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A Brief Review on Power Quality Improvement using UPFC

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Abstract: Load demand is rising rapidly these days, necessitating an increase in generation capacity. Voltage instability arises as a result of external and internal imbalance, causing the bus voltage to vary. The FACTS device Unified Power Flow Controller (UPFC) is used to maintain stable voltage and improve power flow in transmission lines. This study examines the comparison of different FACTS devices as well as the analysis of UPFC to control both. In comparison to other FACTS devices such as STATCOM, which regulates only voltage, TCSC, and SVC, which controls only impedance, UPFC is one of the most promising FACTS devices since it can manage phase angle, voltage magnitude, impedance, and many line parameters selectively or concurrently.
Keywords: UPFC, Active and Reactive power, Dynamic compensation, FACTS device.

I. INTRODUCTION

The flexible AC transmission systems (FACTS) idea, which is based on integrating cutting-edge Power Electronics Technology to existing AC transmission systems, increases stability while increasing useable power transmission capacity to its thermal limit. A UPFC may regulate the transmission line impedance, phase angle, and voltage all at once. The UPFC is made up of two power electronic inverters that are linked together by a shared DC connection. Two transformers are employed to isolate the UPFC and match the voltage levels between the power system and the power electronic inverters. One of the inverters is linked to the transmission line. The series-connected inverter may create a voltage with changeable magnitude and phase angle. As a result, this inverter may supply both real and reactive power to the transmission line. The second inverter typically supplies the series inverter with actual power, although it can also function as an independent VAR compensator. As a result, the UPFC has the ability to manage the flow of actual and reactive power in the transmission line. By splitting the DC side, the two VSIs may operate separately. In that situation, the shunt inverter acts as a STATCOM, generating or absorbing reactive power to control the voltage magnitude at the connection point. The series inverter operates as an SSSC, generating or absorbing reactive power to regulate current flow and, as a result, power flow on the transmission line. The UPFC can be used to improve the power quality due to the separate controlling capability of real and reactive power.

II. LITERATURE REVIEW

Gyugyi's UPFC, introduced in 1991, is one of the most complicated FACTS devices in a power system today. It is generally utilised for independent control of actual and reactive power in transmission lines for flexible, dependable, and cost-effective power system operation and loading. Until recently, all three parameters that affect real and reactive power flow on the line, namely line impedance, voltage magnitudes at the line terminals, and power angle, were separately controlled using mechanical or other FACTS devices such as a Static Var Compensator (SVC), a Thyristor Controlled Series Capacitor (TCSC), a phase shifter, and so on. However, the UPFC provides for simultaneous or independent control of these parameters, as well as real-time switching from one control scheme to another. The UPFC may also be utilised to provide voltage support, increase transient stability, and dampen low frequency power oscillations.

(Thakare and colleagues, 2019) [1] FACTS is a flexible alternating current transmission system used to transport alternating current electricity. FACTS technology enhances power system controllability and power transmission. FACTS devices are used for a variety of purposes. UPFC is used in this paper. UPFC is a hybrid of STATCOM and SSSC. The UPFC regulates the voltage and controls the power flow. This document depicts the various modes of operation for series and shunt converters. The Unified Power Flow Controller (UPFC) is an IGBT-based voltage source converter that displays step change.

(Gandhar et al., 2020) [2] The research developed an impact technique to stabilise reactive power changes in islanded microgrids, resulting in control over voltage instability. The needed voltage adjustment is done by injecting an exact synchronous voltage source into the microgrid through power electronics-based converters.

This study is carried out utilising an advanced flexible AC transmission (FACTS) device and a unified power flow controller (UPFC) coupled to a microgrid. This compensation reference is produced by synchronous voltage management, which avoids the load frequency control loop. The use of the unified power flow controller (UPFC) to increase power system voltage stability during the transient period in an integrated renewable energy source (RES)-based microgrid is examined in this work.

