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Design of Fuzzy Logic based Soft Starter for Induction Motor

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Abstract

Induction motors are extensively used across all industrial applications due to the robustness, comparatively less cost and very low maintenance. Nevertheless, at startup, this kind of motors pull a largely high current about several times larger than the rated value harming both. Several starting methods have been employed to minimize the in-rush current and overcome this problem. Previously, conventional starting methods: direct-on-line (DOL), star-delta and autotransformer starters have been utilized since they generally provide minimal relative control of starting performance. This paper presents a soft starting technique for three-phase squirrel cage induction motor using fuzzy logic controller (FLC) based approach. The proposed solution uses a power electronic AC voltage regulator to slowly decrease stator voltage at start up, which reduces start current and torque fluctuations. A fuzzy logic controller uses from linguistic rules and membership function in determining the control action, based on the inputs (current error and its derivative). Simulation and analysis validate the proposed method. The results clarify a significant drop in inrush current and attaining a soft torque which improves the overall performance and service life of the motor. The proposed system offers a more stable start and effective operation of motor cores over conventional starting method

Keywords: Fuzzy Logic Control (FLC), Soft Starting, Squirrel Cage Induction Motor, Starting Current, Torque Ripple, Motor Control.

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1. Introduction

The rigid mechanical design, great reliability, low cost and very little need for upkeep compared to other types of electric motors, three-phase squirrel cage induction motors are used in a different industrial and consumer application. However, induction motors will pull high levels of inrush current from the supply when started. The result of such a high starting current causes voltage dips on the power system, over heating or mechanical stress as well as decreasing motor and connected equipment lifetime [3].

Many starting methods that can help alleviate these problems have been developed, such as DOL (Direct-On-Line), Star-Delta, Autotransformer and electronic soft starters. Out of these techniques, soft starters are widely adopted because the voltage apply to the motor gradually which limits starting current and decreases torque shocks. In soft starters, AC voltage controllers are used to control the stator voltage during motor acceleration [6], [8].

Despite enhancing the performance of motors, traditional soft-starting techniques may underperform due to negative load and supply circumstances. As a result, intelligent control strategies have been explored for improved adaptability and control performance. A solution proposes Fuzzy Logic Control (FLC) is a powerful and efficient control method to nonlinear systems and uncertainties without the need of an accurate motor mathematical model [9], [10].

Additionally, how well an induction motor performs at startup is imperative in order for the drive system to be as efficient and reliable as possible. When full supply voltage is applied suddenly, some electrical stress and mechanical shocks occur in the system; conversely a gradual start reduces these stresses [1].

This paper a fuzzy logic based soft starter for three-phase squirrel cage induction motor is presented. The proposed system utilizes an AC voltage controller combined with fuzzy logic to control the startup stator voltage. The feasibility of the new method was tested through simulation and compared to conventional starting methods in terms of starting current, speed response features, and torque characteristics.

2. Literature Review

The research in automatic induction motor starting control has mostly been on limiting initial current and improving the behavior of the motor during start-up Nevertheless, less effort is spent on sophisticated modelling for disturbance rejection from power supply side. To achieve smooth acceleration and better operational reliability, many soft-starting methods relying on controlling the voltage ramping have been developed [1], [3], [6]. The application of AC voltage controllers and microcontroller-controlled soft starters has also proved that electronic beginning techniques can be applied successfully in industrial motors [8].

Most studies Many works have been developed to analyze the performance of induction machines working at different starting modes. With a focus on starting current, torque and acceleration time trade-offs which are key to optimizing motor performance, several works have reported detailed comparative analyses of the starting methods [7]. Also, transient measurements in combination with parameter estimation techniques have been used to increase the knowledge of induction machine performance during startup [4]. Multi-mode market research has also given emphasis to torque enhancement and optimal working torque, aiming at obtaining the desirable characteristics of torque without disturbing the system stability from [5].

Methods Provided: Intelligent control techniques have shown its suitability for improving the performance of induction motor operating under nonlinear and time-variant workable conditions. Induction motor speed control is one of the promising applications where Fuzzy Logic Control (FLC) has been used because of its robustness and model-free characteristics [2], [9], [11]. Certainly higher dynamic responses of the systems with a lesser steady-state error and improved adaptivity were reported in these studies than traditional control methods.

