Performance and Harmonic reduction of Nine Switches Based Unified Power Quality Conditioner Using genetic algorithm

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Abstract:

Objective: This paper presents a novel Unified Power Quality Conditioner (UPQC) architecture utilizing a nine-switch converter to improve power quality in distribution systems connected to the grid. The proposed system effectively reduces total harmonic distortion (THD) and minimizes the number of switches required, leading to enhanced efficiency and reliability. The UPQC addresses power quality issues such as harmonics and reactive power generated by nonlinear loads, which are particularly problematic in utility systems. **Methods:** A Genetic Algorithm (GA)-based control strategy is employed in the nine-switch UPQC to optimize performance in mitigating voltage sags, swells, and reducing harmonic distortion on the load side. The effectiveness of the GA-based approach is validated through simulations conducted in MATLAB/Simulink, which demonstrate superior performance compared to conventional control methods. **Applications/Improvements**: The proposed UPQC system, incorporating an nine-switch converter for certain scenarios, demonstrates robust steady-state and dynamic performance in managing nonlinear load conditions and mitigating utility voltage disturbances. The results suggest that the GA-optimized UPQC offers significant enhancements in power quality, making it a compelling solution for contemporary distribution system.

Keywords: Nine Switch Unified Power Quality Conditioner (UPQC), Genetic Algorithm (GA), Total Harmonic Distortion (THD).Non linear load.

Introduction

Power quality is becoming increasingly important in modern electrical systems, especially with the rise of nonlinear loads that introduce significant harmonic distortion. These distortions, including harmonics, notching, and inter-harmonics, can degrade the performance and reliability of the power supply. Devices such as microcontroller-based systems and AC/DC drives, commonly used in various industries, play a role in reducing issues like voltage sags and swells. However, in automation industries that rely heavily on power electronics, the presence of such loads often leads to power quality problems. To address these issues, both active and passive filters are employed to minimize power distortions. Ensuring that the power delivered to consumers is both sufficient in quantity and high in quality is crucial. Harmonics, particularly in inverter outputs, are a common challenge, with AC current being more affected than voltage. Utilities can counteract these harmonics by using Flexible AC Transmission Systems (FACTS) devices to balance and maintain the desired power quality.

A Unified Power Quality Conditioner (UPQC) has been developed to integrate the functions of shunt and series power converters, utilizing a capacitor for voltage regulation. This UPQC is designed to address a range of power quality challenges, including voltage harmonics, flicker, sags, swells, and reactive power management. The innovative nine-switch converter employs a genetic algorithm to optimize the control of both shunt and series active power filters, improving the efficiency and effectiveness of the power conditioning system

In recent days, the usage of power converter has increased and more development in converter topologies. The developed power converter has used in many applications and it contribute towards increase the power quality and also burden of power system by producing the harmonics in voltage and current and enhance the reactive current. Harmonics has increased the losses and also generates the noise signal in communication channel such as voltage and current. The active power filter is mostly used in developing the power quality and also uses various functions such as load balancing, harmonics, damping, segregation and extinction, reactive power control for power factor correction and voltage maintenance [1–2]. The harmonics are decreased by using filter in olden days but proposed method utilizes the controller. The controller has to decrease the harmonic content in load current by using the genetic controller. The UPQC has to solve the power quality problems [3–4]. The DC link voltage is maintained by using the reference voltage. Other controllers, for example PI; PID, fuzzy, model predictive control and sliding mode control are used to compensate the voltage mitigation [7–10]. The UPQC has constructed equally in series and shunt converter. The series converter connects with distribution feeder using an isolation transformer [11]. The shunt converter regulates the load harmonics and series converter is proscribed. The grid current has only fundamental component and which is sinusoidal. The term power quality can be associated with the reliability of the system by the electrical utilities [12–13].

