# An overview of UPQC and its role in the mitigation of power quality issues

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**Abstract: The use of power electronics equipment is increasing as distributed systems are networked and utilized. This will lead to more reliable and sophisticated electricity markets impacting these interconnected power generation system using non-conventional energy including non-linear loads that induce harmonics and voltage fluctuations within the system. These issues can be mitigated by applying a Unified Power Quality Conditioner (UPQC). This custom power device is also used to mitigate current and voltage-related power quality (PQ) issues simultaneously. Among all PQ issues, voltage swags, swells, and harmonics are considered important issues for power distribution systems. Here, we study the integration of UPQC with the fuzzy logic controllers to improve power quality at the distribution level.**

**Index Terms – Unified Power Quality Conditioner (UPQC), Fuzzy Logic Controller (FLC), Distribution Generation (DG), Voltage Source Inverter (VSI), Voltage Source Converter (VSC), Phase Locked Loop (PLL), Hysteresis Voltage Control (HVC), Power Quality (PQ).**

## I. INTRODUCTION

RES such as solar, wind and tidal power are replacing traditional energy sources. Also, RES is abundant, clean, and readily available, which has significantly increased usage. Additionally, with RES we see some good scenarios like less global warming and less carbon dioxide emissions. As a result, RES takes precedence over traditional resources. Adding renewable energy sources to current power systems can help meet increasing load demands. The main disadvantage of using renewable energy is that despite its many advantages, solar and wind energy sources are highly dependent on the environment and location. [26]

Modern power systems face many challenges in today's environment. Reliability status is also important including cost savings, transmission system losses, and high power demand on the load side. Scientists and academics are currently working on alternative strategies using distributed generation to address these issues (DG). The use of this DG provides an alternative to extending the current distribution network. Low to moderate geothermal systems (typically with power ratings of 1 kW to 10 MW) is gaining general acceptance due to improved operating performance and superior efficiency. Currently, the DGs best suited for peak-hour power generation in domestic regions include a variety of devices from renewable energy sources such as micro-turbines, FC and PV. Reportedly, there has been considerable progress in using these machines from renewable sources, which is acknowledged by the use of Int J Pow Elec & Dri Syst ISSN: 2088-8694. Improving Power Quality in Hybrids Using ρ Fuzzy Logic-Based Correction by(Soumya Ranjan Das 577)[30] results found for distributed generation. A microgrid system consists of a group of loads and micro sources. In order for a microgrid to provide good value and reliable power to deal with system anomalies, it must act as a single control unit. Due to the widespread use of his DG in both linear and nonlinear loads, there are problems in synchronizing and managing power quality disturbances. To operate the converters and provide sufficient active and reactive power to the microgrid-connected system, the DGs are coupled in parallel and use the local signal as feedback. [9]. By observing two parameters, frequency and level of the desired voltage, we can achieve power distribution among the DGs. Microgrids are expected to have many power management strategies and associated coordination methods. The effectiveness of microgrids in synchronization and islanding has been examined. Non-linear loads (NL) connected to the microgrid generate harmonics, causing losses in the system and reducing efficiency. Numerous line filters and FACTS controllers can compensate for harmonics and reduce asymmetry issues in three-phase line and load conditions. Series shunt compensators are used and described to maintain efficient power management between utility grids and microgrids. The two major systems' voltage quality is increased with the aid of this compensator.[29]