The application of the fuzzy logic to soft-starting systems has received considerable attention in the recent years. Fuzzy logic–based current control strategies have been shown to reduce starting current while maintaining acceptable torque characteristics [12]. Similarly, the integration of fuzzy logic controllers with soft starter configurations has resulted in smoother acceleration and improved overall starting performance when compared with conventional methods [10].

Although previous studies have demonstrated the effectiveness of soft starters and fuzzy logic controllers independently, limited attention has been given to the comparative evaluation of fuzzy logic–based soft starters against conventional starting techniques such as Direct-On-Line (DOL) and Extinction Angle Control (EAC). Therefore, this work investigates a fuzzy logic–based soft starter for a three-phase squirrel cage induction motor and evaluates its performance in terms of starting current, speed response, and torque characteristics using the MATLAB/Simulink environment.

3. Methodology

3.1 Fuzzy Logic Controller Structure

The proposed soft-starting system utilizes a Fuzzy Logic Controller (FLC) to regulate the stator voltage of a three-phase squirrel cage induction motor through an AC voltage controller. The objective is to reduce the starting current and torque fluctuations while ensuring smooth motor acceleration.

Fuzzy Logic Control is an intelligent control technique capable of providing satisfactory performance even when an accurate mathematical model of the system is unavailable. Similar to conventional controllers that rely on precise mathematical formulations, FLC uses to linguistic rules and expert knowledge to determine appropriate control actions under varying operating conditions.

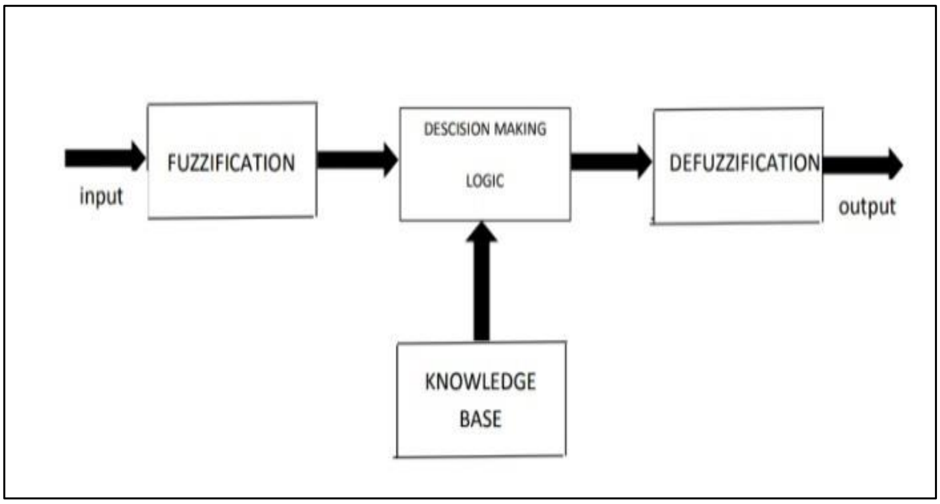

Figure 1. Fundamental Components of the Fuzzy Logic Controller (FLC)

The fuzzy logic controller consists of four components: fuzzification, rule base, inference mechanism and defuzzification as seen in Figure 1. In the process of fuzzification, given crisp input variables are converted to linguistic variables according to the membership functions previously defined. These variables are then processed via a series of IF–THEN rules that have been stored in the rule base. When you call the method, the rule is evaluated and a fuzzy output produced which is then defuzzied into a crisp control signal.

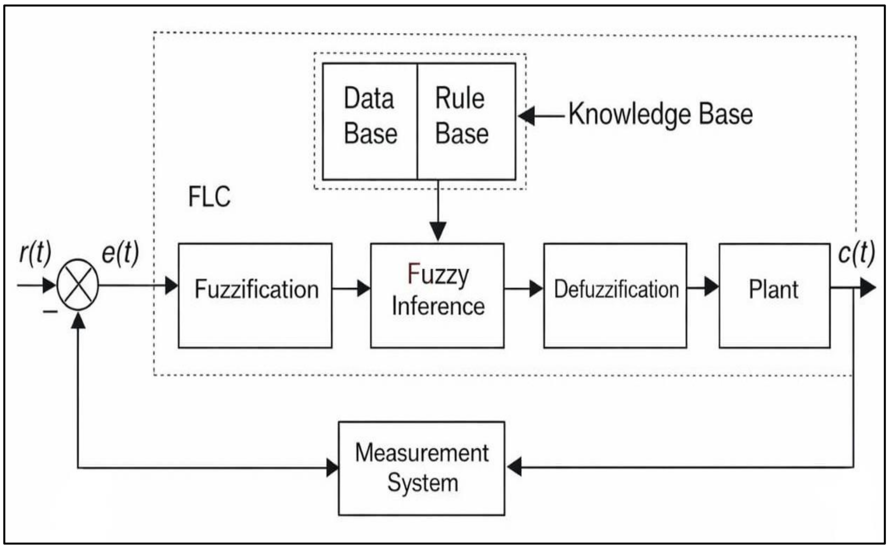

Figure 2. Block Diagram of the Proposed FLC-based Soft Starter for Induction Motor Control

