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SIMULATION STUDY FOR TRANSIENT PERFORMANCE ANALYSIS OF SQUIRREL CAGE INDUCTION MOTOR CONSIDERING DEEP BAR EFFECT AND MAGNETIC SATURATION

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***Abstract* —This paper is present a simulation approach to analysis the transient behavior of three phase squirrel-cage type induction motor. The mathematical model of induction motor is represented by six differential equations of three-phase voltage and current. Deep bar effect and magnetic saturation is most important effect of induction motor for the study of transient behavior of motor. Due to high starting current the value of reactance of stator and rotor are changed by the saturation of rotor. Also the value of resistance and reactance of rotor bar are varied by deep bar effect in the rotor. The commercial software, MATLAB, is used to simulate the transient behavior of the model.**

I. INTRODUCTION

Since many years, three phase squirrel-cage induction motors use normally in industries from the capacity of some kilowatt to thousands of kilowatts as driven unit of pumps, compressors, fans, printing machine, polishing machine, etc. This motor is most widely used on account of its good self-starting capability, simple and rugged structure, medium cost and reliability.

In past year, squirrel cage induction motors had typically used in constant speed application and connected to fixed frequency of sinusoidal power supply. Therefore at that time machine model based on classical rotating-field approach, while in the recent year, the growth of high power switching devices has led to rapid growth in the market for variable speed drive application incorporating ac squirrel cage induction motors and power electronics converter. For this reason, this method is unfit to variable speed drive application due to non-sinusoidal nature of the power supply and variation of rotor speed with time. So at this time the two axis model has been used for these applications. One of the main purpose of this model was to produce a integrate model for all different machine types.

Generally, the motors are maintained time to time. However, when the fault (eg. ground fault, short-circuit fault) occurs in the motor terminal, a motor may be brought seriously. In the worst condition, the motor is not able to start after the restoration of the power supply. According to Wood, Flynn and Shanmugasundaram [1] re-switching the supply onto squirrel cage motor is one of the transient effect of the motor. That can result in production of large negative torque. When supply is removed, the stator current is absent but magnetic flux in the motor cannot change instantly. That’s why to recompense the loss of stator MMF, the rotor current must require change. According to W. Levy and C.F. Landy [2] if the main supply is remade while decaying induced stator voltage, then re-switching torque will present. If the inertia of load is low, the motor speed will fall rapidly after switching off. There for it is possible that supply voltage and induced voltage could be “Out of phase” when re-made the supply. Under these conditions the transient torque produced will swing severely negative having a magnitude of several times the rated full load torque of motor.

We know that almost 90% of induction motor is squirrel cage type. Therefore, it is important to understand the transient phenomena of squirrel cage induction motor under abnormal condition for the optimal design of induction motors. This is possible by simulating the dynamic modeling of squirrel cage induction motor.

II. TWO-PHASE INDUCTION MACHINE MODEL

D-q-0 transformation is use in three phase circuit. For the simulation of induction machine, the two-axis (d-q axis) equation are employed. The three phase stator and rotor variable quantity are transformed to the two phase values. The two-phase model for the induction machine is shown in fig.1. Stator and rotor winding of three phase induction motor is represent as two equivalent coils. One on the d-axis and one on q-axis.

Generally in the case of three phase machine stator and rotor are magnetically coupled. So the transformation can be used to rotate reference frames of ac waveform such that they become DC signals. Therefore simplified calculation can be carried out on their DC quantity. It is required to decouple the mutual effect of induction machine and also reduce the number of equation of model.

