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Performance of Three Phase Induction Motor Using Modified Stator Winding

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Abstract - Induction machine is an important class of electrical machines which finds wide applications as a motor in industry and in its single phase form in several domestic applications. More than 85% of industrial motors in use today are in fact induction motors. The minimization of electrical energy consumption through better motor design becomes a major concern. This paper proposes a novel technique to improve the performance of induction motor. By using a modified stator winding arrangement the efficiency has been improved by 7% and tested in laboratory. Experimental results and simulations have been presented to validate the results.

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I. INTRODUCTION

Induction motor drives with cage-type machines have been the work-horses in the industry for variable-speed applications in a wide power range that covers fractional horse-power to megawatts. These applications include pumps and fans, paper and textile mills, subway and locomotive propulsions, electric and hybrid vehicles, machine tools and robotics, home appliances, heat pumps and air-conditioners, rolling mills, wind generation systems, etc. In addition to the process control, the energy saving aspect of variable-frequency drives is getting a lot of applications nowadays.

During the last few years, the significance of the squirrel cage induction motors in speed and position controlled drives have grown drastically. In recent years due to the advances in the development of high speed computers and power electronics technology with associated high speed microcontrollers, AC drive systems have been a viable alternative to DC machines for variable speed applications. This increased interest in induction motors is because of its merits over the other types of industrial motors [1].

These merits include: lightness, simplicity, ruggedness less initial cost, high torque-inertia ratio, capability of much higher speed, ease of maintenance etc. Moreover the most important feature which makes

the induction motor most viable alternative to DC drive system is its cost per KVA which is approximately one fifth of that of DC motor and its suitability in hostile environment. Thus in the present situation induction motor consumes large amount of electric power and an increase in the efficiency of the motor will reduce the consumption of the electric power which in turn further reduces its cost [2].

The major losses in the induction motor are in the stator windings in terms of stator copper loss. This paper proposes a novel method of reducing the stator copper loss by using modified stator winding arrangement.

The design of motor is done by increasing the active material part in the motor. Using active material effectively will increase the efficiency of the motor to a considerable extent. The proposed motor is modeled and simulated with the help of SIMULINK model. [3]

Alternating current supplied to the primary winding from an electric power system includes an opposing current in the secondary winding, when the latter is short circuited or closed through external impedance. Relative motion between the primary and secondary structure is produced by electromagnetic forces corresponding to the power transferred across the air gap by induction.

The essential feature which distinguishes the induction machine from other type of electric motors is that the secondary currents are created solely by induction, as in a transformer instead of being supplied by a DC exciter. The equivalent circuit of the induction motor is very similar to that of a transformer. The rotor currents are at a slip frequency and it is incorporated into the circuit in a simple way [4].

II. EFFICIENCY IMPROVEMENT

The efficiency of the motor is increased by using multi-strand with multi turn coils in the stator winding. Two conductors separated from each other by a pole pitch form one turn. Multi strand with multi-turn coils will increase the area of the conductors in a slot. This increases the active material present in the stator winding resulting in increase of efficiency. The reduction in the stator resistance is explained by the following equations:

The resistance of stator winding with single strand with multi turn coil, $R = \rho l / A$

Where, R= Resistance of the stator winding and

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ρ =Resistivity of the winding

l =Length of the winding

Stator copper loss = $I^2 R = I^2 \rho l / A$

Resistance of the winding with multi strand with multi-turn coil with X number of strand per turn.

$$R = \rho l / XA$$

Stator copper loss = $I^2 R = I^2 \rho l / XA$, where $X=1, 2, 3 \dots N$

Therefore, with increase in number of strands in a turn, the area of the coil increases, hence stator resistance decreases to a considerable extent. (The inductance value is same as the existing motor)

III. MEASUREMENT OF MOTOR PARAMETERS

a) Stator Resistance

The stator resistance per phase is measured using a suitable meter. The resistance values in the order of few ohms and the resistance values are crucial to determine the winding data. Hence the resistance should be measured with high accuracy.

