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Enhancing Power Quality and Harmonic Analysis for Constant Power Supply Using ANN Based Satic Var Compensator (SVC)

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ABSTRACT

The consistent power failure that has jeopardized business activities in the country are anchored by Harmonic Distortion, Voltage Sag/Surge, Overloading of Transmission Lines, Unbalanced Loads, Electrical Noise (EMI/RFI), Capacitor Switching Transients, Frequency Variations, Power Factor Issues, Poor Grounding and Short Circuits and Electrical Faults. The constant power failure observed was overcome by introducing enhancing power quality and harmonic analysis for constant power supply using ANN BASED SATIC VAR COMPENSATOR (SVC). To achieve this, it was done in this approach, characterizing and establishing the causes of power failure in power quality and harmonic analysis for constant power supply, training ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply. Developing a SIMULINK model for SVC, developing an algorithm that will implement the process, designing a SIMULINK model for enhancing power quality and harmonic analysis for constant power supply using ANN based SATIC VAR COMPENSATOR (svc) validating and justifying percentage improvement in the reduction of causes of power failure with and without power failure. The results obtained are the conventional harmonic distortion that caused power failure in power quality and harmonic analysis for constant power supply was 25%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it drastically reduced to21.53%., the conventional Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply was 20%. Meanwhile, when an ANN BASED SATIC VAR COMPENSATOR was inculcated in the system, it decisively reduced Voltage Sag/Surge that caused power failure to17.23%. However, the percentage improvement in the reduction of Voltage Sag/Surge that caused power failure was 2.77% and the conventional power factor issues that caused power failure in power quality and harmonic analysis for constant power supply was5%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it automatically reduced power factor issues that caused power failure to 4.3%. Finally, the percentage improvement in the enhancement of power quality and harmonic analysis for constant power supply was 0.7%

INTRODUCTION

The imperative need for reliable and high-quality power supply has become increasingly paramount in today's interconnected and technologically advanced world. The proliferation of sensitive electronic equipment, coupled with the growing demand for electric power, has underscored the significance of maintaining stable voltage levels and mitigating harmonic distortions. To address these challenges, advanced power system control technologies have emerged as promising solutions.

Static Var Compensators (STATCOMs), a type of Flexible AC Transmission System (FACTS) device, have gained significant attention due to their ability to rapidly and accurately control reactive power flow in electrical networks. By injecting or absorbing reactive power, STATCOMs can effectively regulate voltage levels, enhance system stability, and mitigate harmonic distortions.

However, the effectiveness of STATCOMs hinges on accurate and timely control strategies. Traditional control methods, while functional, may exhibit limitations in adapting to dynamic system conditions and handling complex harmonic interactions. To overcome these challenges, Artificial Neural Networks (ANNs) have emerged as a powerful tool for intelligent control.

This research explores the integration of ANNs into STATCOM control systems to enhance power quality and perform robust harmonic analysis. By leveraging the learning capabilities of ANNs, the proposed system aims to achieve:

- Improved voltage regulation: Precise control of reactive power injection or absorption to maintain stable voltage levels.
- Enhanced system stability: Effective damping of power oscillations and prevention of voltage collapses.
- Mitigated harmonic distortions: Accurate identification and compensation of harmonics to ensure clean power delivery.
- Adaptive control: Real-time adjustment of STATCOM operation based on changing system conditions and load characteristics.

Through a combination of STATCOM technology and ANN-based control, this research seeks to contribute to a more reliable, efficient, and sustainable power grid.

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Problem Statement

The increasing complexity and sensitivity of modern electrical systems have highlighted the critical need for reliable and high-quality power supply. The proliferation of nonlinear loads, such as power electronic devices and variable speed drives, has led to significant harmonic distortions, resulting in voltage fluctuations, increased losses, and potential equipment damage. Additionally, the growing demand for electric power has put immense pressure on power grids, necessitating effective voltage regulation and system stability.

Traditional control methods for Static Var Compensators (STATCOMs), while functional, may exhibit limitations in adapting to dynamic system conditions and handling complex harmonic interactions. These limitations can compromise the overall performance of STATCOMs in maintaining power quality and ensuring system stability.

Therefore, the primary objective of this research is to develop an advanced control strategy for STATCOMs, utilizing Artificial Neural Networks (ANNs), that can effectively address the challenges posed by harmonic distortions and dynamic system conditions. The proposed ANN-based control system aims to:

Improve Voltage Regulation

Achieve precise control of reactive power injection or absorption to maintain stable voltage levels.

Enhance System Stability

Effectively damp power oscillations and prevent voltage collapses.

Mitigate Harmonic Distortions

Accurately identify and compensate for harmonics to ensure clean power delivery.

Enable Adaptive Control

Real-time adjustment of STATCOM operation based on changing system conditions and load characteristics.

By addressing these challenges, the research seeks to contribute to a more reliable, efficient, and sustainable power grid.

Aim and Research Objectives

Aim

The primary aim of this research is to develop an advanced control strategy for Static Var Compensators (STATCOMs) using Artificial Neural Networks (ANNs) to enhance power quality and perform robust harmonic analysis. The proposed ANN-based control system seeks to:

Improve Voltage Regulation

Achieve precise control of reactive power injection or absorption to maintain stable voltage levels.

Enhance System Stability

Effectively damp power oscillations and prevent voltage collapses.

Mitigate Harmonic Distortions

Accurately identify and compensate for harmonics to ensure clean power delivery.

Enable Adaptive Control

Real-time adjustment of STATCOM operation based on changing system conditions and load characteristics.

By achieving these objectives, the research aims to contribute to a more reliable, efficient, and sustainable power grid.

Objectives

1. To characterize and establish the causes of power failure in power quality and harmonic analysis for constant power supply
2. To train ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply.
3. To develop a SIMULINK model for SVC
4. To develop an algorithm that will implement the process.
5. To design a SIMULINK model for enhancing power quality and harmonic analysis for constant power supply using ANN based SATIC VAR COMPENSATOR (svc)
6. To validate and justify percentage improvement in the reduction of causes of power failure with and without power failure.

Scope of the Work

The scope of this research encompasses the following key areas:

LITERATURE REVIEW

A comprehensive review of existing research on STATCOM control strategies, ANN applications in power systems, and harmonic analysis techniques.

ANN Model Development: Design and development of suitable ANN architectures for STATCOM control, including selection of appropriate activation functions, training algorithms, and network topologies.

Harmonic Analysis Algorithm

Development of an ANN-based algorithm for accurate identification and quantification of harmonic currents in the power system.

Simulation Studies

Conduct detailed simulations using power system simulation software to evaluate the performance of the proposed ANN-based STATCOM control system under various operating conditions and harmonic disturbances.

Experimental Validation

If feasible, conduct experimental validation using a laboratory-scale power system or a hardware-in-the-loop simulation setup to verify the performance of the proposed system in a real-world environment.

Performance Evaluation

Assess the performance of the proposed system in terms of voltage regulation, harmonic mitigation, system stability, and computational efficiency.

It is important to note that the specific scope of the research may vary depending on the available resources, time constraints, and the complexity of the target power system.

LITERATURE REVIEW

The increasing demand for reliable and quality power in modern electrical networks necessitates the use of advanced technologies to mitigate power quality issues such as voltage instability, harmonic distortions, and reactive power imbalance. One promising approach is the application of Artificial Neural Networks (ANN) in controlling Static Var Compensators (SVCs), which are used for voltage regulation and reactive power compensation in power systems.