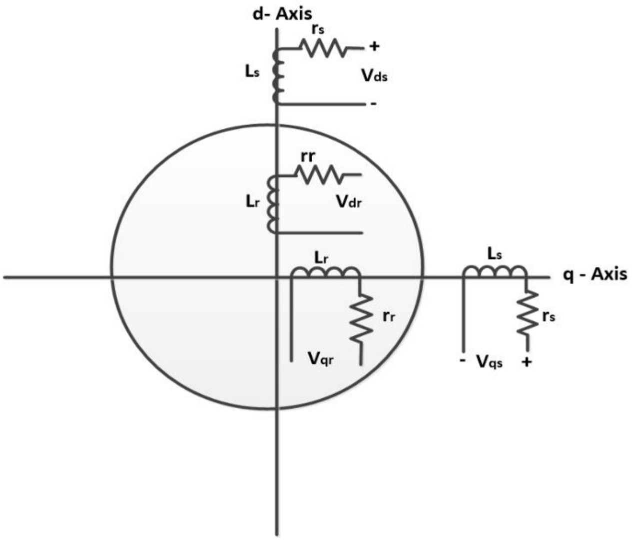


Fig.1:-Two-phase axis representation of induction machine

III. DEEP BAR EFFECT

Deep bar effect is produced in deep rotor bar. Deep rotor bar used for obtain high starting torque and reduce starting current of induction motor. Deep bar indicate the bar comprises in cage compare to normal rotor bar. A bar may be assumed to be number of narrow layer connected in parallel. The below figure.2 there is three layer A, B and C

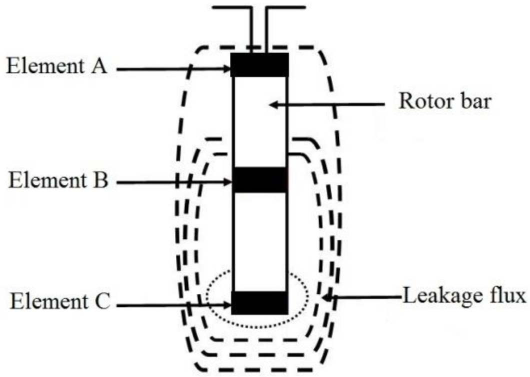
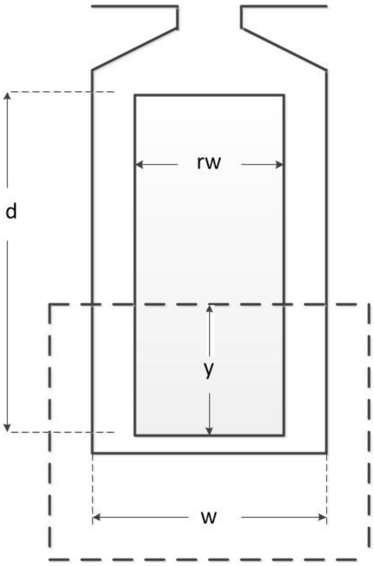


Fig.2:- Effect on Deep rotor bar

The upper layer is denoted by element A is linked with minimum leakage flux. Therefore leakage inductance of upper layer is minimum, while the lower layer is denoted by element C which is linked with maximum leakage flux, so the leakage inductance of lower layer is maximum. At standstill condition rotor frequency is same as the supply frequency. The lower layer offer more impedance compare to upper layer. Therefore; maximum current flow in upper layer and minimum current flow in lower layer. The effective rotor resistance is increase and reactance is decreased because of unequal distribution of current. So the starting torque is high and starting current is lower due to high resistance. At running condition rotor frequency is very small. A reactance of all layer is small and almost equal compare to resistance. Therefore current distribution depends on resistance of each bar. The resistance of rotor is small because of high cross-section area, which results in high efficiency during normal condition. This phenomenon is known as deep bar effect.

The ideal motor should have a varying secondary resistance, large at standstill, and decreasing as the speed rises. Boucherot was the first to accomplish this by means of the “deep-bar effect”, or variation of resistance with frequency. If the squirrel-cage bar is made very deep and narrow, the current will be crowded up toward the top of the bar at full frequency, increasing the effective resistance; while at full speed, when the slip frequency is low, the current will be uniformly distributed, giving low resistance. This is true because the bottom filament in the bar is linked by all slot-leakage flux, whereas the top filament is linked only by the external flux. This additional reactance of the bottom filament causes its current to be smaller and more lagging in time phase than the current in the top filament.



