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Development of An Improved Electromagnetic Braking System of Induction Motor For Domestic And Industrial Safety

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ABSTRACT : *Various accidental situations have been reported in the industries concerning rotating machines powered by electric motors and when emergency stop buttons of the machines are applied, the rotating machines do not usually come to halt immediately, and thus undergoes a retarded rotation until it comes to a halt after some time, thereby helplessly aggravating the danger that is intended to be prevented. In this paper, we present the development of an improved electromagnetic braking system for induction motors which is considered to be more flexible and economical than most frictional brakes in a scenario whereby the need suddenly arises to bring a moving machine to a halt abruptly as a result of emergency in order to prevent an accident. In the developed system, the stationary coil of the induction motor is made to generate a steady magnetic field in the vicinity of the rotor thereby setting up eddy currents in the rotor core and emf in the rotor coil. These combine together to retard the rotating rotor to a halt. The strength of the steady magnetic field created determines the time duration to bring the rotor to a halt after the stop button has been applied. The system was setup experimentally in the laboratory, and tested. Results obtained showed a satisfactory performance and therefore the system is recommended for domestic and industrial use.*

KEYWORDS : *Electromagnet, Brakes, Motor Control, Eddy Current, Rotating Machine.*

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I. INTRODUCTION

Electromagnetic brakes can be eddy-current or regenerative that captures and store the kinetic energy o f a moving object in the form of electrical energy for re-use. This is a more energy-efficient approach than the fr ictional break that merely turn the energy into useless heat. Dynamic braking, on its own is used when energy ne eds to be dissipated periodically, and regeneration is generally preferred when the motor is frequently acting as a generator. From an application standpoint, overhauling loads (a condition where the load is moving faster than t he designated motor speed, such as conveyors and cranes), cause energy to be generated continuously and make recovery and reuse more cost-effective [2]. But applications where the deceleration speed varies, such as fans, ar e suitable for dynamic braking. While regeneration lowers energy usage, dynamic braking reduces wear on braki ng components that rely on friction. And although energy is wasted as heat in dynamic braking, its upfront cost i s significantly less than that of regenerative drives.

In an emergency, when the need arises to brake quickly, the only thing that comes between safe stoppin g and disaster is the simple science of friction, whereby machine slows to a halt when two surfaces rub together. Friction brakes have more than proved their worth and they are applied everywhere like car, bicycle, airplane, a nd most factory machines. But they have a big drawback in that they wear out a little bit by bit every time they a re used. This means they're relatively expensive. Therefore, we think about an alternative, and one option is to sl ow things down with the force of electromagnetism instead of friction. This is the basic idea behind eddy-curren t brakes, which can cost half as much to run over their lifetime as traditional friction brakes [3].

II WORKING PRINCIPLE OF THE IMPROVED ELECTROMAGNETIC BRAKING SYSTEM

It is important to look at the operation of the induction motor that we hope to bring to a halt immediately the source of power is removed. The bulk of the domestic motors and SME machines are single phase and when the ac voltage is applied to the stator of the induction motor, rotating magnetic field (RMF) is set up in the stator winding due to the time varying voltage applied. The stationary rotor allows the creation of relative speed between stator RMF and rotor conductor causing an induced emf in the rotor conductor [5]. Emf is induced in the rotor conductor in accordance with Faradays law of electromagnetic induction. Current flows in the conductors of the rotor through the short circuiting rings at the ends. This current in turn produces a magnetic field. It is the interaction between the rotor magnetic field and the squirrel cage bars that induces the torque and causes rotation [4].

The block diagram of the Improved Electromagnetic Braking system is as shown in figure 1. The frequency of current and voltage in the rotor is scaled down by the value of the slip. If the motor is at standstill, the frequency in the rotor is equal to the frequency in the stator and if the motor is running at exactly at synchronous speed, the frequency is zero [7]