The main goal here is to solve power quality problems related to voltage and current caused by non-linear loads and sources. UPQC's Voltage Source Inverter (VSI) consists of two inverters coupled through a common DC link, acting as an interface between the grid and the photovoltaic array. The grid is connected in series with one inverter of the voltage source and the nonlinear load is shunted with the other inverter. It can solve reactive power, voltage source sizing, current and voltage harmonics as well as other power quality problems. To satisfy the voltage-fed inverter's imperative direct current bus requirements, the PV voltage is boosted by a bidirectional DC-DC converter. Static VAr compensators are a type of FACTS (Flexible AC Transmission System) device used to respond to load reactive power near a predefined load or transmission system. Active power filters are a type of power electronic device designed to automatically adapt to disturbances caused by the supply voltage and associated to not linear and resistant loads. Depending on the need and their incorporation into the electrical supply, power filters that are active are divided into parallel and series power filters.[27][26][24]The parallel connected power filter is made up of the shunt type active power filter (SAPF), parallel type active filter (PAF), Distribution Static Synchronous Compensator, and static synchronous compensator. These filters' primary function is to balance the load and safeguard the network against imbalanced loads and commercial interruptions. Additionally, it seeks to balance the load's reactive and harmonic power. The main function of the Series Active Filter (SAF) and Dynamic Voltage Regulator (DVR) that make up the Series Active Filter is to protect the associated load from line voltage sags, surges and distortions. Various efforts are sometimes made to provide proactive and adaptive solutions to power quality issues. Lossless passive filters with L-C matched components are one of the popular power quality solutions to reduce harmonics. A passive filter with low initial cost and high initial efficiency is desirable. However, instability, fixed compensation, resonance with the source and load, and line impedance are only a few of its numerous problems. These restrictions were overcome by the use of active power filters (APF). Shunt, series, and hybrid designs are among the options for active power filters. Combining the series and shunt type results in a hybrid. Series APF is used to correct voltage-based distortion, and shunt APF corrects current-based distortion. Higher-order harmonics are filtered with hybrid APF. In typical scenarios, their power rating can be extremely comparable to the demand (up to 80%) which is a problem. This will not give you the desired mesh quality. The result is power outages and customer dissatisfaction. UPQC is employed to enhance the quality of power in grid-connected PV systems. Over the past decades, sophisticated power electronic control devices have been introduced to address power disturbance problems and the dependability of power distribution systems has been increased through the usage of FLCs. Custom power devices are made possible by the development of power electronics controllers. One of his custom power supplies has UPQC uses active filters that operate in series and parallel. The unified power quality conditioner is also called a hybrid active power filter because it combines two different inverters.[26][24]

Maintaining proper power quality has always been difficult. There was a lot of discussion about how poor network quality can be detrimental. Poor power quality in general can lead to increased power loss, strange and undesired device behavior, interference with surrounding communication cables, and more. The increasing use of power electronics techniques that generate higher harmonic voltages and currents, as well as higher reactive currents, puts additional strain on energy systems. When discussing ways to improve power quality, the term active electric power filter (APF) is frequently used. APF is effective in mitigating some of the most serious concerns about electricity quality. A comprehensive study of APF technology across various topics is available here. UPQC is a member of the Active power filter family that combines shunt and series power filter that is active functionality to control multiple power quality issues simultaneously. This essay aims at a thorough analysis of the topic of UPQC. Content reviews are conducted to categorize over 150 publications. Since UPQC has the potential to enhance power quality at the transmission level, more than half of all UPQC publications have been released in the preceding five years, pointing out the increasing enthusiasm in UPQC. The physical structure of UPQC and the techniques used to describe supply voltage sag/dip are two main categories that can broadly divide these research papers. UPQC systems can be built in a variety of interesting structures and configurations. UPQC is then divided into three categories: 1) Electrical system (single phase 2 wire, three phase 3 wire and 4 wire). 2) type of converting (voltage or current supply); 3) newly developed 1- phase and/or a 3-phase arrangement of systems.It was also discovered that many acronyms are commonly used by researchers, including UPQC-P, UPQC-Q, UPQC-L, UPQC-R., UPQC-D, UPQC-DG, UPQC-I, UPQC-MC, UPQC-MD, UPQC-ML, UPQC-S, and UPQC-VAmin are all 12 types known till date.[6] (Refer the fig 3 for Key UPQC Acronyms)

