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Analysis of Power Quality Issues and Implementation of UPQC Topologies to Enhance Power System Stability

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ABSTRACT

Due to the depletion of fossil fuels, coal, and oil, traditional electricity generation has a difficult task for utilities. A cheaper and more efficient method of doing this is required. A different source is required to fulfill the consumer's power requirements. The alternate source should be sustainable and capable of meeting the consumer's requirements. The integration of renewable energy into the grid is a useful way to fulfill demand. Renewable energy integration confronts three major problems; frequency variation, power quality concerns, and power system instability. The following problems were of critical importance. An analytic hierarchy approach-based expert system is utilized to identify and categorize power quality incidents. Before, it could sense things like sag, swell, transients, harmonics, interrupts, and flickers. An error-free event classification system has been suggested. Simplified procedure allows for improved detection and categorization of power quality incidents. an investigation of power quality incidents and their mitigation using unified power quality conditioners (UPQC) An Adaptive Neuro Fuzzy Inference System (ANFIS) is used to minimize various power quality issues. Integrating renewable energy sources efficiently minimizes the environmental impact. The suggested method provides a solution to voltage unbalances and lowers overall harmonic distortion at the point of common coupling (PCC). The addition of an ANFIS-controlled DVR is used to reduce voltage irregularities caused by integrating renewable energy sources and faults in the transmission line. An artificial fault was added to power quality events with the goal of making use of renewable energy. To minimize the adverse effects of power quality incidents, the ANFIS-controlled DVR proposal is in place. ANFIS controlled DVR is contrasted to a traditional technique of surveillance. Distributed static compensator (D-STATCOM) is used to prevent voltage flickers, and total harmonic distortion, caused by nonlinear loads. D-STATCOM is suggested to use three control methods: Instantaneous power theory, Synchronous vector PI Control, and Harmonic elimination. Under extreme load circumstances, the D-efficacy STATCOM's is evaluated. The suggested expert system and the bespoke power devices will be analyzed and discussed using various control techniques.

KEYWORDS: *Power Quality Improvement; Renewable Energy; Custom Power Device's FACT's; UPQC; PCC; DVR; STATCOM; Neuro Fuzzy (ANFIS); PI Controller*

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INTRODUCTION:

Electric power distribution networks are vast and play an important role in the infrastructure that supports commercial, residential, and industrial establishments. These networks are constantly changing because to the requirement for age-related renewal, the use of clean and renewable energy sources, power sector deregulation, and increasing or reduced demand [1]. These problems have resulted in the proposal of new structures, devices, control systems, management techniques, and even power distribution system restructuring, where new network architecture has been suggested or new devices have been deployed. Furthermore, the installation of photovoltaic cells (PVs) has grown considerably in recent years, having a major effect on radial distribution networks. As a result, it is essential to consider renewable integration problems for efficient and safe power system operation and maintenance, while also keeping track of modernization.

1.1. DISTRIBUTED ENERGY RESOURCES

The phrase "distributed energy resource" (DER) refers to a broad category of energy resources that includes renewable energy producers, batteries, and electric cars (EVs). These resources are supplied through low voltage feeders at client locations. While the term distributed generator (DG) refers to an electric power source that is directly linked to the distribution network or is located on the customer side of the meter. It is becoming more popular as a result of its low cost and global environmental consciousness. As a consequence, the operational structure of low voltage distribution networks is undergoing change. Despite the fact that current data show that DG connections range between 0.45 and 10.86 percent of average load, DG penetration in LV networks may reach 100 percent of average load in the next decades [2]. Photovoltaic (PV) cells are expected to overtake reciprocating engines and wind turbines as the primary method of distributed generation between 2010 and 2020 [2]. In addition to this, other types of distributed generators such as microturbines, biogas engines, and fuel cells will be widely accessible [2]. The installation of these will fundamentally transform the character of the LV networks, since each LV section will resemble a small power system. Furthermore, these networks will no longer be radial, necessitating significant changes in their security hardware and tactics.

Despite the availability of a substantial mix of nuclear, hydro, and wind energy, traditional fossil fuel-based power production (e.g., coal, natural gas) remains the primary source of power generation. Coal and gas plants produce greenhouse gases, whereas nuclear facilities are deemed hazardous. Furthermore, hydro plants are heavily reliant on geographical topography. Electric power production based on renewable sources, on the other hand, is often referred to as ecologically beneficial green electricity. Figures 1.1 and 1.2 depict the diagrams of energy production using conventional and green power, respectively. Table 1.1 lists the power generating capabilities.

