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ARTIFICIAL NEURAL NETWORK BASED SOFT-STARTER FOR INDUCTION MOTOR - A REVIEW

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Abstract—The necessity of soft-starter is increasing day by day to reduce the starting current & to maintain the torque smoothly according to the load requirement. Now intelligent soft-starter is developed to improve the performance of conventional starter. This paper focused on the designing of an artificial neural network controlled soft-starter .Back-propagation algorithm is used as learning algorithm in the artificial neural network. Error correcting capability of this learning algorithm makes it more suitable to use in neural network. For comparative performance analysis two different types of back propagation algorithms are used in the neural network learning process. According to condition of learning rate parameter gradient descent with momentum back-propagation algorithm provide better response. A comparative study between conventional starting method (Direct on Line) and proposed soft-starter. Artificial Neural Network controlled soft-starter is able to reduce starting current compared with DOL method & able to accelerate the load at starting period efficiently compared with star-delta starting method.

Keywords - ANN, Soft-starter, back propagation etc.

I. INTRODUCTION

In recent years with the development of the industrialization and the need of electrical system for manufacturing processing of the goods are taking more attention for use of efficient & easy controllable equipment. Electrical machine are one of the most common in industries. Induction motor (IM) is replacing the traditional motor like DC or Synchronous motor due to their features like low cost, rigid construction & easy control mechanism in the industrial processing. Controlling their speed, torque & current are taking much more attention in the research and development. Today's Induction motor starting is the most challenging task.

The starting process of induction motor effects on the entire power system adversely. Due to the rapid technological progression the application of the power electronic devices & AC drives are increasing day by day. To maintain the power system quality, appropriate starting technique should be used otherwise electrical network fluctuation may be occurred which affects the all running electrical & electronic devices that are connected to the victim power system. During the choice of starting methods some factors need to be considered which are inrush current, torque, voltage dip, acceleration time, frequency dip, robustness, cost, reactive power & starting power factor. There are different types of starting techniques such as Primary resistor, Star-delta, Auto transformer etc.. These starting techniques are not enough to reduce the inrush current . To overcome this problem soft starter becomes useful to start up the motor smoothly. The torque can be adjusted according to the condition of loading.

Today it is needed to start motor more smoothly according to the variation of the load in order to avoid unwanted situation. Although soft starter performs better than conventional starting systems to start motor smoothly, it has also some drawbacks that makes it imperfect to the application where smooth starting with different loads is the big concern. To overcome the problems of conventional soft- starter, intelligent soft-starter is being used .The intelligent soft-starter should have the ability to adapt to a new environment & to changes in the current environment, the ability to acquire knowledge from the environment, capacity for reason & abstract thought, ability to evaluate & judge. The features mentioned above makes the soft-starter intelligent to start motor so smoothly with variation of loads that desired response can be achieved without any mechanical hazards.

The big revolution in the control scheme comes with the application of intelligent algorithms in the control system. Soft- starter of an Induction Motor (IM) using Neural Network (NN) based Feedback Estimator can control the inrush current & adjust the firing angle of thyristor for a specified load. This ANN based controller have two inputs (torque & speed) & single output (firing angle) [3]. Soft starting of an induction motor using adaptive neuro-fuzzy inference system reduces the inrush current & vibrations in the output torque. This controller uses artificial neural networks (ANN) & adaptive neuro-fuzzy inference system (ANFIS) based intelligent techniques for the selection of the firing angle of the thyristor of the voltage controller fed induction motor and moreover the speed characteristics is not good enough compare to reference speed [2]. Soft-starting of induction motors using ANN & adaptive neuro-fuzzy inference system uses ANN estimator to adjust the firing angle of thyristors of AC voltage controller under different

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loading conditions. This soft-starting system eliminates pulsations in the developed torque & controlled inrush current significantly .

