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Estimating Parameters of a Three-Phase induction motor using Matlab/Simulink

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Abstract-Steady-state analysis of a three phase induction motor can be carried out by using computer simulation software such as MATLAB. From Simulink/Power system block set (PSB) library, the induction motor model can be effectively used to simulate the effects of DC resistance, no-load and blocked rotor tests. These tests are performed on a machine to estimate the values of stator and rotor resistances and leakage reactance's. Since the skin effect and temperature are not taken into consideration with DC resistance modeling but still the results derived are approximate and reasonably good.

Index term-Induction motor, DC resistance test, no-load test, blocked rotor test, modeling of induction motor.

1. INTRODUCTION

Since its invention by Nicola Tesla in 1800s, induction motor has remained as the most popular electrical machine due to its simple and rugged construction. Though they are considered as a low-maintenance machine, sudden failures can be catastrophic. Scientific tests performed in field, to study machine behavior and estimate faults, have proven costly, owing to time required, and involvement of heavy and costly test set-ups and measuring instruments. Also they impose a limitation on the time duration [9] , the test can be performed in field. Simulation tools such as MATLAB can be a cost-effective approach, to estimate machine parameters.

This paper models a three phase induction motor to derive its parameters based on the magnetically-coupled model of the machine. Tests such as DC resistance, no-load, blocked-rotor tests can be effectively modeled using MATLAB to derive resistance and inductance of the machine for motor diagnosis and analysis.

Similar to other electrical machines, an electrical equivalent model can be represented for an induction motor Fig (1). In fact, an induction motor can be treated as a rotating transformer in which primary winding is stationary and the secondary winding is free to rotate. This represents the per phase equivalent circuit of an induction motor as recommended by IEEE

R_1- Stator resistance
X_1- Stator leakage reactance
X_o- Magnetizing reactance
R_o- Machine core loss resistance
X_2- Rotor leakage reactance
R_2- Rotor resistance
s- Slip

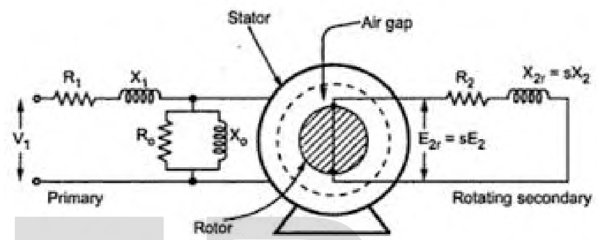

Fig 1 Electrical equivalent circuit of induction motor

Core loss resistance is included to account for hysteresis and eddy currents as a function of frequency.

2. DC RESISTANCE TEST

The simplest element to be determined is the stator resistance. It can be measured using an ohmmeter after examining the motor terminal block connections Fig (2).[10]

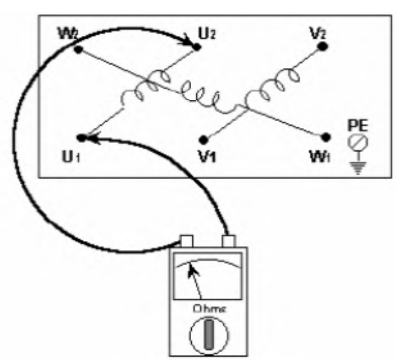

Fig 2 Resistance test on motor terminal block

This test is carried out on an isolated motor, to check the resistance of stator windings. To make an accurate measurement, either a low reading Ohmmeter or a

