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ENHANCED PERFORMANCE OF GRID -CONNECTED HYBRID SYSTEM USING DPFC OPTIMIZATION

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ABSTRACT

The main aim of this project is to introduce a framework for the design and modelling of a photovoltaic (PV)-wind hybrid system and its control strategies. The purpose of these control techniques is to regulate continuous changes in the operational requirements of the hybrid system currently, in power system networks, the distribution of energy plays a major role in maintaining power reliability in distribution systems. In this study, the proposed hybrid system was incorporated with a combined PV and wind energy system. Maximum power point tracking (MPPT) methods have been proposed to achieve maximum efficiency from the designed system. In addition, this study focused on improving the stability of the hybrid system. To improve the power quality and transient stability of the proposed system, we introduce a novel control strategy called the distributed power flow controller (DPFC) implementation with an optimization technique called the Proportional Integral (PI) technique. This PI control technique was developed in the application of a DPFC controller in a grid-connected system. The control technique was developed using signals from the system parameters, that is, voltage and current. To tune these parameters, this study used fuzzy logic and Proportional Integral and techniques. The proposed system with controllers was tested in MATLAB/Simulink and the results were compared

1.INTRODUCTION

1.1 INTRODUCTION A power system consists of interconnected components that produce, transmit, and consume energy, with the grid being the most common type. The electricity is generated at power plants, transmitted to load centers, and delivered to consumers through the distribution system. However, power quality issues often arise in the distribution system, causing voltage imbalances, low power factors, and current harmonics. These issues are caused by modern electronic loads, such as unbalanced loads, switching loads, and non-linear loads, leading to disturbances like voltage sag, swell, and harmonics. To address these power quality challenges, active filtering circuits like the Shunt Active Power Filter (SAPF) and Dynamic Voltage Restorer (DVR) are used. The SAPF compensates for current harmonics, while the DVR protects sensitive loads from voltage variations. A DC linking capacitor is used to connect the SAPF and DVR in a Dynamic Power Flow Controller (DPFC), which helps filter out unwanted harmonics and ensures consistent service. The generation of a reference signal is crucial to eliminate these harmonics, maintaining clean energy flow in the power system. 1.2 PQ ISSUES PQ issue is often linked to non-sine voltage or current waveform. When non-linear loads are connected to the grid in a number of typical places, the power quality deteriorates dramatically. various definitions of the PQ may result in various interpretations. From the designer's vantage point, power quality is achieved when the power system is free of voltage fluctuations and other disturbances. Increasing nonlinear load utilization and power system problems have a profound effect on power quality (PQ). Enhanced power quality is crucial because of the widespread usage of digital control systems and electrical appliances. Because of how sensitive these devices are to PQ variations, even little changes in PQ may result in significant costs. Voltage sag, current harmonics, and voltage surge are three examples of common PQ issues shown in Figure 1.1.

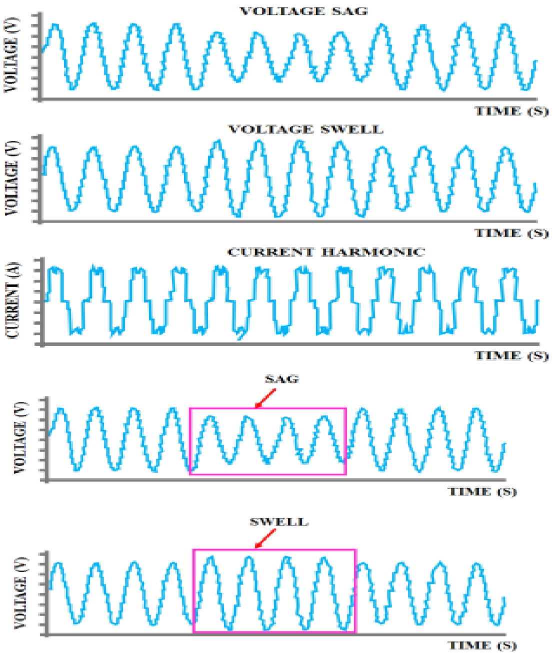


Figure 1.1 (a) Common PQ issues (b) Depiction of Sag and Swell

1.2.1 Harmonic Distortion

In a power system, harmonic voltage distortion results from a non-sinusoidal load current, hence harmonic voltage distortion is also a kind of current distortion. A variety of modern electronic gadgets, including compact uninterruptible power supplies, fluorescent light ballasts, variable speed drives, and switching mode power supplies, have contributed to the development of current harmonics. Many issues with the operation of electrical grids may be Enhanced Performance of Grid -Connected Hybrid System Using DPFC Optimization traced back to harmonic disturbances. Circuit breakers tripping unexpectedly, skin effect, transformer overheating, uneven loads, and overloaded neutrals are all examples of such issues. The following formula may be used as a rough estimate of Total Harmonic Distortion: $THD\_F = \sqrt{(V_2^2 + V_3^2 + V_4^2 + \ldots + Vn^2)} / V1$