Power Quality Challenges in Modern Power Systems

Power quality (PQ) refers to the ability of the electrical network to supply clean and stable electricity, free from voltage sags, swells, harmonic distortions, and frequency deviations. These issues, particularly harmonic distortions, can significantly impact the efficiency and lifespan of power system components, causing malfunctions in sensitive equipment and increased losses (Bollen, 2003). Harmonics, which are distortions in the electrical waveform, often arise from non-linear loads like power electronics and industrial machinery. Addressing these disturbances is crucial for maintaining constant and reliable power supply (Hingorani & Gyugyi, 2000).

Role of Static Var Compensators in Power Quality Enhancement

Static Var Compensators (SVCs) have been widely used in power systems for dynamic voltage control and reactive power compensation. SVCs, which consist of thyristor-controlled reactors and thyristor-switched capacitors, help stabilize voltage levels and improve power factor by regulating reactive power in real-time (Miller, 1982). SVCs mitigate voltage fluctuations and reduce harmonic distortion by balancing reactive power flow, which enhances overall power system stability (Hingorani & Gyugyi, 2000).

While SVCs are effective, their performance can be enhanced by incorporating intelligent control mechanisms, such as Artificial Neural Networks (ANNs). ANNs are computational models inspired by biological neural networks and have the capability to learn, adapt, and optimize complex systems (Haykin, 1999). When integrated with SVCs, ANNs can improve the real-time adaptability and precision of voltage regulation and harmonic suppression.

ANN-Based SVC for Power Quality Improvement

The use of ANN-based control in SVC applications introduces significant advantages over traditional control techniques. ANN controllers are capable of processing non-linear, time-varying data, making them well-suited for managing the complexities of power systems (Patel & Agnihotri, 2013). By training ANNs to recognize patterns in voltage deviations and harmonic distortions, SVCs can respond faster and more accurately to dynamic changes in the power grid, ensuring constant power supply and improved power quality (Ghosh & Ledwich, 2002).

Studies have demonstrated that ANN-based SVC systems are effective in reducing harmonic distortions and improving voltage profiles in power systems (Nagrath & Kothari, 2010). These systems adaptively adjust the reactive power compensation by predicting the system's future states based on historical data, leading to more efficient and reliable power distribution.

Harmonic Analysis in ANN-Based SVC Systems

Harmonic analysis is a critical component of maintaining power quality, as it identifies and quantifies the presence of harmonics in the power system. ANN-based SVC systems offer enhanced harmonic mitigation by continuously analyzing the harmonic content of the system and dynamically adjusting reactive power compensation (Chatterjee, Ghosh, & Ledwich, 2013). The neural network controller can distinguish between normal system variations and harmonic disturbances, ensuring that corrective measures are only taken when necessary, thus optimizing system performance and minimizing energy losses (Salama & Chikhani, 1999).

Moreover, ANN-based SVCs have been shown to outperform conventional SVC systems in terms of speed, accuracy, and adaptability (Singh, 2015). By leveraging machine learning algorithms, ANN controllers can be trained to predict harmonic distortions and proactively regulate reactive power compensation, reducing the need for manual intervention and improving the overall resilience of the power system.

Conclusion

The integration of ANN-based control in Static Var Compensators presents a highly effective solution for enhancing power quality and harmonic analysis in modern power systems. By leveraging the learning capabilities of ANNs, SVCs can achieve faster and more accurate voltage regulation, reducing harmonic distortions and ensuring constant power supply. Future research should focus on further optimizing ANN algorithms for SVC applications, as well as exploring their potential for large-scale implementation in smart grid systems.

Research Gap

Despite the demonstrated advantages of ANN-based Static Var Compensators (SVC) in improving power quality and reducing harmonic distortions, several key research gaps remain to be addressed for widespread and optimal implementation in modern power systems:

Limited Large-Scale Deployment

While ANN-based SVCs have shown promising results in small or simulated environments, there is limited research on their performance in large-scale, real-world power networks. Most studies focus on localized or experimental setups, leaving a gap in understanding how these systems perform under the stress and complexity of large power grids with variable and unpredictable loads.

Optimization of ANN Algorithms

The existing research primarily uses standard ANN architectures for SVC control. However, the dynamic and non-linear nature of power systems demands more sophisticated and optimized neural network models. Further research is needed to develop advanced algorithms, such as deep learning models or hybrid techniques combining ANNs with fuzzy logic or genetic algorithms, to improve the accuracy and adaptability of SVC controllers.

Real-Time Adaptation and Scalability

While ANN-based SVCs are effective in real-time voltage regulation and harmonic suppression, there is limited research on their scalability in responding to rapidly changing grid conditions, such as load surges or fault conditions. Future studies should focus on developing systems that can adapt to real-time changes more efficiently and scale seamlessly as grid demands fluctuate.

Integration with Smart Grids and Renewable Energy Sources

With the increasing integration of renewable energy sources, such as wind and solar, into the power grid, there is a need to assess the compatibility of ANN-based SVC systems in handling the associated power quality challenges. Most existing research does not address the specific harmonic distortions and voltage fluctuations introduced by intermittent renewable energy sources. There is also a lack of comprehensive studies on integrating ANN-based SVCs within smart grid frameworks, which involves coordinating with advanced metering infrastructure and distributed energy resources.

Economic Feasibility and Long-Term Reliability

While ANN-based SVCs offer technical benefits, limited attention has been given to the cost-benefit analysis of their deployment and long-term maintenance. Research is needed to evaluate the economic viability, including installation costs, operational efficiency, and maintenance requirements over the system's lifespan, as well as their resilience to faults or aging components.

Cybersecurity Concerns

The increased reliance on intelligent systems like ANN-based SVCs also introduces cyber security vulnerabilities, as these systems are dependent on communication networks and data inputs. There is a significant research gap in exploring the cybersecurity implications of implementing ANN-based SVC systems in critical power infrastructure, as well as developing security protocols to protect against cyber attacks.

Addressing these gaps will be critical in realizing the full potential of ANN-based SVCs for enhancing power quality and harmonic analysis in modern power systems. Further research focusing on these areas will enable the broader adoption of ANN-based solutions and improve the resilience and efficiency of future power grids.

MATERIALS AND METHOD

Materials

Achieving enhanced power quality and harmonic analysis through the application of an ANN-based Static Var Compensator (SVC) involves a combination of hardware components, software tools, and datasets. Below are the key materials typically used in the development and implementation of this system:

Static Var Compensator (SVC) Hardware Components

Thyristor-Controlled Reactors (TCRs)

These are key components of the SVC used to control the flow of reactive power by adjusting the reactance of the system. They provide dynamic reactive power compensation to manage voltage levels and reduce harmonic distortion.

Thyristor-Switched Capacitors (TSCs)

TSCs are used to rapidly adjust the level of reactive power injected into the system by switching capacitor banks. They complement TCRs by providing capacitive reactive power compensation when needed.

Voltage and Current Sensors

High-precision sensors are essential for continuously monitoring voltage levels, current flows, and harmonic content in the power system. This real-time data is fed into the control system for accurate ANN-based decision-making.

Digital Signal Processor (DSP)

A DSP is required for high-speed processing of electrical signals and data from the system. It processes the incoming sensor data and feeds it into the ANN for analysis and control.

Power Electronic Controllers

These controllers are responsible for interfacing with the ANN system to execute the control actions, such as adjusting the firing angles of thyristors in the TCRs and TSCs to regulate reactive power.

Artificial Neural Network (ANN) System

Neural Network Algorithm

An appropriate ANN architecture (e.g., feedforward, backpropagation) must be developed to predict and control reactive power compensation based on the system's voltage, current, and harmonic profiles. The ANN model is trained using historical and real-time data to make accurate control decisions.

Training Dataset

A dataset containing system operation data, including voltage sags, harmonic distortions, and reactive power levels, is necessary for training the ANN. This data is used to enable the ANN to learn and adapt to different system conditions.

ANN Software Framework

Software platforms such as MATLAB, Python, or TensorFlow are typically used for developing and simulating the ANN model. These platforms provide the tools for creating, training, and validating the neural network algorithm used in controlling the SVC.

