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Review on Modern Power System Practices for Stability Enhancement using FACTS Devices

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Abstract: Dynamically efficient active power filters present a promising solution to address recent challenges of power system applications. They are capable of effectively suppressing harmonics, compensating reactive power, and mitigating resonance issues. Unlike passive compensation techniques, active power filters can dynamically adapt to varying load conditions, ensuring reliable operation. Furthermore, Flexible AC Transmission Systems (FACTS) devices offer additional benefits by dynamically regulating reactive power flow under various load conditions and compensating for harmonic currents. By utilizing active power filters and FACTS devices, power systems can enhance transient and dynamic stability while effectively managing reactive power and harmonic issues. This comprehensive approach not only ensures reliable operation but also optimizes the overall performance of interconnected power systems and micro-grids.

Keywords: FACTS, STATCOM, D-STATCOM, UPQC.

1. Introduction:

Nowadays, with the high penetration of distributed generation resources in low voltage networks and with the increase of non-linear and unbalanced loads that have a major portion of the total load of a small-scale system creates many challenges in terms of power quality in these networks which requires extensive research in this field. Since the systems based on centralized production are facing two limitations, the lack of fossil fuels and the need to reduce pollution; Therefore, the importance of distributed generation resources has increased by connecting renewable energy systems to grids. In order to make optimal use of distributed generation resources, microgrids have been widely considered. Microgrids are local networks that include distributed generation sources, energy storage systems, and loads that can be operated in two grid-connected and island modes. The most important challenges facing microgrids is power fluctuation control, voltage control, power distribution control, and maintaining power quality in both grid-connected and island modes [1].

In general, power quality problems in the microgrid can be divided into two separate categories. First, the problems that are related to the voltage delivered at the point of common coupling and include voltage harmonics, overvoltage, undervoltage, voltage swell, voltage sag, voltage imbalance, voltage fluctuations, outages, etc. Second, the problems related to the current drawn from the network by non-linear loads such as electric arc furnaces, uninterruptible power supplies, speed control systems, etc., which can lead to power quality complications, including improper power factor, high reactive power, harmonic currents, unbalanced currents, etc. Therefore, in order to improve the level of power quality in a network, the proposed solutions should solve the power quality problems from both perspectives and try to ensure that under any conditions of network problems, the voltage delivered to the load is standard [2].

2. Related Work:

Abdelnasser In order to improve voltage stability and power quality, Nafeh et al. (2021) examined the impact of D-STATCOM coupled to an AC-DC microgrid under various conditions. To the compensator, fuzzy-PI and fuzzy PID controllers are applied. Connecting renewable energy sources is made easier by the micro grid. The authors investigated how the compensator affected the system in the event of abrupt failures and fluctuations in dynamic load. The compensator can enhance dynamic performance and power quality while successfully reducing voltage fluctuations.

The goal of Amany M. Amr et al. (2021) was to manage the 11 kV AC grid that was integrated with STATCOM.The STATCOM is fed by a DC micro-grid. The AC grid values are taken into consideration while designing the STATCOM parameters, and the reactive power support of STATCOM ensures the stability of the AC grid voltage. The suggested control approach is simulated through the usage of PSCAD simulation.

ANFIS-PSO algorithm was used by Kotha Ravali et al. (2021) to enhance second order integrator and Frequency Locked Loop (FLL) to enhance PV systems' maximum power point tracking. By using this technology, irradiance measuring sensors and oscillations are reduced. The Voltage source converter receives control signals from the upgraded controller. The controller's performance is contrasted with the sharpest descent MPPT.

A study conducted in 2021 by Bahram Pournazarian et al. examined the microgrid's modest signal stability. Microgrid instability is caused by the connectivity of distributed generation sources. About 140 data points are given into the ANFIS for training after the PSO algorithm is employed to gather virtual inductance data from islanded microgrids. Reactive power mismatch and stability under various load scenarios are minimized by this approach. The trained converter can function regardless of the value and position of the load.

The hybridized ANFIS and PSO algorithm for MPPT under varying solar radiation was developed by Neeraj Priyadarshi et al. in 2020. There are no tracking oscillations with this method, and it doesn't require any additional sensors to assess temperature or irradiance. To provide high-quality inverter output current, this technology uses a hysteresis current controller based on space vector modulation technique. Connected between the PV module and the load regulator circuit, the PSO-ANFIS-controlled zeta converter acts as an impedance matcher and displays zero harmonics at the output. Using MATLAB interfaced with dSPACE, the controller's performance is compared with various algorithms such as P&O, PSO, ant colony, and artificial bee colony.