DG units are used in a variety of applications in electrical systems, depending on the system's structure, such as:

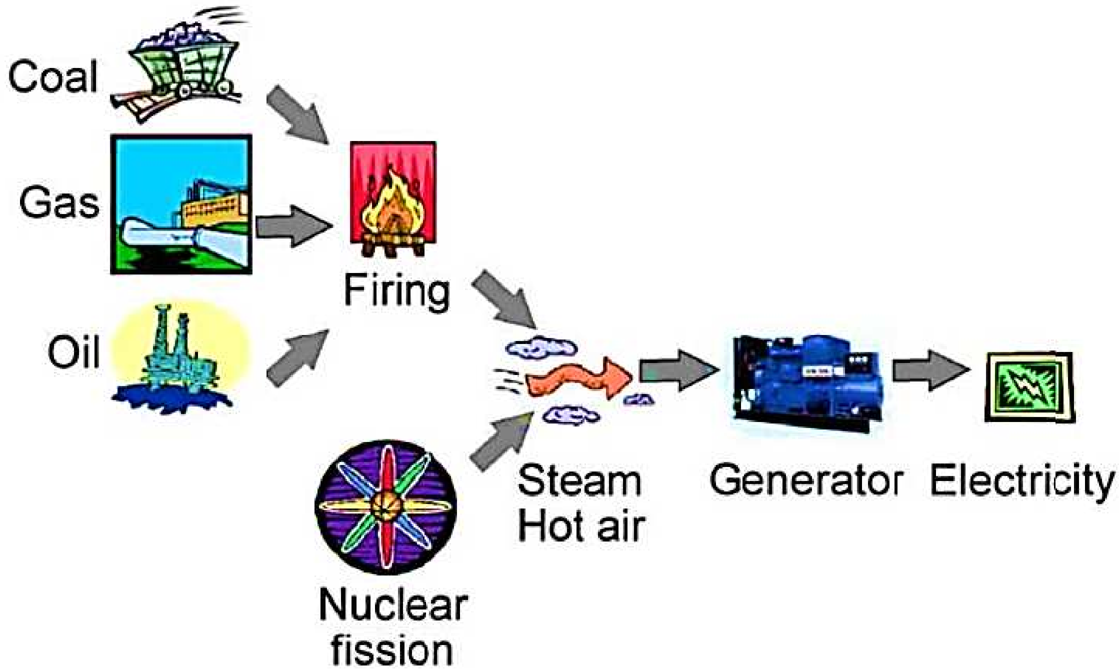


Fig 1.1: Power Generation through convention energy sources

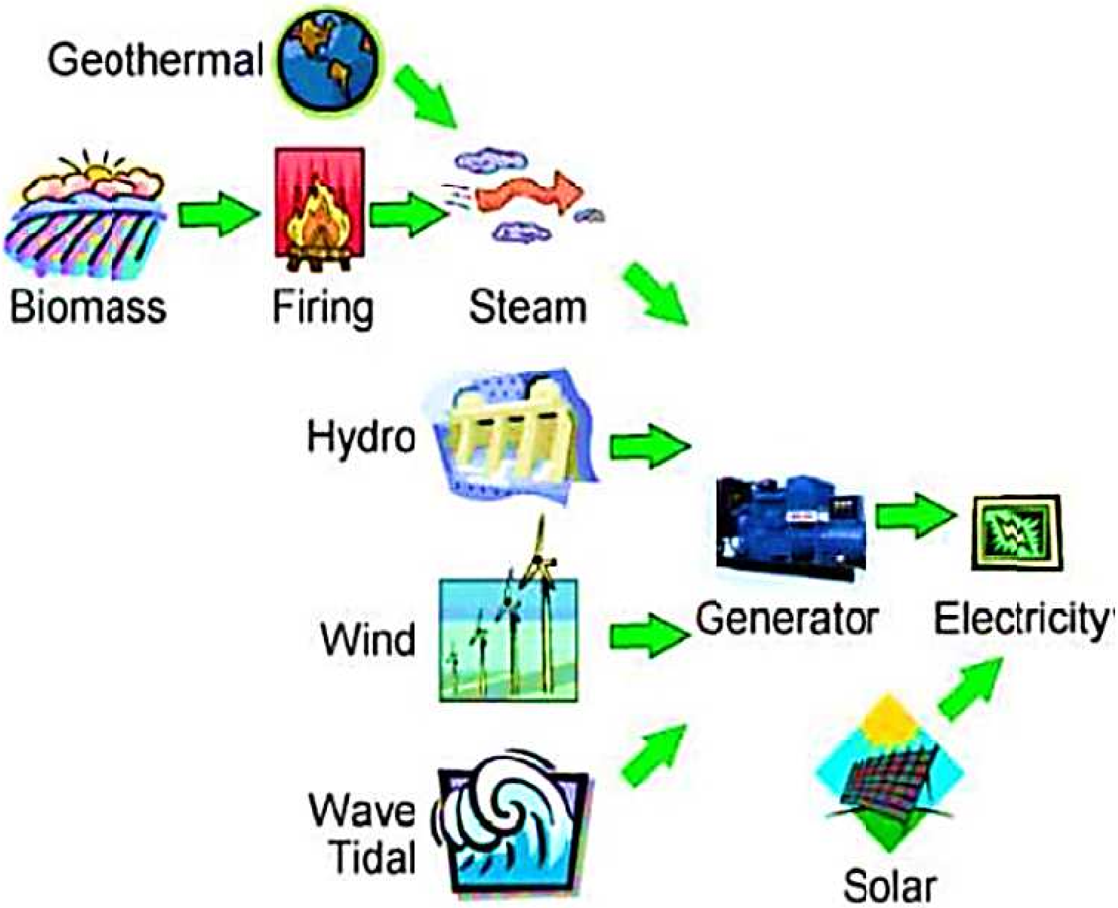


Fig 1.2: Power Generation through Renewable energy sources

1.2. POWER QUALITY PROBLEMS

The Institute of Electrical and Electronic Engineers Standard (IEEE Std 1100) defines power quality as "the idea of powering and grounding sensitive electronic equipment in a way appropriate for the equipment" [9]. "Power Quality is a set of electrical limits that enables a piece of equipment to operate in its intended way without substantial loss of performance or life expectancy," according to a more succinct definition [10]. Primarily, power quality at the transmission and distribution levels relates to voltage remaining between +/- 5% [11]. It is suggested that the voltage violation be corrected within 2 seconds of its occurrence [12]. Poor power quality has an impact on an electrical device's performance and life expectancy. They are both inextricably linked to the voltage, current, and frequency delivered to the electrical equipment [10]. An ideal distribution system is intended to have pure sinusoidal voltage and current waveforms of fundamental frequency, with the amplitude of the voltage remaining within certain predefined limits. The majority of power quality issues arise in the distribution system network, particularly when the majority of the system is comprised of overhead wires rather than subterranean cables. There may be many natural causes for the disruption, such as contact of the lines with each other, particularly on windy days, or due to birds or contact of tree branches with wires, cutting of the lines owing to falling trees or branches, lightings, and