(Taher et al. 2020) [3] A unified power flow controller (UPFC) is used to control both the bus voltage and the power flow via a power system. Because of the adjustments necessary for incorporating UPFC characteristics, solving optimum power flow (OPF) issues with UPFC is a critical and challenging undertaking. To reduce programming complexity, this paper recommends incorporating a simplified UPFC model into an OPF code. Furthermore, a contemporary physical-based optimisation approach known as lightning attachment procedure optimisation (LAPO) is used to solve an OPF issue using a UPFC model. Different objective functions are explored, such as minimising fuel cost and fuel cost with valve point effect (VPE), reducing emissions, enhancing the voltage profile, and increasing the voltage stability index.

(Jmii et al. (2016)) [4] FACTS (Flexible AC Transmission System) optimal site has a considerable influence on power system stability. This research identifies the optimum placement of UPFC (Unified Power Flow Controller) for voltage stability enhancement of an IEEE 14-bus case study. First, the system's critical zone is established using a numerical simulation-based technique.

Second, comparative studies based on various UPFC locations are explored. It was discovered that putting UPFC in the right place considerably improved voltage profiles and increased maximum loading capacity, resulting in improved voltage stability.

(Ferdosian and colleagues, 2013) [5] The need for wind power producing capacity is always increasing. This circumstance necessitates a change of grid code standards in order to remain connected during grid faults, i.e., to ride through faults and contribute to system stability under fault conditions. In a typical fault state, the voltage at the Point of Common Coupling (PCC) drops below 80% instantly, causing induction generator rotor speeds to become unstable. In this study, the Unified Power Flow Controller (UPFC) is utilized to enhance the low voltage ride-through (LVRT) of a wind energy conversion system (WECS) and to dampen induction generator rotor speed oscillations under fault situations.

(Vijay Kumar and Srikanth 2015) [6] This research proposes a hybrid technique-based optimal positioning and size of UPFC to increase dynamic stability. Because the generator outage influences power flow limitations such as power loss, voltage, real and reactive power flow, the largest power loss bus is chosen as the most advantageous site for repairing the UPFC. The Artificial Bees Colony (ABC) algorithm was used to select the best placement.

The Gravitational Search Algorithm (GSA) optimises the needed amount of the UPFC to regain the starting operating state based on the violated power flow quantities. The suggested work is then implemented in the MATLAB/simulink platform, and the performance is assessed by comparing other methodologies such as ABC and GSA. The comparative findings show that the recommended technique is superior and has the ability to address the problem.

(Alharbi and Abu-Siada, 2015) [7] In this research, a new unified power flow controller (UPFC) controller strategy is presented to increase the low-voltage-ride-through (LVRT) capacity of a DFIG-based WECS during voltage sag. A hysteresis current controller (HCC) and proportional integral controllers (PI) are used to manage the UPFC's shunt and series converters, respectively.

Detailed simulation is carried out using MATLAB/SIMULINK software to highlight the impact of UPFC in improving the overall system performance during grid fault. (Shetty et al., 2019) [8] The demand for the power generation from wind is constantly growing. This situation forces the revision of the grid codes requirements, to remain connected during grid faults. Immediately, the voltage level will drop below 80% when fault occurs at PCC (point of common coupling) and the rotor speed of IG (induction generators) becomes unstable. In this work, UPFC are used under fault condition to improve the low voltage ride-through (LVRT) of wind energy conversion system (WECS) and damping of rotor speed oscillations of IG.

Furthermore, following a malfunction, the UPFC functions as a virtual inductor, causing the WECS terminal voltage to rise. WECS using a DFIG-based system is being examined here.

(Ahmed, 2019) [9] FACTS controllers are power electronics-based devices that may rapidly affect transmission system characteristics such as impedance, voltage, and phase to govern transmission or distribution system behaviour. FACTS controllers that use a voltage source converter interface to power system with a capacitor on a dc bus will gain the most from energy storage. This FACTS controller class can be linked to the transmission system in parallel (STATCOM), series (SSSC), or combination (UPFC) mode, and they can use or divert the available power and energy from the ac system.

Flexible AC Transmission System (FACTS) devices have been studied and used in the field of power engineering. There are several benefits of employing FACTS devices. It can improve dynamic stability, transmission line loading capabilities, power quality, and system security.