Huu Vinh Nguyen et al. (2020) optimized STATCOM's size and placement in relation to a useful network. To maintain the network's voltage stability and transient stability, STATCOM trades reactive power with the linked network. The PSO technique is utilized to determine the best position for UPQC, and ANFIS's online neural network training helps to preserve the network's temporary stability. To confirm the system's capacity to compensate for reactive power, a three-phase fault was applied. MATLAB is used for the suggested system's verification.

In 2020, Zubair Yamin et al. assessed how well a microgrid fueled by wind energy could continuously supply nearby loads. Even a small disruption or shift in load might cause instability in a microgrid.

When the Micro-grid is in island mode, the STATCOM integrated with pitch angle control and battery brings the system voltage and frequency back to a stable state. MATLAB is used to actualize the system's effectiveness, and comparative findings are shown.

In a micro-grid setting, Sachin Tiwari et al. (2020) investigated how UPQC functionsed for power factor correction, harmonic removal, and voltage enhancement using active and reactive power support. Microgrids built with battery-integrated solar PV and microhydro are vulnerable to voltage swings and frequency changes. Batteries are connected to the grid using a bidirectional converter. With the aid of MATLAB Simulink, the UPQC's capacity to preserve the stability of the grid is confirmed.

In order to mitigate power quality difficulties in an isolated micro-grid consisting of wind, solar PV, fuel cells, and battery energy storage system, Ahmed Hussain Elmetwaly et al. (2020) presented the adaptive type D-Facts device. The performance of the PID controllers of STATCOM and ASFC (Adaptive Switched Filter Compensator) was examined by the authors using the grass hopper optimization approach to adjust the parameters. The STATCOM controller performs exceptionally well in preserving the system's power quality.

Alfaki Mohamed Faroug and colleagues (2020) investigated how STATCOM performed in a grid-connected wind energy system. When it comes to preserving system stability in the face of faults or disturbances, fuzzy controlled STATCOM and traditional PI controlled STATCOM are contrasted. By supplying the necessary reactive power and preserving voltage levels, STATCOM helps the system in the event of a disturbance or malfunction. Because of its superior compensating capabilities, the fuzzy regulated STATCOM keeps the system stable.

In 2020, Linggom Enrico Christian and colleagues established a microgrid that utilizes solar and wind power systems. However, the micro-grid's islanded operation is problematic because of voltage variations and a lower power factor.

Voltage and power factor profiles improve with STATCOM integration. The effectiveness of the controller is demonstrated by simulating the operation of STATCOM placed in a radial network under various conditions.

Reactive power compensation and economic dispatch were coupled by Shruti Singh et al. (2019) using STATCOM. To guarantee the lossless and safe operation of the generators in the micro-grid, the economic dispatch is incorporated. In this case, noise is seen as a significant impediment to optimizing the economic dispatch mechanism. Because STATCOM will handle the reactive power support, voltage levels, power factor, and power are all maintained. The proposed control approach is validated by MATLAB simulation.

Panda Deepsika et al. (2018) looked into the present control and features of voltage control of a microgrid made up of a STATCOM, a PV system with battery backup, and a self-excited induction generator based micro hydro. Since the generator's load-carrying capability is fixed, frequency variations and voltage dips occur when the load varies. Both active power control and reactive power maintenance are supported by the fuzzy controlled STATCOM. A real-time simulator is used to test the designed controller's capacity under various load scenarios.

A fuzzy controlled STATCOM was developed by Bhagyashree Jena et al. (2017) for a hybrid micro-hydro and solar PV system. A BESS is installed on the DC side of the STATCOM to supply both reactive power correction and real power support. Multiple load scenarios are simulated for the designed system.

The reactive power compensation capabilities of STATCOM to preserve power factor and voltage profile in an islanded micro-grid were examined by Mohammad M. Hashempour et al. (2017). When a microgrid operates at low voltage without the main grid, it becomes more unstable. By coordinating through communication networks, this study considers the whole length of the power line as well as all DG buses for power factor rectification and voltage regulation at all PCC locations. MATLAB Simulink is used to validate the suggested system. The outcomes demonstrate that the system is not confined to the installation location and can efficiently adjust reactive power at all places.

