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Design single phase inverter using sinusoidal pulse width modulation (SPWM) for Automatic Transfer Switch (ATS) of solar panel and grid

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ABSTRACT

In everyday life, humans cannot live without electrical energy. Electricity has become a basic need that must be fulfilled. A backup source of electrical energy is needed when there is a disturbance of the main voltage source going out and can save electrical energy costs. This research will create a 1-phase inverter circuit using EGS002 as a sinusoidal pulse width modulation generator. SPWM is a modulation between the carrier wave and the main wave. The use of the SPWM method can also reduce the value of harmonic distortion arising from the energy conversion process. Inverter is a circuit that converts DC voltage into AC voltage in the form of a sinusoidal signal after going through wave formation and filter circuit, the resulting output voltage must be stable both the amplitude of the voltage and the frequency of the voltage produced, low distortion, no transient voltage and cannot be interrupted by a condition, the value of voltage and frequency can be adjusted To change the voltage from the main source to the backup source, a supporting device is needed in the form of an Automatic Transfer Switch (ATS). Automatic Transfer Switch (ATS) is system equipment that can regulate the alternation of electrical power supply from the main PLN power source to a backup power source or generator that works automatically by controlling the timing. This research will change the voltage from the PLN source to the backup source from the solar power plant.

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1. INTRODUCTION

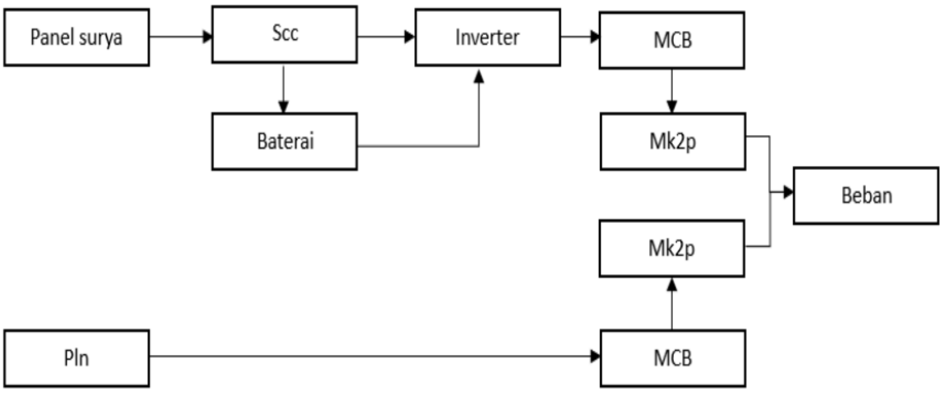
In everyday life, humans cannot live without electrical energy. Electricity has become a basic need that must be met. Today, electricity has been widely used as input for the sustainability of various forms of socio-economic activities in various sectors, both for consumption needs and in production and distribution activities [1]. The rapid increase in population is also accompanied by economic growth, causing the need for electrical energy to increase, so that there is a need for adequate provision and distribution of electrical energy both in terms of technical and economic aspects. The use of electrical energy is currently one of the important needs in people's lives and is often considered as one of the benchmarks of people's welfare along with technological developments [2]-[3]. To support the demand for electrical energy with the use of soaring fossil fuels but still meet the needs, renewable energy is needed, including energy from solar power. Solar energy is an energy that has the potential to be developed in Indonesia, considering that Indonesia is a country located in the equatorial region with optimal utilization [4]-[6].

A backup power source is essential when there is a main power source outage and can save electricity costs. The process of changing electricity from the main power source to the backup power source must not cause the power to go out due to a time lag in changing the voltage source. Therefore, a supporting device is needed in the form of an Automatic Transfer Switch (ATS) [7]. An Automatic Transfer Switch (ATS) is a system device that can regulate the change of electricity supply from the main PLN power source to a backup power source or generator that works automatically by controlling the time setting [8]-[9] .

