Implementation of The STM32F407 Microcontroller Based 5-Level Inverter

Eko Yoyok Pujianto[1*], Leonardus Heru Pratomo[2]
[1,2] Soegijapranata Catholic University, Semarang
[1,2] Gajahmungkur, Semarang City 50235, Central Java, Indonesia
*18f10013@student.unika.ac.id

Abstract - Technological developments continue to increase, this can be seen by the increasing number of electronic equipment used in daily needs, one of which is in the science of converting electrical energy, namely the 5-level inverter. The 5-stage inverter is a voltage changer that can convert DC electricity into AC electricity. Many studies have been carried out in order to obtain a sinusoidal 5-level inverter voltage waveform output by means of harmonic elimination technique. Harmonic elimination technique is a 5-level inverter signal processing technique for maximum switching patterns in order to obtain a sinusoidal output waveform and a minimum THD value with a combination of the STM32F407 microcontroller control signal generator circuit and the Mosfet Driver circuit, this 5-level inverter is expected to have a high output waveform. sinusoidal. testing is done with software in the form of PSIM software and real implementation. Based on the results, the method used is able to produce inverter output current and voltage with a THD of 4.38%.

Keywords: 5-Level Inverter, Harmonics, Mosfet Driver.

I. INTRODUCTION

Electrical Energy is very important in everyday life. With the increasing population and technological advances from year to year, the need for a stable and equitable distribution of electricity is very important. Therefore, to make the current always maximum requires a power converter with a maximum curve algorithm. In order for the current to be used a current converter is needed. Converting direct current to alternating current requires a power circuit called an inverter. The inverter has many types of switching, such as unipolar, bipolar etc. Inverters generally have two types, Voltage Source Inverter (VSI) and Current Source Inverter (CSI). In addition to these two types, inverters have different topologies, both single-phase and three-phase. Single-phase inverters generally use one arm so they are used more often. Because it works at a low frequency compared to three phases, it does not require a large inductor filter. The use of inverters in independent generators, conventional single-phase inverters require using only low frequencies and small filters. The IEEE 519 Total Harmonic Distortion (THD) standard used is with a maximum harmonic value of 5% for a voltage of 2.3-68 Kv.

II. METHODS

This study uses a method such as the flow chart shown in Figure 1. First, examine the regulation of the 5-level inverter as a sinusoidal wave former. By using the one-wavelength method as the output waveform reference, STM32F407 is used as the controller. After that formulate existing problems and make simulations to overcome them. Verification is carried out by implementing hardware as well as conducting testing and data retrieval. In the last section to form conclusions about the existing problems.

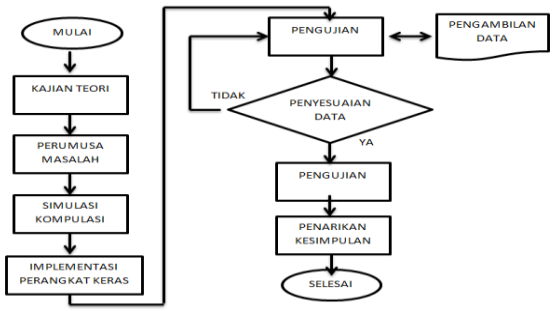

Figure 1. Flow chart of research methods

5-Level Inverter

Multilevel Inverter is a converter that converts DC quantities into AC quantities where the output produced has several (more than two) voltage levels. The output voltage of multilevel inverters is of higher quality and multilevel inverters can reduce harmonics that can cause interference and damage to electrical devices. In this research, a five-level inverter is designed to produce a voltage wave with small harmonic distortion [1] [2].

Multilevel inverters have several types of topologies that can be applied according to needs. These topologies include Neutral Point Clamped (NPC), Flying Capacitor (FC), and Cascaded H-bridge Multilevel Inverter (CHMI) [3] [4]. These topologies have their own advantages and disadvantages. When viewed from the construction, the NPC topology requires additional components such as capacitors and diodes in large numbers and will increase as the inverter level

increases. For the FC topology, the number of capacitors will increase quadratically as the number of levels increases. In this study, the topology that will be used is the CHMI topology because it does not require additional components such as diodes or capacitors [5] [6].

