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# Performance Analysis of Three Phase Induction Motor With Variable Frequency Drives Using Pulse Generator PWM and SVPWM

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***Abstract*— Three-phase induction motor is an alternating current motor that is most widely used in industry or offices. In principle, the induction motor is operated at a constant speed, if the induction motor is given a load that is not balanced with its constant speed, the speed of the induction motor will change. For this reason, one of the common methods used to adjust the rotational speed of an induction motor as desired is to use a Variable Frequency Drive (VFD). The VFD can be controlled by pulse generator PWM (pulse width modulation) and SVPWM (space-vector pulse width modulation) which are part of the value of the frequency and modulation index. In this final project, what is investigated and compared for more optimal results is the PWM and SVPWM output values with the variables of Rotor Speed, Slip, Fslip, Stator Current, and THD (Total Harmonic Distortion). In this thesis, a comparison of simulation with MATLAB between PWM and SVPWM is carried out using design and experimental methods. The final result obtained is for Rotor Speed, SVPWM control is more optimal with an average percentage of 2.2%. For more optimal SVPWM control slip reaches 1.53%. for Fslip control SVPWM is more optimal reaching 0.76%, SVPWM control produces a smaller current consumption at a frequency of 50 - 40 Hz. for THD Current, PWM control is more optimal with a percentage of 1.07%***

***Keywords*—Motor induction, PWM, SVPWM, Total Harmonic Distortion, Variabel Frequency Drive.**

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## I. Introduction

Three-phase induction motor is an alternating current motor that is most widely used in industry or offices. In principle, the induction motor is operated at a constant speed, if the induction motor is given a load that is not balanced with its constant speed, the speed of the induction motor will change. For this reason, one of the common methods used to adjust the rotational speed of an induction motor as desired is to use a Variable Frequency Drive (VFD).

VFD can be controlled by pulse generator PWM (pulse width modulation) and SVPWM (space-vector pulse width modulation)[1], [2] which functions to adjust the value of the frequency and modulation index [2]. By controlling two quantities, namely torque and speed with the aim of adjusting the rotational speed to the desired or with the requirements of the process, adjusting the torque to the requirements of the process, saving energy and increasing efficiency.

In this journal, Performance Analysis of three phase induction motor with variable frequency drives using pulse generator pwm and svpwm is carried out to compare which control method is more optimal for use in industry or officeswith variable Rotor Speed, Slip, Fslip, Stator Current, and THD (Total Harmonic Distortion).

## II. Literature Review

The electrical machine analysis and performance calculation is a very important aspect of efficient drive system design. The development of power electronics devices and power converters provide smooth speed control of Induction Motors by changing the frequency of input supply and includes the performance analysis of three phase induction motor with three-phase AC direct and variable frequency drives (VFD) [1].

And then, presents the simulation of three phase voltage switching inverter in MATLAB/Simulink using Sinusoidal Pulse Width Modulation (SPWM) scheme. The carrier wave (triangular) is compared to the reference (sine wave), whose frequency is the desired frequency. The modulation index is varied from 0.4 to 1 by changing the amplitude of the modulating signal. The output phase and line voltages are observed in scope along with their Total Harmonic Distortion (THD) which varies with modulation index. In SPWM technique, the amplitude is constant but the width of the pulse varies by changing the duty cycle for each period. The width of the pulses are modulated to provide gate signals to the switches (IGBTs) connected in the inverter [2].

And furthermore, induction motors are very widely used, especially in the industrial industry because they have advantages, namely simple and sturdy motor construction, relatively cheaper prices, easier maintenance compared to other types of motors. Besides these advantages, it turns out that the three-phase induction motor also has a weakness, namely the rotational speed is difficult to control which results in the speed not varying. The speed of the induction motor is influenced by the frequency of the motor supply and the number of poles on the motor. To control the speed of the induction motor, it can be done by changing the frequency of the motor supply, which is done using an inverter called a Variable Frequency Drive (VFD) or commonly called a Variable Speed Drive (VSD). In this thesis, a simulation comparison with Matlab is made between the Pulse Width Modulation (PWM) and Sinusoidal Pulse Width Modulation (SPWM) induction motor speed control methods.

And furthermore The induction motors were characterized by complex, highly non-linear and time-varying dynamics, and hence their speed control is a challenging problem in the industry. Speed control of three phase induction motors by variable frequency drives. The variable frequency drive for induction motors is achieved using SPWM which provide better efficiency and higher performance [3].

The motor speed is investigated both at fixed load and variable load. More over a close loop PI controller was designed at rated load based on dynamic behavior of error signal. It has been found that by designing a proper PI controller the motor starting current is reduced significantly. Moreover at rated torque efficiently speed of motor can be controlled. PI speed controller not help to reduce dynamic performance of the system but also help to reduce the steady state error, the error sensibility, high performance and smooth speed response. The complete mathematical model of the system is described and simulated in MATLAB/SIMULINK [4].

Three phase inverter is extremely important electronic module utilized in modern industry. most the induction motor drives use inverter for desired controlled output. Inverters are also utilized in various sectors like high voltage (HV), heating, uninterrupted power supply (UPS), induction motor drives, textile mills, electric vehicles,home appliances and energy system. Amongst the numerous Pulse Width Modulation (PWM) techniques employed in variable speed frequency drives multiple step pulse width modulation is simple to device and popular PWM technique employed in industries today.

In accordance with this, it's proposed to change the coefficient of proportional link of this control loop per the amplitude of the inverter current reference. At low values of the load current, the modulation frequency increasing is desirable. The structure of the system with a corresponding change within the parameters of this control loop within the case of employing a non-linear reactor is proposed. The MATLAB Simulink of the “three phase inverter” was performed with a linear and non-linear reactor with an estimate of the power losses within the inverter switches [5].