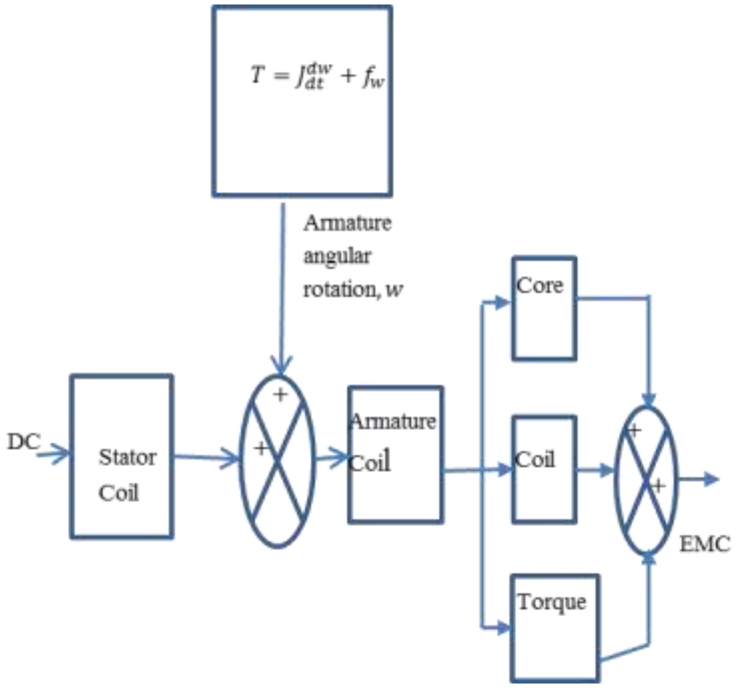

Fig. 1: Block Diagram of Improved Electromagnetic Braking System.

If, f_s is the frequency of the supply voltage and f_x is the rotor frequency then;

Slip (s) $= f_s - f_r / f_s \times 100$ …………… (i)

And, $f_r = sf_s$ ………………………… (ii)

The input power is approximately equal to the converted mechanical power plus power loss in the rotor coil i.e.

$P_{ac} = P_{RC} + P_{cv}$ ………………… (iii)

$P_{ac} = SP_{ag} + (1 - S)P_{ac}$ ……….. (iv)

Where, P_{ag} is the power delivered to the air gap, P_{ac} is the input power from the ac supply to the motor and, P_{cv} is the converted mechanical power.

But,

$$P_{cv} = T\,w$$

Hence,

$T = P_{cv}/w$. ……………………….… (v)

Also,

$T_{ind} = K_m B_R \times B_s$ ………………………… (vi)

Where, T_{ind} is the induced torque, B_R is the rotor magnetic flux density and B_s is the stator magnetic flux density

$P_{cv} = w K_m B_R B_s$ ………………… (vii)

Equation (vii) is the kinetic energy of the rotor that must be overcome immediately the supply power is taken off and replaced with a dc supply.D C voltage to the stator creates steady magnetic field in the stator (depending on the number of pole of the stator coil). The magnetic field created by the stator coil will create magnetic flux in the air gap between the rotor and stator and also linking the rotor. Hence there is no eddy current on the stator core but on the rotor core.

The rotor is rotating at w rad/sec under the influence of the steady magnetic field from the stator coil and will experience an induced current in the rotor coil by Faradays law. The induced current in the rotor coil will set up torque by Lorentz force law that will oppose the rotation of the rotor by Lenzs law.

II. MATERIALS AND METHODS

The following materials were used in the experimental set-up of the improved Electromagnetic braking system of induction motor; two units of digital multimeter, MASTECH MY62, 11Ω-100W Rheostat, 0.5 Hp ac motor,1Hp ac motor, control module (this was constructed), and a stop watch.

The experiment for our Improved Electromagnetic Braking System of Induction Motor was set up. The schematic diagram of which is as shown in figure 2, below. When the switch is closed, the rheostat here is used to set the dc current for motor braking, while the braking duration is observed using a digital stop watch.

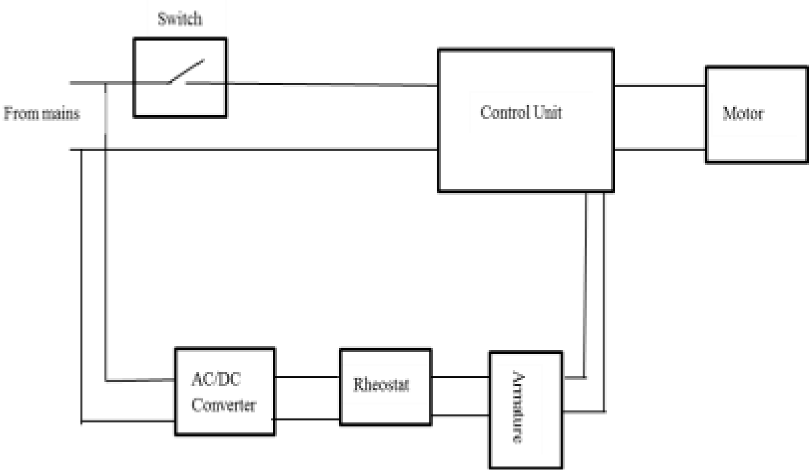

Fig. 2: Experimental Set-Up of Improved Electromagnetic Braking Syatem.

