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MATLAB Simulation of Closed-Loop Speed Control of Three-Phase Induction Motor using Slip Control Method and Sinusoidal PWM Technique

Mohit Desai[1]
Undergraduate Student
Electrical Engineering Department
Navrachana University
Vadodara, India

Deepak Mishra[2]
Undergraduate Student
Electrical Engineering Department
Navrachana University
Vadodara, India

Rohan Patel[3]
Undergraduate Student
Electrical Engineering Department
Navrachana University
Vadodara, India

Ketan Bhavsar[4]
Assistant Professor
Electrical Engineering Department
Navrachana University
Vadodara, India

***Abstract*- MATLAB simulations to find out the best method to control the speed of a Three-Phase Induction Motor using a Three-Phase Inverter were seen. For this project, two different methods were used. The first is by giving a normal pulse through a pulse generator, second is by SPWM (Sine Pulse Width Modulation) which is further divided into, i) Open-loop control, and ii) Close-loop control. The aim of the project as mention above is to control the speed of a Three-Phase Induction Motor with the help of a Three-Phase Inverter. For this reviewing papers on different pulse width modulation techniques mentioned above and their simulation was carried out. It was noted that in the pulse generator a high Total Harmonic Distortion of load current was seen, this value is reduced when SPWM was simulated. In the open-loop and closed-loop control, the close loop method is preferred because the process need not be stopped to change the parameters each time.**

I. INTRODUCTION

Power Inverter is a power electronic circuitry that changes Direct Current to Alternating Current. The resulting AC (Alternating Current) frequency obtained depends on the device employed. The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power hence, the DC (Direct Current) is provided by the DC (Direct Current) source. Power inverters are primarily used in electrical power applications where high currents and voltages are present; circuits that perform the same function for Electronic signals[12]. For this project, MATLAB simulations for controlling the speed of a Three-Phase Induction Motor using a Three-Phase Inverter were performed. It will be seen for Three-Phase Inverter with different methods. i) Using pulse generator, ii) Sine Pulse Width Modulation for a) Open-Loop Control and b) Closed-Loop Control. It was seen that SPWM gives us less THD (Total Harmonic Distortion) for load current which is desirable and that closed-loop control is better because the parameters can be changed in real-time and the change can be seen in the working of the motor without having to stop the simulation repeatedly.

II. DESIGN OF THREE-PHASE INVERTER AND SPWM

An inverter is a power electronic circuit that converts direct current to alternating current. The frequency of the output of the inverter depends on the switching frequency of the semiconductor switches used in the inverter[1]. An inverter can be a Single-Phase or Three-Phase depending on the configuration. It can also be a voltage source or current source, as per the required constant in the output. There are also many other basic types of inverters like series inverter, bridge inverter, parallel inverter, multi-level inverter.

Here a design a Three-Phase Inverter for its closed-loop operation for the speed control of the induction motor is shown.

A) Quality of the Inverter

The output of the inverter is not a pure sine wave but it has harmonics in addition to the fundamental components in the output of the inverter. The presence of harmonics in the output leads to the deficient performance of the inverter as well as reduced system efficiency [1]. Therefore, the quality of the inverter depends on the harmonics. These harmonics can be reduced by different type of modulation techniques as well as by designing a filter to filter out the harmonics of higher frequencies. Here we have simulated two types of pulse for inverter and have compared the output of the inverter and its harmonics.

B) Design of Three-Phase Inverter using Pulse-Generator

In this inverter, a pulse of 50Hz is given to the semiconductor switch. At a phase difference of 120 degrees to a different phase.

Here there are three legs and six switches that are controlled according to the pulse given to it.