Izadpanahi et al. (2017) created a non-linear controller that managed STATCOM in an IEEE 9 bus system with a wind turbine based on DFIG. Input-output feedback in a linearization controller supplies the necessary reactive power. The developed controller can sustain voltage and reactive power while withstanding the transient conditions of the DFIG-based wind system.

An optimal controller for STATCOM was created by Asit Mohanty et al. (2015) to function in a stand-alone wind diesel hybrid system. They adjusted the STATCOM's PI control parameters using Particle Swarm Optimization and Genetic Algorithms. The reactive power compensation and voltage stability for varying wind factors and fault circumstances are improved by the suggested design. Additionally, transient stability is examined.

In Zahariah et al. (2021), the effectiveness of fuzzy logic controllers and PI in reducing harmonics when dispersed generation is connected to the grid was examined and contrasted. In Jun Qi et al. (2020), a new coordination between the wind generator and STATCOM is introduced for improved reactive power compensation. The reactive power compensation capability of STATCOM is compared with SVC. In Chandrasekaran et al. (2021) and Kulkarni et al. (2022), the dynamic ability of STATCOM is tested to improve voltage stability in the presence of renewable energy sources. To compensate for power quality issues, flywheel energy systems are used instead of battery energy sources. A comparison is made between the diesel generator wind energy hybrid system's performance using the ANFIS-PID and fuzzy-PID controllers for STATCOM. (2015) Anulal et al. Comparatively speaking, ANFIS-PID controllers suppress voltage variations more than Fuzzy-PID and PID controllers do. Because fuzzy logic control is easy to implement and has a simple architecture, it has gained popularity. However, the trainer's skill and knowledge are the only factors that affect how well the membership features are tuned. Conversely, the processing and convergence times of an ANN-based controller are lengthy. Because it combines the best features of each of the aforementioned approaches and addresses their drawbacks, the adaptive neurofuzz inference system is becoming more and more popular. The system's performance was limited to approximately 89% to 90% because of the large number of switches and related losses. Therefore, the controller was created with a simplified switch idea in order to maximize efficacy.

An ANFIS controller encodes the fuzzy IF-Then rules into a neural network-based structure, after which an appropriate learning algorithm is used to train the data set and lower error. Furthermore, because there is no rule sharing and a single weight assigned to each rule, training fuzzy membership to lower error using the ANFIS controller is still a useful technique. ANFIS controllers are also simple to use and have an adaptable and self-learning nature.

PSO tuning of the STATCOM controller parameters is recommended because it minimizes voltage deviations, optimizes system parameters, and lowers the overall loss in the system (Masha Kashani et al. 2020).

This study uses a static compensator with a PSO-based learning algorithm for the ANFIS controller to enhance reactive power compensation and voltage regulation in a microgrid powered by renewable energy. The advantages of particle swarm optimization over alternative techniques are its ease of implementation, robustness when regulating parameters, and great computational efficiency. PSO will tune for the ideal ANFIS parameter value in the suggested cascaded ANFIS-PSO controller. Through simulation, the STATCOM controller's performance was examined under various load scenarios. The results achieved utilizing the system's PI and ANFIS controllers are compared to the efficacy of the suggested controller.

Many power electronic devices are used in today's contemporary power system at the transmission and distribution level because they have many benefits. Non-linear loads, such as saturated transformers, and microprocessor-based devices can cause semiconductor switches to draw non-linear current. As a result, the utility services must be able to reduce harmonics and supply the reactive power that is required. Reactive power issues and harmonics are bad for the grid because they cause excessive power losses and component failure (Hossain et al. 2018). A brief investigation into custom power devices is conducted to mitigate power quality difficulties. DVR is capable of managing voltage-related issues like as swell and sag. DSTATCOM reduces current harmonics and power factor-related issues. However, UPQC can provide solutions for issues with voltage and series circuits, including unbalance, swell, flicker, sag, and harmonics. Furthermore, it can manage issues with power, harmonics, and unbalance that are related to shunt circuits and current. Thus, the significance of specialized power devices for UPQC has grown recently. Thus, the examination of UPQC in grid-connected mode is taken into consideration in this work's second section.

A cascaded H bridge multilevel based STATCOM was constructed by Martynas Sapurov et al. (2022) to handle the reactive power of a low voltage grid. MOSFET (Metal Oxide Field Effect Transistor) switches are used in the second stage of the inverter's high frequency operation, while ordinary thyristors are used in the first stage for grid frequency operation. Three times as much reactive correction is used in the converter's operation as in a traditional inverter.

