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Speed Control of Induction Motor Using Variable Frequency Driver (VFD) Method Based On Arduino Nano

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Abstract. This research aims to control the speed of an induction motor by exploiting changes in the fundamental frequency. The inverter as the main part of the variable frequency driver (VSD) uses the IRFZ44n Mosfet as a power switch with a full bridge topology to convert the DC source to AC power. Fundamental frequency manipulation takes place during the conversion process. The method used is to change the variable fundamental frequency of the SPWM signal generated by the Arduino nano to control the power switch. Experiments are carried out based on two stages, namely simulation, and experiment. The simulation is performed using the Pspice A/D Lite software to take time sample data (HIGH and LOW) at each frequency change of 13Hz, 25Hz, 38Hz, and 50Hz, then the sample data is input on the Arduino nano as an SPWM signal generator to control the power switch. The results of the variable frequency drive test are the frequencies generated to drive the induction motor at 12.50 Hz, 24.04 Hz, 35.71 Hz, and 48.54 Hz at motor speeds from 227.7 to 1359.6 rpm.

Keywords. Arduino Nano, Induction Motor, Variable Frequency Driver (VSD)

1 Introduction

The development of electric vehicles is currently being pursued very intensively to convert the use of fossil energy resources to electric energy. The drive system of electric motorcycles and electric cars, in general, includes electric motors such as AC motors and DC motors. In particular, the induction motor has been developed and used in the Tesla Model S smart car [1][2]. In addition, induction motors are also widely used in industry and households because of their easy operation, strong construction, good efficiency, and constant rotation despite load changes [3]–[5].

The application of induction motors in electric vehicles requires a controller that regulates the speed of the electric motor according to the user's wishes. Induction motors use AC voltage, so the easiest way to adjust the speed of an induction motor is to change the frequency. The inverter is an electronic device used to convert DC voltage to AC power, which uses solid-state switch switching technology in the conversion process, which uses various techniques to generate a solid-state switch control pulse [6][7]. The inverter can also be used as a variable frequency drive (VFD) by adjusting the pulse width modulation (PWM) on the solid state switch to change the output frequency. [3][8][9]. In addition, using VFD with an induction motor also has advantages over using traditional methods or using an induction motor without using VFD. Induction motors with fixed frequency VSD have better energy efficiency [4][5], [10]–[12].

Therefore, this research attempts to change the speed of a single-phase induction motor in response to changes in frequency. This research uses Sinusoidal Pulse Width Modulation (SPWM) technique as the semiconductor switching control. An inverter with a full-bridge configuration is used as the VFD. Then the type of motor used is a single-phase induction motor. The simulation has performed with the PSpice A/D Lite software.

2 System Description

2.1 Induction Motor

An induction motor is an alternating current (AC) motor in which the motor rotor current comes from the current induced on the stator from the relative difference between the rotation of the rotor and the rotating magnetic field. [13] [14]. The synchronous speed (ns) can then be written with the following equation:

$$n_s = \frac{120f}{p}\ (rpm) \quad (1)$$

Where f is the frequency and p is the number of poles.

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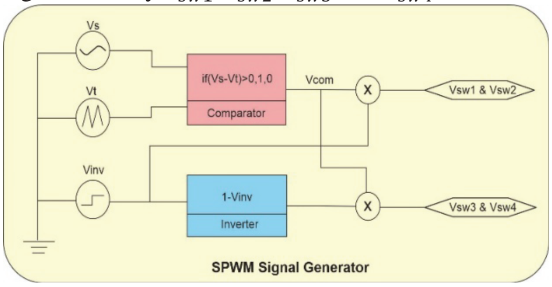
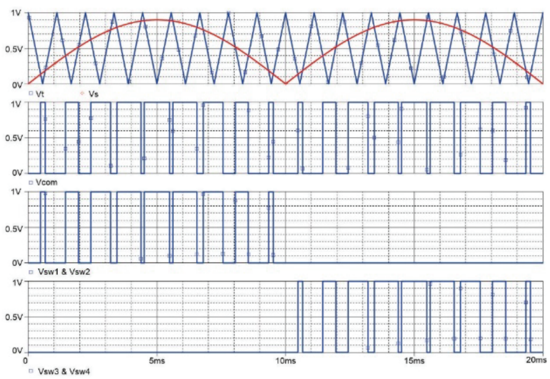
2.2 Positioning