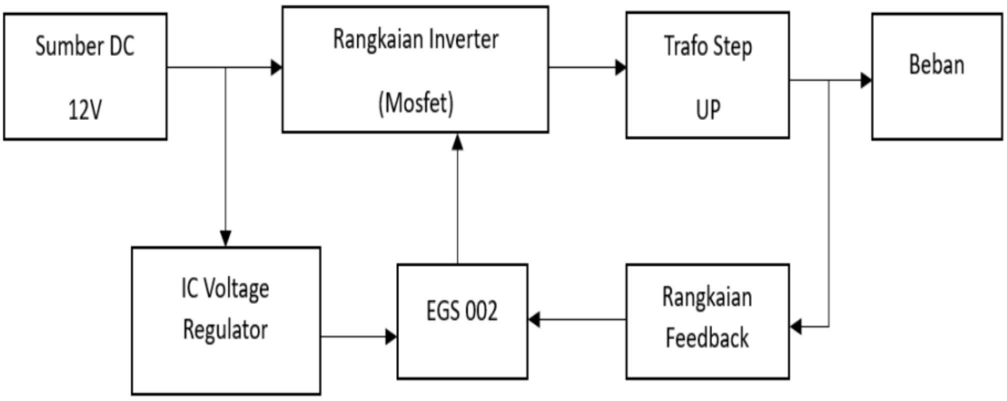
To change the direct current source from a 12V DC or 24V DC battery to 220V AC, a tool called an inverter is used [10]. An inverter is a circuit that converts DC voltage to AC voltage in the form of a sinusoidal signal after going through wave formation and a filter circuit, the output voltage produced must be stable in both the voltage amplitude and the frequency of the voltage produced, low distortion, no transient voltage and cannot be interrupted by a condition, the voltage and frequency values can be adjusted [11]-[12]. In the inverter switching process, it requires the generation of Pulse Width Modulation (PWM) waves in order to generate high and low waves. In ac voltage, the waves produced are sine waves or alternating. To obtain PWM wave results with sine wave characteristics, in this paper the signal modulation uses the Sinusoidal Pulse Width Modulation (SPWM) method. SPWM is a modulation between the carrier wave and the main wave. The use of the SPWM method can also reduce the value of harmonic distortion arising from the energy conversion process [13]-[14] . The inverter also uses the EGS002 driver, a special driver board for single-phase pure sine inverters. The EGS002 uses the IC EG8010 as the control chip and the ir2110 as the driver chip. This driver board integrates voltage, current, and temperature protection functions, LED warning indication and fan control. The output configures AC 50/60 Hz. Configurations are also available, such as soft start and dead time modes. The EGS002 is an improved version of the original EGS001 [15].

2. METHOD

This study aims to design a 1-phase inverter using ESG002 as a sinusoidal pulse width modulation (SPWM) generator for automatic transfer switch (ATS) on PLTS and PLN. Figure 1 shows the block diagram of the circuit, figure 1(a) shows the block diagram of ATS PLN PLTS and figure 1(b) shows the block diagram of the inverter.



(a)



(b)

Figure 1. Block diagram of the circuit, (a) block diagram of ATS and (b) block diagram of the inverter.

In the ATS PLN PLTS block diagram, it can be explained that the PLTS source will later be stored in a battery which will then change its current from DC to AC in the inverter, then the AC current from the inverter will enter the MK2P relay which will switch the PLTS and PLN power sources, and will supply electrical energy to the load. Then in the inverter block, it can be explained that the source used to make a 1-phase inverter is a 12V DC source. This voltage will be converted to AC voltage using a switching circuit, namely using a mosfet. The mosfet switching process will be driven by a control circuit, namely EGS002, so that an SPWM wave is obtained that is reversed from the mosfet switching. This control circuit will move the mosfet transistor for switching. The voltage for EGS002 is obtained from the battery, but before the voltage enters, the IC 7812 and IC 7805 will lower the voltage first. From the output of this inverter, it is in the form of AC voltage which will then enter the step-up transformer. The step-up transformer functions to increase the voltage from 12V AC to 220V AC. From the output of this transformer then enters the feedback circuit where this feedback circuit will later give a signal to EGS002 with a voltage of 3V on pin 15 EGS002. After the transformer output voltage is higher than the input, the inverter will be tested with a load. Hardware design is a design related to the components that will be used in the tool assembly process. This design includes determining the nature and specifications of the tool, selecting components, creating circuit designs and installing components. For the design of this tool has a circuit as in Figure 2.

