Temperature Monitoring System for Unbalance Phase Analysis of Induction Motor

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Abstract—**This paper presents the temperature measurement and monitoring system for industrial induction motor (Squirrel Cage Rotor Motor). The aim of temperature monitoring system is to analyze and alarm an abnormality of the motor and prevent the damage in case of unbalance voltage. This system was tested by an induction motor of pointing machine. The experiment setup consists of a temperature measurement circuit using IC LM 35DZ with analog transformer used as a temperature sensor and transducer and the personal computer with data acquisition card from National Instrument PCI 6014 using Lab View version 7.1 for analyzing temperature data. The AC source was performed by adjusting voltage unbalance of 10%, 20% to 50% for each phase to monitor the temperature changes. This scheme can alert the operation of the motor in order to prevent damage and to extend the life time reducing maintenance costs.**

***Index Terms*—Temperature sensor, Unbalance phase analysis, Induction motor maintenance**

I. Introduction

Three phase induction motors are widely used in industrial, commercial and residential systems, because of their ruggedness, simplicity and relatively low cost. Approximately 65% of the electricity consumed in industry is used to drive electrical motors. Therefore, the efficiency and reliability of induction motors operation is of major importance, in order to improve the energy efficiency in industry [1]. Squirrel cage induction motors are the most important AC machines in industry. Low cost, high reliability, low inertia and high transient torque capacity are among the advantages of these motors. Many resources show that 35%–45% of motor failures are caused by stator insulation breakdown. For small induction machines, thermal overloading is one of the major causes of the stator winding insulation degradation process [2].

Manuscript received December 08, 2011; revised January 31, 2012. This work was supported in part by Dept. of Instrumentation and Control Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520

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Thermal devices and models, which assume fixed thermal characteristics of the motor, are not capable of providing sufficient thermal protection since they have no means of giving a correct temperature estimate when the thermal characteristics change. Therefore, in order to extend the insulation life, it is critical to monitor the stator winding temperature and protect the motor under thermal overloading conditions such as motor stall, jam, overload, unbalanced operation, and situations where the cooling ability of the motor is accidentally reduced [3]. The stator temperature can also be estimated based on the stator resistance measurement and another accurate method deals with the direct measurement of motor heating using temperature sensors installed in stator windings and rotor parts[4],[5]. The stator temperature has been obtained using two methods, which are temperature measurement with sensor installing method and DC injection method. Each method is implemented on the 1.1kW/ 50Hz/ 1400rpm three-phase squirrel cage induction motor. For verifying the DC injection method, different tests have been done under unbalance condition [6],[7].

Researches about the deteriorating of induction motors under unbalanced voltage conditions have been reported in the literature since 1959 .The most accurate method for deteriorating under unbalanced voltage conditions is to reduce the induction motor load so as to limit the temperature rise to the normal value. The complexity of the thermal behavior of an induction motor under unbalanced voltages makes necessary the development of experimental studies with an accurate measurement of the temperature inside the motor; however in the literature few experimental works with this methodology are reported [7].

The purposed of this paper is to detect the temperature of induction motor for unbalance phase analysis, we apply the effects of thermal to define the abnormal operation of both mechanical and electrical of the motor by adjust the unbalance voltage source of 10%,20%,30%,40% and 50%. Aim of research is to find an appropriate method to improve the efficiency of the three phase induction motor.

II. Material and Method

This article studies the relation between temperature and unbalance voltage of three phase induction motor in order to design the temperature monitoring system for unbalance phase analysis. The induction motor from SIEMENS model IEC 63 class B for pointing machine is used as a case study. The measurement and storage temperature of the motor is used on a daily basis if the temperature rises abnormally, the alarm is operated to prevent damage due to voltage unbalance, or other circumstances that make it heat up disorders such as shaft bearing imbalance or to prevent damage to the motor.

