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A Novel and Laudable Advent of Intelligent Soft Starting Technique in Three Phase Induction Motor for Industries

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Abstract— **This paper presents a novel soft starting technique of the Squirrel Cage Induction Motor (SCIM). This is used to start the three phase Squirrel Cage Induction Motor and adjust its stator voltage. At the time of starting the three phase SCIM is subjected to both mechanical stress and electrical stress due to the high torque and large inrush current, which is seven times greater than the rated current. In order to overcome these effects, the supply voltage is to be controlled and the starting current must be at safe level. The paper systematically investigates and compares the characteristics of control techniques like Direct On Line Control (DOL) and Extinction Angle Control (EAC) by adjusting the firing angles of the MOSFET switches. The results are obtained and the vital parameters were compared by the way of MATLAB/SIMULINK based simulation. The result shows that both torque pulsations and inrush current were reduced substantially at the time of starting.**

Keywords-inrush current; electrical stress; Direct On Line Control; Extinction Angle Control.

I. INTRODUCTION

The three phase induction motors are also called as asynchronous motors, which are most commonly used type of motor in industrial applications. In particular the SCIM are widely used electric motors in home and industrial applications.

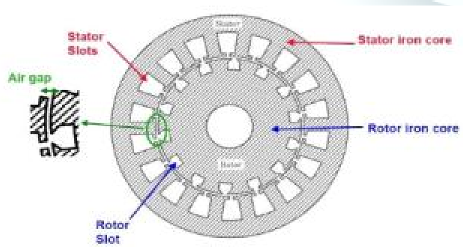

Fig.1.Construction of SCIM

The rotor is the rotating part of the induction motor and is mounted on the shaft of the motor to which any mechanical load can be connected as shown in figure 1. Almost 90% of induction motors are squirrel cage motors. This is because the squirrel cage motor has a simple and rugged construction. Squirrel cage motor consists of cylindrical laminated core with axially placed parallel slots for carrying rotor conductors.

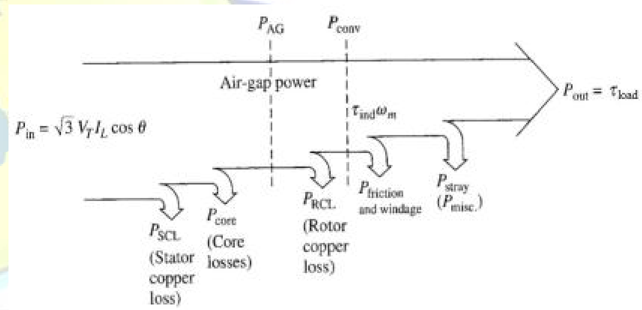

Fig.2.Powerflow of SCIM

Torque produced by three phase induction motor depends upon the following three factors. Firstly the magnitude of rotor current, secondly the flux which interact with the rotor of three phase induction motor and is responsible for producing emf in the rotor part of induction motor, lastly the power factor of rotor of the three phase induction motor as shown in the figure 2 .

Maximum Torque Condition for Three Phase Induction motor is

$$T = \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2} \times \frac{3}{2\pi n_s} \qquad (1)$$

The rotor resistance, rotor inductive reactance and synchronous speed of induction motor remain constant according to equation 1. The supply voltage to the three phase

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Induction motor is usually rated and remains constant, so that the stator emf also remains constant. The transformation ratio is defined as the ratio of rotor emf to that of stator emf. So if stator emf remains constant then rotor emf also remains constant. 3-phase induction motor is practically self starting. The stator of an induction motor consists of 3-phase windings, which when connected to a 3-phase supply creates a rotating magnetic field. When the induction motor is directly switched, it takes five to seven seconds time their full load current and develops only 1.5 to 2.5 times their full load torque. The initial excessive current is objectionable because it will produce large line voltage drop that, in turn, will affect the operation of other equipment connected to the same lines.