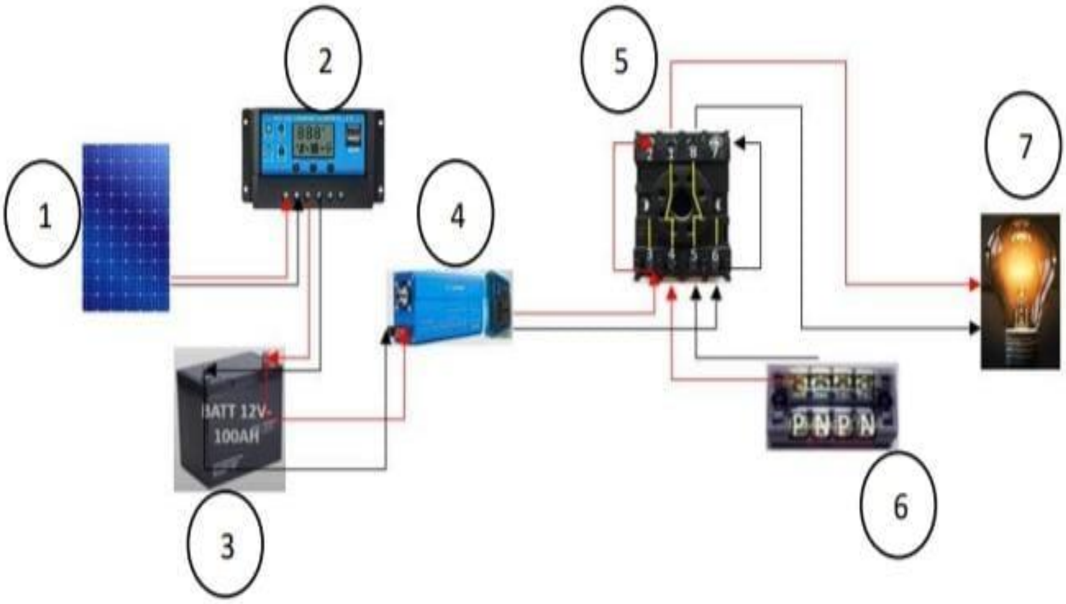
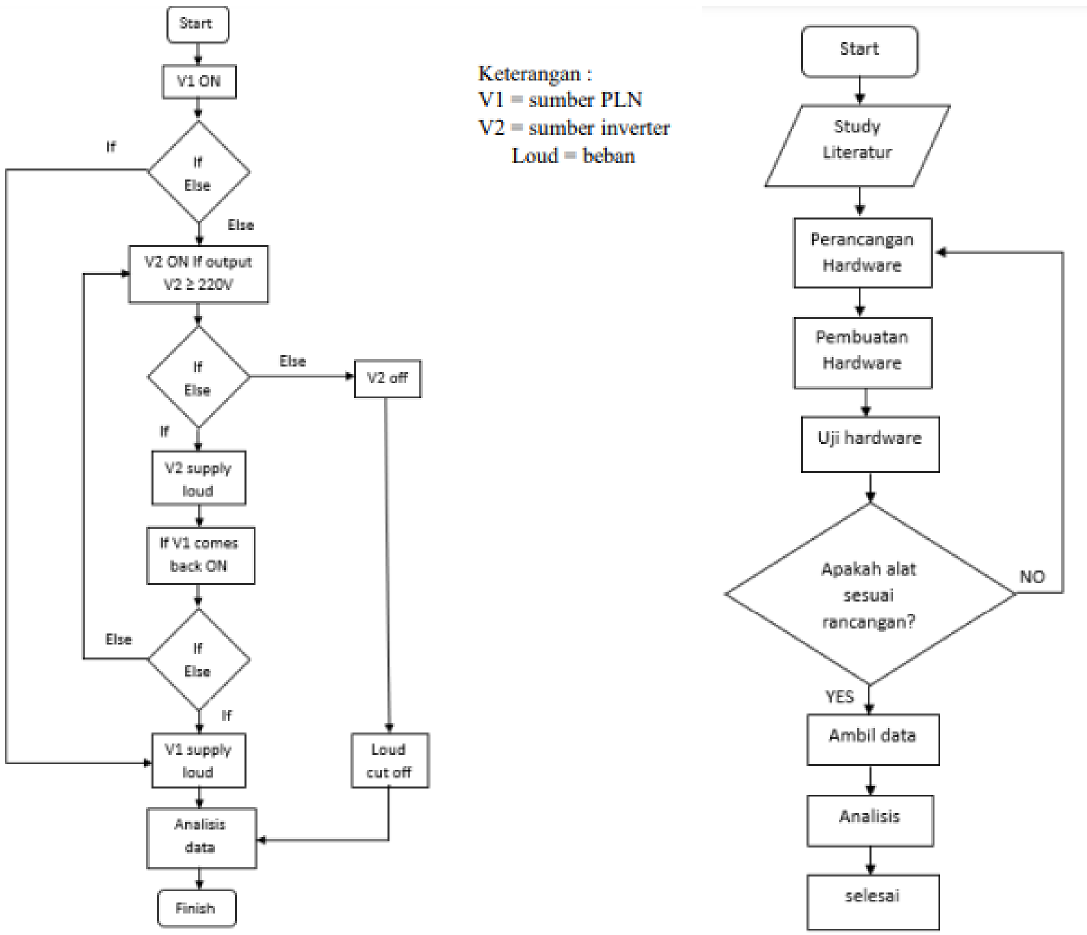


