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Designing a Simulation Model in MATLAB Simulink to Analyze the Performance of 4000-Watt Synchronous Three-Phase Induction Motor under Varying Load Conditions

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Abstract: The study aims to investigate the motor's response to diverse loads, including light, moderate, and heavy conditions. Through simulink, the model incorporates parameters such as torque, speed, and power to assess the motor's efficiency and stability across varying loads. The simulation results offer invaluable insights into the motors behavior under different operating conditions, adding in the optimization of its performance for real-world applications. Simulink provides a graphical environment for modeling dynamic system, allowing to you simulate the behavior of three –phase induction motor under various conditions. This helps in understanding the system response before actual implementation. The visual diagram representation in simulink makes it easier to design, analyze the debug complex control systems for induction motor. It enchases the clarity of the system structure.

I. INTRODUCTION

Three-phase induction motors are widely used in various applications. They operate on the principle of electromagnetic induction, where a rotating magnetic field is produced by the interaction of three alternating currents. [2] The rotating field induces currents in the rotor, generating torque and causing the motor to rotate. These motors are robust, reliable and efficient, making them the preferred choice are broadly utilized for changing for powering many devices, from pumps and fans to conveyor system and manufacturing equipment.

They power a wide range of industrial machinery, from pumps and compressors to conveyor systems. Their versatility makes them essential in various applications. Three phase induction motors are highly efficient, converting electrical energy into mechanical energy with minimal energy loss. Three-phase induction motor's are cost effective to manufacture and maintain, contributing to their widespread use for instance, copper as a choice rather in industrial and commercial setting. [2] They provide high torque and power output, making them suitable for heavy duty applications in industries such as manufacturing, mining and transportations. Weather for small applications or large industrial machines, three phase induction motors comes in various sizes, making them scalable for different applications.

A. Three Phase Induction Motors

Three-phase induction motor's relatively ease to control using various methods such as variable frequency drives (VFDs), enabling precise control of speed and torque in industrial processes. In summary, the three phase induction motor's versatility, efficiency, reliability, cost effectiveness, powerful performance, stability and ease of control make it a cornerstone in the real world, powering a multitude of essential processes across various industries.

II. CONSTRUCTION OF THREE-PHASE INDUCTION MOTORS

A. Stator

The stator of three-phase induction motor is the stationary part of the induction motor and it is made up of silicon steel and it generates a rotating magnetic field. [1] It consist of three sets of windings spaced 120 degree apart, corresponding to the three phases of AC power supply When AC voltage is applied to these windings, it creates a magnetic field that rotate due to the phase difference between the windings. [1] In summary, the stator responsible producing the rotating magnetic field necessary for the operation of a three phase induction motor. [1]

B. Rotor

The rotor in a three phase induction motor is a crucial component responsible for converting electrical energy into mechanical energy. [1] There are two main types of rotors: squirrel cage and wound rotor. Wound rotor consists of laminated iron core with a three phase winding. The winding is connected to external resistors via slip rings. As the motor starts external resistors are initially in the circuit, providing high resistance and limiting the rotor current. [2] As the motor accelerate, the resistors are gradually short-circuited via the slip rings, reducing the rotor resistance and alloying for higher current and torque.

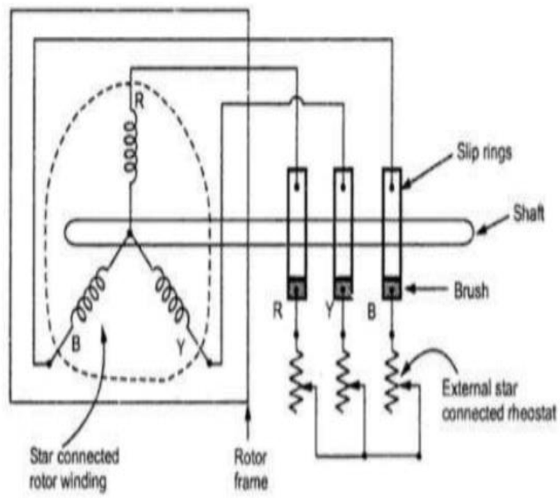

Fig 1-1 Wound Rotor or Slip rings rotor [1]

The squirrel cage rotor is a most common type. [3] Consist of laminated iron core with conductive bars (usually aluminum or copper) embedded in slots. The conducted bars are short-circuited both ends by ends rings, forming a structure resembling a squirrel cage. When three-phase AC power is applied to the stator windings, a rotating magnetic field is created, inducing current in the rotor bars. This induced current interacts with the rotating magnetic field, producing torque and causing the rotor to turn. [2] In both the cases, the interaction between the rotating magnetic field produced by the stator and the induced currents in the rotor leads to the rotation of the rotor, resulting in mechanical output. The squirrel cage rotor is more common due to its simplicity, ruggedness, and lower maintenance requirements.