1.2.2 Voltage Sag

Voltage sag issues are widespread in the electrical grid and may be caused by a number of factors, including system failures, energizing large loads, and overloading distribution lines. The term "sag" is used to refer to a momentary drop in voltage. Particularly susceptible to the effects of voltage sag are relays, circuit breakers, and sensors (air flow sensors, water pressure sensors, etc.).

1.2.3 Voltage Swell

Problems with voltage surges, as opposed to voltage sag, are often the result of design errors. When the RMS value of voltage or current suddenly and dramatically increases, this phenomenon is known as a voltage swell. The activation of a large bank of capacitors, the abrupt removal of a large load, the gradual increase of a smaller load, and the breakdown of insulation are all potential causes of a voltage spike. It decreases the reliability of data storage, shortens the life of sensitive devices (or even causes them to shut down abruptly), and may even physically harm the equipment.

1.3 IMPACTS OF NON-LINEAR AND SENSITIVE LOADS

Non-linear loads such as fax machines, printers, televisions, speed drives, inverters, and rectifiers are becoming more common. These loads cause harmonics to build up in the power distribution system, which can harm any connected devices. Consistent voltage and current waveforms are crucial for the reliability of electrical equipment. When both the fundamental and harmonic waveforms are sinusoidal, harmonics can be subtracted from the fundamental as integral multiples of it. Harmonics from non-linear loads can lead to issues like motor overheating, increased system losses, and damaged equipment. Therefore, it is essential for electrical engineers to remove these harmonics. Other problems, such as voltage spikes, dips, and flickers, can also disrupt the power system, all of which are caused by harmonics from non-linear loads. Overvoltage in capacitor banks is caused by serial and parallel harmonic.

1.4 EMERGING FACTS DEVICES FACTS

(Flexible AC Transmission Systems) devices improve power transmission by dynamically adjusting the bus voltage, phase angle, and line impedance. These devices help boost the reliability and efficiency of power transfer by using power electronics and static controllers. The concept of FACTS was developed in the early 1980s by the Electric Power Research Institute (EPRI) to maintain grid stability. FACTS devices regulate power distribution based on commands from the control center, allowing power systems to operate close to their maximum capacity. Examples of FACTS controllers include semiconductor devices like IGBTs, thyristor-controlled phase-shifting transformers, and static compensators. FACTS controllers are divided into two main groups: one based on power electronics and the other using AC converters. The first group includes devices like thyristor-controlled series compensators and static synchronous compensators (STATCOM). The second group features voltage-source converter (VSC)-based controllers, such as the STATCOM and SVC, which help control reactive power flow and adjust transmission line impedance. FACTS controllers are classified into shunt controllers (SVC, STATCOM), series controllers (SSSC, TCSC), and series-shunt controllers (TCPST, DPFC), based on how they are connected to the network.

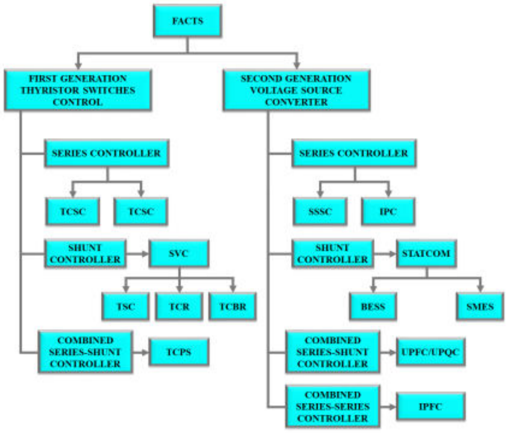


Figure 1.2 FACTS devices classification

1.5 PROBLEM STATEMENT

The extensive incorporation of non-linear and sensitive loads into the power DS has resulted in the generation of voltage/current harmonics, which threaten the safety of devices that are wired into the system. Many issues with power quality may be traced back to voltage and current harmonics, including voltage sag, swell, flickers, surges, transients, voltage imbalances, and more. Power quality is increasingly on the minds of consumers at every level of the energy consumption process. To remove the line harmonics, we use passive LC filters. Passive filters have the drawbacks of being large, not compensating for resonance, and being permanent. Active power filters (APF), on the other hand, substantially eliminate such power supply issues. Power distribution networks have historically employed switched capacitor banks to improve power factor, but they have been dogged by issues such switching transients and power factor degradation over time. Then, the SVC, DVR, and DSTATCOM are used to fix the electrical system's power quality issues. However, these gadgets only solve certain problems with PQ, thus their benefits are limited.

