Thermal Energy Estimation Technique of 3-φ Induction Machine: An Application Review

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Abstract – *Many Industrial applications involves the 3-phase induction machine for various drive purpose. The method of controlling such machine requires proper attentions towards the exact modeling of the system. For loss calculation and efficiency modeling it becomes a prior need for engineers and the researcher for the analysis. In this paper various methods of rotor resistance estimation technique is discussed with its application and requirement. In addition a method is proposed for the development of the same is given for the actual modelling. The whole idea behind this work is to execute the thermal behavior of induction of machine.*

Key Words: Rotor resistance, temperature estimation, fuzzy based system, induction motor modelling, rotor loss model

1. INTRODUCTION

Various techniques have proposed in till present day in order to simulate the power line thermal behavior. But in order to relate the system with the performance of induction machine it becomes very important. The online condition monitoring of induction machine is becoming very important. The relevance of this work is for industrial application with the thermal behavior of induction machine. It is evident that the various application in industries including the daily work life [1]. Major thermal loss in any induction machine is depends on the stator CU-Loss and which further leads to insulation breakdown thermally. In the system it becomes very necessary to determine the temperature of stator. Furthermore, very less work has been proposed till date in this area to generalize the power loss of stator as in terms of the thermal power loss [2-10].

In various literatures estimation of temperature has been presented in order to accomplish the exact modeling and controlling of industrial induction machine. In many VFD (variable frequency drive) a symmetrical and asymmetrical PWM technique are popular for the control of the inverter as virtual and actual system interfacing. In these systems heat may transferred to the atmosphere by radiation and convection. Although, at either end fan is mounted to remove extra heat from the machine, which act as ventilation and circulate air inside. In high rating and specially designed machine temperature sensors such as RTD, Thermistors, and Thermocouple are provided for the actual temperature estimation. However, this technique is also affected by the ambient temperature. The requirement of temperature estimations is very important to prevent the system from permanent damage. The allowable temperature is set accordingly to chemical composition of the insulation. These chemical analyses provide the multiple target behavior of the insulation level.

1.1 Review and Models

In [5] an empirical thermal model has been presented for the analysis of thermal behavior in the system. In this paper author presented an empirical model of the system to develop a thermal mechanism of three phase induction machine. Also, a simulation system is presented to validate the theoretical model. However, some of the parameter in the presented equation carries ambience of the system analysis and can provide a wrong result on the environmental effect.

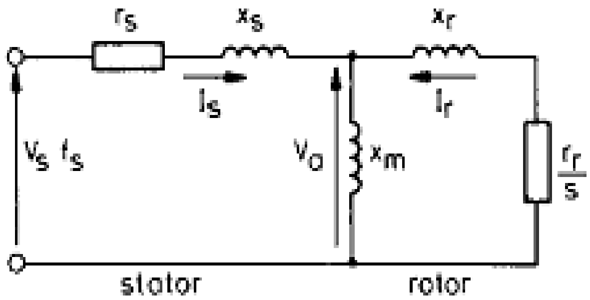

Figure 1 Per Phase equivalent circuit of 3-Phase Induction Machine.

Also this method provide the

$$\text{Iron loss} \propto \frac{V_s^2}{f_s} \tag{1}$$

$$Cu\ \text{loss} \propto I^2 \tag{2}$$

$$P_t = \frac{2}{3} I_s^{\,2} + \frac{1}{3} V_s^{\,2} f_s \tag{3}$$

In figure 1 per phase equivalent model is given, as in traditional way and very popular for the studies in various applications. The system performance is calculated and monitored as per the analysis mentioned in this work.

A developed model of the system with thermal and electromechanical system is presented in [6]. In this paper, author had performed computer simulation on squirrel cage induction machine using coupled thermal and electro-mechanical model of the system. The various effect such as electromechanical interference, iron saturation and variation due to skin effect are taken in account.

Simplified model for induction machine is given in figure 2 provided for the more detailed unites including the effect of saturation of iron, inductive model and slip resistance.

In the model presented in [6] more emphasis was given for the electrical loss model compared to the thermal extraction of the system. In this regard, many author provided the thermal junction temperature analysis of the system with the integer order derivative for the exact calculations. Moreover, some of the authors discussed an electrical equivalent of the thermal model as compared to heat model of the system. Table 1 provides the class of insulation according to their temperature range with peak magnitude settled.

