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Uninterruptable Power Supply based on Switching Regulator and Modified Sine Wave

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ABSTRACT

The availability of the electricity in doing a job lead to a dependency on it. If there is a sudden failure on electricity, it will result in unfinished works. To overcome the undesired situation because of wasting time, it is advisable to have your power supply. The power supply can serve to replace electricity temporarily, or it could be as a replacement for power supply of PLN's (State Electricity Company) electricity nets to meet the daily electricity needs. Backup power available can sufficiently replace the source of PLN's electricity nets with the output of square wave to the ordinary electricity needs. The type of the intended power supply is inverter system as a backup system that supplies daily electricity. In this case, it aims to change the DC (direct current) to AC (alternating current) voltages.

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1. INTRODUCTION

Along with the development of the existing electronic devices, electricity is one of the main things that can make a device to work accordingly to its function. However, the occurrence of sudden power failure is a situation that we cannot avoid when we are using electronic devices. In this regard, a tool that can store electrical power sourced from PLN to be distributed to electrical equipments in case of sudden blackout is needed.

UPS (uninterruptable power supply) [1] is an electrical equipment that serves to provide temporary power when the main power fails. The temporary power is sourced from the DC power stored in a battery. Thus in a UPS device, it is provided a circuit that converts the DC voltage from the battery into AC voltage, so that a UPS can supply electricity as a power source out of PLN's electricity nets.

In technology of conversing DC into AC voltage in UPS, the system that is widely used is square wave in the AC voltage output [2]. This system is extensively used because it is easier to make compared to the sine wave system. In some electrical voltage uses for electronic devices such as for computers, lights, radio, player and so on, the power supply voltage with a square wave is not an issue, but the voltage that can be used to run AC motor is a power supply voltage with sinusoidal output wave. If the AC motor is supplied by square wave power source, the motor will not be able to rotate.

Some researchers have conducted research to improve the power of the UPS as performed by Holtz et al. [3] by using the multi transistor on UPS inverter that can add power from the UPS. Wang [4] controlled the integrated gate-commutated thyristor (IGCT) on the inverter by using PWM voltage to increase the output power at the inverter. Saitou & Shimizu [5] increased the output power at the inverter by using the active filter circuit. Research of soft switching inverter arc welding power supply with high-frequency and high-power has been conducted by Ji et al. [6]. Meanwhile, the research on security and stability of PWM technology of high-voltage high-power three-level NPC inverter has been investigated by Liu et al. [7].

Additionally, some researchers have increased voltage output on the inverter as conducted by Schmitt & Sommer [8] by using a three-level NPC inverter high-voltage IGBT based topology. Amir et al. [9] increased the voltage on the inverter by using continuous conduction LCCL series resonant inverter fed high voltage DC-DC converter. Divya & Prabhu [10] used technology Trans-Z-Source to increase the voltage on the inverter.

Thus the universal power supply voltage that can be used for all devices is electrical voltage with sinusoid outputs. On the other hand, a series of DC into AC voltage converter in a UPS usually use ordinary transformer. This makes the price of UPS expensive and the weight of the UPS heavy and it will increase significantly with the increase in power supply capability of the UPS.

Based on the problem, this paper presents a UPS with modified sine output wave, so that the UPS can be used universally for all electronic devices. The circuit and transformer to be used in this UPS unit is switching regulator circuit and transformer that results in cheaper and lighter expect UPS.

2. RESEARCH METHOD

The first step in the design of the system is to make the system in general overview in the form of a block diagram that represents the entire system, where every block has the function of each. Figure 1 shows an overview of the system in the form of a block diagram.