2.LITERATURE SURVEY

The integration of hybrid systems into the power grid has become a pivotal area of research due to the increasing demand for energy efficiency, reliability, and sustainability. A grid-connected hybrid system typically combines renewable energy sources, such as solar and wind, with conventional power generation systems to provide a stable and continuous energy supply. Recent advancements in power system optimization techniques have contributed significantly to enhancing the performance of these hybrid systems, particularly through the integration of the Dynamic Power Flow Controller (DPFC). The DPFC is an advanced flexible AC transmission system (FACTS) device that offers enhanced control over the power flow in grid-connected systems, improving their stability, power quality, and overall performance.

Several studies have investigated the use of DPFC for optimizing grid-connected hybrid systems. According to Saini et al. (2020), the DPFC plays a critical role in enhancing the performance of hybrid systems by regulating the power flow between different energy sources, ensuring stability even during fluctuations in renewable generation. They argue that the implementation of DPFC improves system efficiency by controlling reactive power flow and mitigating voltage fluctuations in the grid. This is especially crucial when integrating variable renewable energy sources like wind and solar, which can cause instability in the power grid due to their intermittent nature.

In a similar study, Kumar et al. (2021) explored the use of DPFC in a hybrid solar-wind power generation system. Their findings indicated that the DPFC effectively mitigated the power quality issues associated with the variability of renewable energy sources. By controlling the power flow in the transmission line, the DPFC provided a mechanism for dynamic voltage regulation, which enhanced the stability of the grid and ensured a more consistent power supply. The authors also emphasized that the DPFC's ability to control both active and reactive power made it particularly useful in hybrid systems, where the interaction between various generation sources and the grid can be complex.

Research by Li et al. (2019) focused on the dynamic modeling and optimization of DPFC in hybrid systems, revealing that the incorporation of DPFC led to significant improvements in both system performance and energy efficiency. The study showed that DPFC optimization could be effectively used to reduce transmission losses, regulate voltage, and maintain a stable power flow, which is essential for maintaining grid reliability. Moreover, the authors demonstrated that DPFC optimization could improve the power factor, which is an important parameter for ensuring that the energy supplied to the grid is utilized efficiently.

Additionally, Patel et al. (2022) highlighted the integration of DPFC in microgrids, where hybrid systems often operate in isolated conditions and are prone to disruptions in power supply. Their study focused on how DPFC could be used to enhance the hybrid system's ability to operate in both grid-connected and islanded modes, providing more flexibility and stability to the grid. They also noted that DPFC can contribute to reducing the need for backup power and improving the overall energy reliability of the system, which is essential in microgrid applications.

Furthermore, Ahmed et al. (2021) examined the role of DPFC in reducing harmonics and improving the power quality of grid-connected hybrid systems. Their research demonstrated that the DPFC could filter out undesirable harmonics in the system, thereby ensuring a cleaner and more reliable power output. This feature is particularly important in hybrid systems where different power generation sources might introduce harmonics that affect the stability and efficiency of the grid.

The literature suggests that the DPFC optimization technique holds great potential for improving the performance of grid-connected hybrid systems. By enhancing power flow control, voltage stability, energy efficiency, and power quality, DPFC can help address some of the key challenges in integrating renewable energy sources into the grid, making hybrid systems more reliable and sustainable.

3.METHODOLOGY

The methodology for enhancing the performance of grid-connected hybrid systems using DPFC optimization involves several key stages, including system modeling, DPFC design, optimization algorithm selection, and system implementation. The first step is to develop a dynamic model of the grid-connected hybrid system, which typically includes renewable energy sources such as solar, wind, and energy storage systems, along with conventional generators. This model is essential for simulating the system's behavior under different operating conditions and for identifying potential issues related to power flow, voltage fluctuations, and stability.

Once the system is modeled, the next step is to integrate the DPFC into the system. The DPFC is designed to control both active and reactive power in the transmission line by dynamically adjusting the impedance of the transmission network. The DPFC consists of a series of voltage source converters (VSCs) connected in a cascade configuration, with each converter capable of injecting or absorbing reactive power to maintain voltage stability. The DPFC also employs a controller that regulates the power flow to ensure that the hybrid system operates optimally, despite fluctuations in renewable generation or load demand.