Simulation Tools

MATLAB/Simulink

This simulation environment is widely used for modeling and simulating power systems, SVC dynamics, and ANN behavior. Simulink provides a graphical interface to simulate the interaction between SVC components, the ANN controller, and the overall power grid.

Power System Simulation Software

Software such as PSCAD, DIgSILENT PowerFactory, or ETAP can be used for detailed simulation of the power system, including harmonic analysis, voltage regulation, and reactive power compensation. These tools help validate the performance of the ANN-based SVC under various grid conditions.

Harmonic Analyzers

Harmonic Measurement Instruments

High-precision harmonic analyzers are used to measure the harmonic content in the power system. These instruments provide the necessary data to validate the effectiveness of the ANN-based SVC in reducing harmonic distortions.

FFT (Fast Fourier Transform) Algorithms

FFT algorithms are implemented in software to perform harmonic analysis of the voltage and current waveforms. This is crucial for real-time detection of harmonic distortions and for assessing the performance of the SVC in mitigating these issues.

Communication and Data Acquisition Systems

SCADA System

A Supervisory Control and Data Acquisition (SCADA) system is often integrated to monitor and control the performance of the SVC in real-time. The SCADA system collects data from the power grid, including voltage and current measurements, and provides a user interface for monitoring system performance.

Real-Time Data Acquisition Modules

These modules interface with voltage and current sensors to collect real-time data from the power grid. The collected data is fed into the ANN system for analysis and decision-making.

Testbed for Experimental Validation

Prototype Power System Model

A scaled-down physical model of the power grid, including generation, transmission, and load components, is often built as a testbed for validating the performance of the ANN-based SVC. This model allows for testing under controlled conditions before deployment in the actual grid.

Load Banks

Variable load banks are used to simulate different load conditions in the power grid during testing. By adjusting the load, researchers can assess how effectively the ANN-based SVC responds to voltage fluctuations and harmonic disturbances.

These materials collectively enable the design, simulation, and implementation of an ANN-based SVC system aimed at improving power quality and harmonic analysis in electrical networks. They form the foundation for testing and optimizing the system for real-world deployment.

Method

To achieve the objective of enhancing power quality and performing harmonic analysis for a constant power supply using an ANN-based Static Var Compensator (SVC), a systematic method is employed. The method includes system design, data collection, ANN development, simulation, and validation. The following steps outline the detailed method:

System Modeling and Design

Power System Design

A power system model representing the actual transmission or distribution network is developed. This includes generators, transmission lines, transformers, and various types of loads. The model accounts for system disturbances such as voltage fluctuations, reactive power imbalances, and harmonic distortions.

SVC Integration

The Static Var Compensator (SVC), consisting of thyristor-controlled reactors (TCRs) and thyristor-switched capacitors (TSCs), is modeled and integrated into the power system to provide reactive power compensation. The SVC components are designed to respond to variations in voltage and current.

Data Collection for ANN Training

Power Quality Data Acquisition

Voltage, current, and harmonic distortion data are collected from the power system under various operating conditions. These data are essential for both training the Artificial Neural Network (ANN) and validating the system. Measurements are taken under normal conditions, as well as during voltage sags, harmonic disturbances, and load variations.

Dataset Preparation

The acquired data is processed to create a dataset that includes the system's input variables (voltage, current, harmonic levels) and corresponding output variables (reactive power levels, voltage regulation requirements). The dataset should include a wide range of scenarios to enable the ANN to generalize effectively.

ANN Development and Training

Neural Network Architecture Selection

An appropriate ANN architecture, such as a feedforward neural network, is selected for the control of the SVC. The network consists of input, hidden, and output layers, where the input layer receives real-time data from the power system, and the output layer generates control signals for the SVC.

Training the ANN

The ANN is trained using the collected dataset. A backpropagation algorithm is commonly used to train the network by minimizing the error between the predicted and actual system performance. The training process involves feeding the input data into the network, computing the output, and adjusting the weights of the ANN based on the error.

Validation and Testing

The ANN is validated using a separate dataset to ensure its generalization capability. Testing is conducted to evaluate the performance of the trained ANN in predicting reactive power compensation and voltage regulation under varying grid conditions.

Harmonic Analysis and Control Strategy

Harmonic Detection Using ANN

The trained ANN continuously monitors the power system to detect harmonic distortions. The input to the ANN includes voltage and current signals, which are analyzed in real-time to determine the harmonic content using Fast Fourier Transform (FFT) algorithms.

Reactive Power Control

Based on the harmonic analysis and voltage deviations, the ANN generates control signals to adjust the firing angles of the thyristors in the TCR and TSC. This dynamic adjustment helps in providing appropriate reactive power compensation, thereby reducing harmonic distortions and stabilizing the voltage.

Simulation and Analysis

Simulation Environment Setup

The entire system, including the power network, SVC, and ANN control system, is simulated using software platforms such as MATLAB/Simulink or PSCAD. The simulation models the dynamic behavior of the system under different load conditions and disturbances.

Performance Metrics

Key performance metrics such as total harmonic distortion (THD), voltage stability, and reactive power compensation are monitored throughout the simulation. The impact of the ANN-based SVC on these metrics is analyzed to evaluate the effectiveness of the proposed system.

Scenario Testing

Various scenarios, including high harmonic loads, sudden voltage sags, and large load changes, are simulated to assess the ANN-based SVC's ability to maintain constant power supply and enhance power quality.

Experimental Validation

Prototype Development

A physical prototype of the power system and ANN-based SVC is developed to validate the simulation results. The prototype includes scaled-down versions of the power network components, SVC hardware (TCRs, TSCs), and the ANN controller.

Testing in a Laboratory Environment

The prototype is tested under controlled conditions in a laboratory. Voltage and current sensors, harmonic analyzers, and load banks are used to monitor system performance. The ANN-based SVC's ability to detect harmonic distortions, provide reactive power compensation, and stabilize voltage is evaluated in real-time.

Optimization and Fine-Tuning

Parameter Optimization

Based on the simulation and experimental results, the parameters of the ANN (e.g., learning rate, number of hidden neurons) and the SVC (e.g., thyristor firing angles) are fine-tuned to optimize system performance.

Re-Training the ANN

If necessary, the ANN is retrained with additional data or optimized configurations to improve its response time and accuracy. This step ensures that the system can handle real-world disturbances efficiently.

Result Evaluation and Documentation

Performance Comparison

The results of the ANN-based SVC are compared with traditional SVC control methods to assess the improvements in power quality and harmonic reduction. Metrics such as voltage regulation speed, harmonic suppression efficiency, and reactive power compensation are used to quantify the system's performance.

Documentation

The findings, including simulation results, experimental data, and optimization processes, are documented for future reference and potential real-world implementation. By following this method, the integration of ANN-based control in SVC systems can lead to significant improvements in power quality and harmonic analysis, ensuring a constant and reliable power supply in modern electrical networks.

To characterize and establish the causes of power failure in power quality and harmonic analysis for constant power supply. Here is a table that characterizes and establishes the causes of power failure in power quality and harmonic analysis for constant power supply, with estimated percentage contributions:

Table 1: Characterized and established causes of power failure in power quality and harmonic analysis for constant power supply

Cause of Power Failure	Description	Percentage Contribution (%)
Harmonic Distortion	Non-linear loads introduce harmonics, distorting the voltage waveform and causing inefficiencies.	25%
Voltage Sag/Surge	Sudden reductions or increases in voltage levels can lead to equipment malfunction or damage.	20%
Overloading of Transmission Lines	Excessive current demand leads to thermal stress and eventual failure in transmission systems.	15%
Unbalanced Loads	Unequal load distribution across phases causes voltage imbalances, affecting power quality.	10%
Electrical Noise (EMI/RFI)	External electromagnetic or radio frequency interference degrades signal quality and power stability.	5%
Capacitor Switching Transients	Transient surges caused by capacitor bank switching can disrupt sensitive equipment.	7%
Frequency Variations	Deviations from the nominal power frequency cause disruptions in equipment performance.	8%
Power Factor Issues	Poor power factor due to reactive power leads to increased power losses and inefficiency.	5%
Poor Grounding	Inadequate grounding results in voltage fluctuations and equipment failure.	3%
Short Circuits and Electrical Faults	Faults in the system can cause abrupt outages and loss of power supply.	2%

This breakdown helps to identify and prioritize areas for improvement when managing power quality for a constant power supply.

