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Arduino Nano Based SPWM (Sine Pulse Wide Modulation) Single Phase DC to AC Inverter

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***Abstract* – In off grid photovoltaic systems, the DC voltage from PV or batteries must be converted into a sinusoidal AC voltage that matches the AC voltage at home. The problem is that inverters available on the market are expensive. The problem can be solved by making your own SPWM (Sine Pulse Wide Modulation) inverter. This paper discusses the solution to this problem is with making a single-phase SPWM DC to AC inverter with Arduino nano, MOSFET driver IR2110, with full bridge MOSFET with LC filter and step up transformer. Existing Research Objectives, when compared with previous researchers, the existing research gap is that they use half bridge switching, while our research uses full bridge switching. The method used is a single-phase SPWM inverter with a full-bridge MOSFET in the form of design (hardware and software) and testing of AC output voltage, output power, frequency, calculating efficiency. The SPWM inverter section consists of: SPWM signal generator with Arduino nano, Arduino sketch software, MOSFET driver, full-bridge MOSFET switching inverter, LC filter, step up transformer, feedback transformer, SMPS variable voltage power supply. This single phase SPWM inverter is made using 8 pieces of 171A 150V MOSFET, the test results show that when the dc voltage is changed between 21Vdc to 30Vdc the output ac voltage is around 219 Vac to 228Vac, the frequency of the inverter is also stable at 50 Hz, with an average efficiency of 88.36%.**

Keywords: Inverter, arduino nano, SPWM, mosfet full bridge.

I. INTRODUCTION

In an off-grid solar power system, we need to convert DC voltage into 220V AC using an inverter. The problem is that commercially available inverters are expensive. As electronics control hobbyists, to apply our knowledge, we want to build a more affordable inverter using an Arduino Nano controller. Several studies on SPWM inverters have been conducted by previous researchers.

An inverter is a circuit that converts Direct Current (DC) into Alternating Current (AC). Inverter input is taken from various DC sources such as batteries, photovoltaics, fuel cells, alternators, etc. There are two types of circuits used in single phase inverter circuits, namely half-bridge and full-bridge configurations. Inverters have been widely used in a variety of applications, ranging from small switching power supplies for computers to large electric utility applications for transferring large amounts of power. Farhana et al. (2020), in their research, designed, simulated, and built a single-phase inverter consisting of a full-bridge switching circuit, a microcontroller, and an LC filter. The experimental results of the inverter were able to produce an output voltage of 220V AC at 50Hz [1].

There are square wave inverters, modified square wave inverters, and pure sine wave inverters. Among these three types of inverters, the most efficient and suitable for all loads is the pure sine wave inverter which has an output voltage with a pure sine wave. Implemented a single-phase half-bridge inverter using an Arduino Nano. It is more economical, efficient, and reliable and can be used for low-power applications. The experimental results of the inverter were able to produce an output voltage of 230V AC at 50Hz [2].

This type of inverter can provide voltage supply to inductor loads or electric motors with excellent power efficiency. An experiment about a single-phase HERIC SPWM (High Efficient and Reliable Inverter Concept Sinusoidal Pulse Width Modulation) using a full-bridge IGBT. The system utilizes a sinusoidal signal from the power grid and a sine-to-PWM converter to ensure synchronization. Their research results showed that a 311V DC voltage could be converted into a 220V AC output [3].

Arduino can generate pulse width modulation (PWM) signals to control components such as MOSFETs or ICs, to convert DC input into high frequency AC signals. This high-frequency AC signal is then passed through a low-pass filter to remove harmonic components and produce a pure sine wave output. The driver circuit amplifies and shapes the PWM signal from the microcontroller to effectively control the power switch (MOSFET or IC) in the inverter circuit. The power stage, consisting of these power switches, converts DC input to AC output by controlling the current flow through the output transformer and filter. A. Kumar et al. (2023), in their research, developed a single-phase inverter using an Arduino Uno controller to control MOSFET switching. The experimental results showed that the inverter could produce an output voltage of 220V AC [4]. Implemented a single-phase inverter to support a generator, using an ESP32 controller and a fuzzy logic system to control the MOSFETs. Their research results showed that a 12V DC voltage could be converted into 230V AC at 50Hz using a step-up transformer [5].

Power inverters are usually implemented using an H-bridge, so an explanation of the output voltage from the H-bridge is needed as a function of the modulation signal. The transfer function of the Pulse Width Modulation (PWM) model varies when different carriers and modulation techniques are used. Inyama et al. (2023), in their research, implemented a single-phase half-bridge inverter using an Arduino Nano in a renewable energy system. The experimental results showed that the inverter could produce an output voltage of 220V AC with good harmonic quality [6].

The output is generated with various DC levels based on the correct sequence of switching on and off the devices to achieve AC voltage, and the fundamental component of the output voltage is increased by reducing high-level harmonics. Venkateswarlu et al. (2023), in their research, conducted an experiment to develop a single-phase full-bridge inverter with 3–9 level PWM, resulting in improved harmonic performance [7].