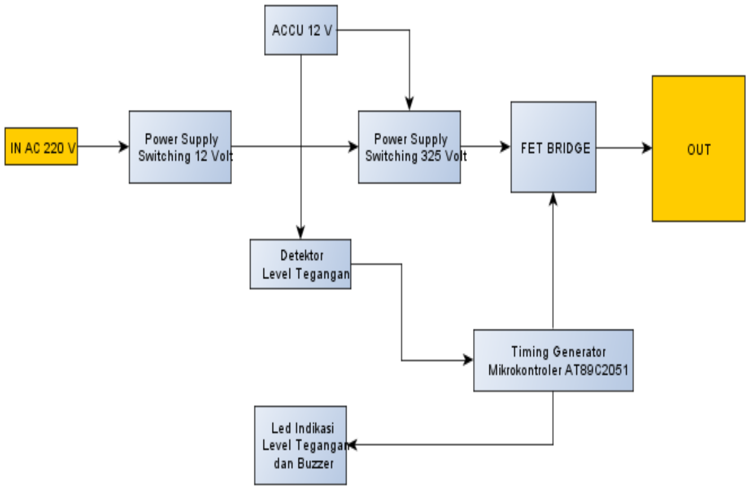

Figure 1. Block diagram of the system

UPS unit to be created is a UPS direct system. The advantage of this system is the absence of resource transfer pause from electricity to battery or vice versa when the electricity goes out and back to life. Power switching regulator functions as both to charge the battery and simultaneously supply DC 12 to 325 Volt DC switching. This is what makes the UPS a direct system.

Voltage converter from DC 12 to DC 325 Volt is used as a voltage source for output. Voltage of 325 Volt is an effective voltage when it has been converted into AC voltage, the effective voltage of 325 Volt will be the RMS voltage that is equal to 325 divided by the root of 2, or 325 : 1.414 = 229 Volts.

FET Bridge will function as a switch flipping through 325 Volt DC voltage in which the control is sourced from modified sine generator. Thus the output of the FET Bridge will be AC wave with a modified sine form. Battery voltage detector circuit is used to detect the battery voltage level. The battery voltage level information is given in the form of led light and buzzer sound when the voltage is below normal.

2.1. Hardware Planning

Hardware design refers to the design of the system by taking into account the characteristics of the component. The design is divided into sections of the circuit, where the design is realized with a series of pictures and descriptions that support.

2.1.1. Series of Power Supply Switching 12 Volt

The main components of the switching power supply 12 Volt is UC IC 3842 which is IC Current Mode Controller by Motorola. In stabilizing the voltage at the output, the work process of the IC is to detect the current flowing in the primary coil of the transformer through the intermediary feet source of FET driver. Any changes that occur is compensated by IC into PWM signal issued to the Gate feet of the FET.

To control the voltage output generated by the power supply voltage not to exceed the set, opto coupler is paired on the output voltage readings and the results are given in the feedback voltage input from the 3842 UC IC. Figure 2 is show a schematic of a power supply switching circuit of the 12 Volt

