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abdelrahim ahmed mohammed ate
School of Mechanical and Electrical Engineering, Dezhou University, Dezhou, Shandong, China, wadalroob@gmail.com

Rihab Gafar
School of Mechanical and Electrical Engineering, Dezhou University, Dezhou, Shandong, China, Eng.rihabgafar@gmail.com

Xiuyun Sun
School of Mechanical and Electrical Engineering, Dezhou University, Dezhou, Shandong, China, sunxy78@163.com

Tahleel Abozead
Control Department, Faculty of Engineering, Alneelain University, Khartoum, Sudan, tahleelabozead93@yahoo.com

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Three-phase AC Induction Motor Speed Control Based on Variable Speed Driver

Abdelrahim Ate[1*], Rihab Gafar[1], Xiuyun Sun[1], and Tahleel Abozead[2]

1. School of Mechanical and Electrical Engineering, Dezhou University, Dezhou, Shandong, China
2. Control Department, Faculty of Engineering, Alneelain University, Khartoum, Sudan

[*]*E-mail: wadalroob@gmail.com*

Abstract

Massive loss of power is a concern for many countries because of the high power consumption of alternating current (AC) motors. The motor speed should be controlled to alleviate this problem and save more power. This paper proposes a simple simulation for a variable speed driver (VSD) to control the three-phase induction motor speed. The VSD consists of three parts. The converter performs from full bridge diodes to convert single-phase AC voltage into direct current voltage, and then this voltage is filtered by the RL filter and transferred to the last part, which is the inverter. The model was simulated by using MATLAB/Simulink. Findings show that the VSD controller provides sufficient control over the AC induction motor speed.

Abstrak

Kendali Kecepatan Motor Induksi AC Tiga Fase berdasarkan Penggerak Kecepatan Variabel. Hilangnya daya secara besar-besaran menjadi perhatian banyak negara yang menjadi penyebab tingginya konsumsi daya motor arus bolak-balik (AC). Kecepatan motor harus dikontrol untuk mengurangi masalah ini dan menghemat lebih banyak daya. Makalah ini mengusulkan simulasi sederhana untuk penggerak kecepatan variabel (*Variable Speed Driver,* VSD) untuk mengontrol kecepatan motor induksi tiga fase. VSD terdiri dari tiga bagian. Konverter menjalankan fungsi dioda jembatan penuh (*full bridge diode*) untuk mengubah tegangan AC fase tunggal menjadi tegangan arus searah, dan kemudian tegangan ini disaring oleh filter RL dan ditransfer ke bagian terakhir, yaitu inverter. Model ini disimulasikan dengan menggunakan MATLAB/Simulink. Temuan menunjukkan bahwa pengontrol VSD memberikan cukup kendali atas kecepatan motor induksi AC

Keywords: IGBT, induction motor (IM), VSD control system

1. Introduction

The conversion of electrical energy into mechanical energy is based on electric motors. The use of alternating current (AC) motors in industrial fields has increased considerably in recent years [1]. Three-phase AC induction motors (IMs) are mainly used in machines and industrial applications [2].

AC motors operate directly from the mains or from variable speed drivers (VSDs). When the IM operates at full speed, its power consumption increases significantly. Thus, to reduce power consumption, the speed of the IM must be controlled [3].

A VSD, which is also known as a variable-frequency driver, uses an IM to monitor the power [4]. The VSD system uses an AC IM and a variable-frequency power supply [5]. The solid-state elements used in the variable-frequency power supply produce a pulse-width modulated current that adjusts the power and frequency supplied to the motor machine [6]. Thus, the IM speed can be controlled robustly over a large range of applications [7]. VSDs are used in conjunction with a wide range of applications such as fan and pump applications to control their speed on demand, often accompanied by a reduction in pressure and energy consumption [8].

The use of a VSD is a good way to control the IM speed in response to the needs of various methods. As with most electronic elements, costs and overall performance have increased dramatically within the last few years [9].

VSDs take the fixed-frequency AC supply and convert this into a variable-frequency AC supply [10]. This conversion controls the power use and mechanical power output so that the motor can run at the most efficient speed. The control of the motor speed can be based on feedback from the process—for example, flow rate, speed, temperature, and pressure—so that process control is improved [11].

Mechanical VSDs are an easy way to control the frequency because they are simple and specialized for some applications. The speed is controlled by the diameter of gears. Hydraulic motor drives are preferred for conveyor power functions due to the inherent smooth initial potential of the hydraulic unit [12]. Eddy current motors, in which the speed of the output shaft relies on the slip between the input and output drums, are managed by using the magnetic field. In the previous decade, three-phase AC IMs with variable-frequency converters for VSDs have become increasingly used, achieving high speed tuning overall performance with the aid of the controller by manipulating the frequency through adjusting the pulse-width modulation (PWM) duty cycle [13].