## III. METHODOLOGY

### A. *MATLAB Simulink for PWM and SVPWM*

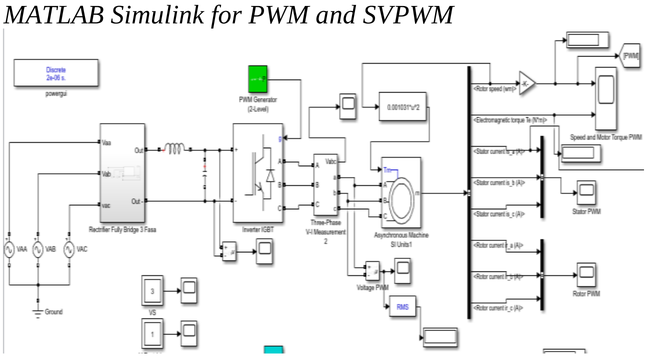

Figure 1. Schematic VFD at load motor induction

The following will explain Figure 1. The voltage source used in this simulation is a three-phase alternating voltage source of 565 Vrms as show table 1, with a phase difference of 120 . The alternating voltage source will then be rectified using a fully controlled 3-phase rectifier as show in figue 2. The direct voltage generated by the rectifier of 808 Vdc [6] will be passed through a filter in the form of a capacitor and an inductor with conduction as to be set show in table 2. The direct voltage generated after being filtered is 840 Vdc. After going through the filter, the direct voltage will produce a universal bridge inverter input. Then the output voltage of the IGBT universal bridge inverter as show in figure 3 will be a three-phase alternating voltage with a certain amplitude and frequency value, according to the values entered in the PWM and SVPWM pulse generator parameter blocks. The three-phase alternating voltage will be the input voltage for the induction motor load.

Table 1. Voltage source AC

| Ac Source | Peak Amplitudo | Phase (deg) | Frequency |
|---|---|---|---|
| Vaa | 420 V | 0 | 50 Hz |
| Vab | 420 V | -120 | 50 Hz |
| Vac | 420 V | -240 | 50 Hz |

Table 2. Time switching thyristor

| Thyristor | Period (secs) | Pulse Width (% of periode) | Phase delay (secs) |
|---|---|---|---|
| T1 | 1/f | 120/360 | 60*(0,02/360) |
| T2 | 1/f | 120/360 | 120*(0,02/360) |
| T3 | 1/f | 120/360 | 180*(0,02/360) |
| T4 | 1/f | 120/360 | 240*(0,02/360) |
| T5 | 1/f | 120/360 | 300*(0,02/360) |
| T6 | 1/f | 120/360 | 360*(0,02/360) |

Where at $\alpha = 30°$,
$\omega t = 0° - 60°$, T5 and T6 conduction
$\omega t = 60° - 120°$, T1 and T6 conduction
$\omega t = 120° - 180°$, T1 and T2 conduction
$\omega t = 180° - 240°$, T2 and T3 conduction
$\omega t = 240° - 300°$, T3 and T4 conduction
$\omega t = 300° - 360°$, T4 and T5 conduction

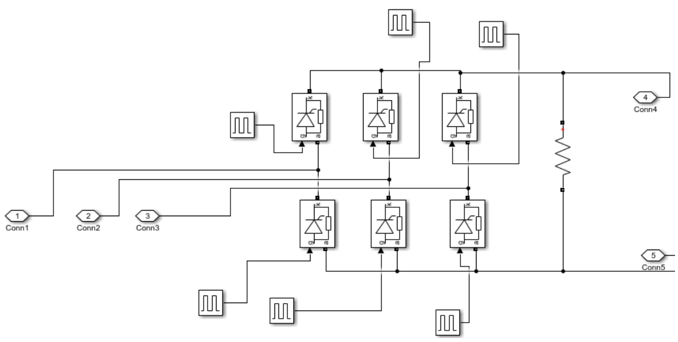

Figure 2. Rectrifier three phase fully controller

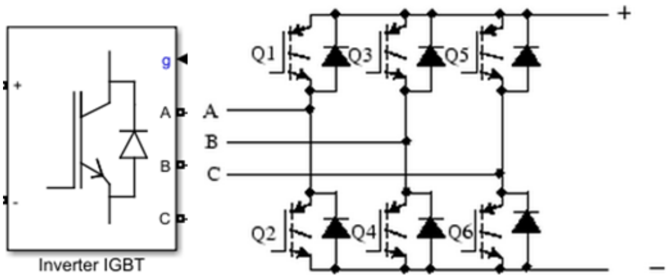


Figure 3. Model universal bridge inverter IGBT

### B. *Model PWM and SVPWM Pulse Generator*


Figure 4. Pulse Pwm Generator (left) and Pulse Svpwm Generator (right)

The magnitude of the output voltage between the phases for pwm is : [7].

$$V_{LL}\_Converter = m * \frac{Vdc}{2} * \frac{sqrt(3)}{sqrt(2)} = m * Vdc * 0{,}6124 \quad (1)$$

The magnitude of the output voltage between the phases for Svpwm is : mohan

$$V_{LL}\_Converter = m * \frac{Vdc}{sqrt(2)} = m * Vdc * 0{,}7071 \quad (2)$$

Where :

VLL_Converter : Voltage between phases output of universal bridge model for inverter in rms

m : index modulation

### C. *Model Induction Motor Single squirrel-cage*

The Asynchronous Machine block implements a three-phase asynchronous machine (wound rotor, single squirrel-cage, or double squirrel-cage). It operates in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque :

- If Tm is positive, the machine acts as a motor.
- If Tm is negative, the machine acts as a generator

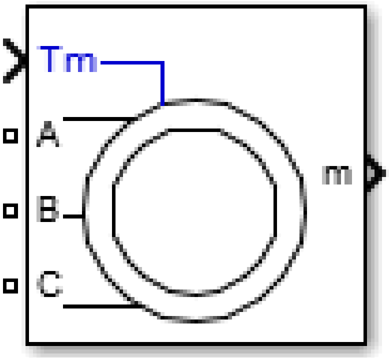


Figure 5 :Asynchron machine

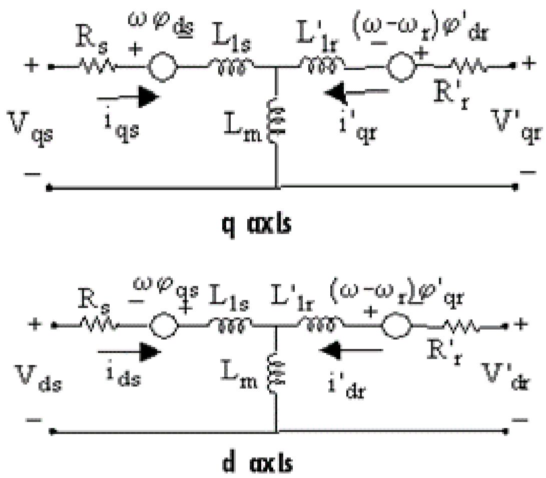


Figure 6. Electrical System of the Wound-Rotor or Squirrel-Cage Machine

Where :

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\varphi_{qs} + \omega\varphi_{ds} \quad (3)$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\varphi_{qs} + \omega\varphi_{qs} \quad (4)$$

$$V'_{qr} = R'_r i'_{qr} + d\varphi'_{qr}/dt + (\omega - \omega r)\varphi'_{dr} \quad (5)$$

$$V'_{dr} = R'_r i'_{dr} + d\varphi'_{dr}/dt + (\omega - \omega r)\varphi'_{qr} \quad (6)$$

$$Te = 1.5p(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}) \quad (7)$$

$$\varphi_{qs} = L_s i_{qs} + L_m i'_{qr} \quad (8)$$

$$\varphi_{ds} = L_s i_{ds} + L_m i'_{qr} \quad (9)$$

$$\varphi'_{qr} = L'_r i'_{qr} + L_m i_{qs} \quad (10)$$

$$'_{dr} = L'_r i'_{dr} + L_m i_{ds} \quad (11)$$

$$L_s = L_{ls} + L_m \quad (12)$$

$$L'r = L'_{lr} + L_m \quad (13)$$

$$\frac{d}{dt}\omega_m = \frac{1}{2H}(T_e - F\omega_m - T_m) \quad (14)$$

$$\frac{d}{dt}\theta_m = \omega_m \quad (15)$$

Setting of the induction machine model used via a parameter block as shown in the figure 7 and 8.

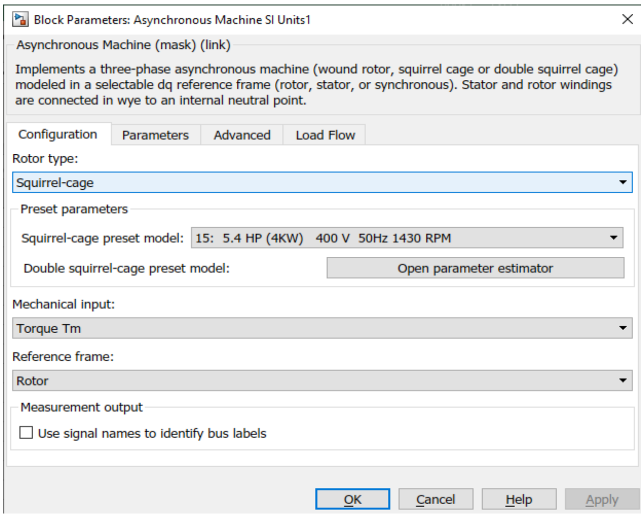


Figure 7. Block Parameter Asynchoronous Machine

All parameter values and conditions used in the configuration block and parameters of the MATLAB induction machine model are obtained from MATLAB Simulink which is used in this journal simulation.

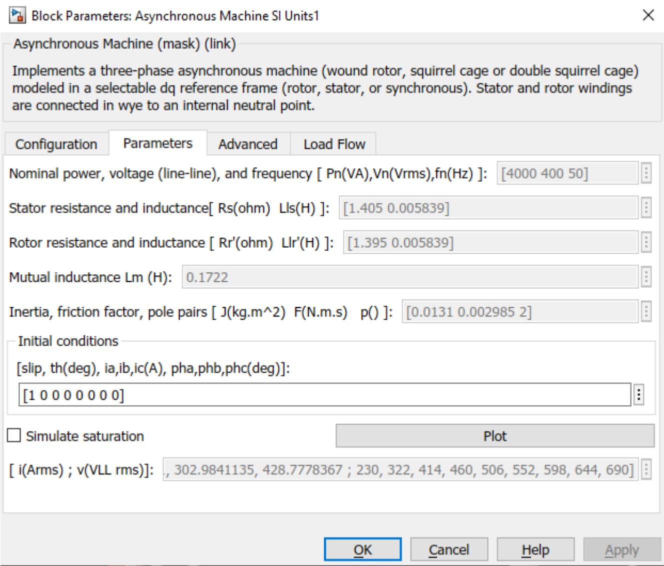


Figure 8. Block Parameter Asynchoronous Machine

For the value of the mechanical torque Tm that is entered in the induction machine model, the nominal torque equation of the engine is used. The nominal torque equation Tn is obtained through the following calculation process : [7].