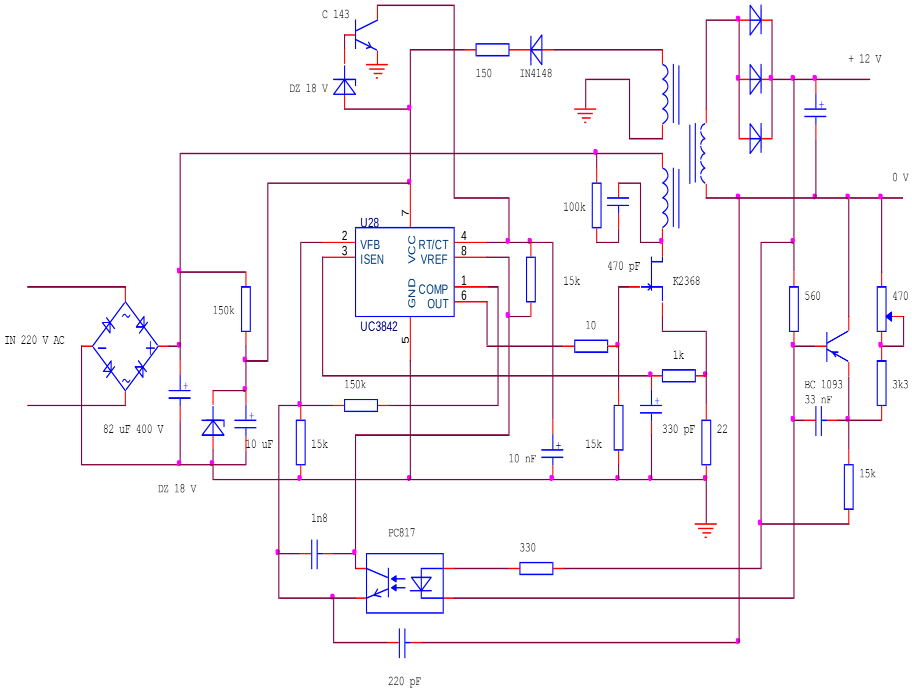

Figure 2. Power supply switching circuit 12 Volt

Transistor 1093 BC at the output functions as led driver in the opto-coupler. Led in the opto coupler is lit when the output voltage exceeds the limit. This led flaring will create photo transistor which delivers and provides increased voltage at the feedback input IC UC 3842. This will make IC UC 3842 reduce the level of PWM fed in FET driver transformer.

Output voltage rectifier used is half wave rectifier because the frequency of transformer is considerably high, so that the density of the voltage pulse charging the grader capacitor is very tight. However, it is advantageous to use of the output capacitor because to stabilize output voltage, capasitor with small capacity is sufficient to use.

2.1.2. Power Supply Switching circuit 325 Volt

As in the previous series, the main components of the power supply switching circuit with the output voltage of 325 volts is also using IC, just with a different series, which is TL 494 C. Figure 3 is the circuit from the power supply.

The main difference with the previous series is in terms of input and output voltages. In the previous series, the input voltage is sourced from 220 Volt AC power and the output voltage is at the level of 12 Volts in other words is a step-down power supply. While in the circuit presented in this paper is a step-up power supply, later it will be converted into AC 3 phase voltage with modified sine output wave.

Generally, the work principle of both circuits are the same, the difference is just opto coupler is not used for this circuit as the excess voltage divider or the output voltage stability setter, but uses current fluctuation reader that enter into the IC that goes into VCC. Thus any change in the value of current at the input will be compensated by the IC in PWM setting that is given to the FET driver transformer, and the IC will keep output voltage stable.

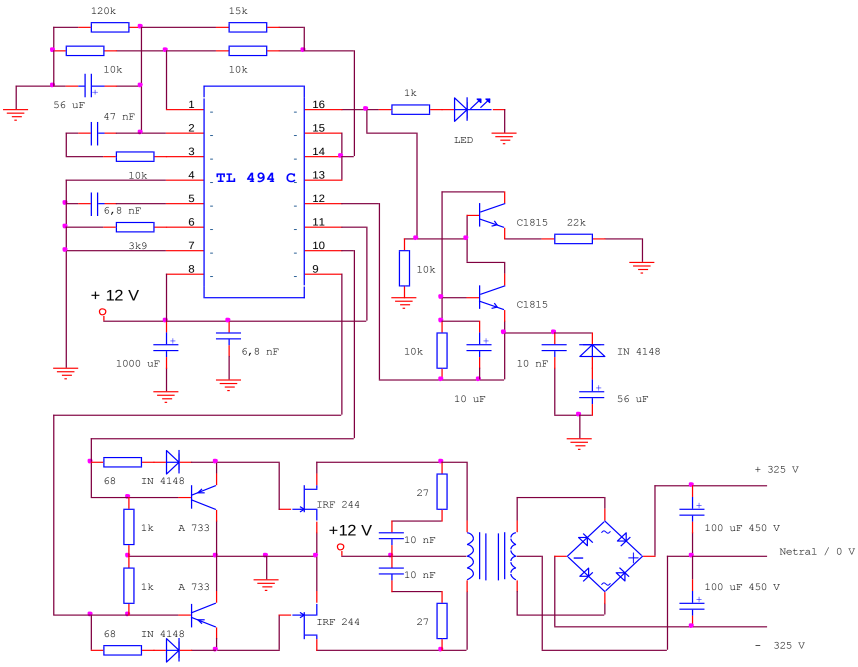

Figure 3. Power supply switching circuit 325 Volt

2.1.3. Voltage Level Detector Circuit

Voltage level detector circuit is built by using comparator IC LM 393[11], [12]. The output of this circuit will be given to the microcontroller as information to the microcontroller whether the input voltage is in normal condition or not. Under normal conditions namely in which there is electrical current or battery is fully charged, then the circuit will provide a high logic to the microcontroller and the microcontroller will turn on the LED lights green to indicate that the UPS ok.