The main components of an inverter are SCR, transistor or MOSFET, all of which are semiconductor components that function as switches. Research about developed a single-phase inverter using a full-bridge MOSFET controlled by an Arduino Uno. The experimental results showed that the inverter could produce an output voltage of 220V AC at 50Hz [8].

The use of a transformer in this inverter design is to distribute power from low voltage to high voltage. The transformer used is a transformer with an iron core. Sujanarko et al. (2018), in their research, developed a single-phase inverter using a full-bridge MOSFET controlled by an Arduino Uno, with an output utilizing a step-up transformer. Their research results showed that the inverter could convert a 12V DC input into a 220V AC output with a power capacity of 100 watts [9].

Inverters with low output voltage harmonics are widely used in renewable energy applications today. Wicaksono et al. (2023), in their research, developed a five-level inverter using an Arduino Uno controller and an LC filter. The research results showed that the output voltage harmonic distortion (THD) was 3.96%. [10].

The filter design in this inverter circuit uses an LC filter circuit. A. Syururi et al. (2022), in their research, developed an inverter using an Arduino Uno controller, a full-bridge MOSFET, an optocoupler driver, and an LC filter. The research results showed that the inverter could produce an output voltage of 220V AC at 50Hz with a power capacity of 600 watts [11]. Research about developed an inverter using an Arduino Uno controller, a full-bridge MOSFET, and an LC filter. The research results showed that the inverter could produce an output voltage of 220V AC at 50Hz [12]. Arduino as a SPWM signal generator. Implemented a single-phase full-bridge inverter using an Arduino Uno in a soil moisture sensor system. The experimental results showed that the inverter could produce an output voltage of 220V AC at 50Hz with an efficiency of 36% [13]. To increase the SPWM signal from low voltage MOSFET to high voltage, a 14V to 220V step-up transformer is used. Implemented a single-phase full-bridge inverter using a filter and a step-up transformer. The research results showed that the inverter could produce an output voltage of 220V AC at 50Hz with a total harmonic distortion (THD) of 1.8% and an efficiency of 98% [14].

By using a sinusoidal wave type inverter, electricity consumption will be more efficient compared to using a square wave type inverter. Rachwanto et al. (2022), in their research, implemented a single-phase half-bridge inverter using an Arduino Uno and a step-up transformer. The research results showed that the inverter could produce an output voltage of 220V AC at 50Hz with an efficiency of 83.34% [15]. Humans cannot be separated from the need for electrical energy to support the use of electronic equipment in every household and industrial activity. Most electricity requires AC voltage to power electrical equipment. For places where AC voltage cannot be reached, an inverter is used as a voltage converter. Research about implemented a single-phase half-bridge inverter using an Arduino Nano and a step-up transformer. The research results showed that the inverter could produce an output voltage of 192V AC at 50Hz [16].

The ESC voltage-current regulation method uses the PWM signal technique, using a 3-phase full bridge switching technique using 6 (3 pairs) large power MOSFETs, the PWM voltage pulse is controlled by an Arduino Nano microcontroller with a MOSFET driver so that the MOSFET gate current can be met. B. P. Jati et al. (2022), in their research, implemented a full-bridge MOSFET using an Arduino Nano for a BLDC motor ESC. The research findings indicated that the quality of the MOSFET driver significantly affects the MOSFET switching process [17].

The research conducted involves the design, development (both hardware and software), and testing of a voltage inverter from 24V DC to 225V AC.

The problem of DC voltage conversion from photovoltaic panels or batteries can be solved using an Arduino Nano-based SPWM inverter, where the SPWM signal is sent to the full-bridge MOSFET switching, allowing the DC voltage to be converted into AC voltage. This SPWM inverter consists of three main parts: the SPWM controller using Arduino Nano, full-bridge MOSFET switching, and a step-up transformer. The AC output voltage can be adjusted by controlling the feedback voltage, which regulates the SPWM signal amplitude. After passing through an LC filter and a step-up transformer, a pure AC voltage of approximately 225V AC can be generated.

This research aims to develop an Arduino Nano-based SPWM inverter with full-bridge switching using 8 MOSFETs rated at 150V DC and 171A to produce high power output. The system consists of several components, including a step-up transformer (14V AC to 225V AC), harmonic filter, full-bridge MOSFET switching, MOSFET driver with IC IR2110, Arduino Nano microcontroller, Arduino Sketch software, and a 24V DC battery. The device developed in this research can also be implemented in solar power systems and used in off-grid household systems.

When compared with previous researchers, the existing gap in research is that they use half bridge switching, whereas we use full-bridge switching.

II. Basic Theory

A power inverter is an electronic device that can convert a direct current (DC) source into alternating current (AC). Inverters have many applications, for example they are used in conditions where only low DC is available such as batteries (Accu) or solar panels, and are needed to supply electronic equipment with AC input.

There are three types of AC waves produced by inverters in general, namely square wave output, modified sine wave, and pure sine wave. The modified sine signal is the output from the inverter in the form of a square wave or modified square wave, where the shape follows a sine wave pattern. This type of sine modification is easier to make than an inverter with a pure sine output. Pure sine inverters produce an output waveform that is identical to the waveform produced by the electrical power provider.