II. METHODOLOGY

A. *Direct On line Control*

Different starting methods are employed for starting induction motors because Induction Motor draws more starting current during starting. To prevent damage to the windings due to the high starting current flow, we employ different types of starters. The simplest form of motor starter for the induction motor is the Direct On Line starter. The DOL starter consists of a Circuit Breaker, Contactor and an overload relay for protection as shown in figure 3.

Features of DOL starting

- Three connection lines
- High starting torque
- Very high mechanical load
- High current peaks
- Voltage dips

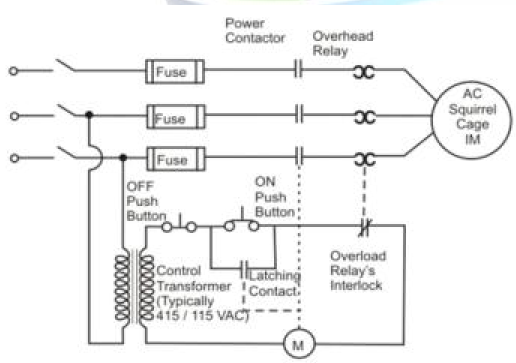

Fig.3 Topology of DOL starter

When supply voltage is not sufficient or there is failure of power supply, the coil is de-energized and motor will be disconnected. The motor is protected against overload by a thermal overload relay which open circuits the control circuit when overload occurs. The normally closed contacts are opened and the contactor coil is de-energized to disconnect the motor from the supply. Rate of temperature is very high so motor may be damaged if the starting period is large.

B. *Extinction Angle Control*

Extinction Angle Control is used in connection with a controlled rectifier. It refers to the time interval from the instant when the current through an outgoing thyristor becomes zero (and a negative voltage applied across it) to the instant when a positive voltage is reapplied. It is expressed in radians by multiplying the time interval with the input supply frequency (ω) in rad/sec. The extinction time (γ/ω) should be larger than the turn off time of the thyristor to avoid commutation failure.

The value of β is calculated for fixed value of γ using following relation

$$I_d = \frac{\sqrt{3}Eph}{2\omega L}(\cos\gamma - \cos\beta) \tag{2}$$

In the present work, the Extinction Angle Control technique aimed at improving the poor power factor of industrial drives is being investigated. The non-sinusoidal nature of the input current drawn by the rectifier increases reactive power, input current harmonics and input voltage distortion. This can be overcome by Extinction Angle Control as shown in figure 4. Three-phase power converters with more commutations per half cycle is proposed for ac power due to the increasing availability and power capability of high frequency controlled-on and off power semiconductor switching devices.

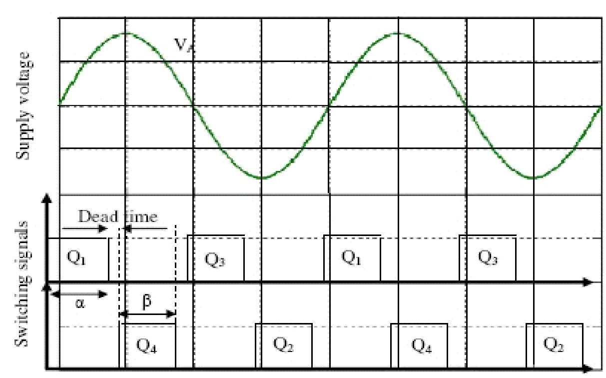

Fig.4 Topology of EAC

As majority of the industrial loads are being inductive, the power factor is less. To improve the power factor, the delayed current is shifted to the input voltage, through a modification of the classical sinusoidal pulse width modulation switching technique.

In this way, the decrease in the phase angle between the input current and voltage is feasible, and consequently, high cost compensation capacitors can be avoided.

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III. MATLAB/SIMULINK SIMULATED RESULTS AND DISCUSSION

The simulation research for the proposed system is carried out using the matlab/simulink.