III. RESULTS AND DISCUSSION

The following assumptions are true for the current induced in the rotor coil:

The current induced in the rotor coil will:

I. Set up torque by Lorentz force law that will oppose the rotation by Lenz's law.

II. Opposes the steady magnetic field of the stator

iii Set up eddy current in the stator core

At the switch off of the induction motor and with the 120V dc connected to the stator coil, very strong reverse torque was observed which brought the motor to a halt immediately. The reverse torque generated is greater than the rotor kinetic energy divided by the speed of the motor, i.e.

$$T_{ind} > \frac{P_{cv}}{w}$$

i.e $T_{ind} > WK_m B_R B_s$

The effectiveness of the torque produced by Lorentz force law is dependent on the dc current flowing into the stator coil.

It then follows that if rotation of the motor is caused by the relative speed between the stator magnetic field and the rotor conductors then,

$(w_s - w_r)K = T_m$ …………………… (ix) Where w_s is the angular frequency of the stator magnetic field and w_r is the angular frequency of the rotor conductors.

When rotor is stationary,

$w_s > w_r$,

Then, T_m is positive and the motor accelerates.

When the ac is replaced with dc current and voltage, then,

$w_s = 0$………………………………… (x)

And, equation (ix) becomes

$$T_m = -Kw_r$$

The torque now is not the one created by the alternating magnetic field in stator since $W_s = 0$, but the one induced by a rotating rotor in a steady magnetic field of the stator. So we call this negative torque or induced torque T_{ind}. And $T_{ind} = KW_r$

Therefore, negative torque is develop which is greater than P_{cv}/w, see equation v and so, the motor comes to a halt instantly.

Torque Set up by Lorentz force

Though the coil in the rotor is arranged in squirrel shape and will take the shape of a parallelogram. If the separation of the edges of the parallelogram is d, then

$T = 2\,|F|\frac{d}{2}\,sin\,\theta$……………………… (xi)

but,

$|F| = |B|il$…………………………… (xii)

where, i is the current flowing in the opposite direction on the two sides of the coil, and l is the length of the wire perpendicular to the magnetic field, therefore equation (xi) becomes,

$T = |B|ild\,\sin\theta$……………….......... (xiii)

Assuming there are N even number of slots carrying conductor, then ,

$T = \frac{N}{2}|B|ildsin\theta$…………………….. (xiv)

$Tm = -Kwr$

$= -Kwr = \frac{N}{2}|B|ildsin\theta$

$T_{ind} = -Kwr = \frac{N}{2}|B|ildsin\theta = K_m\mathbf{B}_R\mathbf{B}_S$

T_{ind} can be made higher than the T_m for effective and instant breaking by increasing the amount of d.c current flowing into the stator coil thereby increasing the steady magnetic field generated in the stator B_s.

It follows that when the a.c supply to the motor is turned-off, the d.c current is applied to the stator coil. The armature of the motor is at steady state speed and possesses kinetic energy given by,

$E_{k(m)} = \; = kT_{ind}$ ………………..…….. (xv)

Where, E_{km} is the kinetic energy of the motor, and KT_{ind} is the torque developed in the motor core respectively.

The kinetic energy was generated by a combination of electric and magnetic energy, and to bring the armature to a halt, the factor, $E_{k(m)}$, must be brought to zero.

The magnetic energy through the d.c current will combine with the kinetic energy of the armature and produce electrical energy that will generate reverse torque; to bring the armature to a halt abruptly.

Hence,

$E_{k(m)} + E_m \; = E_E$…………………… (xvi)

emf is induced in the rotor coil due to the rotational effect of the rotor and the kinetic energy will be converted into electrical energy, at that instance, the motor works like a generator.

The kinetic energy of the rotor is thus converted into electrical energy through the magnetic energy from the d.c current drawn resulting from the source. So the rotating energy of the rotor is converted into breaking energy.

Eddy current is induced in the stator core, the stator core is a conductor though laminated with insulator. When the rotor is on steady state speed at the instance of 'switch-off' of the driving force from the ac supply. The rotor continues to rotate in a steady magnetic field created by the dc current flowing through the stator winding, electric current will be induced in the core but instead of flowing off somewhere, they swirl about inside the materials, thereby dissipating their energy as heat. The contribution of Eddy current is insignificant as the breaking torque. Lorentz force effectively reduces breaking time drastically.

IV. CONCLUSION

Incorporating a dc interrupt at the instance of switch-off of an induction motor across the stator winding will ensure instant stoppage of the rotating machine at switch-off. This will prevent and assist in eliminating domestic and industrial hazards to humans that is saddle with the usage of such industrial machine. There will be no significant additional cost to implementthis improved modification to the existing domestic motors but the benefit made it worth -while implementing

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