Induction Machine, Loss Modelling and Parameter Estimation

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***Abstract*—Induction machines (IMs) are today widely used in various applications. For example, it is by far the most used electrical motor in industry. Asynchronous motors, particularly the squirrel-cage induction motor, enjoy several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives. These facts are due to the induction motor advantages over the rest of motors. The main advantage is that induction motors do not require an electrical connection between stationary and brushes. Induction motor also has low weight and inertia, high efficiency and high overload capability. In addition, due to its practical importance, tremendous amounts of money are still spent today on research regarding its physics and operation. The range of possible research subjects pertaining to IMs is beyond belief. Covering all results and all references available in the literature could easily fill up a thesis all by itself.**

***Keywords*—Induction Machine, Modelling, Thermal Rise, Parameters, Stator and Rotor Winding Resistance**

I. INTRODUCTION

Induction machines (IMs) are today widely used in various applications. For example, it is by far the most used electrical motor in industry. Asynchronous motors, particularly the squirrel-cage induction motor, enjoy several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives. These facts are due to the induction motor advantages over the rest of motors. The main advantage is that induction motors do not require an electrical connection between stationary and brushes. Induction motor also has low weight and inertia, high efficiency and high overload capability. In addition, due to its practical importance, tremendous amounts of money are still spent today on research regarding its physics and operation. The range of possible research subjects pertaining to IMs is beyond belief. Covering all results and all references available in the literature could easily fill up a thesis all by itself.

Hybrid electric vehicles (HEVs), which combine the internal combustion engine of a conventional vehicle with the electric motor of an electric vehicle, are fuel efficient and environmentally friendly. The development of modern technology, including power electronic components, electric machines, computer control and software makes switching power between the gasoline engine and electric drive motor appear to be seamless to the driver. In comparison to the internal combustion engine, an electric motor is a relatively simple and far more efficient machine. The moving parts consist primarily of the armature (DC) or rotor (AC) and bearings, and the motoring efficiency is typically on the order of 80% to 95%. In addition, the electric motor torque characteristics are much more suited to the torque demand curve of a vehicle. Figure 1 depicts the basic classification of induction machine.. The problems associated with existing control technique can only be reviewed and commented after the literature survey. Rotor resistance estimation and modelling of induction machine have been popular for past one decade in the research community. Moreover, fast and accurate control technique and evolutionary development in the digital control techniques opened a new area for research as model based predictive control, sliding mode control and switching transient control.

All these technique of sensorless or encoder-less control promises the faster and accurate control. In **[1]** have presented an article related to sensorless control of induction machine that includes the techniques that estimate the rotor speed based on non-ideal phenomena such as rotor slot harmonics and high frequency signal injection methods. Such methods require spectrum analyses which, besides being time-consuming procedures, allow a narrow band of speed control.

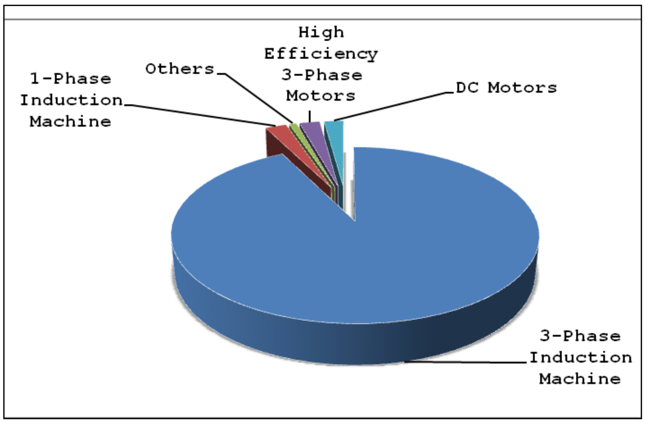

Figure 1 Utilization of Electrical Machine in Different Application

New techniques to evaluate faults have been given, in case of broken rotor bars of induction motors. Procedures are applied with closed-loop control. Electrical and mechanical variables are treated using fast Fourier transform (FFT), and discrete wavelet transform (DWT) at start-up and steady state. The wavelet transform has proven to be an excellent mathematical tool for the detection of the faults particularly broken rotor bars type [2]. The percentage of copper losses in the induction machine (IM) governs the performance and hence the efficiency of the machine.