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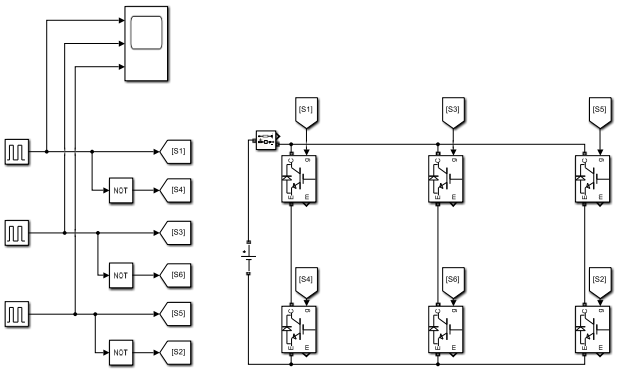

Fig. 1 MATLAB circuit of Three-Phase Inverter using Pulse Generator

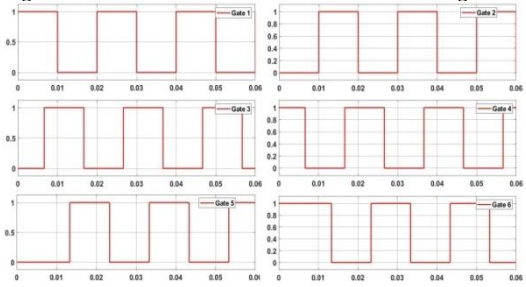

Fig. 2 Waveforms of Gate Pulses provided to all the Six IGBTs

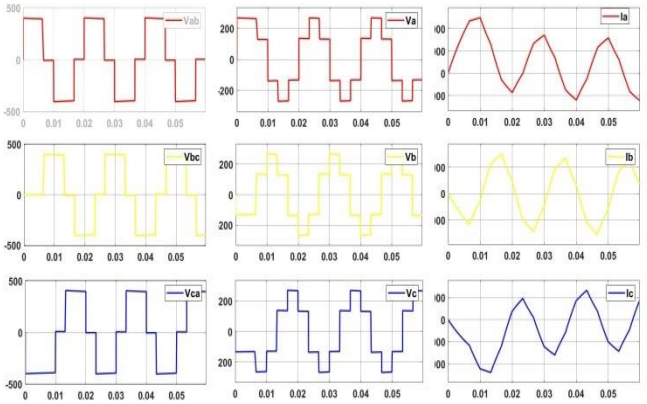

Fig. 3 Output Waveforms of Line Voltage, Phase Voltage, and Line Current

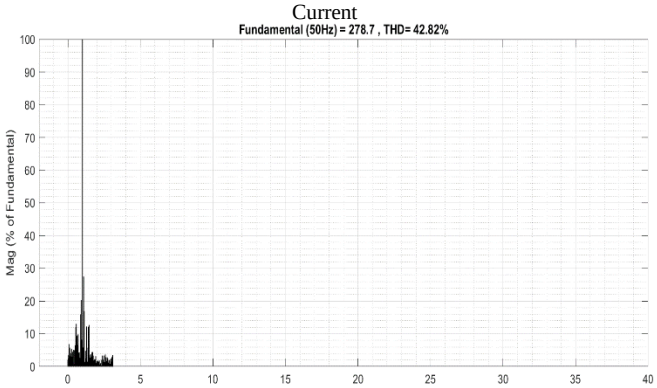

Fig. 4 Analysis of Total Harmonic Distortion of Load Current

C) Design of Three-Phase Inverter using Sinusoidal Pulse Width Modulation

In this technique, a high frequency triangular/saw-toothed carrier wave is compared with reference wave the output of the comparison is a sine pulse modulated signal.