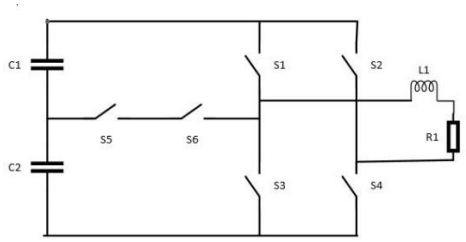

Figure 2. 5-level inverter topology

Pulse Width Modulation (PWM)

Pulse width modulation (PWM) in general is a way of manipulating the width of the signal expressed by pulses in one period. PWM signals generally have a fixed amplitude and fundamental frequency, but vary in pulse width. The PWM Pulse Width is directly proportional to the amplitude of the original unmodulated signal. That is, the PWM signal has a fixed frequency but the duty cycle varies (between 0% to 100%) [8].

Pulse Width Modulation (PWM) is a technique to get an analog signal from a digital device. Actually PWM signal can be generated in many ways, can use the analog method by using an op-amp circuit or by using a digital method. With the analog method every PWM change is very smooth, while using the digital method every PWM change is affected by the resolution of the PWM itself. Resolution is the number of variations in the value change in the PWM

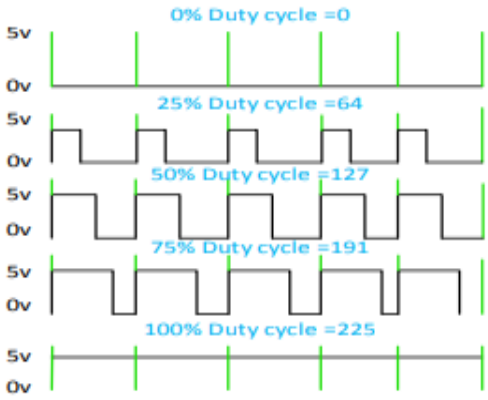

Figure 3. PWM pulses

Harmonisa

Harmonics is a periodic distortion of the sine wave of voltage, current, or power in an electrical energy system. Harmonic waveforms are waves whose frequency is a multiple beyond the number one to the fundamental frequency (frequency 50 Hz or 60 Hz).

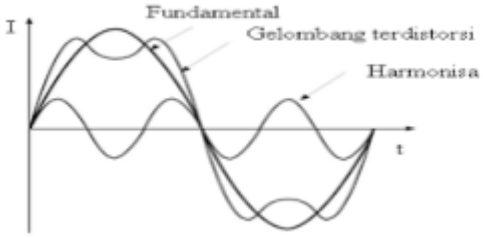

Figure 4. Harmonic Wave

Microcontroller STM32F407

STMicroelectronics with type 32F407VET6 or known as STM32F407 family is a microcontroller that has a 32-bit Arm® Cortex®-M4 processor with FPU, features Adaptive real-time accelerator (ART Accelerator), with a clock speed of 168MHz, execution speed up to 210 MIPS per second, has a digital signal processing (DSP) feature so that it can output analog signals, and has 1MB flash memory, 196KB SRAM. STM32F407 requires a supply voltage of 3.3V. The STM32F4 microcontroller has a 12-bit ADC (Analog Digital Converter) with a speed of 7.2 MSPS and has 12 12-bit timer counters and 2 32-bit timer counters [7].

Mosfet As Switch

In addition to using a signal trigger, a switch is needed in designing the inverter. The component that functions as a switch is the MOSFET. MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a type of transistor that has a very high gate impedance (almost infinite) so that by using a MOSFET as an electronic switch, it is possible to connect it to all types of logic gates [8].

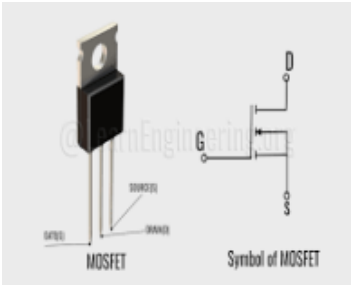

Figure 5. Mosfet

5-level inverter working principle

- First Operation Mode

  Figure 6 shows the first mode of operation. Mathematical model of this mode of operation is shown in Equation (1).

$$E = VL + Vo$$

$$E = L\frac{diL}{dt} + Vo \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

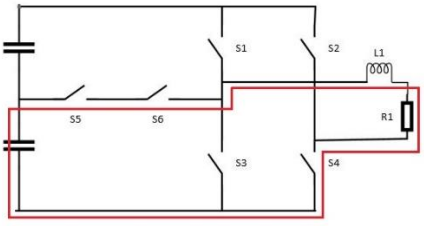

Figure 6. first operation mode

- Second Operation Mode
  Figure 7 shows the second mode of operation. The mathematical model of this mode of operation is shown in Equation (2).

$$E + E = VL + Vo$$

$$2E = L\frac{diL}{dt} + Vo \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