(Ain and colleagues, 2020) [10] Recent advancements in the field of power electronics have resulted in the creation of the FACTS controller to improve power system stability concerns. While different FACTS controllers aid in the mitigation of power system oscillations, the Static Synchronous Series Compensator (SSSC) and Thyristor Control Series Compensator (TCSC) have been determined to be the best appropriate for the problem. The purpose of this study is to discuss the modelling and functioning of SSSC and TCSC controllers in a multi-machine context.

(2022, Penchalaiah and Ramya) [11] Modern power transmission networks are growing increasingly complicated as a result of increased demand and limits on the building of additional lines. One of the major challenges with such a contemporary power system is the lack of stability after an interruption. Transient stability control is a critical principle that ensures the stability of the power system during faults and major instabilities. FACTS tools have shown to be highly useful in enhancing controllability and expanding power transfer capability in a power system transmission network while maintaining the requisite stability margin.

(Sarathkumar and colleagues, 2021) [12] This study explains the operation of a fuel cell as a STATCOM to improve power system stability during various symmetrical and asymmetrical fault circumstances.

Our electric utility is now dealing with a slew of difficulties related to system stability. Installing a flexible alternating current transmission system (FACTS) compensator improves the results. However, the costs of compensating the system for the higher payload are passed on to the customers. As a result, this research presents a unique technique to supply adjustment utilizing a fuel cell (FC). The fuel cell (FC) was created as a STATCOM - a FACTS device. The FC STATCOM's capacity to improve transient stability of two machine systems following a fault incidence. In this research, a fuzzy logic controller was used as the main controller to improve the power system stability of two machine systems.

Moravej and colleagues (2015) [13] A novel set of time-frequency characteristics is suggested in this study for fault-type identification, fault-loop status supervision, and fault-zone detection modules in a compensated transmission line with a unified power-flow controller. The fast discrete orthonormal S-Transform (FDOST) extracts several characteristics from a one-cycle data window on one side of the compensated line, including 3/16 cycle of postfault data. The FDOST, being a time-frequency decomposition, has the same computational load as the fast Fourier transform. The Gram-Schmidt technique uses the support vector machine to classify the ranking features. The graphical representations of retrieved characteristics and the numerical results produced under various settings validate the efficacy of the suggested approach.

Thangella et al. [14] investigate the performance of UPVBSS in 2022 utilizing a number of test scenarios with different source and load characteristics, demonstrating good performance in terms of power quality enhancement, THD, power factor, and waveforms. Power quality has become a key challenge in today's power distribution systems because to the presence of nonlinear loads and devices, as well as power electronics-based drive systems. To alleviate the effects of PQ issues, active line filters and universal power quality conditioners (UPQCs) are utilized. These devices use complex Park and Clarke transformations as well as typical PI (PIC) controllers, which may not be suitable for rapidly changing loads. Furthermore, combining these devices with renewable energy and battery energy storage systems improves their performance.

Ray et al. in [15] in 2022 described a PV-integrated unified power quality conditioner (UPQC) that employs an adaptive compensatory approach based on the VLLMS algorithm. The growing popularity of distributed energy resources and distributed energy storage in the distribution network and microgrid has been fueled by rising awareness of green energy and sustainable energy management. As a result, the usage of power electronic-based devices has increased, creating a severe problem of worsening power quality (PQ) in the distribution system. Because of the presence of the PV feed-forward component in the compensatory mechanism of shunt VSC, it handles power balance between grid, load, and PV while also eliminating the PQ concerns of current harmonics and low power factor at PCC.

Gupta [16] in 2021 discussed that Power Quality (PQ) improvement becomes critical to improving the overall performance of equipment in utility-grid linked systems. This research examines the operational impact of D-STATCOM and UPQC in a cascaded H-bridge Nine-Level Multi-Level Inverter to improve PQ. The efficacy of the suggested architecture is investigated using a constant 200 V DC voltage and two 100 kW SPV arrays. In faulty circumstances at linear load, a PQ comparative analysis is provided. The deployment of competent control mechanisms is essential for the suggested system to work well under changing environmental conditions. Yadav and Yadav [17] in 2021 depicted that renewable energy sources are the future of the power industry and are widely used to reduce the burden on conventional fuels. However, the RES's unpredictable nature makes it cumbersome and uneconomical for large-scale application. As a result, the research attempts to give a complete literature analysis on the various strategies used to reduce power disruptions caused by high scale penetration of RES through the use of effective BESS and UPQC. This article highlighted some of the unique grid configurations and gave a tabular comparison of the review completed for each application sector.