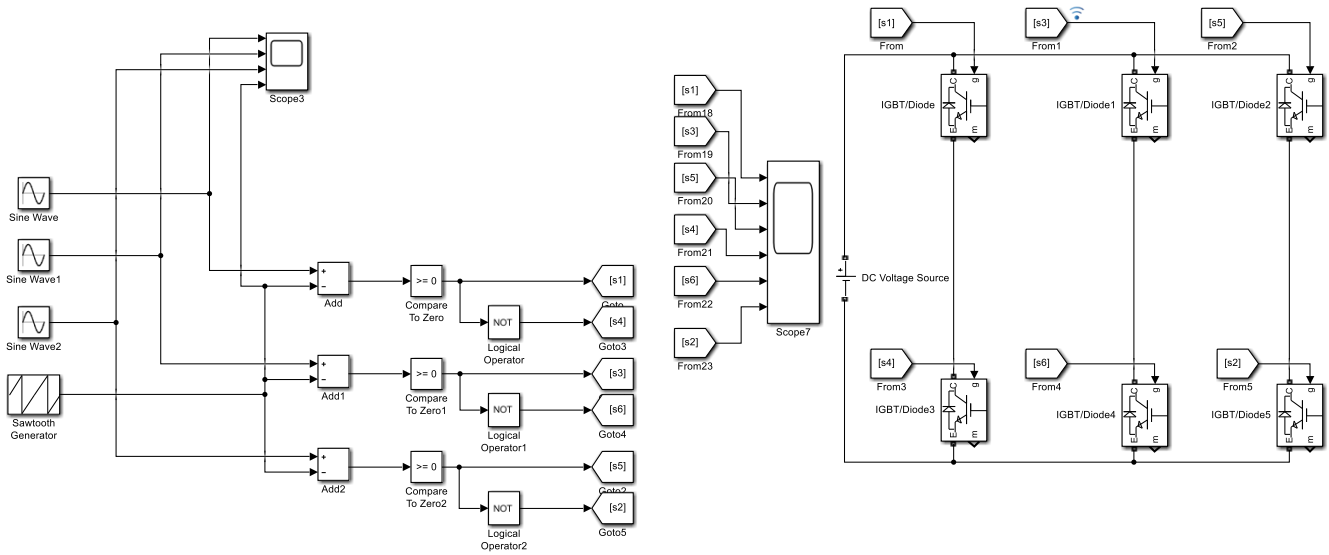

Fig. 5 MATLAB circuit of Three-Phase Inverter using Sinusoidal Pulse Width Modulation

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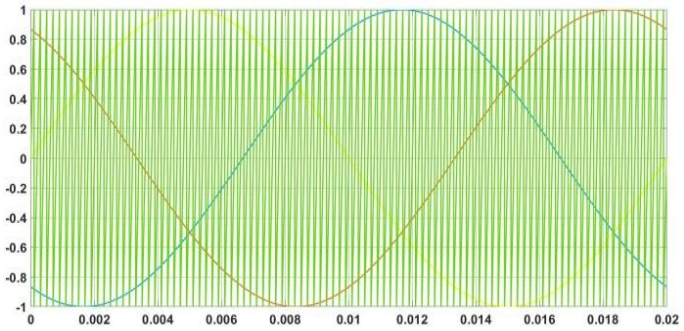

Fig. 6 Waveform of Comparison of Triangular Wave of Frequency 10k Hz with Three-Phase Sinusoidal Wave of Frequency 50 Hz

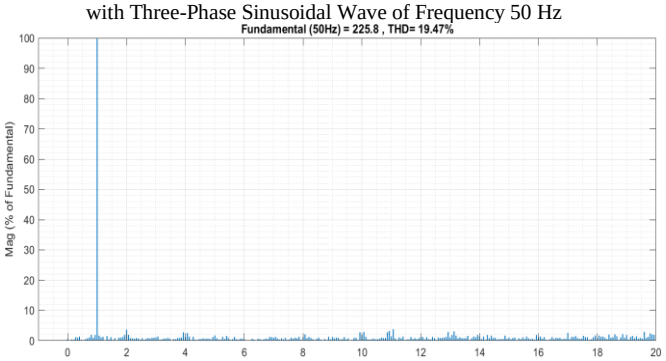

Fig. 7 Analysis of Total Harmonic Distortion of Load Current

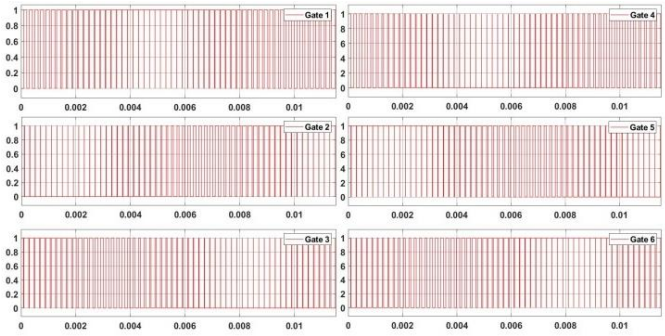

Fig. 8 Waveform of Gate Pulses according to the Sinusoidal Pulse Width Modulation

