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Microcontroller Based Stator Resistance Determination of Induction Motor on Temperature Variations

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ABSTRACT

In this paper an experiment has been conducted to determine the online stator winding resistance of an induction motor, in industries as well as domestic purpose induction motors is largely utilized, as it has both applications of variable and constant torque operation nature. The major requirement of an electric drive system is its independent control of torque and speed; this is achieved in DC motor Drive but has more disadvantages. With the help of fast acting switching devices it is possible to independently control an induction motor, drive various methods are available, direct torque control of induction motor is one of the best method of control compared to other, the only disadvantage is the torque ripple. Stator resistance is one of the parameter for the cause; hence its determination is essential. An experiment is conducted at various loads on an induction motor and then the temperature in the stator winding is noted at different instants using microcontroller, from the tabulated readings stator winding resistance is calculated and compared with the direct measurement by Volt-Ampere method. Further it is suggested that by implementing the actual online value of stator resistance of an induction motor dive torque ripple can be minimized.

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1. INTRODUCTION

When a motor is started for operation heat is produced due to the losses, its temperature rises and varies from one part to another but will be maximum in the windings, this will affect the stator winding resistance and also the thermal insulation [1]. To control any machine its behavior & Characteristics has to be studied and understand first. Depending upon the requirement and its application the power capacity of a machine will be selected. If low rating machine is selected then the production get reducs or the machine gets over headted upand affects the performace and its life. When a higher rating machine is selected then its cost increases and also no load power drawn from source increases resulting power wastage. Most of the electrical machines are self cooled; the rise in temperature will be slow for high speed machines, whereas it is fast for low speed machines. The temperature rise in a machine depends upon its type of usage, the load time variation and the major classes of duty are [2].

a) Continuous duty
b) Short time duty
c) Intermittent periodic duty with starting
d) Intermittent periodic duty with starting & braking

The equivalent current and torque in an induction motor depends upon the above classes, thus affects the temperature, the change in temperature and hence the stator resistance value varies. Precise control of induction motor drive can be achieved with the actual value of stator resistance and the corresponding value of torque and flux estimations. Direct Torque Control (DTC) method of controlling an Induction motor is one of the best methods of controlling, its importance, superiority and methodology are well explained [2]. The DTC of induction motor (IM) drives offers fast instantaneous torque and flux control with simple implementation. This method is less dependent on machine parameters, the only dependent parameter is stator resistance, does not require a complex field orientation block, a speed encoder and an inner current regulation loop [3].

With a soft starter connected to an ac motor the thermal recovery time has been improved for intermittent periodic duty cycles operating machine. The importance of this technique is based on only voltage & current measurements [4].

Simulation analysis of fuzzy logic DTC of an IM drive using simulink AC4 model has been discussed, the main aim of this study is focused on motor failure & component loss due to high torque ripple [5].

On line stator resistance has been estimated using ANN, in the proposed method the effect of stator resistance variations has been studied. It is also noted that the value of stator resistance has varied from 6.03 Ohms to 8.0 Ohms and the corresponding drop of stator current is clearly shown. Further it is concluded that the relationship between stator current & stator resistance is non linear which has easily mapped with NN [6].

For small to medium sized mains-fed IM the rotor temperature has been obtained by taking only voltage & current sensors, the inductances are estimated using equivalent circuit, the rotor temperature is calculated from the linear relationship between the temperature & rotor resistance [7].

The Direct Torque Control is a highly-dynamic and high performance control technique for induction motor drives which is one of the possible alternative solution to DC drives. In direct-torque-controlled adjustable speed drives the motor flux and the electromagnetic torque are the reference quantities. Its estimation is very important, parallel identification scheme for both speed & stator resistance of sensorless IM drives using sliding mode observer and modified sliding mode observer based on speed estimation scheme for field weakening operation has been proposed [8]. With only one phase current & rotor speed adaptive stator resistance estimation has been proposed [9].

Temperature distribution in an air-cooled asynchronous induction machine is proposed using thermal Finite Element Analysis the estimation has been carried out by joules losses in stator windings [10].