Where, d = depth of bar in cm,

w = width of slot in cm,

r = ratio of bar width to slot width,

y = distance up from bottom of the bar in cm,

Alger [3] gives equations dependent on the bar dimensions to correct the DC value of resistance and inductance for any applied frequency. The limitation of these equation is valid only in rectangular bar. In these equation Alger represent depth-wise analysis of bar. He derived equation of change in resistance and reactance during starting in the machine for different depth considering skin-effect in the bar. In this paper, two different depth of rotor bar are considered for same motor rating. As depth of rotor is vary, the reactance and resistance are also vary, which can be shown in following equation.

$$\Delta R = (\alpha d - 1)R_0, \text{ if } \alpha d > 2 \quad (1)$$

$$= \frac{4(\alpha d)^4}{45} R_0, \quad \text{if } \alpha d < 1.5 \quad (2)$$

$$\Delta X = \left(1 - \frac{3}{2\alpha d}\right) X_0 = K\left(1 - \frac{3}{2\alpha d}\right) R_0, \text{ if } \alpha d > 2 \quad (3)$$

$$= \frac{8(\alpha d)^4}{315} X_0 = K \frac{8(\alpha d)^4}{315} R_0, \quad \text{if } \alpha d < 1.5 \quad (4)$$

IV. MAGNETIC SATURATION EFFECT

The value of inductance used in mathematical equation of induction motor model is constant. In this paper magnetizing inductance, stator and rotor leakage inductance is assumed to be saturate. This implies in model that magnetizing inductance and leakage inductance vary with magnetizing current. In this paper saturation effect is consider according to B-H curve of cast iron [5].Therefore saturation curve of the motor is determined. Magnetizing current (I_m) is defined as following equation.

$$Im = \sqrt{Iqt^2 + Idt^2} \quad (5)$$

Where,

$$Iqt = Iqs + Iqr \quad (6)$$

$$Idt = Ids + Idr \quad (7)$$

1. SATURATION OF STATOR LEAKAGE INDUCTANCE

When current flowing through stator winding increase beyond limit, the wedge part of stator slot is magnetically saturated, this is called stator leakage inductance saturation.

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2. SATURATION OF ROTOR LEAKAGE INDUCTANCE

When current flowing through rotor bat is increases than certain limit, the leakage reactance of tip part of rotor teeth become small by increasing magnetizing current, this is called as rotor leakage inductance saturation.

3. SATURATION OF MAGNETIZING INDUCTANCE

When the magnetizing current of induction motor increases beyond limit, the specific permeability of core is decrease, that means magnetizing inductance decrease, this is called as magnetizing inductance saturation.

V. MATHEMATICAL MODEL OF THREE PHASE INDUCTION MOTOR

There are numerous ways of formulating the equations of an induction machine for the purpose of simulation. In particular, the computer representation of symmetrical induction machine in arbitrary reference frame will be used as basis of various mode of operation are represent [4]. The basic block diagram of simulation of a symmetrical three-phase induction machine in the arbitrary reference frame is shown in fig.3. In this block first stator variable and rotor variable (transferred to stator side) are converted to qd0 form by using transformation matrix Ks. In arbitrary reference frame, first solving the flux linkages equation. By using this equation solve the equation of current. Finally we can get electrical torque equation of induction machine and angular speed of of rotating machine.

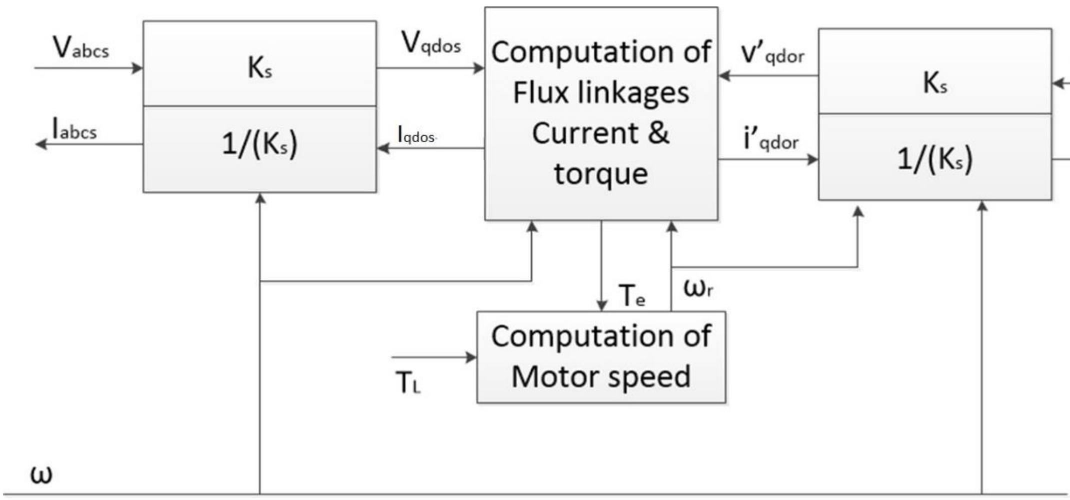

Fig.3:-Block diagram of simulation of a symmetrical 3-phase induction machine in the arbitrary reference frame