Optimization algorithms are then applied to enhance the performance of the DPFC in the grid-connected hybrid system. Several optimization techniques can be used, including genetic algorithms (GA), particle swarm optimization (PSO), and simulated annealing (SA). These algorithms are designed to minimize power losses, improve the power factor, and optimize the distribution of power between the various sources within the hybrid system. The optimization process involves adjusting the DPFC's control parameters to ensure that the system operates efficiently while meeting power quality and stability requirements.

A key aspect of the optimization process is the dynamic adjustment of the DPFC's parameters in response to changes in system conditions. For example, when solar or wind generation fluctuates, the DPFC controller adjusts the power flow to ensure that the system remains balanced and stable. This real-time optimization enables the hybrid system to adapt to changing conditions, ensuring that renewable energy sources are utilized effectively while minimizing the reliance on conventional power generation.

The system is also subjected to performance evaluation under various operating conditions, such as varying load demands, grid disturbances, and fluctuations in renewable generation. This helps to assess the effectiveness of the DPFC optimization in improving the system's efficiency, stability, and power quality. The results of the performance evaluation are used to refine the DPFC control strategy and optimize the system further.

Finally, the methodology involves the implementation of the optimized system in a real-world environment or simulation platform. The system is tested for reliability, efficiency, and robustness in various scenarios, and the results are analyzed to determine the impact of DPFC optimization on the overall performance of the grid-connected hybrid system.

4.PROPOSED SYSTEM

The proposed system aims to enhance the performance of grid-connected hybrid systems by incorporating DPFC optimization techniques. The system consists of a hybrid power generation setup that includes renewable energy sources such as solar and wind, along with conventional power generation units. The DPFC is integrated into the transmission network to regulate power flow, ensure voltage stability, and improve overall system performance.

The primary function of the DPFC in the proposed system is to control the active and reactive power flow between the hybrid system and the grid. By dynamically adjusting the impedance of the transmission lines, the DPFC ensures that the power flow is balanced, and voltage stability is maintained. This is particularly important in hybrid systems, where the integration of renewable energy sources can lead to fluctuations in power generation and potential instability in the grid.

The DPFC in the proposed system consists of multiple voltage source converters (VSCs), each designed to manage the flow of reactive power in the system. These converters are connected in a series configuration, allowing for precise control over the power flow. The system also includes a sophisticated controller that monitors the system’s performance in real-time and adjusts the DPFC's parameters to optimize power flow and minimize losses. This controller is designed to adapt to varying load demands, changes in renewable energy generation, and disturbances in the grid.

Optimization techniques are employed to improve the efficiency of the DPFC in the proposed system. The optimization algorithms are used to minimize energy losses, optimize the distribution of power, and improve the power factor. The system is designed to continuously adjust the power flow based on real-time data, ensuring that the hybrid system operates efficiently and sustainably, even during periods of fluctuating renewable generation.

The proposed system also includes features for improving power quality. The DPFC is capable of filtering out harmonics that may be introduced by different power sources, ensuring that the power delivered to the grid is clean and stable. This contributes to the overall reliability and stability of the power grid, particularly when the hybrid system is connected to the distribution grid.

Furthermore, the proposed system can support grid stability by providing reactive power support during periods of high demand. The DPFC's ability to manage both active and reactive power ensures that the system can adapt to grid fluctuations and help stabilize the power grid when needed.

The system is designed to be scalable and flexible, allowing for integration with different types of renewable energy sources and varying grid conditions. This flexibility makes the proposed system suitable for a wide range of applications, from small-scale microgrids to large-scale grid-connected hybrid systems.

5.EXISTING SYSTEM

Existing grid-connected hybrid systems generally rely on the integration of renewable energy sources such as solar and wind, along with conventional power generation systems, to provide a stable energy supply. These systems, however, face several challenges related to power flow management, voltage stability, and power quality, particularly due to the intermittent nature of renewable energy generation.

Current solutions for enhancing the performance of grid-connected hybrid systems often involve basic power flow control strategies, such as using static VAR compensators (SVCs) or conventional FACTS devices. While these devices help manage reactive power and improve voltage stability, they do not offer the same level of dynamic control as the DPFC, which can regulate both active and reactive power in real-time.

