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Comparison of PI Controller, Fuzzy Controller and Practical Swam Optimization for Dual Three Phase Induction Motors Drives Control Based on Indirect Field Vector Oriented Method

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ABSTRACT

To reduce the cost and the system complexity in power applications, voltage source five-leg modulation inverter of space vector pulse width (FLI) is designed to drive dual induction motors. This paper presents independent control of dual induction motor fed by five-leg inverter. The control conducted through Indirect field- is applied separately by each motor. With three controllers; PI-controller; fuzzy controller; practical swarm optimization. Generation of the signal of switching for FLI a double space vector pulse width modulator is utilized and a double zero-sequence modulation technique (DZS) is employed to generate the modulation signals. Finally, a comparison of three presented controller are carried out for the two motors operate under different operation condition was the result that proved that dual induction motor independently can be put under control of the FLI with FLC.

Keywords: Indirect Field Oriented Control, Five Leg Inverter, DZS, Dual IM, Practical swarm optimization.

Introduction

Recently, for Ac drive, the power demand is increasing. The rendering of machine drives is enhancing by detraction, the charge and size of, the controller. Multi-Machine System (MMS) is one solution for that [1]. In different manufacturing fields such as electric trains, textile, paper making and mining, systems of multiple motor drive (MMS) are demanded, where two motors may be operated in a parallel method [2]. Generally, this system requires a lot of power switches and high-performance control for the number of the converter. The result reached states that a large number of power electronic switches (IGBTs) semiconductor is needed which lead a complex structure and higher cost. To limit and decrease the structure complexity of and coast, a known DC bus is utilized separately with the two motors has its three-phase inverter [3]. Probably, in a frequent analyzing way, and a switch being reduced, topology being counted for, derived by two motors, a five-leg (ten-switch) VSI is employed. Each motor is connected to the leg of, the five-leg VSI, by one phase each to while the two phases of each machine that are remaining are independently supplied from the four inverter legs [4]. The Five legs and the inverter fed in addition to the drives are suitable for the applications such as the electric hybrid vehicles, applications of aerospace, and propulsion of ships that require high levels of efficiency and reliability. The control of speed of IM is conventionally handled using fixed gain PI controllers, this controller is extremely sensitive to load disturbances and parameter variations. This controller parameter may be continuously adapted and many control techniques are used to solve the problem. The design of the controller is based on the mathematical model system and from difficultly to make an accurate mathematical model because of unavoidable parameter variations and unknown load variation [30]. The above problems can have solved by FLC. The FLC can replace the conventional controller, it has some advantages such as more simplicity, stability in design, improvement the response in the transient, and does not demand the system mathematical model .It relies on linguistic rules within general structure of IF-THEN, that is the basis of the logic of humans [70].

In this research the comparison offers not an dependent control of the system of dual induction motor drives that are fed by a five-leg inverter which is presented by using PI Controller and Fuzzy controller, practical swam optimization is utilizing to

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tuning parameters of PI and comparison the results. In most, each induction motor adopts an indirect vector control that is field-oriented and applying space vector pulse width modulation (SVPWM) for the purpose of limiting the switched count in comparison with the methods of conventional PWM with the five-leg inverter (FLI). However, structure of control is made of four PI regulators with the current loops and for speed, the two PI regulators, which are rather not simple construction in tuning of the whole regulators for making the performance of the system. much better Moreover, two induction motors and two inverter stages are modulated by SVPWM share the common leg of the inverter. The principle independent control of two three-phase induction motor drive by five-leg voltage source inverter is investigated.

