Battery Protection System Against Undervoltage and Overvoltage in Off-Grid Systems Photovoltaic

Dwi Nur Fitriyanah[1], Nicken Ayu Febrianti Soeyoto[1], Imam Abadi[1]

***Abstract*— Electrical energy at this time is widely used by most humans. The disturbances too in the distribution of electricity cause inhibition of daily human activities. The disturbance that occurs can be classified into various kinds, one example is Undervoltage and overvoltage. Of course, these disturbances can arise when the use of electrical loads that are sensitive to damage. To secure electrical loads that are sensitive to damage, a control system is made overvoltage and Undervoltage using a microcontroller Arduino Mega, and the actuator is a relay. This research tries to solve the problem of over voltage, under voltage, and unbalanced voltage with a visual basic-based voltage protection system. This system research uses visual basic as an interface and as a data logger to facilitate operators in analyzing disturbances and with the help of the Arduino Mega2560 microcontroller which can be used to process and send data to the visual base. Thus, this research is expected to help users to e easily monitor and analyze disturbances.**

***Keywords*—Protection system, Undervoltage, Overvoltage, Arduino mega**

I. Introduction

The off-grid photovoltaic system is a power generation system that only relies on solar energy as the only main energy source [1]. Off-grid systems use batteries as storage media. Fluctuating photovoltaic output entering the battery can cause damage and shorten battery life[2]. To improve the quality of the battery, it is necessary to reduce the various problems that cause the battery to be less than optimal[2–4]. Some of the causes of these problems are Undervoltage and overvoltage. Undervoltage and overvoltage are the rise and fall of the voltage amplitude over a long period (more than 1 minute). The cause of Undervoltage is due to excessive loading on the system (overload) [5–8]. Meanwhile, the because of overvoltage is due to underloading. An interruption in the electricity supply can, of course, affect and even damage a system. Various disturbances occur, for example, surges or voltage drops (overvoltage and Undervoltage) [9–11]. If the interference is connected to electrical or electronic equipment and exceeds its nominal voltage tolerance limit, then it can interfere with the performance of the equipment and may damage it [12–14].

Previous research describes the protection of electrical equipment from overvoltage and Undervoltage disturbances on power lines. It causes damage, using a potential transformer which will process by the Arduino Uno microcontroller as an automatic relay controller in the event of a disturbance [14].

Furthermore, other research reported the design the system to detect voltage stability using a programmed sensor that can detect 1-phase voltage [15]. Then the input data and voltage detection, will be sent to the microcontroller for processing. The processed results will be sent again to several components to determine the program output and be used to control the relay as protection in the event of Undervoltage or overvoltage.

Moreover, other report explained current and voltage monitoring devices generated by solar panels remotely based on IoT and using the NodeMCU microcontroller as a data sender via the internet network to the Thingspeak server [13]. The results of this study are data retrieval every 15 seconds, which is directly uploaded to the database. This monitoring is very efficient because the results can be saved in the form of a Spreadsheet.

Based on several existing reviews, in this study, a device or battery protection system will be designed against Undervoltage and overvoltage. Because the consequences of Undervoltage and overvoltage can shorten the life tool, cause an explosion, heat the motor, can damage the rotor winding too. So that in this research, a battery protection system against Undervoltage and overvoltage make in an off-grid photovoltaic system. The battery output energy will be sensed by the INA219 current and voltage sensor to determine the current and voltage value. If the value does not match the setpoint, the Arduino Mega controller will send a signal to the relay to cut off the battery flow to and from the load. And the results of measuring the current and voltage values will be displayed on the GUI (Graphical User Interface). By doing this research, it is hoped that it can help prevent the occurrence of harmful impacts caused by Undervoltage or overvoltage loads or equipment to extend the life of the battery.

II. Method

A. Hardware Design

From the figure 1, there is an iron frame, photovoltaic, and panel box. The panel box contains an Inverter, Battery, Power Meter, LCD, RS485 to TTL, Relay, Arduino, Arduino Mega Pro, INA219, and Buck Converter.

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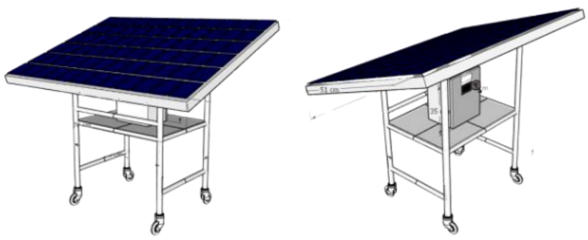

Figure 1. Design Hardware Battery Protection System

The block diagram of the battery protection system is shown in figure 2.