## II. UPQC

It consists of an inline filter that acts as a regulated voltage generator and is either an active filter or an inline converter connected in series through a supply transformer. At the common junction, Voltage inconsistency, the presence of harmonical disturbances and control of voltage (PCC) can all be overcome with series filters. The harmonic separation between distribution networks and sub-transmission networks is another benefit. The second component is connected in parallel with the load and produces a rectified current which is the parallel current harmonic produced by the load by sinking the current harmonic. In addition, it also maintains the DC current at the required level. An additional component of a power line stabilizer is an energy storage intermediate circuit inductor. Active power filters require a small amount of power to remove harmonics. No external power supply is required as the DC inductor acts as the DC power source. As a result of active filter losses, a moderate background current must be drawn to maintain a constant DC current in the energy storage component.[27]

The Unit Vector Prototyping (UVTG) control system is one of the most frequently used control mechanisms. In this control technique, A phase lock loop was used to extract a single sine wave signal (PLL) multiplied by the rms voltage to provide a reference source voltage. The PI controller compares the generated reference supply voltage with the load voltage and then sends the necessary switching signals to the series inverter. The PI regulator controls the inverter in series. Monitor indefinitely the root mean square value of the tuned voltage at the load squared and the RMS value of the measured supply voltage. The supply voltage is continuously compared to the recorded load voltage (V2 RMS), which is the reference (power supply) voltage. This setup controls the magnitude of grid voltage variations, such as Voltage fluctuations.[5]

UPQC's shunt inverter is managed by a fuzzy logic controller. A popular artificial intelligence-based control technique is fuzzy logic control. It uses the functional personnel's prior knowledge of the system being handled. Function holders' primary objective is to develop criteria for decision-making by analyzing the system's conduct and the input from linguistic elements within the system's context. Before creating an output, FLC's inputs must go through three major processes: fuzzification, decision-making, and defuzzification. Input variables are transformed into linguistic variables in a fuzzification stage (MF) using the specified membership functions. It then uses the results of the fuzzification step to generate fuzzified output according to a given set of rules. The final dimming output is converted to the desired output which is used to control the system in the defuzzification step. Similarly, the centroid method is suitable for the defuzzification of sharp variables. Inverter output current is managed using Hysteresis Band Current Control Technology (HBCCT). In order to keep the output of the inverter current inside a predetermined range, the reference current signal containing an error and the inverter current signal are supplied to relay switches. This zone employs a single-phase control technique that is applied to each phase separately and is constructed around a reference current. A three-phase system can be challenging to expand with three independent control circuits. Unbalanced supply voltages, unbalanced load currents, and distorted supply voltages can all be handled by single-phase p-q control algorithms. Consider using a single tripod inverter to control each phase individually. In a three-phase system, single-phase control is used to a) compensate for the reactive power generated by the load and b) provide a line-side sinusoidal current waveform in the event of unbalanced line voltage and unbalanced load. side current.[18]

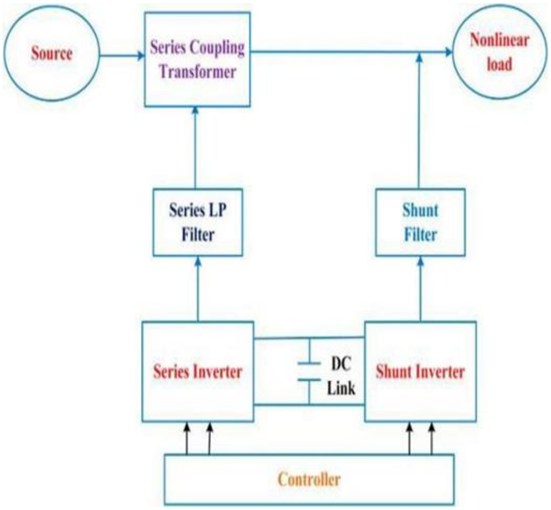

Fig1: Block diagram of UPQC

Hysteretic Voltage Control (HVC) is used to control a series converter in a voltage supply inverter-based UPQC (series filter). The current harmonics from demand to supply and origin to output. headers are blocked by series-connected active filters that also serve as a controlled voltage source. The primary purpose of a series compensator is to remove harmonic content from the power supply. The reference charge voltage is obtained by multiplying the unit vector (UVT) model based on the phase-locked loop (PLL) by an amplitude constant equal to the most considerable of the base incoming voltage, generating a load voltage sinusoidal shape. By comparing the actual signal and the offset signal through the serial converter, the control signal required for the serial converter is deduced. The resulting error is received by the delay controller.