The estimation of stator flux, speed and frequency for flux oriented vector control methods, becomes inaccurate due to stator resistance variation. The inaccurate flux vector computation gives error not only in the flux magnitude, but in the phase angle also, which affects the response of the drive. The direct torque control method of the induction motor drive is similarly affected by the error in stator flux estimation; the feedback signal estimation accuracy is dependent only on the stator resistance variations. The stator winding resistance primarily varies with winding temperature. The resistance at different temperatures can be calculated as [11].

$$R_{new} = R_0 \{ 1 + \alpha (T_1 - T_0)\} \quad (1)$$

Where:

R_{new} is Resistance at new temperature
R_0 is Resistance at room temperature
α is Temperature coefficient
T_1 is Temperature (new) at which Resistance value to be determined
T_0 is Room Temperature

The stator copper and iron losses will contribute to stator winding temperature rise. In this paper, the value of stator resistance changes, based on stator winding temperature has been calculated.

2. Mathematical Modeling of Induction Motor

In order to make the calculations simple and easy modeling of induction motor is to be analyzed. An induction motor can be compared with a transformer; the major parameters of induction motor are given as Stator resistance, rotor resistance, stator and rotor leakage reactance, magnetizing components and the load equivalent component. The parameters of induction motor can be easily determined by performing a no load test and a blocked rotor test on an induction motor.

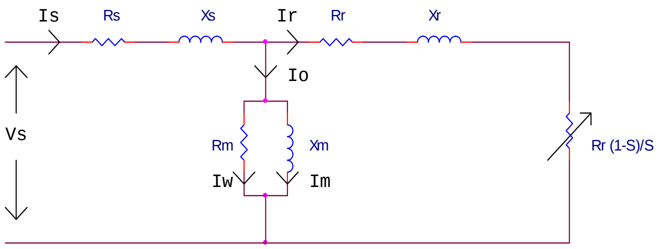

Figure 1. Per Phase Equivalent Circuit of Induction Motor

Where:

I_S & I_r are stator & rotor currents
I_o the no load current
I_w & I_m Active & magnetizing Currents
R_S & R_r are Stator & Rotor Resistances per phase
X_S & X_r are Stator & Rotor Reactance's per phase
R_m is Resistance of the core
X_m is Magnetizing Reactance
Load equivalent Resistance = $R_r(1 - S) / S$
S = Slip

When a balanced three phase supply is fed to the stator winding of an Induction motor results in developing a rotating magnetic field with a speed depending up on the number of poles and the supply frequency, this speed is called as the synchronous speed. Rotating magnetic field as it cut by the rotor bar conductors hence an emf gets induced in the rotor conductors resulting in current flow through the bar conductors as they are short circuited through endrings, due to this action the rotor starts rotating in the same direction as that of the rotating magnetic field at a slightly lesser speed than the synchronous speed. The difference in speed is expressed as slip speed. Depending upon the value of load applied, the slip of a machine changes. The temperature of machine during its operation changes due to the losses that occurs in it, and are given as:

Stator Copper loss = $3\, I_s^2\, R_s$
Rotor Copper loss = $3\, I_r^2\, R_r$
Stator Core loss, Mechanical & Magnetic losses

All these losses are in the form of heat, and get transfers to the various parts of the machine by conduction and convection process. The heat produced is maximum in the winding; the temperature in the winding slowly increases, thus affecting the winding resistances and also the life of insulation.

3. Direct Torque Control

In DTC of induction motor it is possible to control the machine very easily, it has more advantages compared to others, few of them are; Coordinate transformation is not required, Sensorless operation, Robust nature.