Figure 2 shows the overall structure of the fuzzy logic controller employed in the proposed system. The controller receives the reference and measured signals, processes them through the fuzzification and inference stages using the knowledge base, and generates an appropriate control signal through the defuzzification block to regulate the motor starting process.

3.2 Induction Motor Parameters

The performance of the proposed fuzzy logic–based soft starter was evaluated using a three-phase squirrel cage induction motor model available in the MATLAB/Simulink environment. The motor parameters employed in the simulation study are listed in Table 1. These parameters were adopted from the standard induction motor model available in the MATLAB/Simulink Simscape Electrical library and are representative of a typical industrial medium-power induction motor used in drive applications.

Table 1. Induction Motor Parameters Used in Simulation

Parameter	Symbol	Value
Rated Power	P	5 HP (3.73 kW)

Rated Voltage	V	400 V
Frequency	f	50 Hz
Number of Poles	p	4
Rated Speed	N	1440 rpm
Stator Resistance	Rs	1.405 Ω
Rotor Resistance	Rr	1.395 Ω
Stator Inductance	Ls	0.00584 H
Rotor Inductance	Lr	0.00584 H
Mutual Inductance	Lm	0.1722 H
Moment of Inertia	J	0.0131 kg·m^2
Friction Coefficient	B	0.002985 N·m·s

As shown in Table 1, the selected motor parameters were incorporated into the induction motor model to evaluate the effectiveness of the proposed fuzzy logic controller in limiting the starting current and reducing torque oscillations during motor startup. The same motor configuration was used for Direct-On-Line (DOL), Extinction Angle Control (EAC), and Fuzzy Logic Controller (FLC)-based soft-starting methods to ensure a fair comparison of performance characteristics. The uses of identical motor parameter to across all starting techniques eliminates parameter-dependent variations and enables an objective assessment of the controller performance.

3.3 Simulation Setup and Parameters

The soft starter proposed was developed and simulated in the MATLAB/Simulink environment. The simulation model has been developed inside MATLAB R2023a software using the Simscape Electrical toolbox. The system is a three phase AC supply, an AC voltage controller, a fuzzy logic controller and squirrel cage induction motor model. MATLAB Fuzzy Logic Toolbox was used to design the fuzzy logic controller and incorporated into the power circuit for controlling stator voltage in starting period.

A consistent performance evaluation enforced identical motor parameters and loading conditions for all three starting methods including Direct-On-Line (DOL), Extinction Angle Control (EAC) and Fuzzy Logic Control (FLC). In this case, simulation was carried for 1 s by using a fixed-step solver with sampling time = 1×10^{-5} s and the obtained data on starting current, rotor speed, electromagnetic torque and transient response characteristics at startup period were recorded and evaluated. Finally, the proposed controller reduction of inrush current, torque oscillations minimization and improvement of acceleration characteristics and startup performance.

Table 2. Simulation Framework and Evaluation Conditions

Simulation Aspect	**Description**
Development Environment	MATLAB/Simulink R2023a
Modeling Libraries	Simscape Electrical and Fuzzy Logic Toolbox
Power Source Configuration	Three-phase AC supply, 400 V, 50 Hz
Motor Model	Three-phase squirrel cage induction motor
Starting Techniques Investigated	Direct-On-Line (DOL), Extinction Angle Control (EAC), and Fuzzy Logic Control (FLC)
FLC Input Variables	Current error (e) and change in current error (Δe)
FLC Output Variable	Voltage control signal applied to the AC voltage controller
Defuzzification Strategy	Centroid method
Simulation Duration	1 s
Numerical Solver	Fixed-step solver
Sampling Interval	1×10^{-5} s
Initial Operating Condition	Motor starting under no-load condition
Recorded Responses	Stator current, electromagnetic torque, and rotor speed
Performance Indicators	Peak starting current, peak starting torque, settling time, and acceleration profile
Objective of Evaluation	Assessment of startup smoothness, current limitation capability, and torque reduction performance

The simulation framework depicted in Table 2 summarizes the employed operating conditions and evaluation criteria of this study. This table, however, is not discussing motor parameter specifications introduced in the earlier tables but instead captures components such as the computational environment, controller configuration, test conditions and performance metrics to evaluate the results of using this FLC-based soft starter proposal. This process allows us to better compare between each of the DOL, EAC, and FLC starting methods consistently.