This paper performs speed control analysis of an AC IM based on VSD. Speed response analysis was conducted by using MATLAB/Simulink with respect to various frequencies.

2. Related Works

A method of controlling the speed of an AC IM by using a micro-controller was presented [14]. The voltage drop is controlled across two TRIAC terminals by the gate voltage. The gate is controlled by DIAC, and its input is controlled by an R-C drive circuit. The TRIAC input voltage and output voltage are simulated by using the Electronic WorkBench software.

A three-phase voltage switching inverter was simulated in MATLAB/Simulink by using the sinusoidal PWM scheme [15].

VSDs are an important power monitoring device. Typically, a VSD consists of a three-phase AC induction machine with an unstable frequency supply. In this paper, a model was simulated in which a pulse-width modulated current is outputted by the IM motor, whose power and frequency is controlled by the VSD, thus enabling the IM speed to be controlled over a wide range of applications. [16].

3. Proposed Method

Proposed design. The VSD mainly consists of three parts, which are included in the design using MATLAB: AC to DC converter, DC bus, and inverter (DC to AC converter). When the constant AC voltage in the AC converter is fed to the DC converter, the AC voltage is converted to DC voltage. This voltage is then transferred to the DC bus, which consists of capacitors and is used to store voltages and eliminates ripples in the DC voltage, thus resulting in a smooth waveform. The inverter is the last and most important part because it converts DC to AC by approximating the square wave shape with that of the sine wave, whose pulse is tuned to control the voltages and frequency of the motors.

Figure 1 illustrates the block diagram of the general components for VSD drive and control.