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The temperature dependence of stator resistance results in inaccurate performance prediction if temperature is not taken into account in advance [3]. Estimation of both stator and rotor resistances are dealt with, in order to monitor the thermal behavior of the induction machine in real time. For this, a reduced-order electrical model is presented and introduced in extended Kalman filters. [4] A new technique for stator-resistance (R/sub s/)-based thermal monitoring of small line-connected induction machines is proposed in this paper.

A simple device is developed for injecting a small DC signal into line-connected induction machines for estimation of R_s. The proposed DC injection device is capable of intermittently injecting a controllable DC bias into the motor with very low power dissipation [8].

II. INDUCTION MACHINE AND LOSS MODELLING

Figure 2 gives the definite arrangement of the induction machine with detailed assembly. It is very much obvious that the heat flow in the machine is part of the air and ventilation provided by the structure. There are several indian standards which are more prominent for the design of induction machine with definite heat flow to cool the machine for the ambient issue.

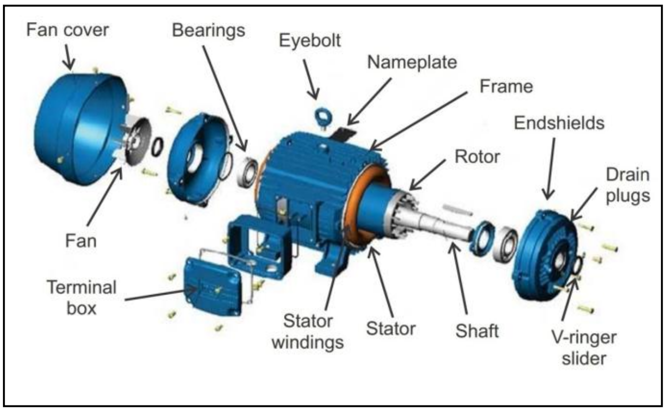

Figure 2 Part of the Induction Machine

Figure 2 is more elaborative as part of induction machine is given where as the insulation in between the contact is provided in the machine. The insulation in the system is given in the classes and categorized with the highest and average heat with the operation.

Table 1 Level of allowable temperature for Various Insulation Class

Class of Insulation	Temperature Level [°C]
Y	90
A	105
E	120
B	135
F	150
H	180
C	>180

Table -1 provides the class of insulation for the different temperature range as per the improved analysis and in the degree centigrade. The class is useful for the selection of the insulation applied in the induction machine with rise in the temperature and fall in the heat flow as depending on the operation of the induction machine. Here, the heat flow modelling is not given for the simplicity of the paper. However, the reason due to which the heat generated in any electrical machine is classified in the figure 3. No load loss and full load loss are the basic division and had been studied throughout the literatur

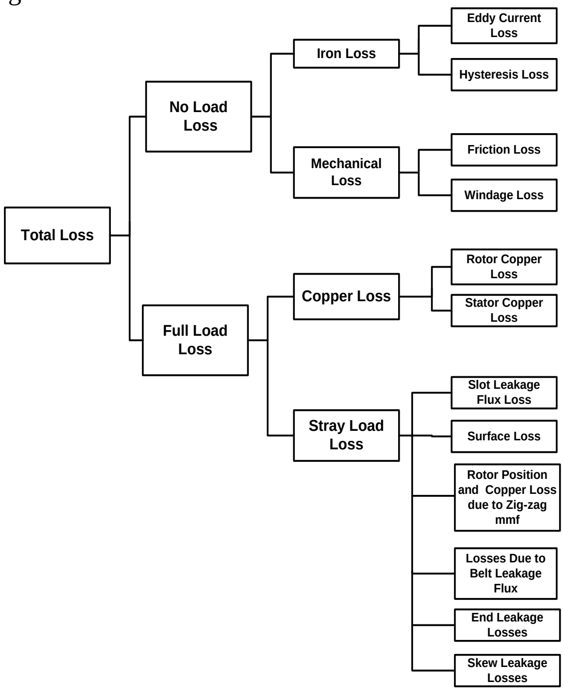

Figure 3 Separation of Losses

Losses are produced by magnetic fluxes and electric currents in machines which have complicated distribution such that the sources of losses are often ambiguous. In addition, when heat is generated its dissipation follows yet another complicated thermal pattern.

