American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Speed Control of Single Phase Induction Motor Using Fuzzy Logic Controller

Ali H. Ahmad[a]*, Farazdaq R.yasien[b]*, Ahmed S. Abdullah[c]*

[a,b]*Assist. Prof. Dr., electrical engineering department, university of technology, Baghdad, Iraq*
[c]*master student, electrical engineering department, university of Mosul, Mosul, Iraq*
[a]*Email: ah_control2007@yahoo.com*
[b]*Email: farazdakrafeek@yahoo.com*
[c]*Email: love_13486@yahoo.com*

Abstract

The Proportional Integral (PI) controller of A.C drives are commonly employed in industries and many other applications, because of its simplicity, but it does not give high degree of speed control of single phase induction motor. The intelligent control systems become a powerful tool for control nonlinear system in present time. This paper proposes the Proportional Integral (PI) controller designed based on fuzzy logic system as an intelligent speed controller of single phase induction motor. In addition, The mathematical modeling and simulation single phase induction motor capacitor run type as asymmetrical two phase induction motor is represented too Also, two phase four leg voltage source PWM inverter with Sinusoidal Pulse Width Modulation (SPWM) switching technique is demonstrated and simulated. The overall system for the proportional-integral (PI) controller designed based on fuzzy logic system is simulated using MATLAB/Simulink environment. The results shows high response of the controller to the change of load which make a wide range of speed variation and make the speed return to its reference value.

Keywords: Speed control of single phase induction motor; Sinusoidal PWM; the proportional integral (PI) controller; fuzzy logic controller; voltage source PWM inverter.

----

* Corresponding author.

1. Introduction

Single phase induction motors are vastly employed in many home and industries applicants. Motor speed control is very important in rotating machines applications that have been developed based on dependent theories of controlling the speed [1]. The popularity of these motors is increasing day by day due to primarily the robust construction, simplicity in design and cost effectiveness, on the other hand there are some unfavorable features like motor nonlinearity, time varying and the difficulty to get wide

Range of speed [2], the unsymmetrical two-phase induction motor computer is employed to simulate and describe the transient and steady state of various types of single phase induction motors [3]. Induction motors like variable voltage, variable frequency, variable voltage variable frequency (v/f) [4], changing stator poles, rotor resistance, doubly fed motor, Kramer circuits and etc...[5]. variable speed drive circuits employed different power electronics switches with various switching patterns to drive and control the speed of single phase induction motors [3] [6], one of these electronic drive circuits is the inverter which are vastly employed in industrial application, they are generally classified in to single and three phase inverters, in general the pulse width modulation switching technique are used to provide an AC output signal to these inverters [6], control the voltage as well as frequency to have an inverter AC output voltage as close as possible to sinusoidal waveform [3]. There are various PWM techniques that can suit most industrial and other application such as sinusoidal PWM, space vector pulse width modulation which are widely used, the main subject of PWM is to control the output voltage and reduce the harmonics [6].

In recent years, intelligent control has emerged as one of the most active and fruitful areas of research and development (R&D) within the spectrum of engineering disciplines with a variety of industrial applications [7], speed controllers of single phase induction motor employed some of the intelligent control techniques algorithm such as neural network , particle swarm optimization and etc.., they were suffering from several problems such as small rang of controlled speed, but there are some techniques that are simple and can be employed in different process such as fuzzy logic controllers [1].

Software computing techniques such as fuzzy logic or fuzzy control (FC) provide a schematic method to incorporate human knowledge in the controller [8], it is a control algorithm depends on linguistic control strategy, which is proposed to employ the human experience knowledge to an automatic control strategy. While on the other hand, other control systems employed difficult arithmetic calculation to provide a model of the controlled plant, it only employs simple arithmetic calculation to model this experience. For The good performance of this control strategy, it can be or will be one of the best available answers for a broad class of challenging control problems [9].

This paper proposed the proportional integral (PI) controller designed based on fuzzy logic control system with optimized base rules and the output is the frequency which is applied to sinusoidal pulse width modulation technique employed to drive the two phase four leg inverter with (v/f) speed control technique to control the speed of single phase induction motor capacitor run type.

2. Mathematical modeling of single-phase induction motor

The mathematical modeling of Induction motor consists of derivation of the basic stator and rotor voltage equations and also the flux and torque equations. In this analysis of this kind of machine, the transient and steady-state modes of performance of asymmetrical two-phase induction motors that characterized by equations can be decided by taking into account the primary configuration of two-pole motor shown in fig.(1). the single Phase induction motor is divided into two asymmetrical windings. Therefore, the secondary winding (α) has less number of turns than that of the primary winding (β) which are displaced by ninety electrical Degrees between them. Fig (2) indicates the graphical configuration of two-phase induction machine represented in reference frame theory, the stator windings are unsymmetrical windings have unequal resistance and number of turns while the rotor windings are symmetrical which have equal resistance and number of turns[3]. Auxiliary winding in α – axi Main winding in β – axis.

