A COMPARATIVE ANALYSIS OF SOFT STARTING PERFORMANCES OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

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Abstract: *In this paper the performance optimization of soft starting the three-phase induction motor using intelligent controller is analyzed and compared with conventional starting schemes. The paper systematically evaluates and compares the performance characteristics of AC voltage controller fed induction motor and Selective Harmonic Elimination Pulse Width Modulation (SHEPWM) technique for various types of soft starting schemes. Experimental verification is done using MOSFET based analogue circuit designed in the laboratory. The originality of the work lies in the advancement of simple and humble models for MATLAB oriented simulation purpose. To increase the performance of the induction motor during soft starting, PAC, EAC, FLC, NNC and SHEPWM controllers are used and compared its results with conventional DOL, Auto transformer starter and star delta starter. As per the test results, intelligent control technique, outperforms the conventional controllers and reduces the inrush current and torque pulsations in the test motor.*

Keywords: *induction motor, soft analysis, thyristors, MATLAB Simulink model*

1. INTRODUCTION

Basically, a soft starter is an AC voltage controller. The voltage is adjusted by varying the fire angle α of the thyristor of the ac voltage controller or soft starter. The two thyristors are connected in anti-parallel in each phase. The Figure1 shows the schematic diagram of a basic soft starter.

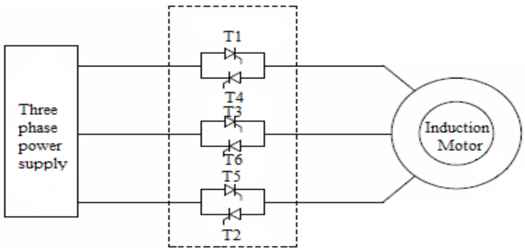


Fig.1. Schematic diagram of basic soft starter

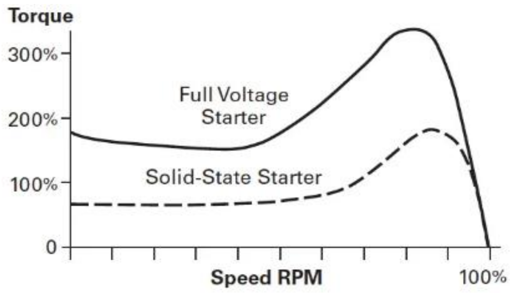
According to the sequence of firing pulses, the thyristors are fired in this method. The firing sequence of anti-parallel connected six thyristors in the circuit of soft starter is shown in Figure 1.

We can understand that at least two thyristors must conduct simultaneously at a time to allow the current flow through the load and measured the corresponding firing angle α of phase voltage at the time of zero crossing [1].

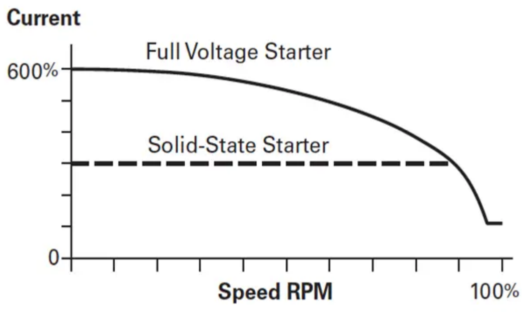
2. ADVANTAGES OF TORQUE CONTROL

Soft starter provides only the torque needed to accelerate the load which gives the constant acceleration rate, independent of motor load. Soft starter produces torque ramps and gives constant acceleration torque for different torque loads [2]. Certain variable torque load applications such as pumps and fans, it provides acceleration and deceleration ramps for torque control.

The soft starter can vary the MOSFET switching pattern for variety of application to accommodate different types of acceleration ramps and deceleration ramps. Soft starter can be designed to give constant acceleration torque for any types of constant or variable torque loads [3]. This allows a linear acceleration ramp for constant acceleration, smooth from zero to full speed as shown in Figure 2 (a) and (b).



