International Journal of Computational Science and Engineering Research
ISSN: XXXX- XXXX(Online) , http://www.ijcser.com/
Regular Issue , Vol. 1, Issue. 1 (October – December) , 2024 , Pages: 1 - 4
Received: 04 May 2024 ; Accepted: 20 August 2024 ; Published: 25 September 2024.
Research Paper , https://doi.org/10.XXX/XXXX.XXXX.XX.XXXX

DSTATCOM enhanced Controller for Harmonic Reduction using Artificial Neural Networks

K. Krishna Reddy [1*], N V Kishore Kumar [2]

[1,2] Department of EEE, Mother Theresa Institute Of Engineering and Technology (A),Palamaner, JNTUA, AP, India ; krishnareddy206@mtieat.org

Abstract: Harmonic amplification presents a significant challenge in power system networks, often leading to power quality degradation. This study aims to address and mitigate the impact of such harmonic disturbances. A novel control strategy based on artificial intelligence (AI) is introduced and integrated into a Distribution Static Synchronous Compensator (DSTATCOM). As a type of Flexible AC Transmission System (FACTS) device, the DSTATCOM provides efficient reactive power compensation, playing a key role in suppressing or minimizing harmonic amplification within the network. The performance and effectiveness of the proposed approach are validated through simulations carried out in the MATLAB/Simulink environment.

Keywords: Distribution Static Synchronous Compensator (DSTATCOM), Neural Network, Harmonics, Power Quality

1. Introduction

In recent years, power system stability has become a major concern for engineers, especially in light of increasing occurrences of blackouts. A Distribution Static Synchronous Compensator (DSTATCOM), which functions as a shunt-connected Flexible AC Transmission System (FACTS) device, has emerged as an effective solution to enhance system stability. The STATCOM operates by injecting reactive current in phase quadrature with the supply voltage, effectively simulating the behavior of capacitive or inductive elements as needed.

The widespread use of nonlinear loads in modern electrical networks has introduced significant challenges, primarily in the form of harmonics. These harmonic distortions are typically a result of resonance interactions between inductive (L) components and power factor correction capacitors, particularly in systems employing power electronic equipment. To mitigate such issues, both transmission and distribution sectors have increasingly adopted FACTS devices for harmonic suppression through damping techniques [1, 2].

DSTATCOMs are particularly well-suited for this role, as they offer dynamic reactive power support to maintain voltage stability and improve power quality. Compared to other custom power solutions such as Dynamic Voltage Restorers (DVRs) and Unified Power Quality Conditioners (UPQCs), DSTATCOMs provide a cost-efficient means of managing reactive power and correcting load imbalances in distribution systems. Ensuring high power quality is crucial for customer satisfaction and system reliability. However, with the growing prevalence of nonlinear devices and power electronic converters, power quality concerns are expected to intensify.

To address these emerging challenges, this study introduces an AI-based control strategy designed to enhance the inverter's performance in terms of Total Harmonic Distortion (THD). While earlier approaches have applied artificial neural networks (ANNs) and standard backpropagation algorithms for controlling Shunt Active Filters (SAFs) \[3–5], many of these lack real-time adaptability and have not been thoroughly tested under varying load conditions.

Electrical faults, regardless of their location along transmission lines, can significantly affect power system hardware [6, 7]. Such disturbances in both transmission and distribution networks lead to voltage instability and can damage consumer equipment [8]. To counteract this, FACTS devices have been utilized to enhance the operational efficiency of power networks. These controllers are capable of supporting grid functionality under both normal and stressed operating conditions. Variants of FACTS devices include STATCOM, Unified Power Quality Conditioner (UPQC), Static Var Compensator (SVC), Solid-State Generator (SSG), Thyristor-Controlled Reactor (TCR), Thyristor-Switched Capacitor (TSC), Thyristor-Switched Reactor (TSR), and Static Synchronous Series Compensator (SSSC). This study focuses specifically on the performance of DSTATCOM.

The reactive power output of a STATCOM is influenced by the voltage amplitude of its internal source. When applied in distribution networks, this configuration is often referred to as a Distribution STATCOM (DSTATCOM) [7, 9]. Previous research \[10–12] has explored integrating similar control methods into generator frequency control loops to stabilize frequency fluctuations, especially in grids with high penetration of renewable sources like wind, solar, and electric vehicles. However, limited attention has been paid to the challenges in implementing advanced pulse-width modulation (PWM) techniques using adaptive dynamic programming (ADP) controllers.