II. NN BASED INTELLIGENT SOFT-STARTER

Our developed system composed of five main parts which are supply unit, thyristor unit, synchronization unit ,synchronized pulse generator & artificial neural network controller. Fig.-1 shows the design flowchart. Six back to back thyristors are fired by a pulse generator. The thyristor unit is placed between thes apply and Induction Motor. A synchronization unit gives the information about the supply voltage's phase and frequency according to which thyristors gets fired. The Artificial Neural Network (ANN) Controller gives the gate delay to pulse generator. According to the control signal the power flow to the motor is controlled hence the starting current is reduced. We used artificial neural network based controller that makes the soft-starter intelligent.

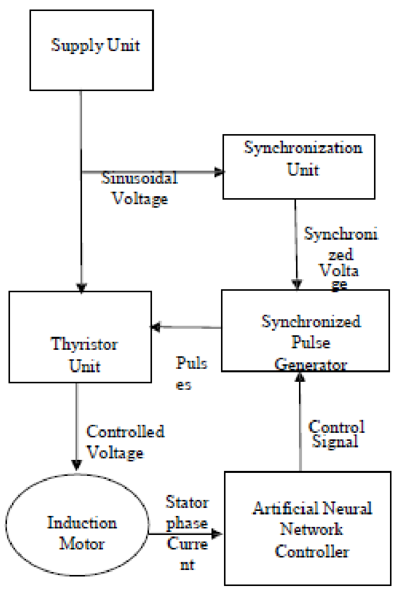

Fig.1. Functional Representation of the control process.

A. Supply Unit

We used three AC voltage source for three phase supply each have 330V peak amplitude that provide 233Vr.m.s phase to neutral voltage. The three phase supply unit is given in figure-2

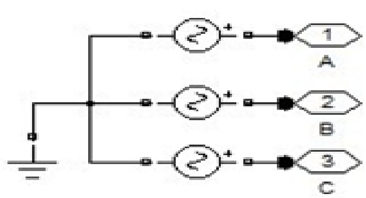

Fig. 2 Simulation model of three phase supply unit.

B. Synchronization Unit

The function of synchronization unit is to provide three line to line synchronization voltages for synchronized pulse generator. These synchronization voltages are made from supply end by building delta loop with using voltage measurement blocks. The output voltages of the synchronization unit are connected to the six synchronized pulse generator. The simulation model of synchronization unit is shown in figure-3

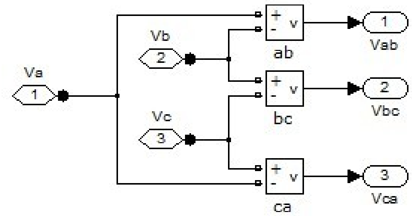

Fig.3. Simulation model of synchronization unit

C. Synchronized Pulse Generator

The thyristor unit consists of six back to back thyristors shown in Fig.4. We configured our pulse generator to function in double pulsing mode & 60 degrees pulse width. In double pulsing mode, two pulses are provided for each thyristor; after reaching delay angle (alpha degree) the first pulse is sent, then 60 degree later the second pulse is sent.

It is important to note that, the delay angle (alpha degree) of the pulse generator is supplied from the intelligent controller. The intelligent controller controls the starting voltage & current by providing appropriate delay angle. The simulation model of the six pulse generator is shown in figure-4. Figure-5 shows Generated six gate pulses for 'trained' training function by the synchronized 6 pulse generator.

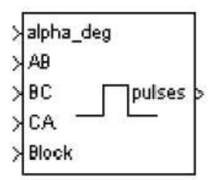

Fig 4 Simulation model of synchronized six pulse generator

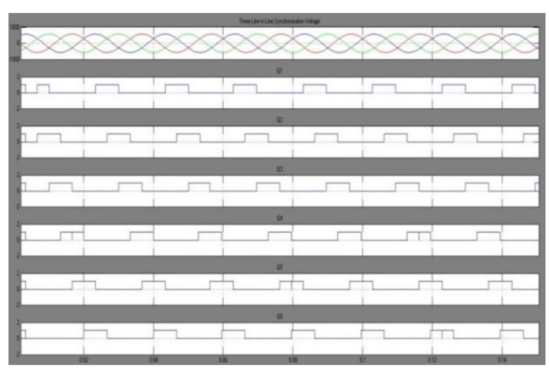

Fig. 5. Generated six gate pulses for 'trained' training function by the synchronized 6 pulse generator.

