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Analysis and Performance Improvement of Induction Motor drive for Traction Application

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Abstract – Induction motor is widely used in many fields due to its simple structure, well-grounded operation, and small capacity of precise power. The conventional traction motor drives have been observed experimentally that there is a presence of speed deviation and torque ripples. Therefore, it becomes much essential to verify the control performance of the system by including its non-linear characteristics. To overcome the disadvantages mentioned above, the parameters of an induction motor which is most efficient will be estimated. The induction motor is dynamically modelled using this estimated parameter. So the proposed system focuses on improving the performance of traction motor drive by implementing the multilevel inverter fed sensor less induction motor using modified model reference adaptive system and compared with conventional model reference system based voltage source inverter. The simulation and hardware results will be realized for proposed system and compared with conventional system.

Keywords – Three Phase Induction Motor; Neutral Point Clamped Inverter; Modified Model Reference Adaptive System; Parameter Estimation And Field Oriented Control

1. Introduction

Ac motor has many well-defined advantages, especially simple structure, well-grounded operation and small capacity of precise power. With the constant magnificence and progress of large power variable frequency device and its domination technique, the relevance of AC motor as a locomotive traction motor has become an important development of traction drive. Currently the induction motor implemented in traction drive has many disadvantages like stability, speed deviation, high torque ripple, control method and thus not efficient. The conventional traction motor drives has been faded with the combination of rectifier, boost converter and voltage source inverter coupled with two or more induction motor connected in parallel. Induction Motors were initially controlled by scalar control techniques. They were complicated due to computations. Tacho-generators or encoders were used to sense the speed of the motor. This increases overall expenses [1-3]. But, motor drives without speed sensors have been developed by advancements in technology [4-5].

Lyapunov formula is used to verify the speed deviation of the feedback system. From Experimentation, it can be finalized that the method presented can be dealt with the difficulty of ripple force LHSM drive [6-7]. The recent progress in electric traction for rail and road Vehicles are discussed. These include the increase in modularity of new traction inverters in all sizes and the introduction of new hybrid vehicles which use advanced power electronics [8].In vector control, connect orientation in steady and transient state can be obtained by controlling the instantaneous positions of voltage, current and flux space control variables and torque can be obtained by coordinate transformations to new field coordinates [9-11]. The sensor less speed control for low speed performance are analyzed [12-15]. Layer multiplexing is used to bring down cost and for efficient utilization of resources. For this, the minimum bit precision is implemented using layer multiplexing technique. The estimator designed has been tested on Spartan FPGA kit and the corresponding results are presented [16]. The distribution of temperature is calculated both at steady state and at transient conditions. Thermal analysis is necessary to develop smaller and more efficient motors [17-19].But all the methods mentioned above the speed deviation is not reduced satisfactorily. The type of motor which is designed in motor solver is 1HP, 415V, 0.78Kw, 4 pole induction motor [20].

In the proposed model Voltage Source Inverter has been replaced by Multilevel Inverter and it has been observed experimentally that Performance is improved compared to the existing oneby diminishing the harmonics. For improving the performance of induction motor, Electrical parameters have been estimated by no load and blocked rotor test and mechanical parameters estimated by model reference adaptive system where the dynamically modelled induction motor can achieves good

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performance for sensorless drive. Induction motors are controlled by field oriented control techniques with PI controlled based speed controller.

2. Modelling of Induction Motor and Parameter Estimation Methods

The parameter assessment for induction motors qualify to develop induction motor models from creator data such as nameplate rating, and motor staging attributes. The parameters which are best fitted in to get the highest efficiency are taken into consideration. The design and modelling of induction motor is carried out using those parameters. Two types of parameters have been determined for designing the induction motor i.e. electrical and mechanical parameters. In the conventional methods old data for the particular machine was considered and showed good performance. But after five years the performance of the same machine will decrease. Electrical parameters such as rotor and stator resistance, leakage inductance, mutual inductance is estimated and in mechanical parameters speed and torque of induction motor by MRAS technique is estimated. The test carried out for the determination of electrical parameters are direct current Resistance test, No Load Test and Blocked Rotor Test.

2.1Direct current Resistance Test

The uncomplicated element to be determined is the resistance of stator. It can be sustained using an ohmmeter after examining the motor terminal connections, Resistance test on motor terminal block test is executed on an individual motor, to identify the stator resistance. In step 1 separate the motor electrically and if mandatory mechanically and step 2 Distinguish the method of connections. In star connections two links are connected. Discard the tie-up and give cables before performing the test. In Delta connected, three links connect U toW2, V1 to U2, W1toV2. Discard the tie-up and give cables before performing the test. Stator resistance values were estimated using Direct current resistance test and the values are 6 ohms for motor 1 and 10.3 ohms for motor 2. The simulation of Direct current resistance test is shown in Figure1.

2.2 No Load Test

The value of slip is small in the motor under no load, thus Resistance and current in rotor winding is very small as compared to the magnetizing current. Magnetizing branch value X_m is calculated by evaluating voltage, power and current at no load. At No load test motor run at standard voltage and no load current and then active power is studied. Since at no load the magnetizing component is connected in parallel by a high resistive branch, the reactance of this parallel composition is nearly same as X reactance. Therefore, total reactance X_{nl} sustained is equivalent to X_l+X_m. The equivalent circuit of induction motor at no load is illustrated in Fig 2.