Modeling of Three Phase Induction Motor Drive

The induction motor of mathematical model in stationary hint can be represented by equations as follows [6]: The voltage of the stator winding given by

$$v_{qs}^{s} = \frac{2}{3}v_{as} - \frac{1}{3}v_{bs} - \frac{1}{3}v_{cs} \quad (1)$$

$$= \frac{2}{3}v_{ag} - \frac{1}{3}v_{bg} - \frac{1}{3}v_{cg} - v_{sg} \quad (2)$$

$$v_{ds}^{s} = \frac{1}{\sqrt{3}}(v_{sc} - v_{bs}) = \frac{1}{\sqrt{3}}(v_{cg} - v_{bg}) \quad (3)$$

The flux linkages as follows:

$$\psi_{qs}^{s} = \omega_b \int \left\{ v_{qs}^{s} + \frac{r_s}{x_{ls}}\left(\psi_{mq}^{s} - \psi_{mq}^{s}\right)\right\} dt \quad (4)$$

$$\psi_{ds}^{s} = \omega_b \int \left\{ v_{ds}^{s} + \frac{r_s}{x_{ls}}\left(\psi_{mq}^{s} - \psi_{md}^{s}\right)\right\} dt \quad (5)$$

$$\psi'^{s}_{qr} = \omega_b \int \left\{ \begin{array}{c} v'^{s}_{qr} + \frac{\omega_r}{\omega_b}\psi'_{dr} \\ + \frac{r'_r}{x'_{lr}}\left(\psi_{mq}^{s} - \psi'^{r}_{qr}\right) \end{array} \right\} dt \quad (6)$$

$$\psi'^{s}_{dr} = \omega_b \int \left\{ v'^{s}_{dr} + \frac{\omega_r}{\omega_b}\psi'_{qr} + \frac{r'_r}{x'_{lr}}(\psi_{md}^{s} - \psi'^{r}_{dr}) \right\} dt \quad (7)$$

The electromagnetic torque is described by:

$$T_{em} = \frac{3}{2}\frac{P}{2\omega_b}\left(\psi_{ds}^{s} i_{qs}^{s} - \psi_{qs}^{s} i_{ds}^{s}\right) \quad (8)$$

Where v_{ag},v_{bg}, and v_{cg} are the three applied voltage to the terminal of the stator, and v_{as},v_{bs}, and v_{cs} are the three voltage of stator; r_s, r'_r, ω_r, ω_b are stator resistance, rotor referred resistance, actual rotor speed, and the base electrical angular frequency, respectively. The mutual linkages flux is ψ_{mq}^{s} and p represents poles pairs number. The stator & rotor windings leakage reactance are $x_{ls}$and x'_{lr}, respectively.

Topology of Five Leg Drive System

The topology of five-leg VSI supplies dual machine drive induction of three-phase as it is in Figure (2), that will be saving two switches and results in a limitation to a lower level in capital cost with respect to the standard configuration of dual three-phase voltage source inverter (VSI).

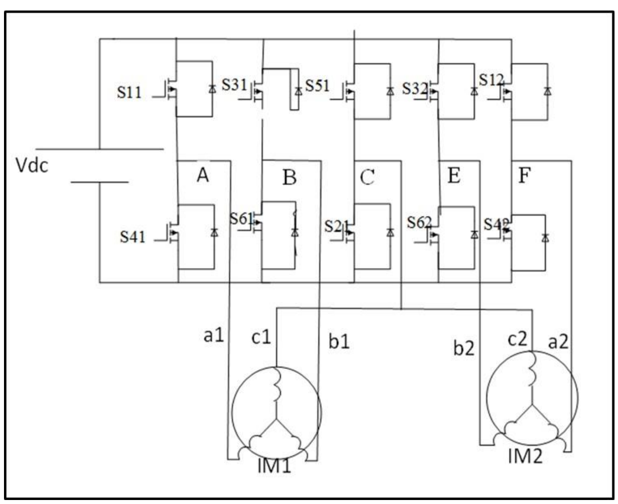


Fig.1 FL VSI supplies two identical induction motors of three phase.