b) No Load Test

The stator of the induction motor is energized by applying rated voltage at rated frequency. The corresponding input power per phase and line current is measured accurately under no-load conditions.

c) Locked Rotor Test

The rotor of the induction motor is locked to keep it at standstill and a low voltage is applied to circulate rated stator currents. Input power per phase is measured along with the input voltage and the stator current. The slip is unity for the locked rotor condition and hence the circuit resembles that of a secondary-shortened transformer.

d) Efficiency of Induction Motor

In an induction motor the total losses consist of copper losses, core losses and friction and windage losses are occurred. There are copper losses and core losses in the stator, and copper losses and friction losses in the rotor. Actually there is some core losses in the rotor. Under operating conditions, however, the rotor frequency is so low that it may logically be assumed that all core losses occur in the stator only. The efficiency of induction motor is determined by loading the motor and measuring the input and output directly.

$$\eta = P_{\text{output}} / P_{\text{input}}$$

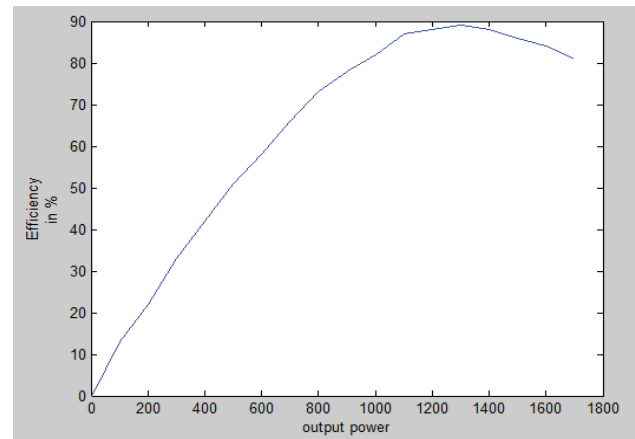


Fig.1 : Efficiency characteristics of induction motor

e) Power Factor of Induction Motor

When the winding is changed from single strand with multi turn coil into multi strands multi-turn coil the power factor increases from 0.8 to 0.85.

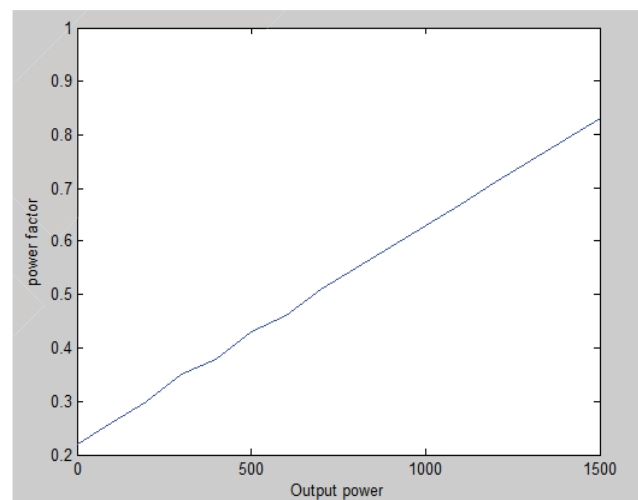


Fig.2 : Power factor of induction motor

IV. COMPUTATION OF STEADY STATE PERFORMANCE OF INDUCTION MOTOR

The slip is chosen in place of rotor speed as it is non dimensional and so it is applicable to any motor frequency. Near the synchronous speed, at low slips, the torque is linear and is proportional to slip beyond the maximum torque the torque is approximately inversely proportional to slip.

V. DYNAMIC SIMULATION OF THREE PHASE INDUCTION MOTOR

Torque and speed characteristics are obtained from this model.

