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Design A Sinusoidal 1 Phase Inverter With Low-Frequency Transformer On The Asper-19 Robot

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Abstract

Along with the increasing development of covid-19, an innovation is needed that can be used to help deal with covid-19. SME Robotics University of Jember researched to create robot assistant nurse 19 (ASPER-19) to minimize contact with patients. This robot requires AC voltage while the input voltage used is DC voltage in carrying out its performance. Therefore, changing the voltage from DC to AC using an inserter tool. In this study, the inverter used is used by utilizing the EGS002 module as an SPWM driver. The switching process uses four pieces of MOSFET with hy4008 type arranged on an h-bridge basis. To increase the voltage to 220VAC utilizing a kind of low-frequency transformer. The low-frequency transformer that is a low-frequency transformer is an iron core transformer, in this study using a used UPS transformer. In this study, the inverter using an input voltage of 12V DC produced an inverter power of 140 watts and a frequency of 50 Hz. The results of tests conducted on the ASPER-19 robot obtained a relatively stable output voltage of 221.5 V with a frequency of 50 Hz and a THD value produced below 5%.

Keywords: ASPER-19 Robot,Inverter,EGS002 Module,H-bridge

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1. INTRODUCTION

Along with the development of the industrial world in various fields and the development of industries that require electricity as a source of energy that is proliferating, this also makes human life easier [1]. The use of electricity in household appliances uses the PLN electricity network to meet the 220V AC voltage with a frequency of 50 Hz. However, when there is a stop in the flow of electricity, such as when there is a blackout for hours, the electrical equipment cannot perform its function. To overcome this, we need a source of electrical energy (e.g., batteries) that can be processed, which will later be used as electrical energy with a voltage of 220V AC and a frequency of 50 Hz. One tool that can be used to process this is an inverter [2].

The inverter is an electronic circuit that converts direct current (DC) voltage into alternating current (AC) voltage with a specific frequency. Direct current (DC) voltage can come from solar panels, batteries, DC motors, and other DC sources [3], [4]. As in the world of robotics, one of them is the

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Asper-19 robot which uses a 12V DC battery source while the need is alternating voltage (AC) so that later it will be processed from DC electricity to AC at 220 V AC with a frequency of 50 Hz [5]. This research uses the egs002 module as the SPWM driver. The complete Bridge circuit is used as a rectifier (DC) converter into alternating voltage (AC). After that, it will pass through the transformer; the transformer used is a step-up transformer. Then the output from the transformer goes to the filter capacitor, which is used to reduce ripple, after which it goes to the load [6].

2. LITERATURE REVIEW

Inverter design is done using Proteus software to make it easier to make tool designs. A voltage regulator circuit is used for voltage. In this circuit, the voltage regulator produces 5 V Vout. A single-phase full-bridge consists of four switches in an arrangement resembling an H circuit. The H Bridge acts as the main core of the pure sine wave inverter. Filters are used to refine sinusoidal waveforms. AC voltage feedback circuit as a voltage controller from the transformer [7].

The working principle of the proposed inverter research is the generator that comes from the EGS002 module. When the MOSFET Q1 and Q4 are active (high), then the MOSFET Q2 and Q3 are inactive (low) conditions so that the current flows from Q1 to Q4. When MOSFET Q2 and Q3 are active (high), then MOSFET Q1 and Q4 are not involved (low), so the current flows from Q2 to Q3. The process will continue to occur alternately and convert 12V DC to 12V AC. Then proceed with increasing the voltage using a step-up transformer from 12V AC to 220V AC. the output of the transformer will increase the load. In the output transformer, an ac voltage feedback circuit is also used to find the output value of the step-up transformer.

The output from the transformer will go to the filter used to smooth the wave. Then, a DC fan will function as a cooling tool when working. In a full-bridge configuration circuit using 4 MOSFET to get an AC wave. This full-bridge uses a 12V DC input circuit that will be converted into a 12 V AC voltage. The main component used for the design is a MOSFET with the Hy4008 type used as a switching. In the above circuit, the voltage regulator is used as a voltage reducer to maintain the performance of the EGS002 module used. The voltage drop is done from the input voltage of 12 volts to the output voltage of 5 volts [8], [9].