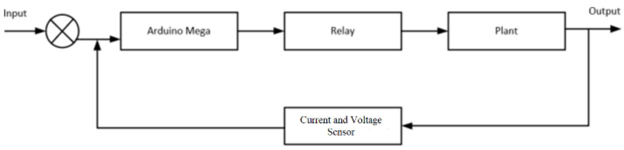

Figure 2. Battery Protection System Block Diagram

From the close loop block diagram above, the work process in this research is the Arduino Mega as a controller will send a control signal and the actuator that uses a relay, where the relay will open and close the current and voltage flow to send manipulation variables to the battery. Then the voltage and current sensors send feedback on the measurement results to be compared with the setpoint processed by the controller. Then the controller sends an output signal to control the relay so that the current and voltage values supplied from the battery match the setpoint. The wiring of the block diagram above is shown in figure 3.

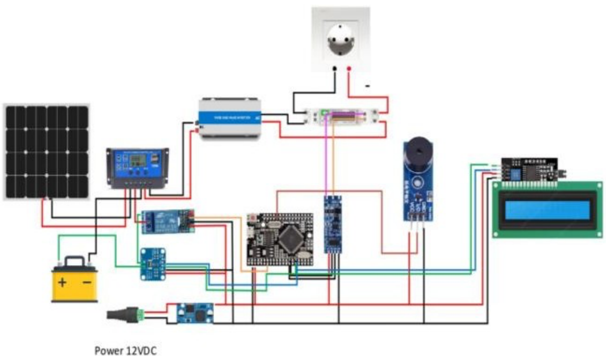

Figure 3. Wiring Battery Protection System

B. *Hardware Design*

The battery protection system begins with the initialization of the sensor, namely the AC load input. After that, the volt and amperage data are read from the circuit. In the AC circuit, if the volt value is less than 10 Volt it will return to the input process. AC load, if more than 10v then the relay will cut off the current.

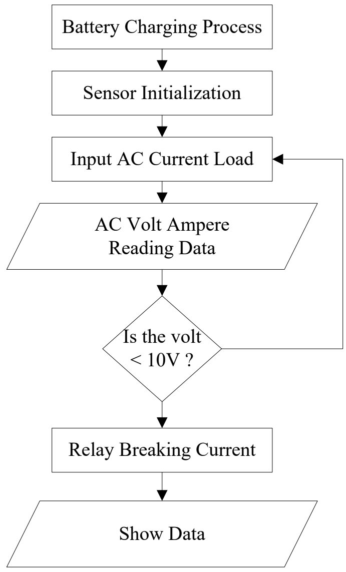

Figure 4. Flowchart of Battery Protection System

Then the data will be displayed on the GUI. There is also an image of the battery protection system GUI design in figure 5.

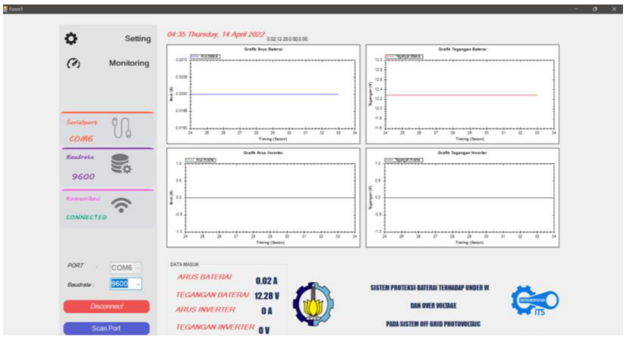

Figure 5. Battery Protection System GUI Design

There are several features used in this battery protection system. The first feature is to display the current and voltage of the battery and load. The second feature has an indicator where when the load will be disconnected from the battery due to undervoltage or overvoltage.

III. Results and Discussion

Several tests were carried out to obtain data that would later be processed and analyzed. Tests in this study include component testing, and battery charging testing using photovoltaic.

A. Power Meter iEM2050 Voltage Validation

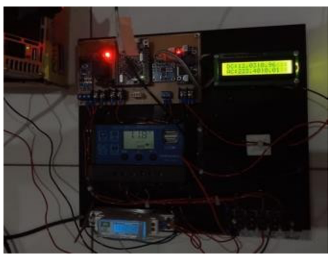

Figure 6. Validation of Power Meter Voltage

Testing of the iEM2050 power meter was carried out to validate the current and voltage values read by the power meter and standard clamp meter for a current and digital multimeter for voltage. The following are the steps for testing the iEM2050 power meter. The validation is carried out by comparing the readings in the table 1.

TABLE 1.