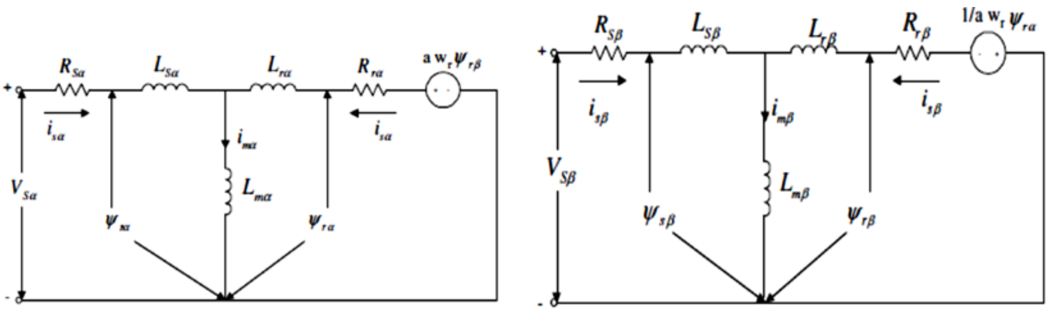

Figure 1: Equivalent circuits of an asymmetrical two-phase Induction machine in the (α β) stationary reference frame theory.

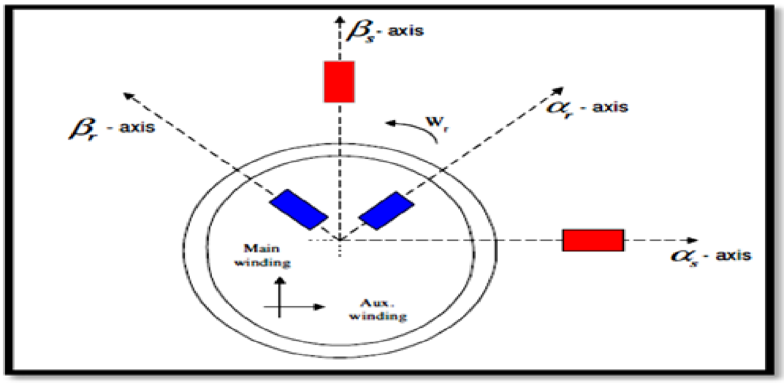

Figure 2: asymmetrical two-phase Induction Motor

The dynamic model conditions of an asymmetrical two-phase induction machine may be rewritten in (αβ) variables of reference frame theory, this will develop the computerized model of asymmetrical two-phase induction machines and then enhance this model to imitate various applications of single phase motor applications.

The stator voltage equations are written as [3],

$$Vs_{\alpha}=Rs_{\alpha}\, i_{s\alpha} + \psi s_{\alpha} \quad (1)$$

$$Vs_{\beta} = Rs_{\beta}\, is_{\beta} + \psi s_{\beta} \quad (2)$$

The equations of rotor voltages are written as,

$$Vr_{\alpha} = 0 = Rr_{\alpha} ir_{\alpha} + \psi r_{\alpha} + a\, \omega_r \psi r_{\beta} \quad (3)$$

$$Vr_{\beta} = 0 = Rr_{\beta} ir_{\beta} + \psi r\beta - \omega_r \psi r_{\alpha} \quad (4)$$

Where

Vsα, isα, Rsα, ψsα are the Secondary winding voltage, current, resistance, flux linkage respectively

Vsβ, isβ, Rsβ, ψsβ are the primary winding voltage, current, resistance, flux linkage respectively

Vrα, irα, Rrα, ψrα are the Secondary winding rotor voltage, current, resistance, flux linkage respectively

Vrβ , irβ , Rrβ , ψrβ are the primary winding rotor voltage, current, resistance, flux linkage respectively

ωr = rotor speed

a = turns ratio

Stator and rotor flux linkages component of can be written as:

$$\psi_{s\alpha} = L\, s_{\alpha}\, is_{\alpha} + L\, m_{\alpha} ir_{\alpha} \quad (5)$$
$$\psi s_{\beta} = L\, s_{\beta}\, is_{\beta} + L\, m_{\beta} ir_{\beta} \quad (6)$$
$$\psi r_{\alpha} = L\, m_{\alpha}\, is_{\alpha} + L\, r_{\alpha} ir_{\alpha} \quad (7)$$
$$\psi r_{\beta} = L\, m_{\beta}\, is_{\beta} + L\, r_{\beta} ir_{\beta} \quad (8)$$

Where

$L\, s_{\alpha}$, $L\, r_{\alpha}$ are the Secondary winding stator and rotor inductances

$L\, s_{\beta}$, $L\, r_{\beta}$ are the primary winding stator and rotor inductances

$L\, m_{\alpha}$, $L\, m_{\beta}$ are the Secondary and primary winding magnetizing inductances

Using equations (5)–(8), the stator and rotor currents equations are given by:-

$$is\alpha = \frac{(Lr\alpha * \Psi s\alpha - Lm\alpha * \Psi r\alpha)}{(Ls\alpha * Lr\alpha - Lm\alpha^2)} \quad (9)$$

$$is\beta = \frac{(Lr\beta * \Psi s\beta - Lm\beta * \Psi r\beta)}{(Ls\beta * Lr\beta - Lm\beta^2)} \quad (10)$$

$$ir\alpha = \frac{(Ls\alpha * \Psi r\alpha - Lm\alpha * \Psi s\alpha)}{(Ls\beta * Lr\beta - Lm\beta^2)} \quad (11)$$

$$ir\beta = \frac{(Ls\beta * \Psi r\beta - Lm\beta * \Psi r\beta)}{(Ls\beta * Lr\beta - Lm\beta^2)} \quad (12)$$

The machine generates the electromagnetic torque and then given by the equation:-

$$T_e = P_P\,(L\ m_\beta\ is_\beta\ ir_\alpha - L\ m_\alpha\ is_\alpha\ ir_\beta) \quad (13)$$

Where

T_e , P_P are the electromagnetic torque and pole pairs

The dynamic mechanical model is given by the equation

$$J\omega r = T_e - T_L - B\omega_r \quad (14)$$

Where

$T_{L,}$ B, J are the load torque, viscous resistance coefficient and moment of inertia respectively.