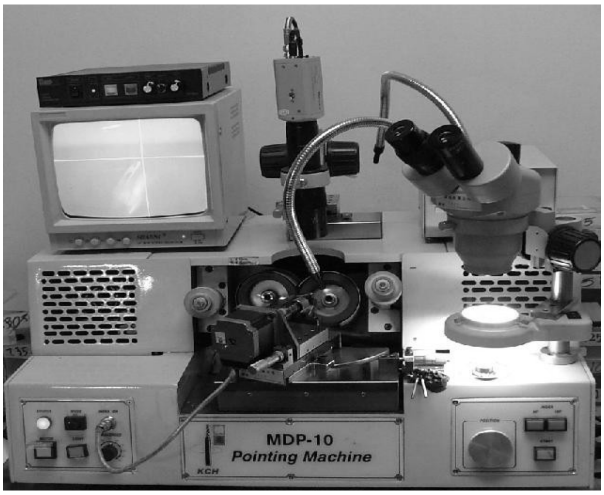

Fig.1 Pointing Machine

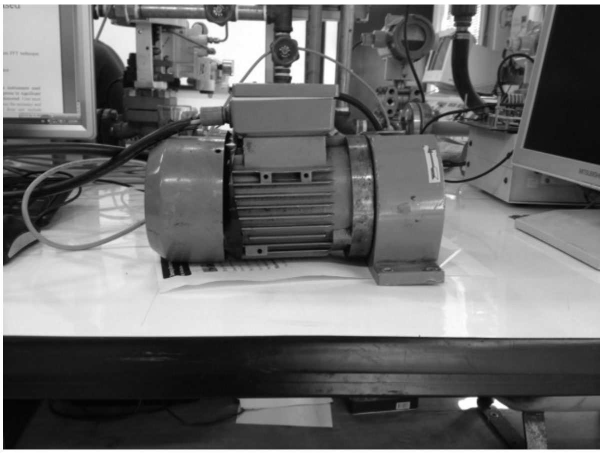

Fig.2 Induction motor SIEMENS IEC 63 class B

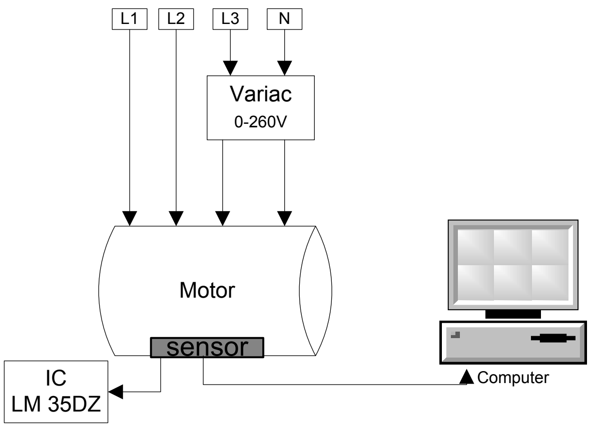

Fig.3 Experiment setup

The variac is an adjustable voltage from 0 – 260 V for simulating unbalance voltage condition. The temperature sensor circuit is created using LM 35DZ with signal conditioner circuit. The temperature of induction motor can be measured from its case. The data acquisition card from National Instrument PCI 6014 and Lab View were used to monitor and analyze data in real-time as shown Fig.8.

Effect on the motor when the voltage changes.

When motor is voltage overload or operated at higher than rated voltage. The Current in the stator winding will be reduced. The higher voltage employed to the motor making the electromagnetic field of the iron core is saturated, therefore, the exciting current is much higher than 110 percent of the rated load capacity of the shaft-power load. The heating rate is increased due to the current at voltage higher than rated.

$$\%heating \approx \left[\frac{I}{I_{rated}}\right]^2 \times 100 \qquad (1)$$

Where

I = current at voltages higher than rated (A)

I_{rated} = Rated current of the motor (A)

Calculation the percentage of voltage unbalance

The calculate the percent voltage unbalance has been determined by the Nation Electrical Manufacturers Association (NEMA) [8,9]. The percentage of the maximum voltage deviation between any phase to another phase voltage and the average of the 3-phase voltage can described as the following equations.

$$\%VUB = \frac{V_{\max\ dev}}{V_{avg}} \times 100 \qquad (2)$$

$$V_{avg} = \frac{V_{ab} + V_{bc} + V_{ca}}{3} \qquad (3)$$

Where

$\%VUB =$ Percent voltage unbalance

$V_{avg} =$ Average Voltage between phases. (V)

$V_{\max\ dev} =$ Maximum voltage deviation between one phase to another phase. V_{avg}

$V_{ab} + V_{bc} + V_{ca} =$ Voltage between phases (V)

The relation of temperature and voltage unbalance

Percent increase in the different temperature inside the motor is the result of voltage unbalance.

$$\%\Delta T = 2 \times (\%VUB)^2 \qquad (4)$$

Voltage unbalance can be obtained from the following equation.

$$T_{rise,umb} = T_{rise,rated} \times \left[1 + \frac{\%\Delta T}{100}\right] \qquad (5)$$

Where

$T_{rise,umb}$ = Higher temperatures due to voltage unbalance $T_{rise,rated}$ = The maximum temperature rating of insulation that can be acceptable.

