

Source Current Harmonic Cancellation in Distribution System by Using ANFIS Controller

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Abstract. . Ensuring a reliable and stable power supply to consumers is of utmost importance in modern distribution systems. Many power quality issues, such as voltage fluctuations, harmonic distortions, transient events, load forecasting, and voltage sag/swell compensation, can lead to operational inefficiencies and compromise the performance of sensitive electronic equipment. The main causes of power quality problems are short circuits and overloads, reactive power imbalance, transients, equipment malfunctions, and ground issues. The ANFIS model leverages the strengths of both neural networks and fuzzy logic to effectively address power quality challenges. Thus, by using the ANFIS model for power quality improvement, we reduce the supply current harmonics by maintaining IEEE 519 standards. The stimulation results are implemented using MATLAB Simulink software. The simulation results are verified source current, load current and supply voltage, The THD value of source current.

1 Introduction

ANFIS is used in power electronics for various applications, including system modeling, control, fault diagnosis, and predictive maintenance. It can model the nonlinear behaviour of power converters, inverters, and compensators with high accuracy. Additionally, ANFIS-based control strategies can adapt to varying load conditions and parameter uncertainties in power electronic systems [1]. ANFIS provides a versatile and adaptive approach for modelling and control tasks in power electronics, making it a valuable tool in improving system performance, efficiency, and power quality [2]. Advantages of ANFIS: ANFIS provides linguistic interpretations of the input-output relationships, making it easy to understand and interpret the system's behaviour. Nonlinearity Handling: ANFIS can capture and model multifaceted nonlinear relationships between input and output data. Adaptability: The model can adjust its parameters based on the learning algorithm, allowing it to adapt to changing system dynamics and uncertainties. Data Efficiency: ANFIS can work well with relatively small datasets, reducing the need for extensive data collection [3]. Applications: ANFIS finds applications in various fields, including system modelling, control, pattern recognition, prediction, optimization, and decision-making. It is used in engineering, finance, medicine, robotics, power systems, and many other domains where complex systems need to

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be modelled and controlled. In today's rapidly advancing world, ensuring a reliable and stable power supply to consumers has become a matter of paramount importance in modern distribution systems [4]. Power quality issues, such as voltage fluctuations, harmonic distortions, transient events, load forecasting challenges, and voltage sag/swell compensation problems, can severely impact the efficiency of the distribution system and compromise the performance of sensitive electronic equipment [5]. To maintain a high standard of power delivery, it is crucial to identify and address the main causes of power quality problems, including short circuits and overloads, reactive power imbalances, transients, equipment malfunctions, and ground issues. In this context, the ANFIS emerges as a powerful solution to effectively tackle power quality challenges. ANFIS, a hybrid intelligent system, combine the strength of both NN and FL to effectively address power quality challenges [6]. Its unique ability to capture complex and nonlinear relationships within a distribution system makes it an ideal candidate for power quality improvement. The ANFIS model can effectively predict and control power quality parameters, offering a robust mechanism to reduce supply current harmonics and tackle other power quality issues. By leveraging its adaptive capabilities and fuzzy inference rules, the ANFIS model can be trained using historical data and system parameters to accurately predict and control power quality parameters. Through comprehensive simulations and implementation using MATLAB Simulink software, we demonstrate the efficacy of the ANFIS-based power quality improvement technique [7]. This research offers a reliable platform to evaluate the model's performance in a realistic distribution system environment, providing valuable insights into its potential practical applications. Among the array of emerging technologies, the ANFIS stands out as a compelling solution to address power quality challenges in distribution systems. The focal point of our project is to harness the potential of ANFIS for PQ improvement in distribution systems. By employing historical data and system parameters, the ANFIS model can accurately predict and control PQ parameters, making it a robust tool for reducing supply current harmonics and tackling other power quality issues [8]. To validate the effectiveness of the proposed approach, we conducted comprehensive simulations using MATLAB Simulink software. Through these simulations, we demonstrate the significant impact of ANFIS on improving power quality and maintaining adherence to vital standards such as IEEE 519. In the following sections, we will delve deeper into the ANFIS model's architecture, its training process using historical data, the implementation of IEEE 519 standards, and the detailed simulation results obtained through MATLAB Simulink software. Through rigorous analysis and evaluation, we aim to establish the ANFIS model as a pioneering solution for improving power quality in distribution systems with potential applications across various industries and sectors [7]. The primary objective of our paper is to use the ANFIS model to enhance power quality and, in particular, reduce the supply current harmonics while adhering to the prestigious IEEE 519 standards.