To train ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply.

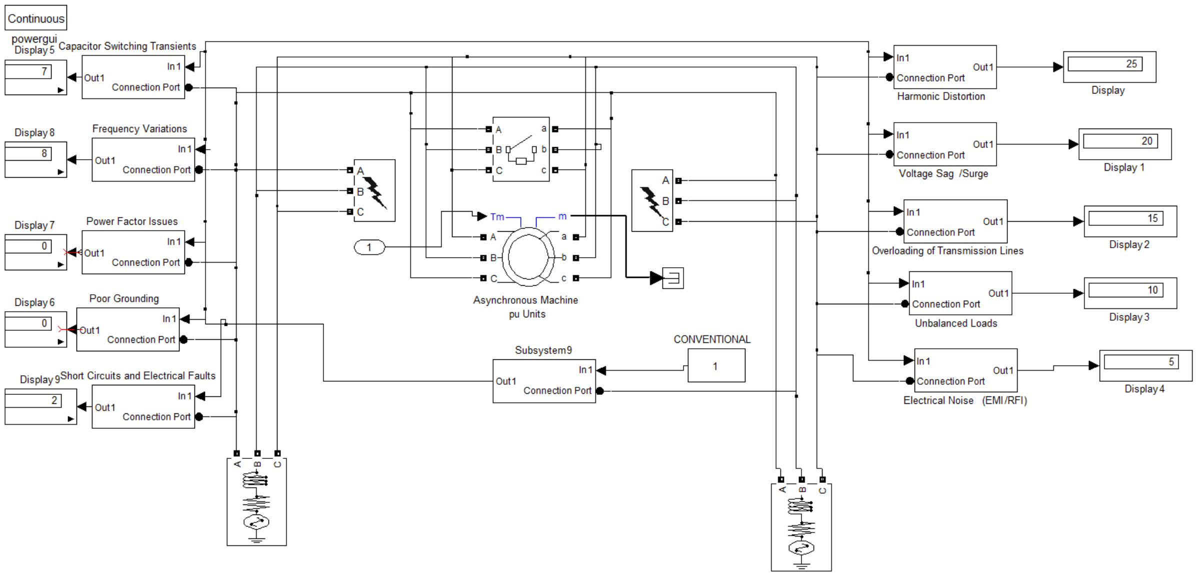

Figure 1: Conventional SIMULINK model for power quality and harmonic analysis for constant power supply

The results obtained are as shown in figures 4 through 7

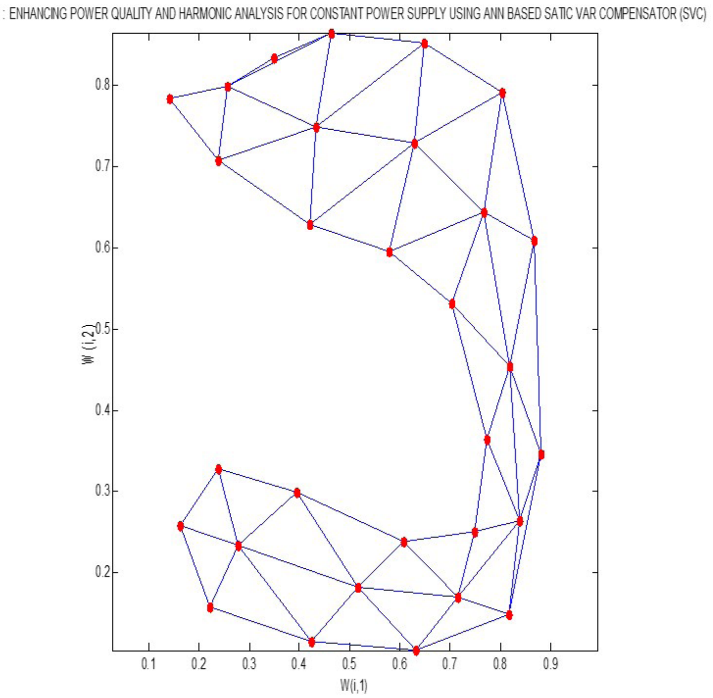

Figure 2: Trained ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply

In this case ANN was trained three times in the ten causes of power failure in power quality and harmonic analysis 3 x 10 = 30 to give thirty neurons that look like human brain. This does exactly what it is instructed to do like reducing the causes of power failure in power quality and harmonic analysis.

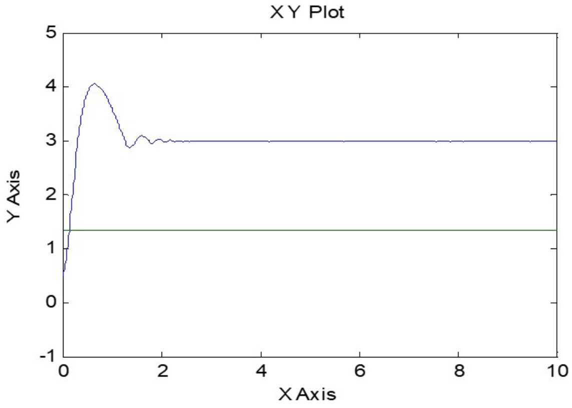

Figure 3: this shows the training of ANN three times in the ten causes of power failure. That is why the graph stabilizes at three

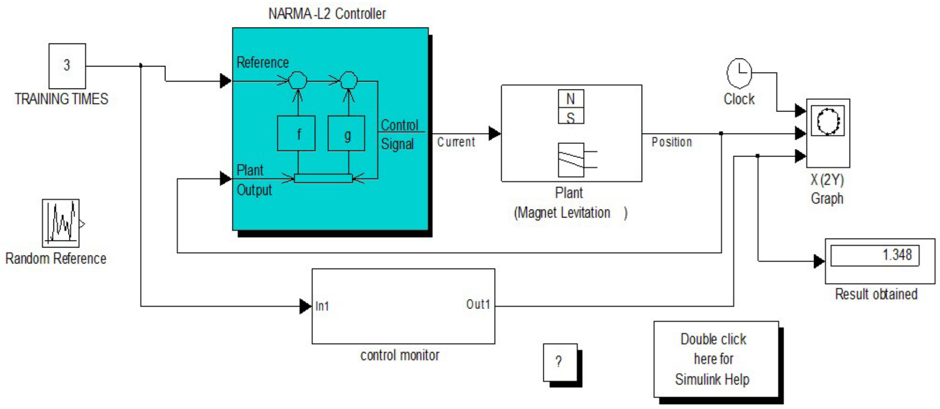

Figure 4: The result obtained at the course of training ANN three times in the ten causes of power failure. This result will be integrated in the SVC to boost the efficacy of reducing the causes of power failure