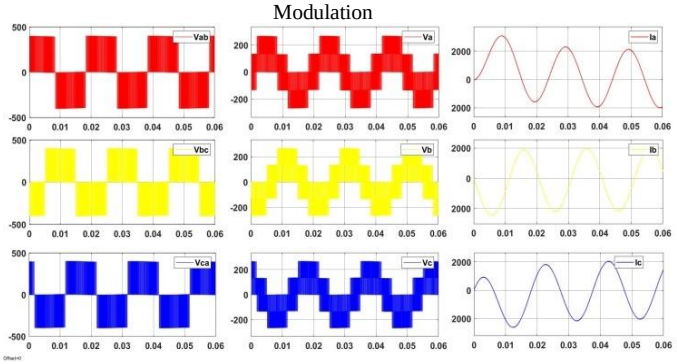

Fig. 9 Waveforms of Line Voltage, Phase Voltage and Line Current

D) Open-Loop Speed Control of Three-Phase Induction Motor

Open loop control means feedback is not taken from output and fed to input for control. It is more stable and less costly system. Where else close loop system is a system in which feedback from the account is taken and given to the input for the control. The main advantage of having a close loop inverter is that, at instant of time if we want to change the values of the parameters, we can do it without stopping the process and running it again. This allows us to have a more convenient piece of equipment which can be used without frequent halts in the process.

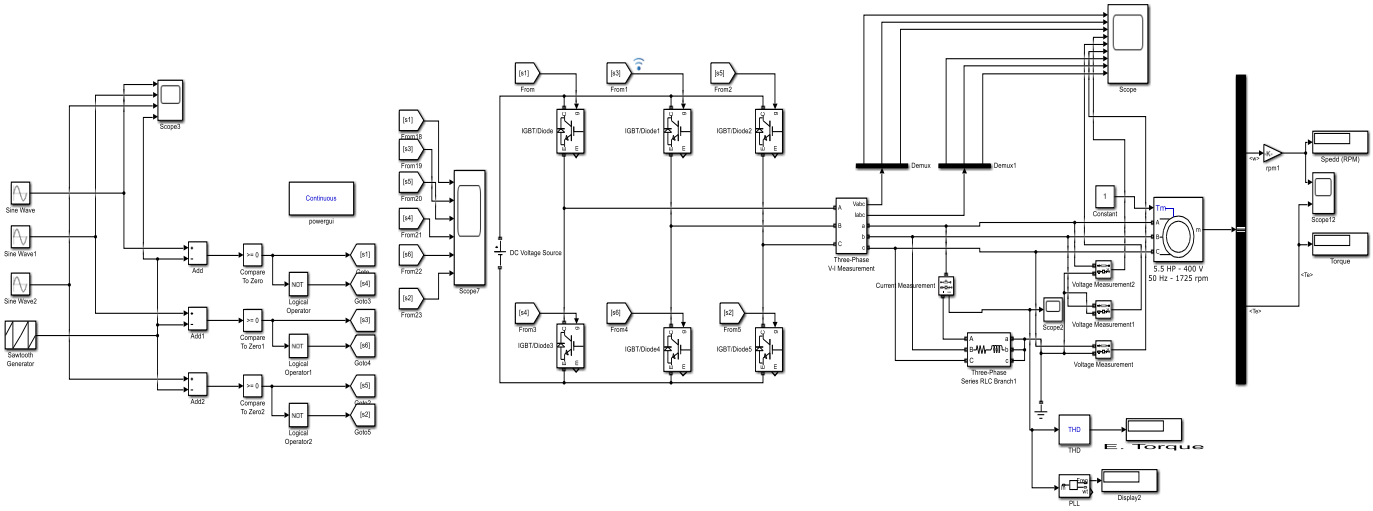

Fig. 10 MATLAB circuit of Open-Loop Speed Control of Three-Phase Induction Motor using Three-Phase Inverter and Sinusoidal Pulse Width Modulation