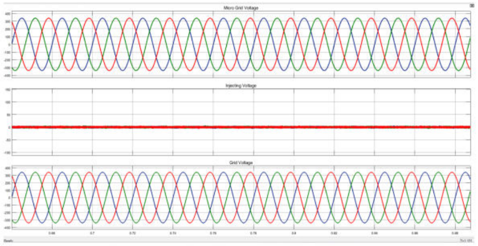
In existing systems, the integration of renewable energy sources often results in fluctuations in power generation, which can lead to voltage instability and power quality issues. Although energy storage systems (such as batteries) are sometimes used to mitigate these fluctuations, they are often not optimized for efficient power flow management. The lack of a sophisticated control mechanism means that these systems are more prone to inefficiencies, especially when the demand for power changes rapidly or when there are disturbances in the grid.

Additionally, most existing hybrid systems lack the advanced optimization algorithms that can improve system efficiency and reduce energy losses. As a result, the power flow in these systems is often less efficient, and the system may rely more heavily on conventional generation during periods of low renewable generation, leading to higher operational costs and increased carbon emissions.

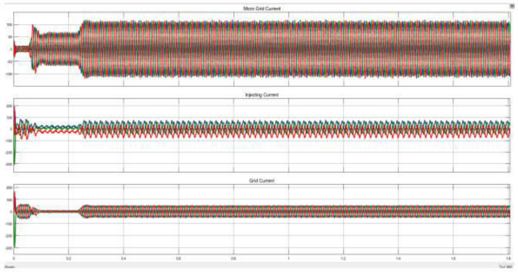
The proposed DPFC optimization technique provides a significant improvement over existing systems by offering more precise control over power flow, reducing losses, improving system stability, and enhancing the overall performance of grid-connected hybrid systems.

6.SIMULATION RESULTS AND DISCUSSION

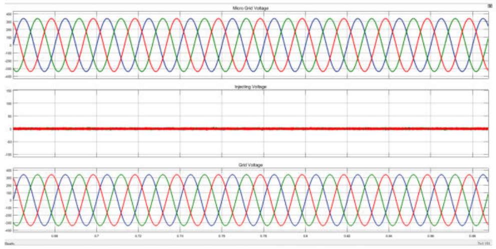
WHEN BOTH INPUTS ARE ACTIVE VOLTAGE WAVE FORMS



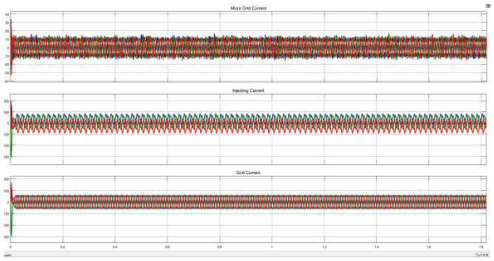
CURRENT WAVE FORMS



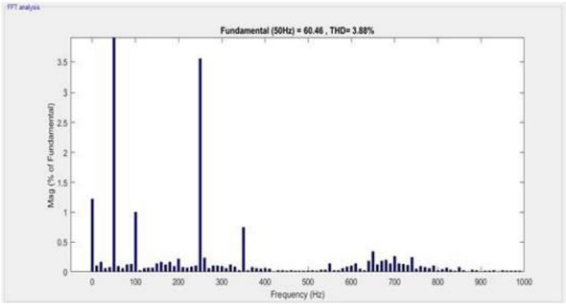
When both inputs are Zero Voltage Wave Forms



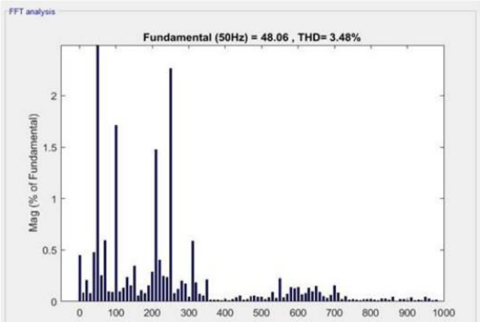
Current Wave Forms



Total Hormonic Distortion for PI



Total Hormonic Distortion for Fuzzy Controller



7.CONCLUSION

The power grids face problems like fluctuating voltage and unwanted harmonics. A DPFC helps stabilize the grid and improve power quality. Combining a DPFC with solar panels (PV) and batteries (ESS) is even better. The PV generates clean energy, and the ESS stores it for when the sun isn't shining. This combination provides a reliable power source and smooths out the power flow to the grid. Because the PV and ESS work together to provide a consistent power output, it simplifies the control of the system's voltage. The system is tested under various real-world conditions to ensure it's reliable. Using a special filter makes the system even better at handling unbalanced loads. This combined PV-DPFC approach is a promising way to improve our power grids, making them more efficient and reliable while also using clean energy. Tests show that the system meets required power quality standards.

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