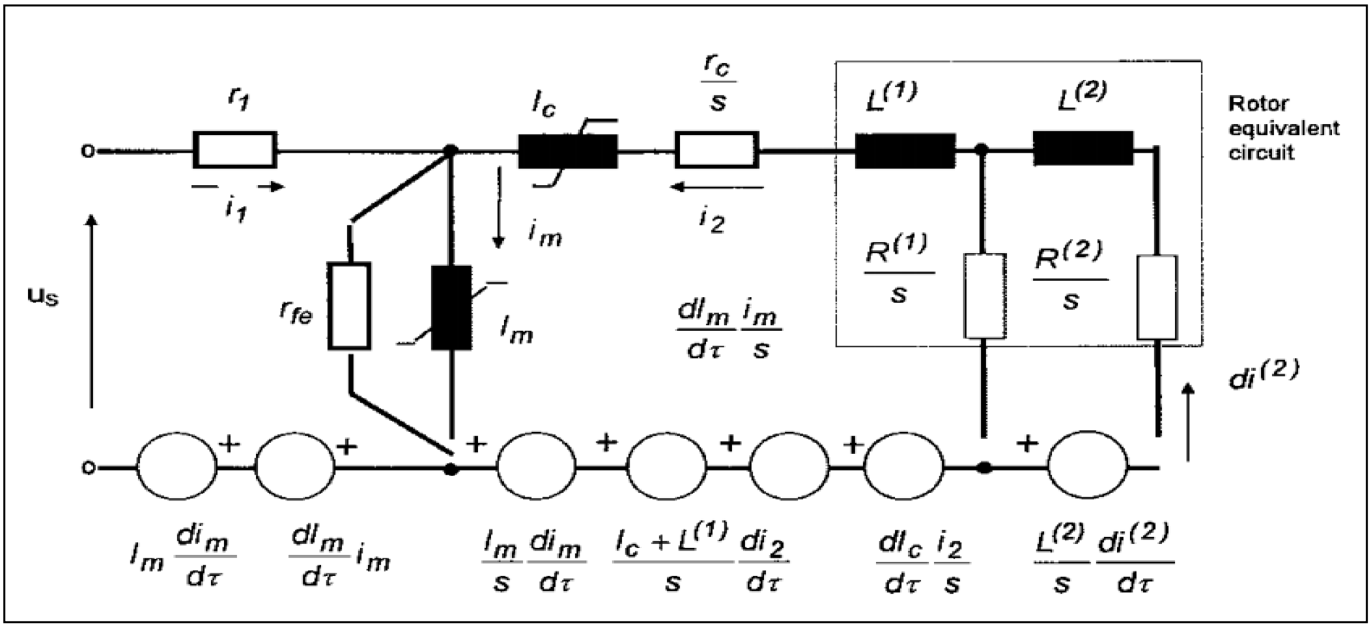

Figure 2 Detailed Equivalent Circuit of Induction Machine [6]

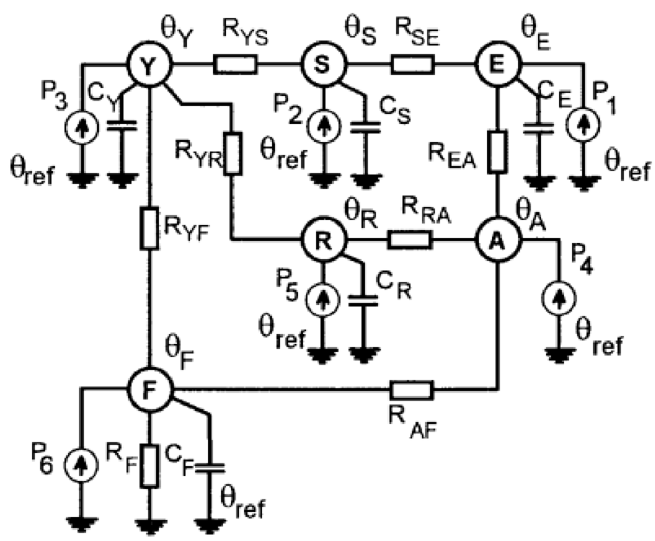

Figure 3 Simplified thermal model of Induction Machine

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

In addition, lifetime analysis of any equipment is done on the bases of the class of insulation and mean time temperature variations. If the class of insulation is selected properly for the equipment the lifecycle of the same will be increased by a exponential multiplier.