3. Voltage Source PWM Inverter

The fundamental objective of Voltage Source PWM Inverter is to transform the applied DC voltage to an output AC voltage for the desirable magnitude. The output voltage waveforms of the typical inverters must be sinusoidal, but the industrial inverter output voltage are non-sinusoidal waveforms, for that, when high range of power applications with low value of total harmonic distortion is needed, a very fast power switching devices are employed with various types of switching techniques to achieve this goal [6].

One of these techniques is the sinusoidal pulse width modulation which is employed to generate the sinusoidal waveform with varying width by filtering an output pulse [6]. Sinusoidal pulse width modulation (SPWM) technique with unipolar modulation employed four sinusoidal waveforms with 90 degree phase shift between them and have the same magnitude compared to a common triangular waveform as shown id figure (3), for that , it was used to generate two-phase PWM output voltages [10].

The Voltage Source PWM Inverter topology employed are the two phase four leg configuration which consists of eight switches (IGBT/diode) with carrier frequency of (5KHz)as shown in figure (4) , this configuration is simulated as two inverters to represent the variable voltage variable frequency drive circuit that feed the asymmetrical two phase induction motor with two reference orthogonal voltages.

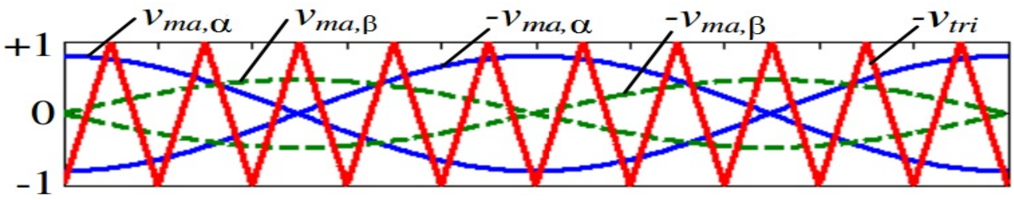

Figure 3: Sinusoidal phase width modulation (SPWM)

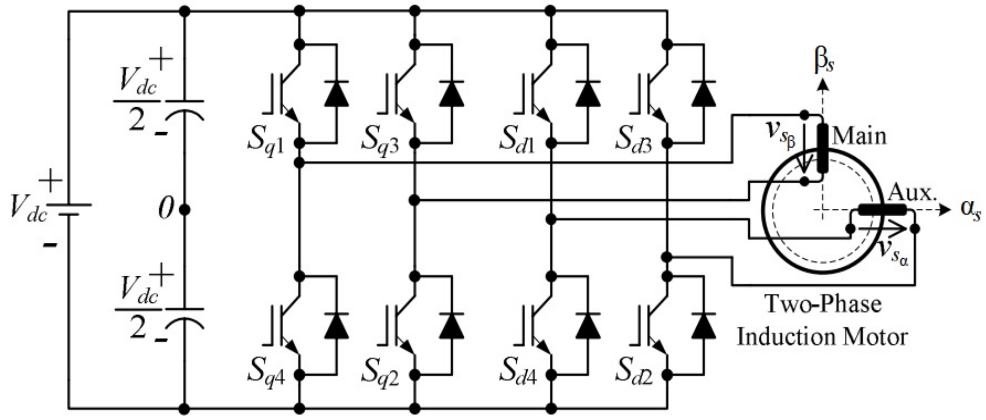

Figure 4: Schematic diagram of two phase four leg inverter topology

4. The proportional-integral controller designed with fuzzy logic system

The dictionary meaning of the word "fuzzy" is "not clear, indistinct, non-coherent, and vague". By contrast, in the technical meaning, fuzzy inference systems are accurately defined systems, and fuzzy control systems are accurately defined method to control non-linear. The specific goal of fuzzy logic is to improve on "human-like" reasoning. "Fuzzy systems are knowledge-based or rule-based systems". Specifically, the basic components of fuzzy system's knowledge base are the set of IF-THEN rules supplied by human knowledge and experience [2].In general this type of FLC contains four main parts, two of which perform transformations; which are:- Fuzzifier (transformation 1), Knowledge base, Inference engine and Defuzzifier (transformation 2) as shown in figure (5) [8].

