FAULT DIAGNOSIS IN INDUCTION MOTOR

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Abstract- The paper demonstrates simulation and steady-state performance of three phase squirrel cage induction motor and detection of rotor broken bar fault using MATLAB. This simulation model is successfully used in the fault detection of rotor broken bar for the induction machines. A dynamic model using PWM inverter and mathematical modelling of the motor is developed. The dynamic simulation of the small power induction motor is one of the key steps in the validation of the design process of the motor drive system and it is needed for eliminating advertent design errors and the resulting error in the prototype construction and testing. The simulation model will be helpful in detecting the faults in three phase induction motor using Motor current signature analysis.

Keywords- Squirrel Cage Induction Motor, Pulse Width Modulation (PWM)

I. INTRODUCTION:

The controls of high-performance induction motor drives in industrial applications and production automation have received more interests in the recent years. Three–phase squirrel cage induction motor is widely used motor in the industrial ap plications for its simple design, reliable operation, rugged construction, low initial cost, easy operation and simple maintenance, high efficiency and having simple control gear for starting and speed control. Induction motors are the most widely used motors for appliances, industrial control, and automation; hence, they are often called the workhorse of the motion industry.

When power is supplied to an induction motor at the recommended specifications, it runs at its rated speed. However, many applications need variable speed operations. For example, a washing machine may use different speeds for each wash cycle. Historically, mechanical gear systems were used to obtain variable speed.

Recently, electronic power and control systems such as PWM inverter have matured to allow these components to be used for motor control in place of mechanical gears. These electronic devices such as PWM not only control the motor's speed, but can improve the motor's dynamic and steady state response. In addition, electronics devices can reduce the system's average power consumption and noise generation of the motor.

The utilization of static frequency inverters comprehends currently the most efficient method to control the speed of induction motors. Inverters transform a constant amplitude voltage into a variable (controllable) frequency-variable (controllable) amplitude voltage. The variation of the power frequency supplied to the motor leads to the variation of the rotating field speed, which modifies the mechanical speed of the machine.

II. SIMULATION MODEL OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR:

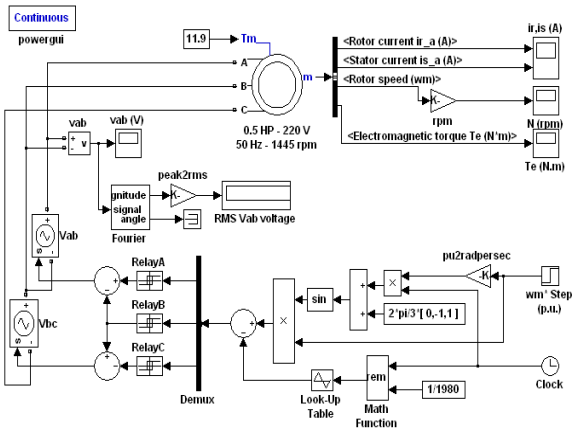


Fig. 1: Simulation Model of 3- Phase Squirrel Cage Induction Motor:

This Squirrel cage Induction machine block can be operated in generator as well as motor mode. It depends upon the sign of mechanical torque (T). If Tm is positive as shown in fig.1, machine acts as motor and if Tm is negative it acts as generator. The Simulink block input is the mechanical torque at the machine's shaft. The simulink output block has one output but that contains 21 signals. It is possible to demultiplex these signals by the Bus Selector block provided by the simulink library. Note that the neutral connections of the stator and rotor windings are not available, three-wire Y connections are assumed.

The proposed simulation model of the three phase induction motor shown in fig. 1. The input mechanical torque is applied on the shaft i.e. 11.9 N-m as the full load torque. The node voltage is extracted by the Fourier block which gives 220.7 Volt shown in fig. 1. A three-phase motor rated 0.5 HP, 415 V, 1445 rpm is fed by a sinusoidal PWM

inverter considered. The base frequency of the sinusoidal reference wave is 50 Hz while the triangular carrier wave's frequency is set to 1980 Hz. The Maximum time step has been limited to 10 μs. This is required due to the relatively high switching frequency (1980 Hz) of the inverter. The PWM inverter is built entirely with standard Simulink blocks. Its output goes through Controlled Voltage Source blocks before being applied to the Squirrel cage induction machine block's stator windings. The machine's rotor is short-circuited. Its stator leakage inductance L1s 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 constant and set to its nominal value of 11.9 N-m. The motor is started from standstill condition.