2 DSTATCOM Topology

Figure 1 shows the DSTATCOM stands for Distribution Static Compensator, which is a power electronic device, used in power distribution systems to improve power quality. It is intended to address several problems with power quality, including reactive power imbalance, harmonics, and voltage fluctuations. The topology of a DSTATCOM refers to the arrangement and configuration of its power electronic components. There are several DSTATCOM topologies, but the most common ones include: Voltage Source Converter (VSC) based DSTATCOM: This topology utilizes a voltage source converter, usually a three-phase PWM (Pulse Width Modulation) inverter, to generate controlled voltage and current. The converter is connected in parallel with the load and can inject or absorb reactive power as needed. It can regulate the output voltage and mitigate voltage sags, swells, and flickers

[10]. Current Source Converter (CSC) based DSTATCOM topology; a current source converter is employed to control the load current. The CSC can be connected in parallel or series with the load. It can regulate the load current and help in mitigating current-related issues such as harmonics and load unbalance. Hybrid DSTATCOM topology is combines the features of both VSC and CSC-based DSTATCOMs to achieve improved performance and flexibility. It allows for better control over both voltage and current, making it suitable for addressing a wide range of power quality issues.

Energy Storage System (ESS) based DSTATCOM have installations, an energy storage system is incorporated to store excess energy or provide additional power when needed. Common ESS technologies include batteries, super capacitors, or flywheel systems. Filtering Components for DSTATCOMs may include filtering components like inductors and capacitors to reduce harmonics and ensure that the injected current is of high quality.

Coupling Transformer based DSTATCOM configurations; a coupling transformer is used to connect the VSC to the distribution system. The transformer allows for voltage level matching and galvanic isolation. A DSTATCOM's primary goals are to keep the voltage and current within reasonable bounds, lessen harmonics, and raise the distribution system's overall power factor. It accomplishes this by supplying or removing reactive power from the system as necessary to maintain the electrical network's stability and effectiveness.