D. Thyristors Unit

This unit consists of three pairs of back to back thyristors. Each pair of back to back thyristor is connected in series with single phase supply; other end

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of back to back thyristor connection is connected in series with motor terminal.

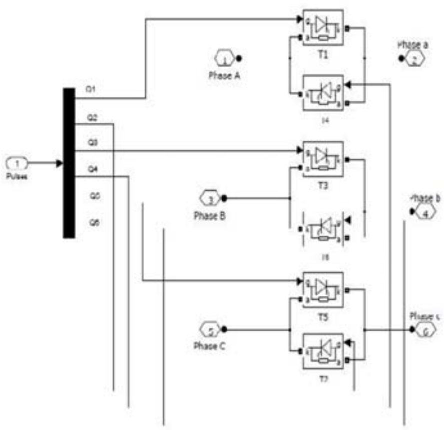

Fig.6. Simulation model of three pairs of back to back thyristors

Figure-6 shows the back to back connection of six thyristors. The gate pulses of the thyristors are provided by synchronized six pulse generator that describes previous section. The thyristor is a semiconductor (power electronics) device that can be turned on via a gate signal (gate pulses). The series snubber circuit is connected in parallel with each thyristor. The value of snubber resistance (Rs) is set to 500ohm & snubber capacitance (Cs) is set to 250e-9F. Snubber circuit has been used to give a dv/dt protection.

E. Neural Network Controller

During starting period, intelligent controller provides delay angle of α = 30.06 degree; pulses are generated after zero crossing of the line to line voltages. This delay angle (α = 30.06) is constant for 0 to 0.05 second, then from 0.05 to 0.1 second the delay angle α = 22.35 degree remains constant, α = 21.11 degree is constant for time 0.1 to 0.15 second; α = 25.31 degree is constant for 0.15 to 0.2 second & so on. According to these delay angles, the gate pulses are shifted & according to these gate pulses the thyristors are fired. Figure-7 shows the control signal (delay angel) generated by ANN controller.

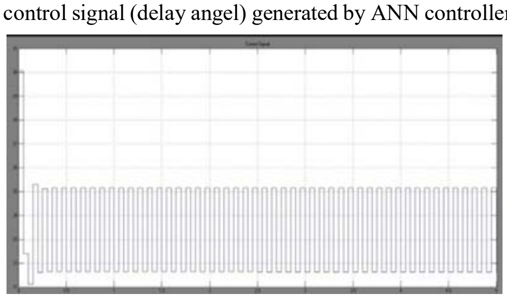

Fig.7. Control signal (delay angle) generated by NN controller.

III. ARTIFICIAL NEURAL NETWORK

Artificial neural network' formed in a manner based on biological neural network. Basically the artificial neural network is the mathematical model or the computational model consists of artificial neurons where neurons are interconnected in a group. Biological neural network consists of real biological neurons which are connected according to the information supplied through in the nervous system; in the area of neuroscience they are formed groups that perform a particular physiological task. On the other hand, artificial neural network made up of interconnecting artificial neurons which have the properties of biological neurons. In the artificial neural network, information processing is done by the connectionist that approach to computation. Artificial neural network may change its construction external or internal way that flow through the network during learning period. We used 'model reference control' neural network toolbox from MATLAB which act as an artificial neural network based controller. The controller structure uses two neural networks one is controller network & other is plant model network. Figure-8 indicates the internal connection between two networks. At first, plant models is identified. Neural network plant model is created on the basis of plant model's input-output characteristics then NN plant model is trained so that it can predict future plant output. In the NN controller, a set of output data is generated for reference model.