Methodology

The UPQC (Unified Power Quality Conditioner) is designed to enhance compensation for voltage sags, swells, and harmonics across both linear and non-linear loads using a nine-switch topology. To regulate the DC-link voltage, a genetic algorithm-based sine PWM (Pulse Width Modulation) technique is employed, ensuring effective control over the sag, swell, and harmonic distortions in the load converter. This genetic control method optimizes the tuning process, leading to improved compensation for voltage sags and swells. Capacitors are incorporated in the DC-Link as well as in the legs of the shunt and series converters. Figure 1 provides a schematic overview of the UPQC system,

Nine Switches Based UPQC

This research investigates a nine-switch power converter designed for distribution systems to enhance power quality. The nine-switch Unified Power Quality Conditioner (UPQC) topology is employed to reduce harmonics and address issues such as high switching stress and elevated DC link voltage. The UPQC includes both shunt and series converters, with the converters connected back-to-back via a DC link capacitor. The shunt converter acts as a current source, while the series converter serves as a voltage source. The shunt converter compensates for current harmonics, and the series converter compensates for voltage harmonics.

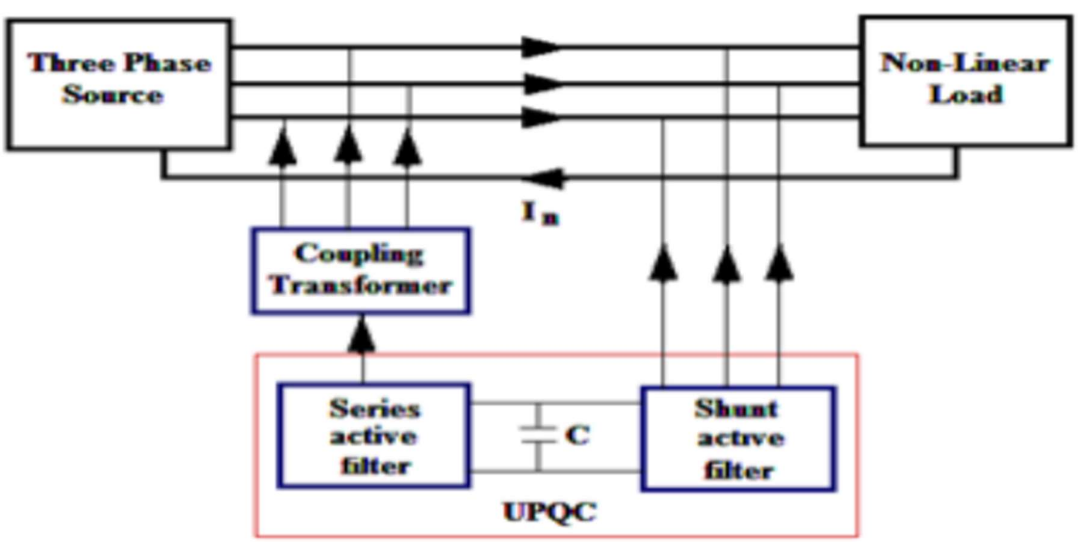

Figure 1. Basic representation of UPQC

UPQC, or Unified Power Quality Conditioner, is a FACTS (Flexible AC Transmission System) device designed to improve power quality by addressing both voltage and current issues in the electrical system. It compensates for voltage sags, swells, harmonics, and unbalanced loads to ensure a stable and reliable power supply.The classification or prediction function for UPQC typically involves identifying and mitigating power quality issues. It might use measurements from the electrical system to classify conditions such as voltage sags, swells, or harmonic distortions.