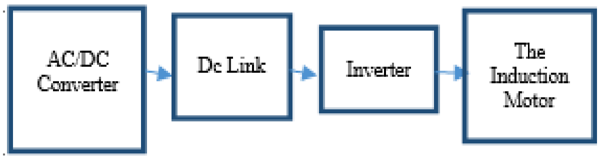

Figure 1. General Block Diagrams

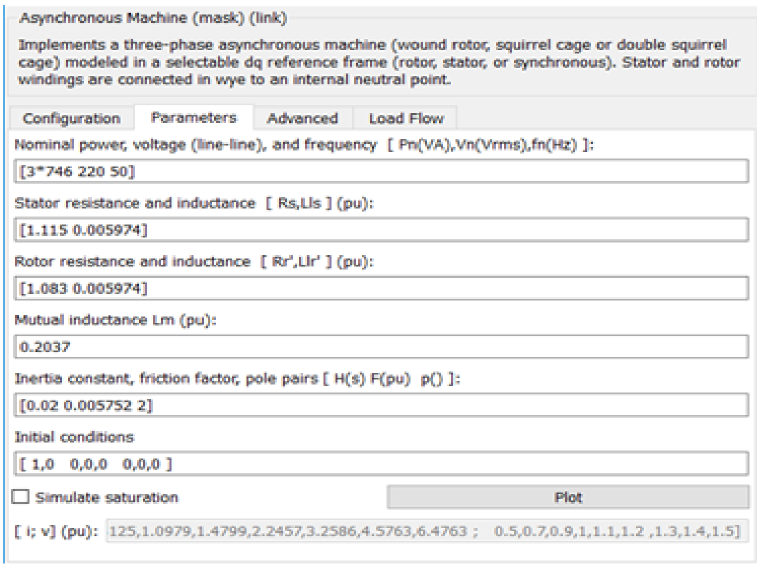

Figure 2. VSD Model

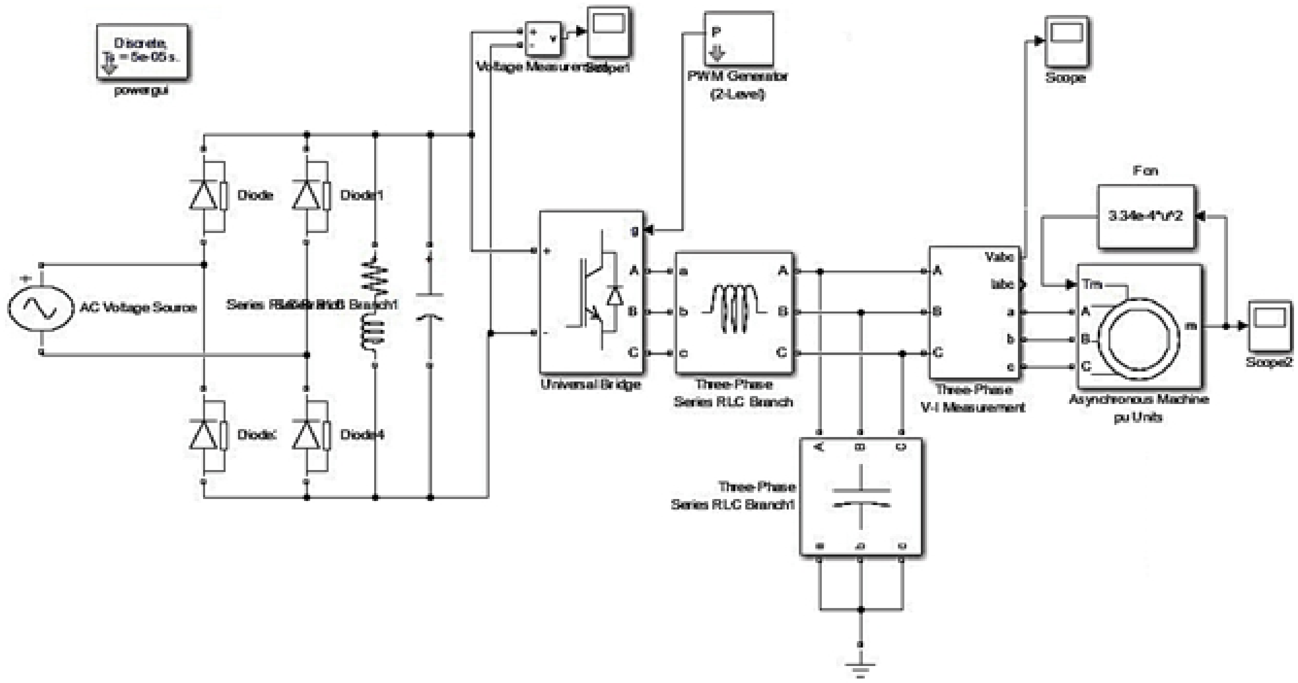

Figure 3. IM Parameters

Simulink model. The VSD model is designed using MATLAB/Simulink, and the selected inverter is an IGBT inverter. Simulations of the rotor speed control of the IM with the variable-frequency method are conducted. Figure 2 shows the VSD model.

Figure 3 shows the selected IM parameters and selection adjustment initialization.

4. Experiment and Analysis

The simulation results are presented to evaluate the effectiveness of the proposed control scheme for different operating conditions. The IM parameters used to simulate the model are shown in Figure 2. The speed varied according to the frequency variation. Four cases are presented to illustrate this variation.

Case 1 (10 Hz). The speed is changed according to the change of the PWM generator frequency. At a frequency of 10 Hz, the interval between 0.05 and 0.1 appears in the quarter-cycle of the phase. Figure 4 shows the three-phase 10 Hz and the speed of the motor based on the current frequency.

Figure 5 shows the effect of 10 Hz on the IM as displayed in its response in nearly 0.43 s, which indicated the motor speed.

Case 2 (15 Hz). When the PWM generator frequency increased to 15 Hz, the cycles increased in one interval at almost one cycle for one phase and a half-cycle for the other two phases. Figure 6 shows the three-phase frequency at 15 Hz.

Figure 7 shows the effect of 15 Hz on IM as displayed in its response in nearly 0.36 s, exhibiting fewer ripples than 10 Hz in Figure 5.

Case 3 (30 Hz). When the PWM generator frequency increased to 30 Hz, the cycles for one phase increased in one interval—for example, one cycle for one phase at a 0.05–0.1 interval. Figure 8 shows three phases at 30 Hz.

The effect of 30 Hz on IM is displayed in its response in nearly 0.29 s, as shown in Figure 9, being smoother than those shown in Figures 5 and 7.

Case 4 (40 Hz). When the PWM generator frequency increased to 40 Hz, the cycles per interval for each phase increased to about two cycles for each phase. Figure 10 shows the three phases at 40 Hz.

The effect of 40 Hz on IM is displayed in its response at nearly 0.375 s, as shown in Figure 11. Evidently, increasing the frequency results in a smoother wave and reduced speed.