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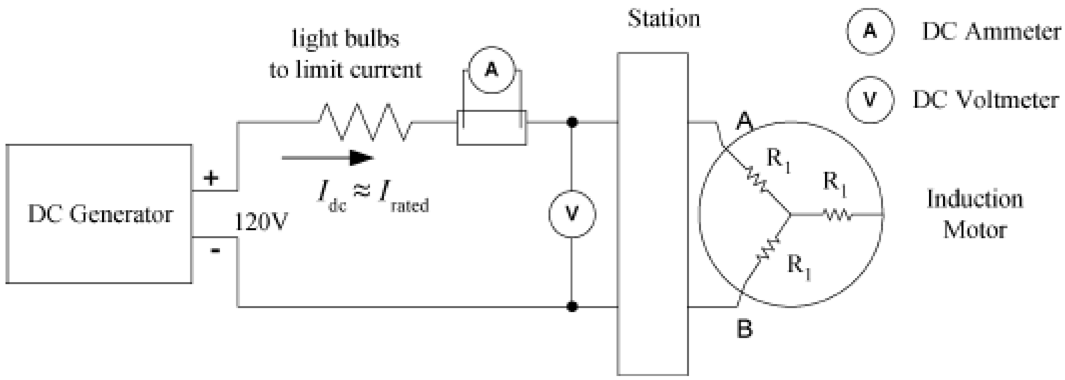

Fig 3 Set-up for measurement of stator resistance

high resolution DMM is used.
Step 1: Isolate the motor electrically and if necessary mechanically.
Step 2: Identify the way the motor block is connected.

- Star connected: Two links connect U2-V2-W2. Remove the links and supply cables before carrying out the test.
- Delta connected: Three links connect U1 toW2, V1 to U2, W1 to V2. Remove the links and supply cables before carrying out the test.

However for larger machines it is measured using dc source, so that it can be determined at rated value of current. Under dc condition the leakage reactance offered by stator winding is zero; hence stator equivalent circuit for dc condition can be represented as shown in Fig (4)

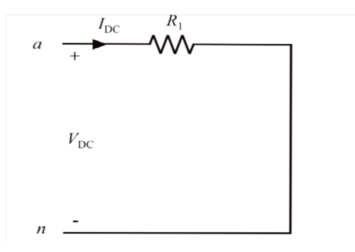

Fig 4 Stator equivalent circuit for DC test

Fig (3) shows an experimental set up of the dc test conducted at the interconnected power system laboratory (IPSL) of Drexel University. A 120-V dc power source is connected across the two phases of a Y-connected induction motor. A group of light bulbs are installed as resistive loads in order to adjust dc current to the rated value. The values of Idc and Vdc are recorded and R1 is computed as[1];

$$R1 = 0.5\ Vdc/\ Idc \quad (1)$$

Simulink/PSB model for implementing DC resistance test is shown in Fig (6). The stator resistance calculated from DC test is an approximated value since skin effects and temperature are not considered, that are produced due to an ac supply. However this approximation is quiet reasonable.

3. NO LOAD TEST

When an induction motor runs at no load, the slip is exceedingly small. This means that R2/s is very high and so current in rotor winding is negligible compared to the magnetizing current. At no load, the equivalent circuit of an induction motor consists of magnetizing branch X_m. This value can be determined by measuring voltage, current and power at no load. No load test is carried out by running the motor at rated line-to-line voltage and measuring the values of no load current and total 3Φ active power. Since at no load the magnetizing component is shunted by a very high resistive branch representing the rotor circuit, the reactance of this parallel combination is almost same as X_m. Therefore total reactance X_{NL} measured at no load at the stator terminals is essentially X_1+X_m. The equivalent circuit at no load is shown in fig (5).