$$ns = 60x\frac{\omega s}{2\pi} = \frac{120}{p}f \quad (16)$$

$$ns = \frac{120}{4}50 = 1500\,rpm \quad (17)$$

$$\omega s = 1500\,x\,\frac{2\pi}{60} = 157{,}14\,rad/s \quad (18)$$

Then in figure 8 at nominal power Pn = 4000 W, then nominal torque Tn is :

$$T_n = \frac{Pn}{\omega s} = \frac{4000}{157} = 25{,}478\,Nm \quad (19)$$

Assuming the torque-speed characteristic is a quadratic function, we get :

$$T = k\,x\,w^2 \quad (20)$$

Input the nominal torque equation (Tn) at the input constant parameter Shaft mechanical torque induction motor by adjusting the input frequency using the Fcn block contained in the Simulink library as shown in figure 1.

## IV. Results

The simulation in this research was carried out by varying the frequency value and amplitude of the input voltage on the stator of the induction motor, where the setting of the input voltage amplitude value on the stator was carried out through setting the modulation index value and switching frequency in the PWM pulse model and SVPWM generator. The values to be analyzed in this simulation are Shaft mechanical torque (Tm), Electromagnetic torque (Te) N.m, Rotor Speed (wm) Nr, V Stator (Vrms), Stator Current (is)Irms, Rotor Current (ir)Irms, Slip (%), Slip Frequency (Hz), THD Vs (%) and THD is (%).

The voltage source used in this simulation is a three-phase alternating voltage source of 565 Vrms with a phase difference of 120. The alternating voltage source will then be directed using a fully controlled 3-phase rectrifier. Direct voltage generated by the rectifier of 808 Vdc will be passed through filters in the form of capacitors and inductors. The direct voltage produced after being filtered is 840 Vdc. After going through the filter, the direct voltage will produce into a universal bridge inverter input. Then the output voltage of the IGBT universal bridge inverter will be a three-phase alternating voltage with a certain amplitude and frequency value, according to the values entered in the PWM pulse parameter block and SVPWM generator. The three-phase alternating voltage will be the input voltage for the induction motor load.

Simulation of Three-Phase Induction Motors [8][9] with Variable Frequency Drives (Vfd) Using PWM and SVPWM Pulse Generators is done to vary the speed and torque of the load by changing the modulation index (1 - 0.3) and frequency (50 - 20 Hz).

Table 3. PWM and SVPWM Inverter Simulation Results with modulation index = 1-0.3 using a frequency of 50 - 20 Hz

