ATS and AMF System Design for Solar Cell, Genset, and PLN at 2200 Watt Household Load

Hasdari Helmi Rangkuti, Muhammad Abiyyu Fathin Siregar
Sumatera Utara University,Jl. Almamater, Kampus USU Medan 20155 INDONESIA

Abstract

The electricity generated by the generator is not always continuous in its distribution, the discontinuity of the electrical energy disturbs consumer comfort. The control system for moving from one source to another requires ATS (Automatic Transfer Switch) and AMF (Automatic Main Failure). In designing this control system, it will be made with Arduino mega and connected to the rele module, Arduino will regulate the transfer from each source to the load.The rele module is connected to several sources, such as PLN, Solar Cell, Generator Starter and Genset. Solar Cell operating hours are set at 12 noon to 5 pm, if at that hour the battery voltage is below 12V then the system will operate PLN as a voltage source and if at that hour PLN experiences a blackout then the system will operate the Genset as a voltage source. operational using PLN, if there is a blackout outside 12 noon to 5 pm then the system will operate the Genset for the electricity source and if at that time the Genset experiences a starter failure then the system will considered as turn off . The clock reading uses the RTC programmed on the Arduino Mega.The system is considered off when the PLN source experiences a blackout, the 100Ah 12V solar cell battery voltage does not exceed 12 V and the generator starter on the 3000 Watt Motoyama Generator fails so that the Arduino system reads the blackout. Arduino Mega is required to be able to read currents and voltages that occur in the system through current sensors and voltage sensors and will display on the LCD how much voltage and current is when the system is running. The duration of the move from the PLN source to the Solar Cell is 1s and the Genset starter duration reaches 5-10 s. This ATS and AMF system can be made at a household load of 2200 Watt, 220V,10A.

Keywords: *Arduino, Rele, ATS; Genset, Solar cell, RTC; PLN*

I. INTRODUCTION

Indonesia is a country with a tropical climate with 2 seasons, such as the rainy season and the dry season.[1] During the dry season, solar energy in Indonesia can be utilized using a PV (photovoltaic) system. This can really help the community in areas where blackouts are frequently happen by the PLN.[2],[3],[4] In the PV system, a control is needed that can move from the PLN source to the solar cell automatically, and is usually called an Automatic Transfer Switch (ATS).ATS or Automatic transfer switch is a Full Automatic Power Inverter switch control circuit with PLN. This tool is useful for turning on and connecting the Power Inverter to Load automatically when the PLN goes out. When the PLN comes back to life, this tool will transfer the resources to the load from the power inverter to the PLN. In the PV system, emergency power is also needed where when the solar cell cannot function and PLN experiences a blackout, emergency power is needed, such as a generator.[5],[6] However, Genset requires a control that can turn on the Genset automatically, and is usually known as Automatic main failure (AMF).[7] In designing an Automatic Transfer Switch (ATS) and Automatic Main Failure (AMF) system for solar cells, generators, and PLN using rele modules, RTC (Real Time Clock), battery batteries, current sensors, voltage sensors and Arduino Mega. The Automatic Transfer Switch and Automatic Main Failure devices only use PLN, Solar Cell and Generators as emergency supplies.[8],[9]

II. METHODS

2.1 Automatic Transfer Switch dan Automatic main failure

ATS is an abbreviation of the word Automatic Transfer Switch, this tool serves to move the connection between one voltage source and another voltage source automatically. Because of this function, ATS is often also called Automatic COS (*Change Over Switch*). Meanwhile, AMF stands for Automatic Main Failure. This tool functions to turn on the generator engine if the load being served loses the main source of electrical energy / PLN.[10],[11] From the brief explanation above, it can be seen that the function of this tool is a tool that functions to start the generator engine if the main power source dies / goes out (performed by AMF) and connects the power / electricity generated by the generator to the load (performed by ATS).[12],13],[14]

2.2 Solar Cell

A solar cell or solar cell is a device or component that can convert sunlight energy into electrical energy using the principle of the photovoltaic effect.[15],[16] What is meant by the Photovoltaic Effect is a phenomenon in which an electric voltage appears due to the connection or contact of two electrodes that are connected to a solid or liquid system when they receive light energy. Therefore, solar cells or solar cells are often referred to as photovoltaic (PV) cells.[17],[18]

The wide surface of the Solar Cell makes this Solar Cell device more sensitive to incoming light and produces a stronger Voltage and Current than Photo Diodes in general. For example, a solar cell made of silicon semiconductor material can produce a voltage as high as 0.5V and a current as high as 0.1A when exposed to sunlight.[19],[20]

The two power cables output from the solar panel are forwarded to the solar charge controller which is then set to charge the battery (battery) and also load it to the inverter. Because the electric current that will flow to the SCC, battery and inverter is quite large, the cable used must be adjusted. For example, the current in the electric circuit is 10 Ampere, so the cable used is a cable that is 2.5 mm2 (standard PUIL calculation).[21] If less than that, the cable will heat up and burn. The battery used is certainly not a mediocre battery. The battery used must be able to store a large enough electric charge so that it can be used for some time.