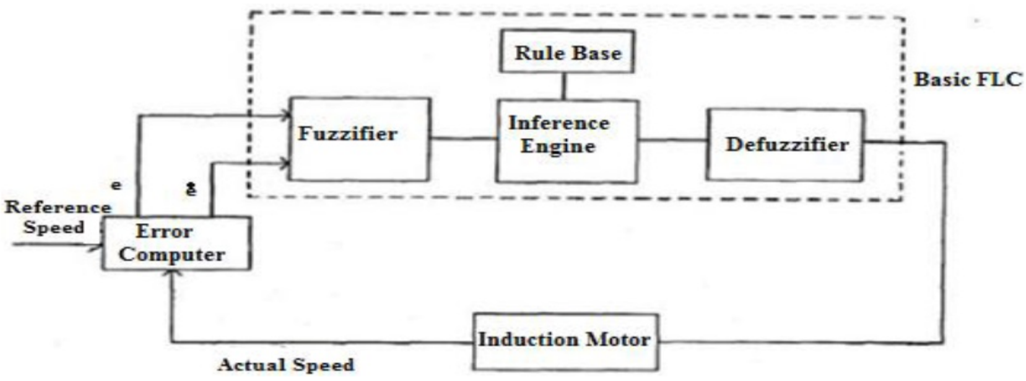

Figure 5: block diagram of fuzzy logic controller

The fuzzifier scales and maps input variables to fuzzy sets, inference engine with the help of rule base does the approximate reasoning and decide the control action. Defuzzifier converts fuzzy output values to control actions [9].

Fuzzy logic technique became widely accepted in expert systems, control units and in wide range of applications because of its fast adaptation, high degree of possibility, smooth operation, reduction the effect of non-linearity, easy if-then logics and inherent approximation adaptability. A fuzzy logic controller (FLC) has already been proved analytically to be parallel to a non-linear proportional integral (PI) controller when a non-linear defuzzification method is employed which can reduce the effects of non-linearity and improve the performance of a controller [9].

The Gaussian membership function type which are seven for each variable, the rule-base are seven optimized if-then statements with two inputs which are error and change of error and one output is the frequency as shown in figure (6). .