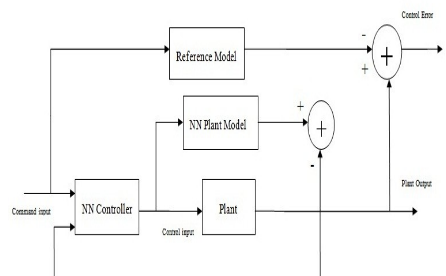

Fig. 8. Internal connection between NN controller network & plant model network.

After that the controller is trained such a way that the plant output follows the reference model. On the basis of following characteristic, the NN controller generate control signal which is connected to the soft-starter as 'delay angle'. The NN plant model & NN controller both have three layers; one of them is input layer and other two are hidden layer & output layer. There is an option to select number of neuron to use in the hidden layers. For training artificial neural network plant model training function named 'trained' has been used which is a gradient descent with adaptive learning rate back propagation algorithm that updates weights & bias values according to the gradient descent with adaptive learning rate [8]. For training the controller we used training function 'trainbfgc' (BFGS quasi-Newton back propagation). It is a network training function that updates weight and bias values according to the BFGS quasi-Newton method [8].

A MATLAB based simulation model has designed to simulate the ANN controlled soft-starter. In this simulation model we used three phase squirrel cage motor; the stator & rotor winding of the motor are connected in we connection to an internal neutral point. The rating & internal specifications of the induction motor are given below:

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Rated Voltage =230V
Frequency =50Hz
Rated speed =1430rpm
Rated power =4kW
Mechanical input (load)=10Nm
Stator resistance = 1.405 ohm
Stator inductance = 0.005839H
Rotor resistance = 1.395 ohm
Rotor inductance = 0.005839H
Mutual inductance = 0.1722H
Inertia = 0.0131 Kg.m²
Pole pair = 2

Figure-9 represents simulation model of soft starting method with artificial intelligent controller. Simulation model consists of Synchronization unit provides three line to line synchronization voltages for synchronized pulse generator. These synchronization voltages are made from supply end by building delta loop with

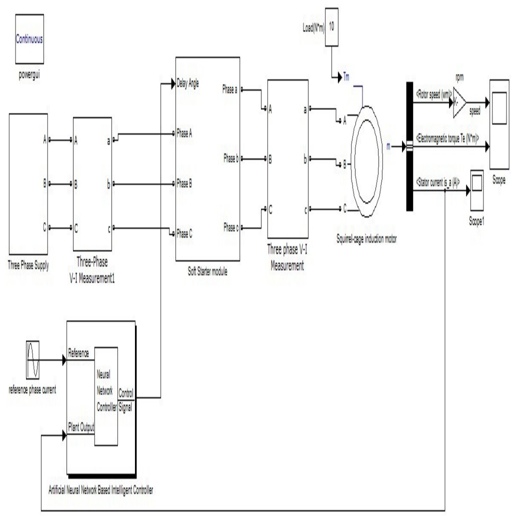

Fig 9. Simulation model of the soft starting method with artificial neural network controller

using voltage measurement blocks. The output voltages of the synchronization unit are connected to the synchronized pulse generator. The artificial neural network controller provides control signal (delay angle) for the pulse generator. The reference input of the artificial neural network controller is stator phase current of the induction motor. The starting current of the induction motor basically controlled by control signal that produced from artificial neural network controller. Thyristor unit controlled the stator phase voltages according to the gate pulses generated by synchronized pulse generator. The gate pulses are connected to the gate inputs of the corresponding thyristors.

