ENEGRY EFFICENT 3Φ SQUIRREL CAGE INDUCTION MOTOR AND ITS DYNAMIC MODELLING

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Abstract

Three phase induction motors are employed in almost all the industries for its simple construction and easy operation. It is predicted that more than 60% of the electrical energy generated is being consumed by the induction motors. Any attempt to improve the efficiency and power factor will be cost effective. A multi Winding Induction Motor (MWIM) would be an alternative for the induction motor which efficient operation with power factor improvement is possible. MWIM consists of more than three windings on the same stator Core and conventional squirrel cage rotor. One set of windings is connected to a three phase supply which works as a conventional induction motor to meet the mechanical load. In addition, energy conservation is possible due to loading the multi set of winding for which separate supply is not required.

1.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 now days. 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. 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.

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.

2. Three-Phase Induction Motors

In the integral horsepower sizes three-phase induction motors of various types drive more industrial equipment than any other means. The most common three-phase (polyphase) induction motors fall within the following major types:

NEMA (National Electrical Manufacturers Association)

- NEMA design B: Normal torques, normal slip, normal locked amperes
- NEMA design A: High torques, low slip, high locked amperes
- NEMA design C: High torques, normal slip, normal locked Amperes
- NEMA design D: High locked-rotor torque, high slip
- Wound-rotor: Characteristics depend on external resistance
- Multispeed: Characteristics depend on design—variable torque, constant torque, constant horsepower.

There are many specially designed electric motors with unique characteristics to meet specific needs. However, the majority of needs can be met with the preceding motors.

I.NEMA Design B Motors

The NEMA design B motor is the basic integral horsepower motor. It is a three-phase motor designed with normal torque and normal starting current and generally has a slip at the rated load of less than 4%. Thus, the motor speed in revolutions per minute is 96% or more of the synchronous speed for the motor. For example, a four pole motor operating on a 60-Hz line frequency has a synchronous speed of 1800 rpm or a full-load speed of

(1800)- (1800-SLIP)
=1800-(1800-0.04)
=1800-72
=1728rpm
Or
1800*0.96=1728 rpm.

In general, most three-phase motors in the 1- to 200-hp range have a slip at the rated load of approximately 3% or, in the case of four pole motors, a full-load speed of 1745 rpm. Typical construction for a totally enclosed, fan-cooled NEMA design B motor with a die-cast aluminum single-cage rotor. The typical speed-torque curve for the NEMA design B motor. This type of motor has moderate starting torque, a pull-up torque exceeding the full-load torque, and a breakdown torque (or maximum torque) several times the full-load torque. Thus, it can provide starting and smooth acceleration for most loads and, in addition, can sustain temporary peak loads without stalling. The NEMA performance standards for design B motors.

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In the past, there were no established standards for efficiency or power factor for NEMA design B induction motors. However, NEMA had established standards for testing and labeling induction motors. Recently, NEMA has established efficiency standards for energy-efficient polyphase induction motors.

3. Efficiency Improvement By Multi-Winding

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

ρ =Resistivity of the winding

l=Length of the winding

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

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 = $I^2R = I^2 \rho l/XA$,

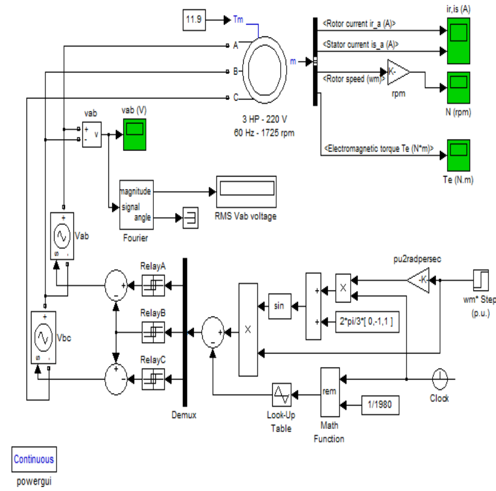
Where X=1, 2, 3 ...N

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)

4. Dynamic Simulation of Three-Phase Induction motor

The dynamic model of induction machine is built by SIMULINK model. Torque, speed, stator and rotor current are obtained from this model.

A three phase motor rated 3hp, 410V, and 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



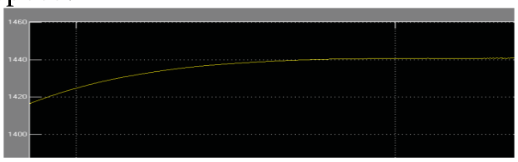
SIMULINK blocks. Its output goes through controlled voltage source blocks before being applied to the asynchronous machine block's stator windings. The machine's rotor is short circuited. Its stator leakage inductance is set to twice its actual value to simulate the effect of a smoothing reactor placed 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.

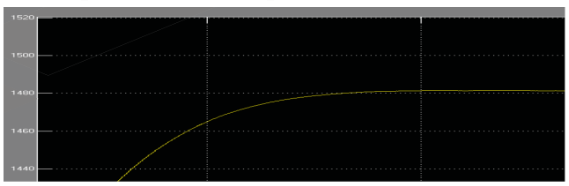
5. Simulation Results

a) Rotor speed of an induction motor

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.



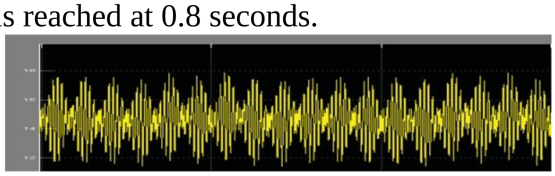
Above Figure shows the motor with single strand with multi turn coil attain a steady state speed of 1440 rpm.



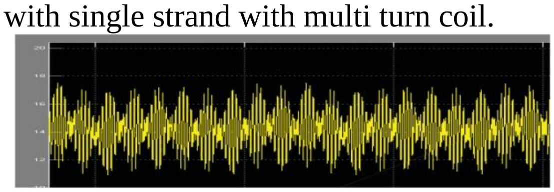
Above Figure shows the motor with multi strand with multi turn coil attain a steady state speed of 1480 rpm.

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

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.



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



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

6. Conclusion

To increase the efficiency of three phase squirrel cage induction motor is proposed. 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 SIMULINKmodel.

7. References

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