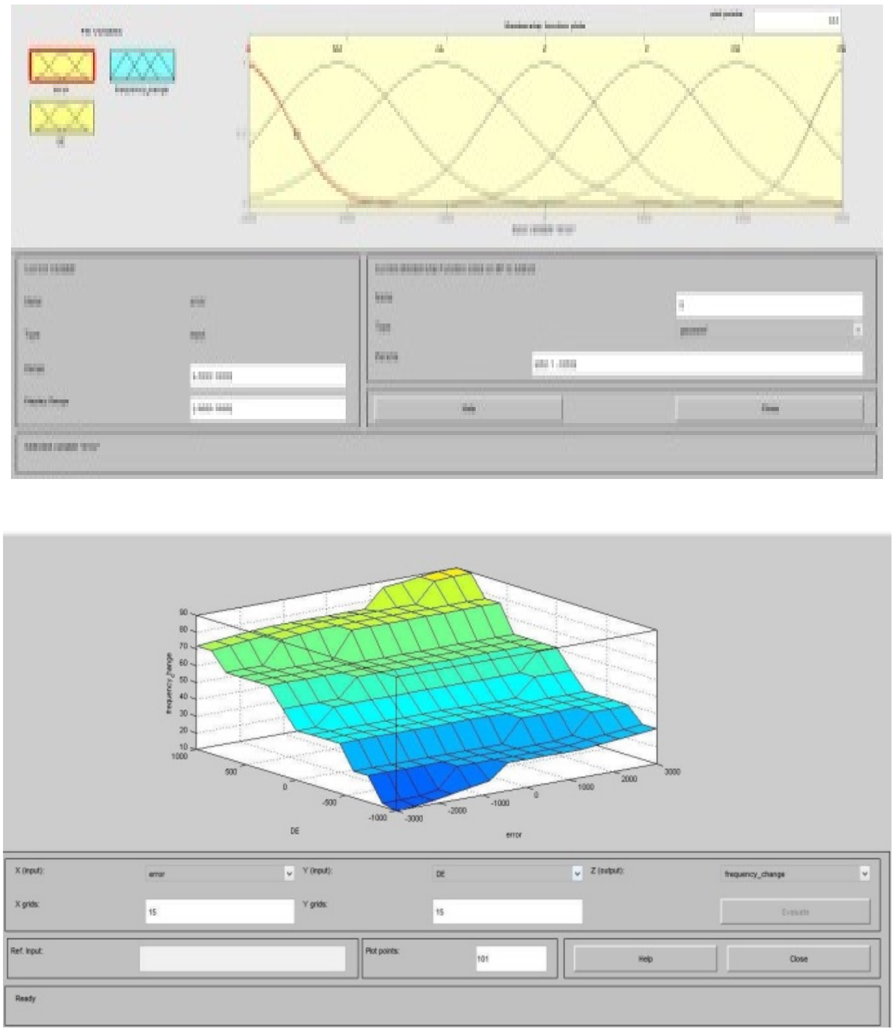

Figure 6: the membership function of input and output

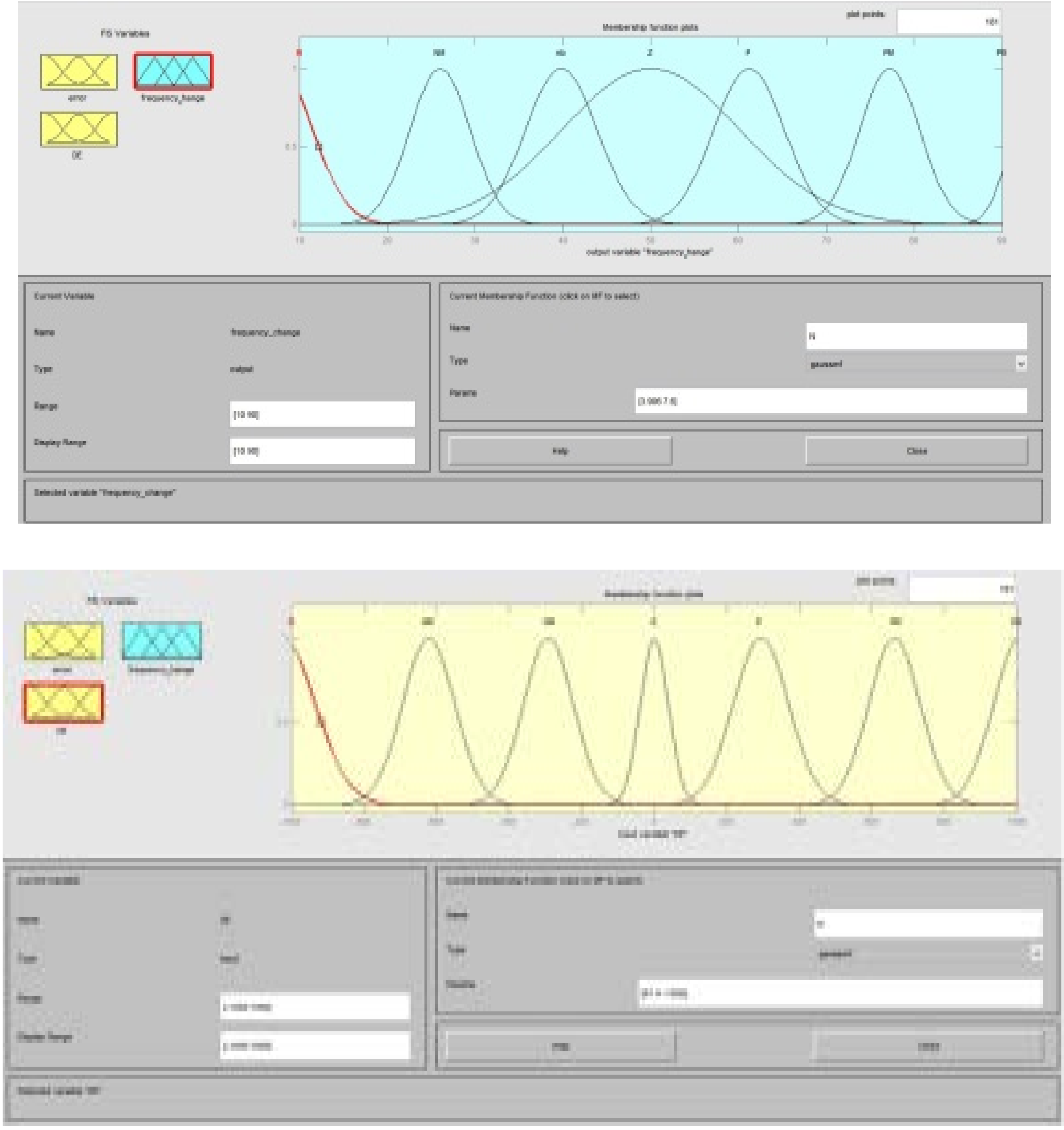

Figure 7: the surface viewer

5. Field oriented control strategy

Vector control, which is also called field-oriented control (FOC), is a variable frequency drives (VFD) control strategy which controls AC electric motor output by means of two controllable (VFD) inverter output variables, the frequency and voltage magnitude.

For any single phase induction machine field oriented control technique is one of the best techniques for the speed control, It allows the decoupled control of the motor flux and electromagnetic torque which is employed to drive the asymmetrical two phase induction motor as shown in figure (8) [11].