(a) Speed vs torque



(b) Speed vs current

Fig. 2. Speed torque and speed current characteristics of SCIM

3. SELECTIVE HARMONICS ELIMINATION PULSE WIDTH MODULATION (SHEPWM) TECHNIQUE

The AC voltage controller based soft starting scheme is prone to increased source current harmonics. The AC source system is polluted due to the presence of high harmonics in the source current [4]. Therefore, the SHEPWM technique is used to adopt minimal harmonic source current.

In the traditional voltage control technique, one portion of the half cycle is non-conducting instead of keeping a continuous portion of every half cycle as conducting [5]. But in the SHEPWM technique, the quarter wave symmetry is achieved. The conduction periods for the entire half cycle are symmetrically distributed with alternate conducting and non-conducting periods within each half cycle [7]. The complete system of the soft starting scheme using SHEPWM based AC voltage controller is shown in Figure 3.

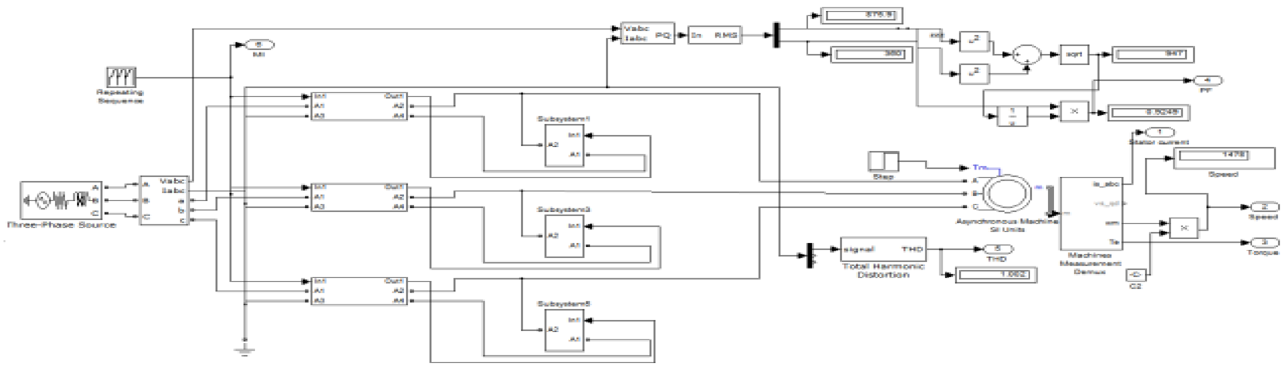


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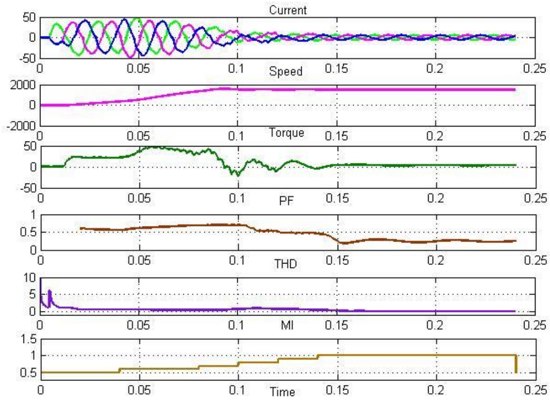
Fig. 3. MATLAB Simulink model of soft starting scheme with SHEPWM technique



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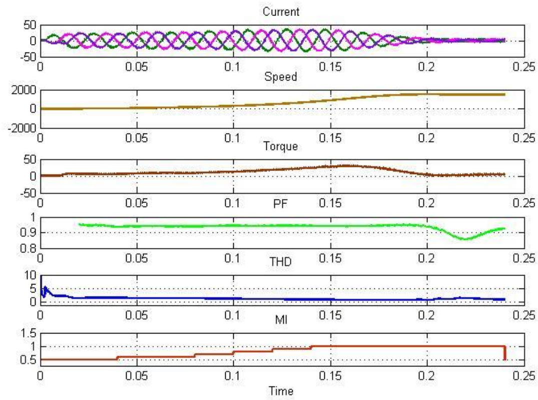
(a) Response of PAC technique



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(b) Response of SHEPWM technique

Fig. 4. Electromechanical parameters of different schemes

The modulation Index (MI) will be varied in fixed number of steps during the period of soft starting. In this work, the modulation index to be varied from 0.3 through 1 in steps of 0.1.

