PROTOTYPE OF AUTOMATIC TRANSFER SWITCH (ATS) FOR SOLAR POWER PLANT BASED ON ARDUINO UNO

MUHAMMAD ALFIAN HARIS PRASTYA, *BAMBANG PURWAHYUDI

Study Program of Electrical Engineering, Universitas Bhayangkara Surabaya

Jl. A. Yani 114, Surabaya, Indonesia

E-mail: bmp_pur@ubhara.ac.id

*Corresponding author

ABSTRACT

Electrical energy plays an important role in supporting daily human activities. The need for electrical energy always increases according to population growth. However, the supply of electrical energy is not proportional to population growth. To meet the demand for electrical energy, it is necessary to develop and use alternative energy such as solar energy. In this paper, the prototype of Automatic Transfer Switch (ATS) for PLN and solar power plant (SPP) is carried out so that the supply of electrical energy to the load can be distributed continuously. ATS is electromechanical equipment that operates automatically to move the source of electrical energy from the main grid (PLN) network to SPP when the PLN network occur a faults or blackout. ATS will restore the source of electrical energy from PLN automatically when the supply of electrical energy from PLN has returned to normal condition. ATS components consist of voltage and current sensors, microcontroller and relay respectively. ATS use microcontroller Arduino Uno ATmega328 type to control the main switch (relay) automatically. The test results show that ATS succeeded in moving the source of electrical energy from PLN to SPP when there is a disturbance or blackout condition and ATS will returns the source of electrical energy to PLN when conditions back to normal.

Keywords: *Automatic Transfer Switch (ATS), Solar Power Plant (SPP), Microcontroller, Inverter.*

1. INTRODUCTION

The electrical energy resources are one of the important factors to support the daily human activities in the sectors of resident, industrial and also transportation. For this reason, electrical energy from The State Electricity Company (PLN) must be continuously supplied to customers or load so that the daily human activities can be carried out well. In fact, the supply of electrical energy from PLN is not always continuous sometimes it is discontinuous suddenly due to faults or maintenance. Thus, alternative energy such as solar energy, micro hydro energy and wind energy are needed to meet the demand for electrical energy [1]. To overcome this problem, an Automatic Transfer Switch (ATS) is needed which connects the load to two or more electricity sources consisting of main and alternative electricity sources. Many ATS have been researched and discussed by many researchers. ATS has been used for solar power plant (SPP) and PLN using Programmable Logic Controllers (PLC) [2,3], solar power plant (SPP) and Generator Set [4], and solar power plant (SPP) and wind power generation [5]. In addition, ATS is also needed to control the electricity source from PLN, PLTS and Generator Set [6].

In Indonesia, solar energy as an electrical energy resource has not been optimally utilized in the daily activities. Solar energy is safe energy recourses, free, unlimited and environmentally friendly. The average solar radiation energy intensity is 4.5 kWh/m2 per day [7,8]. In this paper, the design and implementation of Automatic Transfer Switch (ATS) for PLN and solar power plant (SPP) is carried out so that the continuity of the electricity source to the load can be maintained. ATS is electromechanical equipment that operates automatically to move the source of electrical energy from the main grid (PLN) network to SPP when the PLN network occur a faults or blackout. ATS will restore the source of electrical energy from PLN automatically when the supply of electrical energy from PLN has returned to normal condition. ATS components consist of microcontroller, voltage and current sensors, relay, inverter and battery respectively. ATS use microcontroller Arduino Uno AT-mega 328 type to control the main switch (relay) automatically.

The test results show that ATS succeeded in transferring the source of electrical energy from PLN to SPP when there is a disturbance or blackout condition and ATS will returns the source of electrical energy to PLN when conditions back to normal.