The nonlinearity of electronic load and power is increased by power grids, resulting in harmonics DC. Quantified voltage is compared to a standard voltage, signal error is managed, and the amount of three-phase reference current is displayed using a parallel converter (parallel filter) capable of eliminating remove these harmonics. The phase unit vector is used for the calculation of the reference current. [27 ]With respect to harmonic isolation, series APFs form a barrier between the distribution system and the sub-transmission system. Furthermore, it enables voltage regulation and compensation of harmonics, voltage jitter, imbalance and unbalance at Point of Common Coupling (PCC) (Prasad et al., 2012; Kumar et al., 2012a). When there are harmonics and voltage imbalances in the mains voltage, the series segment makes up for them. The harmonic blocking filter function of the longitudinal segment can dampen oscillations of the source. Reactive power/load current imbalances and load current harmonics are both corrected by the shunt. For the intermediate circuit capacitor, the shunt section also regulates voltage. The amount of energy used or absorbed by the shunt section determines the amount of energy needed by the series compensator and the amount of energy needed to absorb the loss.

## III. TYPES OF UPQC

UPQCs can be classified according to the physical configuration used to solve the power quality problems of the system under study. These classifications are mainly based on three factors: 1) the energy-storing devices used; 2) The multitude of phases. 3) Actual position of series shunts and inverters. This part also looked at some of the most modern UPQC topologies and system configurations. Classification based on converter topology: Shunt and UPQC series inverters share a single DC link. A shunt inverter is in charge of keeping this self-contained DC connection at a specific fixed point. A current source inverter (CSI) with pulse width modulation (PWM) and a shared energy storage coil (Ldc) can be used to create UPQC. To implement this architecture, an insulated gate bipolar transistor must be coupled in series with a voltage-blocking diode. The Direct current through the inductor is changed to the mean output power plus the UPQC power loss to change the average input power.

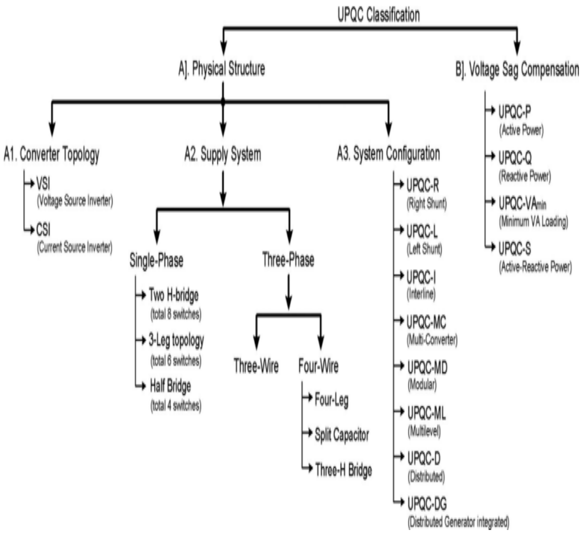

Fig2: List of all types of UPQC [37][36]