In this study, a filter capacitor is used to refine the waveform so that the waveform becomes a pure sine. The filter capacitor used does not require an inductor because a transformer can replace this function. A diode bridge circuit is used to secure the egs002 module, whose working area is in direct voltage (DC). In a potentiometer, the principle works like a resistor; the greater the resistance value, the smaller the voltage value. When the resistance value of the potential is small, the voltage value will be more excellent [10].

This study uses a transformer of two types: a transformer as a step up and a step-down transformer. The transformer used in this research is a step-up transformer. The transformer used is a low-frequency transformer characterized by using the transformer using an iron core. Low-frequency transformers have specifications, with these transformers working at a frequency of 20 Hz to 20 kHz.

3. Method of Proposed Models

The working principle of the inverter by controlling four is shown in Figure 2.4. when S1 and S2 are active (on), the DC will flow to the load R from S1 to S2 while S3 and S4 are inactive (off). If the switch S3 and S4 are active, DC electricity will flow through the load from S3 to S4.

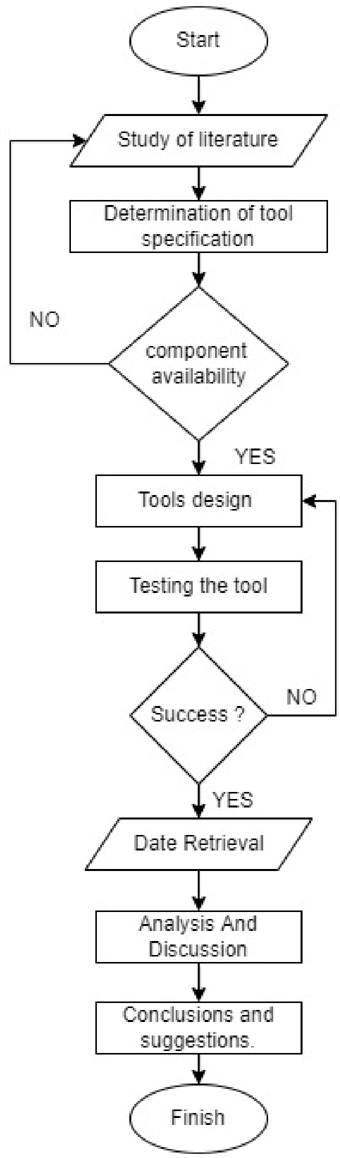


Figure 1. Research Flowchart

Based on the flow chart above, it can be seen that the research steps are as follows;

a. Study of literature.

At this stage, namely looking for or collecting various sources of information related to the research to be carried out so that it can be used as a reference to achieve research results

b. Determination of tool specifications.

After collecting the sources of information from several supporting literacy and the modelling results, it will be carried out to plan the components specifications. Purchase of tools and materials as needed.

c. Tools design.

At this stage, a simulation is carried out in advance of the design made using Proteus software. This is so that when the procedure is carried out in practice, there are no problems that cause failure. After doing the simulation through Proteus software, it is followed by hardware design, which includes making PCB schematics to installing components on the PCB.

d. Perform tool testing.

At this stage, after designing tools and installing components on the PCB, the inverter is tested as a whole. This test is carried out to obtain the required data

e. Data retrieval.

After testing the tool, it will also take the necessary data. These data will then be processed.

f. Analysis and Discussion.

Based on the data obtained when testing the tool, the next step is processing the data obtained and will be continued with an analysis of the data obtained.

g. Conclusions and suggestions.

After analyzing the data obtained, the next step is to draw conclusions and provide suggestions for the research that has been done.