2. RESEARCH METHODOLOGY

ATS system proposed consists of voltage and current sensor, microcontroller and relay, respectively. Microcontroller used in ATS is Arduino Uno AT-mega 328 type to control the main switch (relay) automatically. The block diagram of ATS system for Solar Power Plant (SPP) and the research methodology employed to implement the prototype of automatic transfer switch (ATS) for solar power plant (SPP) can be seen in Figure 1 and Figure 2.

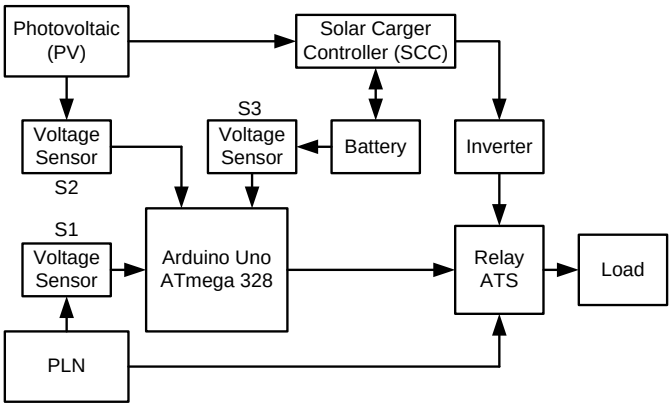

Figure 1. Block Diagram of ATS Proposed.

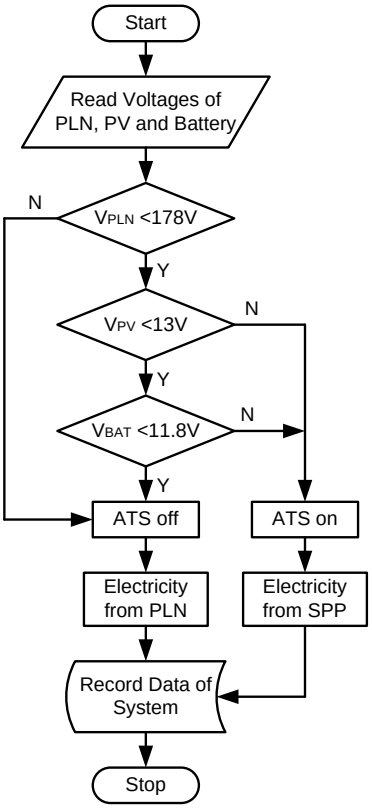

Figure 2. Research Methodology for the Prototype of ATS.

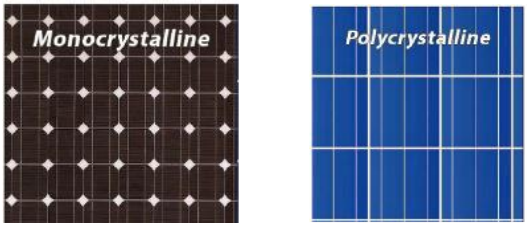

Figure 3. Types of Photovoltaics

a. PWM type b. MPPT type

Figure 4. The Solar Charge Controller (SCC) Types

Figure 1 shows that Solar Power Plant (SPP) system employs solar panel or photovoltaic (PV), Solar Charger Controller (SCC), Battery and Inverter. Voltages of PLN, PV and battery are read using sensors S1, S2 and S3 respectively. The output of these sensors is used by the microcontroller to control the ATS relay. Then, the ATS relay will select a load source from PLN or PV based on the control process from the microcontroller. Figure 2 describes that the ATS relay operates under voltage conditions of PLN, PV and battery respectively. ATS relay will not turn on when the voltage of PLN is greater than 178 volts. Whereas ATS relay will turn on when the voltage of PLN (V_{PLN}) is less than 178 volt and the voltage of photovoltaic (V_{PV}) is greater than 13 volts or the voltage of battery (V_{BAT}) is greater than 11.8 volt.