Pragnyashree et al. (2022) focused on the degradation of power quality brought about by the network's penetration of power electronics converters and renewable energy sources. To enhance the system's power quality, a PV-fed UPQC controlled via adaptive controlling technique is used. A soft computing approach called variable leaky least mean square is employed, which has the capacity to rapidly converge. In order to regulate series and shunt converters of UPQC, it does away with the need for low pass filter 42 or moving average filter for fundamental component extraction from source voltage and load current. The control is seamless, and it can efficiently reduce issues with power quality and regulate voltage. The suggested controller is validated in a hardware and simulation environment.

Linghui Meng et al. (2022) focused on the instantaneous power variance that can cause ripples in the DC-link voltage between a series and parallel converter. This weakens UPQC's capacity to compensate. In the event of a parallel inverter, a notch filter is added, which may prevent ripples from getting into the primary control loop. The inner loop's selective harmonic correction restricts the current harmonics. Dc-link voltage is conveyed as feedback in the event of a series inverter to limit voltage ripple. Prototype and MATLAB simulation are used to confirm that the converter reduces THD effectively.

The effects of combining solar PV and UPQC with battery integration on a microgrid for a smooth transition between grid-connected and stand-alone mode were investigated by Sachin Devassy et al. in 2021. The behavior of the system during mode transition, variations in supply voltage or solar PV output, changes in load, etc., are all thoroughly studied. Prototype hardware modules and simulation are used to validate the suggested system. When there is an unbalanced load, sudden weather, or load unavailability, the incorporation of PV fed UPQC keeps the key loads running.

A hybrid connection model was presented by Jiangfeng Wang et al. (2021) to integrate DG with UPQC. Two dc ports (high voltage and low voltage) are generated at the dc-link. DG is connected to the UPQC indirectly using a low voltage port on a dc-dc converter. The DG and UPQC are directly connected via the high voltage port. Depending on the state of the system, the ports are used alternately. The direct 43 arrangement, which eliminates the dc-dc converter and its related power loss, can be used with a series converter to provide good results if the dc voltage is low. The design is feasible, as demonstrated by the experimental findings.

A Quadruple-Active-Bridge (QAB) based UPQC was presented by Jian Han et al. (2021) to address power quality issues. The UPQC is made up of a three-phase shunt converter linked with three single-phase series converters and QAB situated at the dc-link. The low frequency transformers and their corresponding weight are eliminated in this type. At QAB, high frequency transformers are used to lower weight and volume while increasing system power density and flexibility. The accuracy of the suggested model is confirmed by the use of Hardware in loop and MATLAB Simulink.

A common converter topology for linking the UPQC's series and shunt converters to the grid was presented by RadwaAbdalaal et al. in 2021. The functioning of an inductive or capacitive reactance is controlled by adjusting the phase angle between the input voltage and current. There are two intended voltage control loops: an ac voltage control loop and a dc link voltage control loop. The circuit is controlled by altering the inner current loop in response to the output from the two outer loops. This technique does away with the need for an extra sensor. A prototype model is used to assess the system's small signal modeling for stability in both the steady state and the transient states.

Parul Gaur et al. (2021) optimized the Cascaded H Bridge multilevel based STATCOM's operation with less materials by utilizing the PSO method. The PSO algorithm regulates the switching sequence of IGBTs (insulated gate bipolar transistors). Because there are fewer materials used in the converter's design, the output has a lower overall harmonic content, more modularity, and fewer losses. Utilizing MATLAB Simulink, the designated controller is validated.

A 15-level inverter was used by Dhanamjayulu et al. (2021) to harvest energy from PV modules. Cost, loss, and complexity reduction are guaranteed by the inverter's simplified component modeling. Simulink software and the RTI1104d SPACE controller are used to test the suggested inverter module for both linear and non-linear types of loads. Reductions in conduction loss and switching loss are the outcomes of this paradigm.

Sayanee Das et al. (2020) created a fault classifier for UPQC compensated line fault detection that uses fuzzy logic control. UPQC is integrated to handle both reactive and real power in order to lower harmonics and preserve the system's voltage profile. In order to determine the type of fault, the fuzzy controller looks at the current value at any point along the line and compares it with the supplied data to check for possible increase current values. Results from simulations are given to bolster the work.