2.3 Generator Set (Genset)

Genset engine (Generator Set) is a backup power generator that uses kinetic energy. The electricity that can be generated is adjusted to the size of the generator. The working principle of the generator is that a combustion engine (diesel engine or gasoline engine) will convert fuel energy into mechanical energy, then the mechanical energy is converted or converted by the generator to produce electric power. Generators have two types, namely AC generators or commonly called alternators and DC generators.[22],[23] An AC generator (alternator) is a generator that produces alternating current (AC) electricity, an AC generator (alternator) uses two drag rings (slip rings) to produce alternating current. Following is the construction of the generator in Figure 1.

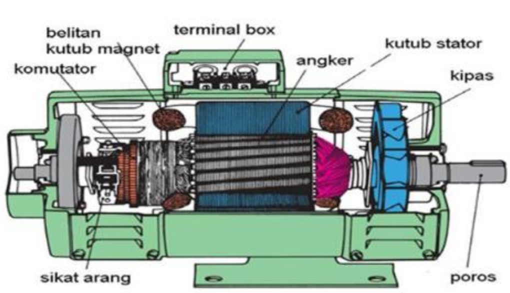

Figure 1.Generator Construction

The most widely used alternating current (ac) motor, its name comes from the fact that motor current is an induced current as a result of the relative difference between the motor rotation and the rotating magnetic field or rotating magnetic field generated by the stator current. the rotating field in the stator will cut the conductors in the rotor.[24],[25],[26]

2.4 Arduino Mega

Arduino is a microcontroller-based board or open source electronic circuit board in which there is a main component, namely a microcontroller chip of the AVR type. The microcontroller itself is a chip or IC (integrated circuit) that can be programmed using a computer. The purpose of embedding a program in a microcontroller is so that the electronic circuit can read the input, process the input and then produce the desired output.[27],[28] So the microcontroller acts as a brain that controls the process of input and output of an electronic circuit. Arduino Mega type 2560 in Figure 2.

Figure 2. Arduino Mega

The reason why many people choose Arduino Mega corresponds to this board that has quite a lot of I/O pins, a total of 54 digital I/O pins (15 of which are PWM), 16 analog input pins, 4 UART pins (hardware serial port). The Arduino Mega 2560 is equipped with a 16 Mhz oscillator, a USB port, a DC power jack, an ICSP header, and a reset button. This board is very complete, already has everything needed for a microcontroller.[29],[30],[31]

2.5 ZMPT101B Voltage Sensor

ZMPT101B is an AC voltage sensor module that uses an isolation transformer with a voltage ratio of 1:1. This sensor manufacturer does not provide a resolution equation so the sensor must be calibrated manually. The calibration process is carried out by comparing the readings of the analog output voltage bits of the sensor with the voltage readings using a digital multimeter. The results of this comparison are then used to create a bit-to-voltage conversion equation.[32],[33],[34] The working principle of this sensor is to lower the input voltage using a step down transformer, then enter the op-amp and get a stable output value depending on the input value. The picture of the voltage sensor is in Figure 3.

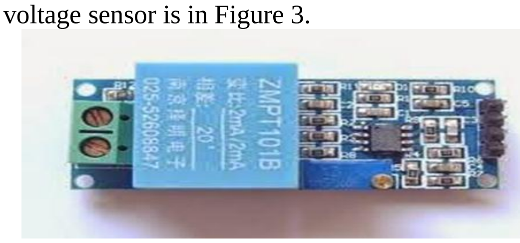

Figure 3. ZMPT101B Voltage Sensor

2.6 Current sensorACS712

The current sensor used is in the form of an ACS712 current sensor module which has the function of detecting the amount of current flowing through the terminal block of the ACS712 Current Sensor Module as shown in the figure, can detect currents of up to 30A and this current signal can be read through the Arduino analog IO port. Products are available on the market for this module is 30A, 20A, 5A. For this demonstration, we will use ACS712 for 5A current. The ACS712 current sensor can measure positive and negative currents within a range of -5A to 5A. This sensor requires a power supply of 5V. To read the middle value (zero Amperes) the sensor voltage is set at 2.5V which is half the power source voltage VCC = 5V. At negative polarity a current reading of -5A occurs at a voltage of 0.5V. The level of change in voltage is linearly correlated with the amount of current of 400 mV/Ampere.[35],[36]