When there is an electricity failure and as a result of the use of the UPS battery voltage is going down, then the voltage level detector circuit will provide low logic on the microcontroller, and the microcontroller will turn off the control on the FET Bridge, turn on the red LED lights and sounding the buzzer. Below is the circuit of voltage level detector.

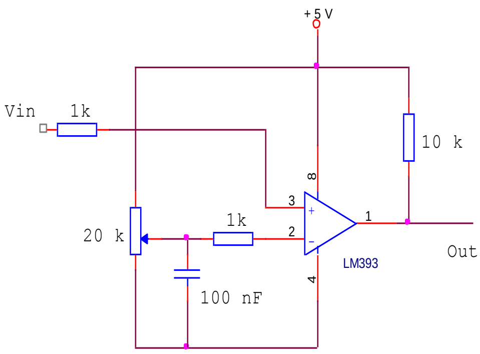

Figure 4. Voltage level detector circuit

Vin input is sourced from the positive supply batteries. Vin input will always be compared to a reference voltage which value has been set at a certain value by a variable resistor. When Vin value is above the value of the reference voltage, the comparator output will always have high values. When the Vin value is below the reference voltage, the comparator output will have low logic. The output of this circuit will be given to the microcontroller.

2.1.4. Minimum Microcontroller System AT 89C2051 circuit

Microcontroller AT89C2051 requires a clock signal generated from the internal oscillator by using of 12 MHz crystal and two capacitors 30 pF to operate. Reset circuit consists of resistor 10k and capacitor electrolyte 10 µF / 10 V. System reset on AT89C2051 is active (high) with the understanding if given logic 1 then the circuit will be reset. The circuit of minimum system microcontroller AT89C2051 for this tool can be seen in Figure 5.

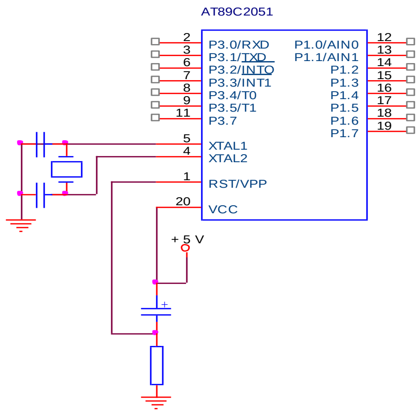

Figure 5. Microcontroller minimum system AT89C2051 circuit

2.1.5. FET Bridge circuit

FET bridge circuit is a circuit that is directly related to the load attached to the UPS, thereby attached FET should have the ability to deliver large currents. Figure 5 shows the FET bridge circuit.

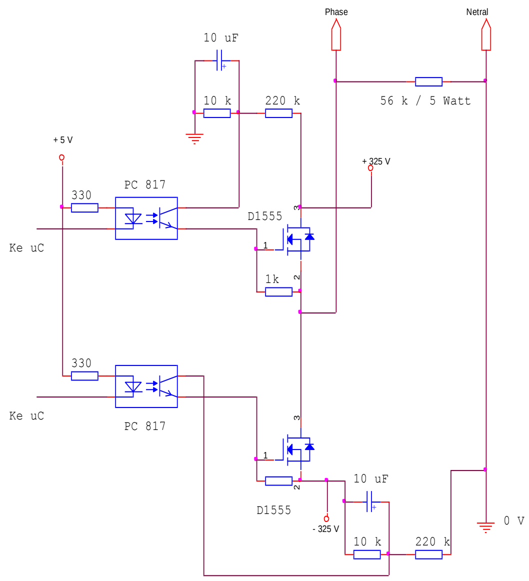

Figure 6. FET Bridge circuit.