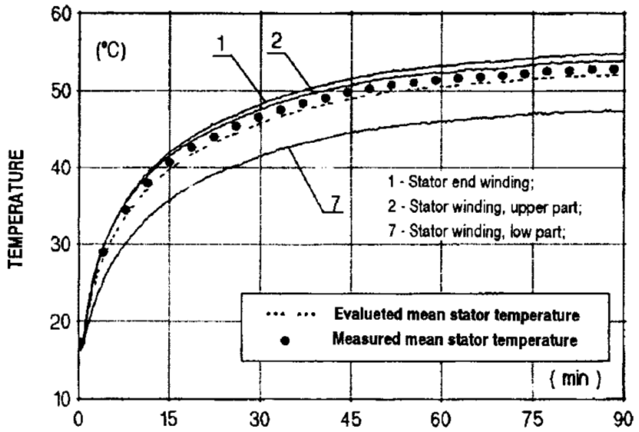

Figure 4 Temperature analysis for various part of the IM

Figure 4 shows the Temperature analysis of the induction machine for various parts. In circled waveform the mean stator temperature is evaluated through the equations used in [6]. 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.

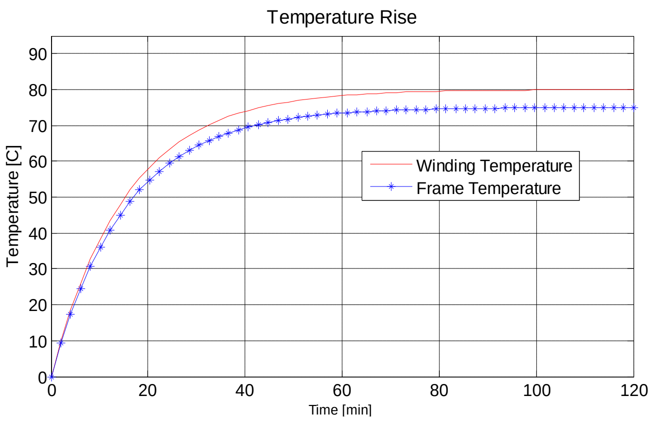

Figure 5 Temperature Rise under No-Load Condition

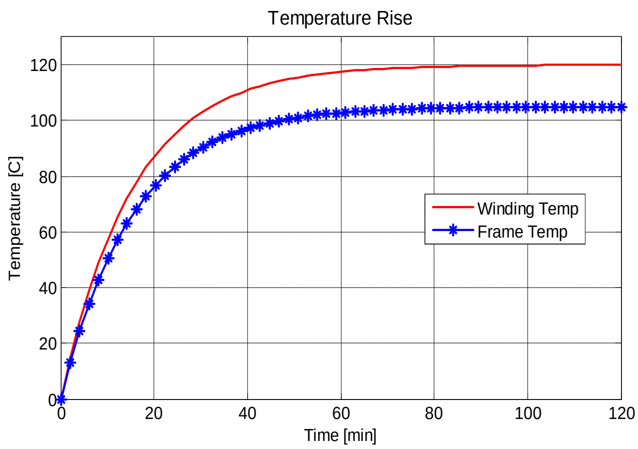

Figure 6 Temperature Rise under Loaded Condition

In figure 5 and figure 6 waveforms for the temperature variation is given with respect to winding temperature and the temperature of frame. However, figure 5 is provided for the no-load operation. In fact, during no load all the power drawn by the system is fed to the unit of consumption of the no-load losses. Moreover, when load is connected other than the fixed loss various more loss will also draw power from the source to compensate and fulfill the demand of the power loss.