The motor investigation is

Power -10HP (7.5KW)

Voltage input- 400V

Frequency -50Hz

Speed -1440RPM three phase squirrel cage induction motor.

A. *Open Loop Control*

In open loop control technique the conventional soft starter of DOL control and Extinction Angle Control techniques was combined to get smooth characteristics. And it is compared with the closed loop control technique by fuzzy logic controller. In DOL control technique at the time of starting rated voltage is applied to the motor at the full load condition. By comparing these two techniques, performance of following parameters were obtained, which are Current, Speed, Torque, THD, Power factor.

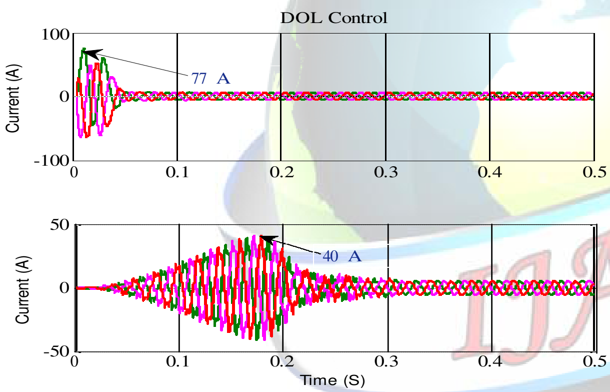

Fig.5 stator current comparison

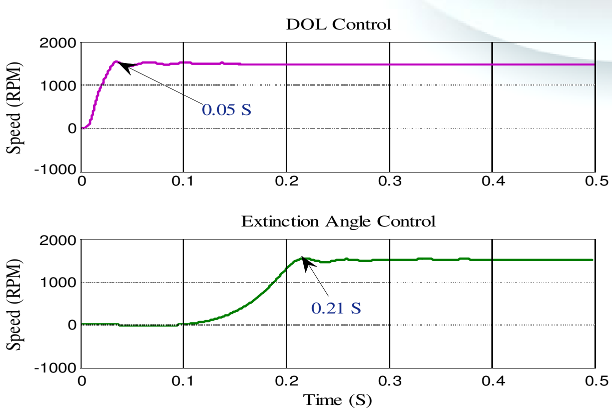

Fig.6 Time to reach steady state comparison

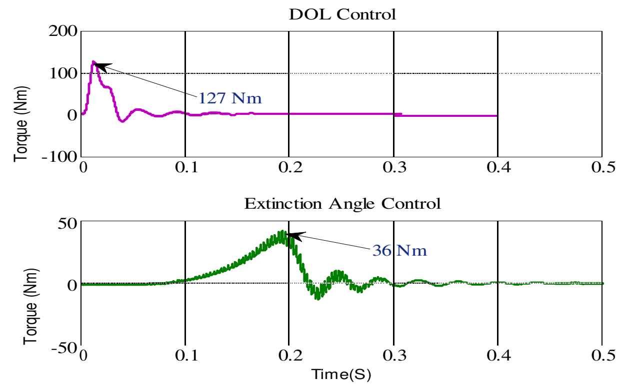

Fig.7 Torque at starting instant comparison

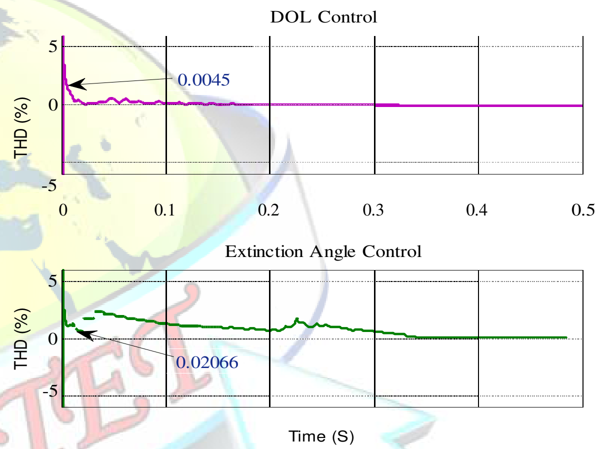

Fig.8 THD Comparison

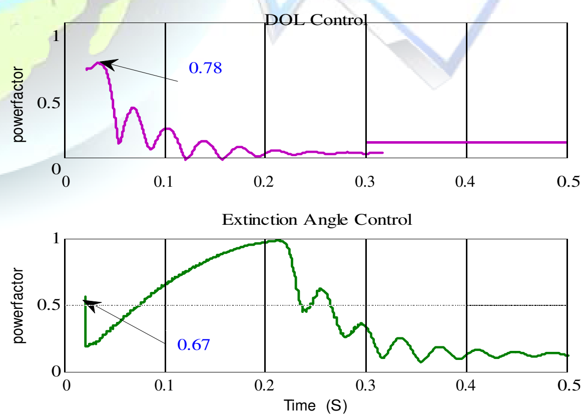

Fig.9 Power factor Comparison

In Extinction Angle Control technique repeating sequence is the important factor to control the firing angle.

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For an Extinction Angle Control left handed slope is used in repeating sequence. Figure 5 shows the starting current is controlled as 38 amps so that it has lower acceleration at the starting condition. In the case of extinction angle control the acceleration is gradual and figure 6 shows the motor takes a longer period to reach the rated speed. Extinction angle scheme offers much smoother starting characteristics. Figure 7, 8, 9 shows the torque, THD level of SCIM and power factor.

For the DOL control technique at the time of starting, current is very high (approximately 7 times greater) than rated current. By using these techniques in open loop control high inrush current and large torque ripples are neglected. Figure 5 show the torque developed by the motor exceeds the load torque at all speeds during the start cycle and the motor will reach full speed. The maximum average torque is initially larger for duty cycle at 25% and for switch 2 duty cycle is 20%. Step input gives larger time taken to reach the rated speed and high torque at the starting condition.

B. Closed Loop Control

In closed loop control system fuzzy logic controller is used. For the fuzzy logic controller mamdani model is used to create the rule matrix and surface. There are 25 rules to control the firing angle by varying the speed and current.