Due to increased loss, high cost, and inability to be used in multi-tier configurations, CSI-based UPQC architectures are not commonly used. The second topology, which is the most widely used and well-liked converter design for UPQC, consists of Pulse Width Modulation VSIs sharing a single Cdc energy-storing capacitor. The majority of published studies on UPQC use VSI-based topologies. This VSI topology has a number of benefits over CSI, including being lighter, cheaper, able to operate at multiple levels, and flexible overall control 2) Power system-based classification The single-phase (two-wire) and three-phase (three-wire or four-wire) AC loads and equipment in the power system are powered in turn. energy supply. To reduce power quality issues for these systems, a variety of UPQC setups are possible and can be categorized based on the type of utility system. With the exception of the requirement for additional voltage imbalance compensation in three-phase systems, voltage-related aspects of power quality for 1-phase and 3-phase systems are the same. In single-phase systems, reactive current from the load and current harmonics are major issues. In 3-phase 3-wire (3P3W), current imbalance must also be considered in addition to reactive and harmonic currents. A separate neutral current compensation loop is needed in a three-phase, four-wire system (3P4W). To address the quality of power issue in a 1-phase 2-wire (1P2W) supply system, the most popular UPQC system configuration uses two H-bridge inverters. A VSI-based 1P2W UPQC architecture and CSI-based topologies for 1P2W-UPQC and single-phase half-bridge UP switches can also be built. These 2 topologies can be considered for lower prices and applications of power. Switches S1 and S2 form the series inverter for the first leg of the three-leg topology and switches S3 and S4 form the shunt inverter (leg). Both series and shunt inverters share the third branch, switches S5 and S6. In the half-bridge architecture, the shunt and series inverters each have one leg. The compensation performance of UPQC may be impacted by reduced switching devices. The half-bridge topology-based UPQC system investigated a bidirectional DC/DC isolated converter topology using two H-bridges in order to detach the series inverter from the shunt. With the aid of a higher frequency transformer, two inverters can be connected. A bidirectional isolated DC/DC converter-like device, the phase shift of the voltage between two inverters can be altered to regulate the transfer of power between them. Many non-linear loads, including arc welders, arc furnaces, current regulators, frequency converters, variable speed drives powered by 3P3W, and current regulators present a combination of the above power quality issues. There are often combined loads in industrial plants in addition to three-phase loads. B. A 3P4W power supply provides power to a number of 1-phase and 3-phase loads. A neutral on the fourth wire will result in an excessive amount of neutral current, which requires additional compensation. The neutral current in 3P4W (3HB) systems has been reduced using a variety of shunt inverter layouts, such as split capacitor (2C), four legs (4L), and three H-bridges. Two split capacitors make up the DC side of the 2C architecture. It is assumed that the fourth wire, which is connected to the capacitor's center, has a potential of zero. To prevent the passage of circulating currents in a 2C architecture, it is important to keep the voltage on both capacitors at the same level. Additional control circuitry is required for governing the voltage of Direct current bus capacitors in 2C topologies. Two semiconductor switches are used as additional branches to account for zero load current in the 4L topology. A dedicated 4th branch allows the 4L architecture to better control the neutral current. The three single-phase H-bridge inverter units used in the 3HB architecture are each connected to a separate UPQC DC bus. When the neutral current is taken into account, the series inverter is implemented as 3HB and the shunt-wound inverter as 2C. Based on the inverter 3HB series 3P3W system of UPQC incorporates superconductive magnetic storage of energy components. Shunt and series inverters can both be used to create a 3HB unit (24 semiconductor switches in total). Using the active shunt filters' 2C, 4L, and 3HB topologies as a comparison, the shunt component of the UPQC system can also be improved. For high-voltage applications, a 3HB topology can be used to reduce the voltage requirement of the UPQC system by a factor of 1.732. This configuration, however, increases the overall count of semiconductor devices, the UPQC system's loss, the system's overall size, and its cost. A 3P3W UPQC and an additional star-hex/T-connected transformer that circulates the 0-sequence current component comprise the neutral current compensation topology. 3) UPQC configuration-based classification [36]:This section describes various UPQC configurations. 1) UPQC-R and UPQC-L or Right and Left Shunt UPQC: The placement of the shunt inverter relative to the series inverter can be used to classify UPQC. A shunt inverter can be accommodated to the right or left of the series inverter, denoted respectively by the designations Right Shunt UPQC (UPQC-R) and Left Shunt UPQC (UPQC-L). in both UPQC-L and UPQC-R system configurations. Of the two configurations, UPQC-R is the more common. The current flowing through the UPQC-series R's transformer is primarily sinusoidal, regardless of the kind of current at the end of load present in the system (if the shunt inverter effectively compensates for current harmonics, reactive currents, imbalance, etc.). As a result, the UPQC-R performs better overall than the UPQC-L. One inverter is connected in series to one of the branches, while the other is shunt connected to the second branch. It is feasible to concurrently regulate both supply voltages with such a structure. Furthermore, the actual power flow between the two feeders can be managed and controlled by UPQC-I. The above configuration, though, has some restrictions and can only be used in certain circumstances Only the feeder line where the inverter is shunted may effectively solve power-related issues (such as harmonics and imbalance). On the other hand, only branches connected to series inverters can sufficiently minimize voltage harmonics. 3. UPQC multi-converter (UPQC-MC): Study examined into the possibilities of enhancing system performance by taking into account a 3rd converter unit in addition, assisting the direct current bus. The third converter in the MC-UPQC is wired in series with a feeder right next to it. Like UPQC-I, MC-UPQC can connect to two distinct power lines. Multi-converter UPQC refers to the configuration utilized in the study to create a three-converter UPQC system (UPQC-MC). By coupling a battery to the DC bus, it is possible to capture more Distributed Generated power and use it as an alternate source of energy.. A further feature of the UPQC-DG system is that it powers the load in the event of a power outage (uninterruptible power supply operation). Also, there are various additional ways to distribute DG power, including island mode and connectivity mode (power to grid and load). There have been a lot of appealing UPQC system setups mentioned in the past. Some of these configurations might result in restrictions, interface problems, an overall circuit that is more complex, and higher costs[37].