Sivarajankakkattil Narayanan et al. (2020) integrated 10 kW PV to the distribution grid using UPQC with Battery to preserve voltage stability. Two components that were combined to produce the UPQC, DVR and STATCOM, were designed with differential inverters. The differential inverter provides active power decoupling. In order to keep the voltage profile constant, solar PV injects active power into the distribution network. Verification of the system performance through experimentation is done using UPQC.

Muhammad Alif Mansor et al. (2020) looked into how battery energy storage systems, solar PV, and UPQC all functioned together. PV integration helps with active power injection in addition to the UPQC converter's reactive power adjustment capabilities. The PV's intermittent power source can be continuously supported by a battery system connected to it. The unit vector production technique combined with a self-tuning filter produces the synchronization pulses required for both series and shunt converters. Using MATLAB Simulink, the suggested synchronization technique is 45 compared to the output of the phase-locked loop and standard synchronous reference frame techniques.

To lower the price and size of UPQC, Ashish Patel et al. (2020) optimized the size of the shunt and series converter components. Interconnections of renewable energy sources are made easier and the system's power quality is enhanced by the integration of UPQC. The amount of reactive power correction shared by series and shunt converters is determined by the power angle. Therefore, the Volt-Ampere limit constraint increased power angle control technique is used to optimize converter size. Both the hardware in loop model and Simulink are used to verify the design.

In-depth discussion of power quality issues in a power system network and the use of D-facts devices in the rectification process was provided by Naeem Abas et al. (2020). Their primary focus has been on the 3rd and 5th harmonic current and how DVR affects the system's ability to improve power quality. The third and fifth harmonics of the load voltage harmonics are successfully reduced by DVR to 2.69% and 4%, respectively.

An integrator was altered by Sanjenbamchandrakal Devi et al. (2020) to remove DC offset when UPQC is powered by solar energy. Reference current values for the UPQC shunt filter are produced by processing and sampling the load current. The control method aims to improve reactive power compensation, reduce harmonic imbalance, sag, and eliminate harmonics in addition to properly balancing grid currents. Using a hardware prototype and the MATLAB/Simulink environment, the controller's effectiveness is evaluated. The answers are in the affirmative.

The effectiveness of single-phase and three-phase UPQC in preserving the network's power quality was examined by Mohanraj et al. (2019). For UPQC control, adaptive distributed power balanced control is employed. The work describes in detail how UPQC works to mitigate issues with power quality. During disruptions, the dispersed 46 generation helps with compensating. The internet of things, or IOT, is used to gather data and track system efficiency.

In order to reduce energy loss, Shubh Lakshmi et al. (2019) created a non-linear optimization problem. The goal function is maximized while preserving the maximum levels of voltage and current flow, as well as the best possible reactive power extraction from the inverters. As the optimization problem is being solved, the load variation on an hourly basis is taken into consideration. The optimization problem is resolved by using the CONOPT solver. Infrastructure needs for useful prototyping are also listed, along with the investment cost and benefit ratio. MATLAB/Simulink is utilized to verify the system that has been simulated.

In order to create a UPQC, TashinKoroglu et al. (2019) integrated a dynamic voltage restorer and a hybrid shunt active filter using an isolated DC-to-DC converter with bidirectional capability. Utilizing a hybrid active filter lowers the size and cost of the DC Link. It also lowers switching losses. In addition to allowing for bidirectional power transfer, a bidirectional converter keeps the voltage at the DVR's DC link constant. On the other hand, the hybrid active filter's DC link voltage fluctuates. To reduce sag/swell, upgraded PLL techniques and improved Clarke transformation are used. Hardware performance validates the controller and algorithm design.

A multilayer inverter STATCOM was implemented by Ramyani Chakrabarty et al. (2019) with a simplified switch model. With this variant, the need for diodes has been removed, and there is only one DC source utilized. Good isolation is provided by the transformer-based connection. When analyzing circuit parameters, the model predictive controller takes the circuit's current loss and power loss into account. As a result, the compensator exhibits improved harmonic reduction and DC link voltage maintenance.

For solar PV applications, Shuvangkarshuvo et al. (2019) created a 5-level cascaded H bridge multilevel inverter with 6 switches and 2 DC sources. Proteus and MATLAB are used to simulate the planned inverter, and the outcomes are compared to those of traditional controllers. To demonstrate the effectiveness of the controller, the planned inverter is implemented hardware-wise.