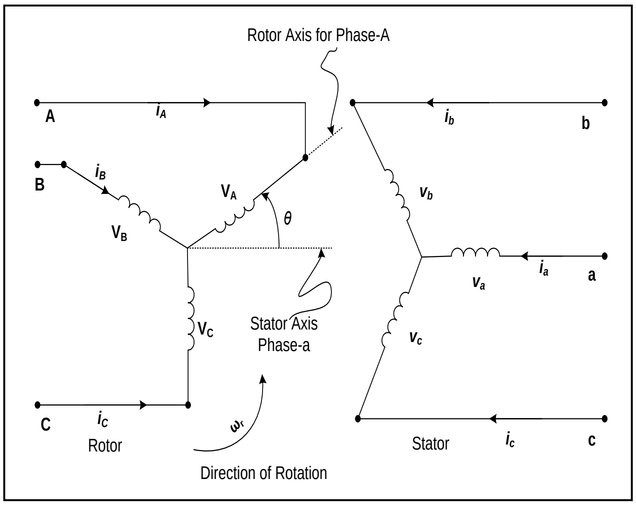

Figure 4 Stator and Rotor winding of Electrical Machine

The d-q Transformation

For induction machine the very preferred reference frame is one with the axes rotating at synchronous speed. In d-q axis it is assumed to be 90 phase displacement between the d and q axis. The d-q variable transformation is given as:

$$i_{ds} = \frac{2}{3}\left\{ i_a \cos(\omega_s t) + i_b \cos\left(\omega_s t - \frac{2\pi}{3}\right) + i_c \cos\left(\omega_s t + \frac{2\pi}{3}\right)\right\} \quad (3.1)$$
$$i_{qs} = -\frac{2}{3}\left\{ i_a \sin(\omega_s t) + i_b \sin\left(\omega_s t - \frac{2\pi}{3}\right) + i_c \sin\left(\omega_s t + \frac{2\pi}{3}\right)\right\}$$

And the inverse transformation is given as;

$$i_a = i_{ds}\cos(\omega_s t) - i_{qs}\sin(\omega_s t)$$
$$i_b = i_{ds}\cos\left(\omega_s t - \frac{2\pi}{3}\right) - i_{qs}\sin\left(\omega_s t - \frac{2\pi}{3}\right) \quad (3.2)$$
$$i_c = i_{ds}\cos\left(\omega_s t + \frac{2\pi}{3}\right) - i_{qs}\sin\left(\omega_s t + \frac{2\pi}{3}\right)$$

Similarly, all the transformation can be applied for voltage and flux linkages of the induction machine for 3-phase to 2-phase conversion. However, for the rotor quantities in relation to synchronously rotated d-q axes need to be determined. Let us assume that the θ_r is the angle by which d-axis leads phase A axis of rotor.

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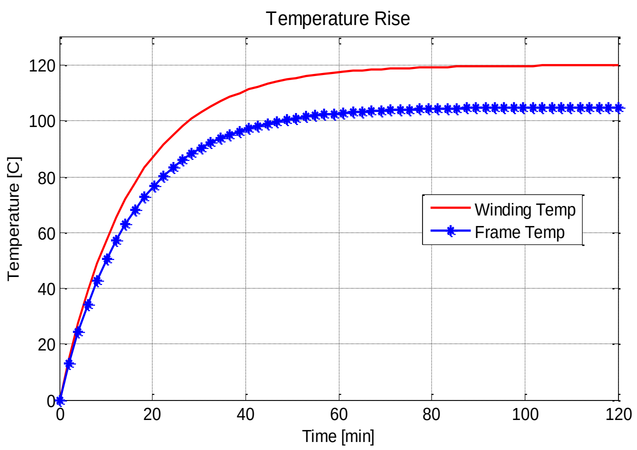

Figure 5 Temperature Rise in the Induction Machine

However, the system used in the experiment is low rating and the mounting mechanism is used in order to develop the analytical study for the thermal behaviour.