Implementing both shunt and series inverters as a 3HB unit (24 semiconductor switches in total) is also possible For these settings to actually work, these issues need to be handled properly. However, these topologies offer more approaches for implementing UPQC-based system configuration. B. Classification Using Sag Compensation Approach One of the significant power quality issues is system sag. You can see the special emphasis on reducing system voltage droop using UPQC. This section presents a classification of UPQC based on the applied voltage dip reduction method. Currently available research recommends four main methods for correcting voltage sags in UPQC-based systems. (UPQC-P) Active Power Control This technology uses active power to reduce voltage droop, hence the term UPQC-P (P for Active/Active Power). In theory, a series inverter is used to inject a common-mode voltage component into the line and smooth out the voltage drop. This common mode component corresponds to the desired load voltage value at a reduced voltage magnitude. In addition to the losses associated with UPQC, UPQC's shunt inverter draws the real power required by the series inverter to achieve efficient sag compensation. As a result, a larger source current is seen during the voltage drop compensation of the UPQC-P approach. 2) Reactive power control (UPQC-Q): By supplying reactive power using UPQC series inverters, voltage drop can also be minimized. It is referred to as UPQC-Q in this instance (Q for Reactive Power). The objective is to feed quadrature voltages into the UPQC's series inverters until the vector sum of the input and output voltages at the load bus terminals equals the required nominal voltage. The UPQC shunt inverter must function at a unity power factor on the power side. As a result, injecting a series inverter voltage in phase with the supply voltage eliminates the real power needed to correct system sag. Yet, the generated voltage changes the supply voltage's phase angle in relation to this. UPQC-Q adjusts for the same amount of sag as UPQC-P but requires a greater series injection voltage. Series inverters for UPQCQ applications have therefore been given greater ratings. UPQC-Q does not lessen system bloat, either. Out of the two strategies he stated before, UPQC-P is the one that is most frequently employed to account for sag in UPQC applications. 3) UPQC-VA min, often known as a minimum VA load In an effort to use less energy, the UPQC-VA load during brownout compensation has recently been decreased. This technique injects the series voltage at an ideal angle to the source current. This voltage drop compensation method with UPQC is known as UPQC-VA min. While determining the UPQC minimum VA load, it is also necessary to take into account the current used by the shunt inverter (to regulate the DC bus and overall power balance) in addition to the series voltage injection. In order to eliminate voltage droop, the UPQC-P, UPQC-Q, and UPQC-VAmin approaches are compared. 4) UPQC-S with concurrent control of reactive and active power: This method use a series inverter to supply both active and reactive power, much like UPQC-VAmin. This method seeks to completely utilise the available VA load of the series inverter, in contrast to UPQC-VAmin. In a shunt inverter, the UPQC series inverters are controlled to compensate for sag and overvoltage while sharing the reactive power of the load. In this case, the UPQC-S series inverters (S for complex power) generate both active and reactive currents. His UPQC as UPQC-S is controlled by many control loops, which makes the control system appear to be quite challenging to handle. However, it is simpler to accomplish if it is managed digitally with a DSP. A new phase in research and development on UPQC-based power quality enhancement has been marked by talks of the two methodologies known as UPQC-VAmin and UPQCS, where best attempts are made to utilize series inverters. Concepts like UPQC-I, UPQC-MC, UPQC-MD, UPQC-ML, UPQC-D, and UPQC-DG offer intriguing elements which can be taken into account in a variety of UPQC applications [37][36]