Sinusoidal Pulse Width Modulation (SPWM) is a method used in power electronics to produce a sine wave output from a DC input. This method involves setting the pulse width in the signal to match the amplitude of the sine wave at various points in time. By adjusting the pulse width, SPWM effectively simulates the desired sine wave, enabling efficient control of AC motors and inverters. This technique reduces harmonic distortion, improves power quality, and improves the performance of electronic devices. SPWM is widely used in applications such as motor drives, renewable energy systems, and power converters due to its efficiency and precision.

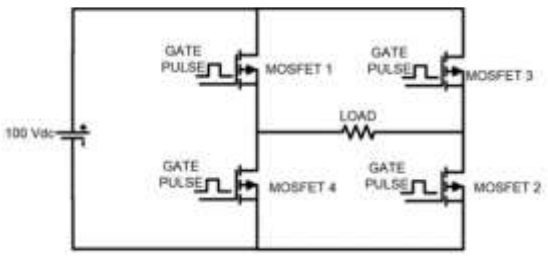

Figure 1. Full bridge MOSFET switching [17]

In MOSFET switching techniques, there are two types: the switching half-bridge, which utilizes only one MOSFET to control PWM switching voltage, and the second type is the switching full bridge, which employs 4 MOSFETs to control the direction of current, allowing the direction of motor rotation to be adjusted forward or backward, as shown in Figure 1.

PWM is a modulation technique that can control the average voltage value in electronic devices by rapidly turning power on and off. The ratio of ON time to the signal within one period is the duty cycle, and the average voltage is shown in Figure 2 and Equation 1.

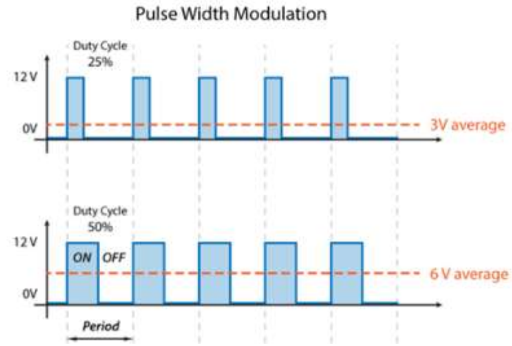

Figure 2. Relationship between duty cycle and voltage [17]

$$V_{out} = duty\ cycle \times V_{in} \tag{1}$$

Two sinusoidal waves are used as reference signals and a triangular wave as a carrier signal is used in PWM technique. The pulses obtained depend on two parameters modulation index and modulation frequency [1]. The model of the SPWM generator can be simulated using MatLab, the control circuit consisting of two sinusoidal waves, a triangular wave and relational operations, can be seen in Figure 3.

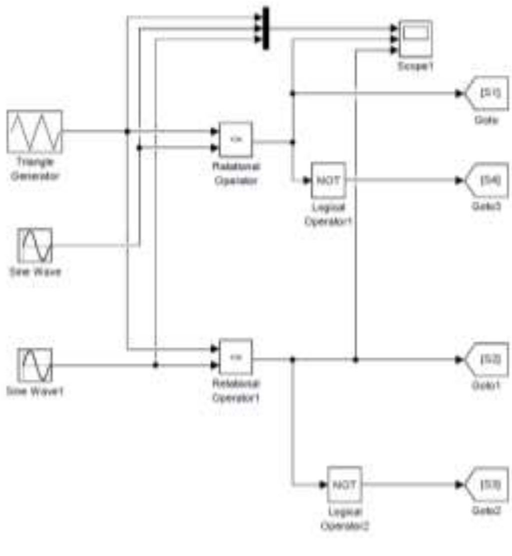

Figure 3. Simulation model of the control circuit [1]

The output waveform from the SPWM inverter is shown in Figure 4.

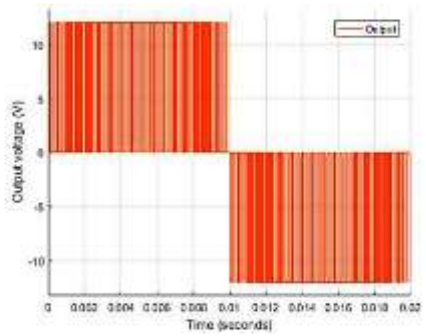

Figure 4. Output waveform of SPWM inverter

III. METHODS AND DESIGN

The research flowchart includes: determining the operating voltage, selecting the inverter type, designing the MOSFET driver, designing the full bridge MOSFET switching, creating the software flowchart, designing the inverter SPWM software, testing the system to ensure proper operation, as shown in Figure 7.

The SPWM inverter in this study uses four switches controlled by Arduino nano so that voltage can be generated during the positive cycle and during the negative cycle, as shown in Figure 5.