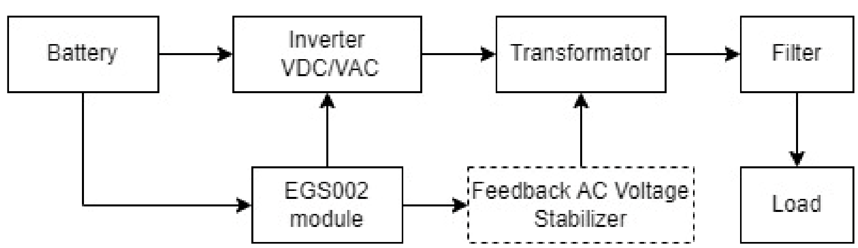


Figure 2. Diagram of Block System

An inverter converts direct voltage (DC) into alternating voltage (AC). This study uses a 12 VDC battery voltage source from the battery. Then the battery is used as input to the EGS002 module and the inverter circuit. In converting DC to AC, switching from the MOSFET uses an H-Bridge circuit, while the EGS002 module is used as the SPWM driver. Then the output from the inverter will be forwarded to the transformer to increase the voltage to 220V. In the filter section, it is used to reduce the ripple that occurs in the output waveform. Then the transformer output can be controlled using a feedback ac voltage stabilizer circuit. Bias from hidden neurons with low error rates were measured using the Mean Square Error (MSE).

4. RESULT AND DISCUSSION

This analysis and discussion are carried out by obtaining data from the inverter testing tool. In this study, an inverter was used for monitoring the Asper-19 robot. The designed inverter is an inverter equipped with a dc fan as a MOSFET cooler; there is a trimpot used to regulate the output voltage of the resulting step-up results. While the transformer used is a low-frequency transformer. The transformer used is an iron core transformer, where the more significant the power capacity produced, the larger the size of the transformer. A test with varying load values is carried out to determine the inverter's capacity. An oscilloscope is also inverter testing to determine the frequency value and the output waveform generated when loaded. An inverter is a device that can convert direct electric voltage (DC) into alternating electric voltage (AC).

4.1. Load Design

The loads are lamp and ASPER-19 robot. The lamp load uses up to 140 watts, while the ASPER-19 robot uses an LCD monitor and a Tower Light with a buzzer. The power consumption required on the LCD monitor is 26 watts, while the light tower with a buzzer consumes 4 watts of power. The MOSFET used is type HY4008 with a Vds value of 80V, VGS 25V, Id of 144A and the maximum power on the MOSFET based on the datasheet is 173 watts.

$$P=\sqrt{3}\times V\times i \tag{1}$$

Based on the calculations, the MOSFET can work with a maximum power of 2992.98, but in the datasheet stated on the MOSFET HY4008, the maximum power that the MOSFET can pass is 173 watts.

4.2. Inverter Circuit Design

In manufacturing an inverter with a full-bridge topology by designing a path through PCB express, the tool uses 4 MOSFETs DC fans. It utilizes the egs002 module used as the SPWM driver. A capacitor is added at the transformer output, used as an output wave filter. The capacitor used is a mylar 2.2 uF 400V capacitor. The transformer output is connected to a diode bridge circuit connected to a trimpot as a voltage regulator by rotating it and connecting it to the feedback pin on the egs002 module. This feedback circuit serves to adjust the transformer output voltage to be adjusted.

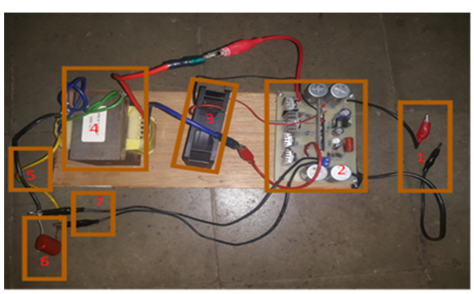


Figure 3. Inverter design

4.3. Inverter Circuit Test

The inverter circuit is carried out before connecting to a step-up transformer in this test. This test aims to determine the efficiency of the inverter made and the characteristics of the transformer to be used so that the maximum transformer output can be obtained. This test is carried out with different voltage variations using a lime resistor load of 5 watts 10 ohms.