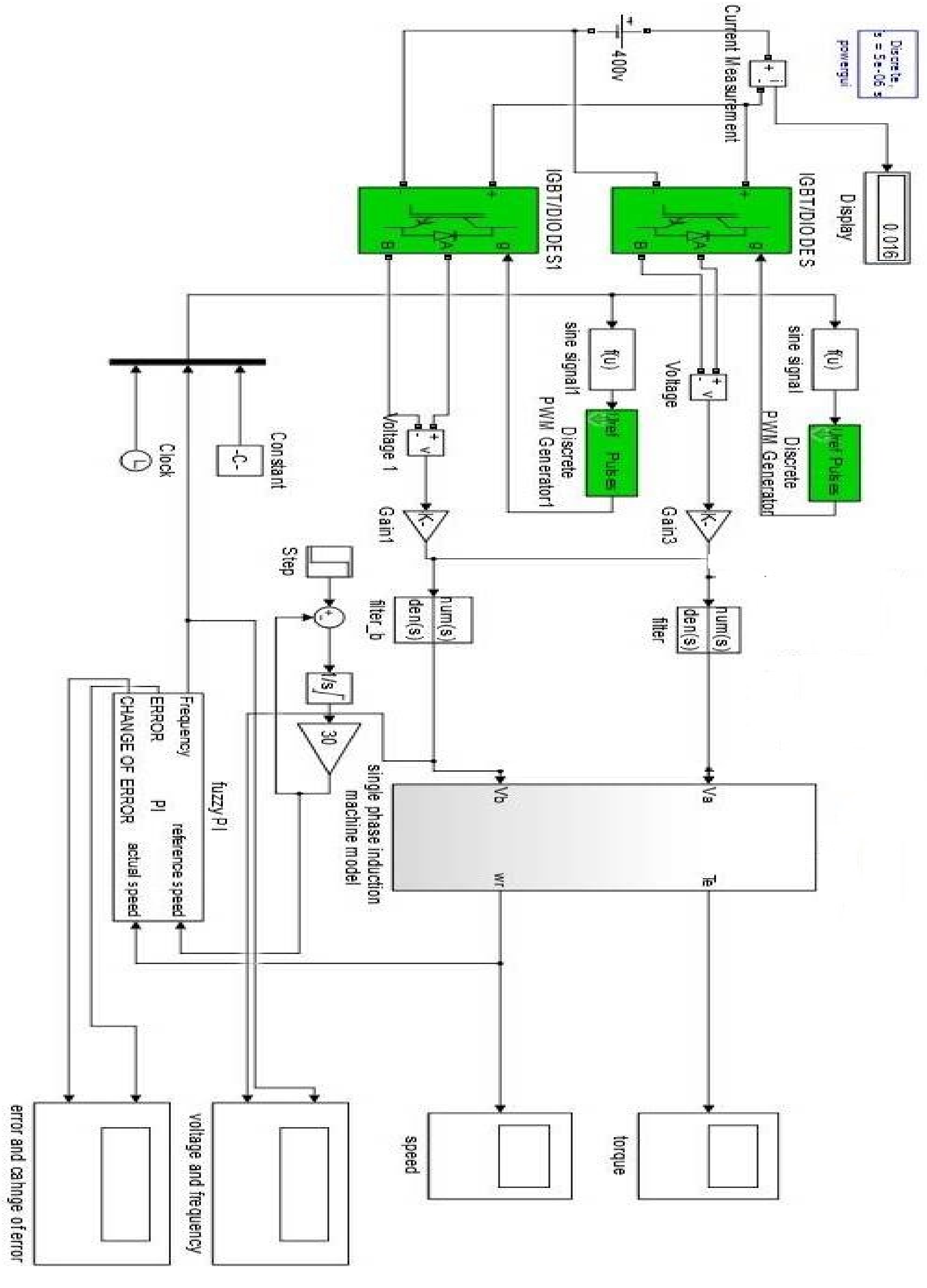

Figure 8: schematic diagram of field oriented control strategy

6. Results

The proposed proportional-integral (PI) designed based in fuzzy logic controller shows high response to the change of load of the single phase induction motor (capacitor run-type) which has the parameters as mentioned in table -1- , the response of the controller to the change of load is shown in figures (9) and (10).