| **Metode** | **Tm (N.m)** | **M. Index** | **Te (N.m)** | **rpm (Nr)** | **Vs (Vrms)** | **Is (irms)** | **Ir (irms)** | **Slip (%)** | **Fslip (Hz)** | **THD Vs(%)** | **THD Ir(%)** | **THD Is(%)** | **TDD IEEE STD 519-2014** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PWM | 25,45 | 1 | 28,4 | 1466 | 517,5 | 7 | 0,2 | 2,26 | 1,13 | 0,77 | 81,39 | 1,56 | 5% |
| | | 0,9 | 25 | 1458 | 465,5 | 7,2 | 0,12 | 2,8 | 1,4 | 0,77 | 151 | 1,47 | |
| | | 0,8 | 22 | 1447 | 414 | 7,2 | 0,27 | 3,533 | 1,76 | 0,70 | 76,2 | 1,1 | |
| | | 0.7 | 21 | 1430 | 362,9 | 7,5 | 0,3 | 4,66 | 2,33 | 0,33 | 74,37 | 1,04 | |
| | | 0.5 | 20 | 1361 | 258,8 | 9,1 | 1,58 | 9,26 | 4,63 | 0,96 | 80 | 0,81 | |
| | | 0,3 | 13 | 1081 | 155,6 | 12,4 | 6,3 | 27,93 | 13,9 | 1,02 | 71,8 | 0,4 | |
| SVPWM | 25,45 | 1 | 25,4 | 1477 | 597 | 7,3 | 0,3 | 1,53 | 0,76 | 5,6 | 72 | 4,8 | |
| | | 0,9 | 24 | 1469 | 537 | 7,1 | 0,2 | 2,06 | 1,03 | 5,2 | 64 | 4,1 | |
| | | 0,8 | 24 | 1459 | 477 | 7 | 0,1 | 2,73 | 1,36 | 4,58 | 105 | 3 | |
| | | 0.7 | 24,9 | 1447 | 417 | 7,1 | 0,35 | 3,53 | 1,76 | 3,8 | 68 | 2,24 | |
| | | 0.5 | 22,5 | 1369 | 298,5 | 8,3 | 1,03 | 6,93 | 3,46 | 2,26 | 75 | 1 | |
| | | 0,3 | 16 | 1192 | 179,4 | 11,7 | 1,3 | 20,53 | 10,26 | 1,27 | 55 | 0,49 | |
| PWM | 31,81 | 1 | 35,97 | 1171 | 515 | 8 | 0,12 | 2,41 | 0,96 | 3,38 | 125 | 1,8 | 5% |
| | | 0,9 | 31 | 1171 | 464,4 | 7,9 | 0,3 | 2,41 | 0,96 | 2,4 | 44 | 2,18 | |
| | | 0,8 | 27,5 | 1157 | 414 | 7,8 | 0,32 | 3,58 | 1,43 | 1,4 | 97 | 1,3 | |
| | | 0.7 | 25,6 | 1145 | 362,9 | 7,9 | 0,24 | 4,58 | 1,83 | 1,35 | 94 | 1,11 | |
| | | 0.5 | 24,4 | 1092 | 260 | 9,2 | 0,33 | 9 | 3,6 | 2,97 | 75 | 0,98 | |
| | | 0,3 | 17,6 | 895 | 156,9 | 12,1 | 2,6 | 25,41 | 10,16 | 6,38 | 71,2 | 0,52 | |
| SVPWM | 31,81 | 1 | 32,83 | 1177 | 594 | 8,6 | 0,13 | 1,91 | 0,76 | 6,46 | 224 | 3,24 | |
| | | 0,9 | 31,7 | 1171 | 535 | 8,2 | 0,18 | 2,417 | 0,967 | 6,5 | 199 | 2,84 | |
| | | 0,8 | 31 | 1167 | 475 | 7,9 | 0,16 | 2,75 | 1,1 | 6,5 | 162 | 2,89 | |
| | | 0.7 | 30,7 | 1160 | 416,5 | 7,8 | 0,18 | 3,33 | 1,33 | 6,53 | 128 | 2,93 | |
| | | 0.5 | 28 | 1118 | 297 | 8,6 | 1,06 | 6,83 | 2,73 | 6,55 | 77 | 2,27 | |
| | | 0,3 | 20,8 | 970 | 178 | 11,6 | 2,4 | 19,16 | 7,66 | 6,65 | 75 | 1,3 | |
| PWM | 42,42 | 1 | 47,39 | 877 | 517 | 9,9 | 0,16 | 2,61 | 0,78 | 0,74 | 107 | 1,44 | 5% |
| | | 0,9 | 41 | 873 | 465,6 | 9,3 | 0,2 | 3 | 0,9 | 0,76 | 79 | 1,1 | |
| | | 0,8 | 37 | 868 | 414 | 9 | 0,03 | 3,61 | 1,08 | 0,78 | 368 | 0,98 | |
| | | 0.7 | 34 | 860 | 362 | 8,8 | 0,55 | 4,41 | 1,32 | 0,83 | 80 | 1,15 | |
| | | 0.5 | 32,4 | 821 | 258,7 | 9,6 | 1,48 | 8,81 | 2,64 | 0,9 | 79 | 0,95 | |
| | | 0,3 | 24 | 685 | 155,6 | 12,2 | 5 | 23,88 | 7,16 | 1,21 | 74 | 0,6 | |
| SVPWM | 42,42 | 1 | 42,8 | 886 | 597 | 10,9 | 0,05 | 1,6 | 0,48 | 1,49 | 263 | 1,56 | |
| | | 0,9 | 41,4 | 882 | 537 | 10,1 | 0,2 | 2,04 | 0,61 | 1,68 | 100 | 1,44 | |
| | | 0,8 | 41 | 875 | 477 | 9,4 | 0,09 | 2,77 | 0,83 | 1,54 | 151 | 1,3 | |
| | | 0.7 | 40 | 868 | 418 | 9 | 0,31 | 3,52 | 1,05 | 1,4 | 106 | 1,25 | |
| | | 0.5 | 37 | 840 | 298 | 9,1 | 0,99 | 6,7 | 2,01 | 1,12 | 78 | 0,96 | |
| | | 0,3 | 28 | 735 | 179 | 11,5 | 3,8 | 18,3 | 5,5 | 1,14 | 75 | 0,46 | |
| PWM | 63,63 | 1 | 69,10 | 583 | 515,9 | 13,8 | 0,07 | 2,83 | 0,56 | 3,29 | 263 | 1 | 5% |
| | | 0,9 | 61,3 | 583 | 464,7 | 12,7 | 0,26 | 2,93 | 0,58 | 2,89 | 86,43 | 1,1 | |
| | | 0,8 | 55,5 | 578 | 413,6 | 11,8 | 0,34 | 3,61 | 0,72 | 2,51 | 100 | 1,05 | |
| | | 0.7 | 50,6 | 574 | 362 | 11 | 0,11 | 4,4 | 0,88 | 2,1 | 148 | 1 | |
| | | 0.5 | 49 | 545 | 258,7 | 10,6 | 1,38 | 9,13 | 1,82 | 1,66 | 81 | 0,7 | |
| | | 0,3 | 36,7 | 464 | 155,6 | 12,2 | 3,7 | 22,68 | 4,53 | 1,37 | 75 | 0,5 | |
| SVPWM | 63,63 | 1 | 64,4 | 589 | 597 | 15,7 | 0,09 | 1,83 | 0,36 | 3,4 | 296 | 1,34 | |
| | | 0,9 | 63,9 | 587 | 537 | 14,3 | 0,17 | 2,11 | 0,42 | 3,6 | 166 | 1,52 | |
| | | 0,8 | 62 | 582 | 478 | 13 | 0,14 | 3 | 0,6 | 3,85 | 189 | 1,83 | |
| | | 0.7 | 61 | 578 | 418 | 11,9 | 0,02 | 3,73 | 0,74 | 4 | 957 | 2 | |
| | | 0.5 | 56 | 558 | 298 | 10,6 | 0,8 | 6,98 | 1,39 | 4,48 | 92 | 2,1 | |
| | | 0,3 | 43 | 493 | 179 | 11,8 | 1,9 | 17,86 | 3,57 | 5 | 74 | 1,43 | |

This THD current value is still within the permissible limits and complies with the IEEE 519-2014 standard [10]

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Table 3 shows a comparison between PWM and SVPWM controls with the same index modulation at frequency of 50 – 20 Hz. In the first experiment to the twenty fourth experiment, the greater the modulation index value, the greater the value of the stator voltage. This happens because the stator voltage value is a function of the modulation index and direct voltage which is the input of the universal bridge inverter. The value of the rotational speed of the rotor at a frequency of 50-20 Hz increases with the increase of the amplitude of the stator voltage. The rotational speed of the rotor will increase with the increase in the modulation index, this happens because the rotor rotation acceleration of the induction motor is directly proportional to the increase in the electromagnetic torque value according to equation (14). The graph of the increase in the value of rotor rotation speed can be seen in figure 9, 13, 17 and 21 with SVPWM control more optimal than PWM.