VI. RESULT AND DISCUSSION

In this paper simulate the transient model for 11 kw, 3 Phase, 440 V, 50hHz, 1000 r.p.m. squirrel cage induction motor [5] for two cases of depth(d=10mm and d=20mm). The waveform of electromagnetic torque is shown in fig.4 and fig.5. Also the waveform of stator current of phase-a is shown in fig.6 and fig.7.

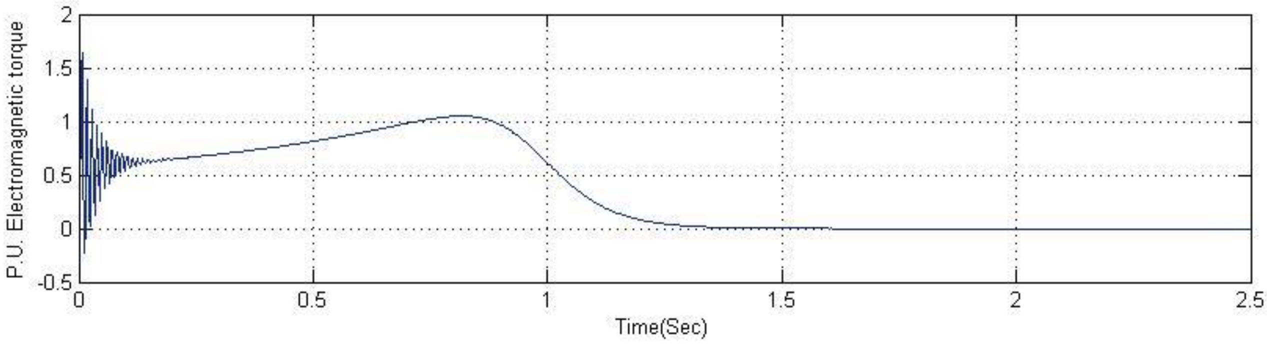

Fig.4:-Electromagnetic torque of 11 kw motor for 10mm depth during free acceleration

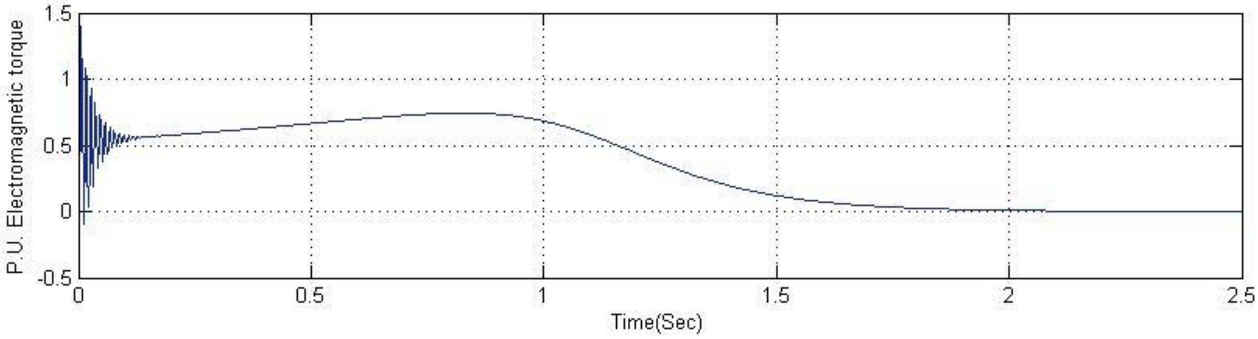

Fig.5:-Electromagnetic torque of 11 kw motor for 20mm depth during free acceleration