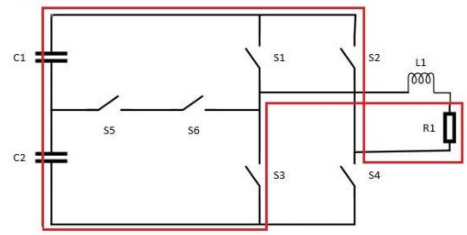

Figure 7. first operation mode

- Third Operation Mode
  Figure 8 shows the third mode of operation. The mathematical model of this mode of operation is shown in Equation (3).

$$VL = Vo - Vd$$

$$L\frac{diL}{dt} = Vo - 0$$

$$Vo = L\frac{diL}{dt} \dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

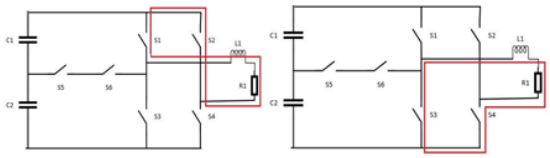

Figure 8. Operation mode three positive freewheeling and negative freewheeling

- Fourth Operation Mode
  Figure 9 shows the fourth operating mode. The mathematical model of this mode of operation is shown in Equation (4).

$$-E = VL + Vo$$

$$-E = L\frac{diL}{dt} + Vo \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

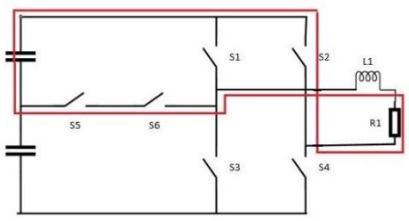

Figure 9. fourth operation mode

- Fifth Operation Mode
  Figure 10 shows the fifth mode of operation. The mathematical model of this mode of operation is shown in Equation (5).

$$-E + E = VL + Vo$$

$$-2E = L\frac{diL}{dt} + Vo \dots\dots\dots\dots\dots\dots\dots (5)$$

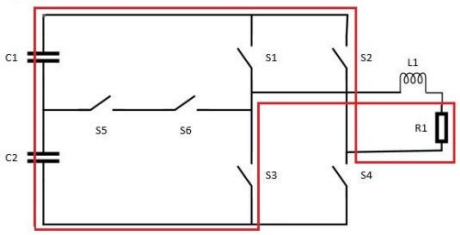

Figure 10. five operation modes

III. RESULT AND DISCUSSION

Based on the discussion about the operating mode, it can be described in the form of a computational simulation with power simulator (PSIM) software with parameters such as table 1. And there is a simulation image in Figure 11.

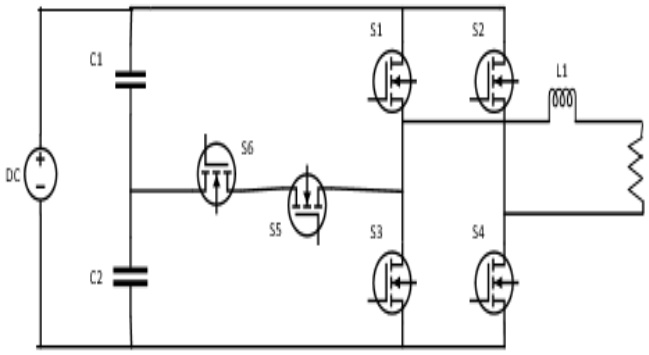

Figure 11. simulation on PSIM software

Table 1. Simulation Parameters

No	Parameter	Score
1.	DC source	12 V
2.	Inductor	6 mH
3.	Load	24 Ohm
4.	Capasitor	4700 uf
5.	Switch	IRFP 460

In addition to doing a simulation on the power simulator (PSIM) software, it is also done making tools or making hardware. Where the hardware parameter values can be seen in table 2. Making or testing this hardware is used to prove that the designed system can work well. The hardware implementation can be seen in Figure 12.

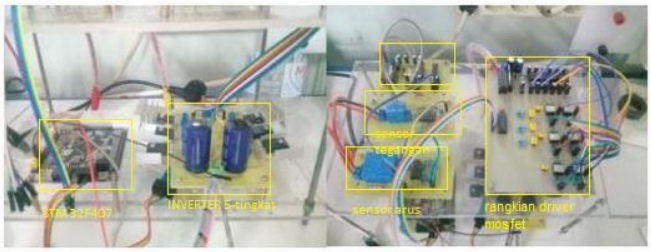

Figure 12. 5-level inverter hardware

Table 2. Hardware Parameters

No	Parameter	Score
1.	DC source	12 V
2.	Inductor	1 mH
3.	Load	24 Ohm
4.	Capasitor	4700 uf
5.	Switch	IRFP 460

And here are the results of the power simulator (PSIM) simulation test and hardware implementation at the Electrical Engineering Laboratory, Soegijapranata Catholic University, Semarang.