The phase voltage from line voltage is given by

$$V_P = \frac{V_L}{\sqrt{3}} \tag{1}$$

The impedance per phase for no load is given by

$$Z_{NL} = \frac{V_P}{I_P} \tag{2}$$

Resistance at no load is represented by

$$R_{NL} = \frac{P_{NL}}{3I_2} \tag{3}$$

Reactance at no load is calculated as

$$X_{NL} = \left(Z_{NL}^2 + R_{NL}^2\right)^{\frac{1}{2}} \tag{4}$$

Using no load test out the total resistance values and also reactance value at no load which is observed which is the sum of stator reactance and magnetizing reactance. Table 1 demonstrates these values at different voltages for machine 1 and machine 2.

2.3. Blocked Rotor Test

In this test, full load is applied on the rotor and thus it does not rotate. The slip value becomes unity since rotor is stationary; and hence R_2/S becomes less. It makes the rotor current much higher than the current in the stimulation branch of the circuit and hence the magnetization branch can be disregard the equivalent circuit of induction motor at blocked rotor test is illustrated in Figure 3.

The resistance of rotor winding is determined from the power dissipation is represented by

$$B_{PR} = 3I_{BR}^2 * \left(R_1 + R_2\right) \tag{5}$$

The impedance of blocked rotor is given by

$$Z_{BR} = \left(\left(R_1 + R_2\right)^2 + \left(X_1 + X_2\right)^2\right)^{\frac{1}{2}} \tag{6}$$

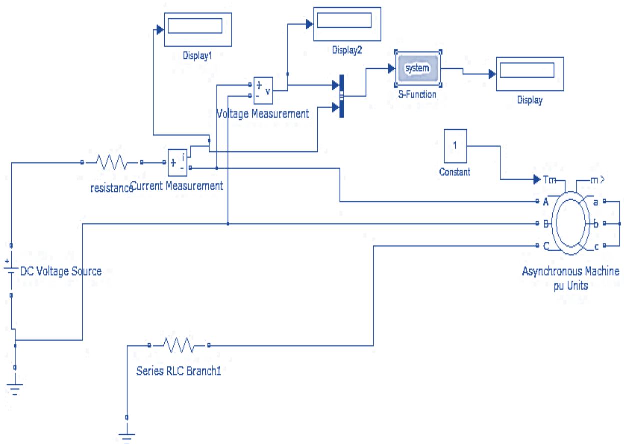

Fig 1. Direct current resistances test

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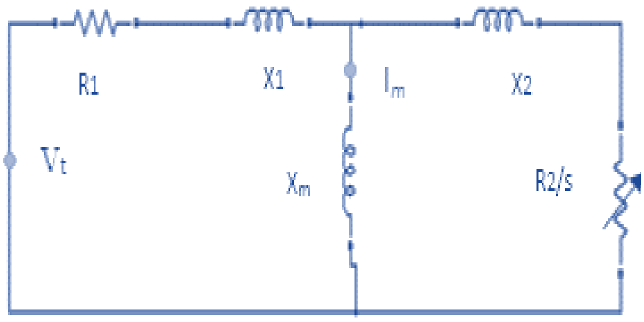

Fig 2. Equivalent Circuit of No-Load Test

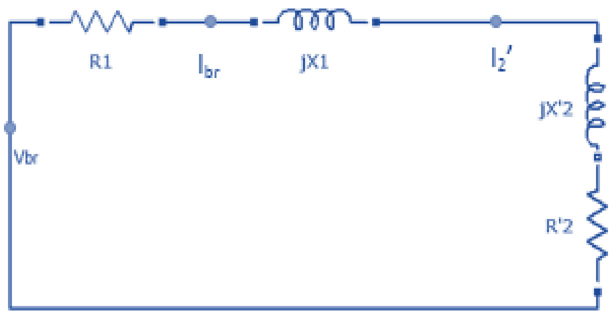

Fig 3. Blocked rotor test equivalent Circuit

Table 1. Estimated Parameter from No Load Test

Machine 1			
Vph(V)	240	320	410
Iph(A)	1.53	2.233	3.733
cosΦ	0.4357	0.268	0.324
P(W)	160	192	496
Q(var)	330.5	688.27	1497.88
Xnl(ohms)	155.198	142.7289	142.8129
Machine 2			
Vph(V)	240	320	410
Iph(A)	0.933	1.466	2.3
CosΦ	0.2	0.204	0.22
P (W)	44.8	96	212.8
Q(var)	217.2	459.192	918.675
Xnl(ohms)	256.5699	217.7725	177.755

Table 2. Estimated Parameter from Blocked Rotor Test

Blocked rotor test		
Machine 1		
Iph(A)	7.5	6
Vph(V)	150	73
X1(ohms)	7.9898	4.8449
X2(ohms)	11.98476	7.2674
Xm(ohms)	138.922	142.06833
Machine 2		
Iph(A)	4	2
Vph(V)	78	48
X1(ohms)	7.73	9.3285
X2(ohms)	11.598	13.9915
Xm(ohms)	209.634	208.036

Through blocked rotor test the above mentioned values are observed. $X_1=0.4X_{br}$ for class F motors. Thus we get X_1, X_2, X_m for machine 1 and machine 2 at two different values of currents are presented in Table 2.In the proposed method, instead taking data from the old references the estimated parameter are used for modelling an induction motor. An induction motor is modelled with estimated parameter using Matlab Simulink then the proposed method results are illustrated .The stator and rotor current are illustrated in fig 4 and 5 respectively .In starting stator current is10A then reduced to 5A similarly rotor current also high in starting then reduced.