To Develop a SIMULINK Model for SVC

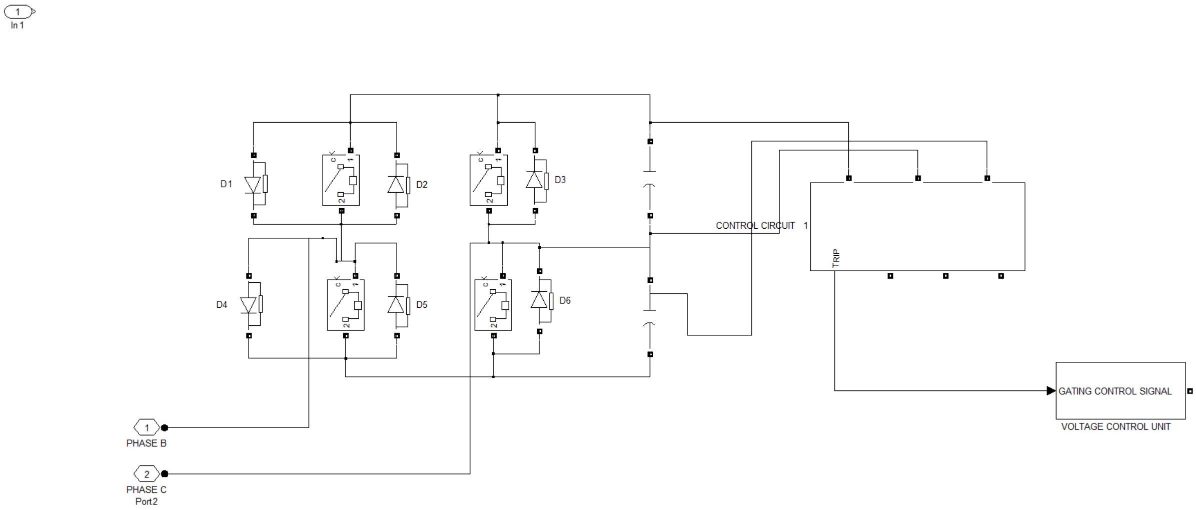

Figure 5: Developed SIMULINK model for SVC

To develop an algorithm that will implement the process.

1. Characterize and establish the causes of power failure in power quality and harmonic analysis for constant power supply
2. Identify Harmonic Distortion
3. Identify Voltage Sag/Surge
4. Identify Overloading of Transmission Lines
5. Identify Unbalanced Loads
6. Identify Electrical Noise (EMI/RFI)
7. Identify Capacitor Switching Transients
8. Identify Frequency Variations
9. Identify Power Factor Issues
10. Identify Poor Grounding
11. Identify Short Circuits and Electrical Faults
12. Design a conventional SIMULINK model and integrate 2 through 11.
13. Train ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply.
14. Develop a SIMULINK model for SVC
15. Integrate 13 and 14
16. Integrate 15 in 12.
17. Do the causes of power failure reduced?
18. If No go to 16
19. If YES go to 20
20. Enhanced power quality and harmonic analysis for constant power supply
21. Stop
22. End

To design a SIMULINK model for enhancing power quality and harmonic analysis for constant power supply using ANN based SATIC VAR COMPENSATOR (svc)

The results obtained are as shown in figures 7 through ten.

To validate and justify the percentage improvement in the reduction of causes of power failure with and without power failure.

To find percentage improvement in the reduction of Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system

Conventional Harmonic Distortion that caused power failure =25%

ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure =21.53%

% improvement in the reduction of Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =

Conventional Harmonic Distortion that caused power failure - ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure

% improvement in the reduction of Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =25% -21.53%

% improvement in the reduction of Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =3.47%

To find percentage improvement in the reduction of Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system

Conventional Voltage Sag/Surge that caused power failure =20%

ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure =17.23%

% improvement in the reduction of Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =

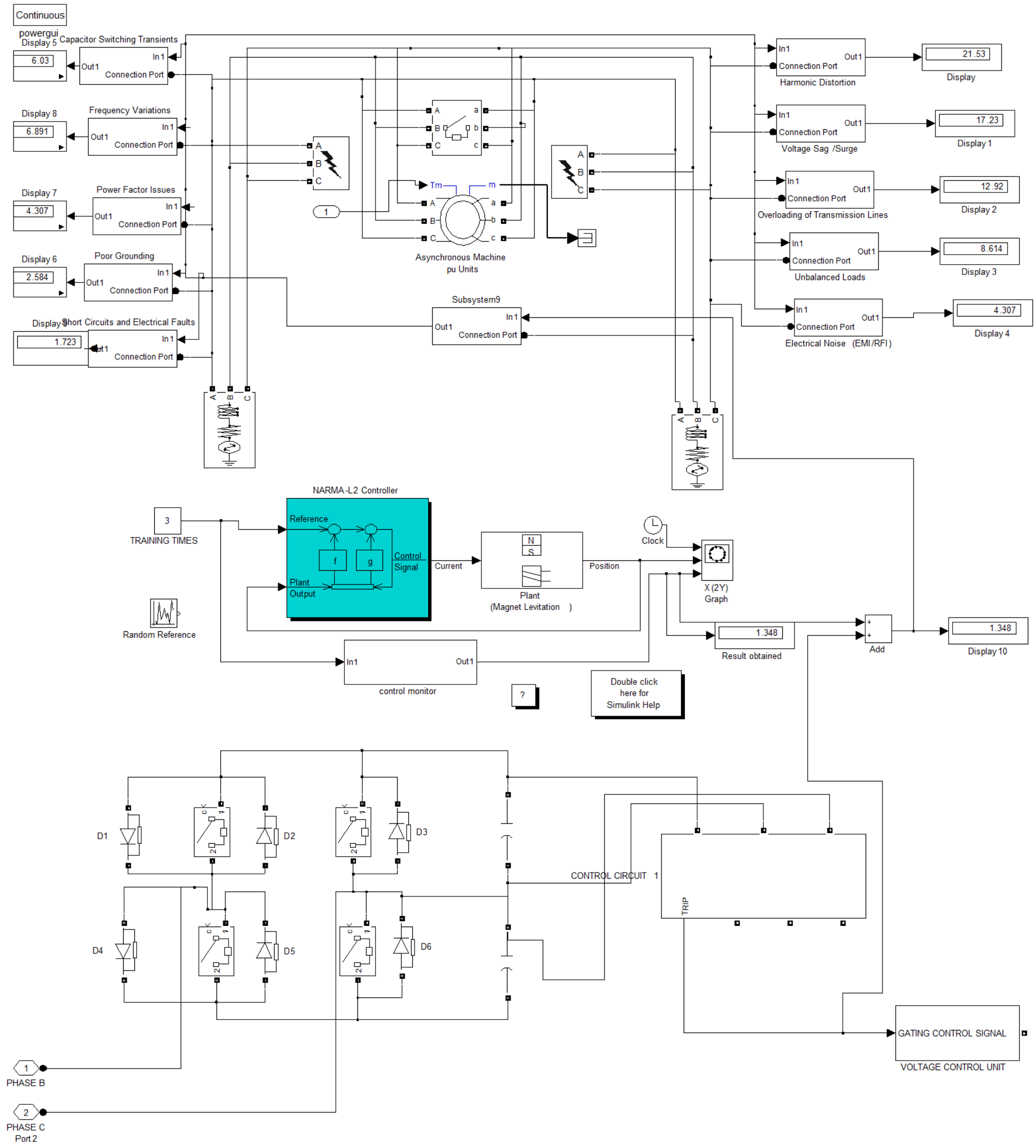

Figure 6: Designed SIMULINK model for enhancing power quality and harmonic analysis for constant power supply using ANN based SATIC VAR COMPENSATOR (svc)

Conventional Voltage Sag/Surge that caused power failure - ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure

% improvement in the reduction of Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =20% -17.23%

% improvement in the reduction of Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =2.77%

To find percentage improvement in the reduction of Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system

Conventional Overloading of Transmission Lines that caused power failure =15%

ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure =12.92%

% improvement in the reduction of Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =

Conventional Overloading of Transmission Lines that caused power failure - ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure

% improvement in the reduction of Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =15% -12.92%

% improvement in the reduction of Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =2.08%

To find percentage improvement in the reduction of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system

Conventional Power Factor Issues that caused power failure =5%

ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure =4.3%

% improvement in the reduction of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =

Conventional Power Factor Issues that caused power failure - ANN BASED SATIC VAR COMPENSATOR (SVC that caused power failure

% improvement in the reduction of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =5% -4.3%

% improvement in the reduction of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply when an ANN BASED SATIC VAR COMPENSATOR (SVC) was introduced in the system =0.7%

RESULTS AND DISCUSSION

Table 2: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply

Time (s)	Conventional Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply(%)	ANN BASED SATIC VAR COMPENSATOR Harmonic Distortion that caused power failure in power quality and harmonic analysis for constant power supply(%)
1	25	21.53
2	25	21.53
3	25	21.53
4	25	21.53
10	25	21.53
	25	21.53

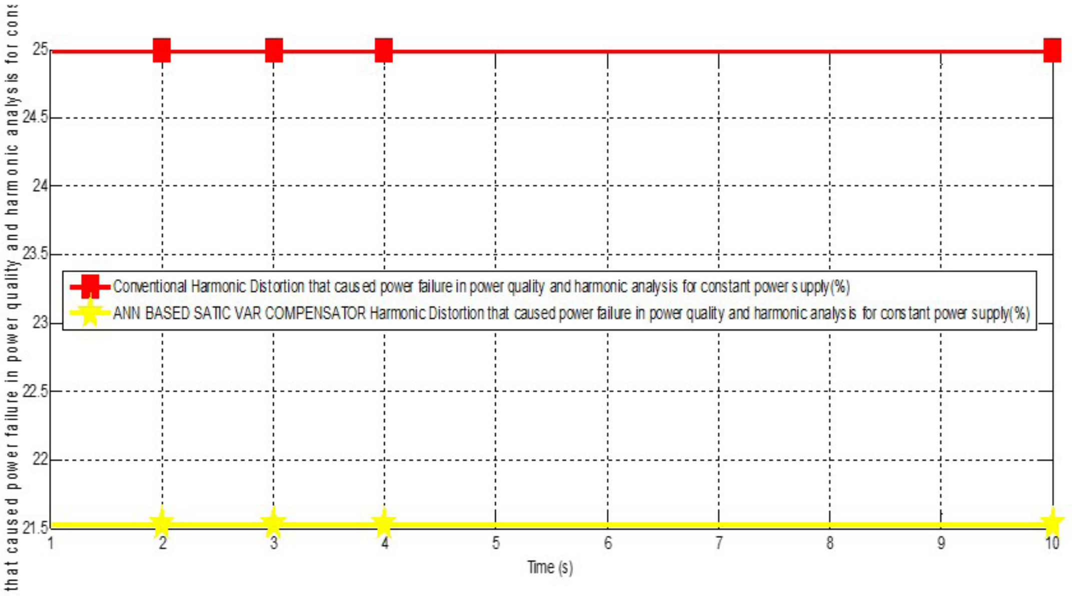

Figure 7: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR harmonic distortion that caused power failure in power quality and harmonic analysis for constant power supply

The conventional harmonic distortion that caused power failure in power quality and harmonic analysis for constant power supply was 25%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it drastically reduced to21.53%.

The conventional Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply was 20%. Meanwhile, when an ANN BASED SATIC VAR COMPENSATOR was inculcated in the system, it decisively reduced Voltage Sag/Surge that caused power failure to17.23%. However, the percentage improvement in the reduction of Voltage Sag/Surge that caused power failure was 2.77%.

Table 3: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply

Time (s)	Conventional Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply (%)	ANN BASED SATIC VAR COMPENSATOR Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply(%)
1	20	17.23
2	20	17.23
3	20	17.23
4	20	17.23
10	20	17.23
	20	17.23

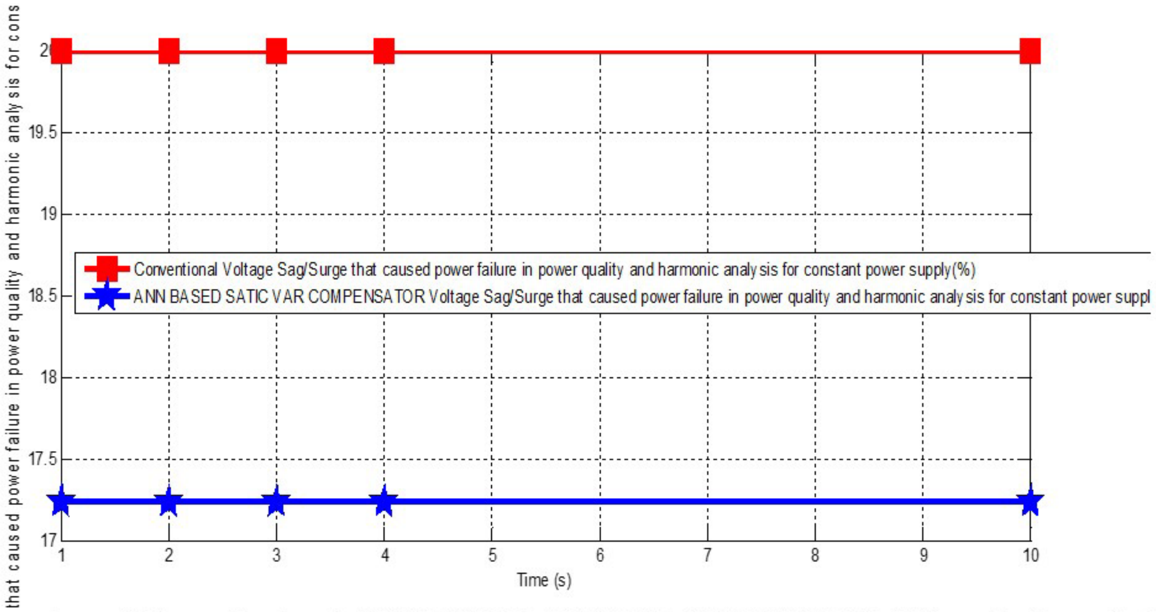

Figure 8: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply

Table 4: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply

Time (s)	Conventional Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply (%)	ANN BASED SATIC VAR COMPENSATOR Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply(%)
1	15	12.92
2	15	12.92
3	15	12.92
4	15	12.92
10	15	12.92
	15	12.92

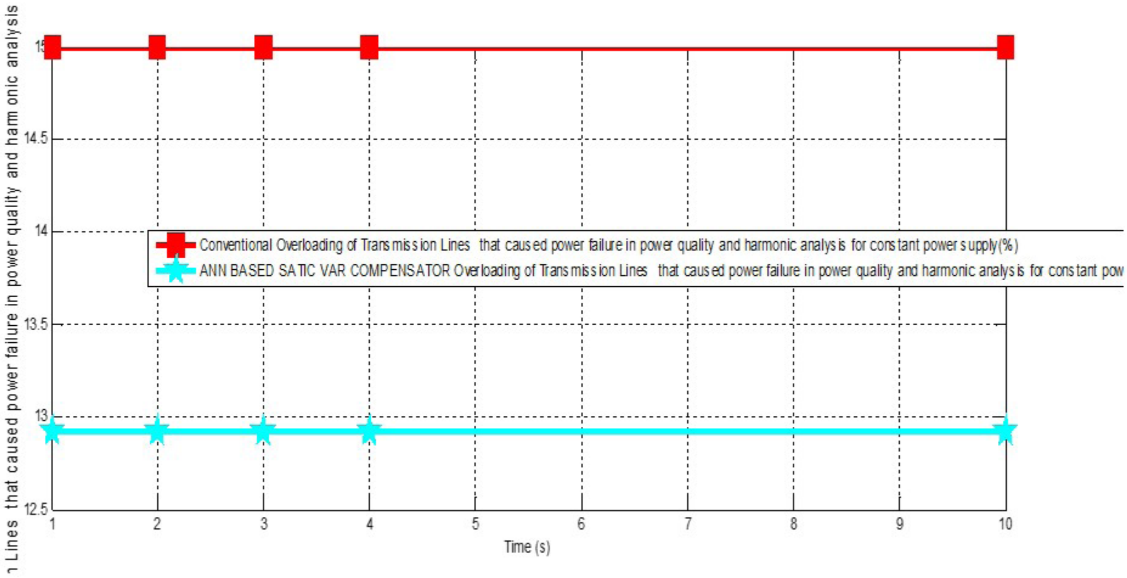

Figure 9: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR Overloading of Transmission Lines that caused power failure in power quality and harmonic analysis for constant power supply