2.1 Photovoltaic (PV)

Photovoltaic (PV) is important instrument in solar power plant (SPP) systems. PV change solar energy into electrical energy through a process of photoelectric. The PV energy provided is direct current (DC) voltage. Currently, PVs have various forms and types, each of which has its own ability. Several types of PV on the market are Mono-crystalline and Poly-crystalline. Types of photovoltaic are shown in Figure 3 [9,10].

Capacity of PV (*Wp*) is calculated from electrical energy (*Wh*) used load in one peroide time (hour) and solar radiation energy (kWh/m2). Several the other factors caused the capacity of PV are temperature (^{0}C), cables, inverter, battery and solar charge controller (SCC). The capacity of PV capacity can be formulated by using Equation (1) [11].

$$Wp = \frac{Wh}{PSH\ x\ \eta} \quad (1)$$

Where Wh, Wp, PSH and η are electrical energy (watt hour), capacity of PV (watt peak), peak sun hour per day and efficiency of PV (0.67-0.75) respectively. PSH duration per day is about 3-4 hour.

2.2 Identification of subsections

Solar charge controller (SCC) is a module which used in the solar power plant system to control battery charging and protects battery from overcharge and over-discharge. The solar charge controller (SCC) which is widely used in the solar power plant systems has two main types. They are Pulse Width Modulation (PWM) and Maximum Power Point Tracker (MPPT). The capacity of solar charge controller (SCC) is determined from the maximum output current of photovoltaic (PV). Types of SCC [8,9] are shown in Figure 4.

2.3 Battery

Battery is electrical-chemical equipment which stores energy and deliver its energy in electricity. In the solar power plant system, battery is a component for storing direct current (DC) electrical energy provided by solar panels or PV, then supply electrical energy to the load when cloudy weather or night. Many types of batteries are available on the market for solar power generation systems such as lead-acid, zinc water, lithium ion, zinc water, nickel cadmium and

other types. The most widely battery types is lead-acid batteries because it have a long life, more safety, easier to implement, and very low cost per cycle. Show Lead Acid battery type is shown in Figure 5 [8,9].

Meanwhile, battery capacity is determined by supplied electrical energy and nominal battery voltage. Battery capacity can be calculated by using Equation (2) [9,12].

$$AH = 1.25\, x \frac{Wh}{V_B} \quad (2)$$

where AH, V_B and Wh are capacity of battery (ampere hour), voltage of battery voltage (volt) and electricity energy (watt hour) respectively.

2.4 Inverter

Inverter is electronic equipment which functions to convert DC (direct current) voltage to AC (alternating current) voltage. The output of inverter is an AC voltage in the form of a sine wave, square wave or modified sine wave. The input voltage source of inverter comes from batteries, solar power, or other DC voltage sources. Generally, inverters require a step-up transformer or boost converter to produce an AC output voltage that is higher than the input voltage [13].

2.5 Relay

Relay is an electromechanical component that is operated using electricity. The relay consists of 2 main parts, such as the coil (electromagnet) and a set of switch contactors (mechanical). Relays conduct using electromagnetic principles to operate its switch contactors. Relays can conduct electricity at a higher voltage by only requiring a small electric current (low power), The physical form of the relay is shown in Figure 5 [14].

2.6 Arduino Uno Atmega 328

Arduino Uno is an open source physical computing platform. Arduino Uno is not just a development tool, but a combination of hardware, programming languages and a sophisticated integrated development environment (IDE). IDE is software that plays a very important role in writing programs, compiling them into binary code and uploading it into microcontroller memory. There are many projects and tools developed by academics and professionals using Arduino Uno. Additional, there are also many supporting modules made by other parties to be connected to Arduino Uno such as sensors, displays, actuators and so on. Figure 7 shows the physical form of Arduino Uno ATmega 328 type [5].

Figure 5. Lead Acid Battery Type

Figure 6. Relay.