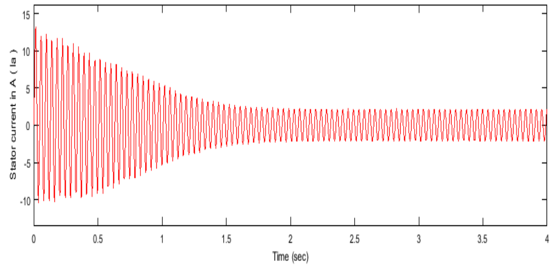

Fig 4. Stator Current of Induction Motor

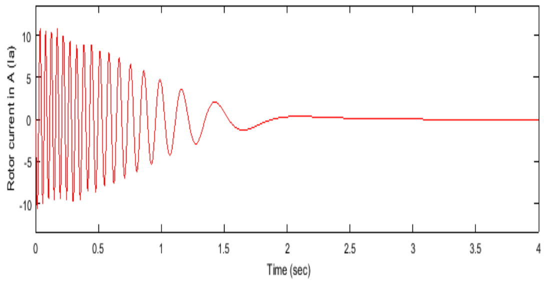

Fig 5. Rotor Current of Induction Motor

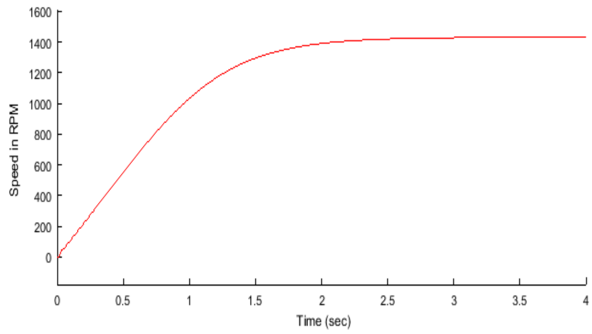

Fig 6. Speed of Induction Motor

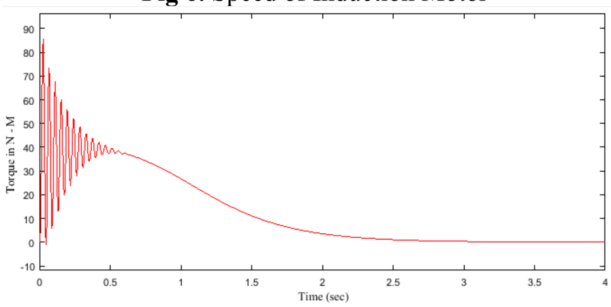

Fig 7. Torque of Induction Motor

Simulation of dynamic modelling for induction motors is done with estimated electrical parameters with 1475 rpm at a settling time of 1 seconds and torque of the induction

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motor with the amplitude of 70 N-M till 0.5 seconds then reduced to initial value are illustrated in Figure 6 and 7 respectively.

3. Performance Investigations of Induction Motor Drive for Sensor less Drive Using Modified MRAS

It has been observed experimentally that the voltage source inverter used in the existing locomotive traction drive consists of distorted output. So in the proposed model VSI has been replaced with neutral point clamped multilevel inverter. By using multilevel on the Direct current bus the neutral point clamped inverter reduces the voltage stress on each and every power device. It has the ability to reduce smaller disturbance by using the step modulation technique at low switching frequency. Output voltages of multilevel inverters is obtained by the use of different capacitor at different switching frequencies .For controlling the switches in the inverter sine PWM technique is implemented. Total harmonic distortion in NPC inverter is 27% without filter this is very less when compared with the harmonic distortion present in conventional Voltage Source Inverter.

The variation in the speed of the induction motor has been observed with conventional two level inverter, multilevel inverter and without inverter. It is observed in both simulation and hardware experiment that the speed control of induction motor is challenging problem in the absence of power electronics component i.e. inverter. But when induction motor is faded with the inverter, the induction motor speed control is achieved. In the proposed method the simulated NPC and modelled induction motor with estimated parameters for sensor less drive with MRAS method is used for speed estimation and control of three phase induction motor. As no sensors are used, it makes the system more rugged, reduced size, stable and less cost. The modelling of the induction motor is derived. Here MRAS method is used for estimating the speed and torque using Field oriented control Procedure with speed controller is used for regulating the speed of an induction motor as it is less complex and more efficient. MRAS contains two model which are Reference and Adaptive model. Output of adjustable model is equated with that of reference voltage model and this contrast is used to estimate the speed of the three-phase induction motor.

3.1 Modified Model Reference Adaptive System

For the adaptive control of the Induction Motor, MRAS technique is used. MRAS scheme is less complex and more efficient. This scheme has two prototype one is voltage reference Model and another one is adjustable model. Here voltage reference model does not require quantity to be determined (rotor speed,) but the adaptive model does. In the MRAS scheme, the output from adjustable model is equated with that of voltage reference model and the contrast is used to drive acceptable adjustable mechanism, whose output quantity is needed to be estimated [21-22]. Output of these two-model is compared till we get no error between two models. With the proper estimate of rotor speed, the fluxes resolved by two models should be equivalent. An adjustable mechanism with PI controller can be used to control the speed until the two-flux value matches. [23-24]. In this proposed method the adaptive model is changed from the conventional model by replacing the adaptive controller based on neural network as mentioned in equation (13) to (17)

The equation of reference models are given by

$$\hat{\psi}^s_{dr} = \int \frac{-1}{T_r}\psi^s_{dr} - \omega_r\psi^s_{qr} + \frac{L_m}{T_r} i^s_{ds} \quad (7)$$

$$\hat{\psi}^s_{qr} = \int \omega_r\psi^s_{dr} - \frac{1}{T_r}\psi^s_{qr} + \frac{L_m}{T_r} i^s_{qs} \quad (8)$$

Adaptive model is given by the equations

$$\hat{\psi}^s_{dr} = \int \frac{-1}{T_r}\psi^s_{dr} - \hat{\omega}_r\psi^s_{qr} + \frac{L_m}{T_r} i^s_{ds} \quad (9)$$

$$\hat{\psi}^s_{qr} = \int \hat{\omega}_r\psi^s_{dr} - \frac{1}{T_r}\psi^s_{qr} + \frac{L_m}{T_r} i^s_{qs} \quad (10)$$