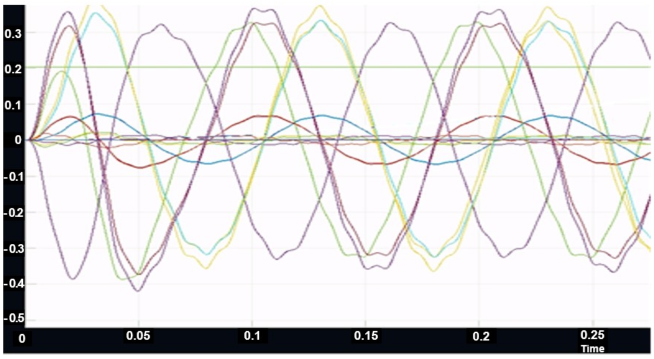

Figure 4. Three Phases in 10 Hz

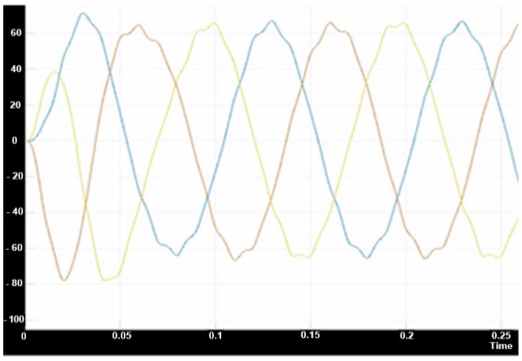

Figure 5. IM Response for 10 Hz

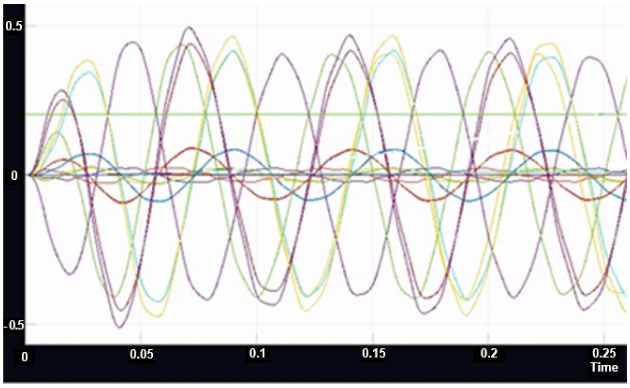

Figure 6. Three Phases in 15 Hz

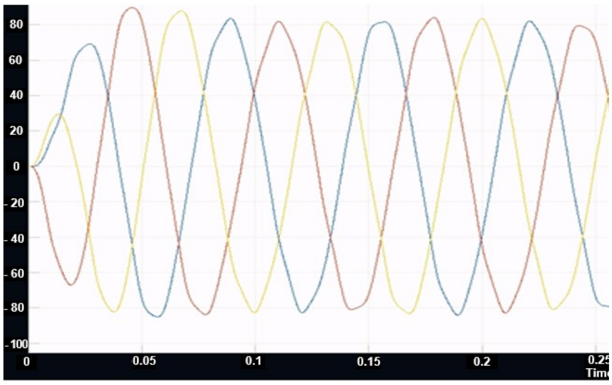

Figure 7. IM Response for 15 Hz

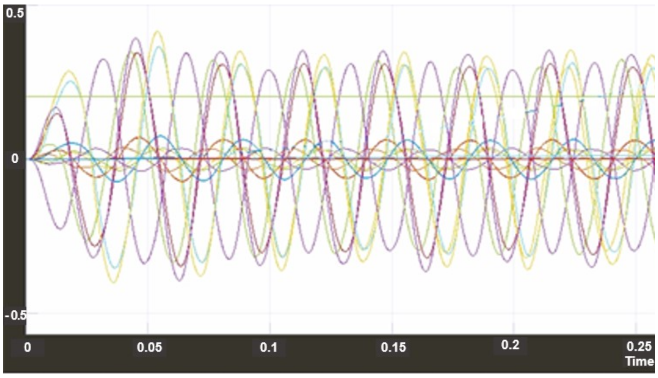

Figure 8. Three Phases in 30 Hz

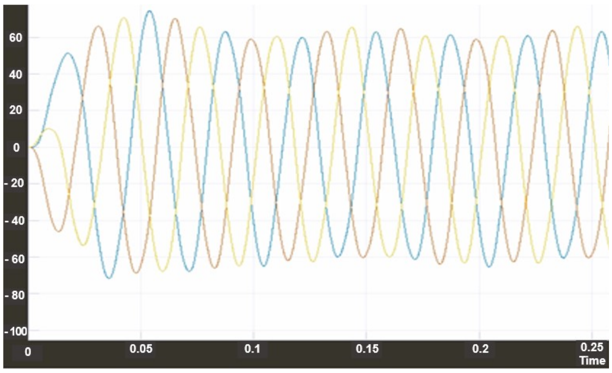

Figure 9. IM Response for 30 Hz

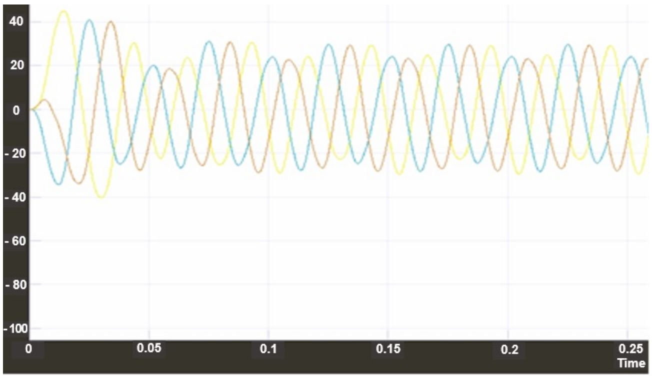

Figure 10. Three Phases in 40 Hz

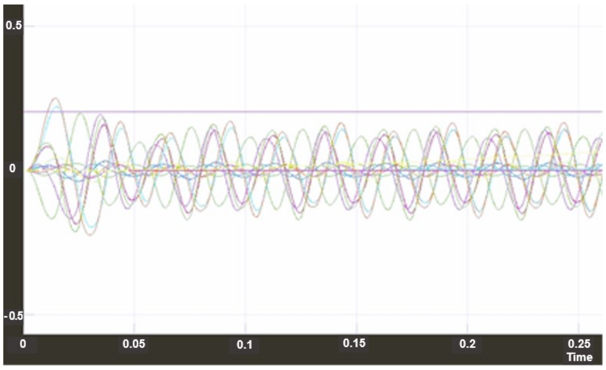

Figure 11. IM Response for 40 Hz

5. Conclusions

In this paper, MATLAB/Simulink was used to simulate the VSD. The VSD was supplied with single-phase AC voltage, which was then converted to DC voltage and fed to the inverter bridge. The speed was controlled by controlling the frequency through adjusting the PWM generator. The filtered output of the inverter is connected to a three-phase IM. A compensator can be added to compensate for the output's loss of voltage when the frequency changes. Mathematical analysis was conducted to analyze the harmonics. The hardware model can be implemented using MATLAB and an Arduino controller.

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References

[1] B.L Theraja (Ed.), Electrical Technology, New Indian Book Agency, Delhi, 2008.
[2] S.H. Güroca (Ed.), Industrial Motion Control Motor Selection Drives Controller Tuning Applications, John Wiley & Sons Ltd., New York City, 2016, p.320.