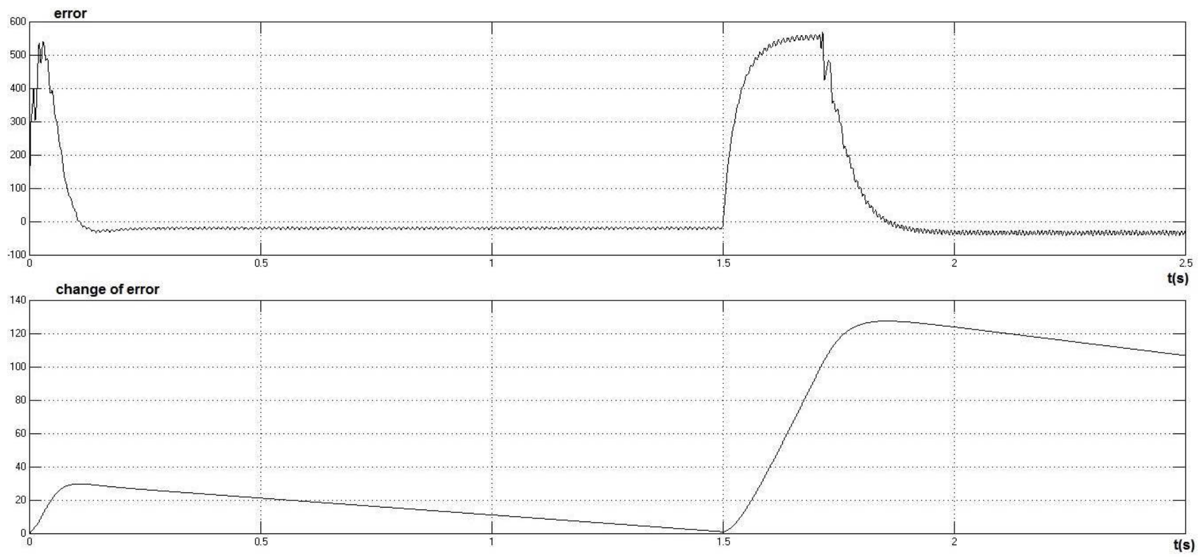

Figure 9: the response of the error and the change of error

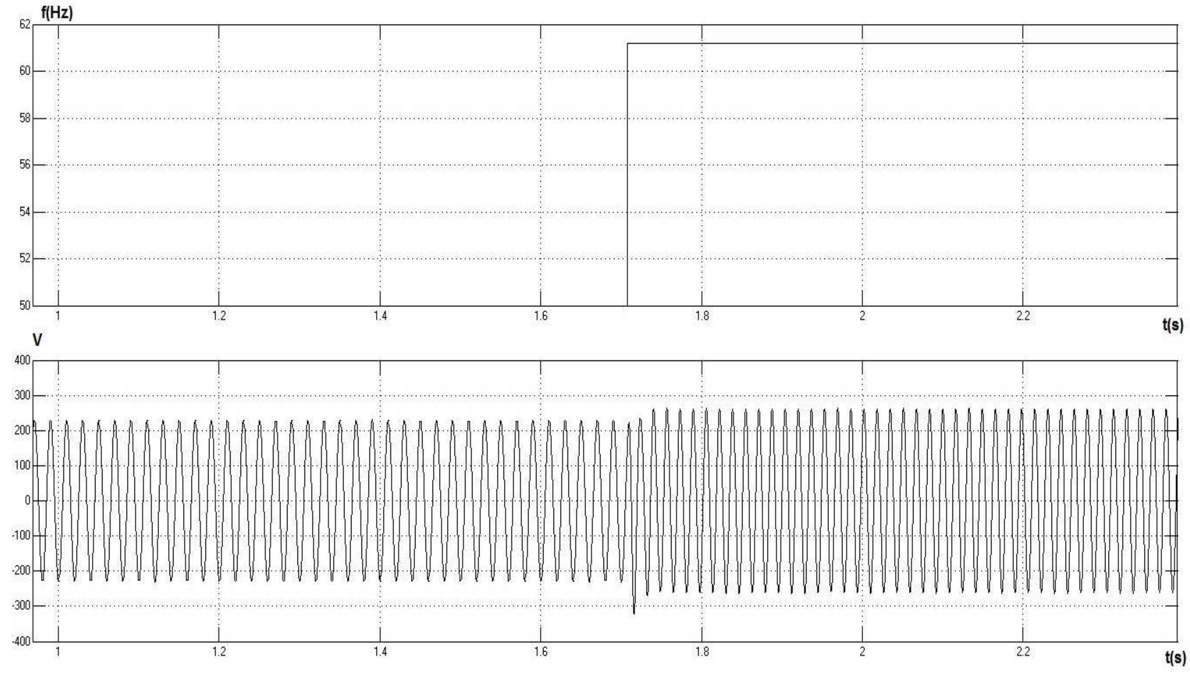

Figure 10: the voltage and frequency response

The applied load torque to the motor is the half of the full load, the controller shows high response to this change of load ,the rotor reference speed is (3000 rpm) when the motor is loaded the speed decreases to specified value, then the controller will respond to this change and make the motor return to its reference speed. Figures (11), (12) and (13) clarify the motor response to load change with the controller action.