Figure 2. Hardware design

From Figure 2 it can be seen that number 1 is a monocrystalline solar panel component, number 2 is the solar charger controller (SCC), number 3 is the 12V battery, number 4 is the inverter that will be used, number 5 is the MK2P relay, number 6 is the PLN source terminal and number 7 is load. In this study, we will use a 25W incandescent lamp load, 40W soldering iron and 46W fan. Figure 3 shows the design flowchart of this study, Figure 3 (a) is the system design flowchart and Figure 3 (b) is the tool design flowchart.

From the flowchart, it can be explained that basically the working principle of this circuit is to create a 1-phase inverter using EGS002 as an SPWM generator. The input used is a 12V DC battery which will be converted to 12V AC using a switching circuit, namely using 8 IRFP640 MOSFETs paralleled into 4 switches, where this MOSFET switching circuit is driven by the EGS002 control circuit to obtain SPWM from the MOSFET switching. At the EGS002 input, it will later receive input voltage from the battery which is reduced to 12V and 5V using a voltage regulator. At the 12V AC MOSFET output, the voltage will later be increased using a CT transformer to 220V.



(a) (b)

Figure 3. Circuit flowchart, (a) system design flowchart and (b) tool design flowchart.

3. RESULTS AND DISCUSSION

The design of a 1-phase inverter using EGS002 as an SPWM generator for ATS on PLTS and PLN was tested in the laboratory. Figure 4 shows the DC input voltage test which aims to ensure that the DC voltage is as expected.

Figure 4. Checking DC voltage input

After checking the DC voltage input, checking the regulator circuit needs to be done because it aims to see how many inputs and outputs there are on the two ICs, namely 7812 and 7805. Table 1 shows the test results of the 7812 and 7805 regulator ICs.

