Design and Prototyping Single-Phase Inverter with Arduino Nano

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***Abstract*— Across the year, the needs of Indonesians in the use of electronic equipment are increasing, which results in higher electricity usage. Because most of the electricity load uses AC power, in the application of a DC power source such as solar cells, an inverter that converts DC to AC power is needed. Therefore, the inverter is one of the tools that are widely developed in power electronics. The output voltage from simulation and real hardware is a sine wave with some distortion due to lack of filter; therefore, there occurs a harmonic. The voltage and frequency were also measured with a multimeter. The result shows that both voltage and frequency are closed to the design specification which is 220V 50Hz with the voltage and frequency difference of 1.09% and 0.4%, respectively.**

Keywords—Inverter, SPWM, MOSFET

I. Introduction

The increasing development of the industrial world in various fields is certainly able to make human life easier. In line with the rapid industrial progress, the need for electricity as a source of energy in industrial operations is also increasing. Electrical energy can be obtained through many electric power plants. Fossil resources are still widely used for fuel generation. For example, coal-fired power plants are still the main power plants with up to 57.2% of the total power plant in Indonesia [1].

Based on geographical location, Indonesia actually has the potential for the development of solar power to achieve the average power of 4kWh/m2. In the western Indonesia region, the spectral power distribution is around 4.5kWh / m^2/ day with 10% monthly variation and around 5.15kWh / m^2/ day with a monthly variation of 9% in eastern Indonesia [2].

In recent years, the need for independent electric power systems has increased. The increasing demand for uninterruptible power supply and consuming fossil fuels has become a reason to switch to the renewable energy sector. Solar energy is one of the renewable sources that can contribute to excess energy demand [3]. The conversion of solar energy into a form of electrical energy to run appliances, especially household appliances, is by using an inverter [4] [5].

In a solar power plant, solar panels are used to convert sunlight into electricity. Solar panels do not emit harmful greenhouse gas emissions as in burning fossil fuels, so the use of solar panels does not contribute to the impact of climate change. The energy output from the solar panels is in the form of DC electricity. Because most of the load uses AC electricity, a device is needed to convert DC voltage to AC, known as an inverter. Therefore, the inverter is one of the tools that are widely developed in power electronics. Inverters also have an important role as backup power providers in vehicles and at home. Batteries that are used as energy storage media certainly require an inverter to convert direct current into alternating current so that it can be used.

The inverter is made using the PWM method as a DC voltage converter which is converted to AC voltage. Analog PWM control requires a reference signal generator and a carrier that feeds to the comparator will produce an output signal based on the difference between the signals. The reference signal is a sin and is at the desired output frequency. The use of this method is because it is more practical and economical to implement and lower harmonic distortion at the output voltage.

This paper is organized as follows. Section II presents the theoretical review of single-phase inverter. In section III, the simulation results are discussed. Finally, the conclusion is in section IV.

II. Single phase Inverter

The inverter is a power electronics circuit that is used to convert a direct DC voltage into an AC voltage. The inverter is the opposite of the adapter which has the function of converting an AC voltage into a DC voltage. There are several inverter typologies, ranging from inverters that only produce alternating voltage, push-pull inverters, to inverters that can produce pure sine voltage without harmonization. In addition, inverters can also be classified into several parts based on the phase, ranging from single phase, three phases, to multiphase. Fig. 1 shows the output waveform of a three-phase and single-phase inverter.

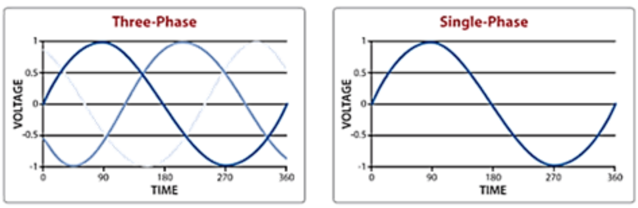

Figure 1. Output of 3 Phase and 1 Phase Inverter [6]

In the inverter circuit, there are several important components used such as semiconductor switches, inductors, capacitors, and resistors. The switch used for the inverter must have a fast response to change from the off state to or vice versa. Therefore, a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) type inductor switch is used. An inverter is said to be ideal if the output voltage waveform is purely sinusoidal.