| | |
|---|---|
| UPQC-D | 3P3W to 3P4W distributed UPQC |
| UPQC-DG | Distributed Generator integrated with UPQC |
| UPQC-I | Interline UPQC |
| UPQC-L | Left shunt UPQC |
| UPQC-MC | Multi-Converter UPQC |
| UPQC-MD | Modular UPQC |
| UPQC-ML | Multi-Level UPQC |
| UPQC-P | UPQC mitigates sag by controlling active power |
| UPQC-Q | UPQC mitigates sag by controlling reactive power |
| UPQC-R | Right shunt UPQC |
| UPQC-S | UPQC mitigates sag by controlling both active and reactive power. Also, load reactive power support using both inverters in the steady-state |
| UPQC-VAmin | Minimum VA loading in UPQ |

Fig3. Key UPQC Acronyms

## IV. METHODOLOGY

Fuzzy Logic Control - According to the fuzzy set theory, on which FLC is based, membership and non-membership functions will inevitably swap places, leading to fuzzy set ambiguity. It is recommended to carry out a variety of mathematical operations using FLC. Fuzzy logic theory blends probability theory and artificial intelligence to offer qualitative solutions to problems since it resembles the human brain and employs approximate reasoning to relate multiple data sets and make conclusions. It can be seen as a predefined multi-valued mathematical logic. Fuzzification, decision-making, and defuzzification are the three fundamental components of fuzzy logic-based control systems and are represented in the diagram below. The FLC input is the mid-circuit voltage value that was measured. Voltage values are transformed into fuzzy values using fuzzification. Fuzzification is the process of converting input data into phonetic values such as positive small (PS), positive mean (PM), positive large (PB), negative big (NB), negative mean (NM), negative small (NS), and extremely small (VS). These values are defined by membership. In fuzzy control systems, input signal measurements are understood as fuzzy singletons using a Mamdani-type inference system that encodes linguistic variables (inputs and outputs) as fuzzy variables. The classic set indicator functions are combined to provide the fuzzy set membership functions. The fuzzy variables are classified by their position, width, shape, or total overlap using membership functions. The controller employs a triangle membership pattern. The fuzzy rule base is built with a 7 x 7 matrix and the crisp function is extracted from the fuzzy set using the central region defuzzification technique.[9].

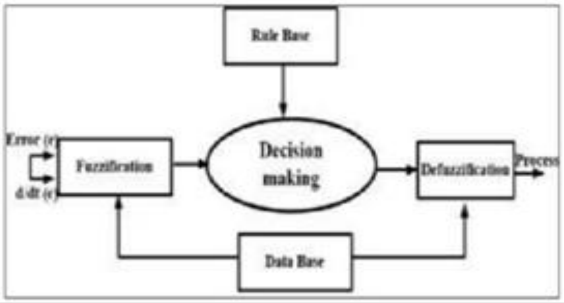

Fig4: Block diagram of Fuzzy Logic Controller[42]

The improvised version of the above model is called as Adaptive FLC. Four steps make up the design process for an adaptive FLC: defining fuzzy logic and fuzzification (ii) intellectual concepts (iii) defuzzification (iv). parameters for the PI operational controllers self tunning.