so on. All of these contribute to power quality problems in the network. Switching on and off huge loads, particularly massive electrical motors in industry, and power electronic devices utilized in Electronic devices, capacitor or inductive bank operation and switching, transformers, and so on [10, 13]. This thesis considers the following power quality events: ·Voltage Fluctuation: Voltage variation (such as sag, swell, or interruption) with a length less than one minute is classified as short time voltage variation, whereas voltage variation with a period more than one minute is classified as long time voltage variation [10, 13]. Voltage fluctuations may cause damage to consumer appliances as well as other power quality issues as a by product. Electricity Factor and Reactive Power: According to the IEEE Recommended Practice for Photovoltaic (PV) System Utility Interface, all PVs must inject power at unity power factor [14]. This PV injection raises the voltage at the connecting point and introduces nonlinearity into the system. However, by controlling the PVs' reactive power, the voltage at the connection point may be adjusted. Ideally, reactive power should be produced near to the demand to compensate for it, freeing up greater capacity on the network's conductors and transformers [10].Despite the fact that certain power quality issues are caused by power electronic loads, the usage of power electronics as a remedy to these issues is also extremely popular [10]. The aforementioned issues will be addressed in this research, and mitigating strategies will be suggested. All of the devices utilized in mitigation will be VSC-based. It should be mentioned that PV is the most common kind of small size DG unit at the moment. As a result, the words DER, DG, and PV are used interchangeably throughout this thesis.