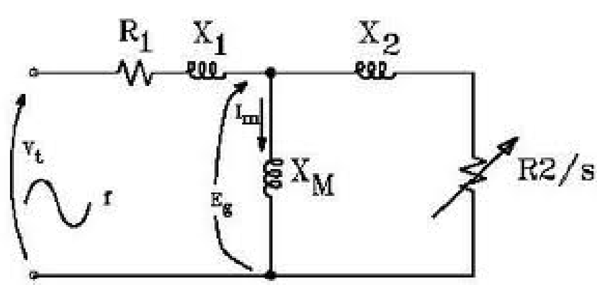

Fig 5 Equivalent circuit for no-load

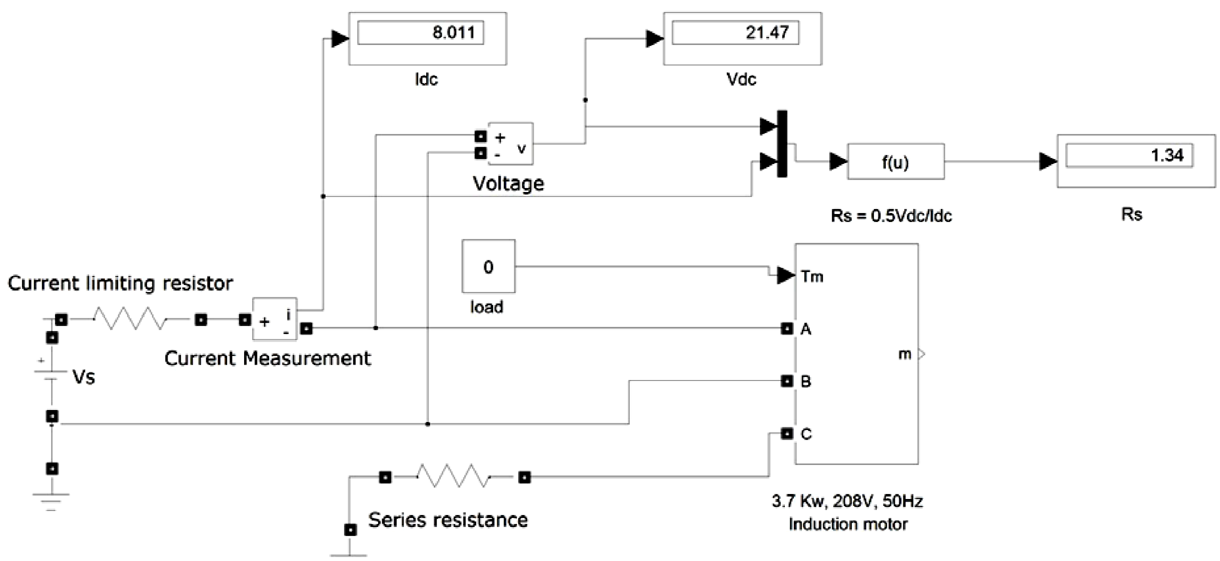

Fig 6 Simulink model for DC resistance test

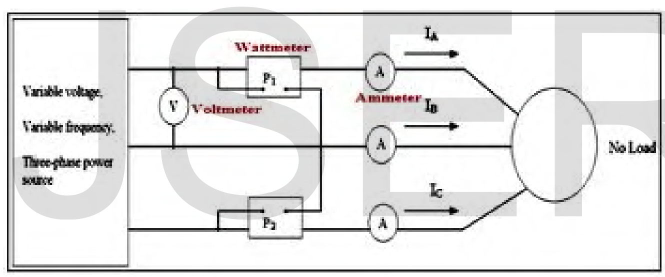

Fig 7 Set-up for no load test

The phase voltage can be calculated as;

$$V_1 = VLL/\sqrt{3} \quad (2)$$

No load impedance per phase will be

$$Z_{NL} = V_1/I_1 \quad (3)$$

No load resistance is;

$$R_{NL} = P_{NL}/3I_1^2 \quad (4)$$

No load reactance is;

$$X_{NL} = \sqrt{ZNL^2 - RNL^2} \quad (5)$$

Where $X_{NL} = X_1 + X_m$ (6)

Thus from no load test we get values of X_1+X_m.
Experimental set-up for no load test is shown in Fig (7). There are some differences between hardware set-up and Simulink model represented in Fig (8). In experimental set-up the total 3Φ real input power is measured, while per-phase-based real and reactive power is measured in simulation model. However this difference is not significant since under the three-phase balanced operation, computations are usually performed using phase quantities. Hence phase quantities are measured in simulation model, as opposed to line-to-line voltage measured in hardware set-up.
In simulation [4], voltage per phase is calculated and