The error signal is given by

$$\xi = \hat{\psi}^s_{dr}\psi^s_{qr} - \psi^s_{dr}\hat{\psi}^s_{qr} \quad (11)$$

$$\omega_r = \xi\left(K_P + \frac{K_I}{s}\right) \quad (12)$$

The neural network based Adaptive model equations are given by the following equations

$$O_k = \sum_{j=1}^{J} \omega_{kj}\O_j(x) \quad (13)$$
$$\omega_{kj}(t+1) = \omega_{kj}(t) + \eta\, e\,(t)\O_j \quad (14)$$
$$c_j(t+1) = c_j(t) + \eta e\,(t)\O_j\omega_j(x-c_j)/\sigma^2 \quad (15)$$
$$\O_j(x) = exp\left[\frac{-\|x-c_j\|^2}{\sigma_j^2}\right] \quad (16)$$
$$\sigma_j(t+1) = \sigma_j(t) + \eta e(t)\O_j\omega_j\|x-c_j\|/\sigma^3 \quad (17)$$

The neural network based adaptive learning algorithm are implemented in the model reference adaptive System to improve the accuracy of the system that mean the response of the system.

3.2 Results and Discussions

The field Oriented Control is used in high-performance motor approach that are demanded to operate evenly. An induction motor can be modelled more positively using two currents that is i_d and i_q rather than the three phase currents implemented to the motor. These two currents are named as direct axis (i_d) and quadrature axis (i_q) currents which are answerable for providing flux and torque in the motor which are independent to each other i.e. if one changes it does not affect other. By denotation,

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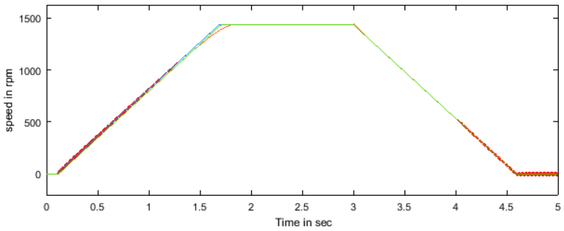
the i_q current is in phase with the stator flux, and i_d is perpendicular to i_q.

In the proposed methodthe rated speed of 1470 rpm is applied to induction motor asa reference speed in green colour from 1.5 seconds to 3 seconds during that period the estimated speed in red colour and actual speed in blue colour also exactly matched with the reference speed. The speed error is zero in the proposed method. From 0 seconds to 1.5 seconds 250 Nm reference torque in blue colour has been applied is exactly matched with the estimated torque in red colourare illustrated in fige 8. From 1.5 to 2 seconds the reference torque has been increased to 1200 Nm during that period there's slight deviation between reference and estimated torque but this error is less compared with the conventionalmethod. Fig 9 shows the speed and torque response of induction motor under 50 percent change in stator and rotor resistances from the rated values. During the parameter variation the estimated speed slightly deviated from the reference speed from 1.5 to 1.8 seconds after that it reaches the steady state. Under low speed region also speed performance is not affected .



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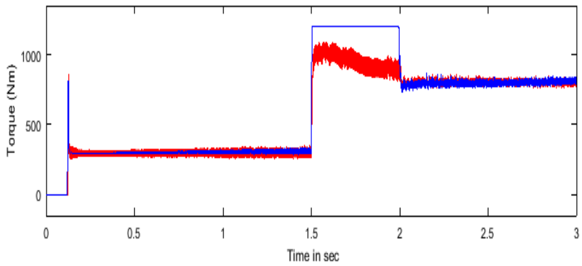
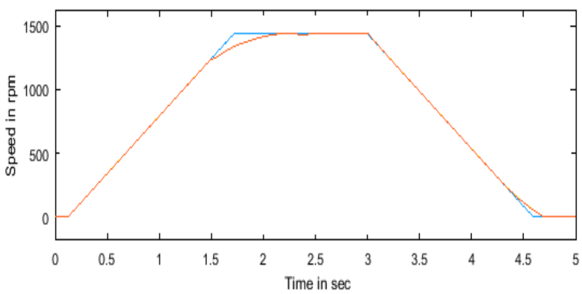


(b)

Fig 8. Performance of induction motor drive for proposed method under high speed region a) Speed b) Torque



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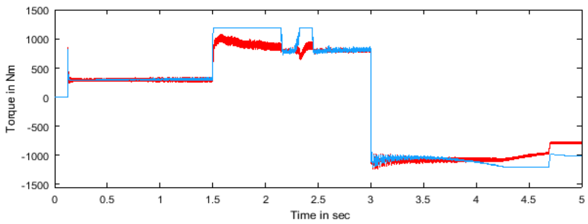
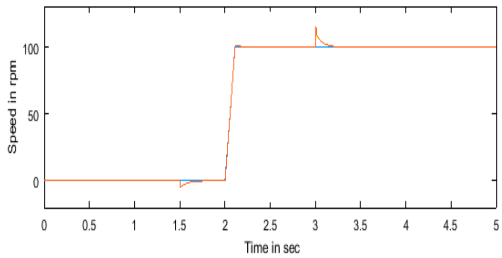


(b)

Fig 9. Performance of induction motor drive for proposed method under parameter variations a) Speed b) Torque