IV. RESULT AND ANALYSIS

For 10 Nm load, the stator phase current of the direct on line (D.O.L) method are shown in fig-10. Fig.10 shows the starting current of DOL method is 81.66A (Peak) & after 0.08 sec.This current reduces to 6.82A (Peak) at running condition. For 'traingda' training function, starting current of soft-starting method is 73.8A (peak) shown in fig-11; that means 7.86A (peak) current is reduced from D.O.L starting current. The current during running condition is 6.8A (peak). The accelerate torque is 124.4 Nm that is enough to accelerate the load during starting condition; the rated speed is reached after 0.15 sec which ha ve been shown in fig-12 and fig-13.

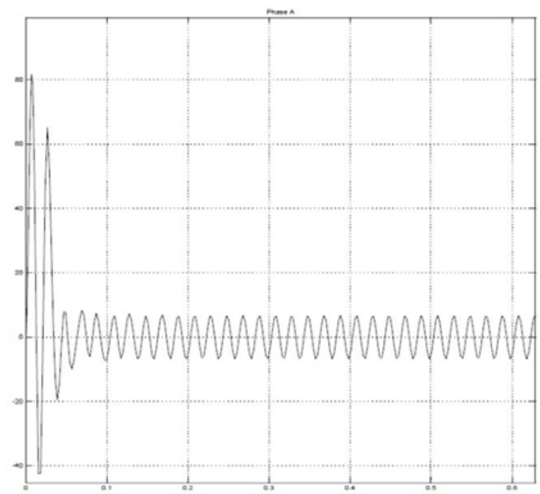

Fig.10.Stator phase current of direct online method

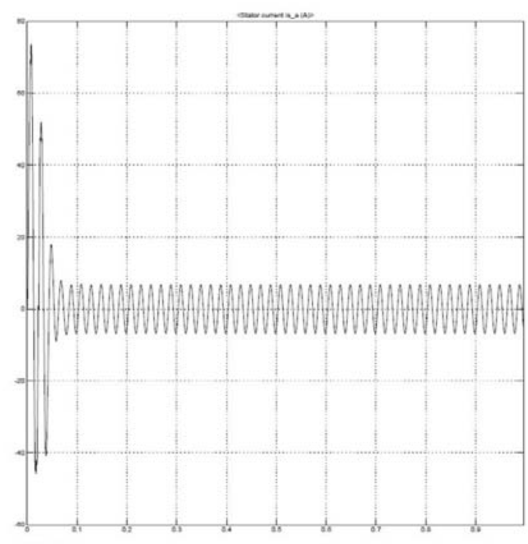

Fig.11. Stator phase current of intelligent soft-starting method using 'traingda' training function

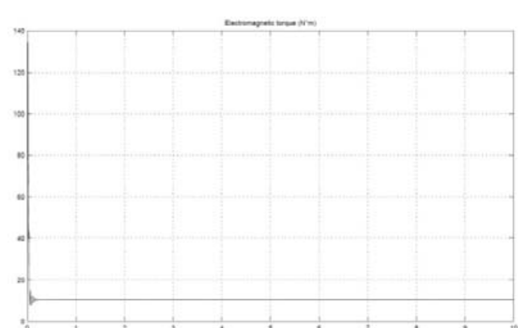

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Fig.12.Torque characteristics of intelligent soft-starting method using ‘traingda’ training function

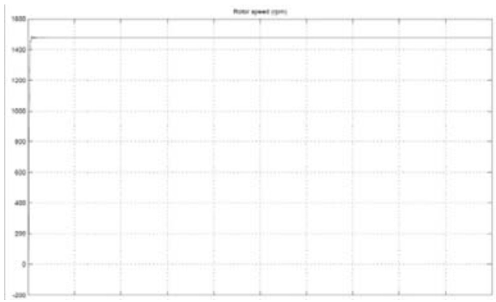

Fig.13 .Speed characteristics of intelligent soft-starting method using ‘traingda’ training function

V. CONCLUSION

A neural network based soft-starter has been shown in this paper. An improved result has been achieved compare to conventional DOL starter and also with the improved new less starting current an adequate speed-torque goal has been achieved. Here on the simulation only one phase has counted for the simplicity.

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