The SPWM technique produces a signal output based on the comparison of the sine signal (V_s) and the triangular signal (V_t). Where the output signal is HIGH when the voltage value is $V_s > V_t$ and is LOW when the voltage value is $V_s < V_t$. The representation of the SPWM signal generation is shown in Figure 1(a). V_{com} is the resulting signal from the comparator and the power switch control signal, namely $V_{sw1}, V_{sw2}, V_{sw3}$ and V_{sw4}.



(a)



(b)

Fig. 1. (a) Block diagram of SPWM signal generation (b) Representation of SPWM signal generation

This research uses Arduino as the control unit for the SPWM signal generator. Arduino is a microcontroller that works sequentially, so it is not possible to generate a sine signal and a triangle signal at the same time. Therefore, the method used is to take HIGH and LOW time data samples based on simulations with PSpice as shown in Figure 1(b).

2.3 Variable Frequency Driver (VFD)

As shown in Formula 1, changing the speed of the induction motor can be done in two ways, namely by changing the p-pole of the induction motor and changing the frequency magnitude f. But the first way is that changing the p pole can lead to changes in the design of the induction motor because you need to add windings to the induction motor stator, which can be difficult and requires a lot of space and cost. The second way is to change the frequency f This method is more commonly used in previous studies because it has better efficiency [3][4][10][11]. Figure 2 shows a block diagram of the VFD system, in which there are several main parts of the system, namely, DC power source, solid-state power switch, SPWM controller, passive filter, and induction motor load. The solid-state power switch uses a full bridge topology with DC input and the power switch is controlled by an Arduino microcontroller that generates an SPWM signal. The SPWM output frequency is manually adjusted by the user with a potentiometer. A passive filter acts as a filter against interference from the switching process. The performance of the passive filter is then increased with a voltage boost to allow the motor to operate.

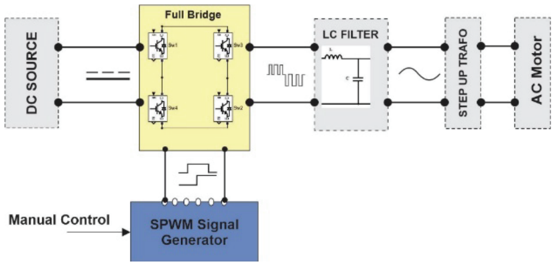


Fig. 2. Block diagram of variable frequency driver system (VSD)

3 Results and Discussion

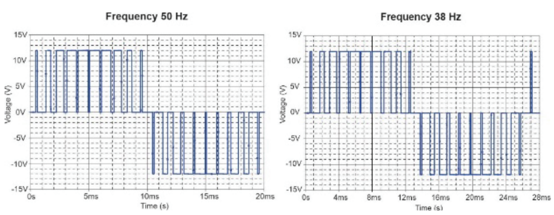
This research has been carried out based on the results of simulations and experiments. The software used to perform the simulation is Pspice A/D Lite before it is implemented into a circuit. The load used is an induction motor with parameters as shown in Table 1. Tests were conducted based on changes in frequencies of 13 Hz, 25 Hz, 38 Hz, and 50 Hz.

Table 1. Induction motor parameters

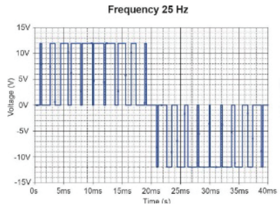
Parameters	Value
Voltage	220 V
Power	50 W
Frequency	50 Hz
Speed	1400 Rpm

3.1 Simulation Result

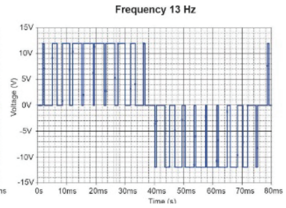
The simulation is carried out by changing the fundamental frequency variable parameter in the SPWM signal which is used to control the power switch. The switching frequency remains unchanged in the order of 10 kHz. The purpose of the simulation is to obtain sample time signal data (HIGH and LOW) for each frequency change of 13Hz, 25Hz, 38Hz, and 50Hz. Figure 3 shows the output voltage generated by the inverter with the maximum voltage value (V_{max}) of 11.9 V.