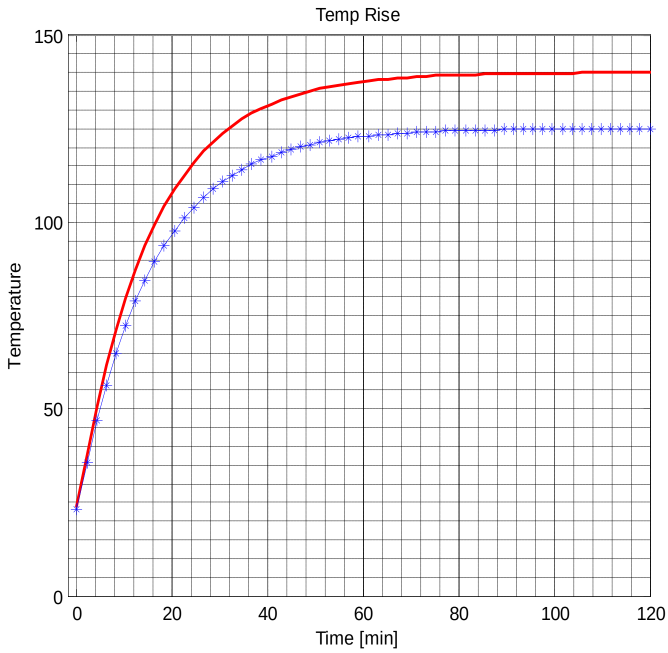

Figure 7 Temperature Rise Including the effect of Ambient Temperature

Figure 7 gives the rise of temperature in the system with respect to the time if the ambient temperature variation is also taken in account.

2. Variable Frequency Drive: A Solution for Complex Temperature Measurement

Variable frequency drives are becoming more and more popular on the industrial application. In this power network all types of measurement are calibrated with the numerical and digital analyzer. These analyzers provide instantaneous fault values and states for the various equipments as it acquire signal continuously for the each instant and the variations.

Variable instances are also recorded during the abnormal situations which provide the real time data for the system. Various equipments temperature that the VFD models sensed are:

- IGBT-Converter Temperature
- Model Converter Temperature
- Machine Temperature
  - Rotor
  - Stator

  - Stator Frame
  - Vent-speed
- Rectifier Temperature
- Maximum and minimum Ambient Temperature

3. CONCLUSIONS

In this paper two popular models for thermal behavior is presented and discussed. The prime aim was to introduce a model which provides accurate result for the thermal behavior of the system. Models presented here was reproduced and discussed with result. More economical and intelligent system for the temperature measurement is achieved by the VFD system. This VFD system has internal mounting of the thermal sensor for the temperature and heat measurement. However, proper notation on this contrary may lead a well developed and sophisticated SCADA network which can further improve the performance of the machine installation.

REFERENCES

[1] 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

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

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

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

[5] 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.

[6] 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.

[7] 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.

[8] 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.

[9] P. H. Mellor, et aI., "Lumped parameter thermal model for electrical machines of TEFC design, " Electric Power Applications, lEE Proceedings B [see also lEE Proceedings-Electric Power Applications], vol. 138, pp. 205-218, 1991.

[10] Boglietti, Aldo, et al. "A simplified thermal model for variable-speed self-cooled industrial induction motor." *Industry Applications, IEEE Transactions on* 39.4 (2003): 945-952.

[11] Zhi Gao, "A Model Reduction Perspective on Thermal Models for Induction Machine Overload Relays "IEEE transactions on industrial electronlcs, vol. 55, no. 10, october 2008 m. Young, the technical writer's handbook. Mill valley, ca: university science, 1989.

[12] Lemmens, J.; Vanassche, P.; Driesen, J. "Optimal Control of Traction Motor Drives Under Electrothermal Constraints", *Emerging and Selected Topics in Power Electronics, IEEE Journal of,* On page(s): 249 - 263 Volume: 2, Issue: 2, June 2014

[13] Ramarathnam, S.; Mohammed, A.K.; Bilgin, B.; Sathyan, A.; Dadkhah, H.; Emadi, A. "A Review of Structural and Thermal Analysis of Traction Motors", *Transportation Electrification, IEEE Transactions on,* On page(s): 255 - 265 Volume: 1, Issue: 3, Oct. 2015

[14] Dr.-Ing. O.I. Okoro (2004) Thermal Analysis of Squirrel-Cage Induction Machine, EPE Journal, 14:4, 31-36,

BIOGRAPHIES

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