Some investigations \[13, 14] have demonstrated the use of vector control in grid-connected inverter/rectifier systems employing ANNs and time-based backpropagation learning algorithms. The primary objective of this work is to demonstrate the effectiveness of DSTATCOM in mitigating harmonic distortion in power systems. An artificial neural network (ANN)-based control method is employed, offering an adaptive and intelligent approach. Simulation studies were conducted using MATLAB/Simulink to evaluate the proposed control strategy's performance**.**

2. Literature Survey

This study focuses on the deployment of a shunt active filter by an electric utility, emphasizing both the control methodology and optimal placement of the filter within a power distribution feeder. The primary role of the shunt active filter is to suppress harmonic propagation resulting from resonance between line inductors and the capacitors installed for power factor correction, rather than targeting a full reduction of voltage distortion across the feeder. Harmonic suppression emerges as a beneficial secondary effect of this resonance damping process. The findings indicate that utilizing a voltage detection-based control approach at the filter's installation point offers enhanced system stability. Additionally, it was concluded that installing the filter at the far end of the feeder, rather than near the source, yields better performance. These conclusions are supported by computer simulations, using an analog circuit simulator, on a radial distribution feeder typical of residential networks.

In another contribution by P. S. Vazquez, a control scheme for active power filters (APFs) using neural network technology is explored. With the growing presence of nonlinear loads, voltage and current harmonics have become increasingly prevalent. APFs are introduced as a solution for harmonic compensation and power factor correction. The proposed control strategy incorporates pulse width modulation (PWM) with two neural network modules: adaptive networks to estimate the reference compensation currents, and a multilayer feedforward perceptron—trained using backpropagation—to act as a hysteresis comparator. The effectiveness of the system is demonstrated through simulation in MATLAB/Simulink under two practical case scenarios.

Further advancing the concept of intelligent filtering, a high-performance neural-based APF is introduced to analyze and counteract harmonic distortion in AC power lines. This filter relies entirely on Adaline neural networks, which are arranged into distinct functional blocks. A novel approach is presented for real-time voltage component extraction using Adalines, enabling restoration of a balanced voltage waveform. Additionally, three distinct harmonic filtering methods are proposed, each capable of isolating the fundamental frequency component from harmonic distortions. These approaches are grounded in either Instantaneous Power Theory or Fourier analysis, guiding the design and input structure of the neural network blocks. Various learning algorithms are employed to regulate the inverter and inject compensation currents accordingly. The effectiveness of each method is validated through simulations and real-time experimental testing. The learning ability of neural networks allows these methods to handle dynamic system parameters, significantly outperforming conventional compensation techniques in adaptive harmonic mitigation.

Lai L. L.'s work on intelligent system applications in power engineering highlights the growing importance of computational intelligence methods, such as evolutionary programming and neural networks, for solving complex power system challenges. His 1998 publication emphasizes that evolutionary algorithms are poised to become a dominant optimization tool in the power sector. By integrating theoretical insights with practical implementation, the work illustrates how neural networks and evolutionary strategies can be effectively applied to tasks such as load forecasting, system operation, and optimization planning. These innovative techniques offer power utilities advanced solutions that exceed the capabilities of traditional optimization methods, thereby driving greater system efficiency and resilience.

Key features of this work include a foundational overview of evolutionary programming and neural networks, which sets the stage for exploring the advantages of integrating these intelligent systems. The text offers practical examples of how evolutionary programming can be applied to reactive power planning and dispatch, enabling rapid and cost-efficient enhancements in transmission capacity and aiding in generator parameter estimation.

The study also delves into several critical areas such as economic dispatch, power flow regulation in Flexible AC Transmission Systems (FACTS), co-generation scheduling, and diagnostic techniques for high-voltage direct current (HVDC) systems and power transformers. Additional focus is given to the evaluation of power frequency and harmonics, with the goal of improving supply quality.

Vol. 1, Issue 1, 2024 , https://doi.org/10.XXX/XXXX.XXXX.XX.XXXX

Other applications discussed include distance protection schemes, fault location identification, and determining fault clearing times, all of which are crucial for maintaining transient stability in power systems. This broad range of topics makes the book particularly useful for graduate students in electrical power engineering, as well as industry professionals. Engineers, software developers, consultants, and utility executives will find valuable insights into how intelligent systems can significantly enhance power system operations and decision-making processes.

Additionally, the IEEE's Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment (IEEE Xplore, 1998) introduces a standard methodology for assessing voltage sag compatibility. This approach is designed to support planning by quantifying both the severity of voltage sags and the sensitivity of process equipment. It provides a framework for evaluating both technical and financial strategies to mitigate compatibility issues, although it does not define performance standards for utility networks, distribution systems, or electronic equipment.