(a) (b)



(c)



(d)

Fig. 3. Inverter output voltage with resistive load (17 kΩ) against frequency change (a) 50 Hz (b) 38 Hz (c) 25 Hz (d) 13 Hz.

3.2 Experiment Result

The experiment has carried out in two stages, the first stage was based on a simulation using an unfiltered resistance load, a step-up transformer, and an induction motor. The SPWM signal generator uses an Arduino nano with a potentiometer as a frequency regulator. The second stage uses a filter, a step-up transformer, and an induction motor as shown in Figure 4.

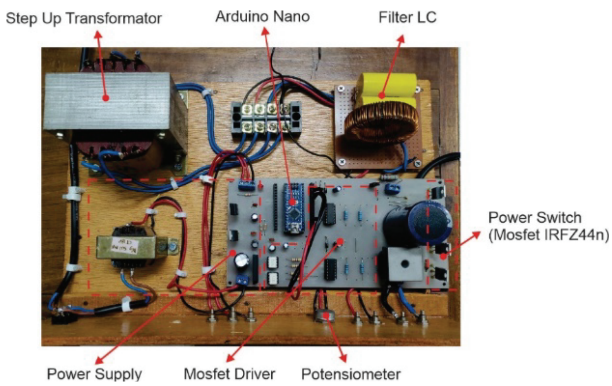
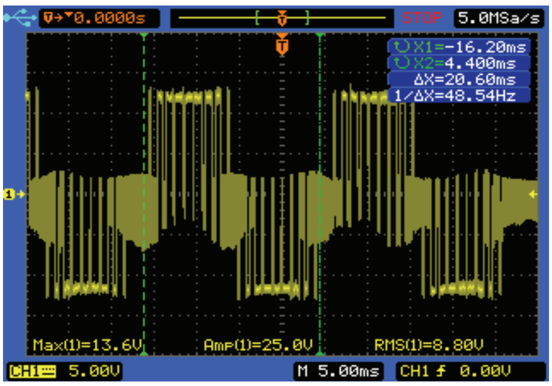
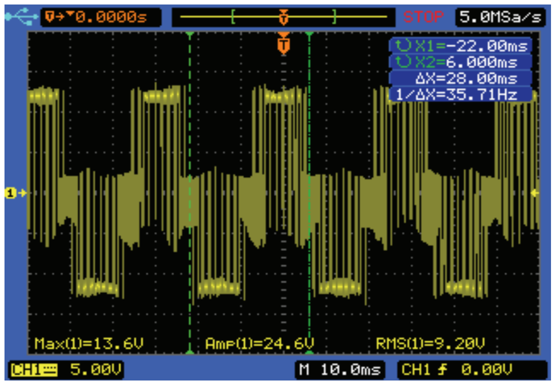


Fig. 4. Variable Frequency Drive (VFD) Device

First Stage (VFD with Resistor Load). A 12 V DC source with a load of 17 kΩ is used as input to the inverter. At this stage compare the results of the simulation with experiments. Figure 5 shows the measurement results with an oscilloscope. The results obtained are the frequencies of 48,54 Hz, 35,71 Hz, 24,04 Hz, and 12,50 Hz. Meanwhile, the V_max voltage is 13,6 V for frequencies (48,54 Hz, 35,71 Hz, and 12,50 Hz) as shown in Figure 5 (a, b, and d) and 14,4 V at frequencies 24,04 Hz, as in Figure 5 (c).