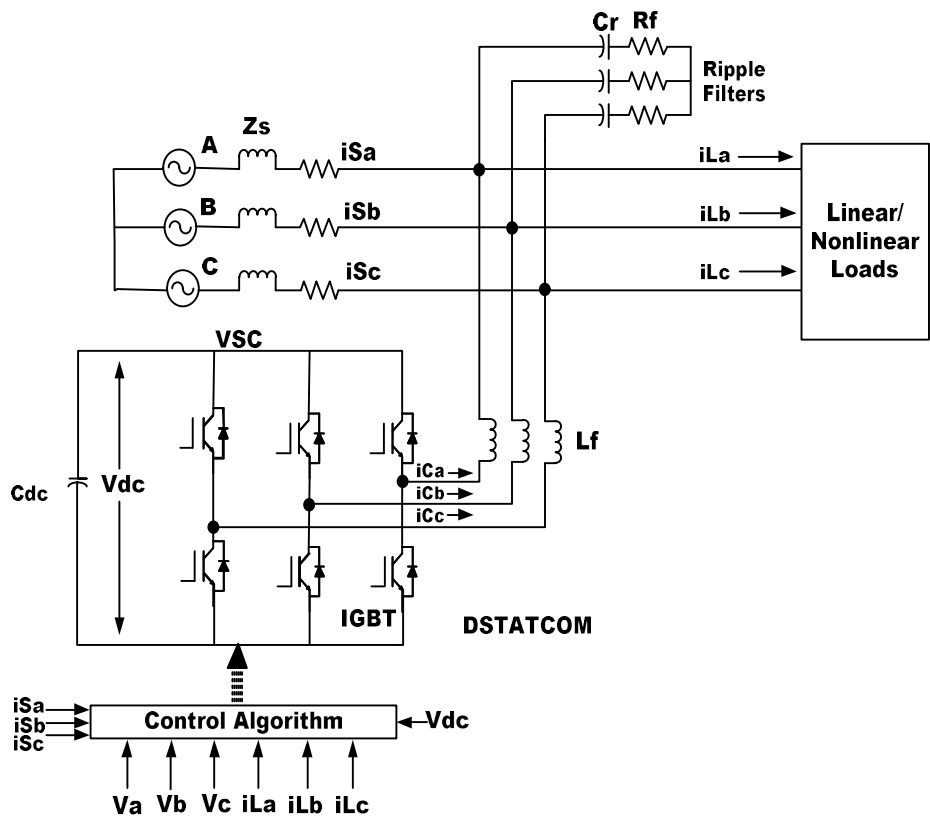


Figure 1 DSTATCOM Topology

3 Layer Structure

The ANFIS structure is depicted in Figure 2. The input layer, the fuzzification layer, the rule layer, the defuzzification layer, and the output layer are the traditional five layers of the ANFIS. After the input layer receives the input data, it computes the membership grades for each input variable. Using the input membership grades and rule parameters, the rule layer determines the strength of each fuzzy rule. The final ANFIS output is created by the output layer after the defuzzification layer has combined the rule outputs. ANFIS combines fuzzy logic and neural networks. ANFIS has an output (f) and two inputs (x , y). Equation below gives the Takagi-sugeno-based ANFIS rules.

Every "i" node in Layer 1 is an adaptive node with a node membership function. Any shape fuzzy membership functions, including trapezoidal, triangular, and Gaussian shapes. Calculate the firing strength of a rule using product operation is the second layer. The layer of fuzzification determines the normalized value that corresponds to the input. The values of membership are the outputs of layer two. The normalized firing strength of a rule from layer 2 is calculated in layer 3. Each node in layer 4 represents a subsequent part of the fuzzy rule. The rule consequent's linear coefficients are trainable. where the linear parameters P_k , q_k , and R_k . By summing the output of all the rules, nodes in layer 5 defuzzify the subsequent part of the rules. The equations are from 1 to 5 ANFIS layers. This paper the ANFIS training data collected from PI controller. The PI controller input and output data from save in workspace first stage. In stage two export data from workspace to ANFIS model and train data by using Hybrid algorithm technique. ANFIS used in this paper for improving performance of the system.

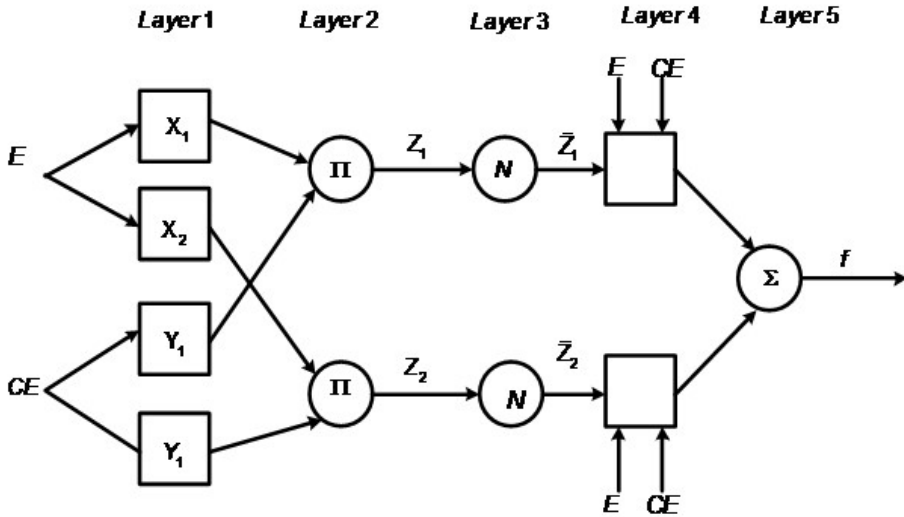


Figure 2 ANFIS Structure

$$o_i^1 = \mu_{A_i}(x), i = 1, 2, \dots \& o_i^1 = \mu_{B_i}(y), i = 1, 2, \dots \quad (1)$$

$$o_i^2 = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y), i = 1, 2, \dots \quad (2)$$

$$o_i^3 = \overline{w_i} = \frac{w_i}{\sum w_i}, i = 1, 2, \dots \tag{3}$$

$$o_i^4 = \overline{w_i} \cdot f_i = \overline{w_i} \cdot (p_k^x + q_k^y + r_k), i = 1, 2, \dots \tag{4}$$

$$o_i^5 = \sum_{i=1}^n \overline{w_i} \cdot f_i = \sum_{i=1}^n \overline{w_i} \cdot (p_k^x + q_k^y + r_k), i = 1, 2, \dots \tag{5}$$

Figure 3 shows the PQ theory with ANFIS controller, this diagram Idg, Iqg are the grid currents and Vdg, and Vqg are the grdi voltages. This voltages and currents are converters DC from AC by using Clark’s transformation.