The fundamental voltage amplitude varied according to the modulation index applied and that all throughout the starting period the selected harmonics will be absent at all modulation indices.

4. FUZZY LOGIC CONTROL (FLC) SCHEME

FLC is one of the advanced control techniques that is meant to give an accurate result when just an approximate model of the system under control is available or no exact model exists at all [8]. The classical controllers can be modelled even when from the available precise mathematical models. But the classical control model is mathematically more deterministic and less robust. It is very difficult to design classical control model because the loading on electric motors are subject to unexpected changes. Also, the classical controller like proportional Integral plus Derivative (PID) controller is robust enough to manage the complete range of loading conditions. So FLC is an intelligent controller to handle approximate and unpredictable values to arrive at a suitable result.

In a drive, controller is a heart of the model and a decision authority that basically contains two part such as hardware and software. Software are programmed into hardware. Software consists of several control techniques also.

Soft computation has used more in electrical drives and control as the improvement and increased number of real time applications of microcontroller in recent days.

Some of the main controllers are:

Fuzzy Logic Set (FLS)

Fuzzy Neural Network (FNN)

Artificial Neural Network (ANN)

Genetic Algorithm Based system (GAB)

Genetic Algorithm Assisted system (GAA)

Also ANN techniques have hard computation and soft computation [2,5].

Expert system is being belongs to hard computation that has been the first artificial intelligent techniques [2,8].

The entire simulink model was developed in MATLAB for validating the FLC based soft starting method. The soft starting model using FLC scheme is shown in Figure 3.

The input variables are to be normalized and the range of membership functions specify them are as shown in Figure 3. Normalization of the inputs are more important and used in model for obtaining faster response.

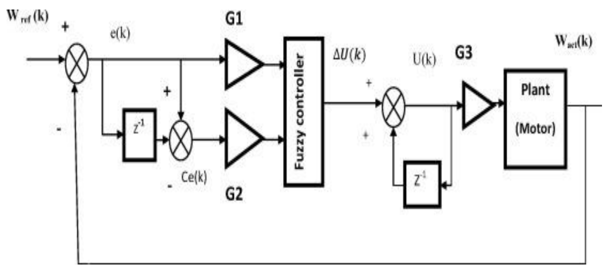

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Fig. 5. Block diagram of PI-FLC

The normalized membership functions for input and output variables are shown in Figure 4 and the set of control logical rule for FLC operation is given in Table 1.

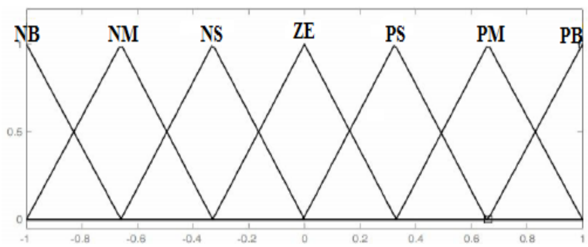

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Fig. 6. Input output membership functions

Table 1. Fuzzy logic control rules

e \ **Δe** / **Output**	**NS**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	NB	NB	NM	NM	NS	NS	ZE
NM	NB	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

Source: Realized by authors

5. RESULTS AND DISCUSSIONS

The prime objective of this work is to compare the conventional soft starting schemes such as PAC which has single ON state and OFF state over every half cycle with the SHEPWM technique which has multiple ON states and OFF state over every half cycle offers more advantages with the support of the rich theory reported in literature it can be stated that the lower order harmonics presented in the source current of an AC voltage controller can be eliminated for any modulation index with SHEPWM technique. By eliminating the dominant lower order harmonics, the torque pulsations can be reduced using the technique SHEPWM.