Output phase is driven by two FETs that both work oppositely and interchangeably to deliver positive or negative supply. FET ignition or activation signal is provided by the microcontroller, and it is the microcontroller that will decide the activation timing differences out of each of the FET combination, thus forming an electric output signal in phase with frequency about 50 Hz in the form of modified sinus. To insulate between the microcontroller circuit as a control FET Bridge which both have difference in working voltage that is 5 Volt for the microcontroller and 325 Volt for the FET bridge opto couplers is used

2.2. Software Design

The work function of a microcontroller on a UPS circuit is conducting simple controls that is to control the ignition time in the FET bridge circuit so as to form the distribution of 3 phase voltage at the output, to read input from the voltage level detector, to give action on any input given by the voltage level detector circuit.

The initial step of the program is to conduct initialization on the usage of pins and memory of the microcontroller followed by the initialization of timer that will be used to set the FET bridge initiation time. Subsequently, the program will perform reading of the signals given by the voltage level detector circuit. When the voltage is ok, the microcontroller will perform the control on the ignition on the circuit of FET bridge and activate indication light of secure input voltage level.

When the input voltage shows the down level, the microcontroller will stop control at the FET bridge followed by lighting Led with red indication and sounding buzzer. The control uses fuzzy algorithm control invented by zadeh that has been used for path planning decision making [13-15] and is used to control quadrotor [16-18]. Below is the flow chart of a program that will be loaded into the microcontroller.

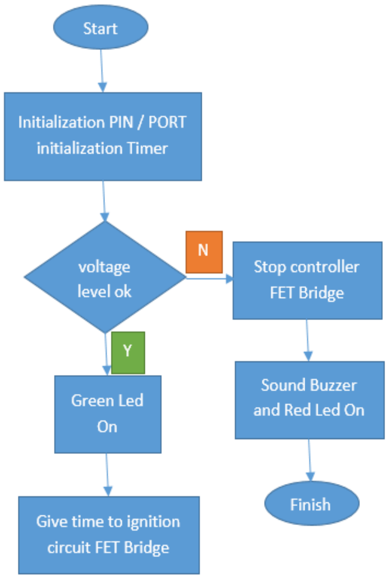

Figure 7. Program on Microcontroller Flowchart.

3. RESULTS AND ANALYSIS

UPS system with the modified sine wave output, before assembled into the whole series, firstly, part by part is tested to determine whether the parts of the circuit works well or not. Having tested, the parts are then assembled to be unity and integrated with the software by downloading the program into the main controller that is the microcontroller. From the test results as parts or as a whole, the author will present the experimental results and the discussion in this chapter. The description of the experimental results of the study will be started from the test on sub series process, and then the test of the entire tools.

For software testing, to determine whether the software is made in accordance with the pre-designed flow chart or not, it can be seen in the overall tool test, in this case it means that the software testing is in one part of the tool test as a whole. The following is the description and analysis of the test results.

3.1. Test Results of Power Supply Switching 12 Volt Circuit

The results of the measurement of the output voltage power supply switching 12 volt is 14.2 Volt. It can be said that the power supply circuit is in accordance with the needs, of which this voltage can conduct the process of batteries charging with 12 Volt working voltage.

3.2. Test Results of Power Supply Switching 325 Volt Circuit

By using the same measurement method as in the previous series, the measurement results obtained on this circuit voltage is 327 Volt. This voltage value is 2 volts above the voltage supposed to be but it is not considered large that is below one percent. This value is still tolerated and the circuit is considered to function properly.

3.3. Test Results of Voltage Level Detector

Input voltage Variations supplied to the voltage level detector circuit are about 10 to 15 Volt. From this range, thepre-determined variations voltage are set at 10, 11, 12, 13, 14 and 15 Volt. Circuit expersion is given in the form of LED light mounted on the output. For additional measurement data, voltage values at the output voltage that occurs when the LED on or off are added. Table 1 is the test table of the voltage level detector circuit.

Table 1. Test results of voltage level detector circuit.