III. WORKING PRINCIPLE OF UPFC

UPFC is made up of two switching converters, which in this design are voltage source inverters with gate turn-off thyristors. Storage capacitor and two voltage source converters linked back-to-back and powered by a shared dc connection. The common dc link allows actual power to flow in both directions between the two converters' ac terminals. At its ac terminal, each converter can generate or absorb reactive power. With the assistance of a series linked converter with phase angle (0360) and voltage magnitude (0VpqVpqmax), voltage in series is injected in line, exchanging actual and reactive power. The series linked converter transforms the demand or excess real power of a transmission line to a common dc bus as a supply or absorber of real power.

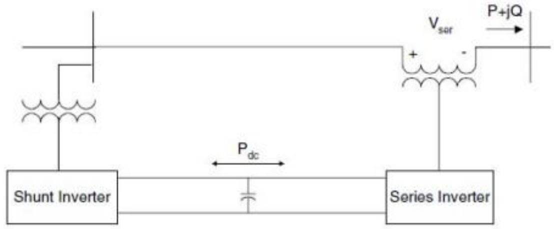

Fig. 1 Basic circuit diagram of UPFC

The demand at the dc link is converted to ac and sent back to the line through a shunt connected transformer. There is a closed direct channel for actual power exchange via a series converter, a dc link, and a shunt converter back to the line. The series linked converter generates or absorbs reactive power locally and fulfils the transmission line demand. As a result, active power is delivered without changing the reactive power flow. In an alternating current transmission system, UPFC must perform as both real-time control and dynamic compensation, while in an industrial power supply, it provides a multifunctional solution.

IV. COMPARISON OF UPFC TO OTHER FACT DEVICES

1) TCSC The main aim of a thyristor-controlled series capacitor (TCSC) is to manage impedance and promote voltage stability in a transmission line. The TCSC is linked in series, and the thyristor-controlled inductor is linked in parallel to the capacitor. The TCSC impedance may be modified in three ways.
a) Blocking Mode: The thyristor valve is not engaged and remains in the non-conducting condition during blocking mode.
b) Capacitive and Inductive Modes: When the thyristor is in the conducting state, line current passes through the capacitors, increasing the effective capacitor and inductive reactance of the circuit.
c) Bypass Mode: The line current passes via the thyristor in bypass mode. When XL = Xc, the thyristor begins to function.

The TCSC has important advantage for to increase the level of power flow, to controlling the fault current and dynamic stability.

2) SVC Static VAR Compensator is a device used to synchronise gearbox voltage and improve power quality of industrial loads. SVC are made up of one or more fixed capacitor or reactor banks and a thyristor-controlled system. SVC is depicted in parallel with the transmission line and is impedance matching at the line's end or the midway of the transmission system, with no spinning portion, and is equal to the asynchronous condenser. Using a thyristor valve to regulate the susceptance of the SVC and bring the power factor closer to unity also provides a quick reaction to changes in the system. The static VAR compensator is more genuine than the synchronous condenser.
3) STATCOM The voltage source converter is required for the static synchronous compensator. This device's primary function is to convert DC input voltage to AC output voltage. Its primary characteristics include the ability to create sinusoidal voltage and fast alter the amplitude and phase angle at the fundamental frequency. STATCOM accounts for both active and reactive power. STATCOM outperforms SVC in terms of performance.
4) SSSC Static synchronous series compensator (SSSC) is a solid-state power electronic device that operates as a synchronised voltage source and is equal to STATCOM. The SSSC inverter converts DC to AC using a gate turn off thyristor (GTO). The SSSC may create three phase voltage, which can then be injected into the transmission line using an insertion transformer linked in series with the transmission line. SSSC indirectly adjusts line voltage by injecting current into the transmission line. The key advantage of SSSC over TCSC is that it does not alter transmission line impedance.