The value of power factor can also lead in the source side since the quarter wave symmetry is achieved. Also, in SHEPWM technique, the multiple pulses of conduction and non-conduction over every half cycle symmetrically placed in every half cycle.

The EAC scheme offers better source side power factor as compared to PAC scheme.

The soft starting element controlling the starting of a squirrel cage induction motor with a 3 phase AC voltage controller has been carried out in MATLAB simulink.

The results of the simulation are given as follows, Table 1 shows the comparative analysis pertaining to all the important parameters in the case of PAC, EAC based soft starting and SHEPWM based soft starting.

It can be concluded from Table 1, that the generation of torque has no ripples and is gentle in the case of FL, NN and SHEPWM based soft starting schemes.

The torque oscillations more and widely in the case of conventional and the other advanced soft starting schemes such as FL and NN.

The more oscillations or pulsations in the torque may lead to much mechanical vibrations and noise.

Table 2. Comparison of simulated parameters

Parameter/Control scheme	**DOL**	**PAC**	**EAC**	**FLC**	**NNC**	**SHEPWM**	**ANFIS**
Time (sec) to reach steady state	0.05	0.2	0.2	0.25	0.3	0.175	0.1
Current during starting (A)	60	41	36	50	40	28	37
Total Harmonics Distortion	0.00459	0.03086	0.0266	0.1902	0.1652	0.956	0.816
Power factor in average	0.78	0.735	0.789	0.763	0.899	0.94	0.8
Maximum Torque (N-m)	127	42	38	58	40	155	60

Source: Realized by authors

Comparisons of the parameters have been carried out in Table 2. The DOL starting scheme exhibits 0.05sec and as a result the motor reaches the steady state at the earliest. Both the Phase angle control and the extinction angle control exhibit the same 0.2sec the motor reaches the steady state almost at the same time. In the case of FLC the time at 0.25 reaches the steady state similar to the PAC and EAC.

The SHEPWM and ANFIS time at 0.175 sec and 0.1 to reach the steady state and both are nearly same time. Thus, the soft starting method using the SHEPWM reaches the steady state which is earlier seconds at low starting current than other so it offers better as compared.

The DOL scheme of starting draws heavier starting current as high as 60 amps. In the case of the phase angle controlled and neural network soft starting scheme the starting current is limited to 41 and 40 amps. In the case of the extinction angle and ANFIS method of soft starting the starting current has been limited to 36 and 37 amps. In the case of the fuzzy logic control soft starting scheme the starting current is 50 amps. In the case of SHEPWM the starting currents is limited much lower to 28 amps.

Thus, it is evident that the soft starting method using the SHEPWM offers much smoother starting characteristics. The SHEPWM scheme exhibits significantly large THD as compared to the other soft starting schemes.The SHEPWM soft starting scheme offers better side power factor as compared to other soft starting schemes. Also, it offers good maximum power factor of 0.94with less THD, quicker reaching of steady state time.The maximum torque is produced by the SHEPWM schemes and it is as high as 155 NM and 127 NM in the case of DOL. In the case of extinction angle control the maximum torque is 38 NM and the phase angle control the maximum torque is 42N-M acceleration is gradual and the motor takes a longer period to reach the steady state.

6. CONCLUSION

In this research paper, soft starter schemes for the induction motor has been carried out. Compares the performance of AC voltage controller fed induction motor and SHEPWM technique for various types of soft starting schemes. By comparing the soft starting techniques of DOL, PAC, EAC, FLC, NNC, SHEPWM and ANFIS then the parameters like starting current, time to reach steady state, maximum torque, power factor and THD have been taken into analysis and compared. The results are obtained and the parameters were compared by the way of MATLAB/SIMULINK based simulation.

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