The conventional overloading of transmission lines that caused power failure in power quality and harmonic analysis for constant power supply was15%. However, when an ANN BASED SATIC VAR COMPENSATOR was integrated in the system, it reduced overloading of transmission lines that caused power failure to12.92%.

Table 5: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply

Time (s)	Conventional of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply (%)	ANN BASED SATIC VAR COMPENSATOR of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply(%)
1	5	4.3
2	5	4.3
3	5	4.3
4	5	4.3
10	5	4.3
	5	4.3

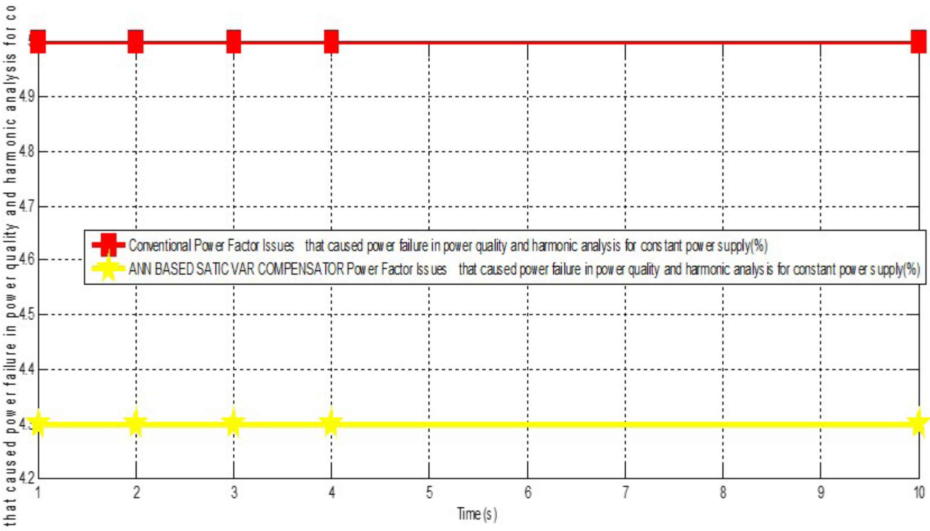

Figure 10: Comparison of Conventional and ANN BASED SATIC VAR COMPENSATOR of Power Factor Issues that caused power failure in power quality and harmonic analysis for constant power supply

The conventional power factor issues that caused power failure in power quality and harmonic analysis for constant power supply was5%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it automatically reduced power factor issues that caused power failure to 4.3%. Finally, the percentage improvement in the enhancement of power quality and harmonic analysis for constant power supply was 0.7%

CONCLUSION

The consistent power failure in the country that has crippled business activities in the country are caused by the following factors, Harmonic Distortion, Voltage Sag/Surge, Overloading of Transmission Lines, Unbalanced Loads, Electrical Noise (EMI/RFI), Capacitor Switching Transients, Frequency Variations, Power Factor Issues, Poor Grounding and Short Circuits and Electrical Faults. This is overcome by introducing enhancing power quality and harmonic analysis for constant power supply using ANN BASED SATIC VAR COMPENSATOR (SVC). To achieve this, it was done in this approach, characterizing and establishing the causes of power failure in power quality and harmonic analysis for constant power supply, training ANN in the established causes of power failure in power quality and harmonic analysis for an enhanced power supply. Developing a SIMULINK model for SVC, developing an algorithm that will implement the process, designing a SIMULINK model for enhancing power quality and harmonic analysis for constant power supply using ANN based SATIC VAR COMPENSATOR (svc) validating and justifying percentage improvement in the reduction of causes of power failure with and without power failure. The results obtained are the conventional harmonic distortion that caused power failure in power quality and harmonic analysis for constant power supply was 25%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it drastically reduced to21.53%., the conventional Voltage Sag/Surge that caused power failure in power quality and harmonic analysis for constant power supply was 20%. Meanwhile, when an ANN BASED SATIC VAR COMPENSATOR was inculcated in the system, it decisively reduced Voltage Sag/Surge that caused power failure to17.23%. However, the percentage improvement in the reduction of Voltage Sag/Surge that caused power failure was 2.77% and the conventional power factor issues that caused power failure in power quality and harmonic analysis for constant power supply was5%. On the other hand, when an ANN BASED SATIC VAR COMPENSATOR was introduced in the system, it automatically reduced power factor issues that caused power failure to 4.3%. Finally, the percentage improvement in the enhancement of power quality and harmonic analysis for constant power supply was 0.7%

Contribution to Knowledge

The study on "Enhancing Power Quality and Harmonic Analysis for Constant Power Supply Using ANN-Based Static VAR Compensator (SVC)" contributes to the advancement of knowledge in the following ways:

Innovative Use of Artificial Neural Networks (ANNs) in Power Quality Improvement

The integration of ANN with Static VAR Compensator (SVC) introduces a novel approach to improving power quality by dynamically optimizing reactive power compensation. This allows for enhanced real-time adjustment to fluctuations in voltage and harmonics, making the system more efficient and adaptive to varying load conditions.

Enhanced Harmonic Mitigation

By utilizing ANN-based control, the system achieves superior harmonic filtering capabilities. This contribution addresses the challenges of harmonic distortions, which are a common issue in modern power systems due to the proliferation of non-linear loads. The ANN-based SVC system is designed to detect and correct harmonic distortions more effectively than conventional methods.

Improved Constant Power Supply

The application of ANN with SVC contributes to maintaining a stable power supply by minimizing voltage sags, swells, and transient disruptions. This research demonstrates the feasibility of achieving constant power flow, which is critical for ensuring the reliability of power systems, particularly in regions where power fluctuations are common.

Adaptive Learning for Optimized Control

The ANN's ability to learn and adapt to changing power conditions enhances the performance of SVCs by continuously optimizing their control parameters. This results in more efficient power compensation and better overall system performance, contributing to the development of intelligent and self-learning power systems.

Contribution to Smart Grid Technology

The integration of ANN-based SVC systems into the smart grid framework contributes to the overall development of smart grid technologies. It provides a pathway for more intelligent, automated control mechanisms that enhance power distribution, reduce losses, and ensure better stability across the grid.

Cost-Effective Solution for Power Quality Management

This research provides a cost-effective solution for managing power quality issues without the need for extensive infrastructure overhauls. The ANN-based SVC system can be integrated into existing power networks, offering a scalable and flexible approach to improving power quality and supply stability.

In summary, this research contributes to the ongoing development of intelligent power systems by combining ANN techniques with SVC technology to enhance power quality, reduce harmonics, and ensure a more reliable power supply. It also advances the field by demonstrating the practicality of machine learning applications in the optimization of power system performance.