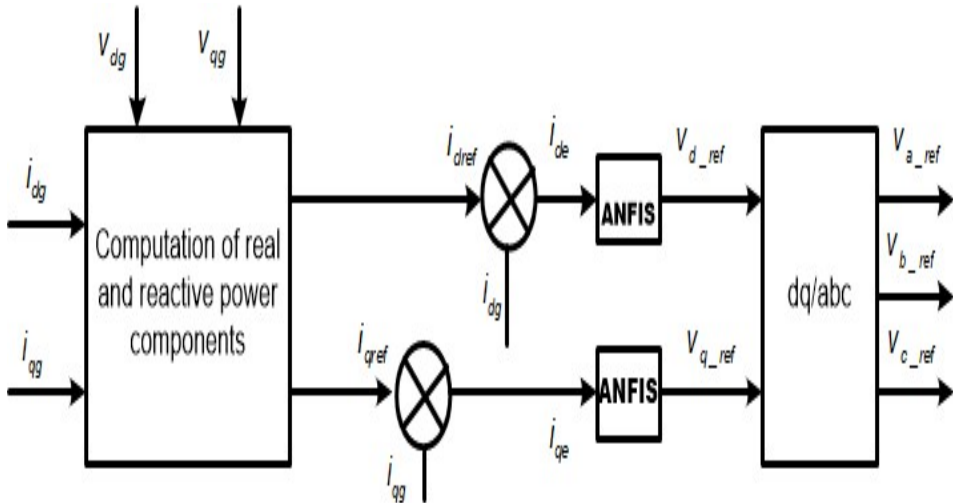


Figure.3 PQ theory with ANFIS controller

4 Simulation Results

The simulation study of DSTATCOM was conducted using the MATLAB/Simulink platform. DSTATCOM implementation involved power electronics and the block set of Simpower system. The control scheme utilized common block sets and the control library within Simpower system. Figure 4 illustrates the pretend consequences of DSTATCOM with an SMC-based SRF. Prior to DSTATCOM operation at t=0.15 sec, the resource current matched the load currents. The source current waveform exhibited high distortion, with a total harmonics distortion of 26.76%. This elevated distortion resulted from the third harmonic current induced by the nonlinear load current. Following DSTATCOM operation at t=0.15 sec, the source current waveforms at the point of coupling transitioned toward sinusoidal shapes. Simultaneously, the power factor of the source current approached unity, and the source current closely followed the source voltages. The dynamic response, including the settling time for the source current to stabilize, ranged from 2 to 3 cycles. Figure 5 displays the corresponding dc side voltage waveform of the DSTATCOM capacitor. The time required for the dc voltage of DSTATCOM to reach a steady state was approximately 50ms. Figure 6 illustrates the total harmonics distortion spectrum of the source current before harmonics elimination with DSTATCOM, indicating a total harmonics distortion value of

26.76%. However, after compensation with DSTATCOM, the total harmonics distortion of the source current significantly decreased to 2.11%, as exposed in outline 7.