An increase in the modulation index value with the same frequency value in the seventh experiment to the twelfth attempt also resulted in an increase in the electromagnetic torque value. This happens because the increasing stator voltage (modulation index) then the resulting air gap flux will increase, so the value of electromagnetic torque will also increase.

The slip value in this experiment with frequency of 50-20 Hz will continue to decrease following the increase in the amplitude value of the stator voltage. This happens because the greater the amplitude of the stator voltage, the value of the rotor rotation speed will also be greater, so that with the value of the stator rotation field speed that remains at 1500, 1200, 900 and 600 rpm, the slip value will decrease.

The slip frequency value on the first to twenty-fourth experiments will continue to decrease as the modulation index increases. This happens because the slip frequency equation of the induction motor is a function of the slip value and stator frequency value, so that with the stator frequency value fixed at 50-20 Hz and the slip value decreasing following the increase in the modulation index, the slip frequency value will also decrease.

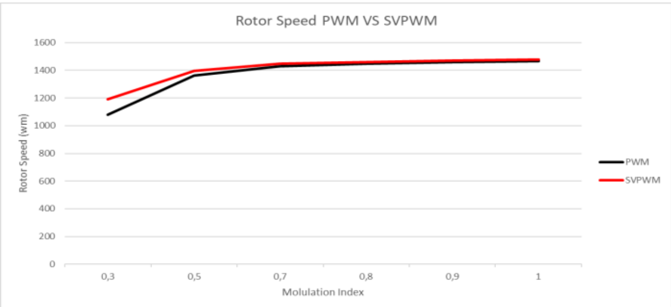


Figure 9. Graph Rotor speed : of Pwm Vs Svpwm at frequency 50 Hz and modulation index 0.3 - 1

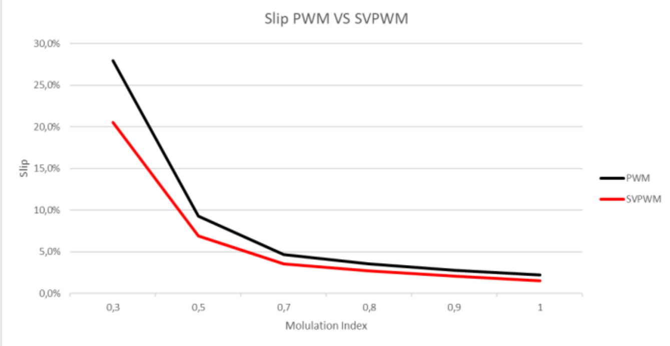


Figure 10. Graph Slip : of Pwm Vs Svpwm at frequency 50 Hz and modulation index 0.3 - 1

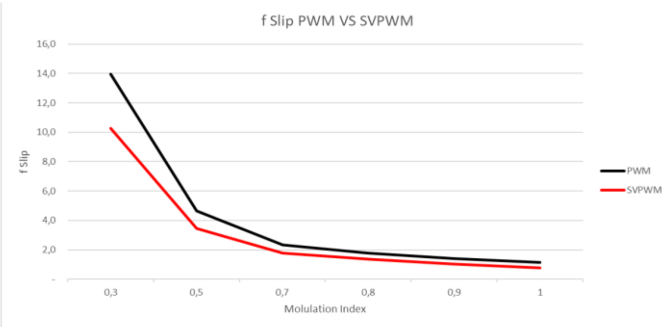


Figure 11. Graph fslip : of Pwm Vs Svpwm at frequency 50 Hz and modulation index 0.3 - 1

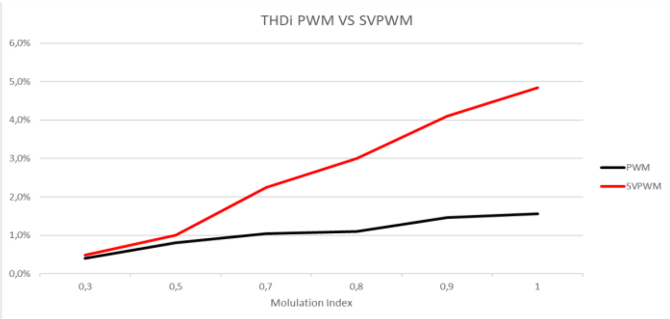


Figure 12. Graph THDi : of Pwm Vs Svpwm at frequency 50 Hz and modulation index 0.3 – 1.