3. Proposed System

The below figure1 shows block diagram of the DSTATCOM with ANN controller. The system consists three phase source, load, DSTATCOM and ANN controller the arrangement is shown in below figure. the DSTATCOM consists DC link capacitor (energy storage), Voltage Source Inverter (VSI) and passive filter. The VSI is controlled by SPWM techniques.

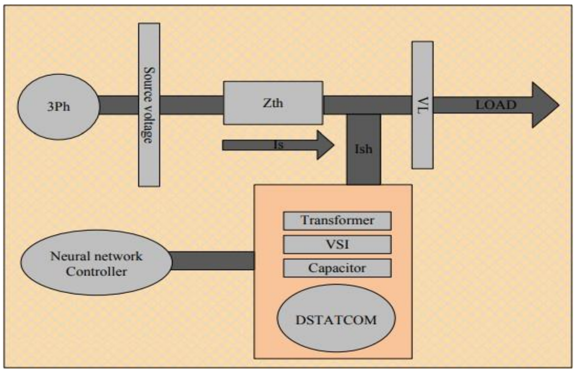

Fig 1 Diagram of the power model with DSTATCOM.

During periods of increased voltage fluctuations, such as those caused by voltage sags, the DSTATCOM adjusts power compensation based on the load bus impedance (Zth) or the corresponding fault level. Voltage regulation is achieved without the need to inject reactive power into the system when the shunt current (Ish) is minimized. The effectiveness of voltage correction by DSTATCOM is closely tied to the accurate estimation of Zth. When the injected shunt current Ish is maintained in phase quadrature with the line voltage (VL), it becomes possible to achieve the desired voltage correction without supplying active power to the system, provided Ish is kept at a minimum. As illustrated in Fig. 1, the DSTATCOM is configured to operate based on the relationship between the source current (IS) and the load current (IL). It employs a basic two-level voltage source converter (VSC), which is regulated using a neural network (NN)-based controller to generate a standard sinusoidal pulse-width modulation (PWM) signal [16].

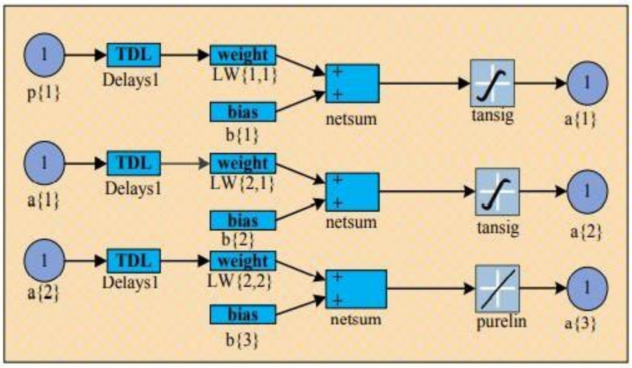

Fig. 2 Neuron in matrix form at each layer

The system's output is fed back to help correct filtering errors, thereby enhancing overall accuracy. In feedback control system design, it is essential to ensure both accurate tracking performance and internal system stability, meaning that all system variables must remain bounded. If these conditions are not met, the closed-loop system may experience severe issues, such as instability or uncontrolled signal growth, which could ultimately lead to system malfunction or damage.

In the context of the neural network (NN) used here, the weights (Wij) are associated with a single neuron—meaning the neuron operates with only one row of weights. The output of this neuron can be described based on these inputs and their corresponding weights. However, using a single neuron with multiple inputs is generally inadequate for complex tasks.

In many cases, a greater number of neurons often more than ten—are organized into what is known as a layer to enable efficient parallel processing, as depicted in Fig. 3. Fig. 4 illustrates how these neurons are structured into layers and interconnected.

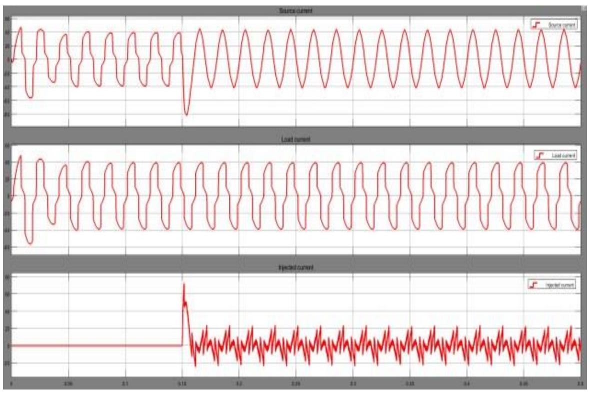
Fig 3. (a)Source current (b) Load current (c)Injected current