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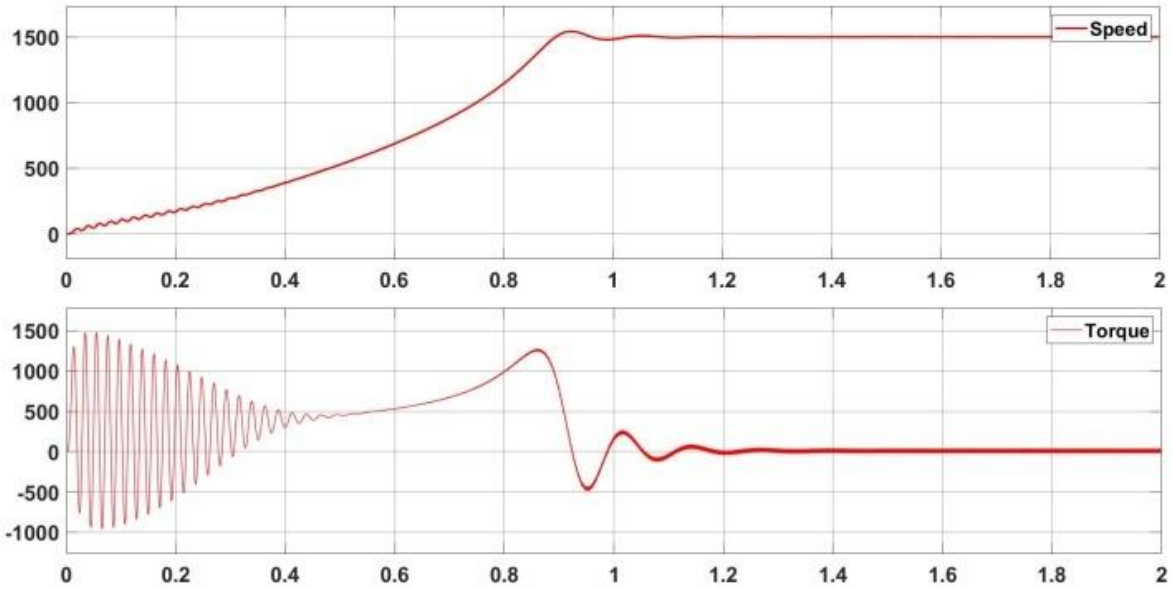

Fig. 11 Waveforms of Speed and Torque of Open-Loop Speed Control of Three-Phase Induction Motor using Three-Phase Inverter and Sinusoidal Pulse Width Modulation

E) Closed-Loop Speed Control of Three-Phase Induction Motor

The output of the inverter is given back to the input so that the system can compare it with the reference input and adjust itself accordingly. Here we are using the speed of the machine in RPM to feed back into the machine.