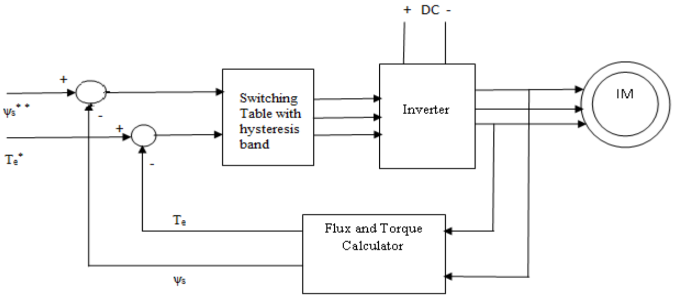

Figure 2. Basic Block Diagram of DTC

Figure shown represents the block diagram of DTC scheme in which the estimated values of electromagnetic troque and flux are compared with the command values of torque and flux, depending upon the errors obtained the corresponding switch gets operated and the control action takes place. Stator flux is a computational quantity, which is obtained using the stator-measured current ‘Is’ and voltage ‘Vs’. The major equations of interest are given as;

$$\psi_s = \int (V_s - i_s R_s) dt \tag{2}$$

$$T_e = (3/2) P_p (\psi_{sd} i_{sq} - \psi_{sq} i_{sd}) \tag{3}$$

$$\psi_{sd} = \int (V_{sd} - I_{sd} R_s) dt \tag{4}$$

$$\psi_{sq} = \int (V_{sq} - I_{sq} R_s) dt \tag{5}$$

The DTC depends upon the values of the stator flux and torque. Stator resistance R_s is a known value; exact evaluation of R_s requires accurate measurements. The value of R_s, varies with temperature, needs either a thermal model or an estimation method.

4. Experimental Setup

4.1. Block Diagram & Circuit Description

Figure 3 & 4 show the experimental arrangement to verify the thermal concept, in which the IM is loaded for different values of load current & corresponding variations in the temperature with respect to time are noted. The readings are tabulated and are as shown in Table I. A Thermistor is used as a temperature sensing device to measure the stator winding temperature. The temperature sensor is connected to the analog to digital (A to D) converter ADC0809 which is an 8 bit converter. It is designed to give fast, accurate repeatable conversions over a wide range of temperature. The digital output is passed on to the micro controller. The micro controller used here is Atmel AT89C51. It is a powerful micro computer which provides a highly flexible and cost effective solution to many embedded control applications. It has 4KB of flash memory, 128 bytes of RAM, 32 programmable I/O lines, 6 interrupt sources and programmable serial I/O channels. As the temperature of the induction motor increases the stator resistance increases, and the micro controller sends the data to the LCD which displays the actual winding temperature.

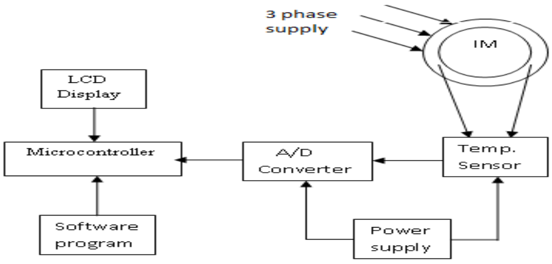

Figure 3. Block Diagram Representation of Model

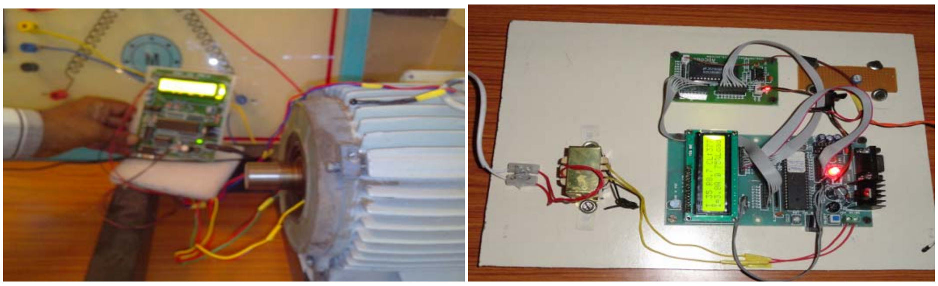

Figure 4. Arrangement of Winding Temperature Measurement & Hardware Model of Microcontroller Temperartue Monitor

4.2. Algorithm

1. Start
2. Initialize LCD and A to D converter
3. Read temperature
4. Display
5. Delay – 2Secs
6. Go to step 3

5. RESULTS

5.1. Experimental Result

An experiment is conducted on IM after inserting the temperature sensing device near the stator winding at two different places in an IM, the machine is loaded at different steps and corresponding values of temperature at different intervals are tabulated. Table 1 gives the details of the tabulated readings. Figure 5 represents the experimental graph of temperature verses time at different loads. It is seen from the graph that the temperature rise is very fast when load on IM is increased.