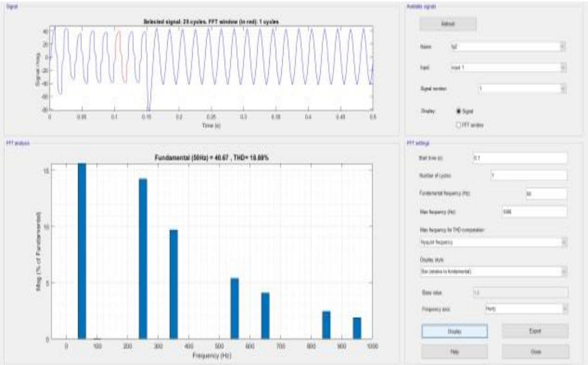

Fig.4 Source current THD% (18.88%) before compensation

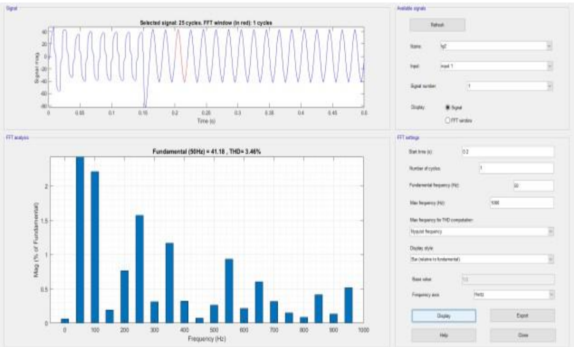

Fig.5 Source current THD% (3.46%) after compensation

4. Conclusion and Future Scope

Harmonics are a common power quality issue that can arise due to distortion in the voltage waveform experienced by customers. This study introduces a discrete-time multilayer neural network-based controller for a Distribution Static Compensator (DSTATCOM). The neural network's weights are adaptively tuned in real-time, guided by the filtered error from the entire closed-loop control system. The DSTATCOM provides both series and shunt compensation to address disturbances in the power system. A simulation model of the distribution control system was developed with the objective of minimizing harmonic distortion. The control strategy was designed and tested in MATLAB/Simulink, integrated within a power distribution network. The simulation assessed system behavior under voltage sag conditions and analyzed the impact on voltage and current waveforms. The goal of implementing DSTATCOM in this context is to improve power quality in distribution systems, particularly when nonlinear loads are present. To mitigate power quality disturbances, appropriate devices compatible with the power network were utilized.

References

[1]. Akagi H. Control Strategy and Site Selection of a Shunt Active Filter for Damping of Harmonic Propagation in Power Distribution Systems. IEEE Trans Power Deliv 1997; 12(1): 354-63. [http://dx.doi.org/10.1109/61.568259]

[2]. R. S. and D. K. Singh. Simulation of D-STATCOM for Voltage Fluctuation 2012 Second IntConfAdvComputCommun Technol. 226- 31.

[3]. P. S. Vazquez. Active power filter control using neural network technologies IEE Proceedings-Electric Power Appl. 54(1): 61-76.

[4]. Abdeslam DO, Wira P, Flieller D. A Unified Artificial Neural Network Architecture for Active Power Filters. IEEE Trans Ind Electron •••; 54(1): 61-76. [http://dx.doi.org/10.1109/TIE.2006.888758]

[5]. Lai L L. Intelligent System Applications in Power Engineering: Evolutionary Programming and Neural Networks. 1998.

[6]. IEEE Recommended Practice for Evaluating Electric Power System Compatibility With Electronic Process Equipment. IeeeXplore 1998.

[7]. Salman GA, Hussein HI, Hasan MS. Enhancement The Dynamic Stability of The Iraq ' s Power Station Using PID Controller Optimized by FA and PSO Based on Different Objective Functions. ElektrotehVestn 2018; 85(2): 42-8.

[8]. H.W.Dugan RC, McGranaghan M F, Santoso S. Electrical Power Systems Quality , Second Edition. In: mcgraw-Hill. 2004.

[9]. Hong AY, Chen YY. Placement of power quality monitors using enhanced genetic algorithm and wavelet transform. IET GenerTransmDistrib 2011; 5(4): 461-6. [http://dx.doi.org/10.1049/iet- gtd.2010.0397]

[10].Guo W, Liu F, Si J, He D, Harley R, Mei S. Online Supplementary ADP Learning Controller Design and Application to Power System Frequency Control With Large-Scale Wind Energy Integration. IEEE Trans Neural Netw Learn Syst 2016; 27(8): 1748-61.

[11].Guo SMW, Liu F, Si J, He D, Harley R. Approximate Dynamic Programming Based Supplementary Reactive Power Control for DFIG Wind Farm to Enhance Power System Stability. Neurocomputing •••; 170: 417-27.

[12].Tang Y, Yang J, Yan J, He H. Intelligent load frequency controller using GrADP for island smart grid with electric vehicles and renewable resources. Neurocomputing 2015; 170: 406-16.