In the inverter of five-leg topology, will use one leg to be the common leg, where it is shared by two motors. The leg C is picked to be shared by two machines. .The Legs A and B are attached to phases a_1 & b_1 directly, and used with machine 1. respectively Legs F and E are attached to phases a_2 & b_2, of machine 2., DC bus has V_{dc}rated value [9]

Control Strategy

Principle of indirect field oriented vector control method

In the IFOC method, it is not needed to determine the position of the flux of the rotor as in another type of control method (direct vector control), where a fit value is applying to the slip frequency to the adjusted appropriate position to the stator current of machine. After the estimation of the slip frequency, it will have been summarized with the actual speed of the rotor to get the frequency of the angular and integrated stator to get the position of electrical angular [15]. Figure(4) demonstrates the diagram of block of an indirect field orient control induction motor drive component of stator current i_{qs} and i_{ds} consider constant in the rotor reference frame. The method of indirect vector control is basically similar to the direct vector control except for that the unit vector is started in an indirect way through the use of the speed that is measured ω_r and slip speed ω_{sl} [15]. Induction motor is fed by an SVPWM inverter, which is to be operated in voltage control mode where real speed of the motor ω_r is to be compared to the reference speed ω_r^* shall result in an error, which is supplied to (PI or any intelligent controller)for the speed controller. The electromagnetic torque T_e component of current i_{qs}^* is the output of the speed controller [16]:

$$T_e = \frac{3}{2}\frac{p}{2}\frac{L_m}{L_r}\left(\hat{\psi}_r\, i_{qs}\right) \qquad (8)$$

The electromagnetic torque reference $T_e^*$is used to calculate the quadrature -axis stator current reference i_{qs}^* is calculated from[16].

$$i_{qs}^* = \left(\frac{2}{3}\right)\left(\frac{2}{p}\right)\left(\frac{L_r}{L_m}\right)\left(\frac{T_e^*}{\hat{\psi}_r}\right) \qquad (9)$$

Where

$$\hat{\psi}_r = \frac{L_m i_{ds}}{1+\tau_r s} \qquad (10)$$

and

$\tau_r = \frac{L_r}{R_r}$, τ_r is the rotor time constant.

Direct-axis current reference of the stator i_{ds}^* is obtained from reference rotor flux input ψ_r^* as in the following equation:

$$i_{ds}^* = \frac{|\varphi_r|*}{L_m} \qquad (11)$$

The rotor flux position $\theta_e$is obtained by added the feedback rotor speed to slip speed frequency ω_{sl}, then the integration is to be done between speed of the slip altogether with the speed of the rotor.

$$\theta_e = \int \omega_e\, dt = \int(\omega_r + \omega_{sl}) \qquad (12)$$

The slip frequency $\omega_{sl}$is generated by the stator reference current i_{qs}^* and the parameters motor.

$$\omega_{sl} = \frac{L_m R_r}{\hat{\psi}\; L_r}\, i_{qs}^* \qquad (13)$$

The two reference currents ($i_{ds}^*$and i_{qs}^*) are compared with feedback current of the motor through Park and Clark Transformation, the error from PI controllers is generated the voltage command signal which summed with decoupled voltage and these are converted to three-phase voltage [17].

Design of speed control of dual induction motors with FLI

The control strategy of vector control of dual independent three-phase induction motor drive is to be fed by the five-leg inverter is shown in Figure (2). The control strategy is based on two classical Indirect Field Oriented Control (IFOC goal is to disengage the couple the torque and flux control). This is achieved by orientation of the flux on the d-axis in the frame d-q.

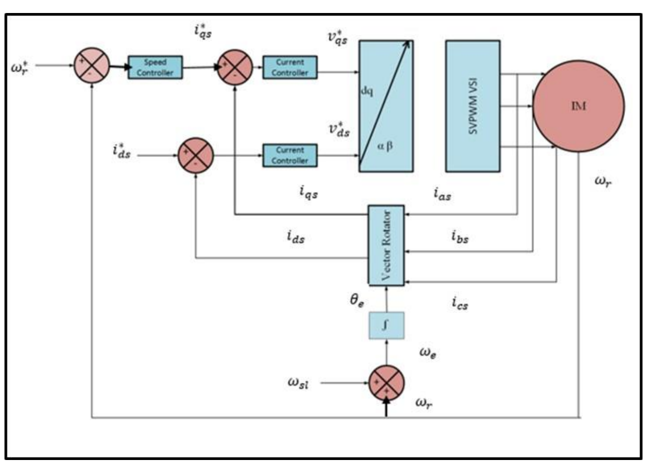


Fig.2 The block diagram of an indirect field orient control IM drive.