POWER METER VOLTAGE VALIDATION TEST RESULTS

No	Power Meter (V)	Sensor (V)	Error
1	221.2	221.6	0.4
2	221.5	221.8	0.3
3	222.0	221.8	0.2
4	221.3	221.9	0.6
5	221.6	221.4	0.2
6	221.5	221.4	0.1
7	221.5	222.1	0.6
8	221.5	222.1	0.6
9	221.5	221.5	0
10	221.2	221.5	0.3
11	222.9	223.2	0.3
12	223.1	223.1	0
13	223.2	223.1	0.1
14	223.0	222.7	0.3
15	223.0	223.0	0
16	223.3	223.0	0.3
17	223.1	223.0	0.1
18	223.5	223.0	0.5
19	223.1	223.0	0.1
20	223.6	223.6	0
amount	4446.6	4447.8	
average	222.33	222.39	0.25

From the data obtained, a comparison chart of the power meter readings with the sensor can be made in figure 7.

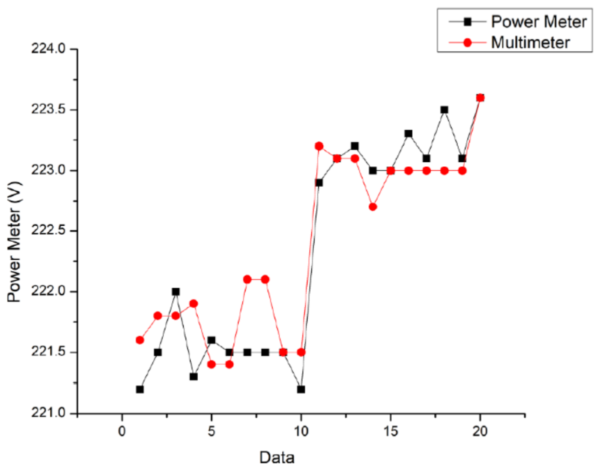

Figure 7. Graph of Power Meter Voltage

From the picture, it can be seen that the voltage reading on the tool is close to the standard. Based on the data obtained from testing the tool, the characteristics of the iEM2050 power meter measuring instrument can be obtained as follows:

- Range : 221.2 – 223.6 V
- Span : 2.4 V
- Accuracy :

$$\left[\left(\frac{|average\ error|}{Max\ value - Min\ value}\right) \times 100\%\right]$$

$$\left[\left(\frac{0.25}{2.4}\right) \times 100\%\right]$$

=0,1

B. Power Meter iEM2050 Current Validation

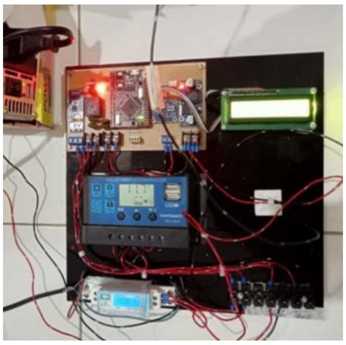

Figure 8. Validation of Power Meter Current

The iEM2050 Power meter test was carried out to validate the current and voltage values read by the power meter and standard clamp meter for a current and digital multimeter for voltage. The following are the steps for testing the iEM2050 power meter. The validation is carried out by comparing the readings in the following table:

TABLE 2.

POWER METER CURRENT VALIDATION TEST RESULTS

No	Power Meter (A)	Sensor (A)	Error
1	0.04	0.04	0
2	0.04	0.04	0
3	0.04	0.04	0
4	0.04	0.04	0
5	0.04	0.04	0
6	0.04	0.04	0
7	0.04	0.04	0
8	0.04	0.04	0
9	0.04	0.04	0
10	0.04	0.04	0
11	0.02	0.02	0
12	0.02	0.02	0
13	0.02	0.02	0
14	0.02	0.02	0
15	0.02	0.02	0
16	0.02	0.02	0
17	0.02	0.02	0
18	0.02	0.02	0
19	0.02	0.02	0
20	0.02	0.02	0
amount	0.6	0.6	
average	0.03	0.03	0

From the data obtained, a comparison chart of the power meter readings with the sensor can be made in figure 9.