1.3. SOLAR ENERGY AND LOAD MANAGEMENT

Solar energy is utilized in two ways –solar photovoltaic (PV) or solar thermal. PV is the most prominent renewable energy sources used in low voltage feeders. A PVs cell work on the I-V characteristics of the elements used in their production The I-V characteristic PV system can be expressed as [16]:

$$I(V) = \alpha I_{\max}\left(1 - e^{\beta}\right)$$

$$\beta = \frac{V}{b(\alpha\gamma + 1 - \gamma)V_{\max}} - \frac{1}{b}$$

where, V and I(V) are the output voltage and current of the photovoltaic array; Vmax is the rated open circuit voltage of PV array when the light amount is the highest, Imax is the maximum current; b is the index constants; α is the light intensity percentage of photovoltaic cells; γ is a linear factor dependent on Vmax. PV can be off grid, grid connected or grid-connected centralized. Regardless of the connection strategy they follow, power electronic interface is needed for PVs for network connection. Usually both dc-dc and dc-ac converters are used. Among the inverters used, the popular types are "central inverters", "Module integrated or module oriented inverters", "String inverters" and "Multi string inverters" [17].From the I-V characteristic relation, it can be seen that the output power of PV is not controlled. Rather it is dependent on instantaneous power from the sun. Though advantageous, integration of PV creates several technical problems to the existing network such as harmonics, voltage profile and power loss. Some of these are investigated in [18-20]. Several studies on the voltage violation due to PV integration have been conducted [21-24]. The studies have been carried out at different countries on different geographic location. From all these studies it is found that distributed networks with PVs faces two types of voltage problems. In the evening when network is in peak hour, the residential load increases while the power output of PVs diminishes. As a result, voltage drop occurs throughout the network. On the other hand, at noon, the PVs are at the peak of their power generation, while the residential loads are at their minimum level. This may lead to an increase in voltage. In [25], it has been found that if the PV rating does not exceed 2.5 kW, the voltage in the network is not adversely affected even with the worst case scenario. But it is not practical to restrict the PV rating because PV rating will be bigger with the advancement of technology and the increased market availability. A comprehensive study on Australian network is reported in [26] and the results show that there is significant voltage rise, feeder loss, voltage unbalance and reverse power flow during midday. A mitigation strategy for neutral current is proposed in [27]using energy storage to balance the power injections into the grid and the power imports from the grid in the three phases. Along with changing the voltage level ofthe network, high (20% or higher) penetration of PV increases voltage imbalance. In[28–30], different VU measurement and calculation methods based on line or phase voltages in three phase and three- and four-wire systems were investigated. From[31], the voltage unbalance can be calculated as

$$\%\text{Unbalnce} = \left|\frac{V_2}{V_1}\right| \times 100$$

where V1 and V2 are the positive and negative sequence voltages, respectively. Minor voltage imbalance may be ignored if the system contains mainly single-phase loads. It may, however, create severe problems for three-phase loads (motors for pumps, elevator etc). Voltage imbalance was investigated in [32] using PV placed on a single feeder. The results indicate that the PV installation has only a small impact on the voltage imbalance at the start of an LV feeder. However, it rises to more than 2% at the feeder's end, which is unacceptable by most standards. Some research suggested remedies to this imbalance issue. In [33], an energy storage-based control method is used to reduce voltage imbalance in a distribution network. [34] proposes a technique for evaluating voltage variation sensitivity owing to PV power fluctuations in an unbalanced network, as well as a solution based on the unbalanced line characteristics and realizing the network's potential. It should be emphasized that voltage/current imbalance is determined by the voltage quantity, which is linked to the bus voltages where the PVs are connected indirectly. As a result, the main emphasis of this thesis has been voltage quality control. The voltages are maintained below the permissible limits of 0.05 per unit by using different mitigating techniques (pu). Rooftop PVs are placed for a typical home distribution network.haphazardly across distribution systems [35] does a stochastic study of two actual LV networks in the North West of England for various PV penetration levels. It has been shown that voltage issues in long lines with heavy load may begin as early as 40% PV penetration. This image may vary based on the area's geographic location and demographics. Several techniques for reducing voltage increase due to PV penetration have previously been proposed and researched.