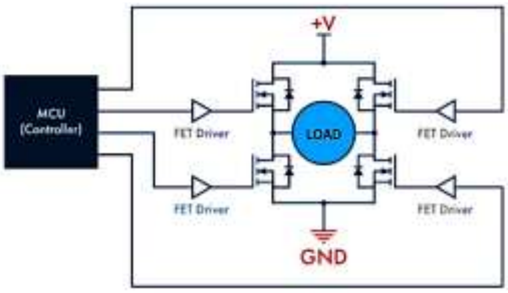

Figure 5. Basic full bridge H-ESC circuit [17]

If you want to provide an input signal to the MOSFET from a microcontroller, you need something to step the voltage up to 12Vdc with a gate current of up to 1A. There are many "logic level" MOSFETs that can be driven from a 3.3V or 2.5V logic level. A MOSFET driver is needed to increase the driving voltage and gate current. In this study, the IR2110 MOSFET driver IC is used. To implement the SPWM inverter, a block diagram is created as in Figure 6.

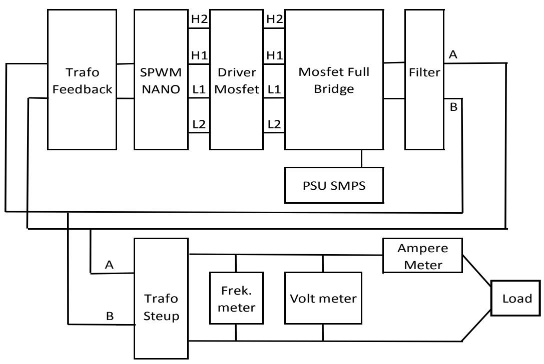

Figure 6. SPWM inverter block diagram with Arduino nano

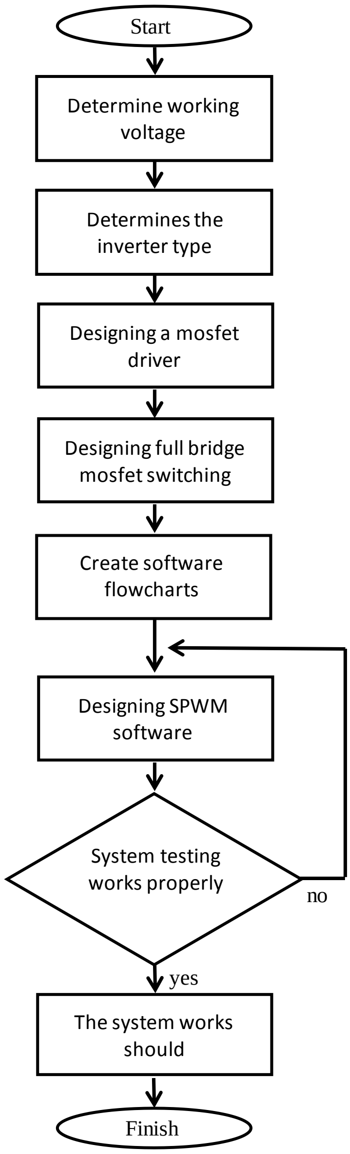

Figure 7. Research flowchart for the design and testing of SPWM full bridge inverter

Figure 6 illustrates the SPWM inverter block diagram which consists of: Arduino nano SPWM generator, MOSFET driver, full bridge MOSFET, LC filter, feedback transformer, step up transformer, SMPS PSU. The PWM signal is synthesized using the control function of the Arduino microcontroller. The number of pins used for controls and sensors is one of the important factors in selecting a suitable controller. The pin requirements for control in this research are: only 5 pins (A0, D9, D10, D11, D12). The Arduino Nano is a suitable controller in terms of pin requirements, sensors used, and physical compatibility. Arduino Nano has 8 analog inputs, 14 input-output pins, 6 of which can be used to control SPWM signals [17].

The software is written in the Arduino programming language and compiled using the Arduino IDE software. The controller and SPWM generator circuit with Arduino are shown in Figure 8.

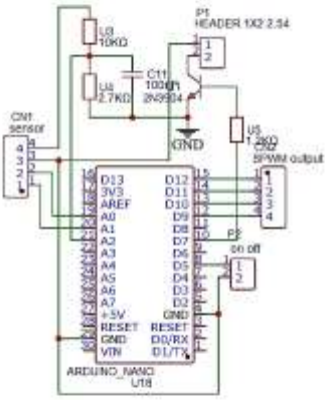

Figure 8. Arduino controller circuit

The Arduino-based SPWM inverter software system flow diagram is as shown in Figure 9.

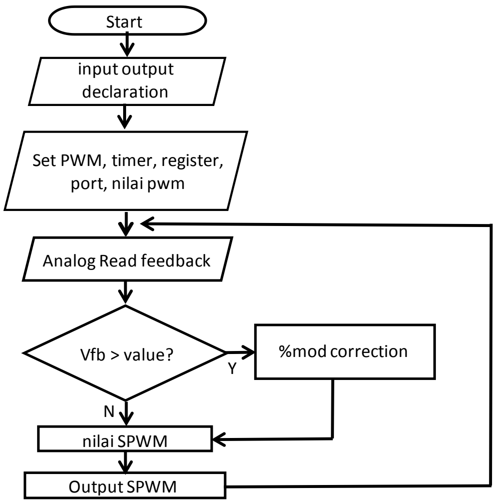

Figure 9. Arduino-based SPWM inverter software flowchart

This SPWM generator was synthesized using the Timer 0 TCCR1A TCCR1B, Compare-Match interrupt OC1A/OC1B control function from the Arduino microcontroller (ATmega328). Timer 1 of the ATmega328 is set at 10kHz to generate the SPWM output signal. The program contains settings for the DDRB PORTB registers of the ATmega328 microcontroller which are configured according to the datasheet. The software was written in the Arduino programming language and compiled using the Arduino IDE software ver 2.3.2.