The control system consists of two machines (IM1 and IM2), voltage source FLI, IFOC 1 for IM1 and IFOC 2 for IM2 and the double zero-sequence modulation as shown in Figure (3). Where two-speed controller PI and four current controllers PI is using. In the IFOC of IM1, the flux component and torque one of the stator current goes through a transformation that is coordinated to supply the voltage amplitude, phase, and frequency. The demanded speed is stated as the speed reference ω_{r1}^* or ω_{r2}^* for IM1 and IM2. The demands of the speed are compared to the actual speeds of the rotor ωr_1 and ω_{r2}, and the deviation is to be amplified within the speed control PI controller and output of the speed controller works as the input to the torque current loop. The reference torque current i_{qs1}^* is to be compared to the actual torque current component, i_{qs1} and this shall result in the error of the torque current , and the error is processed to make the reference voltage torque component V_{qs1}^*. From another angle, the current flux component, i_{d1}^*that is set earlier to a constant value is compared to the real values of the d axis- stator current of the motor i_{ds1}. The signal of the error is applied to the PI controller make the command values of the flux voltage component, V_{ds}^*. Inverse Park transformation reference is stated by using it to transform the reference voltage to the stationary reference (αβ frame) coordination. A same principle is applied to IFOC of IM2. Then both signals that are synthesized by the use of DZS modulation to control the voltage supply is demanded for the motors.

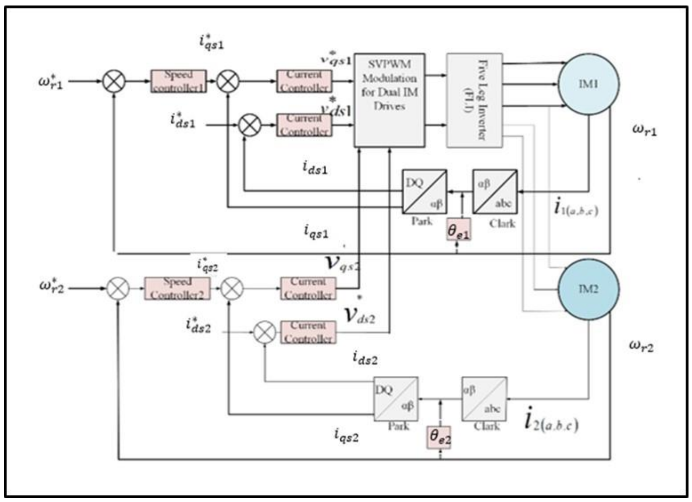


Fig.3 The control strategy of vector control for dual independent three-phase induction motor drive fed by Five Leg Inverter.

Fuzzy logic Controller of Two IMs fed by SVPWM FLI

The double IFOC for two IMs fed by FLI is explained in chapter three and now replaced the PI speed controller of each motor with FLC. Figure (4) demonstrates the diagram of IFOC of two IMs fed SVPWM FLI implements FLC for the speed of the dual motor. Here Mamdani algorithm is utilized as an inference strategy and for defuzzification, the center of gravity is used. The FLC operation depends on the same rules was using in one IM. The membership functions connected to the control variables are chosen with by the use of triangular figures as expressed in Figs. (5) for input variables and (6) for output. The discourse of all the variables of input and output are fixed as [-1, 1].

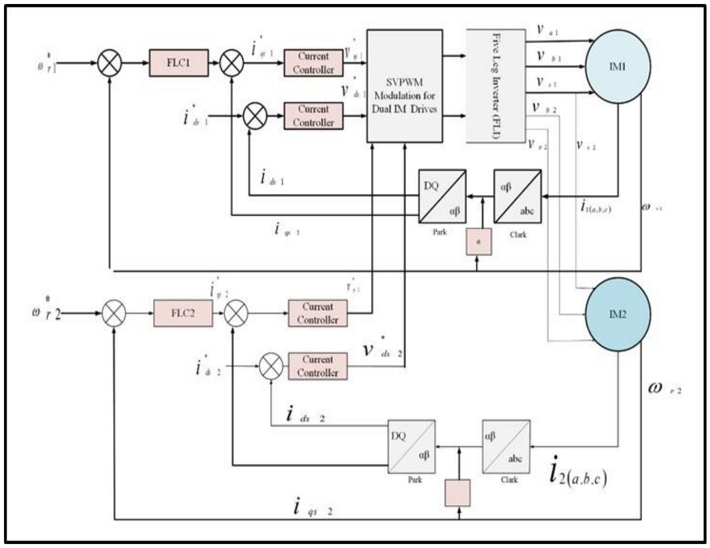


Fig.4 Block Diagram of IFOC of two IMs fed by SVPWM FLI implements FLC.