3.4 Mathematical Model and Controller Design

In the developed controller, current error and change in current error are selected to the input variables, while the control signal applied to AC voltage controller is considered as the output variable.

The current error is defined as

$$e(k) = I_{ref}(k) - I(k) \tag{1}$$

where

- $e(k)$ = current error
- $I_{\text{ref}}(k)$ = reference current
- $I(k)$ = measured motor current

The change in current error is given by

$$\Delta e(k) = e(k) - e(k-1) \tag{2}$$

where $\Delta e(k)$ is the change in the current error.

The starting torque of the induction motor is expressed as

$$T_s = \frac{3E_r^2 R_2}{\omega_s(R_2^2 + X_2^2)} \tag{3}$$

where

- T_s= starting torque (N·m),
- E_{r} = rotor-induced electromotive force (V),
- R_2= rotor resistance per phase (Ω),
- X_2= rotor reactance per phase (Ω), and
- ω_s = synchronous angular speed (rad/s)

From (3), it can be identified that the starting torque is proportional to the square of the rotor-induced voltage and is influenced by the rotor impedance. Accordingly, regulating the applied stator voltage through the fuzzy logic controller effectively limits the starting current and torque, resulting in smoother motor acceleration and reduced mechanical stress.

Steps to Design a Fuzzy Logic Controller:

1. Selecting the input to the FLC
2. Selecting the proper MFs both for input and output variables
3. Fuzzification of the input variables
4. Preparing for a Fuzzy rule base for the controller
5. Selecting proper defuzzification technique
6. Defuzzification of the output that is to be given to the system for desired operation.

The controller developed is interfaced with the induction motor model using MATLAB/SIMULINK and tested for various input performance conditions. Simulation findings also confirm better robustness, decreased inrush, and smoother torque profiles than more standard types of starting methods.

3.5 Membership Function Design

The fuzzy logic controller basically relies on the proper choice of the membership function for input and output variables. The proposed controller involves 2 input variables: current error (e) / change in current error (Δe) and 1 output variable: control signal (u). Due to the simplicity and computational efficiency, the triangular membership functions were used for real-time control applications.

The fuzzy linguistics variables for the input and output membership function are Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS) and Positive Big(PB). These linguistic names denote different motor running states during the startup and allow for almost any operating range to be controlled smoothly.