[3] F.D. Petruzella (Ed.), Electric Motors and Control Systems, 3rd ed., McGraw-Hill, New York City, 2010.
[4] C.B. Smith, Kelly E. Parmenter, Energy Management Principles, 2nd ed., Elsevie, Amsterdam, November 2016, p. 264.
[5] R. Kent, Energy Management in Plastics Processin: Strategies, Targets, Techniques, and Tools, 3rd ed., Elsevier , Amsterdam, 2018, p.105.
[6] A.Z. Latt, N.N. Win, Int. Conf. Edu. Technol. Comput. (2009) 30.
[7] T. Kume, T. Iwakane, IEEE Trans. Ind. Appl. 23/5 (1987) 872.
[8] R. Saidur, S. Mekhilef, M.B. Ali, A. Safari, H.A. Mohammed, Renew. Sustain. Energy Rev. 16/1 (2012) 543.
[9] M.J.S. Zuberi, A. Tijdink, M.K. Patel, Appl. Energy 205 (2017) 85.
[10] N.K. Mitra (Ed.), Principles of Artificial Lift. Allied Publishers Pvt. Ltd., New Delhi, 2012, p.454.
[11] R. Kent, Energy Management in Plastics Processin: Strategies, Targets, Techniques, and Tools, 3rd ed., Elsevier , Amsterdam, 2018, p.144.
[12] A.K. Miller. ASME Int. Mech. Eng. Congr. Expo. 50688 (2016) V014T07A012.
[13] R.D. Shukla, R.K. Tripathi, G. Sandeep, Int. Conf. Power Contr. Embed. Syst. (2010) 1.
[14] R. Khan, M.M.S. Riyadh, Int. J. Comput. Electr. Eng. 3/6 (2011) 865.
[15] A. Gupta, Int. J. Adv. Res. Electr. Electron. Instrum. Eng. 6/5 (2017) 4102.
[16] C.B. Smith, E. Kelly (Ed.) Parmenter, Energy Management Principles, 2nd ed., Elsevie, Amsterdam, November 2016, p.49.