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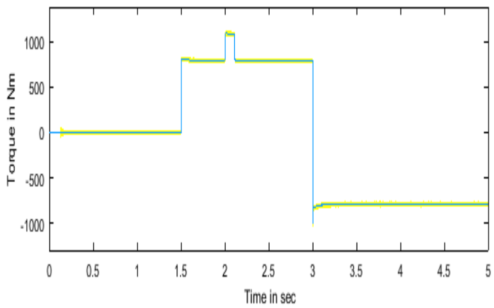
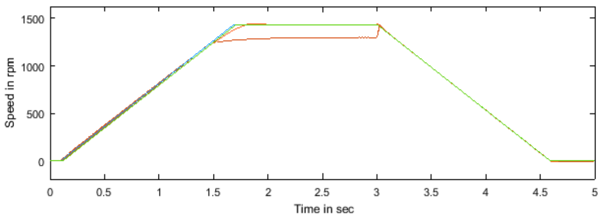


(b)

Fig 10. Performance of induction motor drive for proposed method under low speed region a) Speed b) Torque



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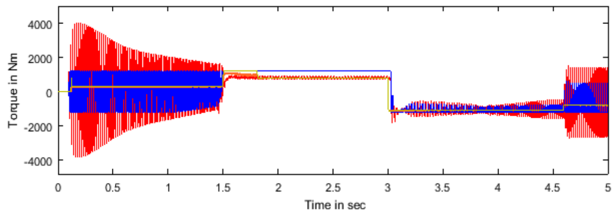

(b)

Fig 11. Performance of induction motor drive for conventional MRAS under High speed region a) Speed b) Torque

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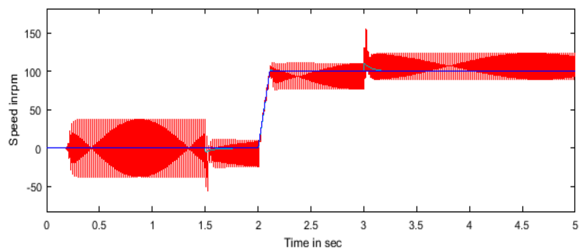
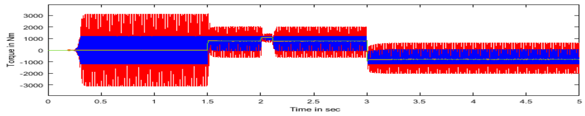


(a)



(b)

Figure 12. Performance of induction motor drive for conventional MRAS under low speed region a) Speed b) Torque

In the conventional methodthe rated speed of 1470 rpm is applied to induction motor as a reference speed in green colour from 1.5 seconds to 3 seconds during that period the estimated speed is 1200 rpm only that is represented in red colour .The speed error is high in the conventional method compared to proposed method. From 0 seconds to 1.5 seconds 250 Nm reference torque in blue colour has been applied is not matched with the estimated torque in red colour. The torque ripple is very high. From 1.5 to 2 seconds the reference torque has been increased to 1320 Nm during that period there's very large deviation between reference and estimated torque compared to proposed method are illustrated in figure 11. Under low speed region, speed error is high in the conventional method are illustrated in figure 12.

3.*3 Inference of Result*

Performance of modified MRAS based multilevel inverter ed induction motor under high speed, low speed and parameter variations is as shown in Figure8, 9 &10

4. Hardware Results and Discussions

4.1 Parameter Estimation

Each stator winding's test is performed separately. In case of capacitor start motor, the condenser is neglected. To carry out the blocked rotor test, stator and main windings are done separately. For each case, input voltage, current and power is measured. To prevent short circuit current and heating, proper measurement is utilized. A rated voltage is chosen to perform the no load test. The main winding is excited and the corresponding measurements of input voltage, current and power are taken. The voltage in the motor is decreased up to the extent, where the motor will just run. This is how the windage and friction loss test is carried out. The power input, which gives the friction and windage losses is measured .The hardware setup for parameter estimation of no load and blocked rotor test are depicted in Fig 13.

respectively. The rotor speed and electromagnetic torque are demonstrated. The amplitude of direct current bus voltage is 600 V. In the electromagnetic torque curve, the reference torque indicated in blue colour is matched to the estimated torque displayed in red colour. In the rotor speed curve, the speed deviation is less, the reference speed represented in green colour and estimated speed in red colour .The speed response displayed in blue colour with the inclusion of controller using modified MRAS is exactly similar to the reference speed represented in green colour compared to conventional method represented in figure 11 &12. The motor 2 output also similar to motor 1.

Simulation output of conventional method is shown Figure 11 and 12. Respectively. The electromagnetic torque and rotor speed are demonstrated. The amplitude of direct current bus voltage is 600 volt. In the electromagnetic torque curve, the reference torque represented in yellow colour is not identical to estimated torque indicated in blue colour. In the rotor speed curve, estimated speed in red colour is deviated in certain period from 1.5 to 3 seconds from reference speed displayed in yellow colour and actual speed in red colour. The estimated, reference and controller speed and torque makes the system more efficient with lesser speed deviation and reduced torque ripple when compared with conventional method even under low speed region. The output of both the motors has less speed deviation compared to conventional method. Conventional quasi z-source inverter is complicated one for these type of applications [25-26].Speed deviation between two motor under parameter variation conditions also less, so stability of the system has been achieved. So the system is robust for parameter variations also as shown in figure 10.The improved performance of proposed method are applicable for locomotive traction applications.