The control process in puresine SPWM which is made in outline is as follows:

a. When the inverter system is turned on, the system will initialize the input output declaration, the pins used.
b. Set PWM settings, timer 0 1 2, register.
c. Sensors the feedback voltage value to determine the SPWM value.
d. Sends the SPWM value to the pin out to be sent to the mosfet driver.

The driver circuit is shown in Figure 10, and the full bridge MOSFET circuit is shown in Figure 11.

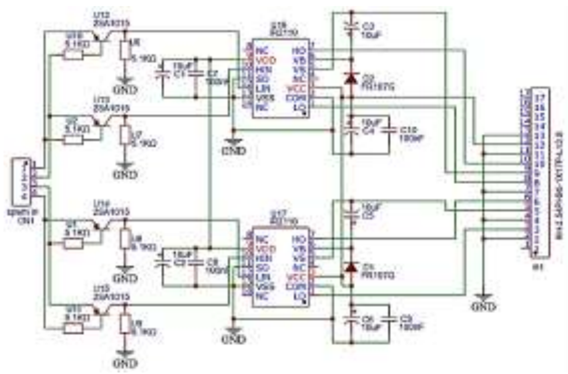

Figure 10. MOSFET driver circuit

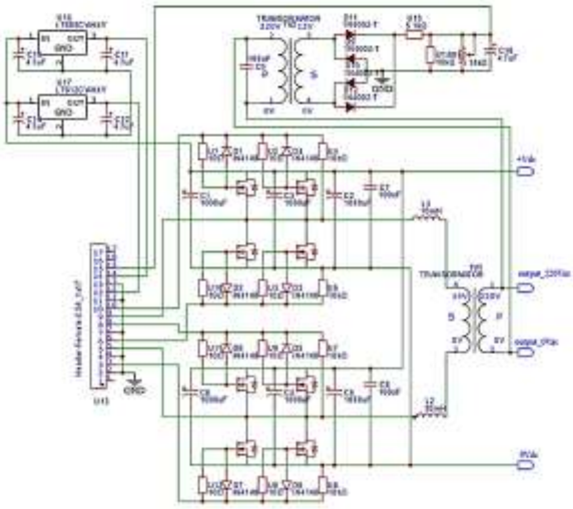

Figure 11. Full bridge MOSFET circuit

The results of the Fulbridge MOSFET test are as follows:

1. A working voltage of 24 Vdc is entered.
2. Testing the high side of the mosfet (close to Vcc), when the gate 1H, 2H is supplied with a voltage of 12V (>5Vdc) the mosfet will "saturate" so that the source to the drain will be connected. When the 1H, 2H mosfet driver input is given a voltage of 5V, the mosfet will "saturate". It can be concluded that the mosfet driver circuit and high side mosfet (near keV cc) can work well.
3. Testing the low side of the mosfet (close to ground), when the gate 1L, 2L is supplied with a voltage of 12V (>5Vdc) the mosfet will "saturate" so that the source to the drain will be connected. When the 1L, 2L mosfet driver input is given a voltage of 5V, the mosfet will "saturate". It can be concluded that the mosfet driver circuit and low side mosfet (close to the ground) can work well.
4. The SPWM generator circuit is tested using an oscilloscope, the output waveform is in the form of a PWM signal.
5. The Full-bridge Switching output sinusoidal signal is connected to the harmonic filter and stepup transformer, turn on the variable voltage PSU so that the transformer output produces a sine signal, adjust the feedback voltage trimpot so that a voltage of 225 VAC is obtained.

6. Test results for an inverter with a 30Vac lamp load that can output a voltage of 225Vac, if the supply voltage is changed from 21Vdc to 30Vdc.

SPWM inverter testing is carried out by observing the inverter output AC voltage value and output frequency value. The Arduino-based SPWM inverter device consists of: full bridge switching MOSFET, MOSFET driver with IR2110 IC, Arduino microcontroller, Arduino sketch software, feedback voltage controller trimpot, switch to turn the device on or off.