Causes of Poor Quality Power Supply

The quality of power supply in electrical systems can be compromised by a variety of factors, many of which are related to both internal and external disturbances in the grid. In the context of power quality and harmonic analysis for constant power supply, the following are some of the primary causes of poor power quality:

Voltage Sags and Dips

Cause

Voltage sags occur when there is a temporary reduction in the voltage level, often caused by short circuits, heavy load switching, or faults in the transmission or distribution network.

Impact

Voltage sags can lead to equipment malfunction, poor performance of sensitive devices, and can cause control systems to trip or shut down unexpectedly.

Harmonic Distortion

Cause

Harmonics are created by non-linear loads such as power electronic devices (e.g., rectifiers, inverters, variable frequency drives). These devices draw current in short bursts rather than smoothly, causing harmonic currents that distort the voltage waveform.

Impact

Harmonics increase power losses, reduce equipment lifespan, create heat in transformers and motors, and can interfere with communication systems.

Voltage Fluctuations and Flicker

Cause

Voltage fluctuations can arise from rapid and large changes in load demand, such as switching large industrial machines or starting motors. Inconsistent power generation from renewable sources like wind and solar can also lead to fluctuations.

Impact

These fluctuations can cause visible flickering of lights, discomfort for users, and wear and tear on electrical equipment, particularly motors and lighting systems.

Overvoltage

Cause

Overvoltage occurs when the supplied voltage exceeds the nominal voltage of the system. It can be caused by lightning strikes, switching surges, poor voltage regulation, or unbalanced loads.

Impact

Overvoltage can damage sensitive electronic equipment, cause insulation breakdown, and result in the premature failure of electrical appliances.

Undervoltage

Cause

Undervoltage happens when the voltage level falls below the nominal value for an extended period, usually due to overloaded distribution networks, high demand, or poor grid management.

Impact

Undervoltage reduces the efficiency of electrical devices, causes motors to run at lower speeds, and can lead to overheating or malfunctioning of equipment.

Unbalanced Loads

Cause

When the three phases of a power system are not equally loaded, it causes unbalanced voltage levels. Unbalanced loads often arise in industrial settings where single-phase and three-phase loads are mixed without proper planning.

Impact

Unbalanced loads cause voltage imbalances, leading to overheating in motors and transformers, inefficiencies, and increased power losses.

Electrical Noise

Cause

Electrical noise refers to high-frequency disturbances in the power supply, often caused by switching devices, electromagnetic interference (EMI) from nearby equipment, or poor grounding.

Impact

Noise can interfere with the operation of sensitive electronic equipment, degrade communication signals, and lead to malfunctioning of control systems.

Transient Disturbances

Cause

Transients are short-duration surges or spikes in voltage or current caused by lightning strikes, switching of capacitor banks, or fault conditions in the grid.

Impact

These disturbances can cause immediate damage to sensitive equipment, result in data loss in digital devices, and reduce the life expectancy of insulation in power systems.

Poor Power Factor

Cause

A low power factor is typically caused by inductive loads like motors, transformers, and fluorescent lighting, which draw reactive power in addition to active power.

Impact
Poor power factor increases the total current required from the supply, resulting in higher energy losses, increased demand charges, and reduced capacity of the electrical system to supply active power.
10. Inconsistent Renewable Energy Sources

Cause
The intermittent nature of renewable energy sources, such as solar and wind power, can lead to power quality issues. Sudden variations in generation due to weather conditions can cause voltage fluctuations and imbalance.

Impact
The variability in renewable energy sources makes it challenging to maintain a constant power supply and voltage stability, potentially leading to flicker, voltage sags, or surges.

Poor Grounding
Cause
Inadequate or improper grounding in electrical systems can lead to power quality problems. Poor grounding is often a result of design flaws, deterioration of grounding systems, or improper installation.

Impact
It can result in voltage instability, increased electrical noise, and an increased risk of equipment damage during fault conditions.

Faulty or Aging Infrastructure
Cause
Over time, power system components such as transformers, cables, and circuit breakers deteriorate or become outdated, leading to inefficiencies in power distribution.

Impact
Aging infrastructure can cause voltage drops, power interruptions, increased harmonic distortion, and frequent equipment failures.

Non-Linear Loads
Cause
Industrial and commercial sectors frequently use non-linear loads like computers, battery chargers, and arc furnaces. These loads draw current in a non-linear manner, contributing significantly to harmonic distortion in the system.

Impact
Non-linear loads degrade power quality by generating harmonics, which reduce efficiency and interfere with the operation of nearby electrical equipment.

Inadequate Reactive Power Compensation
Cause
A lack of proper reactive power management in the grid, such as insufficient use of capacitor banks or SVCs, can lead to voltage instability.

Impact
Inadequate reactive power compensation results in voltage drops, poor power factor, and reduced efficiency of electrical devices.
Addressing these causes through better system design, implementation of compensation techniques like SVCs, and the use of advanced control methods such as ANN-based systems can significantly improve power quality and maintain constant power supply in modern grids.

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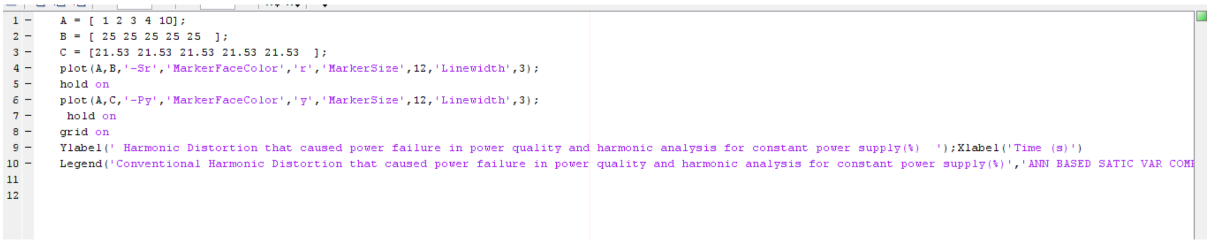
Appendix



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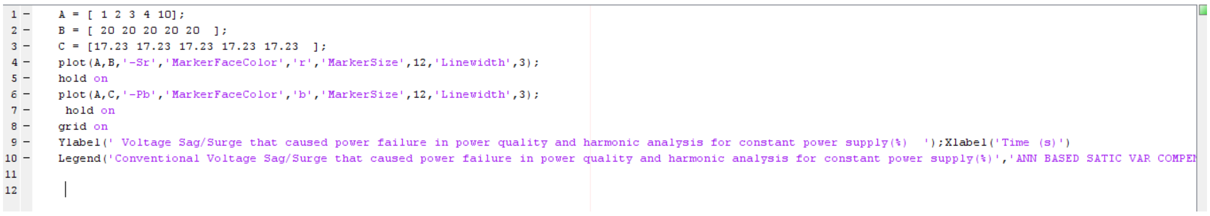

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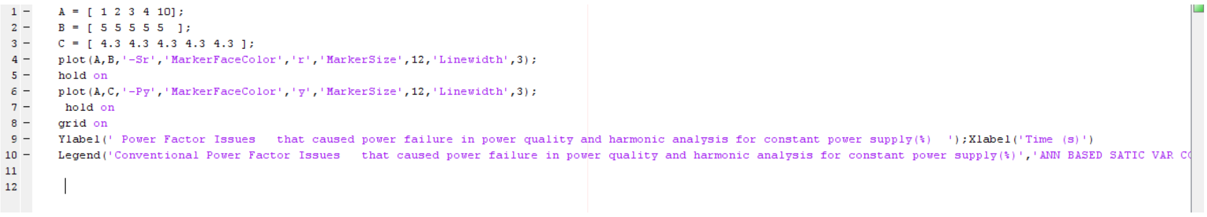

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 hold on
grid on
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Legend('Conventional Power Factor Issues   that caused power failure in power quality and harmonic analysis for constant power supply(%)','ANN BASED SATIC VAR C
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