(a)



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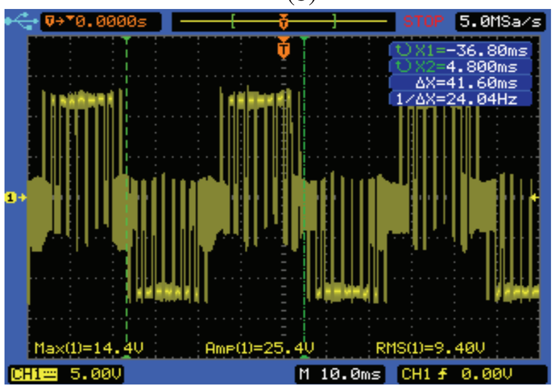

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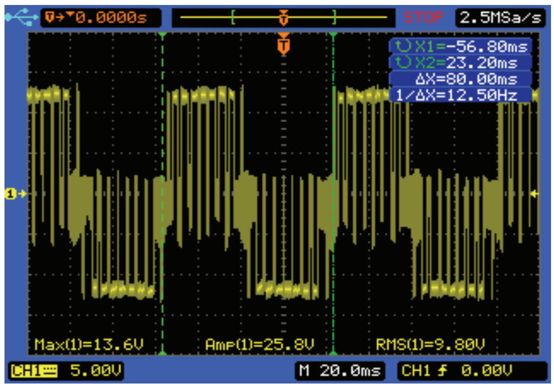

(d)

Fig. 5. Inverter output voltage with resistive load (17 kΩ) against frequency change (a) 50 Hz (b) 38 Hz (c) 25 Hz (d) 13 Hz.

Second Stage (VFD with step-up transformer and induction motor load). In this second stage, the experiment is performed by adding a step-up transformer and an induction motor load. Load changes on the inverter will lead to a change in the input voltage on the inverter to achieve the effective working voltage of the asynchronous motor with a DC input voltage of 17 V. Table 2 shows the results of the tests carried out, frequency changes affect the speed of the induction motor. The RMS voltage at the induction motor tends to be stable in the 223-230V range. The higher the frequency, the faster the induction motor rotates and the lower the power consumption. The highest speed is 1359,6 rpm at a frequency of 48,54 Hz.

Table 2. VFD measurement results with induction motor load.

Frequency (Hz)	Voltage (V)	Current (A)	Speed (rpm)
48,54	223	0,33	1359,6
35,71	226	1,2	1017,8
24,04	228	1,4	671,1
12,50	230	1,6	227,7

4 Conclusion

Based on the VFD simulation and experimental results, the fundamental frequency change from 12,5 to 48,54 Hz on the VFD is directly proportional to the speed change of the induction motor with a speed of 227,7 to 1359,6 rpm. The highest speed achieved is 1359,6 rpm at a frequency of 48,54 Hz. Output voltage stability is maintained in the range of 223V - 230V, where the effective working voltage required by the induction motor is 220V. It is hoped that the induction motor speed control device with the variable frequency adjustment method can be used at low loads.

References

[1]. G. Sieklucki, "An investigation into the induction motor of tesla model S vehicle," 2018 Int. Symp. Electr. Mach. SME 2018, pp. 1–6, (2018), doi: 10.1109/ISEM.2018.8442648.

[2]. P. J. Grbovic and S. N. Vukosavic, "An auxiliary power supply based on the phase voltage ripple employed in a micro inverter for feeding three phase Tesla induction motor," in 2005 European Conference on Power Electronics and Applications, (2005), pp. 8 pp.-P.8, doi: 10.1109/EPE.2005.219273.

[3]. S. Sitorus, "Analisis Pengaruh Penurunan Frekuensi Terhadap Kinerja pada Motor Induksi Lima Phasa," (2017).

[4]. 4S. A. Othman, J. A.-K. Mohammed, and F. M. Mohammed, "Variable Speed Drives in Electric Elevator Systems: A Review," J. Phys. Conf. Ser., vol. **1973**, no. 1, p. 12028, Aug. (2021), doi: 10.1088/1742-6596/1973/1/012028.