V. CONCLUSIONS

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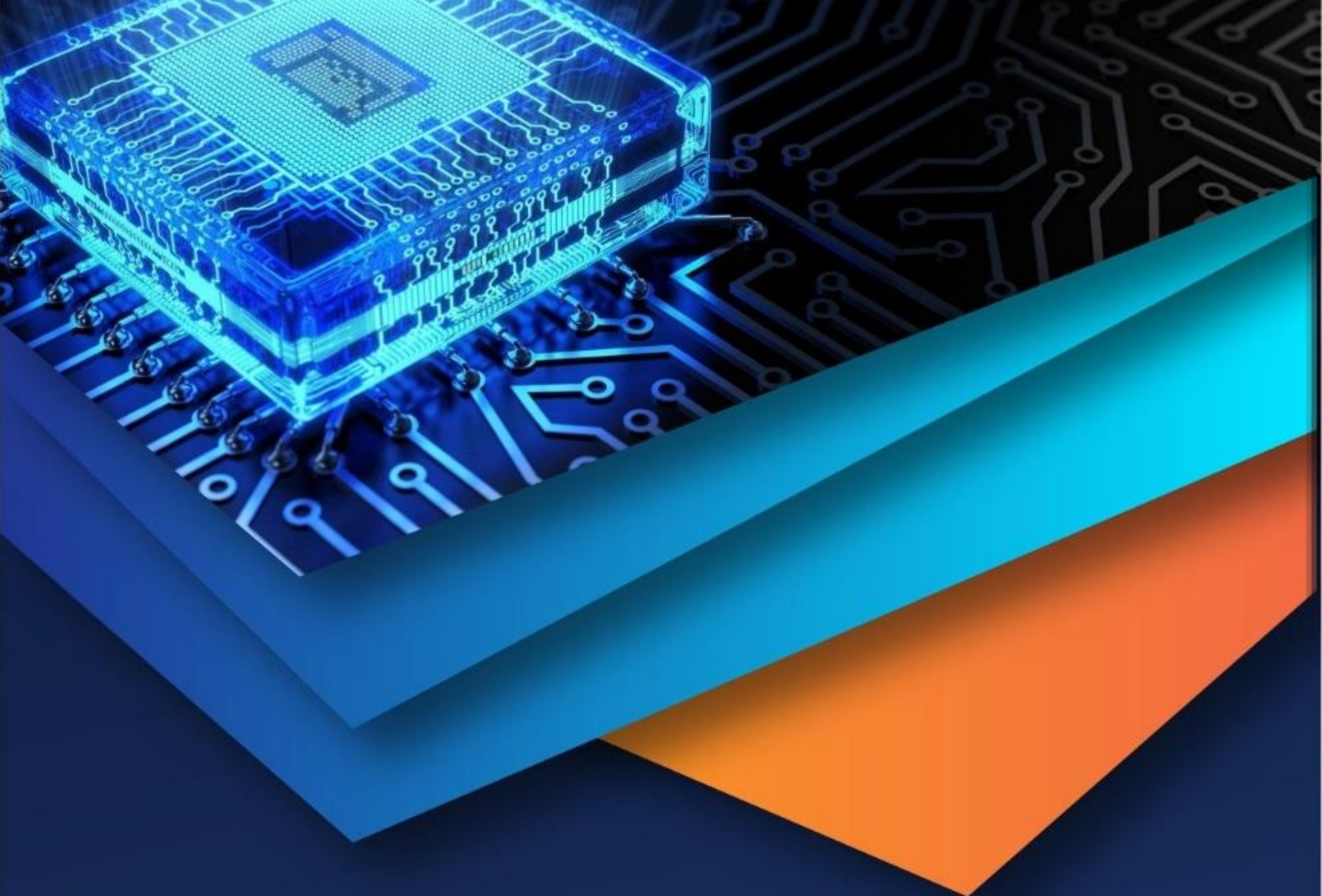

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