2. LITERATURE REVIEW:

"Xin Chen; Emiliano Dall'Anese; Changhong Zhao; Na Li Distribution systems are anticipated to be capable of providing capacity support for the transmission grid as a result of large-scale integration of distributed energy resources (DERs). This article investigates distribution-level power aggregation methods for transmission-distribution interaction in order to efficiently harness the collective flexibility from large DER devices. This article, in particular, provides a technique for modeling and quantifying aggregate power flexibility in imbalanced distribution systems over time, i.e., the net power injection possible at the substation. The suggested approach provides an effective approximate feasible area of net power injection by using network restrictions and multi-phase unbalanced modeling. It is shown that a viable disaggregation solution exists for any aggregate power trajectory inside this area. Furthermore, a distributed model predictive control (MPC) framework is created for the actual implementation of the transmission-distribution relationship. Finally, we show the suggested method's performance using numerical testing on a real-world distribution feeder with 126 multi-phase nodes. Due to its non-dispatch ability, a distribution grid is traditionally regarded as an equal passive load in transmission system operation [1]. In the last decade, there has been a fast growth of distributed energy resources (DERs) in distribution networks, particularly photovoltaic (PV) production, energy storage (ES), and demand response. As the penetration of dispatch able DERs grows, considerable flexibility is being introduced into energy distribution, transforming the distribution networks from passive to active [2]. The power flexibility of distribution systems, like that of transmission systems, refers to the additional power capacity that may be dispatched to ensure safe and efficient system operation, particularly in the event of a crisis. Distribution flexibility is supplied by a large number of diverse DERs, as opposed to large-scale spinning and non-spinning reserves in transmission networks. Although each DER typically has a modest capacity, the coordinated dispatch of ubiquitous DERs is capable of providing substantial flexibility assistance, allowing distribution systems to actively participate in transmission system operation. Power networks may fully utilize potential flexibility and achieve better efficiency and resilience by using coordinated transmission-distribution dispatch.

Smit Solanki; Mihir Trivedi; Poornesh Rawal; Siddharthsingh K. Chauhan; P. N. Tekwani Because of the recent increase in power consumption, an intensively integrated penetration of distributed generation (DG) has become a need. Because of its excellent controllability, grid-connected inverter-based DG is gaining popularity. Voltage imbalance is sometimes seen at the Point of Common Coupling (PCC) owing to changing needs of active-reactive power injection by the DG into the Grid. This article describes the implementation of two alternative grid-tied inverter topologies: traditional two-level three-phase four-wire and three-level T-type Neutral Point Clamped (T-NPC) based DG, both controlled by a three-phase damping control method. The simulation experiments provided show that both of these inverter topologies provide excellent operational management for DG under a variety of operating circumstances. The main purpose of DG is examined, which is to inject electricity into the grid and reduce the load on the traditional generating system. This article describes the effective behavior of the proposed two-level and three-level DGs without causing voltage imbalance. The imbalance index and total harmonic distortion (THD) for PCC voltages and currents are examined in detail. In addition, the performance of both proposed DGs for meeting load requirements while operating in islanding mode is given. The reported findings for single-phase asymmetric faults and three-phase symmetric faults show that DGs have adequate voltage compensation capabilities. The primary characteristics of the proposed DG systems are low voltage ride through capability, reduced imbalance index, and THD within standard norms. Distributed power production encompasses a broad range of methods for producing electricity at a localized level using renewable or non-renewable energy resources in an ecologically acceptable manner. Distributed Generation (DG) effectively delivers dependable, low-cost, high-quality electricity while increasing flexibility. Because of its closeness to the end user, it offers a low-cost transmission option with minimal line losses. The DG is often implemented utilizing renewable energy sources because to the growing demand, simple availability, and eco-friendly nature of renewable electricity. This has enabled renewable energy-based DG to function as a possible backup supply for the localized micro-grid in the event of a main grid breakdown [1], [2]. Grid-connected inverters aid in the implementation of DG systems based on renewable energy sources. Photovoltaic-based DG are increasingly widely used owing to their simplicity of installation and operation. In the case of photovoltaic-based DG, the primary purpose of the grid-tied inverter is to produce output voltage that is of the right magnitude and phase with the grid. A wind turbine-based grid-tied system, on the other hand, offers isolation between two distinct frequencies, namely the changing mechanical frequency of the wind turbine and the relatively constant electrical (power) frequency [3].

3. CUSTOM POWER DEVICES

The introduction of power electronic loads has raised much concern about power quality problems caused by harmonics, distortions, interruptions, and surges. The use of electronic devices increases the power quality problem Equipment such as large industrial drives (e.g., cycloconverters) generate significantly high voltage and current (inter-, sub-) harmonics and create extensive voltage fluctuation. The addition of electronic devices is addition to power quality problem.