[5]. M. Eriyadi, A. Ajimah, D. Usman, Y. M. Hamdani, S. C. Abadi, and A. Suryadi, "Analysis of the implementation of three-phase Variable Frequency Drive on the prototype of a rice drying machine," {IOP} Conf. Ser. Mater. Sci. Eng., vol. **1098**, no. 4, p. 42057, Mar. (2021), doi: 10.1088/1757-899x/1098/4/042057.

[6]. M. Rusdi, F. A. Samman, and R. S. Sadjad, "FPGA-based electronic pulse generator for single-phase DC/AC inverter," in 2019 International Conference on Information and Communications Technology, ICOIACT 2019, (2019), pp. 756–760, doi: 10.1109/ICOIACT46704.2019.8938571.

[7]. M. Rusdi, F. A. Samman, R. S. Sadjad, A. E. Umraeni Salam, and C. Machbub, "Standalone Single Phase DC-AC Inverter with FPGA-based Pulse Modulated Generator Unit," in 2020 International Seminar on Intelligent Technology and Its Applications (ISITIA), Jul. (2020), pp. 7–12, doi: 10.1109/ISITIA49792.2020.9163770.

[8]. A. Z. Latt, "Variable Speed Drive of Single Phase Induction Motor Using Frequency Control Method," pp. 30–34, (2009), doi: 10.1109/ICETC.2009.72.

[9]. E. A. Nugroho, "Implementasi Sistem Kendali Variable Speed Drive Pada Inverter 3 Fasa Menggunakan Mikrokontrol At89S52," Simetris J. Tek. Mesin, Elektro dan Ilmu Komput., vol. **9**, no. 1, pp. 413–424, (2018), doi: 10.24176/simet.v9i1.1988.

[10]. Atmam, A. Tanjung, and Zulfahri, "Analisis Penggunaan Energi Listrik Motor Induksi Tiga Phasa Menggunakan Variable Speed Drive (VSD)," SainETIn, vol. **2**, no. 2, pp. 52–59, (2018), doi: 10.31849/sainetin.v2i2.1218.

[11]. X. Tang, J. Ye, L. Zhang, Y. Yao, and P. Shao, "The design of permanent magnet variable-frequency door-motor with one-driver dual control," J. Phys. Conf. Ser., vol. **1650**, no. 2, p. 22083, Oct. (2020), doi: 10.1088/1742-6596/1650/2/022083.

[12]. K. H. Khudier, K. G. Mohammed, and M. S. Ibrahim, "Design and Implementation of Constant Speed control System for the Induction motors Using Programmable logic Controller ({PLC}) and Variable Frequency Derive ({VFD})," {IOP} Conf. Ser. Mater. Sci. Eng., vol. **1076**, no. 1, p. 12007, Feb. (2021), doi: 10.1088/1757-899x/1076/1/012007.

[13]. Y. Shen, C. Zhu, and X. Wang, "Slot Optimization Design of Induction Motor for Electric Vehicle," {IOP} Conf. Ser. Mater. Sci. Eng., vol. **301**, p. 12081, Jan. (2018), doi: 10.1088/1757-899x/301/1/012081.

[14]. R. M. Antheesh, M. S. Bhat, and I. D. R. Ballal, "Performance Investigation of Single-Phase Capacitor Start -Capacitor Run Induction Motor Drive 12 3," {IOP} Conf. Ser. Mater. Sci. Eng., vol. **1065**, no. 1, p. 12043, Feb. (2021), doi: 10.1088/1757-899x/1065/1/012043.

[15]. A. Z. Latt and N. N. Win, "Variable Speed Drive of Single Phase Induction Motor Using Frequency Control Method," in 2009 International Conference on Education Technology and Computer, (2009), pp. 30–34, doi: 10.1109/ICETC.2009.72.

[16]. S. Mahmodicherati, N. Ganesan, L. Ravi, and R. Tallam, "Application of Active Gate Driver in Variable Frequency Drives," in 2018 IEEE

Energy Conversion Congress and Exposition (ECCE), (2018), pp. 1796–1799, doi: 10.1109/ECCE.2018.8558170.