The functioning of UPQC in symmetrical and asymmetrical fault circumstances, as well as linear and non-linear loads, was examined by Sabir Data et al. (2019). The UPQC control method enables the series converter to lower harmonics and the shunt converter to maintain voltage stability. The work has demonstrated the ability of UPQC reactive power compensation to restore system voltage levels to nominal values and to compensate for various faults.

Sundarabalan et al. (2019) used a fuel cell in conjunction with a unified power quality conditioner to adjust voltage and current in a distribution grid consisting of four wires. The controller's control signals are produced via reactive power theory and synchronous reference frame theory. This paper examines the removal of voltage sag and swell, harmonic reduction, neutral current, and reducing source current imbalance. While the voltage THD is only roughly 0.19%, the current THD is approximately 2.5%.

From the DC voltage input, multi-level inverters can produce a range of AC voltage levels; however, the abrupt change may cause harmonics. Low harmonics are thus produced by smaller power conversion stages in multilayer inverters. Because of its simplicity, the cascaded H bridge inverter is the most popular multi-level inverter topology (Ashique Anan et al. 2018). However, more switches result in higher losses and complexity as well as lower costs, higher system reliability, and higher system efficiency. Thus, the effort made at the input. The inverter produces step wave output that resembles a sinusoidal waveform. But steps must be taken to lessen the constituents.

Amarendu Behera et al. (2018) worked to enhance a 25 kV distribution system's power quality. The system's power quality is improved by the UPQC built into it. Additionally, UPQC will shield the system against serious harm brought on by errors. Given that all other fault categories are not as severe as LLLG fault, it is taken into consideration.

In a radially distributed network, Shubh Lakshmi et al. (2018) determined the ideal placement for UPQC. The cost of the main UPQC components, such as the inverter, PV, and battery, as well as the cost related to energy loss, are constrained by a nonlinear objective function that is optimized. At various network locations, two configurations—such as UPQC-PV-Battery and UPQC-PV—are contrasted for power quality and energy efficiency. The optimization procedure makes use of the PSO algorithm.

A multi-level inverter based UPQC with a hybrid back-propagation control technique was proposed by Veera Nagireddy et al. (2018). The gating pulses of the UPQC are produced using the back propagation control technique, which uses source current and load current. In order to analyze the performance of the suggested controller in a simulated environment, total harmonic distortion, voltage imbalance, and voltage sag mitigation were taken into consideration.

UPQC was created by Mojtabayavari et al. (2018) using non-linear modeling. The authors combined the concepts of sliding mode-based control with active and reactive power theories to create this controller. Through the Simulink environment, the authors confirmed that the controller effectively mitigates issues linked to voltage and current, such as sag, swell, and distortion. However, based on the results, the adjustment capability is only 80%, mostly due to sag.

Reactive power injection was used by Yunfei Xu et al. (2018) to test the voltage sag compensation capacity of UPQC. The angle at which active power injection into the network occurs is ascertained using the 49-designed algorithm. Using PSCAD/EMTDC, the results are validated for different sag severities. However, the other issues with power quality, such as distortion, swell, and harmonics, were not addressed by this controller.

Using a five-level diode clamped converter, Sudheer Vinnakoti et al. (2017) developed an artificial neural network based UPQC. The ANN is trained using the Levenberg-Marquardt back propagation approach. Results from the simulation were recorded for three distinct converter levels. Regarding THD suppression in source current and load voltage, the outcomes are contrasted. If the controller starts far from the minimum, the leven berg-Marquardt may not converge. An increase in level necessitates the inclusion of more diodes in the diode clamped converter architecture. As a result, applying the concept practically to higher levels becomes more difficult. The maintenance of capacitor voltage has its own set of issues.

Senthil Kumar et al. (2017) used the Model Reference Adaptive System (MRAS) to construct the ANFIS controller and tune the PI controller for UPQC online. Voltage sag and optimal DC link voltage regulation were taken into consideration as benchmarks for evaluating the effectiveness of the controllers that were designed.

The transient stability of wind energy systems corrected using static synchronous series compensators (SSSCs) was examined by Lekshmi et al. (2017). This work introduces a frequency oscillation damper to lower harmonics during fault circumstances and increase the wind system's ability to ride through faults. Following a fault, the suggested damping and SSSC keep the rotor angle difference between the wind systems constant.