The research module that has been made is shown in Figure 12, consisting of:

1. Arduino nano
2. DC to DC
3. Sensors
4. Fullbridge mosfet
5. LC filter
6. Transformer
7. Terminal
8. DC power meter
9. AC power meter
10. Load lamp
11. PSU
12. Fan

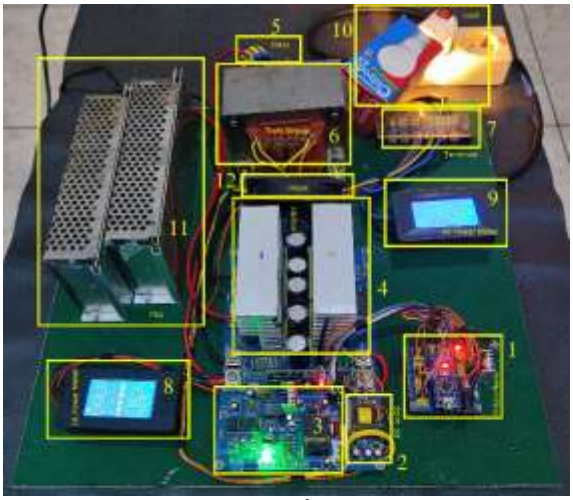

Figure 12. Testing of SPWM inverter

IV. RESULTS AND DISCUSSION

Referring to the block diagram of figure 7, performance testing of the full bridge SPWM inverter device with Arduino nano was carried out in the laboratory using a +24 variable Vdc main supply because the stepup transformer used was a 24 Vac to 220 Vac transformer. The MOSFET driver circuit and low-side and high MOSFETs could work properly.

The SPWM generator circuit is tested using an oscilloscope, the output waveform is in the form of a PWM signal.

The Full-bridge Switching output SPWM signal is connected to the harmonic filter and stepup transformer, turn on the variable voltage PSU so that the transformer output produces a sine signal, adjust the feedback voltage trimpot so that a voltage of 225 VAC is obtained.

Test results for an inverter with a 30Vac lamp load that can output a voltage of 225Vac, if the supply voltage is changed from 21Vdc to 30Vdc:

a. The inverter operating current is between 980mA to 1.32A.
b. The inverter operating frequency is 50Hz.
c. The inverter's operating voltage is between 219Vac to 229Vac.
d. The cable to the PSU and mosfet is not hot.

This Arduino-based inverter SPWM device has the following specifications: operating voltage: 21 - 30 Vdc, output voltage: 219 Vac – 228 Vac, frequency: 50 Hz, maximum mosfet current (2 parallel): 342A, output waveform: pure sinus. modulation type: SPWM, Arduino nano microcontroller, stepup transformer used during testing is a 24 Volt 5a transformer.

Retrieval of Vdc Idc Vac Iac frequency data is carried out by looking at the dc power meter and dc power meter as in Figure 13.

Figure 13. The dc power meter and dc power meter

The full-bridge SPWM inverter test results with a load of 25 W can be seen in Table 1. Showing the measurements of Vdc in, I_{dc} in, Vac out, I_{ac} out, frequency, P_{dc} calculation, P_{ac} calculation, efficiency calculation. The V_{dc} in, I_{dc} in, V_{ac} out, I_{ac} out parameters are used to calculate the efficiency of the device, while the frequency parameter determines the stability of the device when V_{dc} in changes.

Table 1. SPWM Inverter Test Results load 25 W

V_{dc} (V)	I_{dc} (A)	P_{dc} (W)	V_{ac} (V)	I_{ac} (A)	Pa_c (W)	Eff (%)	Freq (Hz)
21	1.29	27.09	219	0.11	24.09	88.93	50
22	1.31	28.82	229	0.11	25.19	87.4	50
23	1.22	28.06	225	0.11	24.75	88.2	50
24	1.17	28.08	224	0.11	24.64	87.75	50
25	1.12	28	227	0.11	24.97	89.18	50
26	1.09	28.34	228	0.11	25.08	88.5	50
27	1.05	28.35	227	0.11	24.97	88.08	50
28	1	28	226	0.11	24.86	88.79	50
29	0.97	28.13	227	0.11	24.97	88.77	50
30	0.95	28.5	228	0.11	25.08	88	50

The graph of Vdc input vs efficiency is as shown in Figure 14 with an average value of 88.36%. The graph of V_{dc} input vs frequency is as seen in Figure 15 is 50 Hz at an input voltage of 21 V_{dc} to 30 V_{dc}.

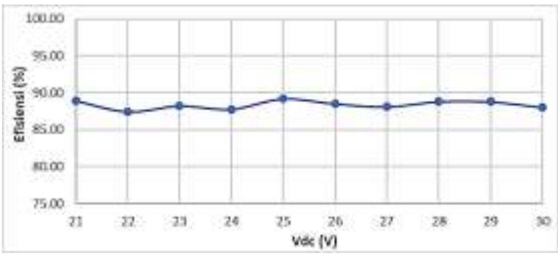

Figure 14. Graph of V_{dc}input vs efisiensi

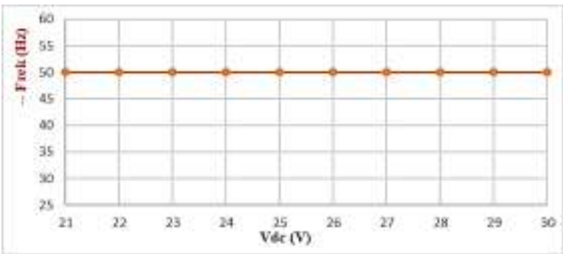

Figure 15. Graph of V_{dc}input vs frequency

Referring to Figure 5, Figure 13, and the data in Table 1 shows the results of the SPWM signal output from the SPWM inverter which is connected to an LC filter, step up transformer and a 25 watt incandescent lamp load. The 225 V_{ac} output voltage is regulated using a feedback voltage potentiometer. The research test results show that the SPWM inverter can output an average pure sine voltage of 226 V_{ac}. When the input supply voltage is changed from 21 V_{dc} to 30 V_{dc}, the sine output voltage is relatively stable between 219 V_{ac} to 229 V_{ac}, when the input voltage is changed from 21 V_{dc} to 30 V_{dc} the inverter working frequency is also stable at 50 Hz, with an average efficiency of 88.36%. The cable to the motor, the cable to the PSU, and the MOSFET are not hot.