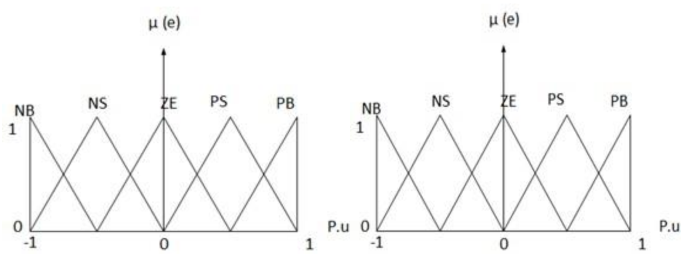


Fig.5 Membership for speed error and change of speed error.

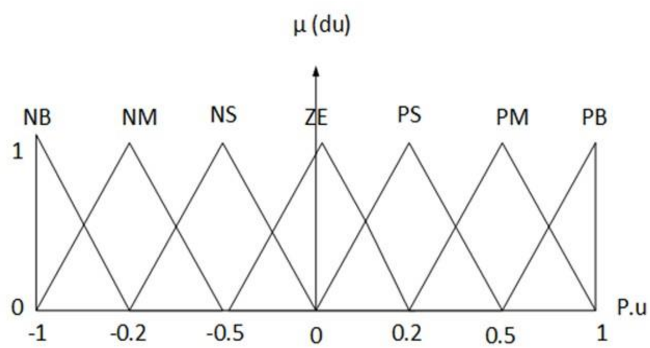


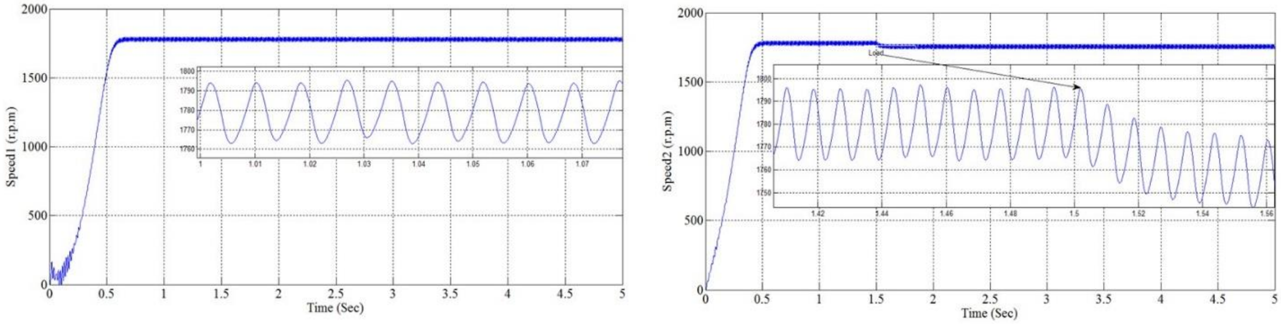
Fig.6 Membership for command current i_{qs}^{*}

Simulation Results

Simulation results of dual IM fed by FLI

The simulation of the IFOC method of dual IM using MATLAB/SIMULINK program. The Simulink model consists of two identical three-phase induction motor both parameters are identical with 1hp 200V and 60Hz, and two independent IFOC method for each motor using single FLI which circuit consists of ten MOSFET and DC bus voltage will use one leg as the main leg, where it is shared in two phases C_1 and $C_2$by two motors leg C is chosen to share by two machines. Inverter Legs A and B are attached to phases a_1 and b_1 directly, for IM 1 while Legs D and E to phases a_2 andb_2, respectively. Vector modulators of two independent three-phase space are used to have control over the dual machines (IM1 and IM2), d–q rotating reference frame was referred to as the voltage reference vector to the dual motor.