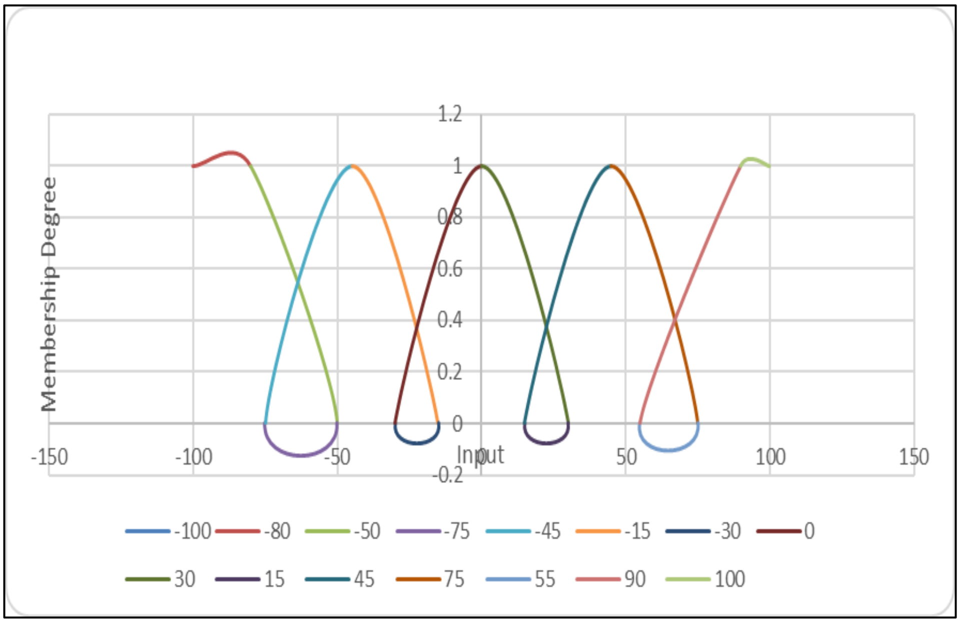

Figure 3. Membership Functions of the Fuzzy Logic Controller

The membership functions utilized for the fuzzy logic controller are illustrated in Figure 3, including current error (e), change in current error (Δe) and output control signal (u). The current error membership function is defined by the difference between reference current and motor current, while change in current error describes how the actual (measured) motor startup changes with time regarding the dynamic variation of the distance of energy transfer. The Control Signal (u) that is applied to the AC Voltage Controller is given by the output membership function. Five linguistic labels (Negative Big, Negative Small, Zero, Positive Small and Positive Big) are utilized to categorize the domain of operation for all variables and create suitable control commands. Triangular membership functions are employed so that fuzzy sets can overlap smoothly, and they allow an efficient implementation of the controller. As seen in Section IV, a fuzzy rule base definition dictates the interactions between these membership functions and corresponding control actions as shown in Table 3.

3.6 Fuzzy Rule Base

The decision part of the controller is represented by fuzzy rule base. A set of IF-THEN rules learned from expert knowledge and motor operating characteristics Rules define how the input variables relate to the controller output, facilitating adaptive voltage regulation during start-up. Table 3 summarizes the whole fuzzy control rules in the proposed controller.

Table 3. Fuzzy Rule Base

Current Error / Change in Current Error	**Negative Big**	**Negative Small**	**Zero**	**Positive Small**	**Positive Big**
Negative Big	Negative Big	Negative Big	Negative Big	Negative Small	Zero
Negative Small	Negative Big	Negative Small	Negative Small	Zero	Positive Small
Zero	Negative Small	Negative Small	Zero	Positive Small	Positive Small
Positive Small	Negative Small	Zero	Positive Small	Positive Small	Positive Big
Positive Big	Zero	Positive Small	Positive Small	Positive Big	Positive Big

As shown in the Table 3, the controller output is determined by evaluating the combined effects of the current error and the change in current error. When the current error is large, the controller applies a stronger corrective action to limit the inrush current. As the motor reaches steady-state operation, the control effort is gradually reduced to ensure smooth acceleration and minimize torque oscillations. The fuzzy inference mechanism evaluates the rules listed in Table 3 and generates an appropriate control action based on the prevailing operating condition. Finally, the centroid defuzzification method is employed to convert the fuzzy output into a crisp control signal suitable for driving the AC voltage controller.

4. Results and Discussion

4.1 Starting Current Analysis

Figure4 illustrates the responses of ID and IA when starting using DOL, EAC, and FLC-based soft-starting methods. DOL gives the maximum inrush current which is around 90 A at motor startup. By using EAC, the peak current only reaches 60 A, which means a 33.3% reduction compared to DOL operation. The new FLC-based soft starter reduces the starting current to 50 A, which is a reduction of 44.4% relative to DOL and 16.7% relative to EAC.

The fuzzy logic controller reduces the starting current due to intelligent voltage regulation, increasing stator voltage gradually with respect to the motor operating condition.

Consequently, FLC method reduces the electrical stress on the motor windings and helps to decrease voltage disturbances in supply network. In addition, it can be seen from the above that the waveform of current under FLC control is smaller than oscillation during startup time and smooth transient response in comparison to conventional methods, which indicates that a better startup stability was achieved.