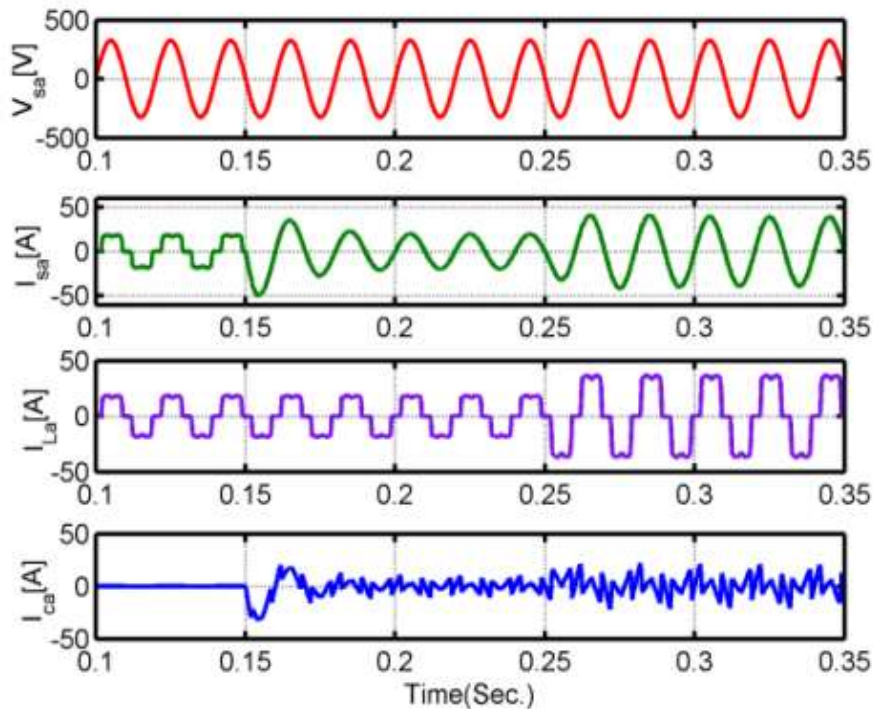


Figure .4 Simulated waveforms

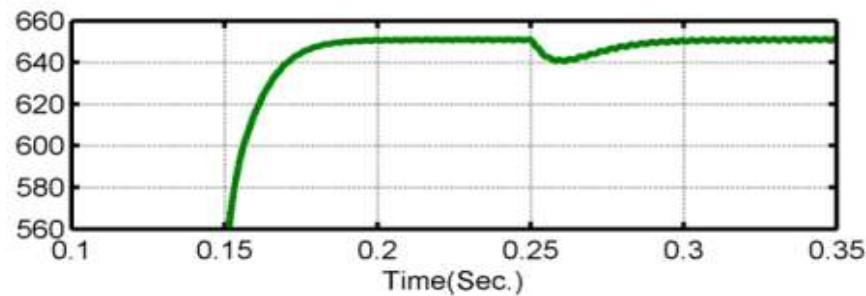


Figure.5 DC link voltage

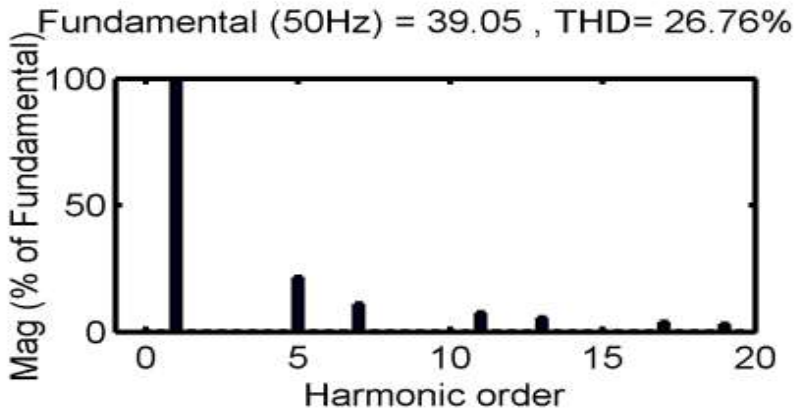


Figure .6 Source current THD without compensation

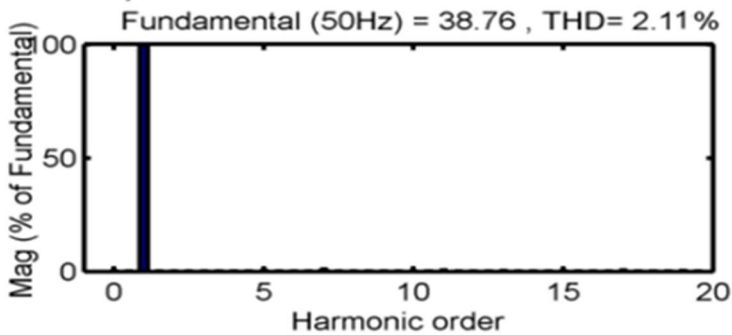


Figure 7. Source current THD with compensation.