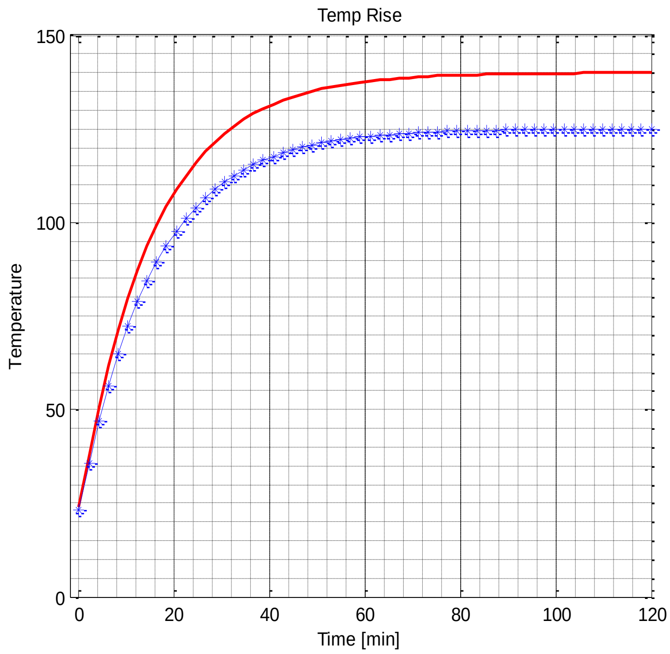

Figure 6 Temperature rise with ambient effect

III. LOSSES IN INDUCTION MACHINE

Iron Loss

Iron loss is more prominent and it is consequences of an alternating magnetic field. The losses comprise hysteresis and eddy currents are comprised and result of induction of current which circulate within the conducting material. The iron losses mainly occur in stator magnetic section, since under normal operating conditions the frequency of the rotor flux is low, resulting in small rotor losses

Friction and Windage Loss

A loss caused by the resistance to the motion within the bearing is classed as *friction loss*. Whereas, in fan cooled machine power required to drive the fan and to overcome the resistance offered by air is called the *Windage loss.* In practical machine it is not possible to segregate these two losses in the machine as both are associated with rotational speed. Generally, friction and Windage loss is proportional to the square root of the speed. In practice, the measurement of iron, friction and windage losses are straightforward using a series of no load tests despite all the complexities involved in their prediction. In the no load test, the machine is run at rated voltage and frequency without any connected load until the power input becomes constant. The power input at the rated voltage will therefore be the sum of the friction and windage, core, and no load primary copper losses. Subtracting the calculated copper losses at the test temperature from the power input gives the sum of the friction and windage, and core losses.

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REFERENCES

[1] Ghosh, Eshaan, et al. "Temperature influenced online stator resistance estimation using an improved swarm intelligence technique for induction machine." Transportation Electrification Conference and Expo (ITEC), 2015 IEEE. IEEE, 2015.

[2] Foulon, E., C. Forgez, and L. Loron. "Resistances estimation with an extended Kalman filter in the objective of real-time thermal monitoring of the induction machine." IET Electric Power Applications 1.4 (2007): 549-556.

[3] Jacobina, Cursino Brandão, Christian César de Azevedo, and Antonio Marcus Nogueira Lima. "On-line estimation of the stator resistance and leakage inductance of a four-phase induction machine drive." Power Electronics Specialists Conference, 2002. pesc 02. 2002 IEEE 33rd Annual. Vol. 4. IEEE, 2002.

[4] Savoia, A., et al. "Adaptive flux observer for induction machines with on-line estimation of stator and rotor resistances." *Power Electronics and Motion Control Conference (EPE/PEMC), 2012 15th International*. IEEE, 2012.

[5] J. Holtz, "Sensorless control of induction motor drives," Proc. IEEE, vol. 90, no. 8, pp. 1359–1394, Aug. 2002.