In this study, an inverter with a Full H-Bridge topology is proposed. Full H-Bridge inverter topology is like Half-Bridge but uses four switches, shown in Fig. 2. There are two-cycle to make an upper and lower side of the sine wave. Switches S1+ and S1- cannot be closed to each other. The first cycle, Fig. 3, in the Full H-Bridge topology switches S1+, in this case, MOSFET 1 and S2- in this case, MOSFET 2 closed simultaneously. While the other switch is open. The current flow is illustrated as the arrow.

The second cycle in the Full H-Bridge topology switches S1- in this case, MOSFET 4 and S2+, in this case, MOSFET 3 closed simultaneously, depicted in Fig. 4. While the other switch is open. Current will flow in as the direction of the arrow in Fig.4, and a -Vdc voltage is formed in the load.

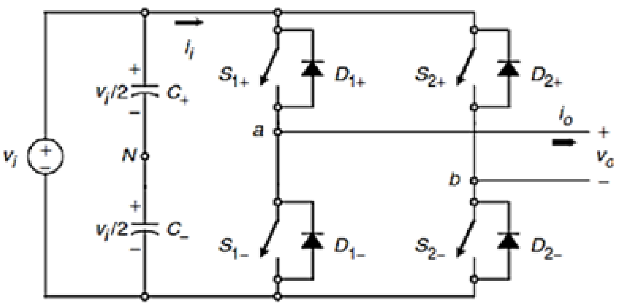
Figure 2. Full H-Bridge Single Phase Inverter [7]

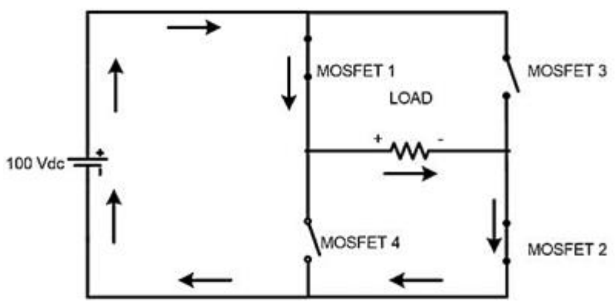

Figure 3. Cycle Up Full H-Bridge [8]

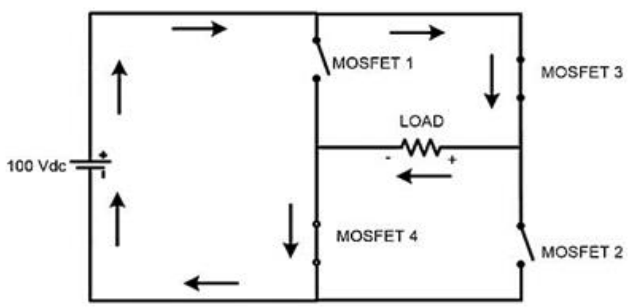

Figure 4. Down Cycle Full H-Bridge [8]

Full H-Bridge Topology is the most common topology used in inverters. The resulting output voltage is the same as the input voltage but requires four switches which of course increases power losses.

At the inverter output, the total harmonics can be reduced by the SPWM method [9]. Harmonics in the unfiltered inverter, there are high-frequency wave defects. However, this does not apply to square wave output. PWM offers a solution to control the output voltage and amplitude. The control process, through waveform modulation, reduces harmonics. In the bipolar switching method, the form of control requires a carrier signal or a triangular wave.