Table 1. Experimental Data of Time and Temperature of Stator Winding

Load Current Time in Min	2.8Amps		3.2 Amps		3.5Amps		3.8 Amps	
	Temp	Resistance	Temp	Resistance	Temp	Resistance	Temp	Resistance
Start	38	8.33	38	8.33	43	8.5	40	8.33
5	50	8.73	56	8.93	60	9.0	58	8.99
10	57	8.96	65	9.23	76	9.6	74	9.52
15	63	9.16	78	9.66	79	9.7	85	9.89
20	68	9.32	81	9.77	85	9.9	98	10.32
25	74	9.52	88	10.00	93	10.16	108	10.66
30	80	9.72	90	10.06	100	10.43	118	11
35	83	9.82	95	10.23	108	10.66	128	11.32
40	91	10.09	101	10.43	114	10.86		
45	98	10.32	110	10.73	119	11.0		
50	103	10.49	115	10.89	128	11.33		
55	105	10.56	120	11.00	135	11.56		

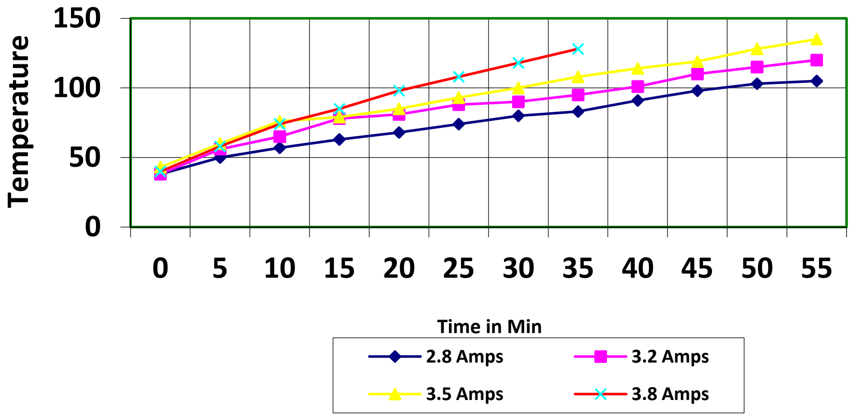

Figure 5. Graph of temp (degrees Celsius) vs time against different load current

5.2. Measurement of Stator Resistance

Table 2 shows the actual readings of stator resistance at room temperature and at a temperature of 125 degrees Celsius. The method used to measure the stator resistance is based on Volt-Ampere method, from the measured values it is clear that the resistance value will vary between 8.33ohms and 10.7ohms with a close conformity to equation (1). It is seen with the earlier investigations made the value of stator resistance of in duction motor has vareied from 6.03 ohms to 8.0 ohms on an Online estimated measurements made [21].

Table 2. Experimental Data Volt-Amp method

Temp.in Deg.Cels	V in Volts	I in Amps	Effective resistance	Resistance Stator winding
38	25	4.5	5.77	8.33
125	32	4.5	7.11	10.7

6. CONCLUSION

In this paper a clear view of stator resistance variation has been presented which is due to the variations of temperature alone, in actual DTC control, the practical change in stator resistance will not be considered. If the actual value of stator resistance is calculated, then a corresponding controller can be suggested to reduce the torque ripple.

7. FUTURE IMPLEMENTATION

The DTC of Induction Motor drive with Variable Stator Resistance values based on thermal consideration can be taken as another input to estimate the values of torque so as to get more accurate values of torque, and hence the torque ripple may further be reduced. Further the method has to be implemented using soft computing techniques like ANN, fuzzy logic, ANFIS, or other computing tools & the performance of the DTC can be further improved in future.

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