The noise introduced by the PWM inverter is also observ edin the electromagnetic torque waveform Te.
However, the motor's inertia prevents this noise from appearing in the motor's speed waveform. The RMS value of the fundamental component of the line voltage at the machine's stator terminals is extracted with a Fourier block. There are three reference frame, possible in the three phase induction motor, in our case we have considered stationary reference frame. For the stationary reference frame the value of rotor angle is set to 0 and the value of β is set to - θr. The speed set point is set to 1.0 pu, or 1445rpm. The descriptions of the elements are used in Simulink block is shown below:

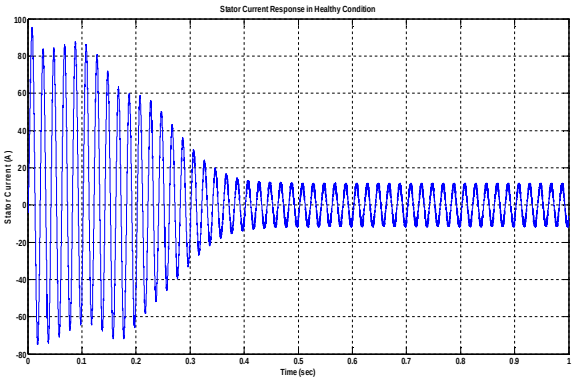
Rotor Type	Squirrel Cage
Reference Frame	Stationary
Motor	0.5 HP
Rated Speed	1445 rpm
Line-Line Voltage	380V
Node voltage rms	220.5V
Frequency	50Hz
Stator Resistance	0.435 ohm
Stator Inductance	2*2.0e-3H
Rotor Resistance	0.816ohm
Rotor Inductance	2.0e-3H
Mutual Inductance	69.31e-3
Inertia	0.089
Pairs of poles	2

After an extensive simulation on the developed model some limitations have been observed:
The Squirrel Cage Induction Machine block (used in sim ulink) doesnot include a representation of iron losses an d saturation. Care should be taken while connection ideal sources to the machine's stator. If choice is done to supply the stator via a three-phase Y-connected infinite voltage source, then the three sources are connected in Y. However, if simulation is done by connecting a delta source then two sources are connected in series. When Squirrel Cage Induction Machine block is used in discrete systems, a small parasitic resistive load is used and connected at the machine terminals, in order to avoid numerical oscillations. Large sample times require larger loads. The minimum resistive load is proportional to the sample time.

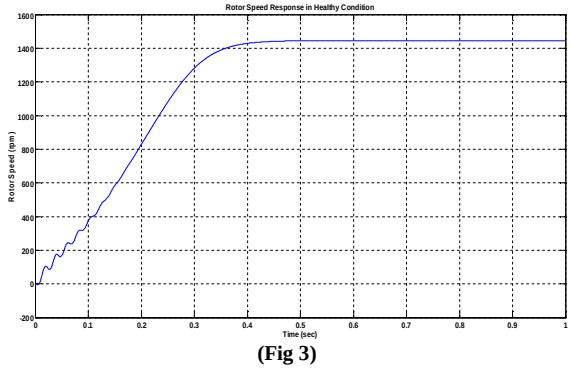
III. CIRCUIT DESCRIPTION:

A three-phase motor rated 0.5 HP, 220V, 1445 rpm is fed by a sinusoidal PWM inverter. The base frequency of the sinusoidal reference wave is 50 Hz while the triangular carrier wave's frequency is set to 1980 Hz. 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 Lls 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 constant and set to its nominal value of 11.9 N-m.

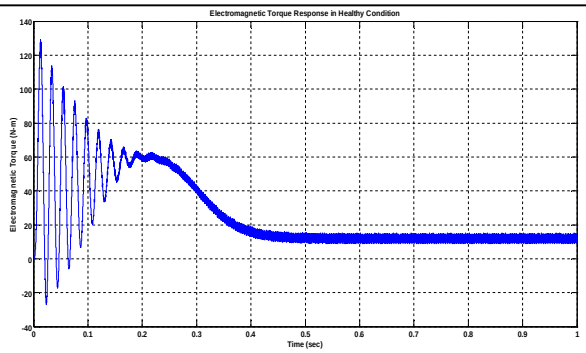
IV. RESULTS OF MATLAB SIMULATION:



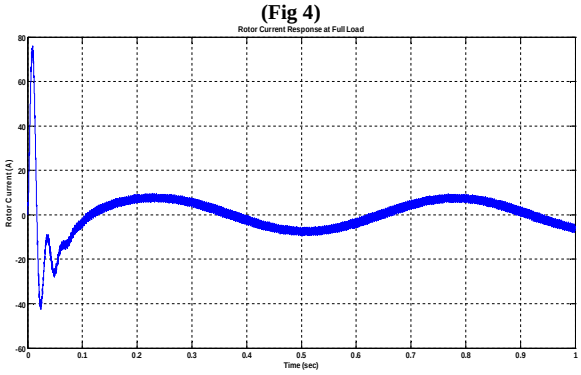
(Fig 2)