The application of harmonic filters and SVCs to radial transmission systems can offer partial solution to high THD levels and voltage fluctuations. Yet, the lack of dynamic capabilities of these devices limits them to bulk correction. In addition, they might be effective in one application but fail to correct other power quality issues.

Hingorani introduced the concept of custom power as the solution to V, P, and Q (voltage, active power, reactive power) compensation and power quality problems at the expense of high cost and network complexity. As FACTS controllers improve the reliability and quality of power transmission by simultaneously enhancing both power transfer capacity and stability custom power devices enhance the quality and reliability of power delivered to the customer. With a custom power device, a customer (e.g., a sensitive load) will be able to receive a prespecified quality of electric power with a combination of specifications including but not limited to:

- Magnitude and duration of over and under voltages with specified limits,
- Low harmonic distortion in the supply, load voltages, and currents.
- Small phase imbalance,
- Low flicker in the supply voltage,
- Control of power interruptions, and
- Control of supply voltage frequency within specified limits.

Classification of Custom power devices are based on their power electronic controllers, which can be either of the network reconfiguration type or of the compensation type. The network reconfiguration devices also called switchgear include the solid state and or static versions or current limiting, current breaking, and current transferring components. The compensation type custom power devices either compensate a load (e.g., correct its power factor, imbalance) or improve the quality for the supply voltage (e.g., eliminate its harmonics). They are either connected in shunt or in series or a combination of both. Custom power devices are classified as follows:

- Network – reconfiguration custom power devices include
- Solid state current limiter (SSCL),
- Solid – state breaker (SSB), and
- Solid state transfer switch (SSTS) Compensation-custom power devices include
- Distributions STATCOM (DSTATCOM),
- Dynamic voltage restorer / regulator (DVR), and
- Unified power quality conditioner (UPQC).
- Custom power devices are designed to improve the quality of power at their point of installation of the power distribution system. They are not primarily designed to improve the power quality of the entire system

3.1. UNIFIED POWER QUALITY CONDITIONER (UPQC)

Figure 3.1 depicts a schematic representation of a UPFC. This is a DSTATCOM and DVR combo linked to a shared DC bus. In a dual control mode, the UPQC is a highly flexible device that can inject current in shunt and voltage in series at the same time. As a result, it can adjust for the load while also controlling the voltage. The UPQC, like DSTATCOM or DVR, may inject unbalanced and distorted voltages and currents.

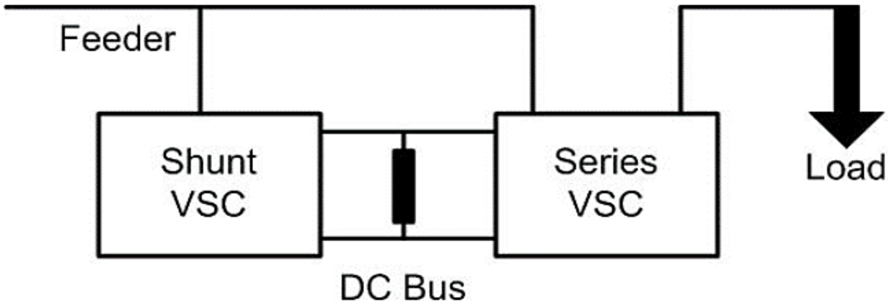


Fig. 3.1. Schematic diagram of UPQC

4. SYSTEM DESIGN IMPLEMENTATION:

As the demand for power is escalating sharply countries have started exploring alternating sources to match the gap. Besides solar power, wind power is the promising option. Due to the research activities fuel cells have also attracted global attention. Various power quality issues may arise due to integrations of renewables with grid composed of more nonlinear loads. Two renewable energy sources like wind and fuel cells along with a non-linear load were considered to be integrated into an electric grid. This chapter highlights the mitigation of power quality events by incorporating suitable controllers for unified power quality conditioner,

4.1. PROPOSED SYSTEM FORANALYSIS

The Proposed system consists of two renewable energy sources were integrated with an electric grid along with a nonlinear load. The schematic diagram of the proposed system for analysis is depicted in the Figure 4.1. The power quality events that may occur during the integration of wind power and fuel cells are voltage sags, flickers, harmonics and transient conditions.