PWM can be said to be a manipulation technique in signal wave processing that uses the principle of switching, namely setting the wave signal in an off and on state. Bipolar modulation produces an output voltage between two values, namely Vdc- and Vdc+. The switching cycle uses only one input signal that passes through the note logic gate to control two switches in each cycle. While unipolar modulation uses two input signals to control the switch. This modulation has three output voltages, namely Vdc+, 0, and Vdc-. Thus, the resulting output voltage will be more accurate than bipolar modulation. The SPWM waveform in bipolar modulation is illustrated in Fig. 5.

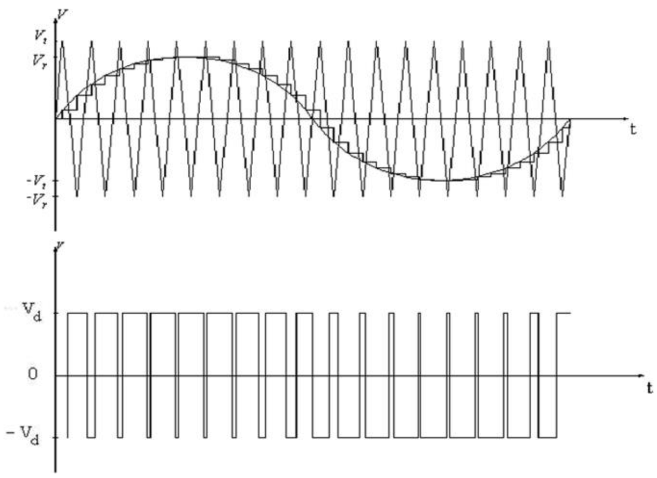
Figure 5. SPWM signal [10]

III. Design and Prototyping of Single-phase Inverter

The design is done in Proteus which is later simulated to get the desired output. After that, the hardware prototyping is done. The feedback control system is applied in the proposed inverter to maintain the output voltage when the load is connected. Figure 6 shows the block diagram of the control system used. The voltage output is measured and send back to the controller to determine the duty cycle of PWM. The detailed design is shown in Fig. 7.