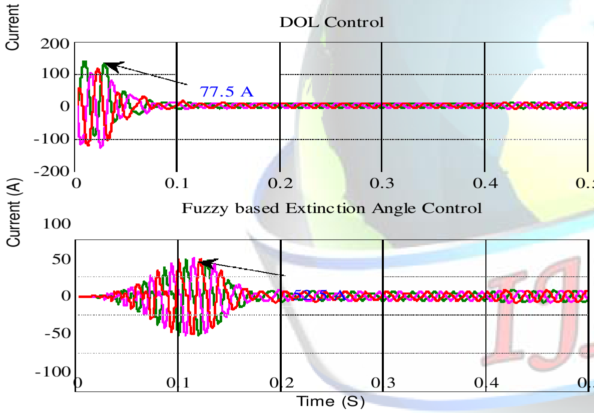

Fig.10 stator current at starting period

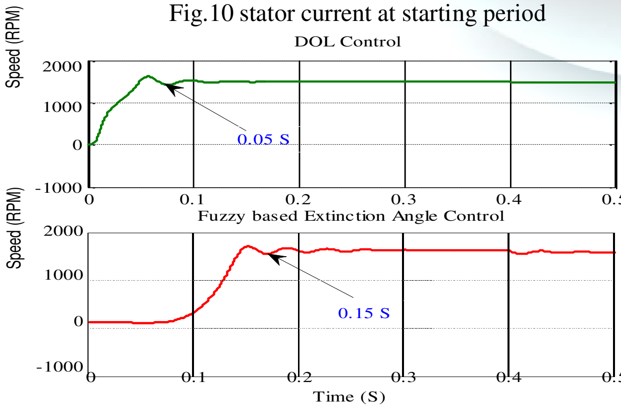

Fig.11 Time taken to reach steady state

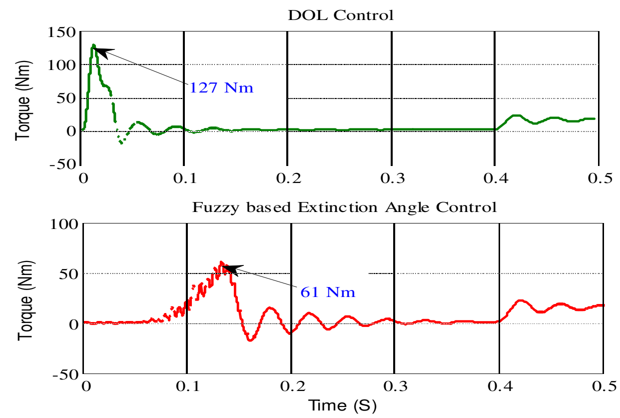

Fig.12 Torque at starting instant

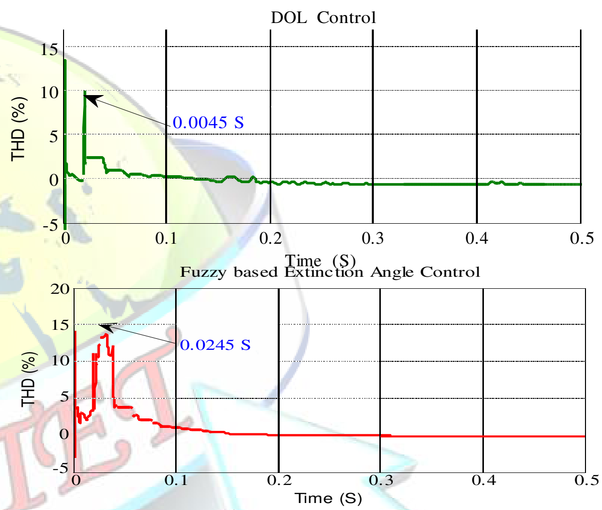

Fig.13 Total Harmonic Distortion

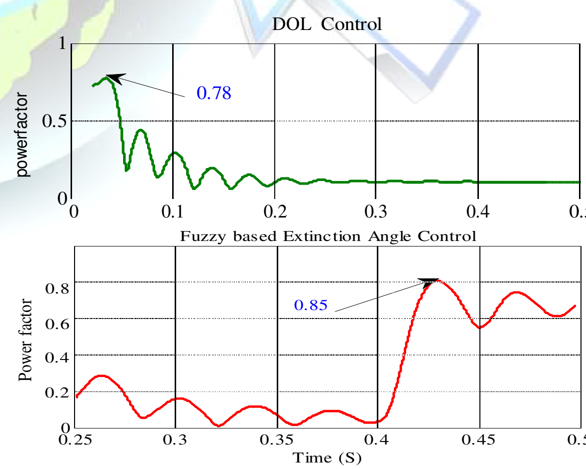

Fig.14 Power factor

Figure10,11,12,13,14 shows the comparison between the starting current of the SCIM and time to reach the rated speed, Torque at the starting instant, THD ,power factor of the squirrel cage induction motor.

IV. CONCLUSION

In this paper, novel soft starter topology for the SCIM has been carried out. By comparing the DOL starter and Extinction Angle Control in open loop and closed loop control system following parameters was obtained stator current, time taken to reach the rated speed, torque at the starting instant, THD and power factor. In closed loop control fuzzy logic controller is used. Compared to open loop control, closed loop control improves the response of induction motor. The efforts have been devoted to develop methods to reduce the time spent on optimizing the choice of controller parameter. The extension of the work can be used to frame an innovative methodology using Adaptive Neuro Fuzzy Interference System (ANFIS) for the expedite future.

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