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

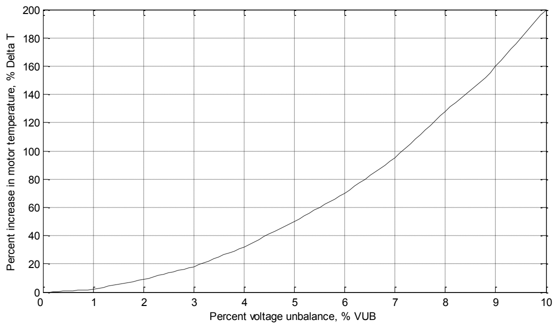

Fig.4 Percent voltage unbalance

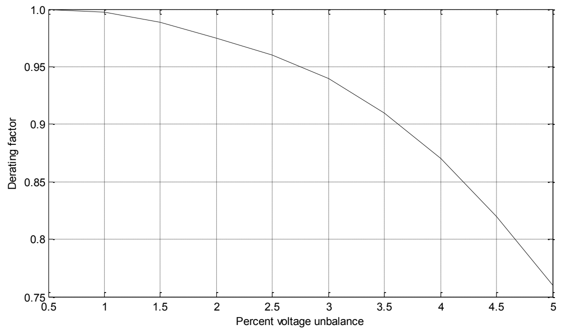

Fig.5 Percent voltage unbalance

According to Fig.5 the effect of unbalance voltage in the induction motor causes performance the induction motor getting down. The unbalance voltage more than 5 percent can be problem to the motor.

Fig.6 Slide regulator

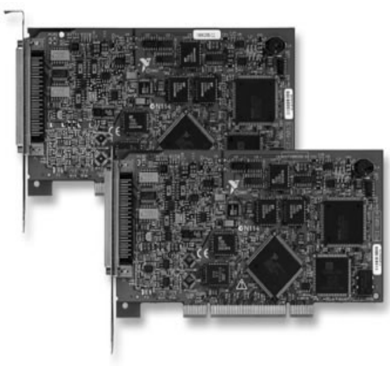

Fig.7 National Instruments PCI 6014

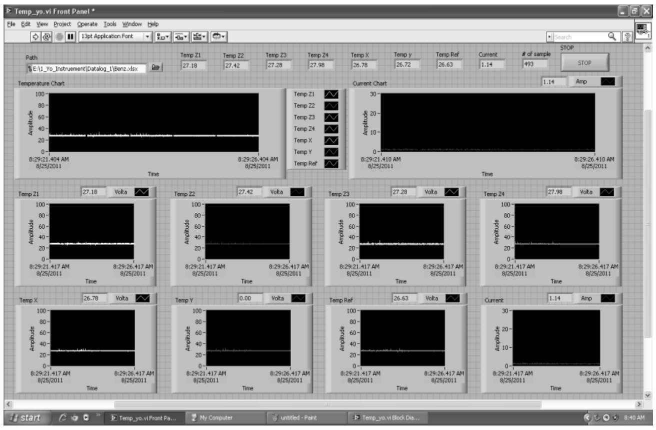

Fig.8 Lab View monitoring and analysis

In this Fig.8 shows display of temperature monitoring and analysis of temperature and unbalance voltage.

III. Experiment Results

The temperature sensor circuit was test and calibrated with the standard thermometer. The error is acceptable to use in this work. The Experimental results were done by adjusting the unbalance voltage source of 10%, 20%, 30%, 40% and 50% as shown in Fig.9 to Fig.14. The temperature variation can describe an effect to unbalance voltage as shown fig.15.