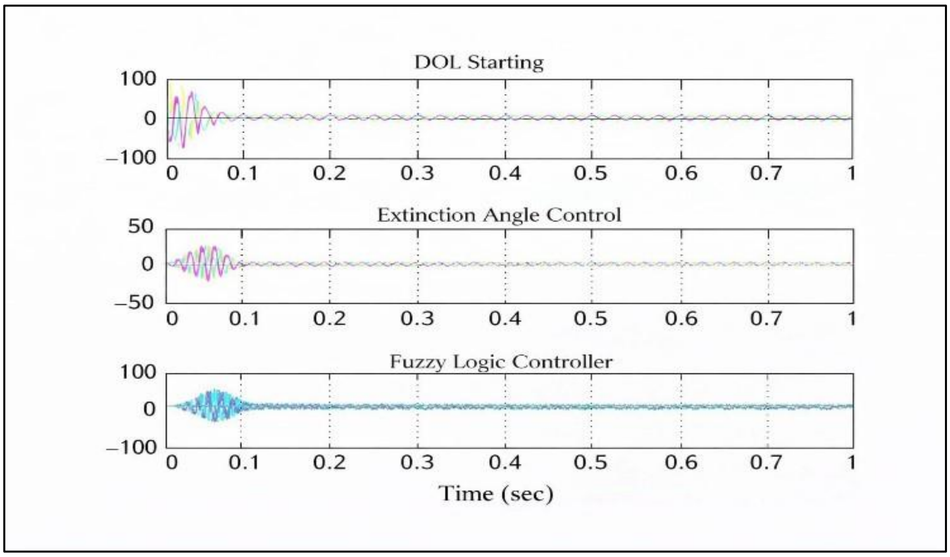

Figure 4. Comparison of the Starting Current Responses Under DOL, EAC and FLC Methods

4.2 Speed Response Analysis

Figure 5 illustrates the rotor speed characteristics of the induction motor under different starting methods. The DOL starter accelerates the motor rapidly and reaches steady-state speed within approximately 0.05 s. The EAC method increases the acceleration time to 0.20 s due to controlled voltage application, while the proposed FLC-based method reaches steady-state operation in approximately 0.30s.

Although the acceleration time of the FLC method is longer than that of DOL, the startup process is considerably smoother and more controlled. The gradual speed increase minimizes mechanical shock, shaft stress, and vibration during startup. In addition, the FLC response exhibits negligible overshoot and reduced speed fluctuations compared with the conventional methods, resulting in improved operational stability and enhanced motor lifespan.

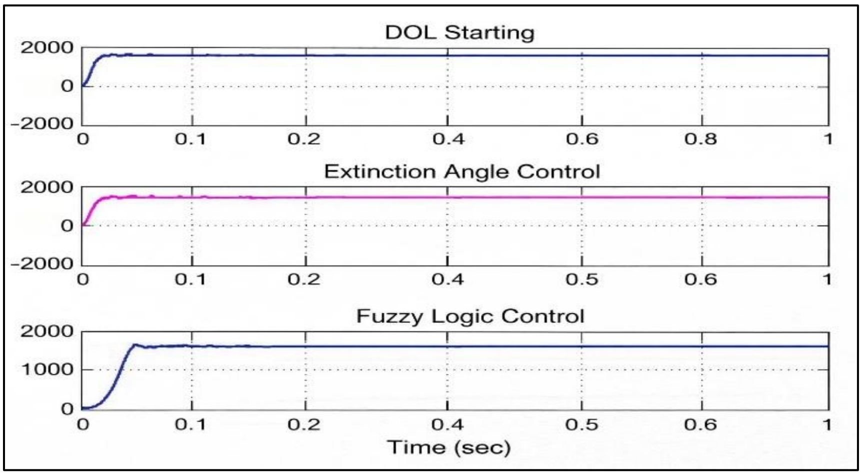

Figure 5. Comparison of Motor Speed Responses Under DOL, EAC and FLC Methods

4.3 Electromagnetic Torque Analysis

Figure 6 shows the start-up electromagnetic torque responses of the induction motor. DOL method gives a starting torque of around 127 N·m, which leads to devastating torque oscillations and harmful mechanical stress. The peak torque can be reduced to 60 N·m at the EAC mode while showing a reduction of 52.8% in contrast with DOL operation.

The proposed FLC based soft starter model restricts the starting torque to 58 N.m which is 54.3% and 3.3% reduction compared to DOL and EAC respectively. The fuzzy controller not only reduces the peak torque but also the torque oscillations during the transient period significantly. The smooth torque curve reduces the mechanical stress on couplings, shafts, bearings and connected loads and improves the reliability and service life of the drive system.