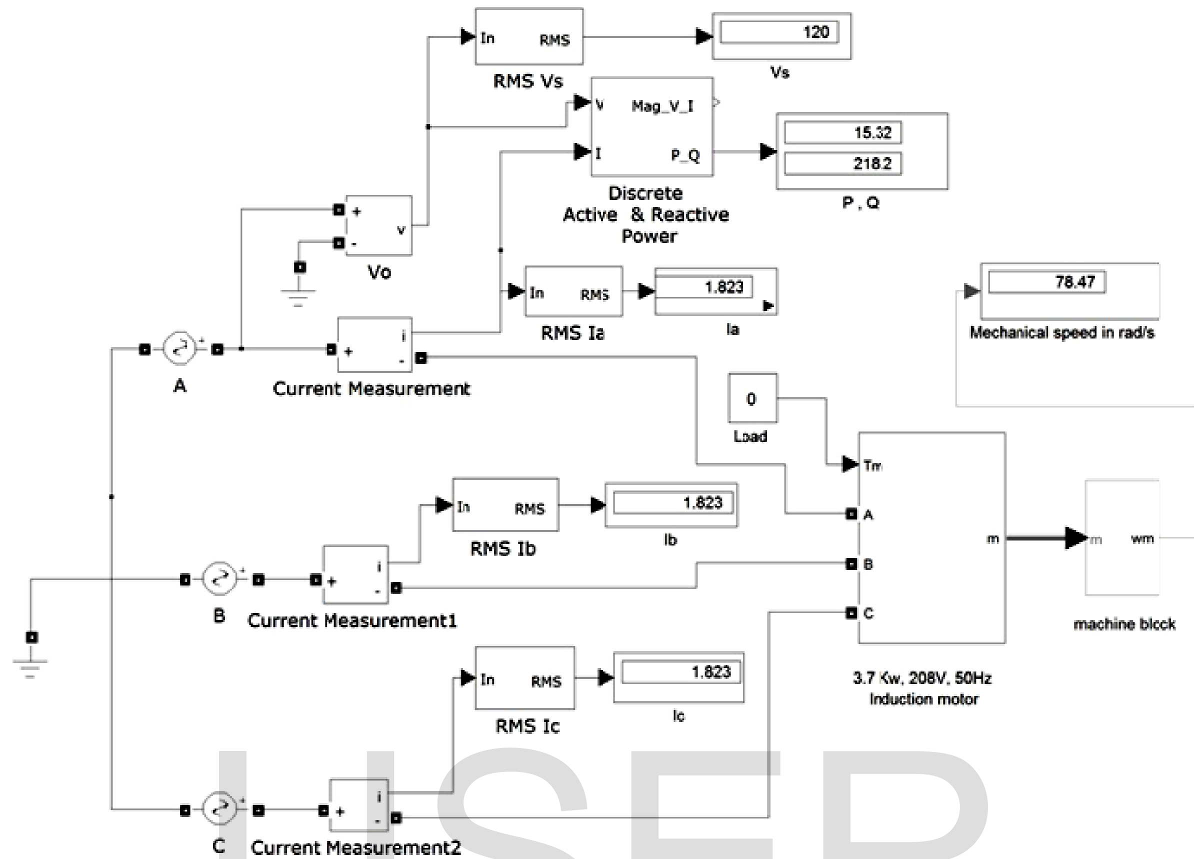

Fig 8 Simulink model for no load test

applied to the model. To simulate the model for no load test, mechanical torque (Tm) is set to zero. The equivalent circuit parameters obtained from experimental data are specified in the machine dialogue box. Current measurement blocks are connected to each phase, which measure the instantaneous values of alternating quantity. These values are not suitable for display; hence it is necessary to obtain rms values of these quantities. This is done by connecting a signal rms block before each display box. The outputs of current and voltage measurement blocks are connected to a power measurement block, which calculates the active and reactive power. A large number of machine parameters can be measured using the machine measurement block. Here it is modeled to display the mechanical speed of the machine in rad/s. It is found that the mechanical display box gives a steady-state value quickly, which means that MATLAB can be used to model steady-state behavior of induction motor as well.