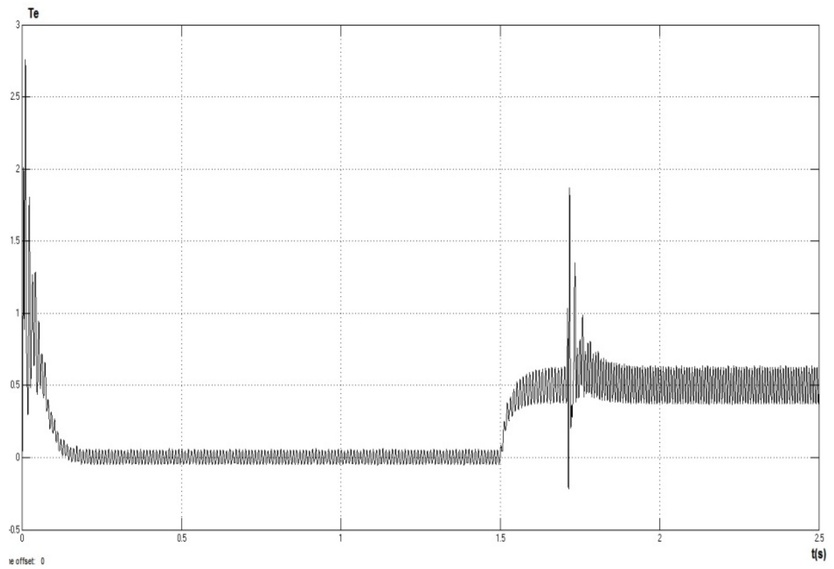

Figure 20: speed response

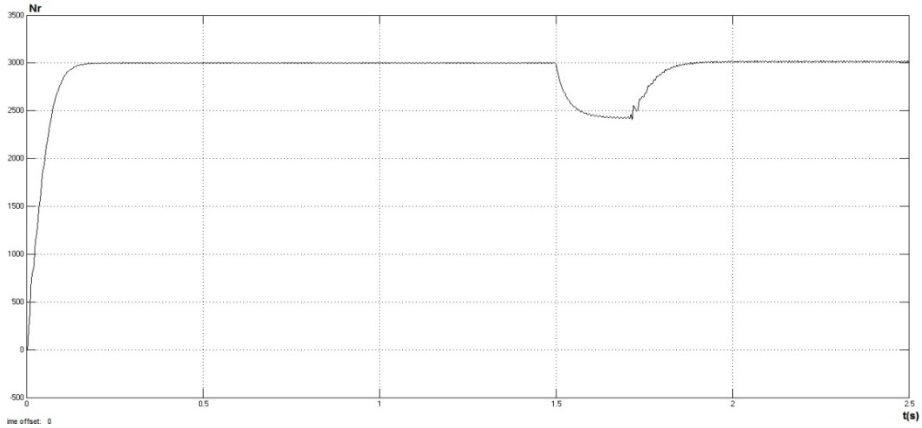

Figure 20: torque response

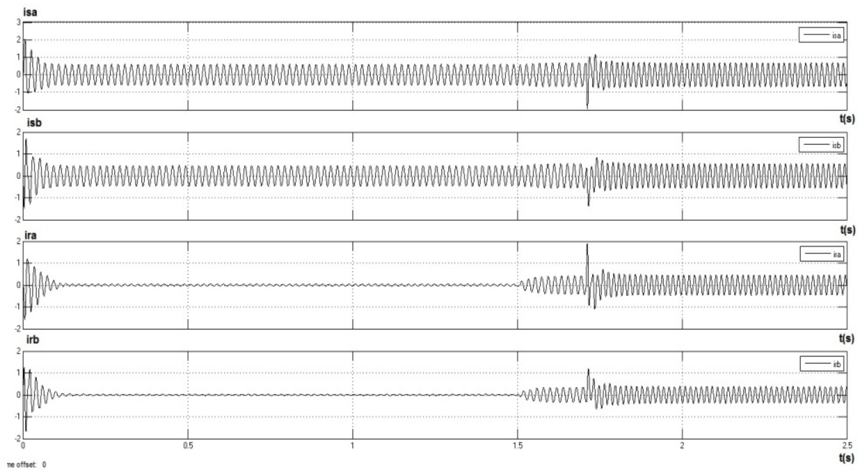

Figure 20: the rotor and stator currents of single phase induction motor

Table 1: parameters of Single Phase induction motor [12]

symbol	value	unit
Rsα	61.3	Ω
Lsα	1.154	H
Msrα	1.12	H
Vn	230	v
Rsβ	68.8	Ω
Lsβ	1.645	H
Msrβ	1.6	H
f	50	Hz
Rrα	87.25	Ω
Lrα	1.174	H
T_L	0.5	Nm
w_r	3000	rpm
Rrβ	109.95	Ω
Lrβ	1.665	H
Np	1	N/A
J	$25.1*10^{-5}$	$Kg.m^2$

7. Conclusions

The conclusions of this work can be summarized in two points

- The single phase induction motor capacitor run type has been simulated as asymmetrical two phase induction motor in MATLAB/Simulink environment; the voltage source PWM inverter using the (SPWM) switching technique has been simulated with MATLAB/Simulink environment.
- The proportional-integral (PI) controller designed with fuzzy logic system in MATLAB/Simulink environment which employed seven optimized base-rules with two inputs error and change of error , the output is the frequency , the results shows high response to the change of load with very short time , the responses of torque , speed , voltage and currents are shown above.

References

[1] Ali H. Ahmad, Ali Abbawi," Single Phase Induction Motor Speed Control Using Frog-Jumping Algorithm Technique", 2nd International Conference on Control, Instrumentation and Automation (ICCIA), Pp(247-252) ,2011

[2] M. Nageswara Rao, A. Rajani "Speed Control of Induction Motor Using Fuzzy Logic Approach"

International Journal of Engineering Research & Technology (IJERT) Vol. 2 ,Issue 8, August – 2013.

[3] S. F. Bandhekar, S. N. Dhurvey and P. P. Ashtankar," Simulation of Un-Symmetrical 2-Phase Induction Motor", International Journal of Computer Science and Network, Vol 2, Issue 3, June 2013.

[4]Mohan N., Undeland M. tore, Robbins P. W. “POWER ELECTRONIS” john wiley & sons, 1995.

[5] R.suneeth and P.Usha," Speed Control of Single Phase Induction Motor Using AC Chopper by Asymmetrical PWM Method ", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 10, PP. (12415-12422), October 2014.

[6] R. Kameswara Rao, P. Srinivas ,M. Suresh Kumar" design and analysis of various inverters using different PWM techniques", The International Journal of Engineering And Science (IJES), ISSN (e): 2319 – 1813 ISSN ,(p): 2319 – 1805, PP (41-51), 2014.

[7] Mo. Jamshidi,A.zilouchian "Intelligent Control Systems Using Soft Computing Methodologies", CRC Press LLC,2011.

[8] D. D. Neema, R. N. Patel, A. S. Thoke “Speed Control of Induction Motor using Fuzzy Rule Base” International Journal of Computer Applications (0975 – 8887) Volume 33– No.5, November 2011

[9] Anmol Aggarwal, J. N. Rai, Maulik Kandpal “Comparative Study of Speed Control of Induction Motor Using PI and Fuzzy Logic Controller” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 10, Issue 2 ,Ver. I,, PP (43-52),(Mar – Apr. 2015).

[10] Y. Kumsuwan, W. Srirattanawichaikul, S. Premrudeepreechacharn, H. A. Toliyat "A four-LEG voltage source inverter fed asymmetrical two-phase induction motor drives", 5th IET International Conference on Power Electronics, Machines and Drives, Pp (1-6) ,2010.

[11] Rajesh Thinga, Sanjeev Gupta, S. P. Phulambikar " Field Oriented Control of Single Phase Induction Motor" , International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 8, August 2014.

[12] Laskody, S. Kascak, M. Prazenica and B. Delbruck ,"Space Vector PWM for two-phase inverter in matlab".