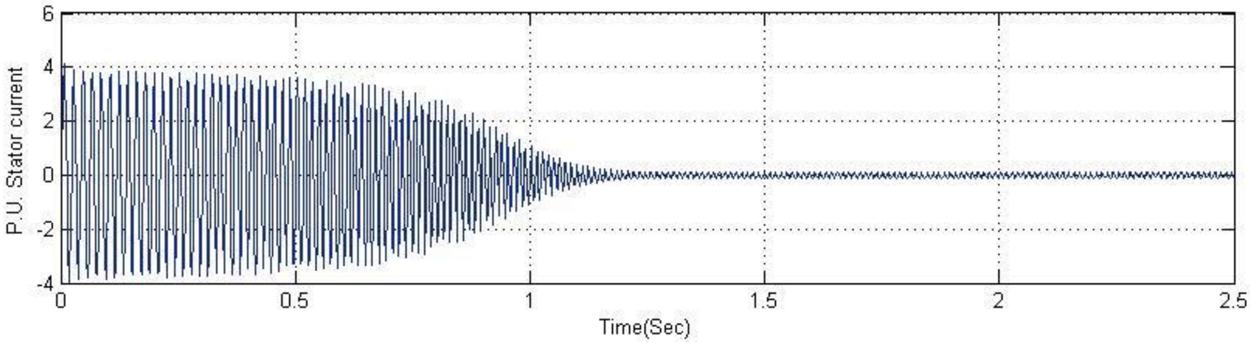

Fig.6:-Stator current of Phase-a of 11 kw motor for 10mm depth during free acceleration

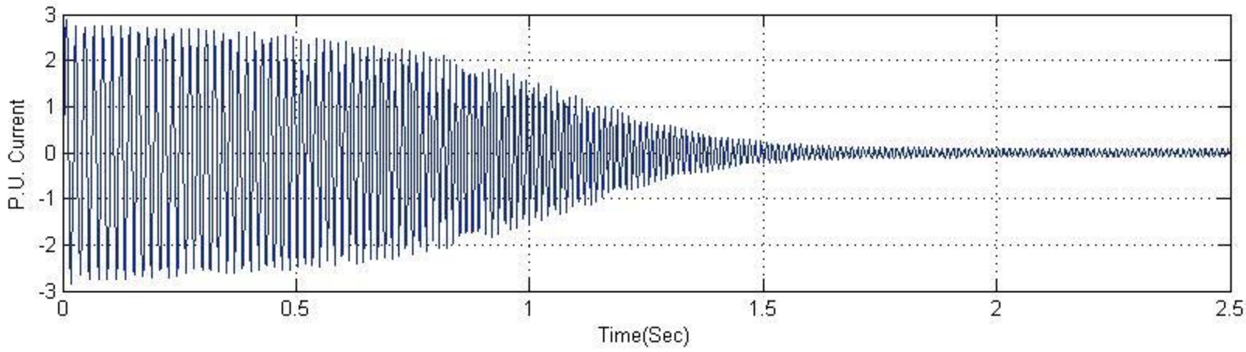

Fig.7:-Stator current of Phase-a of 11 kw motor for 20mm depth during free acceleration

VII. CONCLUSION

In this study, we found that the torque peak and current peak are dependent on design of deep bar of rotor. As depth of bar is increased by keeping constant cross-section area of bar, torque peak and current peak will be decreased. Also it is observed that if saturation effect is considered then torque peak and current peak is low compared to without considering saturation effect. When we consider only deep bar, the peak value becomes 2-3 times than rated value of torque.

REFERENCES

[1] Wood W.S., Flynn F. and Shanmugasundaram A., "Transient torques produced in induction Motors due to switching of the supply", IEE Proc, vol 112. No 7. 1965, p 1348-1354.
[2] C.F. Landy, W. Levy M. McCulloch and A.S. Meyer, "The effect of deep-bar properties when assessing reswitching transient in squirrel cage induction motor" in IEEE Ind. Appl. Soc. Annu. Meeting, 1991, vol.1, pp., 35-39.
[3] Alger P.L. "Induction Machines – Their Behavior and Uses", Gordon and Breach, New York, 1970.
[4] Paul C. Krause, Oleg Wasynczuk and Scott D. Sudhoff, "Analysis of Electric Machinery and Drive Systems". John Wiley & Sons, New York, 2004.
[5] A.K. Sawhney, Dr. A. Chakrabarti, "A Course in Electrical Machine Design", Dhanpat Rai & Co. (P) LTD., 1970.