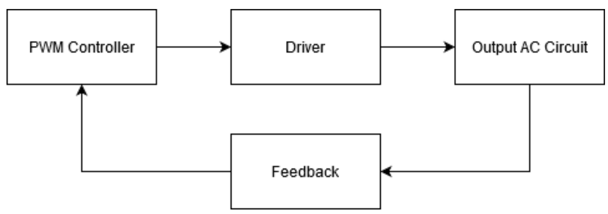

Figure 6. Block diagram of the inverter feedback control

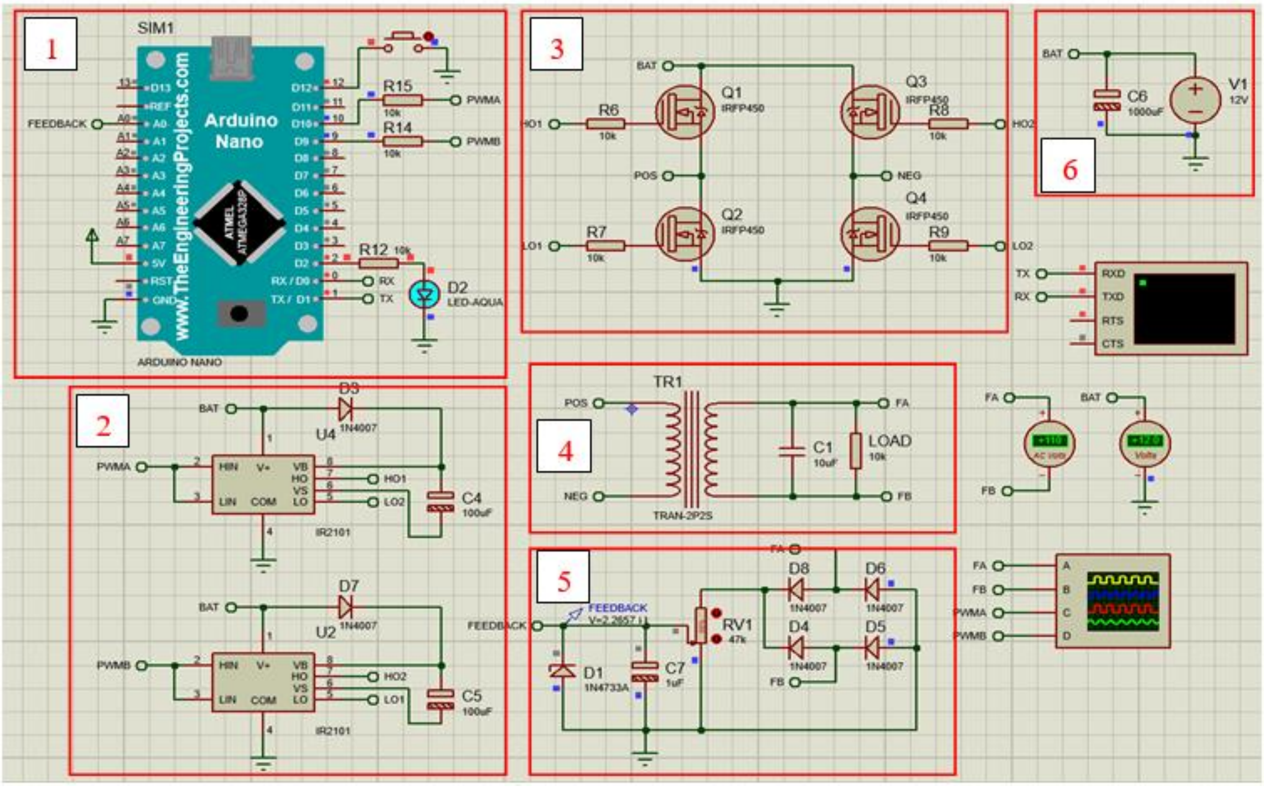

Figure 7. Design of single-phase inverter in Proteus

There is some sub-system in Fig. 7 which are: (1) controller; (2) driver circuit; (3) Full bridge single phase inverter; (4) transformer step-up; (5) sensor feedback; (6) DC input. Whereas the rest is the monitoring system. In this schematic, Arduino will send an SPWM signal from 2 PINs to 2 MOSFET Drivers, then the 2 MOSFET Drivers will adjust the speed of the MOSFET switch which is in the Full H Bridge circuit.

After the 12V DC current is converted into a 12V AC current, the AC current is then connected to a 12V-220V step-up transformer. And ready to be connected to the load/wear. In addition, so that the voltage does not drop when it is loaded, there is a feedback system. This feedback system reads the value of the output voltage when it is loaded and adjusts to a fixed voltage of 220V (by setting the SPWM controller on the Arduino). To read the output voltage value, the output voltage from the step-up transformer needs to be converted to DC with a rectifier, from the rectifier it is then connected to the voltage divider with a resistor and connected to the Arduino A0 Analog pin to be read using the ADC process and used as feedback. When the expected results are obtained from the simulation, then it continues to assembly the system in real hardware. The hardware implementation can be seen in Fig. 8.

IV. Results and Discussion

The simulation result is shown in Fig. 9. It is seen that the half-wave of the output voltage of 110 V. The peak-to-peak voltage of this AC waveform can be measured by counting the box vertically in the oscilloscope and multiply it by the Volt/Div value, from the oscilloscope setting we know that the Volt/Div value is 20V. There are 11 vertical boxes, where the per box has a voltage of 20V. So, the voltage output on the inverter is 220VAC.

Based on the output waveform on the Oscilloscope in Fig. 9, the frequency value of the inverter output is determined by measuring the period of each full wave. From the oscilloscope setting it is to know that the Time/Div of the inverter output is 2ms. There are 10 boxes horizontally everyone has full waves. This means the period T of the inverter output is equal to 0.02s. Therefore, the frequency of the inverter output is 50Hz. The output AC waveform in real hardware is in Fig. 10.