No.	V (in) (Volt)	LED	V (out) (Volt)
1	10	On	0
2	11	On	0
3	12	On	0
4	13	Off	4,9
5	14	Off	4,9
6	15	Off	4,9

LED output condition is on when the input voltage is at 10, 11 and 12 Volts. The output voltage in this condition is at 0 volt. While the condition of the LED output is off when the input voltage is at the level 13, 14 and 15 Volts. The output voltage value in this state is 4.9 volts. The conclusion of this test is the voltage level detector circuit will provide low logic (0) to the microcontroller when the battery voltage is at or under 12 Volts, and provide high logic (1) when the battery voltage is above 12 volts. With the value of the binary logic, the microcontroller can receive information about the batteries condition. This condition states that the voltage level detector circuit is functionable.

3.4. Test Result of Minimum circuit Microcontroller System AT89C2051 Circuit

By inputting a program that can make the I/O pins on the microcontroller having logic 1 and 0, the test is carried out. Below is the table of the test results of pin I/O microcontroller when given program to make all the pin having logic 0 and 1.

Table 2. Test results of minimum microcontroller at89c2051 system circuit.

No. Pin	Program set 1		Program set 0	
	P1	P3	P1	P3
0	4,9 Volt	4,9 Volt	0 Volt	0 Volt
1	4,9 Volt	4,9 Volt	0 Volt	0 Volt
2	4,9 Volt	4,9 Volt	0 Volt	0 Volt
3	4,9 Volt	4,9 Volt	0 Volt	0 Volt
4	4,9 Volt	4,9 Volt	0 Volt	0 Volt
5	4,9 Volt	4,9 Volt	0 Volt	0 Volt

The Table 2 above shows that the expression of logic function of all I/O pins on the microcontroller is functioned properly. Voltage value of 4.9 Volt is a voltage value that is considered to represent logic 1 or higher and 0 Volt represents logic 0 or low.

3.5. Test on circuit Buzzer

Buzzer driving circuit is constructed by using a transistor that functions as a switch controlled by a voltage sourced from a microcontroller. To activate the buzzer, the micro will send low logic to the input of buzzer driving, and high logic to deactivate it. Thus the test process of this series is to provide low or high values on input and observe the buzzer conditions mounted as a load. Figure 8 below is the test scheme of the circuit buzzer.

The Table 3 shows that when the circuit is given logic 0, the buzzer sounds and when the circuit is given logic 1, the buzzer does not sound indicating that the buzzer driving circuit works well.

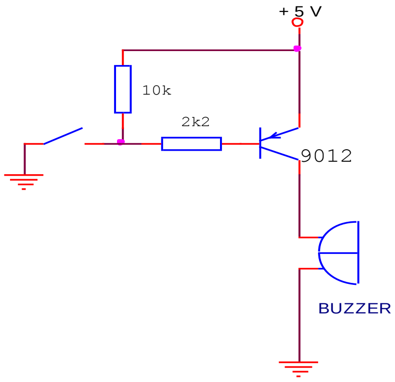

Figure 8. Buzzer circuit test Scheme.

Table 3. Buzzer circuit test data.

Input values	Buzzer condition
5 Volt/Logic 1	No Sound
0 Volt/Logic 0	Sound

3.6. Test on 5 Volts Regulator

The power supply voltage required by the microcontroller circuit is 5 volts, while the power supply for the circuit is from a battery that has the output voltage of 12 Volts. This requires a series of voltage reducer from 12 volts to 5 volts. The main component is the IC LM 7805 that is shown in Figure 9. The following is the scheme of the regulator circuit with the points where the output voltage measurement is conducted.

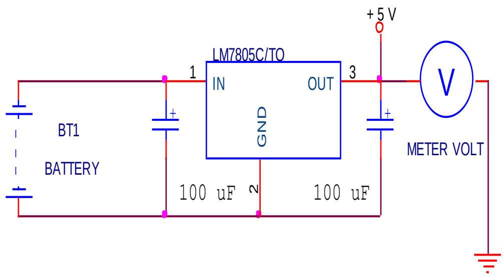

Figure 9. Measurement of the power supply circuit.