2.7 Rele Module

Rele Module is an electronic component that can disconnect or connect electricity indirectly. The rele is also known as a magnetic switch. The way the rele works is that when an electric current is connected, there will be contact between the plates so that an electric current can flow. The main function of a rele is as an electronic switch that is needed to control high currents and voltages [37],[38]. The Rele module schematic diagram is shown in Figure 4.

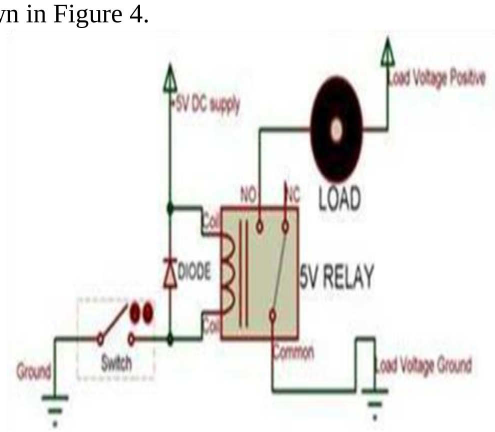

Figure 4. Schematic diagram of the Rele module

The rele module has several parts, namely NO (Normally open), NC (Normally close), COM (common), and coil. if the fault current is detected and the current delay time has been reached, Arduino will turn off or cut off the current to the rele module.[39],[40]

III. RESULTS AND DISCUSSION

3.1 System Design Tool Specifications

The specifications of the Automatic Transfer Switch and Automatic Main Failure using the Arduino Mega which will be designed are shown in Table 1 below.

Table 1. ATS and AMF specifications using Arduino Mega

Measuring Circuits	
Rated Current	1A
Rated Frekuensi	50 Hz
Rated Voltage	250 V
internal operating voltage	5 V dc
Rated Generator Set	3000 Watt
Rated Solar Cell	100 Wp
Rated battery Solar Cell	12 V 100 Ah
Rated Voltage Sensor DC	25 V
Rated Current Sensor	30 A
Rated current Solar Charge controller	20 A
Rated Switching	
PLN- Solar cell	1 s
PLN - Genset	5 s
Solar Cell - Genset	5 s
Trip Contacts	
Rated Voltage	Max 250 V ac
	Max 30 V dc
Maksimum Making Current	10A

3.2 Hardware Design (Hardware)

The design of ATS and AMF as well as the entire system was carried out by connecting the Arduino Mega with one ACS712 current sensor, one ZMPT101B voltage sensor, one RTC, one 4 Channel Rele module, one LCD, one 3000 Watt Genset, and one Solar. cell 100 Wp. The assembly can be seen in Figure 5.

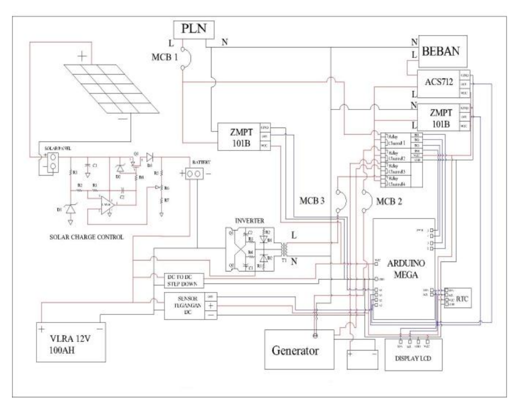

Figure 5. Overall system planning.

3.3 Software Design (Software)

Programming the Automatic Transfer Switch and Automatic Main Failure with Arduino Mega using the C language on the Arduino IDE software, where the program from the Arduino IDE software is then uploaded to the Arduino Mega via a USB cable. ATS and AMF are programmed with Solar cell operating hours from 12 noon until 5 pm and Arduino will give signals Rele 1,2, and 3 from NC to NO, if the voltage on the solar cell battery does not exceed the charger voltage then the solar cell is considered to have a blackout. Setting the following operational hours on the Arduino Mega:

1. If at 12 noon - 5 pm the voltage on the battery does not exceed the charger voltage then the ATS will move the input from the solar cell to PLN, and Reles 2,3 and 4 become NO.
2. If at 12 noon - 5 pm the voltage on the battery does not exceed the charge voltage on the solar cell and the PLN experiences a blackout, the ATS will move the input voltage from the solar cell or PLN to the GENSET, and Reles 1 and 4 experience NO..
3. If outside 12 noon - 5 pm there is a blackout at the PLN, the ATS will move the input voltage from PLN to the GENSET, and Reles 1 and 4 experience NO.
4. If the GENSET cannot be started and the PLN has a blackout, the ATS will see the power in the battery. If the battery voltage exceeds the charger voltage then the voltage source is from the battery and if not it will experience a blackout..
5. If the battery voltage is only 10%, then the voltage source is from PLN or GENSET

Rele as an electromagnetic switch that is connected by a circuit, from a normally open/NO state to a normally closed/NC state or vice versa. The following is the rele design in table 2

Table 2. Rele Design

CONDITION	Channel 1	Channel 2	Channel 3	Channel 4	SOURCES
1	NO	NO	NO	NC	Solar cell
2	NC	NO	NO	NO	PLN
3	NO	NC	NC	NO	Genset
4	NO	NC	NC	NO	Genset
5	NO	NO	NO	NC	Solar cell
6	NO	NO	NO	NO	Turn off

From the rele design scheme, connect the rele module to the voltage source as shown in Table 3.

Table 3. Rele Relations

Rele Module	
Channel 1	PLN
Channel 2	Genset
Channel 3	Starter Genset
Channel 4	Solar Cell

On channel 1 the voltage source comes from PLN, if at 12 noon to 5 pm the voltage source will move to Channel 4, namely Solar cell, and if there is a blackout outside operating hours then the rele will move to Channels 3 and 2. Following is the flowchart of the tool scheme in Figure 6.

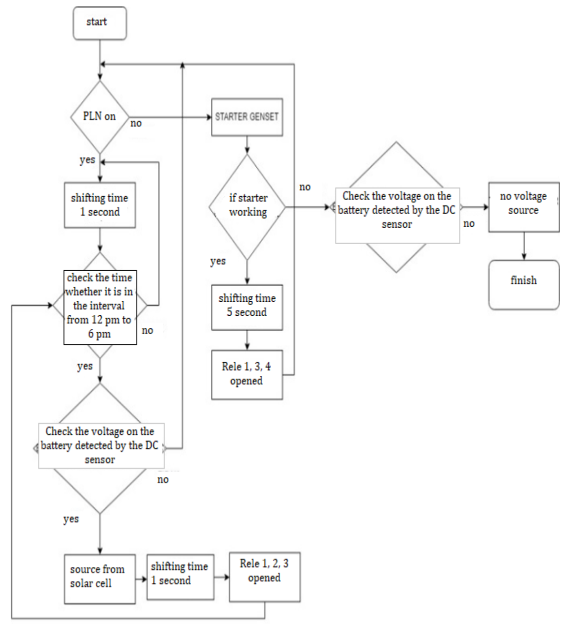

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Figure 6. Flow diagram of the equipment used.

3.4 Control System Testing

The design that was first made was a rele controller circuit consisting of a 4 Channel rele module, LCD, Arduino Mega, ZMPT101 voltage sensor, ACS712 current sensor, and Real Time Clock. The controller design that was successfully built is shown in Figure 7.

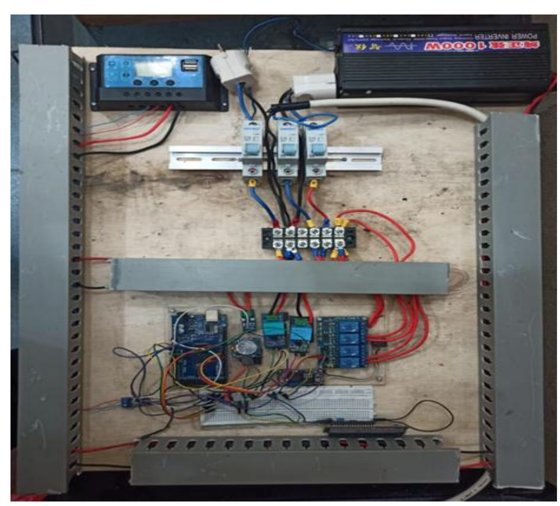

Figure 7. Control system design

3.5. Testing at 12 pm – 5 pm

The results of this test will see the transfer from the PLN voltage source to the Solar Cell voltage source by increasing the power gradually, starting from 0 - 350 watts. The purpose of this test is to see the successful transfer of the Automatic Transfer Switch system between PLN and Solar Cell

3.5.1. PLN displacement test - Solar cell

The results of the displacement test from the PLN source to the Solar cell are shown in Table 4.