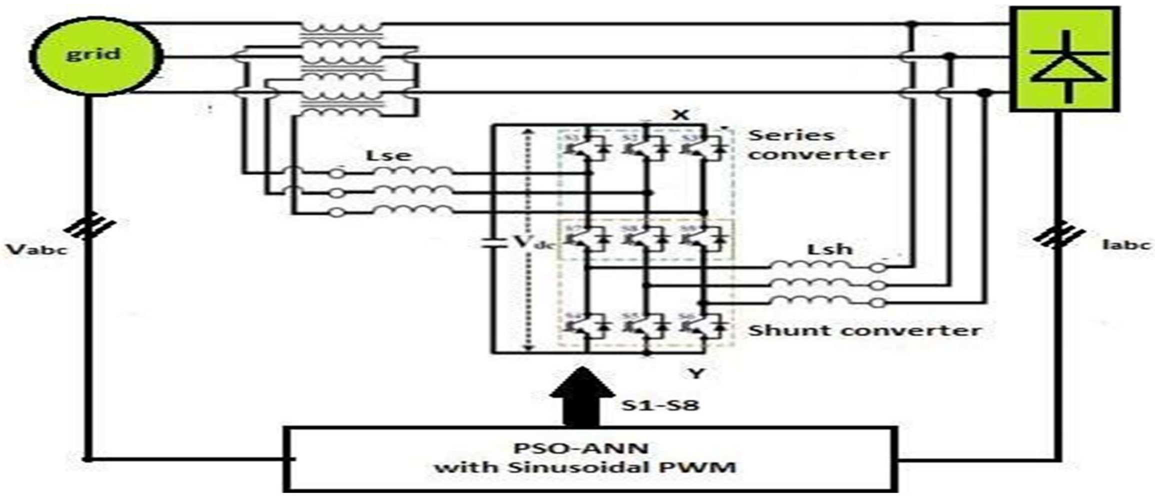

Figure 2: Nine based Unified Power Quality Conditioner (UPQC)

Block Diagram of Nine Switches UPQC

Despite its satisfactory performance, the traditional UPQC topology struggles with computational issues at lower modulation levels in the series converter. The nine-switch UPQC is organized into three legs, each with three switches. Here, combination X represents the series converter, and combination Y represents the shunt converter. The upper switches' reference wave is generated from the load voltage error, while the lower switches' reference wave is derived from the source current error. The gate pulses for the middle switches are generated based on the gate pulses of both the upper and lower switches, as described by:

$S7 = S1 \cdot S4; S8 = S2 \cdot S5; S9 = S3 \cdot S6;$

The reference load voltage and source currents are computed using a modified version of the instantaneous reactive power theory.

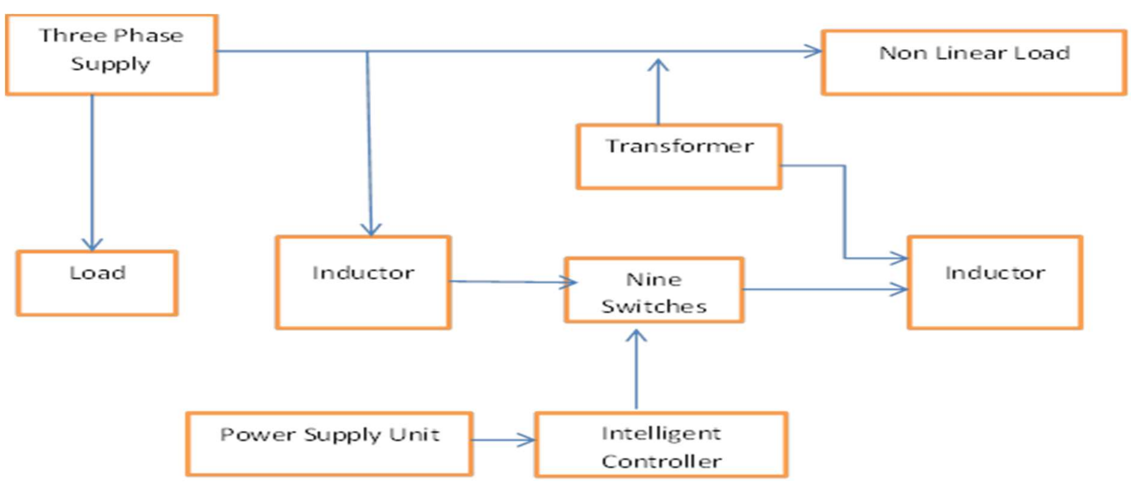

Figure 3: Block Diagram of Nine Switches UPQC

Genetic Algorithm Controller

Genetic Algorithms (GAs) are optimization techniques inspired by natural selection, where stronger individuals have a higher likelihood of surviving and reproducing. This approach can be used to optimize parameters in complex systems, such as tuning control parameters kp and ki in a Proportional-Integral (PI) controller.:

1. Selection Mechanism: GA selects individuals based on their fitness, which in your case could be how well kp and ki perform in controlling the system. Fitter individuals are more likely to contribute to the next generation.
2. Operators:
   Crossover: Combines parts of two solutions to create offspring.
   Mutation: Introduces random changes to individuals to maintain diversity in the pulation.
3. Flowchart Overview: The GA flowchart typically involves the following steps:
   Initialization: Generate an initial population of possible solutions.
   Evaluation: Assess the fitness of each individual.
   Selection: Choose individuals based on their fitness to produce offspring.
   Crossover and Mutation: Apply genetic operators to generate new solutions.
   Replacement: Form a new population and repeat the process.
4. Advantages:
   High Performance: GA can efficiently explore large and complex search spaces.
   Avoidance of Local Minima: By maintaining a diverse population and using genetic operators, GA helps in finding global optima rather than getting stuck in local minima.
   Handling Complexity: GA can manage high-dimensional problems without needing complex derivative-based optimization methods.

In summary, GA is effective for tuning control parameters due to its robust performance in exploring and optimizing complex systems. It leverages evolutionary principles to handle high-dimensional and non-linear problems effectively.

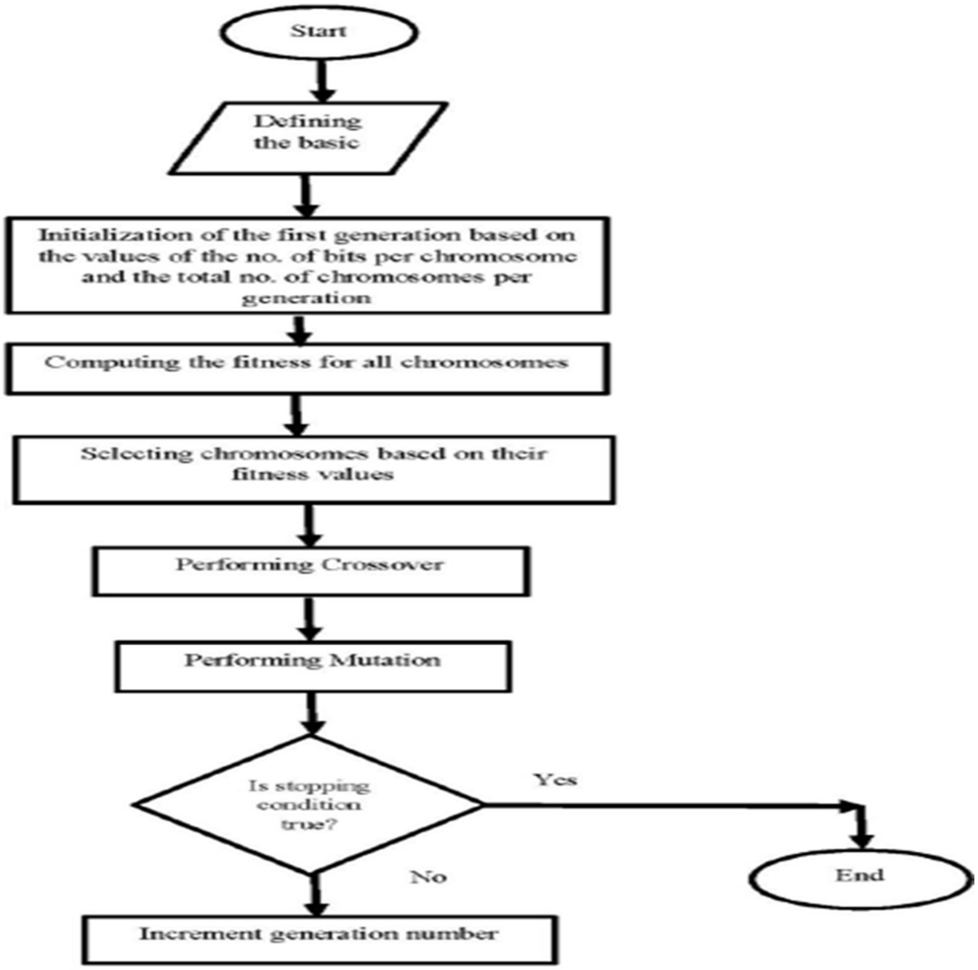

Figure 4: Flow chart of Genetic Algorithm

GA Parameters using Nine Switch UPQC

Parameter	**Value**
Population size	10
Selection	roulette
Mutation rate	0.001
Cross rate	0.6
Generation no	50
tolerance	10^{-6}

Result and Discussion

The UPQC (Unified Power Quality Conditioner) used for compensating voltage and current has been designed and implemented in MATLAB Simulink. Figure 5 illustrates the simulation diagram of the Nine-switch UPQC system.

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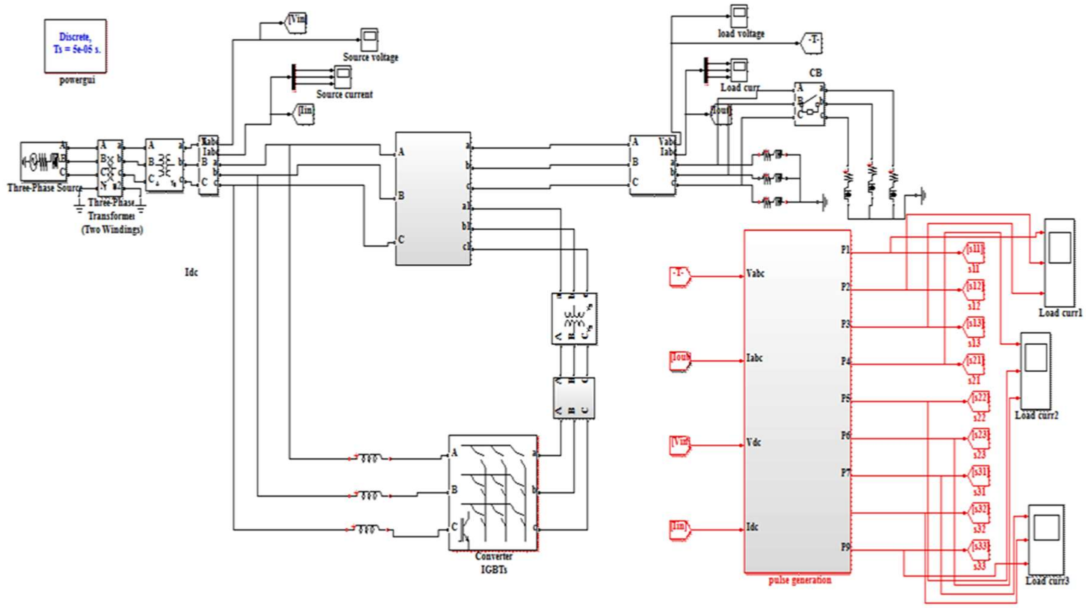

Figure 5: Simulation diagram of nine switches UPQC

Figure 6 presents the input voltage under sag conditions in the grid. The gate pulses required for switching have been generated and applied to the switches. These gate pulses are produced by comparing reference values, which control when each switch turns ON or OFF. Figures 7 and 8 displays the output voltage and current, respectively, while Figure 9 illustrates the total harmonic distortion (THD) of the system