Table 1. Regulator circuit test results

No	IC Regulator	Voltage (V)	
		Input	Output
1	7812	13.5	11.8
2	7805	11.8	4.9

It can be seen from table 1 the results of the regulator circuit test that the input on the IC 7812 and 7805 have quite large inputs and have significant differences in the output voltage produced. Therefore, a cooler (heatsink) must be installed as a cooler to remove heat from the IC which can prevent damage to this regulator circuit. And also for 7812 and 7805 have their own pins on the EGS002 driver, namely the +5V pin (pn 14) for 7805 and the +15V pin (pin 12) for 7812. After testing the IC Regulator, then testing the EGS002 feedback circuit is carried out to ensure the input voltage from the transformer on pin 15. Because if there is no voltage on pin 15, the EGS002 will issue an error sign by flashing the LED on the EGS002 4 times. Figure 5 shows the feedback circuit.

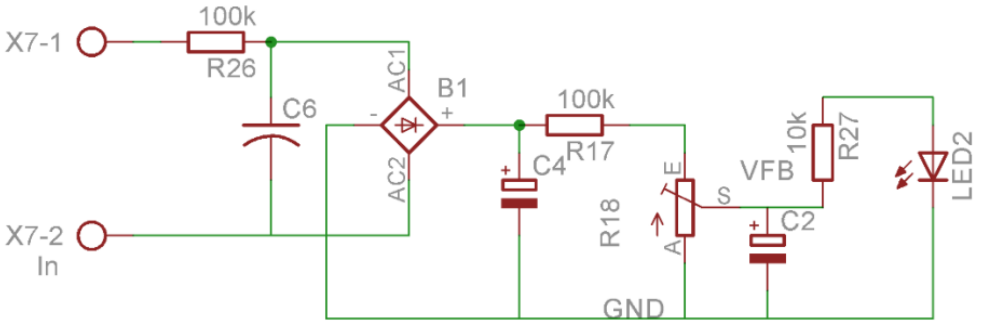


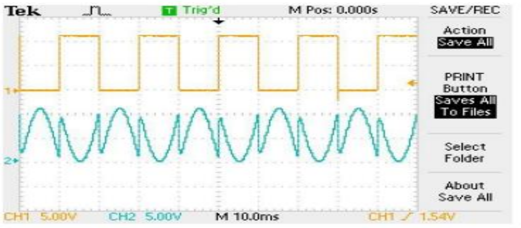
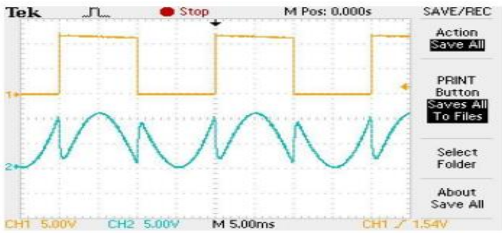
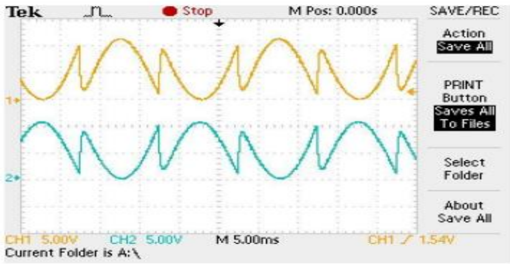
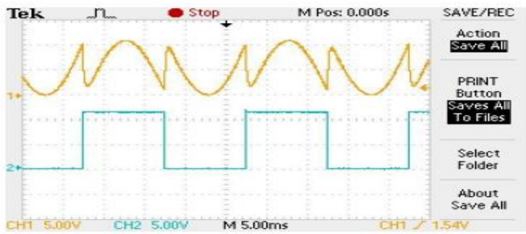
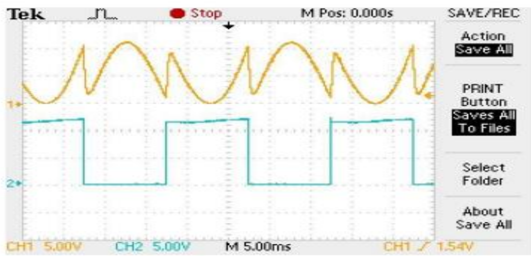
Figure 5. Feedback circuit

It can be seen in Figure 5 that this feedback circuit has the same working principle as the working principle of the diode bridge. Diode bridge or bridge diode is a type of diode that functions as a rectifier of alternating current (AC) into direct current (DC). Diode bridge has 2 legs that are used as input for AC voltage or current while two legs are for output terminals, namely positive (+) and negative (-) output terminals.