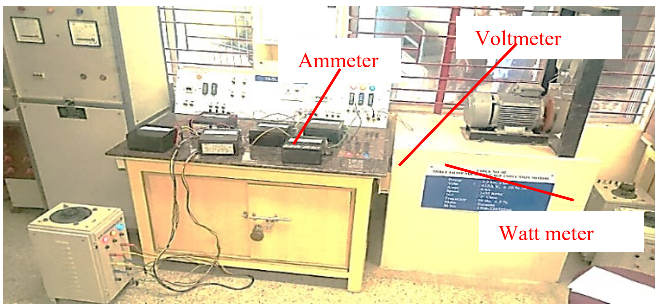


Fig 13. The r parameter estimation

Table 3. Parameter measurement of no load test for motor 1

Voltage (V)	Current (A)	W1 (watts)	W2 (watts)
240	1.5(R) 1.6(Y) 1.5(B)	128	32
320	2.1(R) 2.3(Y) 2.3(B)	140	52
410	3.8(R)	352	144

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3.8(Y)
4.0(B)

Table 4. Parameter measurement of blocked rotor test for motor 1

Voltage(V)	Current(A)	Power(W)
73	6(R)	124
	6(Y)	
	6(B)	
150	7.5(R)	170
	7.5(Y)	
	7.5(B)	

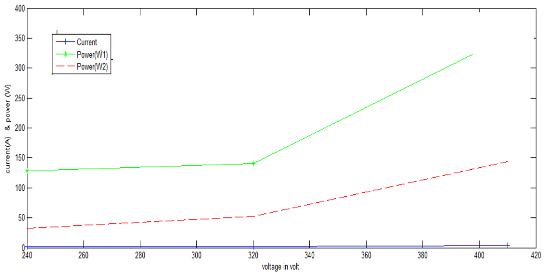

Fig 14. Parameter measurement of no load test for motor 1

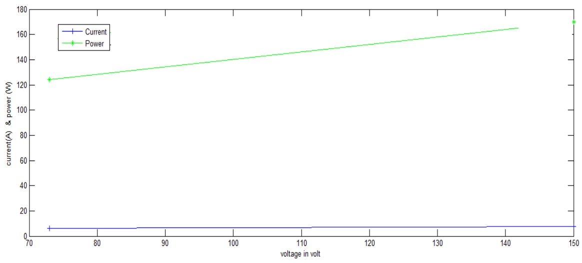

Fig 15. Parameter measurement of blocked rotor test for motor 1

The values obtained from blocked rotor test above mentioned are demonstrated in Table 4. $X_1=0.4X_{br}$ for class F motors. X1,X2, Xm for machine 1 are determined at two different values of current which are at rated current values of 8amps are demonstrated in Fig 15.

Table 5. Parameter measurement of no load test for motor 2

Voltage (V)	Current (A)	W1 (watts)	W2 (watts)
240	1.0(R)	28.8	16
	0.9(Y)		
	0.9(B)		
320	1.5(R)	41.6	54.4
	1.5(Y)		
	1.4B)		
410	2.1(R)	112	100.8
	2.3(Y)		
	2.5(B)		

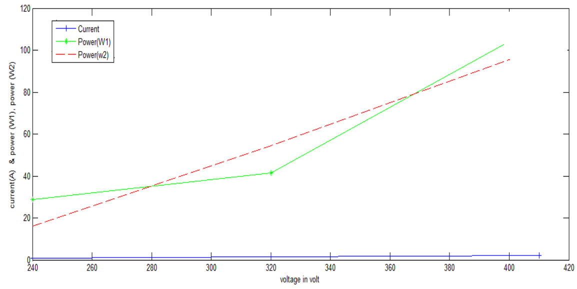

Fig 16. Parameter measurement of no load test for motor 2

No load test is done on motor2 similar to motor 1and the motor readings are listed in Table 5. The performance parameter for motor 2 at no load test are illustrated in Fig 16.

Table 6. Parameter measurement of blocked rotor test for motor 2

Voltage(V)	Current(A)	Power(W)
48	2(R)	68
	2(Y)	
	2(B)	
78	4(R)	124
	4(Y)	
	4(B)	

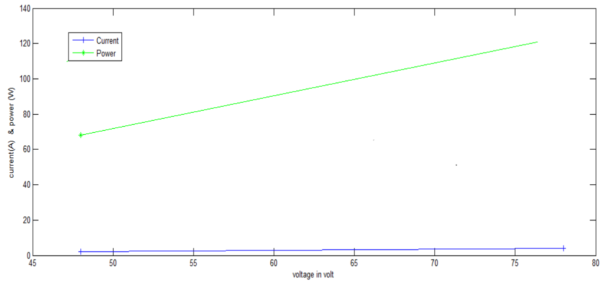

Fig 17. Parameter measurement of blocked rotor test for motor 2

As done before for motor1 the parameter performance of blocked rotor test for motor 2 at the Rated current of 8 amps are carried out and depicted in Table 6 and Fig 17.

4.2 Hardware Setup for Performance Investigations of Inverter Fed Induction Motor for Sensorless Drive

The variation in the speed and torque of the induction motor has been observed with and without inverter. Simulation results are analyzed in chapter 5.The performance obtained in simulation is verified experimentally with hardware setup. The hardware setup for two induction motor connected in parallel without inverter shown in Fig 18.