The research results of the SPWM fullbridge inverter that has been created can lead to the research objectives. It can be used in offgrid PV systems and can be used for battery voltage fluctuations of 21Vdc to 30 V_{dc} with an output voltage of 220Vdc 50 Hz.The output voltage after the step-up transformer can be seen in Figure 16.

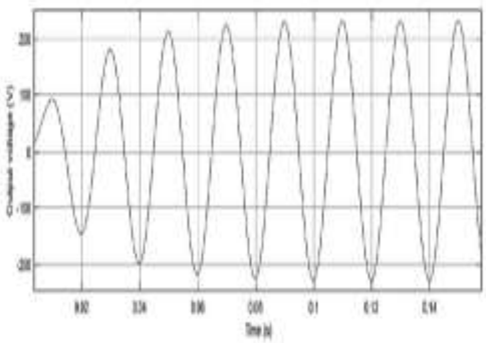

Figure 16. Output waveform after step-up transformer

The SPWM generator circuit with Arduino nano and IR2110 MOSFET driver has been designed on a PCB 2 layer board, which can be seen in Figure 17. The appearance of the PCB design looks 3D SPWM can be seen in Figure 18.

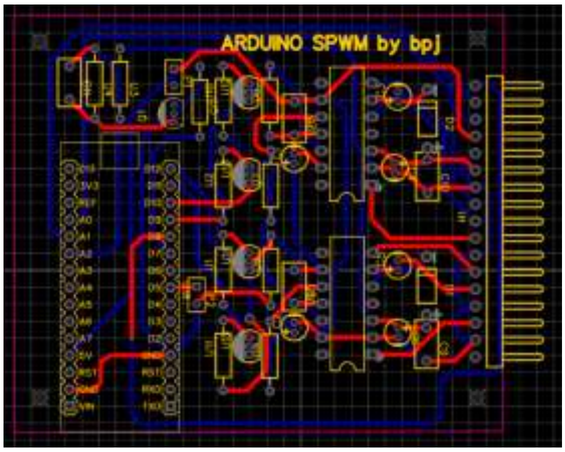

Figure 17. The appearance of 2 layer PCB design SPWM

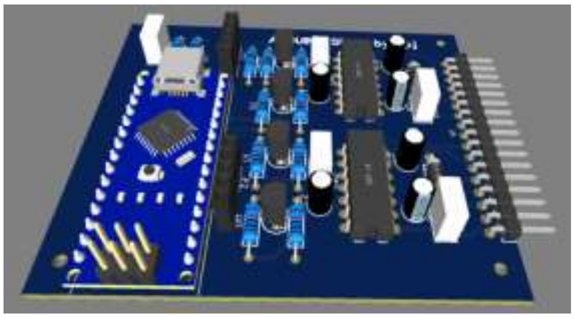

Figure 18. The appearance of the PCB design looks 3D SPWM

V. Conclusion

The SPWM full-bridge inverter can function well, it can produce an output voltage of 225 Vac. When the input supply voltage is changed from 21 Vdc to 30 Vdc, the sine output voltage is relatively stable between 219 Vac to 228 Vac, when the input voltage is changed from 21 Vdc to 39 Vac. The Vdc working frequency of the inverter is also stable at 50 Hz, with an average efficiency of 88.36%. The feedback voltage sensor can work well, when the supply voltage is 20 Vdc (reaches LVD) or reaches 30.5 Vdc (reaches HVD) the inverter can turn off.

The full bridge SPWM inverter uses an Arduino Nano microcontroller, Arduino Sketch software, a MOSFET driver with an IR2110 IC, full bridge MOSFET switching, harmonic filters, step-up transformers (14V AC to 225V AC) that have been made can answer the problems to achieve our research objectives.

References

[1] N. Farhana Abdul Hamid, M. Alleef Abd Jalil, and N. Syafiqah Syahirah Mohamed, “Design and simulation of single phase inverter using SPWM unipolar technique,” J. Phys. Conf. Ser., vol. 1432, no. 1, 2020, doi: 10.1088/1742-6596/1432/1/012021.

[2] F. Ronilaya, S. Ilmawati, M. Huda, W. Anistia, I. N. Syamsiana, and M. N. Hidayat, “A development of an Arduino pure sine wave inverter for a small scale off-grid solar PV

system," IOP Conf. Ser. Mater. Sci. Eng., vol. 1073, no. 1, p. 012043, 2021, doi: 10.1088/1757-899x/1073/1/012043.