4. BLOCKED ROTOR TEST

In the blocked rotor test, the rotor is blocked from rotating; therefore mechanical speed of the rotor is zero. The value of slip for blocked rotor test is unity since rotor is stationary; therefore R_2/s becomes very small. Thus, the rotor current is much larger than current in the excitation branch of the circuit such that excitation branch can be neglected. The resulting equivalent circuit for blocked rotor test is shown in Fig (9).

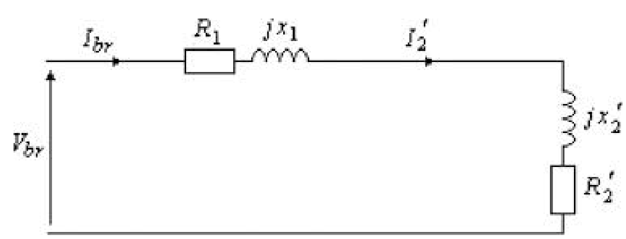

Fig 9 Equivalent circuit for blocked rotor test

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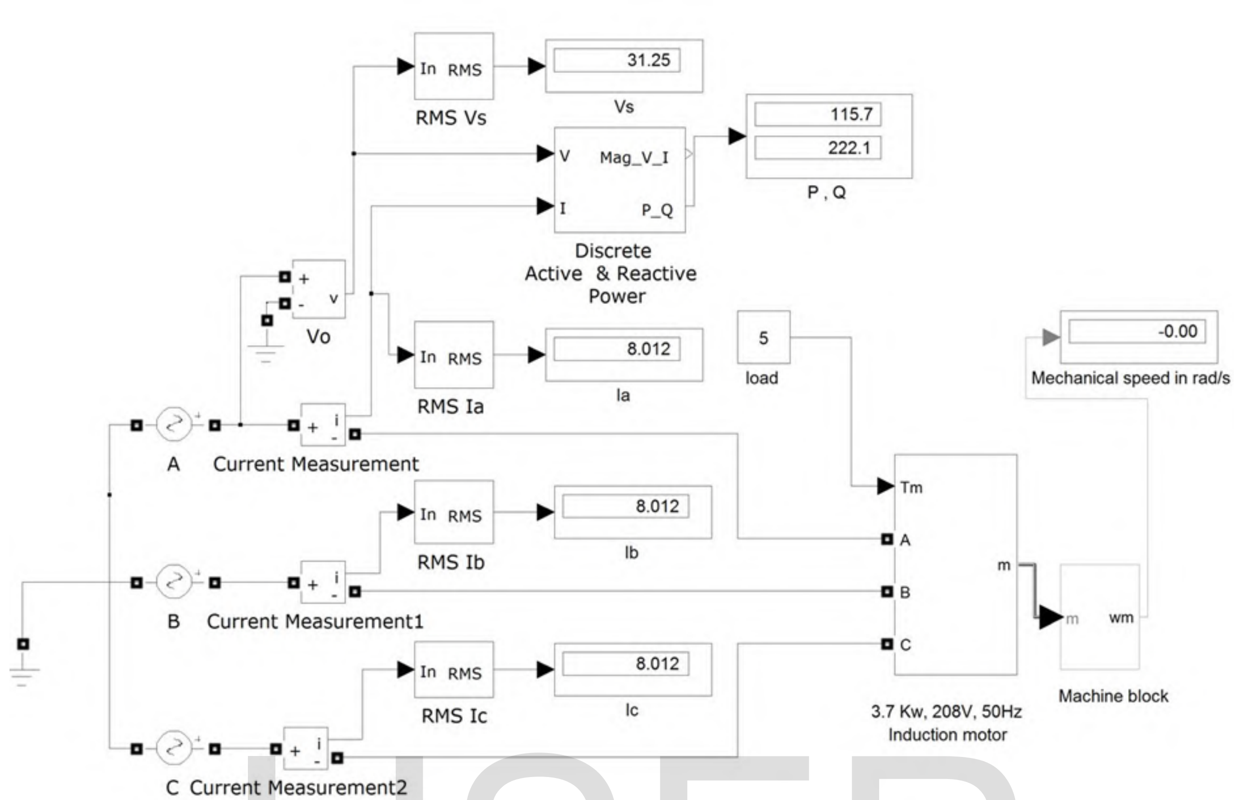