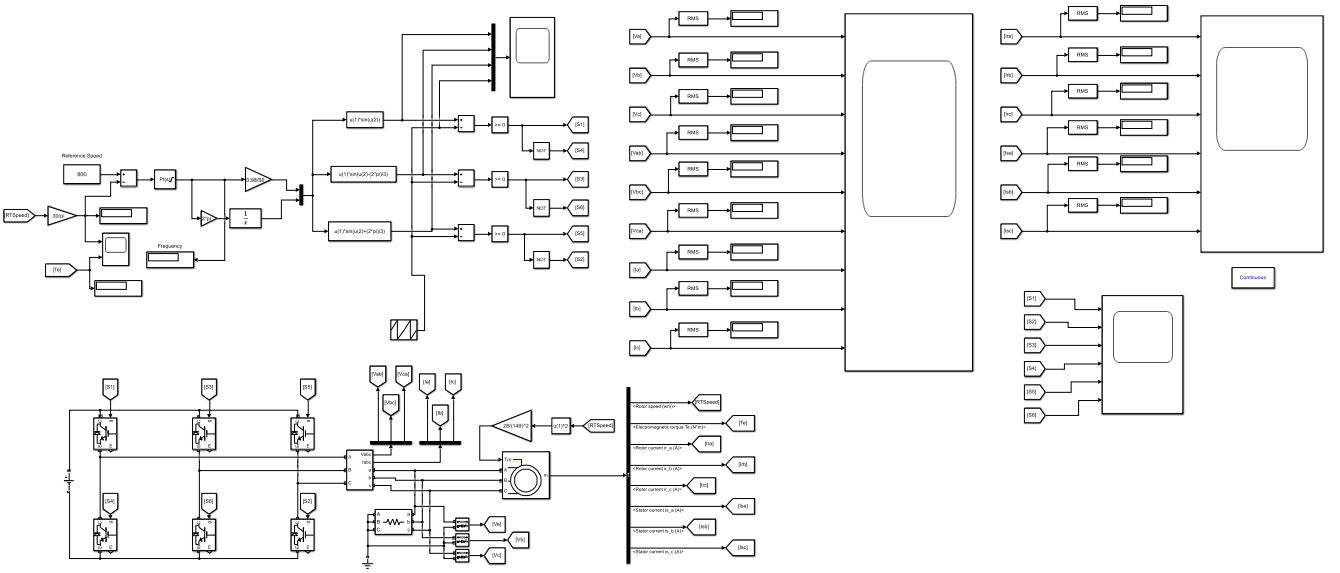

Fig. 12 MATLAB Circuit of Closed-Loop Speed Control of Three-Phase Induction Motor using Three-Phase Inverter and Sinusoidal Pulse Width Modulation

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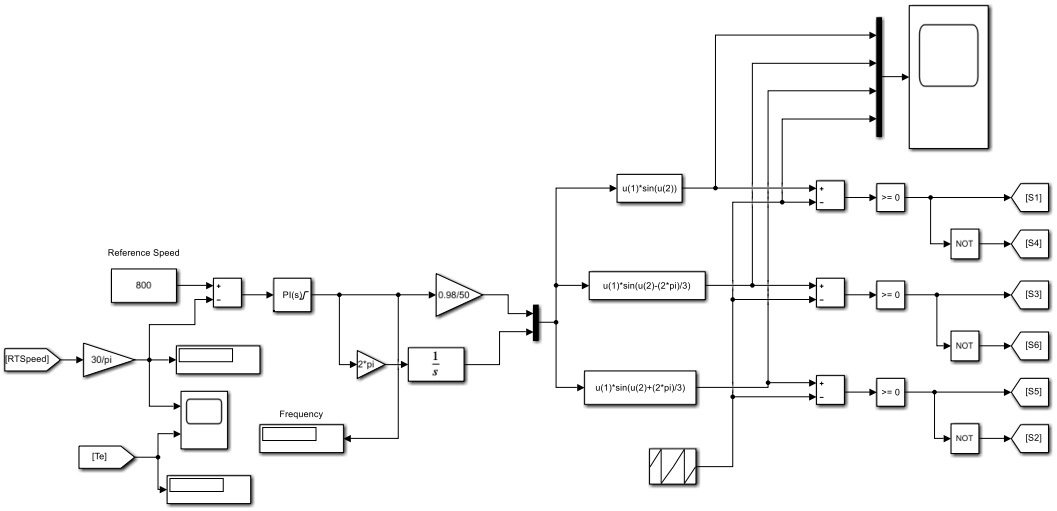

Fig. 13 Feedback of Real Time Rotor Speed given to the PI Controller after comparing it with of Reference Synchronous Speed which in turn controls the Frequency of the Inverter