Figure 6. Results of testing the feedback circuit on pin 15

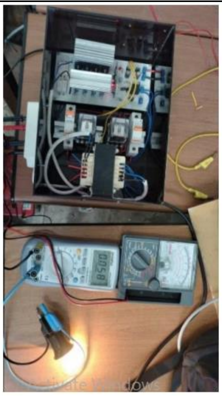
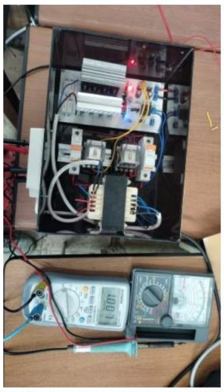
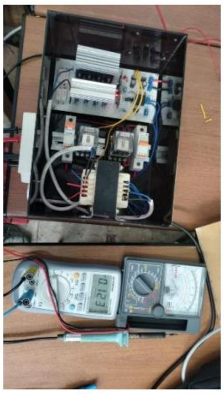
From the results of the feedback circuit testing that has been carried out, the voltage value entering pin 15 EGS002 is 2.978V, which is an ideal value, because pin 15 EGS002 has an ideal range between 2.5V and 3.5V. So when it starts, EGS002 will read whether or not there is a voltage value entering this feedback circuit. After testing the feedback circuit, table 2 shows the EGS002 driver wave test.

Table 2. Results of signal wave testing on pin EGS002

No	Channel 1	Channel 1	Signal waveform
1	Pin 6 (1HO)	Pin 10 (2HO)	
2	Pin 3 (1LO)	Pin 10 (2HO)	
3	Pin 8 (2LO)	Pin 10 (2HO)	
4	Pin 8 (2LO)	Pin 6 (1HO)	
5	Pin 8 (2LO)	Pin 6 (1LO)	

From the test results from Table 2 above, it can be concluded that EGS002 has four pins that can output signal waves, namely pin 1LO (pin 3), 2LO (pin 8), 1HO (pin 6) and 2HO (pin 10). Where each pin has a different signal waveform. And from the results of this test, it can be compared how the signal waveforms are to the four EGS002 pins. Pins 1LO (pin 3) and 1HO (pin 6) always have square waves while pins 2LO (pin 8) and 2 HO (pin 10) always have sine waves but are not perfect. After all circuit testing is complete, table 3 will display the test results of the 1-phase inverter design using EGS002 as SPWM for ATS on PLTS and PLN. This inverter test will be tested with different power or load variations. The test results show that the first experiment used a 25 Watt incandescent lamp load which produced a PLN voltage of 225V and an inverter of 205V, the second test was with a soldering load of 40 Watts which produced a PLN voltage of 225V and an inverter of 170V, the third test was with a fan load that had a power of 46 Watts which produced a PLN voltage of 220V and an inverter of 220V. The last test used a 25 Watt incandescent lamp load and a 40 Watt soldering iron which produced a PLN voltage of 220V and an inverter of 130V.

Table 3. Results of AC voltage output testing on load

No	Inverter		PLN		Inverter Proof	PLN Evidence
	Voltage	Load	Voltage	Load		
1	205 V	25W	225V	25W		
2	170V	40W Soldering Iron	225V	40W Soldering Iron		
3	220V	46W fan	220V	46W fan		
4	130V	25W lamp + 40W soldering iron	220V	25W lamp + 40W soldering iron		

4. CONCLUSION

This study proposes a 1-pass inverter design using ESG002 as a sinusoidal pulse width modulation (SPWM) generator for automatic transfer switch (ATS) in PLTS and PLN. The test results show that the circuit works and the desired voltage value has been achieved. The varying loads on the circuit show that the resulting voltage is able to turn on the load without short circuits or voltage drops and works well.

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