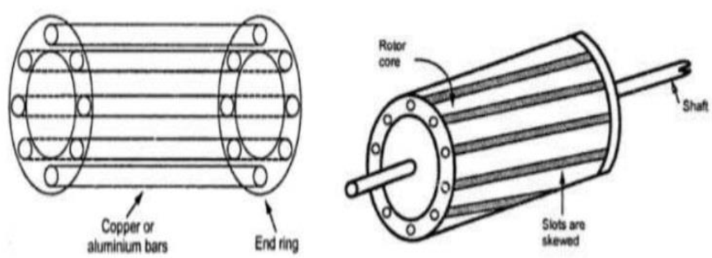

Fig 1-2 Squirrel cage rotor [2]

C. Induction Motor Modeling On Matlab

Design and Implementation of the Asynchronous Three phase motor is done on MATLAB Simulink R2018a. For this we have introduced different load conditions of torque to the designed Asynchronous motor which are as follow:

Types of torques available in the induction motor

T_a = Gross mechanical torque or motor torque.

T_{lost} = loss torque due to friction, wind age and iron losses

T_L = load torque

$T_a = T_{lost} + T_L$

Power ($P_{out} = T_L * \omega$)

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$$T_L = \frac{P_{out}}{\omega}$$
$$P_{out} = 4000\,Watts$$
$$\omega = \frac{2\pi n}{60}$$
$$\omega = \frac{2\pi * 1440}{60}$$
$$= 150.72\,rad/sec$$
$$T_L = \frac{4000}{150.72}$$
$$T_L = 26.54\,Nm$$
$$\frac{T_L}{2} = 13.27Nm$$
$$\frac{T_L}{4} = 6.64Nm$$

On the basis of the above calculations we have achieved the following results:
Model Designed in MATLAB Simulink is shown below with various output graphs.

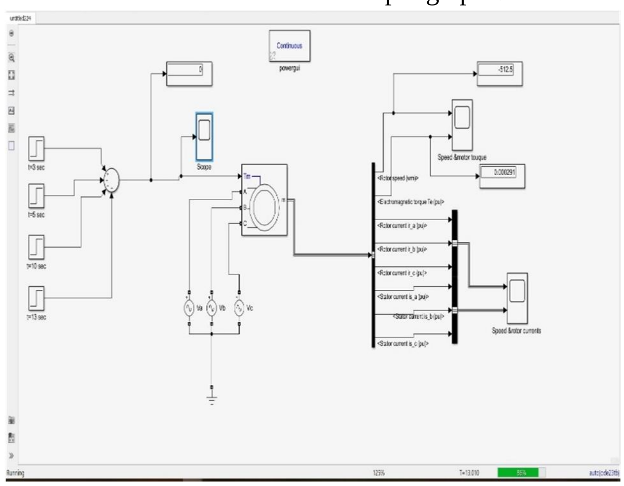

Figure 1-3: Model of Three Phase Induction Motor on MATLAB Simulink.

III. RESULTS

In the reenactment of the unconventional three-stage induction motor model, variation in motor speed and torque were observed under different load conditions. The output analysis is depicted in the figures below.

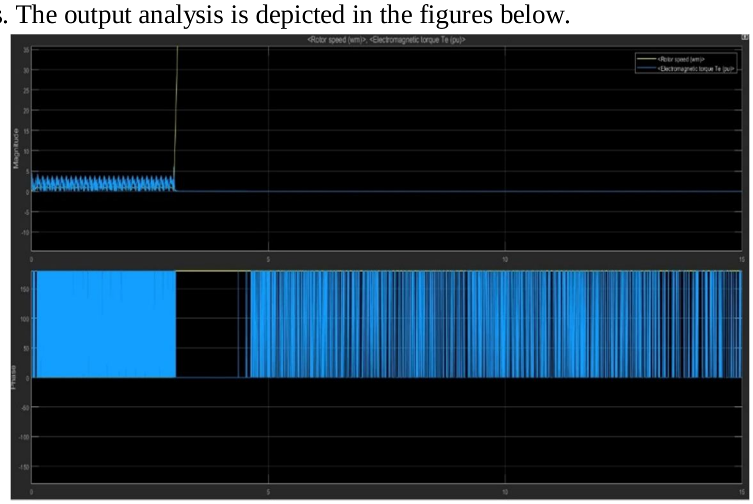

Figure 1-4:Analysis of Speed and Torque for different load Conditions.