Table 1. Inverter Circuit Test

V_{In} (V)	I_{In} (A)	P_{In} (W)	V_{Out} (V)	I_{Out} (A)	P_{Out} (W)	Effisiensi (%)
9,000	0,15	1,35	0,005	0,025	0,00125	0,09%
9,500	0,16	1,52	0,005	0,014	0,00007	0,005%
10	0,156	1,56	3,73	0,264	0,984	63,08%
10,500	0,58	6,09	6,72	0,589	3,958	64,99%
11,000	0,75	8,25	6,84	0,785	5,369	65,08%
11,500	0,88	10,12	7,17	0,878	6,295	62,21%
12,000	1	12	8,1	0,969	7,849	65,41%
12,500	1,06	13,25	8,6	1,027	8,832	66,66%
13,000	1,1	14,3	8,9	1,052	9,363	65,47%

From the tests that have been carried out with varying voltage values ranging from 9 V to 13 V. In the first test, with an input voltage of 9 V. It produces an input current of 0.15 A, an output voltage of 0.005 V, and an output current of 0 A. comparing the output power with the input power, the efficiency is 0.09%. In the second test with an input voltage of 9.5 V, an input current of 0.16 A and an output current of 0.014 A resulted in an efficiency value of 0.005%. In the third test, with an input voltage of 10 V, the input current is 0.156 A, the output voltage is 3.73 V, and the output current is 0.264 A, so the efficiency value is 63.08%. In the fourth test, the input voltage of 10.5 V produces an input current of 0.58 A, an output voltage of 6.72 V, and an output current of 0.589 A so that an efficiency value of 64.99% is obtained.

In the fifth test, the input voltage value of 11 V produces an input current value of 0.75 A, an output voltage of 6.84 V, an output current of 0.79 A, so that an efficiency value of 65.08% is obtained. In the sixth test, the input voltage value of 11.5 V produces an input current of 0.88 A, an output voltage of 7.17 V, an output current of 0.89 A so that an efficiency value of 62.21% is obtained. In the seventh test, with an input voltage of 12 V, the input current value is 1 A, the output voltage is 8.1 V, and the output current is 0.97 A, so the efficiency value is 65.41%. In the eighth test, with an input value of 12.5 V, the input current value is 1.06 A, the output voltage is 8.6 V, and the output current is 1.027 A.

The ninth test, with an input voltage value of 13 V, produces an input current Of 1.1 A, the output voltage is 9.9 V, and the output current is 1.05 A, so the efficiency value is 65.47%.

The greater the input voltage value, the greater the output voltage produced. The more significant the difference between the output and input power, the smaller the resulting efficiency. The input voltage of 9 volts and 9.5 volts has an output of 0 volts, causing the egs002 module to flash, so it doesn't work optimally. The highest efficiency is at the input voltage of 12.5 V, with an efficiency of 66.66%.

4.4. EGS002. waveform output test

The test was carried out on the EGS002 pin module to determine the incoming PWM waveform at the foot gate MOSFET used for switching. Based on Figure 4.2, we get a picture of the output waveform performed on pins 3 and 6 of the interesting egs002 module with a box-shaped oscilloscope with a maximum voltage of 40V and a minimum voltage of -28V. While on the test pin 8 and pin 10 the test results obtained are in the form of a box with a maximum voltage of 16V, and a minimum voltage of -40V. When the MOSFET that works in pairs is activated, the difference between the two waves lies in the pulse width/wave width. The difference in the width of the pulse/wave will be alternately high and low conditions. After heading to the MOSFET, the wave will pass through the H-Bridge bridge and then come out a sine wave with a little ripple which will be smoothed out with a filter.