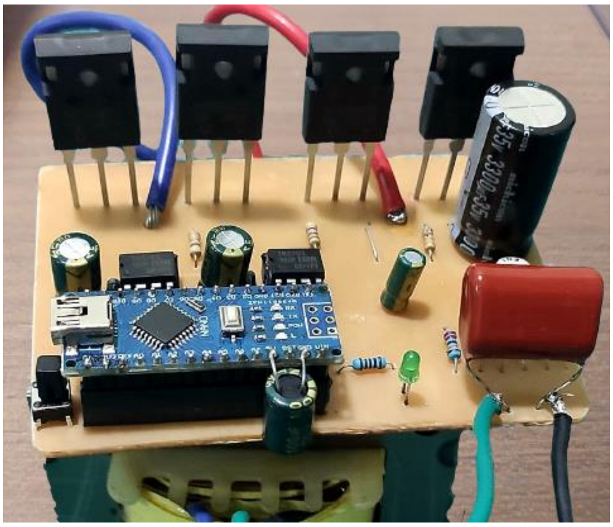

Figure 8. Inverter Schematic from 12VDC to 220VAC

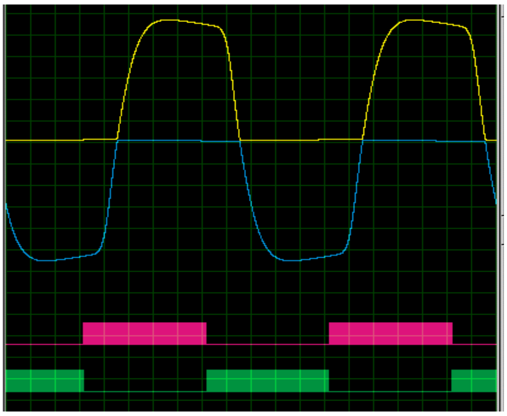

Figure 9. Input and Output Waveform on Proteus

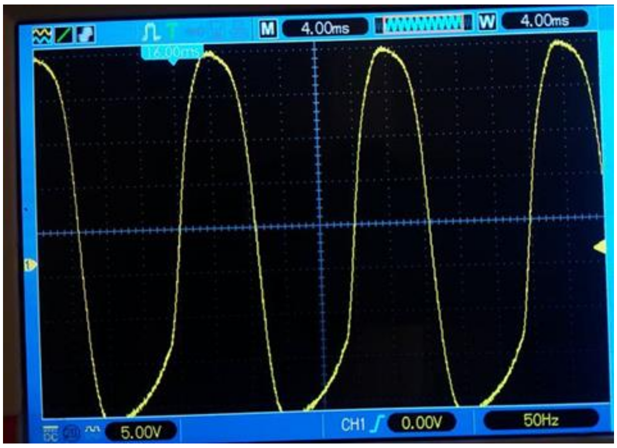

Figure 10. Output AC waveform in real hardware

Figures 9 and 10 prove that the system can work well which gives the sinusoidal output from DC input. To validate it, the multimeter was also used to measure the voltage and frequency output. The result is shown in Fig. 11 and 12. It is seen that both voltage and frequency are closed to the design specification which is 220V 50Hz with the voltage and frequency difference of 1.09% and 0.4%, respectively.

Figure 11. Output voltage measured by multimeter

Figure 12. Output frequency measured by multimeter

V. CONCLUSION

The proposed single-phase inverter with feedback control to maintain the output voltage has already been designed and tested in both simulation and hardware implementation. The output voltage from simulation and real hardware is a sine wave with some distortion due to lack of filter; therefore, there occurs a harmonic. The voltage and frequency were also measured with a multimeter. The result shows that both voltage and frequency are closed to the design specification which is 220V 50Hz with the voltage and frequency difference of 1.09% and 0.4%, respectively. For future work, the proper filter must be designed better to get the pure sine wave output. The harmonic measurement also needed to know the detailed harmonic value.

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