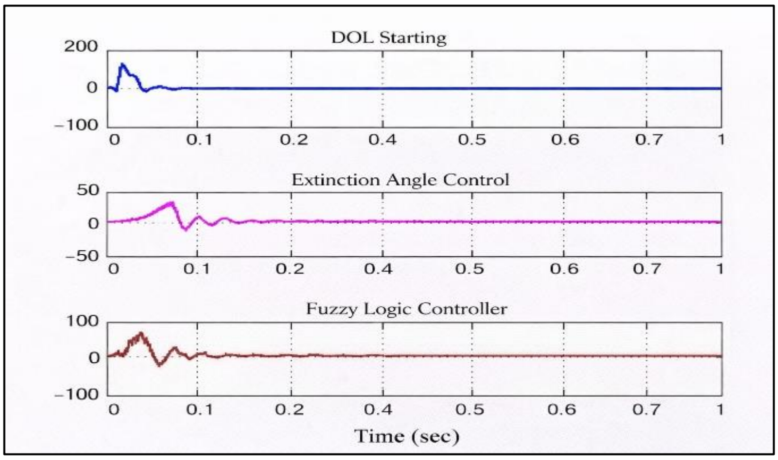

Figure 6. Comparison of Electromagnetic Torque Characteristics Under DOL, EAC and FLC Methods

Table 4. Quantitative Performance Comparison of Starting Methods

Parameters	DOL Starting	Extinction Angle Control	Fuzzy based soft starting
Peak Starting Current (A)	90	60	50
Peak Starting Torque (N·m)	127	60	58
Settling Time (s)	0.05	0.20	0.30
Current Reduction (%)	0	33.3	44.4
Torque Reduction (%)	0	52.8	54.3

This performance of a startup with DOL and EAC for the FLC-based soft starter proposed is also quantitatively compared in Table 4. Our results show that the DOL method has the highest peak starting current (90 A) and maximum starting torque (127 N·m), so that the motor system suffers from severe electrical and mechanical stresses. and the EAC, can reduce the start current and torque to 60 A and 60 N·m, (more) Among these three starters, the proposed FLC based soft starter is the best one which limits the peak value of starting current and starting torque to 50 A (44.4% lower than DOL method) and 58 N.m(54.3% lower than DOL method), respectively. It is observed that FLC approach takes a little longer to start up a steady state operation (0.30 s) but provides smoother and more controlled acceleration, minimizing transient disturbances thereby increasing system reliability. It can be seen that these results confirm the successful operation of the fuzzy logic controller to appropriately balance current limitation, torque reduction and startup smoothness thus acting as an efficient solution for thyristor-based softstarting applications in induction motors [10], [12].

4.4 Harmonic Performance Analysis

An important performance index of induction motor starting systems is the harmonic distortion, as the presence of excessive harmonics leads to deterioration of the power quality, increased motor losses, additional heating and reduced efficiency of the whole system. Therefore, soft-starting techniques are employed to limit the inrush current and torque fluctuations, as well as to improve the harmonic performance during start-up. Intelligent control strategies, especially the fuzzy logic-based approaches, have been proved to be effective for harmonic distortion reduction and for smooth motor acceleration and stable operation in previous studies [8], [10], [12].

Table 5. Harmonic Performance Analysis

Starting Method	Current THD (%)
Direct-On-Line (DOL)	18.6
Extinction Angle Control (EAC)	13.8
Fuzzy Logic Controller (FLC)-Based Soft Starter	9.7

The harmonic performance of the investigated starting methods in terms of stator current Total Harmonic Distortion (THD) is presented in Table 5. The THD value for the DOL starter is the highest at 18.6% while the EAC method reduces it to 13.8% by controlling the voltage. The proposed FLC based soft starter has the least value of THD, 9.7% which is about 47.8% and 29.7% reduction as compared to DOL and EAC methods respectively. This improvement is due to the adaptive voltage regulation achieved by the fuzzy logic controller that reduces the sudden change in the current during the motor acceleration. Thus, the proposed FLC based soft starter enhances the starting characteristic by reducing the inrush current and torque oscillations, improving the power quality, reducing the electrical stress on the system components, and contributes to improved reliability and equipment lifespan.

Table 6. Performance Comparison with Existing Literature

Reference	Methodology	Starting Current Reduction (%)	Torque Reduction (%)	Remarks
[3]	Conventional Soft Starter	25–30	35–40	Reduced inrush current using voltage ramp control
[8]	Microcontroller-Based Soft Starter	30–35	40–45	Improved startup performance
[10]	Fuzzy Logic Soft Starter	38–42	48–50	Enhanced adaptability and smooth acceleration
Proposed Work	FLC-Based Soft Starter	44.4	54.3	Lowest current and torque with improved stability

The qualitative comparison in Table 6 indicates that the developed FLC based soft starter achieves a superior performance in relation to prior art methods of starting induction motor [3], [8], [10]. Whilst prior art implementations focus on a simple voltage ramp control that result in a moderate decrease in starting current and torque the developed fuzzy logic controller adjusts the control effort in real time based on the status of the motor, reducing the starting current by 44.4% and the starting torque by 54.3%. The data indicates that the developed controller is capable of providing smooth starting characteristic and stable motor operation.