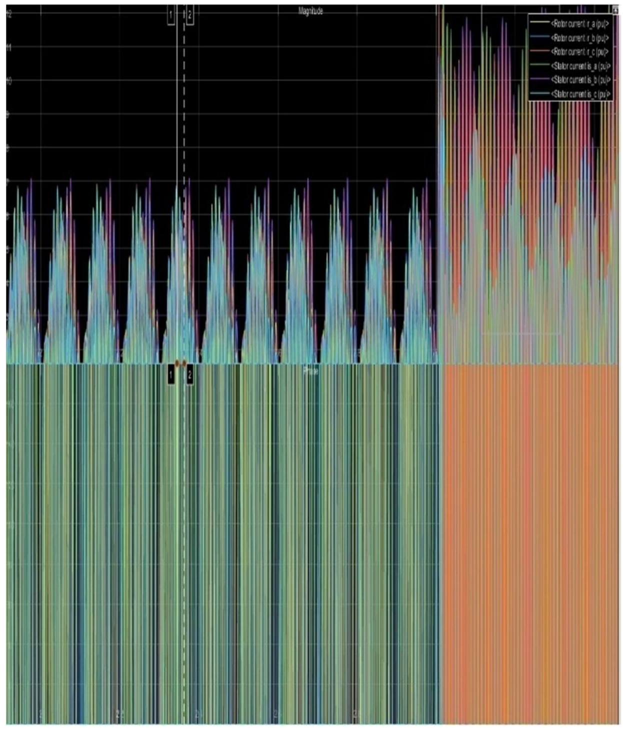

Figure 1-5: Value of Currents in Stator and Rotor for the motor at different time cycles according to the different load conditions.

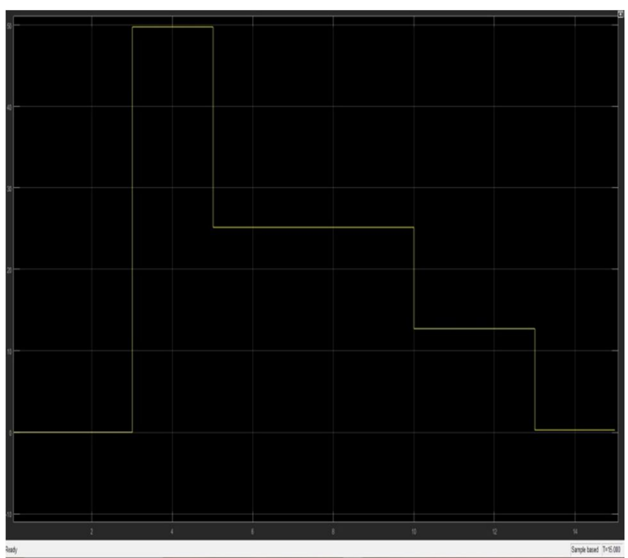

Figure 1-6: Load variation graph of the motor at different load conditions

As per the figure appeared over the motor speed and motor torque can be dissected regarding the reenactment time.
At T=3 when there is full load on the motor.
Speed of the motor will diminish as showed in the figure with yellow line and torque of the motor will increment.
At T= 5 When there is half load on the motor.
Speed of the motor will turn over increment and torque will begin diminishing.
At T=10 when there is ¼ load on the motor.
The speed of the motor will further increment and the torque will keep in diminishing.
At T=15 when there is no heap on the motor.
The speed of the motor will increment and torque will diminish.

IV. CONCLUSIONS

The implementation of a three-phase induction motor in simulink provides a comprehensive simulation platform to analyze its dynamic behavior, performance, and efficiency. Key insights can be gained into factor like torque characteristics, speed regulation, and response to varying loads. Further analysis may involve fine-tuning control parameters to optimize motor's performance, making simulink a valuable tool for motor drive system design and evaluation.

The accompanying end could be produced using is:

1) This type of programming gives great help to the ideal parameters estimations and calculations.
2) This programming also help to understand the structure procedure of electric motors.
3) Such kind of programming can likewise be utilized for structuring vitality effective machine as a future degree in industries.
4) This programming can likewise be utilized to compute the streamline parameters of electric machine

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