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ANN - Based Starting Scheme for Three Phase Induction Motor with Reduced Inrush Current

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Abstract: The objective of this paper is to increase the power quality and to reduce the starting current of the three phase Induction Motor. The new starting scheme of Extinction Angle Control (EAC) is implemented to improve the conventional performance of starter. The new Extinction Angle Control starting scheme is divided into two categories, open loop method and closed loop method. The studies are first focused with open loop advantages of EAC and then with the closed loop advantages of EAC using ANN. In open loop method, based on the firing angle of MOSFET, this starting scheme control the current and speed. In closed loop method, ANN generates the appropriate MOSFET firing angle for any given operating torque and speed of motor. MATLAB/SIMULINK results clearly show EAC advantages. When compared to open loop method, closed loop method gives reduced harmonics, inrush current and improves power quality.

Keywords: AC voltage controller; Artificial Neural Network(ANN); firing angle; induction motor; soft starter; MOSFET.

I. INTRODUCTION

Induction motors are widely used in industries because of its simplicity, ruggedness, less weight, high efficiency, low maintenance and low cost for same power rating. The problem of induction motor is high starting current during starting period. This high inrush current cause adverse effects on Induction Motor and reduces the motor life. Soft starters are introduced to reduce high inrush current. Conventional soft starters such as DOL, Star-delta starter, Auto transformer starter, magnetic starter are used to control starting current.

In DOL starting method, the current flow directly on to the contacts of the motor. So medium and large induction motors draw large current and also it makes the temperature of motor become higher which may lead to motor damage.

The other conventional soft starters perform smooth acceleration during the starting period. Hence it controls the speed and torque of the induction motor. Soft starters reduce mechanical stress and reduce stress on the electrical supply due to low starting current. The reduced inrush current eliminates the voltage dip and saves energy under light load conditions.

The drawback of the conventional soft starter is that, the output quality of starter is poor with high distortion and poor power factor. But the DOL starter has advantage over this, it consists of fewer harmonic, improved power factor and it eliminates torque pulsations.

This paper deals with the study of EAC starting scheme for open loop and closed loop control, then the results are compared with the DOL control. Simulation of matlab clearly shows the advantage of EAC. The disadvantage of phase angle control is retarding of firing angle causes lagging power factor. Moreover discontinuity also occurs.

The intelligent technique ANN used in this paper performs harmonic reduction, less starting current and eliminates starting torque pulsations better than the open loop method by triggering the firing angle. The proposed ANN has been trained and tested with matlab simulation.

II. OPEN LOOP METHOD

When electrical equipment is first turned on, a large current flow that exceeds the steady state current value is called inrush current. In equipment with large capacity smooth capacitors or decoupling capacitors, when power is first turned on, a large current flows through to change those capacitors a necessity when first powering up the equipment. Immediately after the power is turned on, the filament and other parts have low resistance, and large current flows and the current drops to steady state current. To limit inrush current the voltage of the stator has to be reduced. By varying MOSFET firing angle the starting current get reduced.

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Open-loop system, also referred to as non-feedback system, is a type of continuous control system in which the output has no influence or effect on the control action of the input signal. In other words, in an open-loop control system the output is neither measured nor "fed back" for comparison with the input.

This paper compares DOL control and Extinction Angle Control in open loop method. The new starting scheme of Extinction Angle Control performs reduction of harmonics and improves power factor. Harmonic voltages and currents in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors.

Total harmonic distortion (THD) is a common measurement of the level of harmonic distortion present in power systems. THD is defined as the ratio of total harmonics to the value at fundamental frequency.

$$THD = \sqrt{\sum_{h=2}^{h=H}\left(\frac{Y_h}{Y_1}\right)^2} = \frac{\sqrt{Y_2^2 - Y_3^2 + \ldots + Y_H^2}}{Y_1} \qquad (1)$$

Power factor is improved by reducing the phase difference between voltage and current .The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power and it is a dimensionless number in the closed interval of-1 to 1. The power factor of less than one means that the voltage and current waveforms are not in phase reducing the instantaneous product of voltage and current.

$$\text{Power factor} = \frac{P}{S} = \cos\phi \qquad (2)$$

$$\frac{\text{Active power (in watts)}}{\text{Apparent power (in volt amperes)}} = \text{Power factor} \qquad (3)$$

A. DOL Starter

DOL starter does not have any components to control the starting current. It performs over voltage protection and overload protection. This is the most simple and inexpensive method of starting a squirrel cage induction motor. The motor is switched on directly to full supply voltage. The initial starting current is large, normally about 5 to 7 times the rated current but the starting torque is likely to be 0.75 to 2 times the full load torque. To avoid excessive supply voltage drops because of large starting currents the method is restricted to small motors only.

B. Extinction Angle Control

Extinction Angle Control is a scheme of forced commutation for power factor improvement in phase controlled converters. By varying the value of extinction angle one can get the desired load voltage and current waveform. It is just opposite to the phase angle control, the firing angle is given at the turn off period of power semiconductor switches.

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.