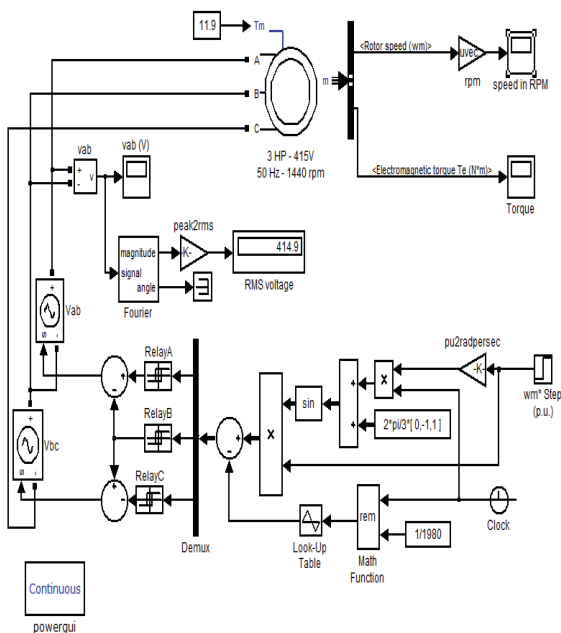


Fig.3 : The SIMULINK block diagram of three phase induction motor

Table.1 : Block parameters of induction motor

Quantity	Input values
No of phases	3
Number of poles	4
Frequency	50Hz
Line voltage	410v
Stator resistance	1.9Ω
Mutual inductance	0.26674H

A three phase motor rated 3hp, 410V, 1440 rpm is fed by a sinusoidal PWM inverter. The base frequency of the sinusoidal reference wave is 50Hz. The PWM inverter is built entirely with standard SIMULINK blocks. Its output goes through controlled voltage source blocks before being applied to the asynchronous machine block's stator windings. The machine's rotor is short circuited. Its stator leakage inductance is set to twice its actual value to simulate the effect of a smoothing reactor placed between the inverter and the machine. The load torque applied to the machine's shaft is kept constant. The motor is started from standstill. The speed set point is set to 1.0pu, or 1440 rpm. This speed is reached after 0.8s.

The noise introduced by the PWM inverter is also observed in the electromagnetic torque waveform. However, the motor's inertia prevents this noise from appearing in the motor's speed waveform.

a) Rotor speed of an induction motor

Figure 4 & 5 shows the rotor speed curve of winding with the single strand with multi turn coil and multi strand with multi turn coil of the induction motor

respectively. The rotor speed is gradually increased to the rated speed.

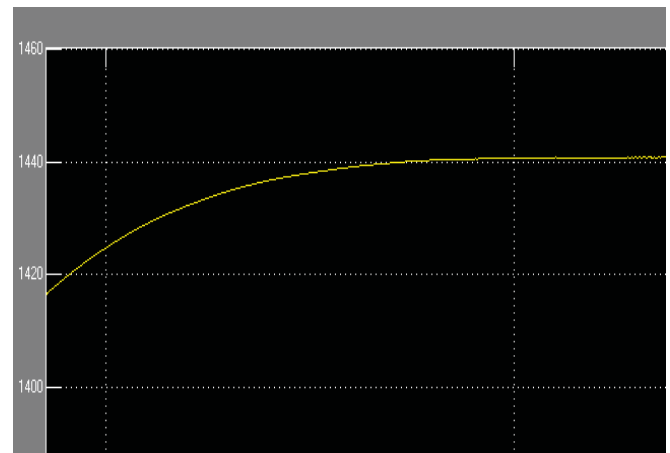


Fig.4 : Rotor speed of existing induction motor

Above Figure shows the motor with single strand with multi turn coil attain a steady state speed of 1440 rpm.

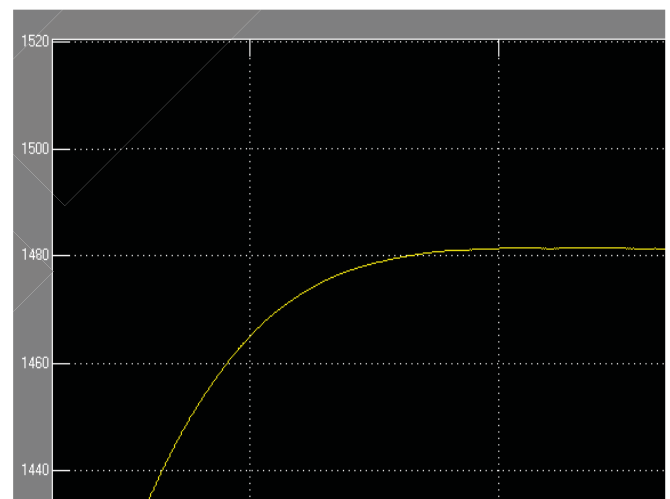


Fig.5 : Rotor speed of new induction motor.