Fig 10 Simulink model for blocked rotor test

The reflected rotor winding resistance is determined from the dissipated power as;

$$P_{BR} = 3I_{BR}^2 (R_1+R_2) \qquad (7)$$

Ratio of blocked rotor voltage and current equals the blocked rotor impedance;

$$V_{BR}/I_{BR} = Z_{BR} = \left(\sqrt{(R1+R2)^2+(X1+X2)^2}\right) \qquad (8)$$

Therefore X_1+X_2 can be computed.
The actual distribution of total leakage reactance between the stator and rotor is typically unknown but empirical equations for different classes of motor as specified by NEMA can be used to determine values of X_1 and X_2 independently.

Squirrel cage	NEMA Std
Class A	$X_1= 0.5\ X_{BR}$
Class B	$X_1=0.4\ X_{BR}$
Class C	$X_1=0.3\ X_{BR}$
Class D	$X_1=0.5\ X_{BR}$

Using these empirical formulas X_1 and X_2 can be determined from the blocked rotor test. Given the values of X_1, magnetizing reactance X_m can be

calculated as ;

$$X_m = X_{NL}-X_1 \qquad (10)$$

$$= \left(\sqrt{ZNL^2 - RNL^2}\right) - X_1 \qquad (11)$$

The simulink model for blocked rotor test is same as that for the no load test, but however the input voltage is not equal to phase voltage. The value of input voltage is adjusted such that the current display records the rated phase current. To make the mechanical speed of rotor to 0 rad/s, inertia of the machine is set to infinity in the machine dialogue box [4]. In blocked rotor test, the mechanical torque is no longer 0; its value used for the model is set to 5 N-m. For electrical parameters of the machine, entered in the machine dialogue box, the values of active and reactive powers are computed.

5. CONCLUSION

Similar to other electrical machines, an induction motor can also be represented using an electrical

TABLE I

	Iph(A)	Vph(V)	P (W)	Q (VA)	cosΦ	X1(Ω)	X2 (Ω)	Xm (Ω)	R1(Ω)	R2(Ω)
No-load	1.823	120	15.32	218.2	0.0702	____	____	_____	_____	_____
Blocked rotor test	8.012	31.25	115.7	222.1	0.5209	1.729	1.729	63.93	1.34	0.462