Table 2. Inverter Testing With Variable Load

Loads (W)	**V_{In} (V)**	**I_{In} (A)**	**Pin (W)**	**V_{Out} (V)**	**I_{Out} (mA)**	**Pout(W)**	**Eficiency (%)**
10	12,650	2,10	26,565	220	75,15	16,500	62,24
15	12,660	2,55	32,283	220,6	91,43	20,075	62,48
25	12,560	3,41	42,8296	220,5	121,22	26,681	62,41
35	12,500	4,49	56,125	220,5	154,58	33,957	60,73
40	12,470	4,94	61,6018	220,4	174,06	38,350	62,28
50	12,410	5,79	71,8539	210,7	213,00	44,879	62,46
90	12,270	7,58	93,0066	199,1	286,00	56,943	61,22
95	12,280	7,9	97,012	196,8	302,00	59,434	61,26
105	12,320	8,49	104,5968	196	326,00	65,856	61,09
120	12,280	9,52	116,9056	180,4	399,00	71,980	61,57
140	12,300	10,91	134,193	178,4	469,00	83,670	62,35

Based on the inverter test with a resistive load, the load varies from 10 watts to 140 watts, while the voltage source uses a 12V battery. The load is 10 watts in the first test with an input voltage of 12.65 V and an input current of 2.10 A. The resulting output voltage is 220 V, and the resulting output current is 75.15 mA. In the 10-watt load test, the efficiency is 62.24% at a load of 15 watts with an input voltage of 12.45 V, and an input current of 2.55 A. The resulting output voltage is 220.6 V, the resulting output current is 91.43 mA, and the resulting efficiency is 62, 48%. In testing a load of 25 watts with an input voltage of 12.56 V, and an input current of 3.41 A.

The output voltage generated at a 25-watt load is 220.5 V, the output current is 121.22 mA, and the resulting efficiency by 62.41%. The load test of 35 watts with an input voltage of 12.5 V and an input current of 4.49 A. The resulting output voltage is 220.5 V, the resulting output current is 154.58 mA, and the resulting efficiency is 60,73%. The load test of 40 watts, with an input voltage of 12.47 V and an input current of 4.94 A. The resulting output voltage is 220.4 V, the resulting output current is 174.06 mA, and the resulting efficiency is 62.28%. The load test of 50 watts with an input voltage of 12.41 V and an input current of 5.79 A. The resulting output voltage is 210.7 V, the output current is 213 mA, and the resulting efficiency is 62.46%. In the 90-watt load test, the input voltage is 12.27 V, and the input current is 7.58 A. The output voltage is 199.1 V, the output current is 286 mA, and the resulting efficiency is 61.22%. In the 95-watt load test, the input voltage is 12.28 V, and the input current is 7.9A. The resulting output voltage is 196.8 V, the resulting output current is 302 mA, and the resulting efficiency is 61.26%. In the 105-watt load test, the input voltage is 12.32 V, and the input current is 8.49 A. The output voltage is 196 V, the output current is 336 mA, and the resulting efficiency is 61.09%.

In testing loads up to 90 watts, the resulting output voltage is 220 V with a tolerance of ±10%. While testing the load above 90 watts to 140 watts, the resulting output voltage is below 198 V, or a voltage drop occurs at loads above 90 watts. Some of the causes of voltage drops or voltage drops that can occur are due to the use of too many jumper cables and too large a load. The greater the load used, the