[3] F. D. Murdianto, I. Sudihato, A. B. Karso, and W. Zulfa, "Design of a Single Phase HERIC-SPWM," INTEK J. Penelit., vol. 9, no. 1, pp. 7–12, 2022, doi: 10.31963/intek.v9i1.2995.

[4] A. Kumar, A. Singh, A. Ali, A. Pandey, and S. Saharan, "Arduino Based Pure Sine Wave Inverter," Appl. Sci. Eng. J. Adv. Res., vol. 2, no. 3, pp. 5–7, 2023, doi: 10.54741/asejar.2.3.2.

[5] Z. M. A. Putra, A. T. Nugraha, Y. Widiarti, W. Safaroz, and R. A. Sobhita, "Design of Unipolar Pure Sine Wave Inverter with Spwm Method Based On Esp32 Microcontroller As a Support of The Ebt System On Ship," E3S Web Conf., vol. 473, pp. 1–10, 2024, doi: 10.1051/e3sconf/202447301008.

[6] K. Inyama, C. Eberechi Uchegbu, and U. Solomon Alamezie, "Modeling of a Pure Sine Wave Power Inverter using Sinusoidal Pulse Width Modulation (SPWM) Technique," Int. J. Innov. Sci. Res. Technol., vol. 8, no. 5, 2023, doi: 10.5281/zenodo.7988564.

[7] M. Venkateswarlu, G. Sateesh, and P. Sujatha, "Modified SPWM technique for single phase variable voltage nine level inverter for PV system," Int. J. Power Electron. Drive Syst., vol. 14, no. 4, pp. 2173–2182, 2023, doi: 10.11591/ijpeds.v14.i4.pp2173-2182.

[8] D. Setiawan, H. Eteruddin, and A. Arlenny, "Desain dan Analisis Inverter Satu Fasa Berbasis Arduino Menggunakan Metode SPWM," J. Tek., vol. 13, no. 2, pp. 128–135, 2019, doi: 10.31849/teknik.v13i2.3470.

[9] B. Sujanarko, R. B. Prabowo, and S. Prasetyo, "Single Phase Full Bridge Inverter Using Arduino Uno R3 Controller," Int. J. Electr. Electron. Comput. Sci. Eng., vol. 5, no. 4, pp. 1–5, 2018.

[10] R. U. H. Wicaksono, "Desain Inverter Satu Fasa 5 Tingkat Berbasis Arduino Uno Prosiding Seminar Nasional Teknik Elektro Volume 5 Tahun 2020," Proseding Semin. Nas. Tek. Elektro, vol. 5, pp. 28–33, 2020.

[11] M. A. Syururi, B. S. Kaloko, and W. Cahyadi, "Design and Build a 600 Watt Inverter With Sinusoidal Pulse Width Modulation Method," J. Tek. Elektro dan Komput., vol. 11, no. 3, pp. 147–154, 2022.

[12] D. Nugraha and K. Krismadinata, "Rancang Bangun Inverter Satu Fasa Dengan Dengan Modulasi Lebar Pulsa PWM Menggunakan Antarmuka Komputer," JTEV (Jurnal Tek. Elektro dan Vokasional), vol. 6, no. 1, p. 340, 2020, doi: 10.24036/jtev.v6i1.108035.

[13] A. Rajagukguk and R. Kurniawan, "Design Inverter SPWM Tow Frequency Based Soil Moisture Sensor Using Arduino," Int. J. Electr. Energy Power Syst. Eng., vol. 4, no. 2, pp. 163–168, 2021, doi: 10.31258/ijeepse.4.2.145-153.

[14] I. Hidayat, A. Mahdali, and M. Afandy, "Analisis Perbandingan Inverter Satu Phasa PWM dan SPWM dengan Trafo," Jambura J. Electr. Electron. Eng., vol. 4, no. 1, pp. 27–32, 2022, doi: 10.37905/jjeee.v4i1.11900.

[15] R. D. Rachwanto, S. Saidah, and A. Amirullah, "Implementasi Inverter Berbasis Square Wave dan Sinusoidal PWM Menggunakan Arduino Uno," Rekayasa J. Sci. Technol., vol. 15, no. 2, pp. 182–191, 2022, doi: 10.21107/rekayasa.v15i2.13454.

[16] L. Santoso, A. M. N. Imron, and B. S. Kaloko, "Perancangan Inverter Satu Fasa Berbasis Arduino Menggunakan Metode SPWM," Techné J. Ilm. Elektrotek., vol. 22, no. 1, pp. 85–96, 2023, doi: 10.31358/techne.v22i1.351.

[17] B. P. Jati and J. P. Hapsari, "ESC Full-bridge 3 Fasa Motor BLDC Berdaya Besar Menggunakan Kontroler Arduino," Cyclotr. J. Tek. Elektro, vol. 5, no. 02, pp. 35–40, 2022, [Online]. Available: http://journal.um-surabaya.ac.id/index.php/cyclotron/article/view/11757%0Ahttp://journal.um-surabaya.ac.id/index.php/cyclotron/article/viewFile/11757/5189.