P-ISSN: 2528-0260 E-ISSN: 2579-5392
p.1-8

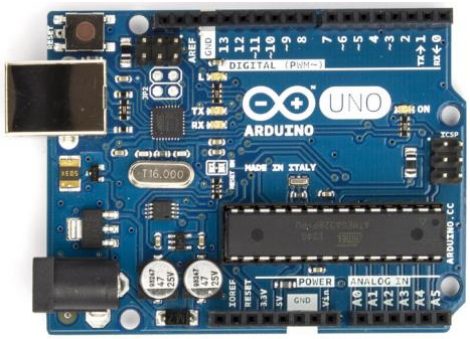

Figure 7. Arduino Uno AT-mega 328

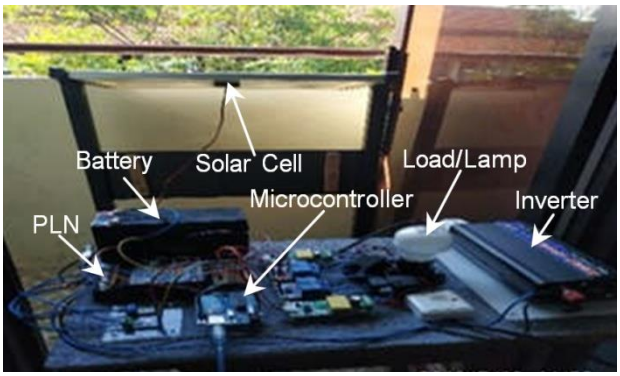

Figure 8. Prototype of Automatic Transfer Switch (ATS) for Solar Power Plant (SPP).

Table 1. Specifications of Equipment

Equipment	Specifications
Microcontroller	AT-mega 328 type
Solar Panel	50 Wp
Battery	VRLA 12V, 7.2AH
Solar Charger Controller	10 A
Load	Lamp 30W
Voltage Sensor	PZEM-004T

Table 2. Result of Solar Panel Testing

Times	Output Voltage (V)
07.00	16.21
08.00	17.19
09.00	18.17
10.00	18.86
11.00	19.55
12.00	19.85
13.00	20.15
14.00	18.75
15.00	17.24
16.00	16.49
17.00	15.73

3. RESULT AND ANALYSIS

Prototype of Automatic Transfer Switch (ATS) for PLN and solar power plant (SPP) can be seen in Figure 8. Test results are needed to clarify the effectiveness of the proposed prototype. The specifications of equipment used in the prototype are shown in Table 1.

3.1 Testing of Photovoltaic (PV) Panel

PV panel testing is carried out by measuring the output voltage of the PV panel from 07.00 am to 5.00 pm. The result of PV panel testing is shown in Table 2. From Table 2 can be seen that the maximum PV output voltage is 20.15 volt at 13.00 and the minimum output voltage is 15.73 volt at 17.00.

3.2 Testing of Voltage Sensor PZEM-004T

Testing of Voltage Sensor PZEM-004T is done by measuring the output voltage of the voltage sensor and compared with volt meter. Table 3 shows the result of voltage sensor PZEM-004T testing. From Table 3 can be seen that the voltage error is under 0.5% and the voltage error read by the sensor is considered very good.

3.3 Testing of Automatic Transfer Switch (ATS) Prototype

Testing of the Automatic Transfer Switch (ATS) Prototype Design is carried out by making PLN, PV and Battery voltages under normal and abnormal conditions. Testing result of prototype can be described in Table 4.

3.4 Testing of Automatic Transfer Switch (ATS) Prototype

Comparison of automatic transfer switch (ATS) proposed with previous ATS can be seen in Table 6. The parameters observed were the sources of electrical energy and the controllers used. D. D. Dewangga, et. al [2] proposed ATS for PLN and solar power plan (SPP) which use programmable logic controller (PLC). Dipociala, et. al [3] has also offer for PLN and solar power plan (SPP), but still use magnetic contactor to control ATS. M. B. A. Aswar, et. al [4] has been proposed ATS for solar power plant (SPP) and generator set, but still also employee magnetic contactor. ATS for solar power plan (SPP) and wind power generation which use Arduino Uno AT-mega 328 has been proposed P. Hermawan, et. al [5]. Next, W. Setyono, et. al [6] proposed ATS for PLN, solar power plant (SPP) and Generator Set, but still use magnetic contactor. According to the results of research in Table 6, then this research has been designed and implemented the automatic transfer switch (ATS) for PLN and solar power plant (SPP) using Arduino Uno AT-mega 328. The results of testing show that prototype of ATS proposed successfully work under normal and abnormal voltage conditions of PLN, PV and battery respectively.