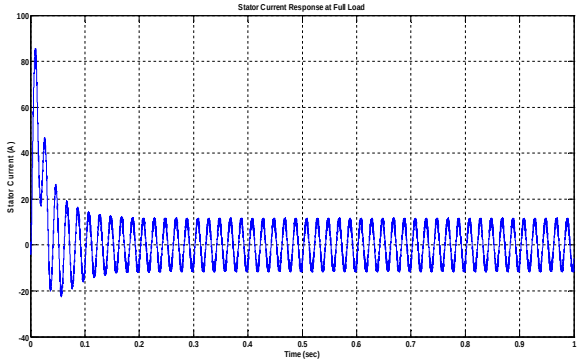
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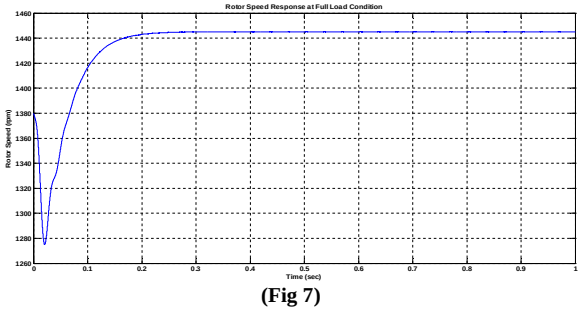
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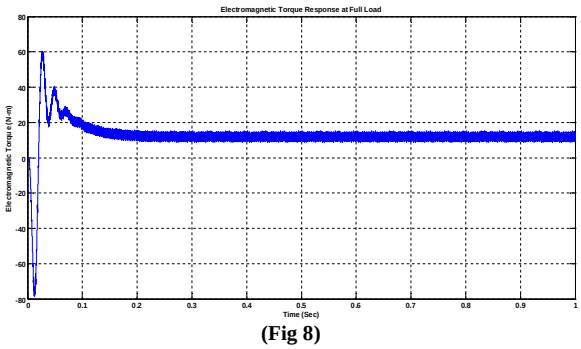
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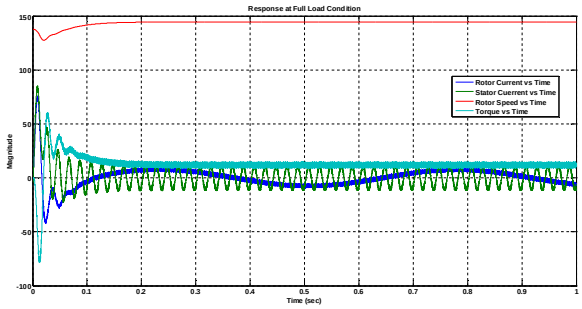
(Fig 6)



(Fig 7)



(Fig 8)



(Fig 9) Combined Response (a) For Healthy condition and (b) For 5 Broken Bar Condition at Full Load

Table: 1 Comparison in Faulty Motor Condition at Different Loads [BRB-Broken Rotor Bars]

Motor Condition	Slip	Load	Rotor Current(A)	Stator Current(A)	Speed (rpm)	EMT (N-m)
Healthy	1	11.9	85.40	95.37	1445	129.19
1BRB	0.04	11.9	79.87	86.70	1440	53.71
3BRB	0.056	11.9	78.42	86.23	1416	56.42
5BRB	0.08	11.9	75.87	85.56	1380	60.14
No-Load	0.01	0	80.72	87.80	1485	44.68

The comparison in faulty motor conditions for various broken bar is shown in Table1. This comparison clearly shows the difference between 1, 3, 5 broken bars in the motor parameters. The comparison is made from healthy motor parameters. The analysis is also done for no-load condition of the motor. It is observed from the table 1, when the rotor bar is broken at that time all the motor parameters are decreased but when the rotor broken bar is increased then the parameters of the motor is being decreased except electromagnetic torque. If a bar broken is increased then fault will be severe and stator current will be further decreased. It is observed that all the mentioned signatures of the motor given in the Table 1, are decreased except electromagnetic torques. The rotor speed is also decreased. Finally from the observation of above tables it may be stated that the signatures of the motors in the healthy condition is completely different from the faulty condition of the induction motor. The combined response of the three phase squirrel cage induction motor for healthy and faulty (5-broken bar) condition is as given in the graph (fig-9). It shows clear variation between the signal magnitudes verses time for healthy and faulty motor.

CONCLUSIONS

The Simulink model is efficiently used in the fault detection of rotor bar broken purpose. The time domain analysis can be used for the rotor broken bar fault detection. For variable speed machines, the motor must be fed by static frequency inverter rather than directly by the sinusoidal power line. The utilization of squirrel cage induction motors with electronic inverters presents great advantage on cost and energy efficiency, compared with other industrial solutions for varying speed applications. The PWM Inverter affects the motor performance and might

introduce disturbance in the main power line. Thus requires a good understanding of the whole power systems as well as the interaction among the parts.

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