The performance of the system is obtained by two tests. The first test is shown in Figure (7). The motor1 is operated at no-load condition. Fig. (7-a) shows the rotor speed of Motor1 which is stable with steady-state at time 0.6 sec, while the motor2 operates at the time the same time of motor1 and sudden load 2 N.m is applied at time1.5 Sec, the rotor speed of motor2 is shown in Fig.(7-b).



7-a 7-b

Fig.7 Dynamic Response of Dual IMs fed SVPWM FLI inverter (a)Speed, of IM1 (b)Speed of IM2.

Simulation and Results with Particle Swarm Optimization (PSO)

The Simulink model of the motor based on IFOC by using the PSO algorithm is obtained. The controller has been implemented as shown in Fig. (8). The results show that the PSO algorithm gives optimal value for the PI controller parameters and enhance the system performance, where the steady-state time and smoothing with PSO is better with respect to PI controller. The PSO parameters are shown in Table (1). Figs. (9a-b) show the motor speed due to the PSO tuned parameters of the IFOC of two IM fed by FLI when the no. of birds is 50 bird and no. of iteration is 50 iterations. The results show independent control for two motors and the steady-state time is better with respect to the PI controller in trial and error method.

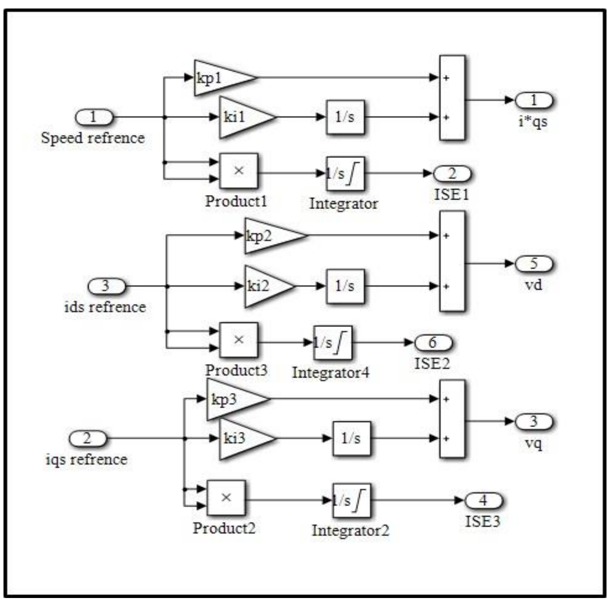
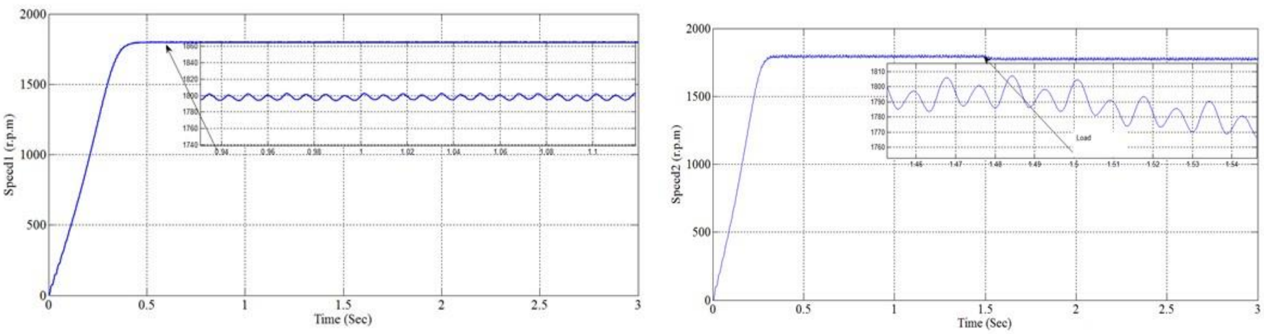


Fig.8 Simulink model for the PSO fitness function calculation.