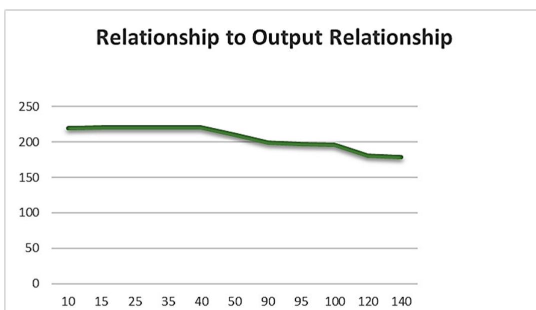


Figure 4. Graph of the relationship between the load and the output voltage

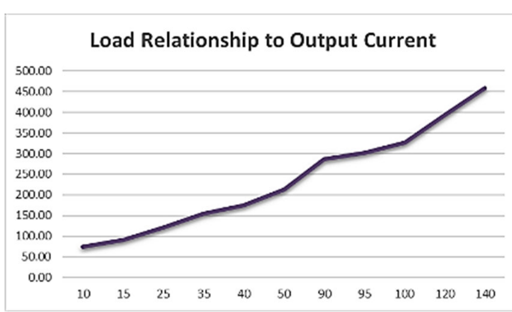


Figure 5. Picture of the relationship between the load and the output current

Based on Figure on above graph of the relationship between the load and the output voltage, it can be seen that up to a load of 90 watts the output voltage is 220V with a tolerance of 10%. The greater the load used, the smaller the output voltage produced. This is because there are losses that can be caused by factors such as the use of too many jumper cables and too large a load.

Figure 3 on the graph of the relationship between the load and the output current shows that the load is directly proportional to the resulting output current. The greater the load used during testing, the greater the output current generated. And vice versa, the smaller the load used, the smaller the output current produced. Based on the Figure 4 graph of the relationship between the load and the output power, it can be seen that the greater the load, the greater the output power. In testing the effect of the load on the resulting waveform, it is done by varying the load using an oscilloscope media to display the resulting waveform and displaying several characteristics such as frequency, peak to peak voltage, maximum voltage, and minimum voltage.

4.5. Inverter Testing with Asper-19 Robot Load

In the inverter test carried out for 120 minutes to determine the effect of time on the frequency and waveform. In the zero minute test, the data obtained from the test results for a peak to peak voltage of 640V, a maximum voltage of 324V, a minimum voltage of -316V and a frequency of 50Hz. In the 5th minute test, the test results on the robot are obtained, namely, the peak to peak voltage is 640V, the maximum voltage is 324V, the minimum voltage is -316V, and the resulting frequency is 50Hz. In the 10th minute test, the peak to peak voltage produced is 640V, the maximum voltage is 324V, the minimum voltage is -316V, and the resulting frequency is 50 Hz. In the 15th minute test, the peak to peak voltage generated is 632V, the maximum voltage is 316V, the minimum voltage is -316V, and the resulting frequency is 50 Hz. In the 20th minute test, the peak to peak voltage generated is 640V, the maximum voltage is 324V, the minimum voltage is -316V, and the resulting frequency is 49.7 Hz.

Table 3. Inverter Output Stability In Asper-19 Robot

Time (minutes)	**V_{In} (V)**	**I_{In} (A)**	**V_{Out} (V)**	**I_{Out} (mA)**
0	12,468	1,30	221,4	44,73
5	12,448	1,30	221,3	44,68
10	12,440	1,29	221,6	44,87
15	12,390	1,30	221,5	44,61
20	12,380	1,30	221,2	44,64
25	12,340	1,30	221,9	44,62
30	12,320	1,30	221,6	44,59
35	12,250	1,31	221,8	44,56
40	12,244	1,32	221,8	44,52
45	12,212	1,32	221,7	44,56
50	12,169	1,32	221,7	44,77

55	12,133	1,33	221,6	44,57
60	12,100	1,33	221,5	44,69
65	12,060	1,33	221,9	44,58
70	12,010	1,33	221,3	44,52
75	11,970	1,33	221,5	44,62
80	11,936	1,33	221,8	44,57
85	11,880	1,34	221,8	44,62
90	11,840	1,34	221,2	44,63
95	11,790	1,34	221,9	44,64
100	11,750	1,34	221,9	44,63
105	11,710	1,34	221,6	44,61
110	11,670	1,33	221,3	44,65
115	11,610	1,34	221,3	44,69
120	11,570	1,34	221,2	44,97

The test on the Asper-19 robot was carried out for 2 hours; based on the test, it was found that the longer the test was carried out, the smaller the input voltage, while the stable input current was at a current of 1.3A.