Table 4. Results of the PLN – Solar cell displacement test

No	LOAD (w)	TRANSFER TIMES (S)	VOLTAGE (V)	CURRENT (I)	STATE
1	0	1	226	0	succeed
2	50	1	226	0.22	succeed
3	100	1	226	0.43	succeed
4	150	1	224	0.65	succeed
5	200	1	224	0.89	succeed
6	250	1	225	1.1	succeed
7	300	1	225	1.33	succeed
8	350	1	225	1.54	succeed

In Table 4 there are how many currents and voltages are read by the current sensor and voltage sensor and are displayed on the LCD, the rele experienced a successful transfer with a transfer time of 1s at 12 noon.

3.5.2. Solar Cell displacement testing – PLN

The results of the displacement test from the Solar cell voltage source to PLN are shown in Table 5.

Table 5. Solar cell displacement test results – PLN

No	LOAD (W)	TRANSFER TIMES (S)	VOLTAGE (V)	CURRENT (I)	STATE
	0	1	225	0	succeed
2	50	1	225	0.24	succeed
3	100	1	225	0.5	succeed
4	150	1	225	0.71	succeed
5	200	1	225	0.94	succeed
6	250	1	225	1.1	succeed
7	300	1	225	1.39	succeed
8	350	1	225	1.54	succeed

In Table 5 there are how many currents and voltages are read by the current sensor and voltage sensor and displayed on the LCD, the rele experienced a successful transfer with a transfer time of 1s at 12 noon. The voltage sensor in the test experienced a constant of 225 volts.

3.5.3. PLN – Genset displacement test

This test is to see the success of moving the Solar cell to PLN from 12 noon to 5 pm by gradually adding a load of 50 watts. In this experiment the battery voltage did not exceed the charger voltage and PLN experienced blackouts. The results of the displacement test from the PLN voltage source to the Genset are shown in Table 6.

Table 6. Results of the PLN-Genset displacement test

No	LOAD (W)	TRANSFER TIMES (S)	VOLTAGE (V)	CURRENT (I)	STATE
1	0	5	223	0	succeed
2	50	5	225	0.22	succeed
3	100	5	221	0.48	succeed
4	150	5	223	0.7	succeed
5	200	5	224	0.92	succeed
6	250	5	223	1.10	succeed
7	300	5	223	1.37	succeed
8	350	5	224	1.54	succeed

In Table 6 there are how many currents and voltages are read by the current sensor and voltage sensor and are displayed on the LCD, the rele has experienced a successful transfer with a displacement time of 5s on the starter. The reading on the voltage sensor does not experience constant readings.

3.6 Testing beyond 12 PM – 5 PM

The results of this test are to see the situation if there is a blackout at PLN outside the operational hours of the Solar cell, which is outside 12 noon to 5 pm. This test looks at the state of the move from PLN to Genset and Genset starter automatically.

The results of the displacement test from the PLN voltage source to the Genset are shown in Table 7.

Table 7. PLN-genset test results outside 12 noon – 5 pm

no	LOAD	TRANSFER TIMES (S)	VOLTAGE (V)	CURRENT (I)	STATE
1	0	5	223	0	succeed
2	200	5	225	0.91	succeed
3	400	5	221	1.3	succeed
4	600	5	224	2.70	succeed
5	800	5	223	3.63	succeed
6	1000	5	221	4.54	succeed
7	1200	5	224	5.47	succeed
8	1400	5	223	6.35	succeed
9	1600	5	224	7.25	succeed
10	1800	5	225	8.20	succeed

In Table 7, there are how many currents and voltages are read by the current sensor and voltage sensor and are displayed on the LCD, the rele has experienced a successful transfer with a displacement time of 5s on the starter. The reading on the voltage sensor is not constant on the reading.

IV. CONCLUSION

To sum up everything that has been stated so far that the research conducted that The design of the ATS and AMF systems works well at a household load of 2200 watts. Also the design of the ATS and AMF systems can back up the voltage from PLN when PLN experiences blackouts. The reading data of the voltage sensor and current sensor are not constant, because the readings from the voltage sensor and current sensor are inaccurate or inaccurate. The transfer from the PLN voltage source to the Solar cell at 12 noon to 5 pm is for 1s. Genset Starter has a duration of 5s to 10 s.

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