will be displayed simultaneously in the form of a GUI. Then to find out the condition of the voltage, current and power by pressing Tab the graph display in such a way. More details can be seen in Figure 3.

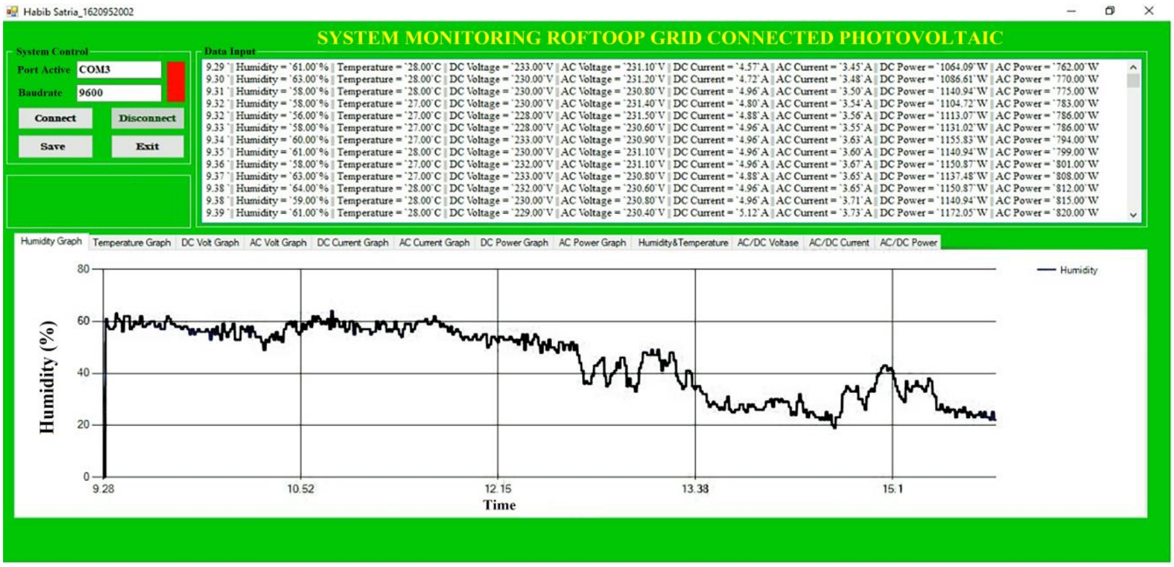

Figure 3. GUI Design using Visual Studio software

3. RESULTS AND ANALYSIS

The visual studio that has been programmed and has passed the test, then run using an active port on COM3 and baud rate 9600 according to the provisions of the Arduino Uno microcontroller. The data recorded on the Arduino is the interface to the visual studio before being transmitted to the MySQL database. Results output of system development data logger obtained data in the form of graphs and tables, among others, where Figure 4 shows output graphs and data on the surface temperature of the panel along with the humidity around the solar panel environment, Figure 5 displays graphs and data output AC voltage at once output DC voltage value, Figure 6 displays graphs and data output AC current as well as the value for DC current, and Figure 7 or the last inform data is a display output AC power data and graphs as well as DC power values.

Results of data analysis from photovoltaic with a capacity of 2.08 kW by connecting to the sensor (DHT11), the module (PZEM-004), sensor (ACS17), and sensor (ZMPT101B) that have been recorded on software visual studio gets the maximum value when the weather is sunny at a temperature of panel surface by 45 ˚C then at the same time the air humidity around the panel decreased significantly to 19%. At the AC voltage, the voltage rating in the sensor measuring instrument readings is very stable, which is between 220 V to 235 V, in sync with the DC voltage reading where the sensor measuring instrument reading reaches 237 Volts. In the analysis of performance in current measurement, the maximum value of AC peak current reaches 8.13 A and the reading for DC peak current reaches 8.66 A. Furthermore, the reading of the AC and DC power graph is observed to be relatively synchronous, where the results of the peak power measurement PV on-grid (Wp) reaches 1827.17 Watts for DC power and for peak AC power reaches 1829.0 Watt of power. Measurements were carried out with time intervals from 09:28 to 15:10. Furthermore, to see the data capacity of polycrystalline accumulation with a capacity of 2.08 kW, it is shown in Table 3.