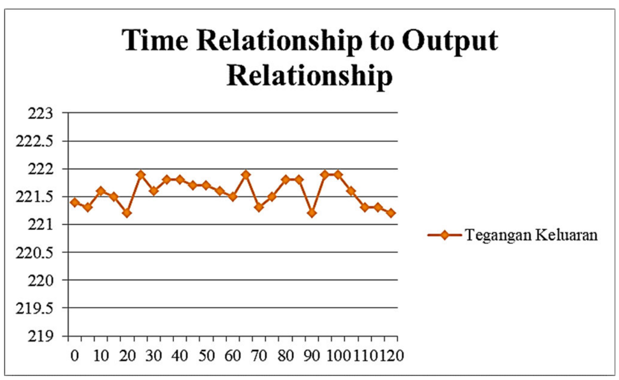
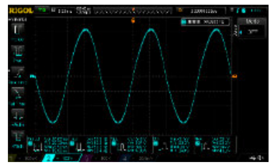
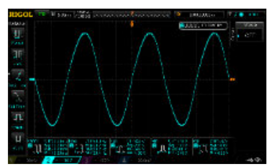
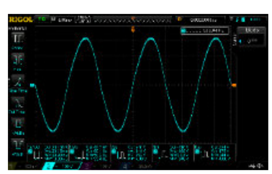


Figure 6. Graph of the Relationship of Time to Output Voltage

Based on research carried out on the ASER-19 robot for 120 minutes, the highest frequency produced is 50.2 Hz and the lowest frequency is 49.7 Hz. While the resulting waveform from the zero minute test to the 120th minute, the waveform is stable in sine conditions. Based on the maximum voltage produced slightly decreased from 324V to 316V in the 50th minute. Starting from the 50th minute to the 120th minute, the maximum voltage is 316V, meaning that the amplitude at the k-50 minute maximum voltage is stable at 316V until the 120th minute.

Table 4. Effect of Time on Waveform and Frequency

Time (Minute)	**Frequency (Hz)**	**Waveform**
0	50	 Figure 8. 0^{th} minute wave
5	50	 **Figure 9.** 5^{th} minute wave
10	50	 **Figure 10.** 10^{th} minute wave
15	50	 **Figure 11.** 15^{th} minute wave
20	49,7	 **Figure 12.** 20^{th}-minute wave

The resulting percent error value is below 5%, the most significant is 3.39%, and the smallest percent error is 0.99%. The total harmonic distortion (THD) test is done using an oscilloscope. On the oscilloscope, the 1st to nth harmonic values are known on the oscilloscope, and the values obtained are measured in dBV units. The unit is first converted to V with the formula:

$$V = 10^{\frac{dBV}{20}} \tag{2}$$

The result of the conversion of dBV into volts, the THD value, can be known by the following formula.

$$\text{THD} = \frac{\sqrt{V2^2+V3^2+V4^2+V5^2+V6^2+V7^2+V8^2}}{V1} \tag{3}$$

In the inverter test on the Asper-19 robot at 5 minutes using an oscilloscope, the THD value is 3.60%.

Based on tests carried out using an oscilloscope from minute zero to minute 120, the overall THD value was below 5%. The smaller the THD value, the better because it can minimize the occurrence of equipment damage caused by harmonics.

5. CONCLUSION

A single-phase sinusoidal inverter with a low-frequency transformer has been successfully designed by utilizing the egs002 module as an SPWM driver and using an ups transformer as a voltage booster. The inverter evidence this can work up to 140 Watt load. Before being connected to the transformer, the inverter output using a 5W 10 Ohm lime resistor load with an input voltage of 10 V-13 V has an efficiency above 60%. While below 10 V, the efficiency is tiny because the egs002 module lacks input voltage, which does not work optimally. In the inverter test using the Asper-19 robot, which was carried out for 120 minutes, the input voltage decreased, but the output voltage was relatively stable at 221.5V.

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