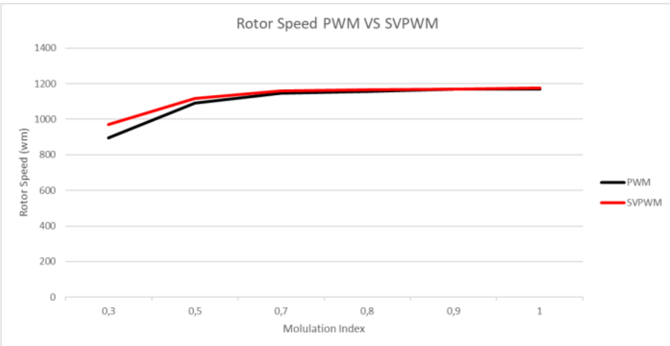


Figure 13. Graph Rotor speed : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 - 1

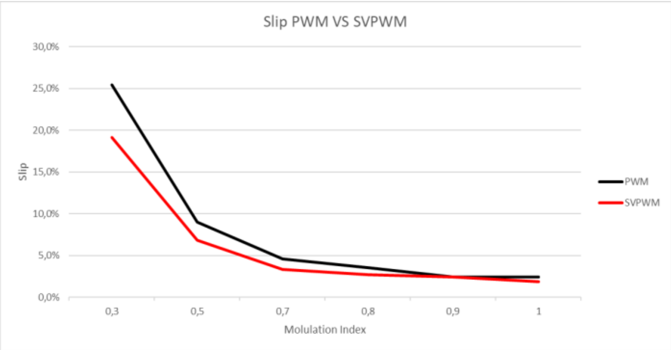


Figure 14. Graph slip : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 – 1

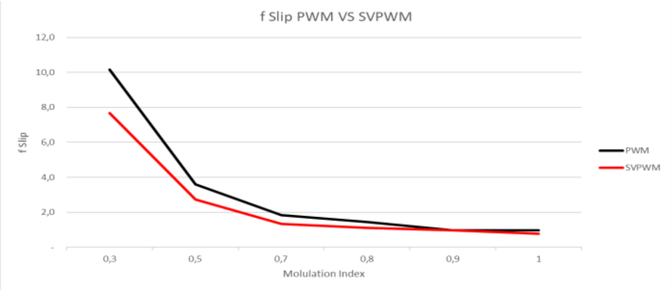


Figure 15. Graph fslip : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 - 1

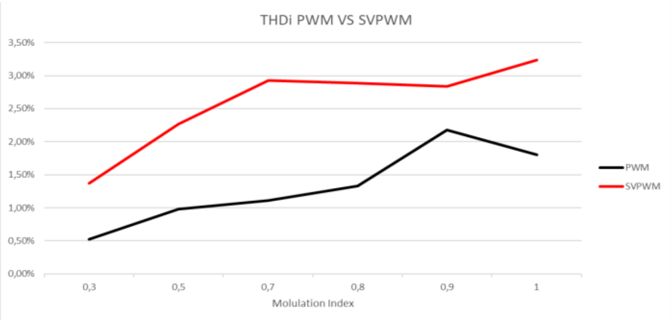


Figure 16. Graph THDi : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 – 1

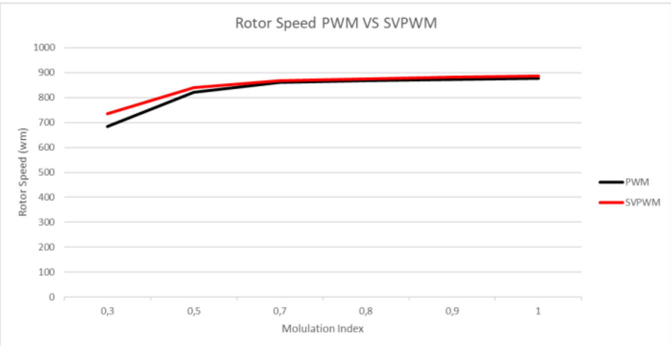


Figure 17. Graph Rotor speed : of Pwm Vs Svpwm at frequency 30 Hz and modulation index 0.3 - 1

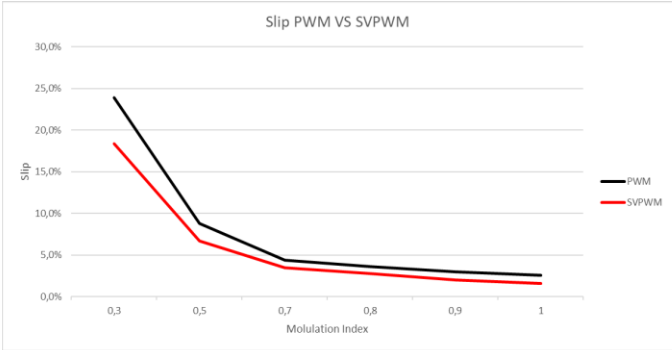


Figure 18. Graph slip : of Pwm Vs Svpwm at frequency 30 Hz and modulation index 0.3 – 1

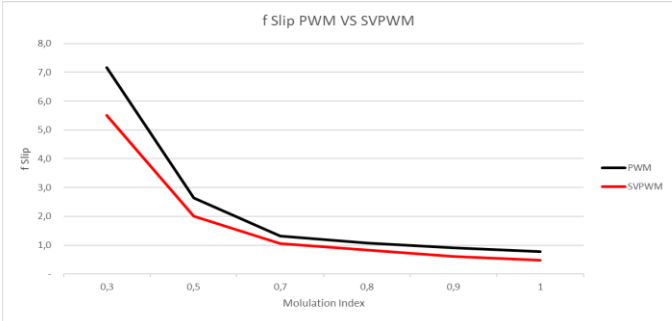


Figure 19. Graph fslip : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 - 1