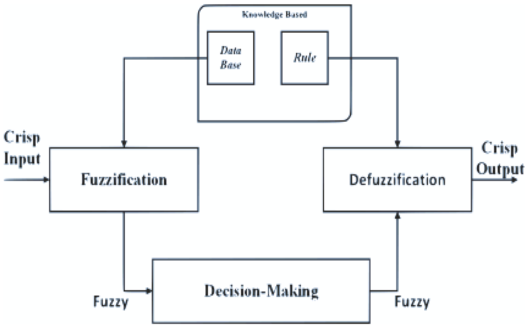

Fig5: Block diagram of Adaptive Fuzzy Logic controller[25]

The below tables show that adaptive FLC is the improved version of FLC, which yields better results when employed.

Table 1: Comparison THD with Fuzzy and adaptive Fuzzy [25]

| SL No | Controller | THD for $I_S$ | THD for $I_L$ | THD for $V_S$ | THD for $V_L$ |
|---|---|---|---|---|---|
| 1) | With Fuzzy | 2.9% | 20.55% | 0.7% | 20.6% |
| 2) | With Adaptive Fuzzy | 2.4% | 19.25% | 0.49% | 19.42% |

Below was a small case study chosen at the time of integrating Solar PV into help of UPQC which concludes to claim for balancing reactive power and harmonics. The simulation findings demonstrate that the PV-UPQC employing FLC is straightforward and solely reliant on sensing line currents. The IEEE 519 standard's harmonic limit of 5% is far below the THD of the source voltage when employing the suggested FLC.

Table2: Comparison Table of Total Harmonic

| Parameter | 2-level Inverter | Multi- level inverter with PI | Multi-level inverter with Fuzzy logic |
|---|---|---|---|
| Current harmonic | 2.51% | 1.60% | 1.36% |
| THD for current with sag condition | 2.48% | 1.60% | 1.36% |
| Voltage Harmonics | 0.52% | 0.52% | 0.52% |

## V. CONCULSION

In this paper, an overview on the topic of UPQC where in which we have given the background of UPQC, with its requirement along with the types & functionalities. The block diagram approach of UPQC in combination with the fuzzy logic controller methodology has been briefed. This methodology has been chosen to avoid the PQ issues being faced today that seem to be more reliable

| Reference numbers | Published Year | Contribution |
|---|---|---|
| [42] | 2022 | UPQC in presence of fuzzy logic controller is used to improve power quality when a photovoltaic generator is linked to the grid. |
| [17] | 2021 | Study on SSSPVA-UPQC which is used to overcome a few power quality problems |
| [7] | 2021 | Power quality problems were able to be resolved using the TS fuzzy controller. |
| [9] | 2021 | Enhancement of power quality by the study of PV-UPQC employing a fuzzy logic controller |
| [8] | 2021 | An analysis of the effects of integrating SPV and WE on power quality |

| | | |
|---|---|---|
| [18] | 2020 | Gives the study on how the series active filter improves the power quality |
| [25] | 2021 | Studies on AFLC–based UPQC for enhancement of power quality |
| [22] | 2021 | Studies on sensitivity analysis with the formation of its index for placement of UPQC. |
| [24] | 2020 | Gives the study on power quality improvements when MC UPQC is used |
| [26] | 2020 | Power augmentation and harmonics minimization evaluation for a PV-WE-ESS-EV grid-connected system |
| [27] | 2020 | Impacts of I-UPQC PV when connected to nonlinear loads |
| [28] | 2019 | Studies into UPQC effectiveness under different load scenarios during symmetrical and asymmetrical disturbances. |
| [7] | 2018 | The load current and source voltage harmonics were efficiently covered by the UPQC method to meet IEEE criteria. |
| [31] | 2015 | Proposes a strategy UPQC -SRI to compensate for voltage sag |
| [37] | 2012 | Gives an account of UPQC with its types and main functionalities |

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