Table 3. Result of Voltage Sensor PZEM-004T Testing

Volt Meter (V)	PZEM-004T (V)	Error (%)
191	190.2	0.41
196	196.5	0.26
198	198.4	0.20
211	211.1	0.05
222	222.7	0.32
242	242.9	0.37

Table 4. Result of ATS Proposed Testing

PLN (V)	Solar Panel (V)	Battery (V)	Relay ATS	Electricity Source
176	12	12.5	ON	Battery
221	12	12.5	OFF	PLN
176	19.5	12.5	ON	Solar Panel
221	19.5	12.5	OFF	PLN
176	19.5	11.2	ON	Solar Panel
221	19.5	11.2	OFF	PLN

Table 6. Comparison of Automatic Transfer Switch (ATS) Proposed and Previous

No.	Authors	Electricity Sources	Controllers
1	D. D. Dewangga, et. al, 2019 [2]	PLN and Solar Power Plant (SPP)	Programmable Logic Controller (PLC)
2	Dipociala, et. al, 2023 [3]	PLN and Solar Power Plant (SPP)	Not Available
3	M. B. A. Aswar, et. al, 2021 [4]	Solar Power Plant (SPP) and Generator Set	Not Available
4	P. Hermawan, et. al, 2020 [5]	Solar Power Plant (SPP) and Wind Power Generation	Arduino Uno AT-mega 328
5	W. Setyono, et. al, 2021 [6]	PLN, Solar Power Plant (SPP) and Generator Set	Not Available
6	**Proposed ATS**	**PLN and Solar Power Plant (SPP)**	**Arduino Uno AT-mega 328**

4. CONCLUSION

Prototype of Automatic Transfer Switch (ATS) for PLN and solar power plant (SPP) has been designed and implemented. SPP system consists of solar panel or photovoltaic (PV), Solar Charger Controller (SCC), battery and inverter respectively. ATS is electromechanical equipment that operates automatically to move the source of electrical energy from the main grid (PLN) network to SPP when the PLN network occur a faults or blackout. ATS will restore the source of electrical energy from PLN automatically when the supply of electrical energy from PLN has returned to normal condition.

The proposed prototype of ATS is tested to clarify its performances based on the voltage conditions of PLN, PV panel and battery. Testing results show that prototype of ATS successfully work under normal and abnormal voltage conditions of PLN, PV and battery.

REFERENCES

[1] S. Saodah and S. Utami, (2019). "*Perancangan Sistem Grid Tie Inverter pada Pembangkit Listrik Tenaga Surya*", ELKOMIKA: Jurnal Teknik Energi Elektrik Teknik Telekomunikasi dan Teknik Elektronika, vol. 7, no. 2, p. 339-350.

[2] D. D. Dewangga, Suhanto, and L. S. Moonlight, (2019). "*Rancang Bangun Protptype Kontrol dan Monitoring Automatic Transfer Switch (ATS) pada PLN dan Solar Sel Berbasis Programmable Logic Controller (PLC)*", Prosiding Seminar Nasional Inovasi Teknologi Penerbangan (SNITP), p. 1-7.

[3] Dipociala, Y. Apriani, Z. Saleh, and W. A. Oktaviani, (2013). "*Automatic Transfer Switch (ATS) Berbasis Sensor Tegangan Baterai untuk PLTS*", ELECTRICIAN – Jurnal Rekayasa dan Teknologi Elektro, vol. 17, no. 1, p. 44-51.