From the results of measurements carried on the power supply circuit, it is obtained 5.1 Volt. From the data it can be concluded that the power supply circuit regulator works well, because the voltage is the work voltage areas of the microcontroller used.

Table 4. Measurement of regulator circuit.

Measurement of voltage	
Input IC 7805	Output IC 7805
14,2 Volt	5,1 Volt

3.7. Test on FET Bridge Circuit

Instructions to activate the FET on the FET bridge circuit is provided by the microcontroller with interface in the form of opto copler. To enable FET, opto copler is given a value of 0, and logic 1. Logic 0 is equal to the voltage of 0 Volt and logic 1 is equal to the voltage of 5 volts. Table 5 below is the table of test results in FET bridge circuit.

Table 5. Test result of fet bridge circuit.

Voltege to OC	Positif Side	Negativ Side
5 Volt	0 Volt	0 Volt
0 Volt	+ 320 V	- 320 V

When high logic or 5 V is given in OC (opto coupler), the voltage value measured on the positive and negative side is 0 Volt. And when it is given low logic or 0 voltage Volt, the value of the positive side is +320 Volts and the negative side is - 320 Volt. This condition states that the FET bridge circuit is functioned well, in this case, the FET can connect or disconnect in accordance with the instructions that is given by the microcontroller.

3.8. Test on the Overall Circuit

Overall tools test means testing tools after the program and hardware are integrated. It can also be interpreted as to test the software whether it is in accordance with the plan or not. Table 6 below is the table of observations data from the test tool.

Table 6. Observation data of tool test

No	Action	Event
1	The tool is turned on and connected to the power source 220	Motor ac on, battery indicator with green light is on, buzzer off
2	Connectors to the electricity sources are disconnected	Ac motors at the load is on, battery indicator with green light is on, buzzer off
3	Condition without electricity resources is continued	Moments later the green light indicator is off, replaced by red, ac motor load is off and the buzzer sounds
4	Connecting the electricity sources	Ac motors on the load is on, battery indicator with green light is on, buzzer off

The analysis that can be drawn from the table are as follows. Number 1 indicates that the tool works where the output voltage is able to activate the load. Currently all condition is normal, marked by the green LED on and buzzer off.

From number 2, the value of the angle obtained is 119.7 degrees, this is because the value of the output of the microcontroller is in digital form not analog and in certain areas, the analog value cannot be reached by the binary digital value precisely. Accuracy up to several decimal places in the binary digital is indeed possible, but this requires greater programming. Phase value of 119.7 degrees can be tolerated in the electrical system because even in the electrical plant, the phase difference between each other is not always precisely 120 degrees. The value that does not fit in the range below 1 degree is considered good.

The actions number 3 and number 4 were conducted to test whether or not the UPS system is functioned. When the electricity sources was disconnected, the UPS systems directly took resources from the batteries indicated by ac motors on the load still on. In a few moments (action number 4), power batteries was decreasing resulted in a decrease in the supply voltage of the batteries. When battery voltage is at the bottom limit, ac motor was off, the red light indicator on and the buzzer sounds.

When these conditions occur, the action number 5 is proceeded that is to reconnect the UPS to the source of electricity and the condition is back to event number 1. And the process of charging batteries is performed by power supply switching 12 Volt circuit.

From the results of overall test tools, it can be concluded that UPS series of tools and the program in the microcontroller is considered works well and in accordance with what has been planned at the beginning of the study

4. CONCLUSION

A number of conclusions that can be drawn from a series of work that has been conducted in this study are as follows: Modified sine system is square wave generation system which the patterns resemble the shape of sine wave patterns and can be used well as the output of the alternating voltage generator with characteristics resemble the original sine wave. Model of power supply switching circuit used is a model of FET driver and FET push-pull. The use of power supply switching system is to reduce the cost and weight of the UPS unit. By using the FET bridge that the on/off timing is controlled by the microcontroller, the conversion of DC to AC voltage by FET bridge circuit can occur. On the other hand, the microcontroller which has a base time in the order of micro-seconds can set the timing and the inter-phase angle narly accurate. By bringing together parts of the circuit as well as the proper programming, the UPS circuit can be realized well.

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