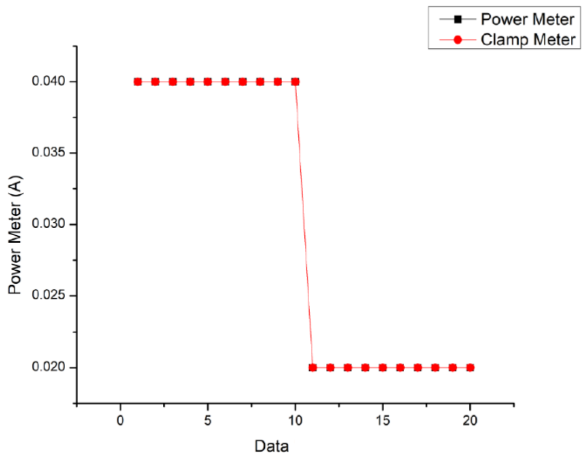

Figure 9. Power Meter Flow Chart

From the picture above, it can be seen that the current reading on the tool is close to the standard. Based on the data obtained from testing the tool, the characteristics of the iEM2050 power meter measuring instrument can be obtained as follows:

- Range : 0.02 – 0.04 A
- Span : 0.02 A
- Accuracy:

$$\left[\left(\frac{|average\ error|}{Max\ value - Min\ value}\right) \times 100\%\right]$$

$$\left[\left(\frac{0}{0.02}\right) \times 100\%\right]$$

= 0

C. INA219 Sensor Validation

The validation is carried out by comparing the readings in the following table:

TABLE 3.
SENSOR VOLTAGE TEST RESULTS

No	Validator(V)	Sensors (V)	Error
1	11.96	11.61	0.4
2	11.96	11.62	0.3
3	11.96	11.62	0.3
4	11.96	11.61	0.4
5	11.96	11.63	0.3
6	11.96	11.62	0.3
7	11.96	11.64	0.3
8	11.96	11.63	0.3
9	11.96	11.63	0.3
10	11.95	11.65	0.3
11	12.04	11.81	0.2
12	12.03	11.80	0.2
13	12.03	11.79	0.2
14	12.02	11.81	0.2
15	12.02	11.79	0.2
16	12.03	11.80	0.2
17	12.03	11.82	0.2
18	12.03	11.79	0.2
19	12.02	11.80	0.2
20	12.03	11.80	0.2
amount	239.87	234.27	
average	11.9935	11.7135	0.3

From the data obtained, a comparison graph of the validator readings with the sensor can be made in the following figure:

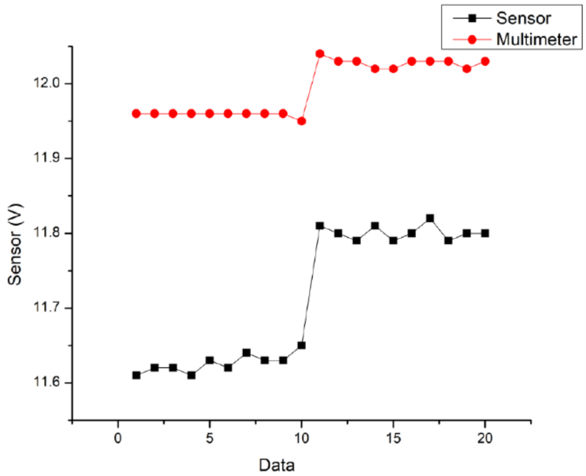

Figure 10. Graph of INA219 Sensor Voltage

From Figure 10 it can be seen that the current reading on the sensor is close to the standard. Based on the data obtained from testing the tool, the characteristics of the INA219 sensor can be obtained as follows:

- Range : 11.95 – 12.04
- Span : 0.09
- Accuracy:

$$\left[\left(\frac{|average\ error|}{Max\ value - Min\ value}\right) \times 100\%\right]$$

$$\left[\left(\frac{0.3}{0.09}\right) \times 100\%\right]$$

=3.3

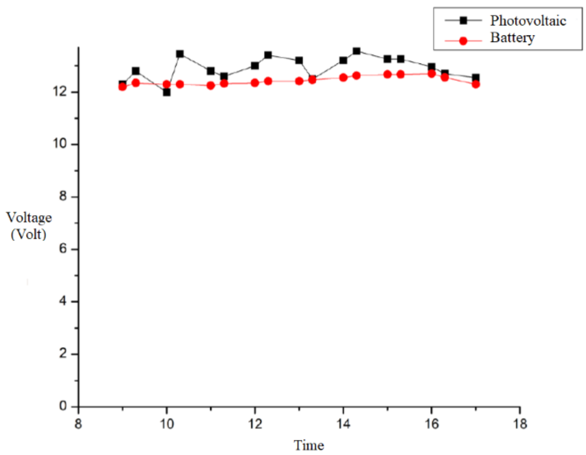

Figure 11. Charge Graph of PV Battery

When testing the battery charging voltage from the solar panel, it can be seen that the initial voltage from the solar panel is 0, which indicates that it is the initial condition of the solar panel before the charging process is carried out with a voltage on the battery of 12.30 V. In the charging process, the voltage on the battery tends to be more stable 12 V compared to solar panels because the voltage from the battery has used a Solar Charge Controller as a stabilizer so as to avoid the battery from overcharging. The voltage from the solar panel fluctuates depending on the intensity of light received by the solar panel.