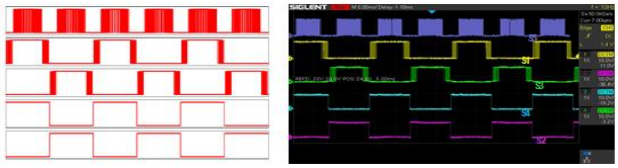

Figure 13. switching results S1-S5

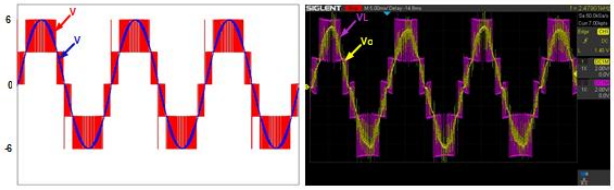

Figure 14. 5-stage inverter output voltage

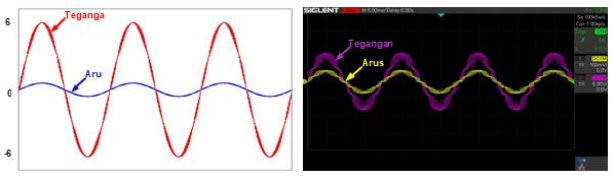

Figure 15. 5-stage inverter voltage and wear

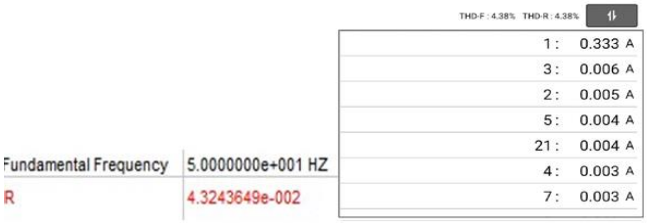

Figure 16. THD 5-level current

IV. CONCLUSION

Based on analysis and testing in the laboratory, it can be concluded that this 5-stage inverter is capable of producing the appropriate output voltage and current. And also this 5-level inverter is capable of producing 120º shifting waves with a current THD of 4.38% which is in accordance with the IEEE 519 standard.

REFERENCES

[1] Faizal Bukhori, Leonardus Heru Pratomo, and Arifin Wibisono. (2021). Analisis Mode Operasi Off-Grid Photovoltaic Solar Power System Terhadap Beberapa Variasi Pembebanan. Prosiding Seminar Nasional Riset dan Teknologi Terapan (Ritektra)

[2] Ivaniles Putra Utama Dagomis and Leonardus Heru Pratomo. (2021). Inverter 5-Tingkat Tiga Fasa Empat Kawat menggunakan STM32F407 untuk Catu Daya Mandiri. ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, dan Teknik Elektronika, 9(1), 177.

[3] Victor Doan Imatua Sinaga, Ayong Hiendro, and Syaifurrahman. (2020). Rancang bangun inverter satu fasa lima level. Jurnal Teknik Elektro Universitas Tanjungpura

[4] Ayong Hiendro. (2011). Multiple switching patterns for SHEPWM inverters using differential evolution algorithms. International Journal of Power Electronics and Drive Systems

[5] Gunawan M. Idris, I Nyoman Wahyu S, and I Ketut Wiryajati. (2015). Investigasi Sudut Penyalaan Inverter Multilevel dengan Struktur Cascaded H-Bridge untuk Sistem PLTS. Dielektrika, 2(2), 81–90.

[6] Leonardus Heru Pratomo, Sandy Pratama Poetra, and Slamet Riyadi. (2022). A Simple Hysteresis Control Strategy in Voltage Regulated Three Phase Four Wire System for Photovoltaic Application. International Journal of Renewable Energy Research-IJRER.

[7] AN4013 Application Note Datasheet. (2021). STM32 cross-series timer overview. ST Microelectronics.

[8] R.Vijayakumar, Alamelu Natchiappan, C. Devilalitha, and R. Mazhuventhi. (2015). Selective Harmonic Elimination PWM Method using Seven Level Inverters by Genetic Algorithm Optimization Technique. International Journal of Engineering Research & Technology (IJERT)

[9] Baqrafi Aswida Yomahudaya and Tole Sutikno. (2017). Pembangkit Sinyal SPWM untuk Multilevel Inverter Satu Fasa Lima Tingkat Berbasis Mikrokontroler ATmega32. Jurnal Ilmiah Teknik Elektro Komputer Dan Informatika