Above Figure shows the motor with multi strand with multi turn coil attain a steady state speed of 1480 rpm.

b) Time Response of Electromagnetic Torque in Three Phase Induction Motor

In Fig.6. the time response of electromagnetic torque of three-phase induction motor is expressed. The electromagnetic torque of three-phase induction motor is firstly variable in 0 to 0.4 second. The rated torque is reached at 0.8 seconds.

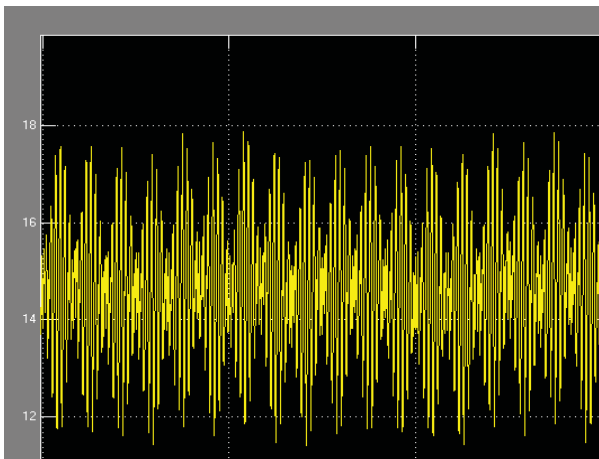


Fig.6 : Time response of electromagnetic torque of existing induction motor

Above Figure shows the torque of the motor with single strand with multi turn coil.

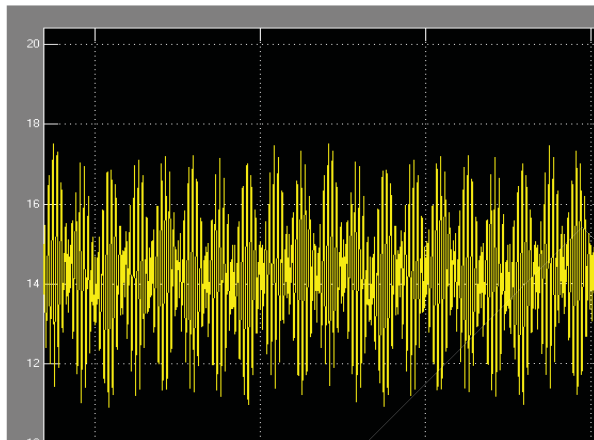


Fig.7 : Time response of electromagnetic torque of new induction motor.

Above Figure shows the torque of the motor with multi strand with multi turn coil.

Table 2 : Comparison of Single –Turn and Multi-Turn Motor

Parameters	Existing motor	Motor with modified stator winding.
Voltage	410v	410v
Frequency	50Hz	50Hz
Efficiency	80.7%	87.8%
Stator copper loss	240w	83w
Rotor copper loss	120w	107w
Fixed loss	167w	167w
Power factor	0.79	0.85

Table 2 shows the comparison of efficiency and losses for the existing motor and new motor. The efficiency is increased in the new motor.



Fig.8 : Existing induction motor

Above Figure shows the winding of the motor with single strand with multi turn coil.



Fig.9 : New induction motor

Above Figure shows the winding of the motor with multi strand with multi turn coil.

VI. CONCLUSION

A novel method to increase the efficiency of three phase squirrel cage induction motor is new. The dynamic simulation of the motor is performed by its mathematical modeling. The stator copper loss is minimized by using modified stator winding arrangement. The hardware is proposed after doing the above modifications and thus the efficiency of the motor is increased, the motor is also modeled and simulated with the help of the MATLAB SIMULINK model.

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