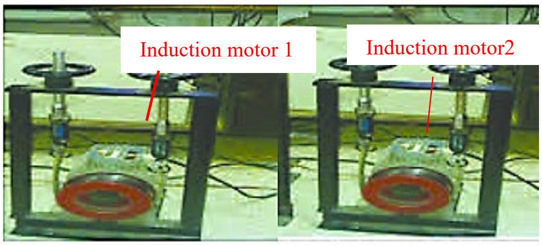

Fig 18. Two induction motor connected in parallel

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Table 7. Two motor in parallel with estimated parameter at no load condition

Voltage(V)	Current(A)	Speed(RPM)
30	1.9(R)	1200
	1.9(Y)	
	1.9(B)	
75	2.2(R)	1482
	2.2(Y)	
	2.2(B)	
100	2.1(R)	1490
	2.1(Y)	
	2.1(B)	
125	2.1(R)	1490
	2.1(Y)	
	2.1(B)	
200	2.0(R)	1492
	2.0(Y)	
	2.0(B)	
350	2.1(R)	1496
	2.1(Y)	
	2.1(B)	
400	3.2(R)	1496
	3.2(Y)	
	3.2(B)	

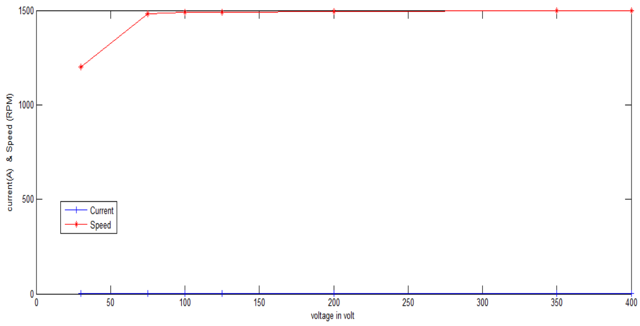

Fig 19. Two motor in parallel with estimated parameter at no load condition

The no load test is performed on two motors connected in parallel without inverter. It is observed that even for large variation in voltages there is very less deviation in speed and this is shown in Table 7. Thus variable speed control becomes very difficult for this condition and this is justified in Fig 19.

Table 8. Two motor in parallel with estimated parameter at balanced load condition

Voltage(V)	Current(A)	Load(Kg)	Speed(RPM)
400	2.0(R)	2.5	1496
	2.0(Y)		
	2.0(B)		
400	2.5(R)	5	1490
	2.5(Y)		
	2.4B)		
400	3.2(R)	10	1480
	3.1(Y)		
	3.1(B)		

In the performance of two induction motor connected in parallel with balanced load conditions, the speed of two different motors is almost same that are demonstrated in Table 8.

Table 9. Two motor in parallel with estimated parameter at unbalanced load condition

Voltage(V)	Current(A)	Load(Kg)	Speed(RPM)
400	2.1(R)	Motor 1	Motor1
	2.1(Y)	2.5	1475
		Motor 2	Motor 2
	2.1(B)	No load	1490
400	2.5(R)	Motor 1	Motor 1
	2.5(Y)	3	1486
	2.4B)	Motor 2	1494
		1	

When the two motors are given different loads, then the speed varies for the two motors. Thus by changing load, the Speed deviation becomes high that is depicted in Table 9. In order to rectify the above mentioned problem, the hardware setup for proposed method is shown in Fig 20. Thus the speed deviation between two motors is less compared conventional method.

Table 10. Multilevel neutral point clamped inverter with two motor in parallel at no load condition (open loop)

Voltage(V)	Current (A)	Set speed (RPM)	Actual Speed (motor1) (RPM)	Actual Speed (motor 2) (RPM)
150	0.8	405	395	398
	0.8	520	512	516
	0.8	625	615	615
200	1.2	405	402	402
	1.2	520	514	515
	1.3	625	617	617

Table 11. Multilevel neutral point clamped inverter with two motor in parallel at no load condition (closed loop)

Voltage (V)	Current (A)	Set speed (RPM)	Actual Speed (motor 1) (RPM)	Actual Speed (motor 2) (RPM)
150	0.8	405	404	404
	0.8	520	520	520
	0.8	625	624	625
200	1.2	405	402	402
	1.2	520	518	518

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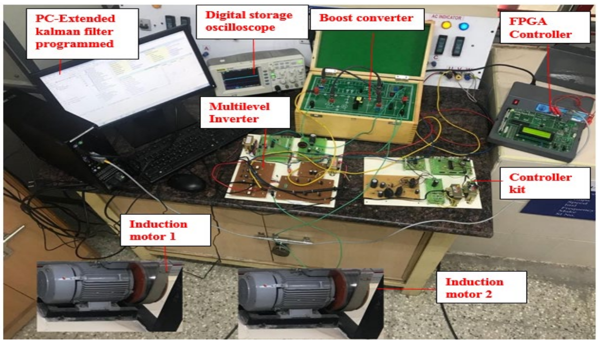

Fig 20. Hardware setup for proposed method

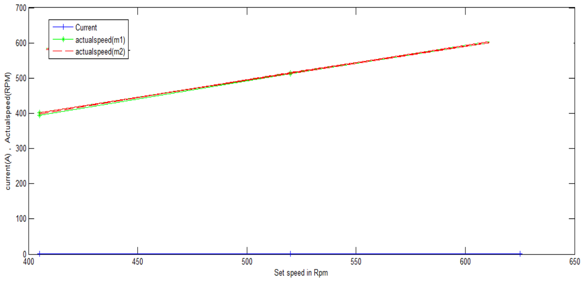

Fig 21. Multilevel inverter with two motor in parallel at no load condition (open loop)

The no load test is performed on two motors connected in parallel with proposed method. Different speed levels are achieved for a particular voltage. Moreover the Speed deviation between two motor is less in open loop condition this is depicted in Table 10 and Fig 21.

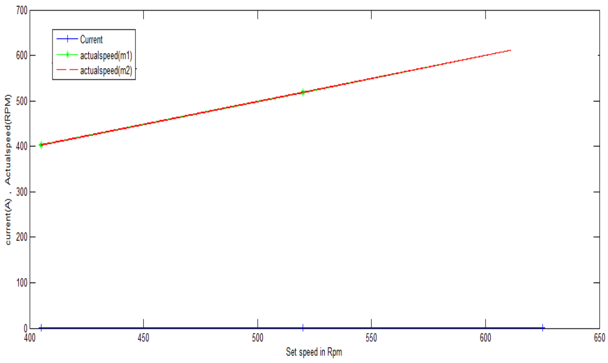

Fig 22. Multilevel inverter with two motor in parallel at no load condition (closed loop)

The same setup is repeated for closed loop. The difference between set speed and actual speed becomes nearly zero and the speed deviation between the two motor is less Compared to open loop that are demonstrated in Table 11and Fig 22.