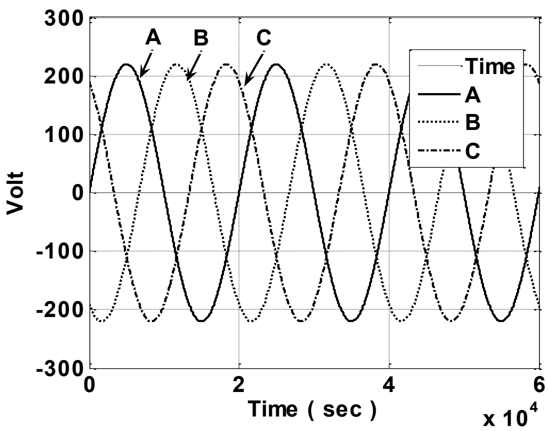

Fig.9 Voltage balance

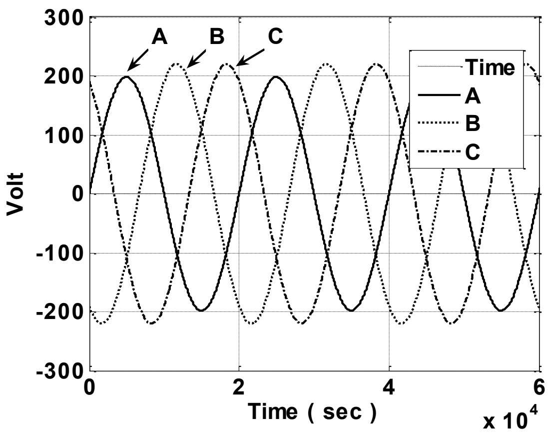

Fig.10 Voltage unbalance at 10%

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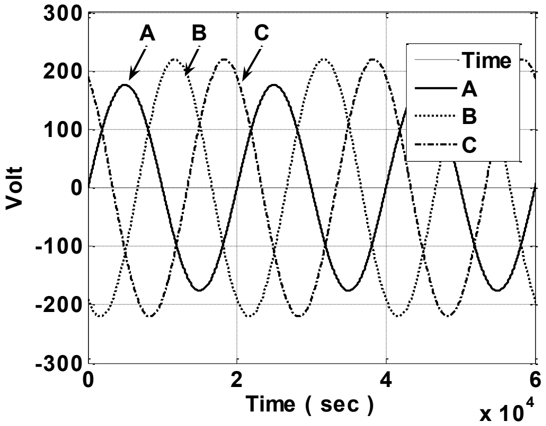

Fig.11 Voltage unbalance at 20%

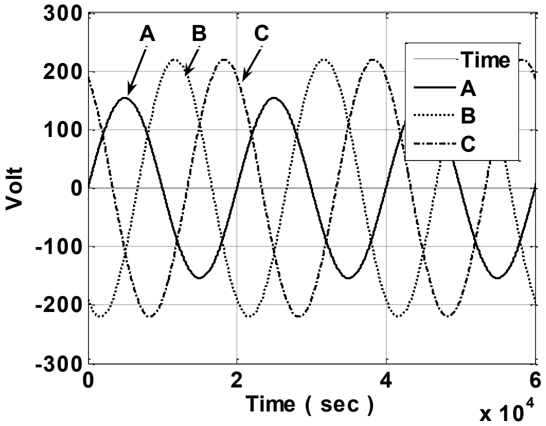

Fig.12 Voltage unbalance at 30%

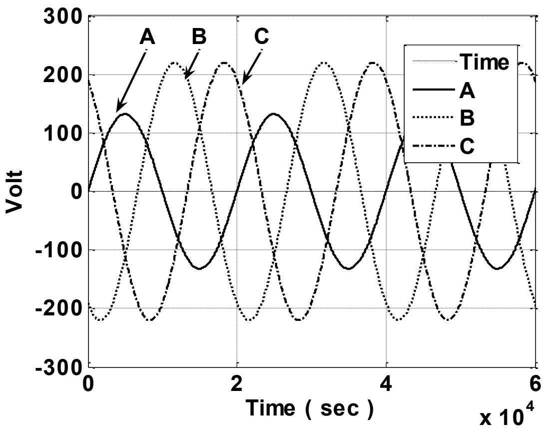

Fig.13 Voltage unbalance at 40%

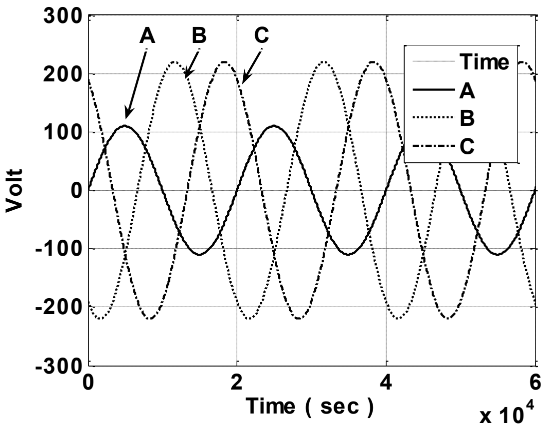

Fig.14 Voltage unbalance at 50%

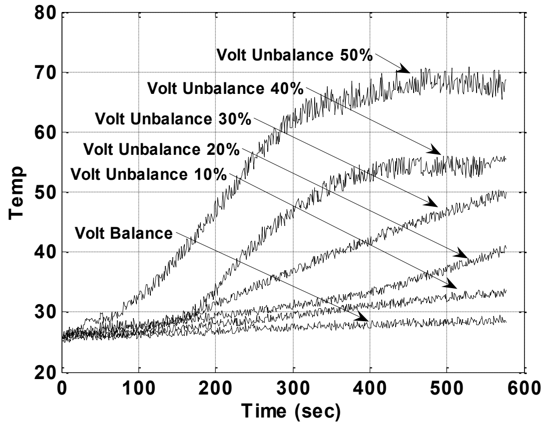

Fig. 15 Temperature effect for unbalance voltage

IV. Conclusion

The experiment results of the phase unbalance on the induction motor can be determined the abnormal operation by the heating effect. The changing of AC voltage source generates the unbalance voltage of 10%, 20% to 50% for each phase in order to monitor the temperature behavior. The temperature of the motor increases at higher rate after phase imbalance greater than 30% of unbalance voltage showing the difference of temperature. The phase voltage should be always balanced by monitoring and defining the suitable period of maintenance. This situation can alert the operation of the motor in order to prevent damage and to extend the life time reducing maintenance costs as well.

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ISBN: 978-988-19251-9-0
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