[6] Q. Gao, G. Asher, and M. Sumner, "Sensorless position and speed control of induction motors using high-frequency injection and without offline precommissioning," IEEE Trans. Ind. Electron., vol. 54, no. 5, pp. 2474–2481, Oct. 2007.

[7] H. Tajima, G. Guidi, and H. Umida, "Consideration about problems and solutions of speed estimation method and parameter tuning for speedsensorless vector control of induction motor drives," IEEE Trans. Ind. Appl., vol. 38, no. 5, pp. 1282–1289, Sep./Oct. 2002.

[8] J. Holtz and J. Quan, "Sensorless vector control of induction motors at very low speed using a nonlinear inverter model and parameter identification," *IEEE Trans. Ind. Appl.*, vol. 38, no. 4, pp. 1087–1095, Jul./Aug. 2002.

[9] G. Guidi and H. Umida, "A novel stator resistance estimation method for speed-sensorless induction motor drives," IEEE Trans. Ind. Appl., vol. 36, no. 6, pp. 1619–1627, Nov./Dec. 2000.

[10] A. B. Proca, A. Keyhani, and J. M. Miller, "Sensorless sliding-mode control of induction motors using operating condition dependent models," IEEE Trans. Energy Convers., vol. 18, no. 2, pp. 205–212, Jun. 2003

[11] A. B. Proca and A. Keyhani, "Sliding-mode flux observer with online rotor parameter estimation for induction motors," IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 716–723, Apr. 2007.

[12] D. P. Marcetic and S. N. Vukosavic, "Speed-sensorless AC drives with the rotor time constant parameter update," IEEE Trans. Ind. Electron., vol. 54, no. 5, pp. 2618–2625, May 2007.

[13] S. Maiti, C. Chakraborty, Y. Hori, and M. C. Ta, "Model reference adaptive controller-based rotor resistance and speed estimation techniques for vector controlled induction motor drive utilizing reactive power," IEEETrans. Ind. Electron., vol. 55, no. 2, pp. 594–601, Feb. 2008.

[14] G. Edelbaher, K. Jezernik, and E. Urlep, "Low-speed sensorless control of induction machine," IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 120–129, Feb. 2006.

[15] H. M. Kojabadia and L. Changb, "Comparative study of pole placement methods in adaptive flux observers," Control Eng. Pract., vol. 13, no. 6,pp. 749–757, Jun. 2005.

[16] E. Cabal-Yepez "Single-parameter fault identification throughinformation entropy analysis at the startup transient current in induction motors " Science Direct, Electric Power Systems Research 89, 64- 69, 2012

[17] "Report of Large Motor Reliability Survey ofIndustrial and CommercialInstallations, PartI, "Industry Applications,IEEE Transactions on, vol IA-21, pp. 853-864, 1985.

[18] "Report of Large Motor Reliability Survey ofIndustrial and CommercialInstallations, PartII, "Industry Applications, [EEE Transactions on, vol. IA-21,pp. 865-872, 1985.

[19] "Report of Large Motor Reliability Survey ofIndustrial and CommercialInstallations: Part 3, "Industry Applications,IEEE Transactions on, vol. IA-23, pp. 153-158, 1987.

[20] J. T. Boys and M. J. Miles, "Empirical thermal model for inverter-driven cage induction machines, "Inst. Electr. Eng. Proc. Electr. Power Appl. , vol. [41, no. 6, pp. 360-372, 1994.

[21] Z. Lazarevic, R. Radosavljevic, and P. Osmokrovic , "A novel approach for temperature estimation in squirrel-cage induction motor without sensors" IEEE Trans.Instrum. Meas., vol. 48, no. 3, pp. 753-757, Jun. 1999.

[22] P. Zhang, B. Lu, and T. G. Habetler, "A remote and sensorless stator winding resistance estimation method for thermal protection of soft-starter connected induction machines, "IEEE Trans.Ind. Electron., vol. 55, no. 10, pp. 3611-3618, Oct. 2008.

[23] P. Zhang, Y. Du, B. Lu, and T. G. Habetler, "A DC Signal Injection based Thermal Protection Scheme for Soft-starter connectedInduction Motors, "IEEE Trans. OnIndustrial Applications, vol. 45, pp. 1351-1358, 2009.

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