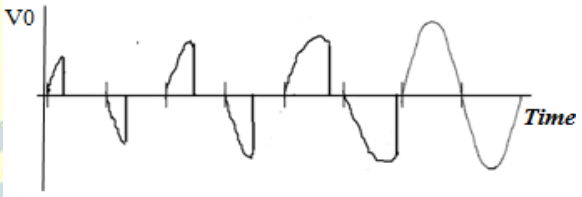

Fig.1. Performance of EAC

At the starting period, the phases are cut by the firing angle so the sinusoidal waveform gets distorted. After sometime it reaches the pure sinusoidal waveform. Hence it reduces the starting current of induction motor. Figure1.shows the reduction of stator voltage during starting period for a particular time.

III. Closed Loop Method

A closed loop control system known as an automatic control system which uses the concept of an open loop system as its forward path but has one or more feedback loops .They are more accurate than open loop system due to their complex construction. In this paper, ANN is used as closed loop control to perform better reduction in inrush current. It is a nonlinear model that is easy to use and understand and then compares to other methods. ANN with back propagation learning algorithm is widely used in solving various classifications and forecasting problems. Advantages of ANN are adaptive learning, Self organization, real time operation and fault tolerance via redundant information coding.

A. Artificial Neural Network

ANN usually learns by examples. If ANN is supplied with enough examples, it should be able to perform classification and even discover new trends. Basic ANN is composed of three layers, input, output and hidden layer. Each layer can have number of nodes and nodes from input

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layer are connected to the nodes from hidden layer. Nodes from hidden layer are connected to the nodes from output layer. Those connections represent the weights between nodes.

The aim is to reduce the inrush current of induction motor. Back propagation algorithm is used in this paper to perform low starting current as well as reduced torque of the three phase Induction Motor. Here the inputs are speed and current the output is the appropriate firing angle. For every input it creates firing angles to perform smooth acceleration. If results are not satisfactory, connection (weights) between layers are modified and process is repeated again and again until it reaches reduced starting current, improved power factor and reduction of harmonics.

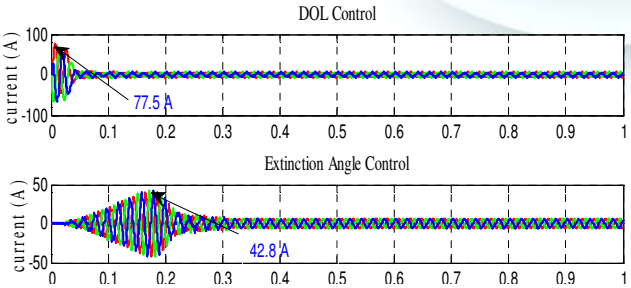
When training ANN, we are feeding network with set of examples that have inputs and desired outputs. If we have some set of 1000 samples, we could use 100 of them to train the network and 900 to test our model. Choosing the learning rate and momentum will help with weight adjustment. In this paper ANN is trained from fuzzy logic.

IV. RESULTS AND DISCUSSION

By using MATLAB/simulation model of DOL control, Extinction Angle Control, ANN Extinction Angle Control, the results are taken and compared. It clearly shows the advantage of open loop and closed loop control of Extinction Angle Control.

B. Stator current

In DOL control, starting current is 77A, which is not suitable for Induction motor. In open loop EAC starting current reduced up to 50% and in closed loop control starting current reduced up to 55%. The reduction of current in all three categories results shown in figure2.ANN EAC gives the desired reduced current.



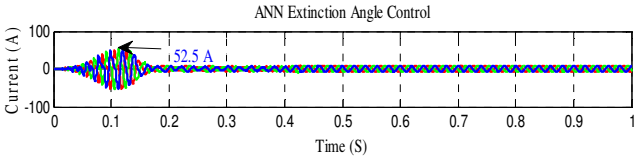


Fig.2. Starting current for DOL, EAC and ANN EAC

C. Time taken to reach rated speed

In DOL control, motor suddenly reaches the maximum speed and does not perform smooth acceleration. EAC performs smooth acceleration and it reaches maximum speed at the time of 0.2 sec but the other soft starters take some more time to reach the maximum speed. ANN Extinction Angle Control reaches the maximum speed in 0.15sec which is better than the open loop control. Figure.3.Shows the speed comparison for all three categories.

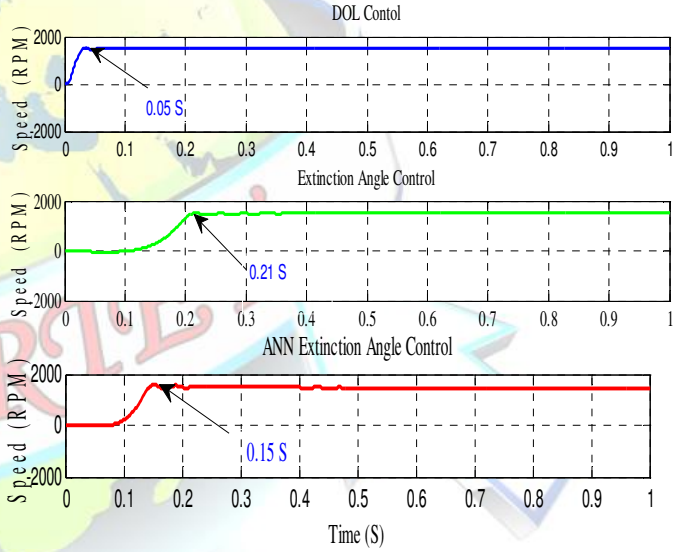


Fig.3. Time taken to reach rated speed for DOL, EAC and ANN EAC.