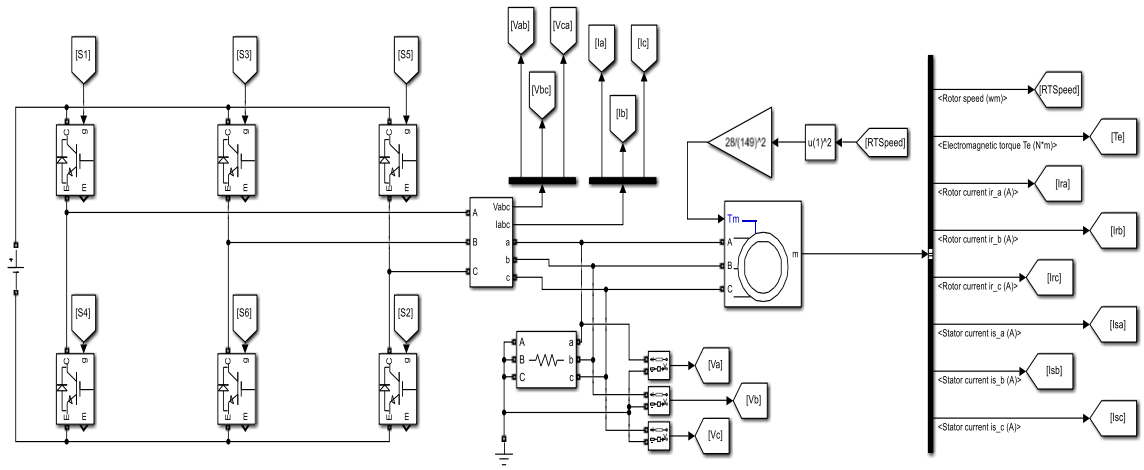

Fig. 14 MATLAB circuit of Three-Phase Induction Motor Drive

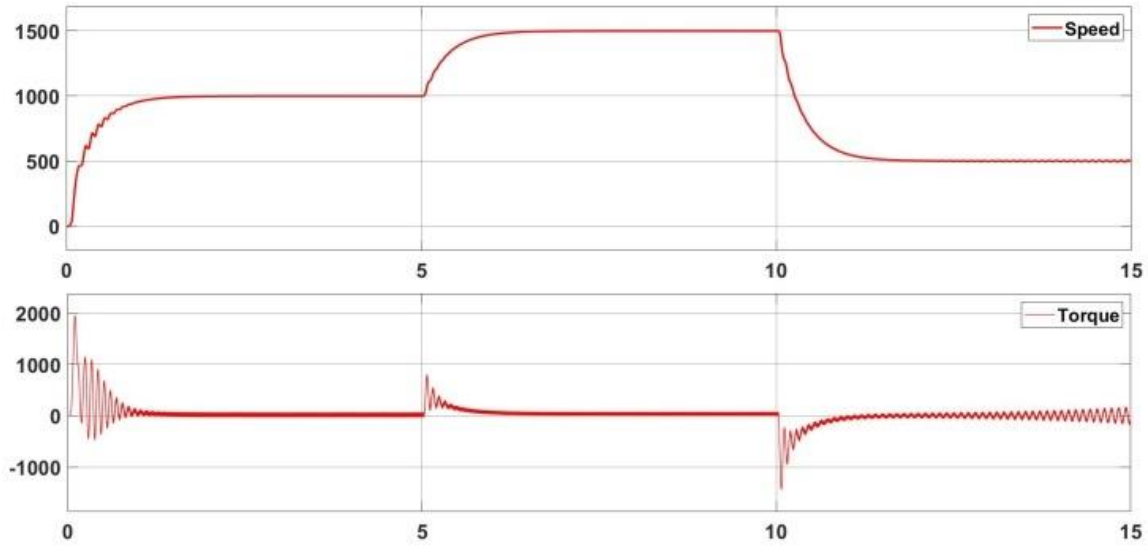

Fig. 15 Waveforms of Speed and Torque at 1000 RPM, 1500 RPM, and 500 RPM

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III. SUMMARY

This project aimed to control the speed of a Three-Phase Induction Motor using a Three-Phase Inverter. This is a common arrangement in the field of power electronics. After performing this experiment, we learn that SPWM has a lower THD than a pulse generator. Also, a pulse generator gives a square wave in the output and SPWM gives us a sine wave, which is more desirable. The main aim was to find the most suitable method to control the speed of the Three-Phase Induction Motor. Hence the Closed-Loop, SPWM method is the most suitable method to control the speed as Closed-Loop allows us to have to change the parameters in real-time without having to stop the process repeatedly and SPWM gives us lower THD with a sine wave output.

IV. FUTURE SCOPE

- The main aim of the research was to control the speed of the Three-Phase Induction Motor using a Three-Phase Inverter.
- In the future, better modulation techniques can be implemented to improve the output.
- The findings of this paper can be implemented industrially or commercially.
- In-depth research can be carried out by making a working model of the circuitry.

V. CONCLUSION

The main aim was to find the most suitable technique to control the speed of a Three-Phase Induction Motor. From the results of this experiment, a Closed-Loop SPWM system is the best method to control the speed of a Three-Phase Induction Motor using a Three-Phase Inverter.

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