equivalent circuit consisting of resistances and leakage reactances. These elements can be calculated by carrying out different tests on an induction motor namely, DC resistance test, no-load and blocked rotor test. In hardware experiments, the input voltage applied to the machine is specified in terms of line-to-line voltage and the value of total (i.e. 3Φ) real power is calculated to compute values of R_1, R_2, X_1, X_2 and X_m. In simulating models, we consider the voltages in terms of phase quantities and the values of per-phase real and reactive powers are calculated. In simulating the behavior of an induction motor, it is necessary to have knowledge of the methods which can be applied for computing a particular electrical parameter of the machine, since; different tests give different electrical parameters. In no-load and blocked rotor tests the measurement devices (i.e. current measurement and voltage measurement blocks) measure the instantaneous values of alternating quantity. If these signals are directly applied to the display box, it will indicate the instantaneous values of the alternating quantities measured over a window of 50 Hz, which would be incorrect. It is therefore necessary to obtain RMS values of these signals before feeding it to the display box. Before carrying out the simulation, number of machine poles, and electrical equivalent circuit parameters derived from hardware experiments, are specified in the electrical machine dialogue box. For no-load test, the mechanical torque input is set to zero, and the mechanical speed of the rotor in rad/s is derived. For blocked rotor test, the input phase voltage is varied to obtain the rated phase current, mechanical torque input is raised above zero, but the machine inertia is set to infinity to model the effect of a stationary rotor. In both the tests it is observed that the mechanical speed of the rotor achieves a steady-state value in a very shorter duration of tine, which supports our conclusion, that MATLAB is an appropriate tool to describe the steady-state behavior of induction machines as well.

References

[1]”Computer-aided teaching using MATLAB /Simulink for enhancing an IM course with laboratory tests”. Amar Bentounsi, Hind.D, Hocine.B, Taher.B and Hamza A, IEEE transactions on education. Vol 54, no 3, Aug 2011.

[2]” Computer modeling for enhancing instructions of electric machinery”. M.H.Nehrir,F.Fatehi and V.Gerez, IEEE transactions education vol.38, no 2, pp 166-170, may 1995.

[3] “Three phase induction motor simulation model based on a multifrequency per-phase equivalent circuits, considering stator winding MMF, Spatial harmonics and thermal parameters”. F.Ferreira, A.Almeida and G.Baoming, in proc, ICEM, Chania, Greece, Sep-2-5, 2006, pp no, 549.

[4] “Induction motor tests using MATLAB/Simulink and their integration into undergraduate electric machinery courses”. Saffet ayasun, Chika. O. Nwankpa, IEEE transactions on education, vol 48, no.1, feb 2005.

[6]”Reinvenying the electrical machines curriculum” M.W.Daniels and R.A.Shaffer. IEEE transaction education, vol 41, pp 92-100, may 1998.

[7] “Modeling and analysis of induction machine: A computational/experimental approach”, IEEE transaction power system. Vol 5, pp 482-485, may 1990.

[8]”Modeling and simulation of the three phase induction motor using simulink”, K.L.Shi, T.F.Chan,Y.K.Wong and S.L.Ho, Int..J.Electrical engg. Education vol 36, 1999.

[9] “Standard test procedure for polyphase induction motors and generators”, IEEE standard 112, 1996.

[10] “Trade of electricians” standards based apprenticeship, induction motors, phase 2, module no.2.4, and unit. No. 2.4.1, john waters, published by-FAS training and employment authority, Ireland, 2007.

[11] P.H.Zope, “Performance and Simulation Analysis of Single-Phase Grid Connected PV System Based on Z-Source Inverter”, 2010 IEEE Conference PEDES-2010-Power India, Digital Object Identifier:

10.1109/PEDES.2010.5712436, Print ISBN: 978-1-4244-7782-1.
[12] P.H.Zope, Dr. Prashant Sonare, "Development of Single Phase Z-source Inverter Using ARM7 for Speed Control of Induction Motor", Second International Conference on Control, Communication and Power Engineering 2011-CCPE Nov-2011, Proc. published by Springer, V.V. Das and N. Thankachan (Eds.): CIIT 2011, CCIS 250, pp. 440–443, 2011, © Springer-Verlag Berlin Heidelberg 2011
[13] P.H.Zope, Dr. Prashant Sonare, "Simulation and Implementation of control strategy for Z-source inverter in the speed control of Induction Motor" International Journal of Electrical Engineering & Technology (IJEET)" (JULY 2011) ISSN 0976-6553 (online), Volume 2
[14] K K Pandey, P H Zope, "Review on fault diagnosis in a three phase induction motor", International journal on computer applications, sept. 2012