Table 1: PSO parameter values.

PSO Parameters	Value
Size of the swarm " no of birds "	200
Maximum iteration number	50
Dimension	6
PSO parameter c_1	1.2
PSO parameter c_2	1
Wmax	0.8

W min	0.2

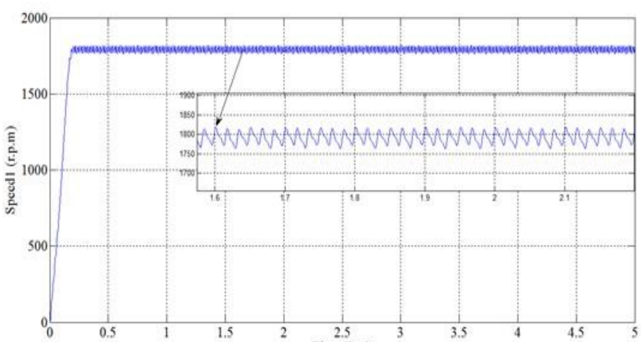


(9-a) **(9-b)**

Fig.8 Dynamic response of two IMs fed SVPWM FLI inverter with PSO. (a) Speed of Motor1 (b) Speed of Motor2.

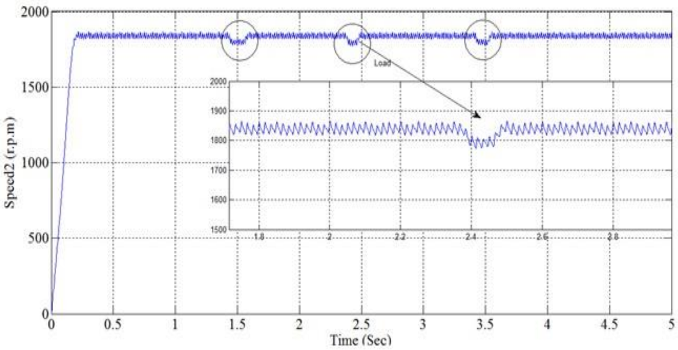
Simulation and Results with Fuzzy Logic Controller (FLC)

Simulation of two identical IMs with FLC for each speed of the motor. The performance of the no-load test



is obtained for motor1 and motor2 with the same reference speed for both two speed FLC. The test is done where two motors are operating at the same time, one machine operates at no load condition, another machine is operating at a same reference speed of motor1 and step load for full load 4N.m, half of the full load 2 N.m and 1N.m one fourth the full load. Figs. (10-a) and (10-b) shows the speed of motor1 and motor2 respectably. From the result is noticed when the motor2 is loaded, the motor1 no effected which means the two motors independently control with FLC. Also, the performance of two motors is better with respect to speed, torque and current in chapter three according to rice time and steady-state. FLC is better than the PI controller.

Using the Template



(10-a)

(10-b)

Fig.10 Dynamic response of IMI and IM2 at no load for IM1 and step load IM2 with FLC. (a) Speed 1 (b) Speed 2.

Conclusion

The model of the two IMs with its control circuit consists of, two IFOC vector controls for both motors are used. The simulated results show the robustness and a stable system and prove that the topology of FLI can be applied to drive dual IM in an dependent way. The term " in an dependent way" refers to each motor that can be operated in various conditions of operating like various direction, motors parameters, speed and load torque. Here IM1 and IM2 work at different operations (here take with respect to load where one motor operates at no load and another motor at different load). It is showed that five-leg VSI that supplied two-motor drive is suited in the best way to constant power applications, such as winders that are center-driven, where the motors are independently controlled and the performance of two identical IMs is better with FLC compared with PI and PSO.

References

[1] J. M. Leza, Z. Ibrahim, M. Sulaiman. A. M. Razali. N. Kamisman, " Independent Control for Dual-PMSM Drives using Five-Leg Inverter", Vol. 64, No. 8, 2015.