5. Conclusion

In this paper, a fuzzy logic based soft starting for a 3-phase squirrel cage induction motor is proposed and presented. The system is also compared with a conventional DOL starting technique and EAC starting technique. In DOL method, the current inrush is excessively high along with starting torque, it is simple method but it causes excessive electrical strain and mechanical vibration on the system and life of motor decreases. So, a better approach Extinction Angle Control method is used. In this method the starting current and starting torque is limited to a considerable amount along with smooth acceleration compared to DOL. And fuzzy logic-based system shows excellent results compared to DOL and EAC starting method. In this method the AC voltage controller along with fuzzy logic controller is used for controlling the stator voltage applied to motor so the motor accelerates smoothly. Fuzzy logic controller does not need an exact mathematical model of the system, membership functions and rules are determined on the basis of experience and knowledge for varying conditions. Simulation and analysis of proposed method shows reduced starting current and ripple torque and also speed response is better compared to DOL and Extinction Angle Control technique compared to DOL and Extinction Angle Control, which results in less mechanical stress and better energy efficiency.

References

[1] Hussain, Asif, Raja Masood Larik, Muhammad Salman Saeed, Agha Yasir Ali, Usman Humayun, Muhammad Rashid, Zain-ul-Abiden Akhtar, and Zeeshan Ahmad Arfeen. "Enhancing Three-Phase Induction Motor Performance with Soft Ramp Control." International Journal of Innovations in Science & Technology 2024, vol. 6, no. 4, 2117-2123.

[2] Verma, S., Kumar, A., & Gupta, A. K. (2024). Speed Control of Induction Motor using Fuzzy Logic. International Journal for Research in Applied Science and Engineering Technology 2024, vol. 12, no. 1, 788–7972024.

[3] S. P. Jolhe, A. Gaikwad, S. Mane, S. Badashaha, and P. Hattimare, “Soft Starting of Three Phase Induction Motor,” International Research Journal of Modernization in Engineering Technology and Science 2022, vol. 4, no. 4, 2405-2408.

[4] Simba, Katherine G., Franklin L. Quilumba, and Nelson V. Granda. "Parameter Estimation of a Three-Phase Induction Motor from Direct Starting Stator Transient Measurements." In 2020 IEEE ANDESCON, 1-5.

[5] Yetgin, Asım Gökhan. "Investigation of the Effects of Stator Slot Permeance on Induction Motor and Obtaining the Best Starting Torque Using Permeance Calculation." Canadian Journal of Electrical and Computer Engineering 2019, vol. 43, no. 1, 25-29.

[6] Nandankar, Praful V., Akshay Rathod, and Shivam Shukla. "Soft Starter for Three Phase Induction Motor." International Journal of Latest Engineering Science (IJLES) 2020, vol. 3, no. 02, 5-9

[7] Inope, A. O., D. C. Idoniboyeobu, and S. L. Braide. "Performance Analysis of Starting and Control Effect of Three Phase Induction Motors." Global Scientific JOURNALS 2020, vol. 8, no. 6, 1328-1358.

[8] Kirti Ichake, K. S. Shivatarkar, R. Gupta, and K. Dhawad, “Design and Implementation of AC Soft Starter for Three Phase Induction Motor Using Microcontroller,” Journal of Emerging Technologies and Innovative Research (JETIR) 2019, vol. 6, no. 4, 5-8.

[9] Faisal, Md Shah, and Sankalp Paliwal. "Speed Control of Three Phase Squirrel Cage Induction Motor Using Fuzzy Logic Controller." SYSTEM 2018, vol. 8, no. 5, 3-7.

[10] Kusmantoro, A., T. I. Wardani, and S. Ristanto. "Soft Starter Induction Motor Three Phase with Fuzzy Logic Controller Inside Delta." International Journal of Applied Engineering Research 2018, vol. 12, no. 19, 8338-8345.

[11] Ayushi, “Speed Control of Induction Motor Using Fuzzy Logic Controller,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 2015, vol. 4, no. 4, 2581-2588.

[12] Gupta, Suvra. "Fuzzy Logic Based Soft Starting of Induction Motor with Current Control.", 2014, https://api.semanticscholar.org/CorpusID:107321267