IV. Conclusion

A Battery Protection System successfully designed using a Relay actuator against overvoltage and Undervoltage. This tool can detect the presence of overvoltage and Undervoltage of the nominal rated voltage and display through the LCD. It can be applied to household electrical safety using AC and DC voltages to avoid damage to the insulator on the component, which results in damage and burning of the components and household appliances due to overvoltage and Undervoltage. The static characteristics of the iEM2050 power meter and the INA219 sensor used in this battery protection system have good accuracy. As well as having a small error value, the two sensors are suitable for use in this research. The results of temporary data collection were carried out using light loads and cell phone chargers.

References

[1] K. Rahmadi and P. N. Jakarta, "RANCANG BANGUN AIR QUALITY MONITORING MENGGUNAKAN MIKROKONTROLER ARDUINO MEGA 2560 PRO DAN SIM800L V2." [Online]. Available: https://www.researchgate.net/publication/340510918

[2] R. Alfanz, F. K. Maulana, H. Haryanto, "Rancang Bangun Penyedia Energi Listrik Tenaga Hibrida (PLTS-PLTB-PLN) Untuk Membantu Pasokan Listrik Rumah Tinggal," J. Teknik Elektro, vol. 4, no. 2, 2015.

[3] Y. Badruzzaman, "Real Time Monitoring Data Besaran Listrik Gedung Laboratorium Teknik Sipil Politeknik Negeri Semarang." J. Teknik, E. Politeknik,

[4] I. Abadi, D. N. Fitriyanah, and A. U. Umam, "Design of maximum power point tracking (MPPT) on two axes solar tracker based on particle swarm fuzzy," in *AIP Conference Proceedings*, Mar. 2019, vol. 2088. doi: 10.1063/1.5095293.

[5] O. O. Apeh, E. L. Meyer, and O. K. Overen, "Modeling and experimental analysis of battery charge controllers for comparing three off-grid photovoltaic power plants," *Heliyon*, vol. 7, no. 11, Nov. 2021, doi: 10.1016/j.heliyon.2021.e08331.

[6] I. Guidara, A. Souissi, and M. Chaabene, "Novel configuration and optimum energy flow management of a grid-connected photovoltaic battery installation," *Computers and Electrical Engineering*, vol. 85, Jul. 2020, doi: 10.1016/j.compeleceng.2020.106677.

[7] H. Tri Monda and P. Santi Rudati, "Sistem Pengukuran Daya pada Sensor Node Wireless Sensor Network."

[8] T. Haryanto, H. Charles, and D. H. Pranoto, "Perancangan Energi Terbarukan Solar Panel Untuk Essential Load Dengan Sistem Switch," *Jurnal Teknik Mesin*, vol. 10, no. 1, pp. 43, 2021.

[9] R. Firanda and D. M. Yuhendri, "Monitoring State Of Charge Accumulator Berbasis Graphical User Interface Menggunakan Arduino," 2021.

[10] E. Permana and A. Desrianty, "PANEL SURYA (SOLAR CHARGING BAG) MENGGUNAKAN QUALITY FUNCTION DEPLOYMENT (QFD) *".

[11] M. Syahwil and N. Kadir, "Rancang Bangun Modul Pembangkit Listrik Tenaga Surya (PLTS) Sistem Off-grid Sebagai Alat Penunjang Praktikum Di Laboratorium," 2021.

[12] I. Kurniastuti, A. Andini, and P. Studi Analis Kesehatan Fakultas Kesehatan Universitas Nahdlatul Ulama Surabaya, "Perancangan Program Penentuan Histogram Citra dengan Graphical User Interface (GUI)," 2018.

[13] D. Erwanto, D. K. Arie Widhining, T. Sugiarto Sistem Pemantauan Arus Dan, T. Sugiarto, and T. Elektro Uniska - Kediri Jl Sersan Suharmadji No, "Sistem Pemantauan Arus Dan Tegangan Panel Surya Berbasis Internet of Things," Online, 2020. [Online]. Available: http://journal.umpo.ac.id/index.php/multitek

[14] Nugraha and B. Arya, "Design of a Microcontroller-Based Undervoltage and Overvoltage Protection System Relay," 2017.

[15] B. Arsyad, A. Sofwan, and A. Nugroho, "PERANCANGAN SISTEM KONTROL OVER/UNDER VOLTAGE RELAY BERBASIS MIKROKONTROLER PADA SALURAN TEGANGAN 220VAC" *Transient*, Vol 8, No.1, 2019.