Table 12.Multilevel neutral point clamped inverter with two motor in parallel at load condition (open loop)

Voltage (V)	Current (A)	Set speed (RPM)	Actual Speed (motor 1) (RPM)	Actual Speed (motor 2) (RPM)
150	0.8	405	385	382
	0.8	520	504	508
	0.8	625	608	610
200	1.2	405	392	398
	1.2	520	506	510
	1.3	625	606	612

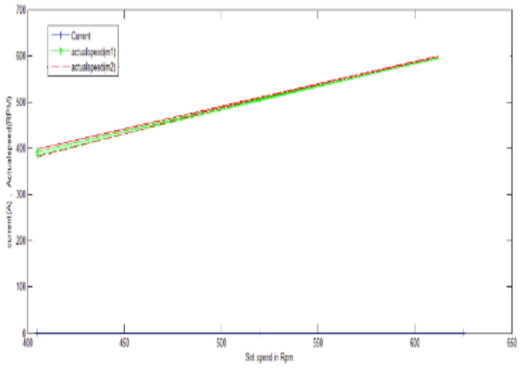

Fig 23. Multilevel inverter with two motor in parallel at load condition (open loop)

Table 13. Multilevel neutral point clamped inverter with two motor in parallel at load condition (closed loop)

Voltage (V)	Current (A)	Set speed (RPM)	Actual Speed (motor 1) (RPM)	Actual Speed (motor 2) (RPM)
150	0.8	405	405	405
	0.8	520	518	519
	0.8	625	625	625
200	1.2	405	403	405
	1.2	520	517	519
	1.3	625	625	625

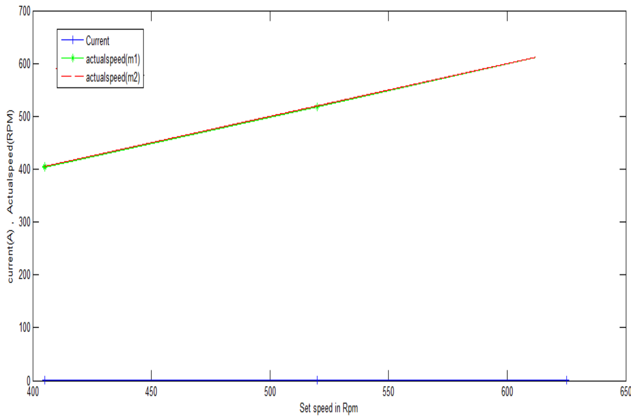

Fig 24. Multilevel neutral point clamped inverter with two motor in parallel at load condition (closed loop)

By conducting load test on the same setup, the different speed at one particular voltage is achieved. But the speed deviation between two motors is high in open loop condition compared to no load test. Table 12 and Fig 23 shows the error is high. To avoid the speed deviation between two motor at load condition closed loop test is performed. Under closed loop analysis the speed deviation between two motor very less and the stability of the system also achieved this is shown in Table 13 and Figure 24.When the same experiment is performed using conventional MRAS the readings obtained are shown in the Table 14 and Fig 26. The difference between the speeds of

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two motors is large .The hardware setup for Conventional method is demonstrated in Fig 25.

Figure 25. Hardware setup for conventional method

Table 14. Performance of voltage source inverter

Voltage (V)	Current (A)	Speed (motor 1) (RPM)	Speed (motor 2) (RPM)
150	0.6	555	539
	0.6		
	0.6		
100	0.5	495	475
	0.5		
	0.5		
225	1.5	563	559
	1.4		
	1.5		

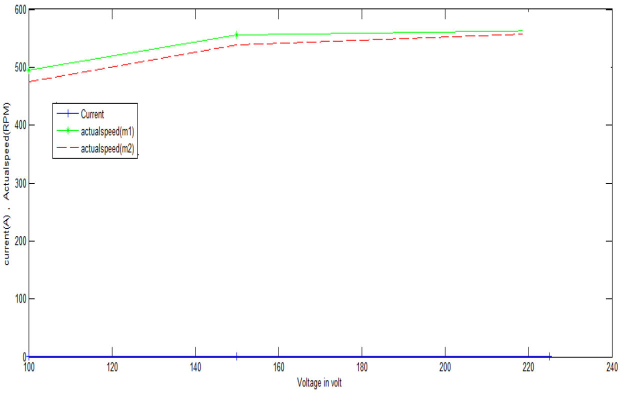

Fig 26. Performance of conventional method

5. Conclusion

The proposed model has been implemented using MATLAB Simulink software and hardware setup. The obtained resultant waveforms were compared with conventional methods. The multilevel inverters attain high-voltage switching by method of a series of voltage steps. In this paper, a multilevel inverter system fed modified model reference adaptive system based induction motor in parallel has been proposed which has better features over existing system. This increases the performance of the system with estimated parameters. Fast response of vector control method makes the system better than the existing method of speed control of induction motor. It makes the system response fast, accurate and provides the better result for different speed of induction motor. Here the speed control of induction motor is done using speed controller in the approach of field orientations. Hence by using the modified MRAS technique with speed controller the performance of estimated speed matches the reference speed. The speed deviation between two parallel motor is very less under parameter variations also compared to conventional method. The simulation and hardware results show good performance of the designed controller compared to conventional method. The improved performance of proposed method applicable for traction applications.

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