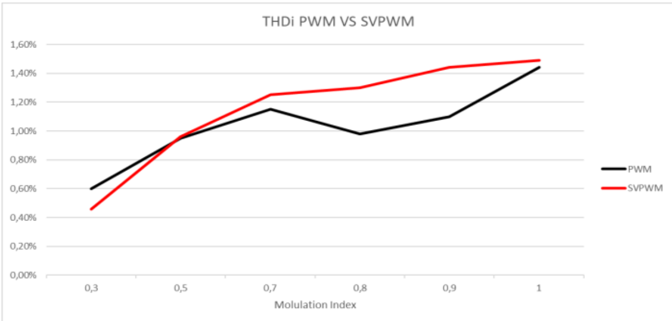


Figure 20. Graph THDi : of Pwm Vs Svpwm at frequency 30 Hz and modulation index 0.3 – 1

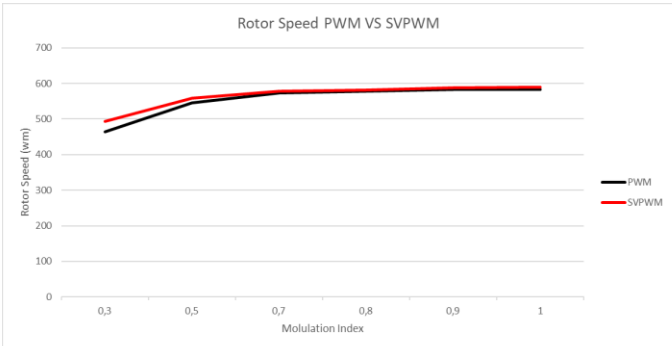


Figure 21. Graph Rotor speed : of Pwm Vs Svpwm at frequency 20 Hz and modulation index 0.3 - 1

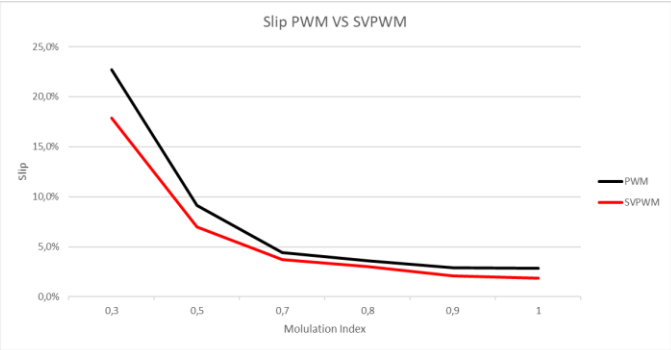


Figure 22. Graph slip : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 -1

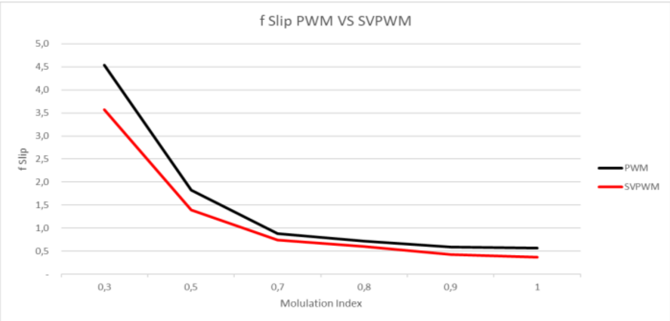


Figure 23. Graph fslip : of Pwm Vs Svpwm at frequency 40 Hz and modulation index 0.3 -1

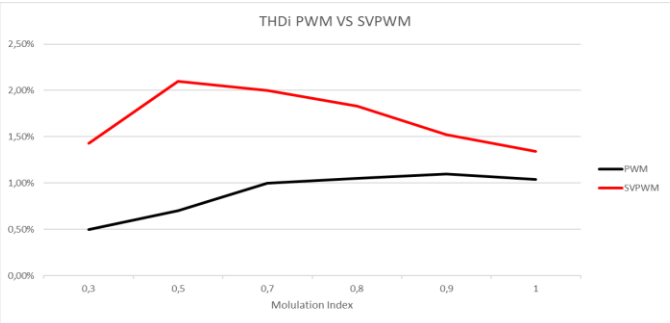


Figure 24. Graph THDi : of Pwm Vs Svpwm at frequency 30 Hz and modulation index 0.3 – 1

## V. CONCLUSION

1. For Rotor Speed, SVPWM control is superior to PWM control. The percentage of superiority of SVPWM if on average it reaches 2.207% of all simulations carried out with a frequency of 50 Hz – 20 Hz and Index Modulation 1 – 0.3.
2. For Slip, SVPWM control has a lower value than PWM, with a slip ratio value for 50 Hz frequency: 1.53% SVPWM and 2.26 % PWM at 40 Hz frequency: 1.91% SVPWM and 2.41 PWM % at 30 Hz frequency: 1.61% SVPWM and 2.61% PWM and at 20 Hz frequency: 1.83% SVPWM and 2.83% PWM.
3. For Slip Frequency, SVPWM control has a lower value than PWM, with a slip ratio value for 50 Hz frequency: SVPWM 0.76 Hz and PWM 1.13 Hz at 40 Hz frequency: SVPWM 0.76 Hz and PWM 0. 96 Hz at 30 Hz : SVPWM 0.48 Hz and PWM 0.78 Hz at 20 Hz : SVPWM 0.36 Hz and PWM 0.56 Hz.
4. For Total Harmonic Distortion Current, PWM control is superior to SVPWM control. The percentage of superiority of PWM if on average it reaches 1.07% while SVPWM reaches 2.01% of all simulations carried out with a frequency of 50 Hz – 20 Hz and Index Modulation 1 – 0.3.
5. The SVPWM control method produces a smaller current consumption so that it is more energy efficient at a frequency of 50 - 40 Hz.

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