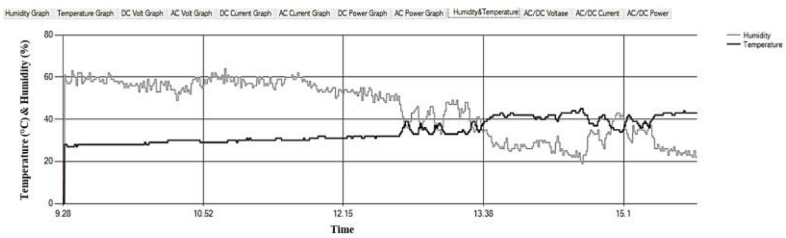

Figure 4. Panel surface humidity and temperature chart

Table 3. Accumulation of maximum data results on PV merged into grid

Power	Max. volt	Max. current	Max. power
DC	221.00	8.66 A	1,827.17
AC	231.60	8.13 A	1,681.00

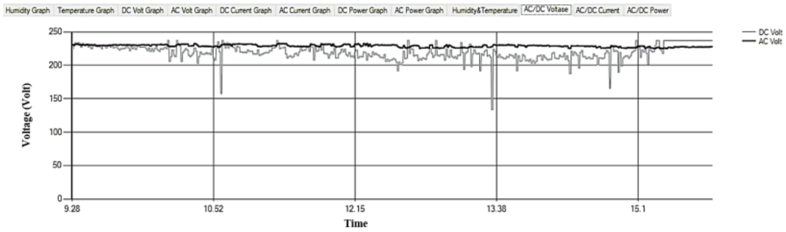

Figure 5. Graph of AC and DC PV voltage on grid

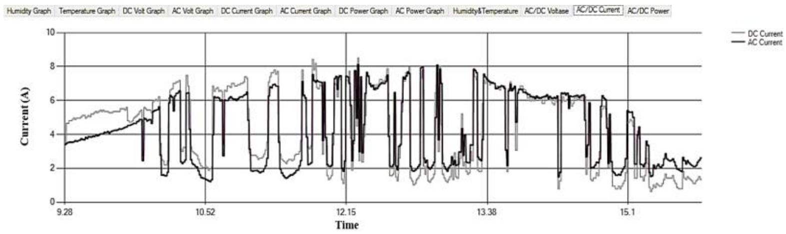

Figure 6. Current graph of AC and DC PV on grid

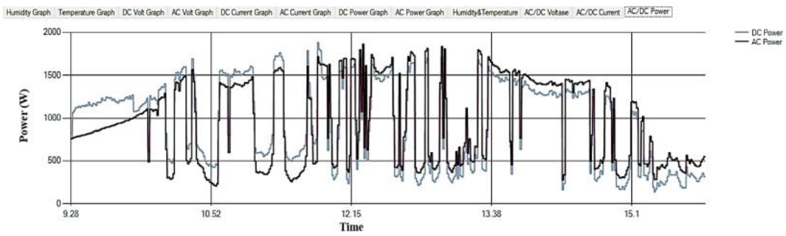

Figure 7. AC and DC PV power graph on grid

3.1. Measurement data results are transmitted on MySQL web

The on-grid PV measurement results that have been stored in visual studio software are then processed and sent to storage media in the MySQL database to be processed and displayed on the designed Web. Tool in executing commands from MySQL storage data operations using phpMyAdmin. In the MySQL database storage, there are results output on the energy conversion of PVon-grid by real-time with a delay of 1 minute. The data storage table on the Web that has been designed consists of a real-time display of the current state of the measurement, the value of the humidity measurement result, the temperature measurement value, the value of the DC voltage measurement, the value of the AC voltage measurement, the value of the DC measurement, the AC measurement value, the value of the DC power measurement and the value of the AC power measurement has been separated into several tables for easy further analysis. In addition, the other goal is to become back up when the computer crashes.

4. CONCLUSION

The design of this data logger produces a PV monitoring device that is connected directly the design of this data logger produces a PV monitoring device that is connected directly to the electricity network in real-time. The GUI design contained in the Visual Studio software can read the output of the on-grid PV simultaneously with the interface on the Arduino Uno microcontroller. The resulting data display is in the form of temperature, humidity, voltage, current, and energy values. Parameter data recorded by the data logger is then sent to the MySQL database with a delay of 1 minute on the web display. The DC voltage sensor calibration value has an error margin of 0.69% and the AC voltage value is 0.57%. The tolerance limits of the International Electrotechnical Commission standards range from ± 3.2% for the current rating and ± 2.5% for the voltage rating). When the weather conditions are sunny, the measurement of PV on grid measurement for DC voltage is 221 V while for the capacity value of AC voltage is 231.6 V, the measurement of DC value reaches a capacity of 8.66 A while for AC it is 8.13 A, and on DC power output measurement the maximum capacity value is 1827.17 W while the AC power output is 1681 W. The irregular graph on the weather fluctuation display on the WinForm Visual Studio is caused by the intensity of sunlight which is sometimes blocked by clouds and results in a drastic reduction in the photovoltaic energy generated.

ACKNOWLEDGEMENTS

Thank you to the DRPM Kemenristekdikti for funding given the research scheme. Acknowledgments to DRPM Kemenristekdikti for the publication funding assistance provided.

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