Figure 8 showcases the source current waveforms of the DSTATCOM employing an ANFIS-based SRF. Initially, before DSTATCOM operation at $t=0.15$ sec, the foundation current closely mirrors the load current. The load current waveform contains triple harmonics and exhibits substantial distortion, primarily stemming from the non-linear load. Upon DSTATCOM compensation at $t=0.15$ sec, the foundation current waveform evolves into a sinusoidal shape due to the DSTATCOM's operation. Concurrently, the foundation power factor converges toward unity, and the source current waveform tracks the source voltage waveform. The time needed for the source current to stabilize is approximately 1-2 cycles. Figure 9 illustrates the corresponding dc side voltage of the DSTATCOM capacitor, with a stabilization time of around 0.05 sec. In Figure 6, the total harmonics distortion of the source current before harmonics elimination is depicted, revealing a value of 26.76%. Following compensation with DSTATCOM, as indicated in Figure 10, the total harmonics distortion of the source current significantly decreases to 2.03%. Notably, the results from the DSTATCOM employing the ANFIS-based SRF-based control scheme outperform those utilizing SMC-based SRF schemes. A comparative assessment of DSTATCOM performances is presented in Table 1.

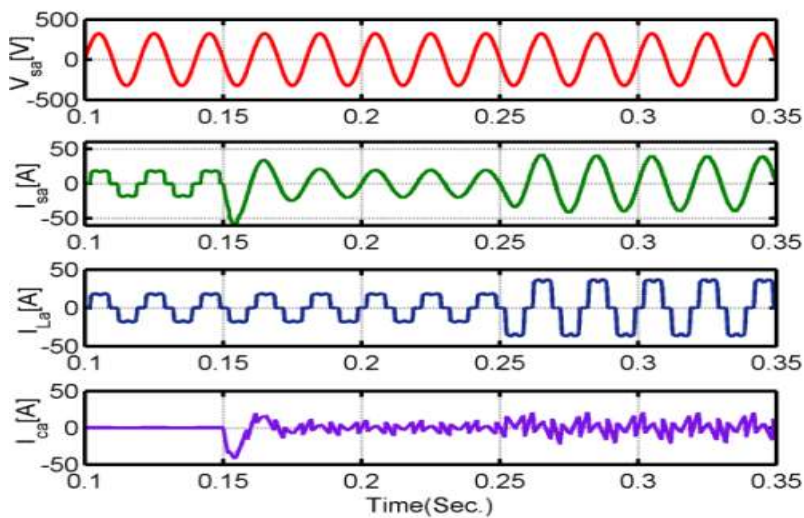


Figure 8. Simulated waveform

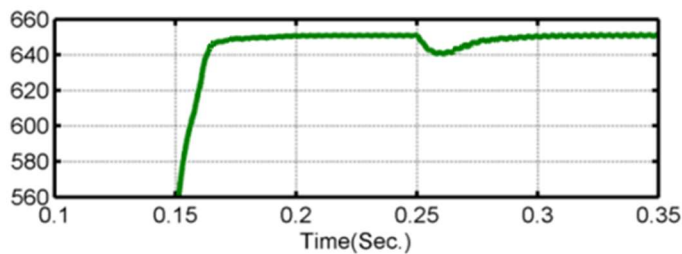


Figure 9. DC link voltage

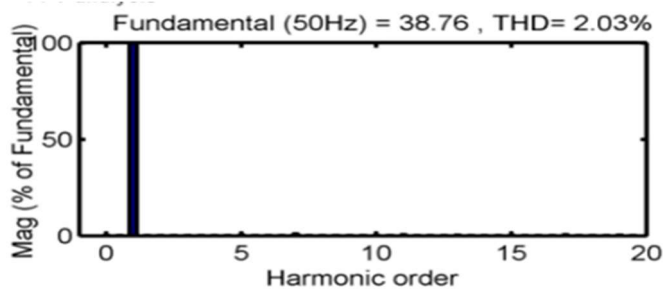


Fig. 10. Source current with compensation.

Table 1: Comparison of dynamic performance of DSTATCOM

Control scheme	Settling time (Sec.)	Percentage THD
PI-SRF	50ms	2.13
ANFIS-SRF	30ms	2.03

5 Conclusion

This paper introduces power quality enhancement in a distribution system through the implementation of PI and ANFIS control techniques. The main objective of this research is to mitigate harmonics in the source current of the distribution system. To validate the simulation outcomes, this study employs MATLAB/Simulation software. The verified results encompass source voltage, source current, compensating current, load current, and DC link voltage. When comparing the results achieved with the ANFIS controller to those with the PI controller, it becomes evident that the ANFIS controller outperforms the PI controller, particularly in steady-state and dynamic conduction scenarios. The ANFIS controller demonstrates superior performance, especially in handling non-linear conduction.

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