D. Maximum torque during starting

Starting torque of induction motor should be in minimum because torque proportional to the speed of the induction motor .DOL control torque is 127 Nm. Open loop control reduces torque up to 36 Nm and closed loop control reduces up to 60 Nm. It clearly shows the closed loop control advantages.

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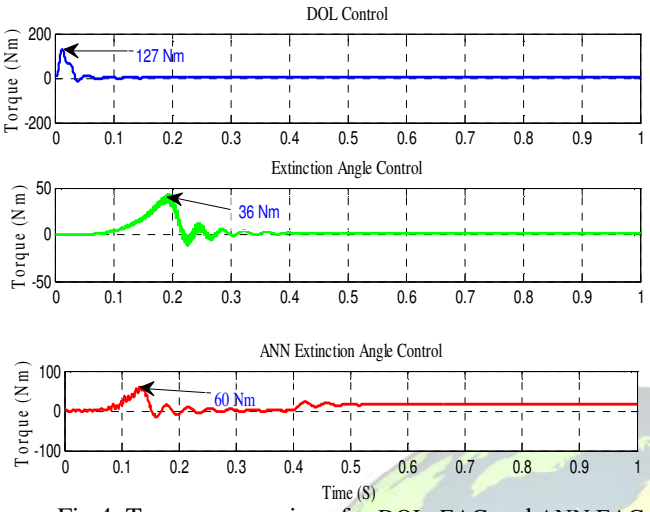

Fig.4. Torque comparison for DOL, EAC and ANN EAC

E. *Total Harmonic Distortion*

THD is used to characterize the linearity of the power quality of electric power systems. When compared to all other soft starters DOL consists of fewer harmonic. In this, ANN EAC reduces harmonics better than other soft starters.

F. *Power Factor*

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred.

The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment .When compared to all these three starting schemes closed loop control of EAC gives better power factor. Figure.6 shows the increased power factor in Extinction Angle Control.

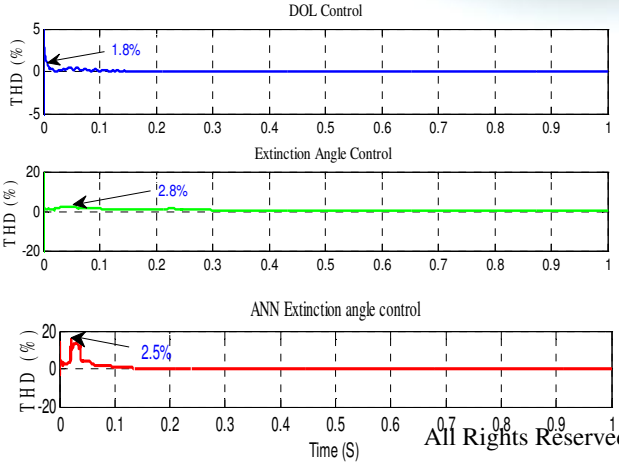

Fig.4.THD comparison of DOL, EAC and ANN EAC

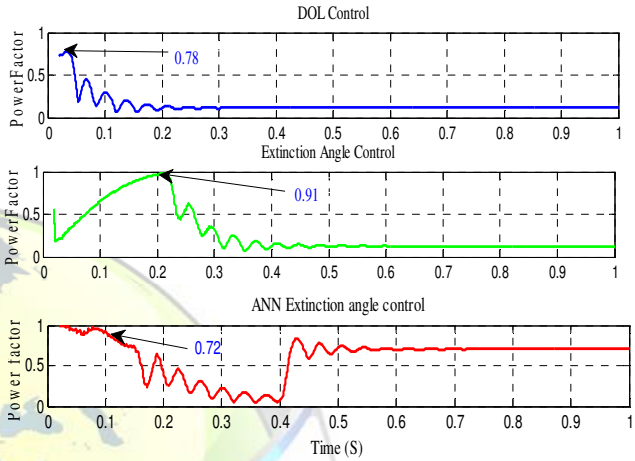

Fig.6.Comparison power factor of DOL, EAC and ANNEAC

IV. CONCLUSION

In this paper, the advantages of open loop method Extinction Angle Control has been focused at first and then with closed loop method of ANN-based Extinction Angle Control. When compared to open loop control, closed loop control results are better in reducing inrush current, time taken to reach rated Speed and reduction of harmonics. In future, ANFIS technology will be used for better results in reduction of stator current, increase power quality and to eliminate torque pulsations.

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