[4] M. B. A. Aswar, F. Mahmuddin, and A.D. Lestari, (2021). "*Perancangan Automatic Transfer Switch (ATS) Pembangkit Listrik Hibrid Panel Surya dan Generator untuk Bagan Apung*", Jurnal Penelitian Enjiniring (JPE), Universitas Hasanuddin, vol. 25, no. 2, p. 141-148.

[5] P. Hermawan and A. Kiswantono, (2020). "*Rancang Bangun Automatic Transfer Switch (ATS) dan Automatic Main Failure (AMF) Berbasis Arduino Uno R328P pada Prototipe Pembangkit Listrik Tenaga Bayu (PLTB) 220V AC*", Seminar Nasional Fortei Regional 7, vol. 3, no. 1, p.101-106. https://journal.fortei7.org/index.php/sinarFe7/article/view/271.

[6] A. W. Setyono, S. I. Haryudo, M. Widyartono, and A. C. Hermawan, (2021). "*Implementasi ATS AMF Menggunakan Sistem Hybid*", Jurnal Teknik Elektro, Universitas Negeri Surabaya, vol. 10, no. 02, p. 341-349.

[7] F. N. Habibi, S. S. Setiawidayat and M. Mukhsim, (2017). "*Alat Monitoring Pemakaian Energi Listrik Berbasis Android Menggunakan Modul PZEM-004T*", Prosiding Seminar Nasional Teknologi Elektro Terapan 2017, vol. 01, no. 01, p.157-162.

[8] U. S. Muhammad and B. Purwahyudi, (2021). "*Design of Solar Power Plant for Electricity Source of The Drying Machine*", Journal of Electrical Engineering and Computer Sciences (JEECS), vol. 6, no. 2, p. 1081-1085.

[9] M. S. N. Rega, N. Sinaga, and J. Windarta, (2021)."*Perencanaan PLTS Rooftop untuk Kawasan Pabrik TehPT Pagilaran Batang*", ELKOMIKA: Jurnal Teknik Energi Elektrik Teknik Telekomunikasi dan Teknik Elektronika, vol. 9, no. 4, p. 888.

[10] B. Purwahyudi, K. Kuspijani, and A. Ahmadi, (2017). "*SCNN based electrical characteristics of solar photovoltaic cell model*", International Journal of Electrical and Computer Engineering (IJECE), vol. 7, no. 6, p.3198-3206.
[11] P. Gunoto and S. Sofyan, (2020). "*Perancangan Pembangkit Listrik Tenaga Surya 100Wp untuk Penerangan Lampu di Ruang Selasar Fakultas Teknik Universitas Riau Kepulauan*", Sigma Tek., vol. 3, no. 2, p. 96-106.
[12] A. Y. Dewi and Antonov, (2013). "*Pemanfaatan energy surya sebagai suplai cadangan pada laboratorium elektro dasardi Institut Teknologi Padang*", Jurnal Teknik Elektro, vol. 2, no. 3, p. 20-28, https://jte.itp.ac.id/index.php/jte/article/view/522/715.
[13] R. Mundus, K. H. Khwee, and A. Hiendro, (2019). "*Rancang bangun Inverter dengan Menggunakan Sumber Baterai DC 12 V*", Jurnal Teknik Elektro Universitas Tanjungpura, vol. 2, no. 1. https://jurnal.untan.ac.id/index.php/jteuntan/article/view/35261/75676582713.
[14] M. Saleh, M. Haryanti, (2017). "*Rancang Bangun Sistem Keamanan Rumah Menggunakan Relay*", Jurnal Teknologi Elektro (JTE) Universitas Mercu Buana, vol. 8, no. 2, p. 87-94. https://publikasi.mercubuana.ac.id/index.php/jte/article/view/1601/1228.