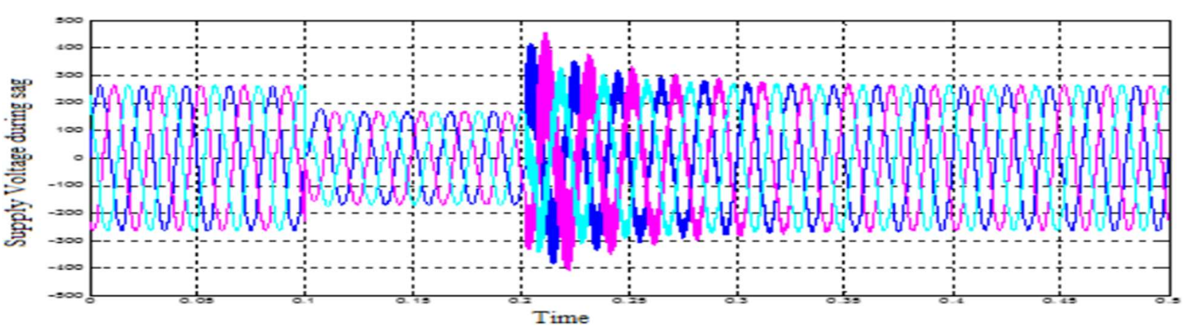

Figure 6. Source voltage during sag condition with nine switch UPQC

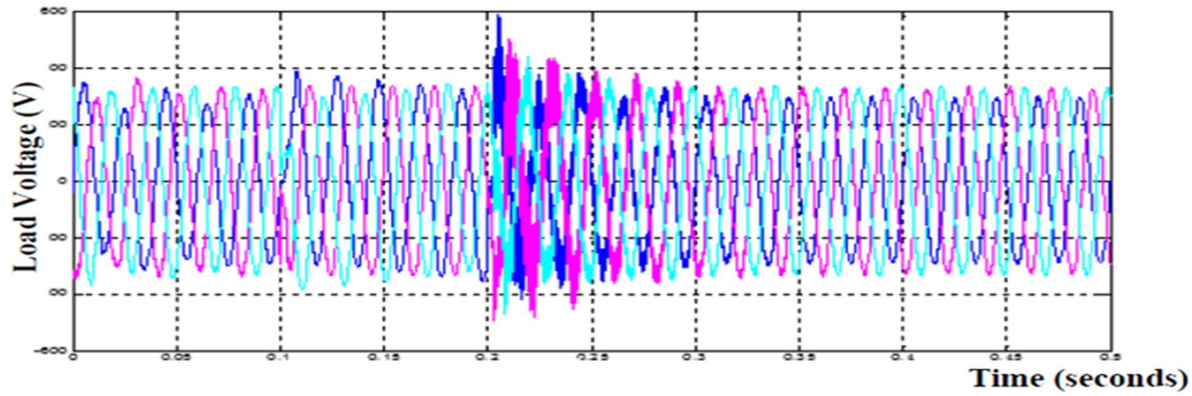

Figure 7. Load voltage in nine switches UPQC using GA

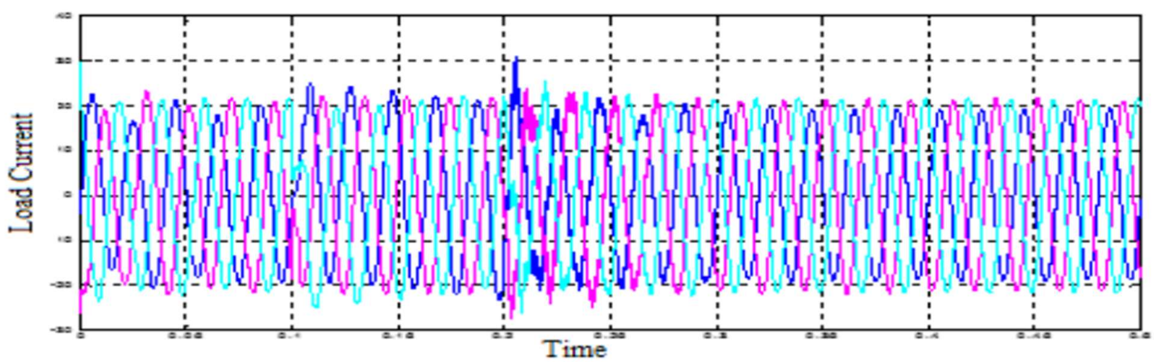

Figure 8. Load current in nine switch UPQC using GA

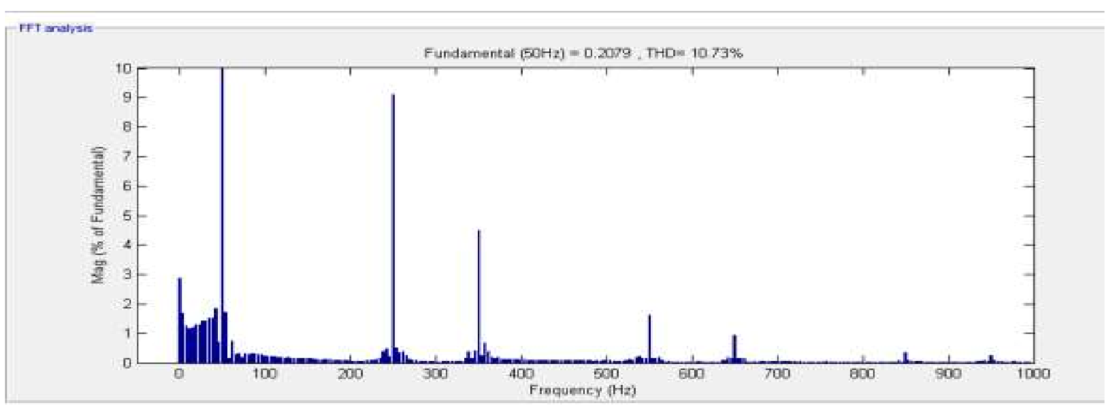

Figure 9: THD for non linear load without nine switch upqc

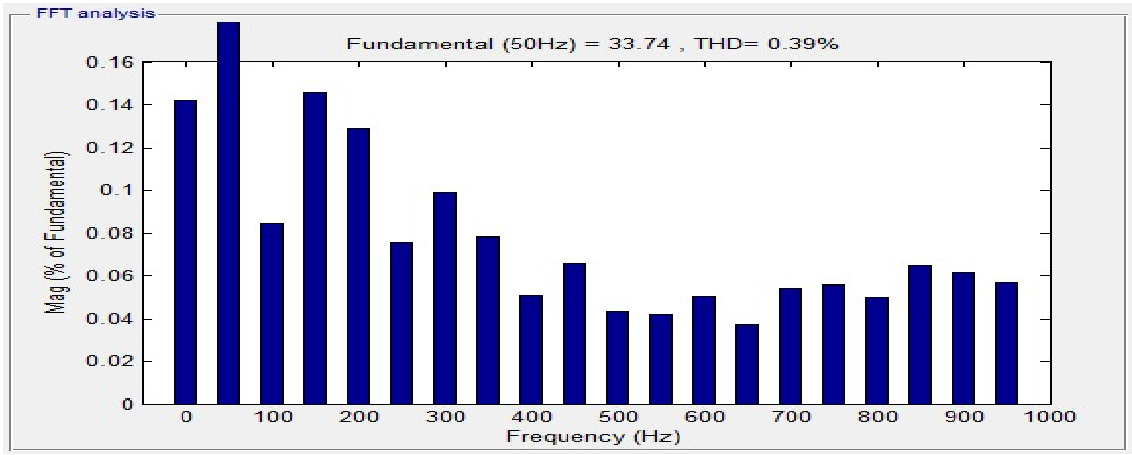

Figure 10: Total harmonic distortion of non- linear load using genetic controller

Conclusion

This study presents a GA-based control method for an eight-switch UPQC, which significantly improves the system's ability to compensate for voltage sags, swells, and reduce harmonic distortion on the load side. The proposed system, supported by simulation results, shows superior performance compared to conventional methods. The reconfiguration process, which involves changes in switching status, effectively addresses voltage sag issues. Additionally, the optimization control techniques enhance reactive power compensation, harmonic reduction, and overall voltage and current regulation. The results demonstrate that the GA-based reconfiguration method is a proficient and practical solution for improving power quality

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