[2] Y. Mei, Z. Yi, L. Wang " A Modulation Method Based on Finite State Machine of Five-leg Inverter for dual motor drives", *International Conference on Electrical Machines and Systems, pp. 909-913, 2014.*

[3] S. N. Vukosavic, M. Jones, D. Dujic, E. Levi, " An Improved PWM Method for a Five-Leg Inverter Supplying Two Three-Phase Motors", ISIE 2008. IEEE International Symposium on Industrial Electronics, pp. 160-165, 2008.

[4] M. Jones, D. Dujic, E Levi," A Performance Comparison of PWM Techniques for Five-Leg VSIs Supplying Two- Motor Drives*", IECON-2008, The 34th Annual conference of the IEEE Industrial Electronics Society, pp.508-513, CD-ROM, pp. 508-513.*

[5] A. G. T, D. Krishnamurthy, M. Raju, and A. Balasubramanian," A Low-Cost SVPWM Controller for Five-Phase VSI Using PIC18F4550", *International Conference on System Dynamics and Control -ICSDC, Vol. 1, No.12, 2010.*

[6] C. M. Ong, "Dynamic Simulation of Electric Machinery", 1989by Prentice-Hall, PTR, Prentice-Hall, Inc., ISBN:0- 13-723785, 1998.

[7] A. Gupta, S. Kinases " Two Single-phase Induction Motor Drives Using a Five-leg Voltage Source Inverter", *International Conference on System Dynamics and Control -ICSDC pp. 156-162, 2015.*

[8] A. Gupta, S. Kumar, " Analysis of Three-Phase Space Vector PWM Voltage Source Inverter for ASD's" International Journal of merging Technology and Advanced Engineering, Vol.14, No.10 2012.

[9] M. H. N. Talib, Z. Ibrahim. Abd. Rahim and, A. Abu Hasim " Characteristic of Induction Motor Drives Fed by Three Leg and Five Leg Inverters ", Journal of Power Electronics, Vol. 13, No. 15, 2013.

[10] R. Omata, K. Oka, A. Furuya, S. Matsumoto, Y. Nozawa, and K. Matsue, "An Improved Performance of Five-Leg Inverter in Two Induction Motor Drives," *in Power Electronics and Motion Control (IPEMC) Conference, pp.1-5, 2006.*

[11] M. Jones, S. N. Vukosavic, D. Dujic, E. Levi, and P.Wright, "five-leg inverter PWM technique for reduced switch count two-motor constant power applications", IET on Electric Power Applications, Vol. 2, No. 5, pp. 275-287, 2008.

[12] A. Ahmad and Dr. R.K Tripathi, " Indirect Field Oriented Control (IFOC) of Induction Motor Using SVPWM Fed with Z Source Inverter " *Engineering and Systems (SCES), 2012 Students Conference on*. IEEE, 2012

[13] M. Ankarao, M.V. Kumar, "Implementation of PI, Fuzzy & Ann Controllers to Improve Dynamic Response of Vector Controlled Induction Motor Drive", *International Journal of Research in Engineering and Technology IJRET, Vol. 4, No. 7, pp. 308-314, 2015.*

[14] B. Baby, A.S. Shajilal, "An Improved Indirect Vector Controlled Current Source Inverter Fed Induction Motor Drive with Rotor Resistance International Conference on Magnetics, Machines & Drives (AICERA-2014 iCMMD), pp. 1-6, (2014).

[15] B. N. Kar, K. B. Mohanty, " Indirect Vector Control of Induction Motor Using Fuzzy Logic Controller", pp. 1-5, (2011).
[16] R.S. Lodhi, P. Thakur, " Performance &Comparison Analysis of Indirect Vector Control of Three Phase Induction Motor", International Journal of Emerging Technology and Advanced Engineering, Vol. 3, No. 10, pp. 2129-2151, (2013).
[17] T.H. Panchal, A.N. Patel, S. Sonigra, " Simulation and Analysis of Indirect Field Oriented Control (IFOC) of Three Phase Induction Motor with Various PWM Techniques", International Journal of New Technologies in Science and Engineering, Vol. 2, No. 2, pp. 76-81, (2015).
[18] B. Tabbache, K. Rebaa, A. Marouani, B. Benbouzid, A. Kheloui", Independent Control of 634 (2014).