In a 2017 study, Niveditha et al. examined how well UPFC might dampen oscillations caused by different defects. Analysis is done on the UPFC's ability to compensate for line-to-ground, three-phase, and double-line faults. In terms of fault settling time, the 50 system response for faults with and without UPFC is compared. When UPFC is present, the system reaction is more stable. In addition to raising power quality FACT.

FACTS devices can enhance system performance in addition to enhancing power quality by limiting the rise in current and keeping the voltage level almost constant. FACTS devices suppress faults within half cycles and function as a fault current limiter. This lessens the burden on protective systems and lowers the rate of component failure.

Jian Ye et al. (2016) used data-driven control to optimize the UPQC system size design. Phase Angle Control along with appropriate compensation allows for UPQC Size optimization. MATLAB simulation is used to validate the results, and OPAL-RT is used to confirm them.

UPQC has the ability to solve the majority of low-quality power issues with specialized power devices. Power systems with connections to renewable energy sources can also benefit from the use of UPQC software. The literature goes into great length about the UPQC arrangement that uses a common capacitor at the DC link to connect the voltage source converter in a back-to-back fashion, as well as related wide control schemes. However, the multilayer inverter will perform better than traditional two-level converters due to less distortion, reduced switching losses because of the device's ability to operate at low switching frequencies, low dv/dt, and lower rating of power electronic switches. The main issue with diode clamped converters is capacitor voltage imbalance, which can be fixed at the expense of higher system costs and dimensions. Numerous control systems, including fuzzy, PID, and PI, were put out in the literature to address this problem. The ANFIS is a powerful tool that combines fuzzy logic controller with neural network capabilities. It has the ability to remember, learn, and execute control actions as needed. Consequently, the ANFIS controller is used in the current work to control voltage at the DC link.

Cascaded H Bridge multilevel is a strong contender for the realization of shunt and series active filter units in the current work because of its decreased component requirements, which translate into low cost and reduced space. The need for many isolated voltages is met, and there are fewer switches needed overall. Himajindhu et al. (2016) and Karthika et al. (2017) describe a seven-level multi-level inverter that uses only five switches. Details include phase opposition disposition PWM, selective harmonic mitigation for multilayer inverters, and phase disposition PWM based on multiple carriers. has made an attempt to alleviate fault current issues in addition to voltage and current difficulties.

Each phase of the PQ theory control scheme can be controlled, although its performance may be impacted by distorted input. However, even in the presence of a contaminated supply, PQ theory, the performance of the harmonic extraction method, and the synchronous reference frame transformation theory work fairly well. As a result, this study includes phase-disposition based Phase Width Modulation and multilevel inverter with fewer switches to realize active filter in series and shunt position. Traditional PI controller topologies for controlling DC voltage limit the system's capacity for correction. Thus, an ANFIS controller is used.

This approach also prioritizes the integration of highly intermittent renewable energy sources, such as wind and solar power, into the system. At the DC link of the UPQC, a photovoltaic system is integrated symmetrically with a capacitor. The integrated PV system aids in the advancement of power quality because it allows for real power injection. To enhance UPQC performance, PV integration at the DC link is taken into account (Devassy et al. 2018). In addition to the advantages of incorporating clean energy, doing so also improves fault ride through capability during transient periods, shields key loads from grid side disturbances, and improves grid power quality. Thus, PV integration is taken into account in this work.

The evaluation has conducted a thorough analysis of STATCOM and UPQC's reactive power compensation capabilities. There are two components to the work's primary goal. The initial task is to use PSO-tuned ANFIS to develop a controller for STATCOM. A microgrid environment is used to analyze the intended controller's performance in terms of its capacity to reduce harmonics, adjust reactive power, and keep the voltage at PCC. The design of the ANFIS controller for the multilayer inverter-based UPQC is the second portion of the task. The controller's performance is examined in both linear and non-linear scenarios, taking into account different power quality metrics such as swell and sag. Analyzed is the controller's effectiveness in maintaining voltage level throughout a malfunction.

3. Conclusion:

This paper presents wide literature review of the various control strategies for STATCOM and UPQC. The paper also listed the research objectives of the work. STATCOM controller forming a renewable energy based microgrid with battery system. We will integrate PSO tuned ANFIS controller based STATCOM at PCC. We analyse the effectiveness of controller in reactive power compensation, voltage regulation and harmonic mitigation.

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