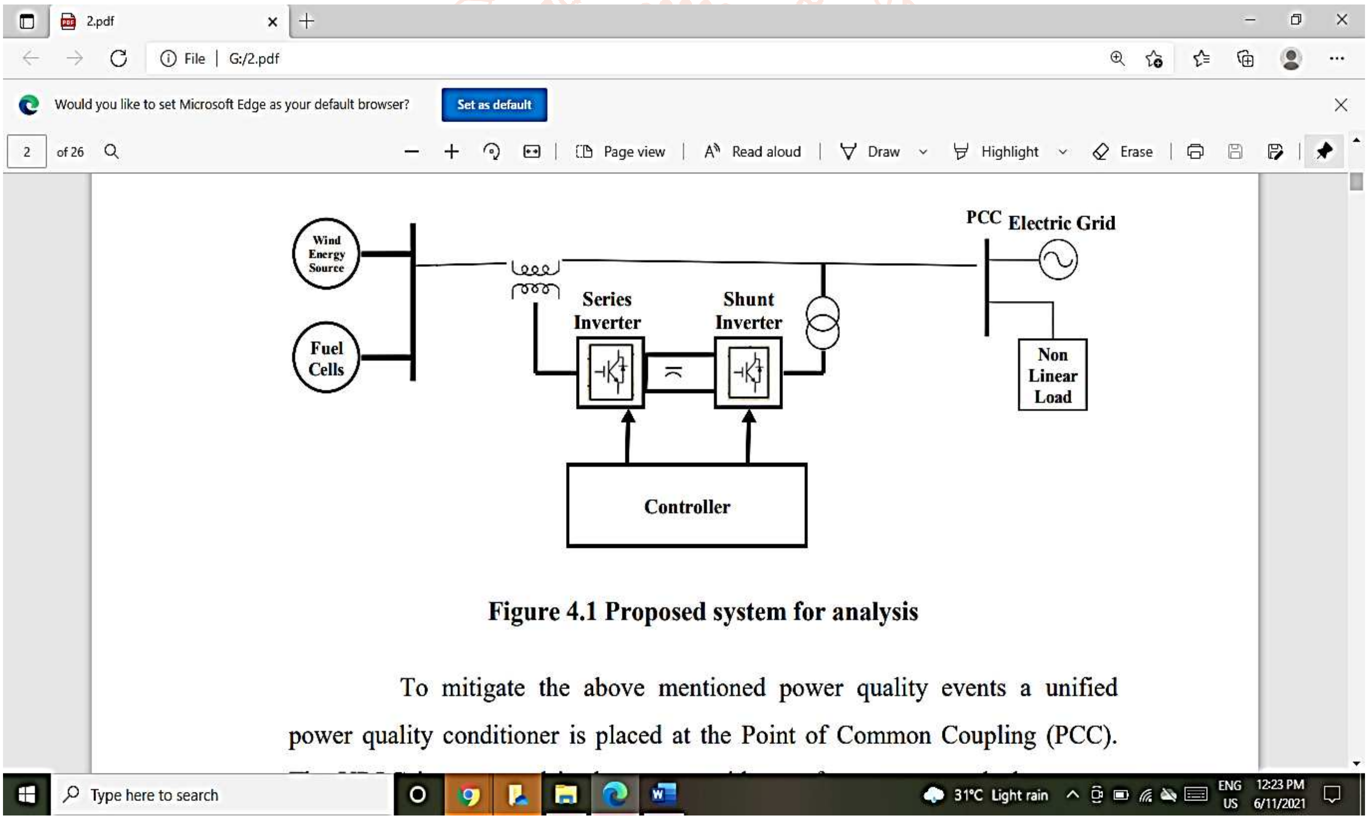


Figure 4.1 Proposed system for analysis

To mitigate the above mentioned power quality events a unified power quality conditioner is placed at the Point of Common Coupling (PCC). The UPQC is connected in the system with transformers to match the system frequency.

4.2. PROPOSED STRUCTURE OFUPQC

Unified Power Quality Conditioner (UPQC) is a combination of active shunt and active series device. It consists of two voltage source inverters connected back to back with each other, sharing a common DC link. The DC-link storage element (Dc-capacitor) acts as active series and active shunt compensator; it splits the current and voltage of two bridges. It is used for single and three phase system and it helps to eliminate the current and voltage harmonics. The structure of unified power quality conditioner is as shown in Figure 4.2

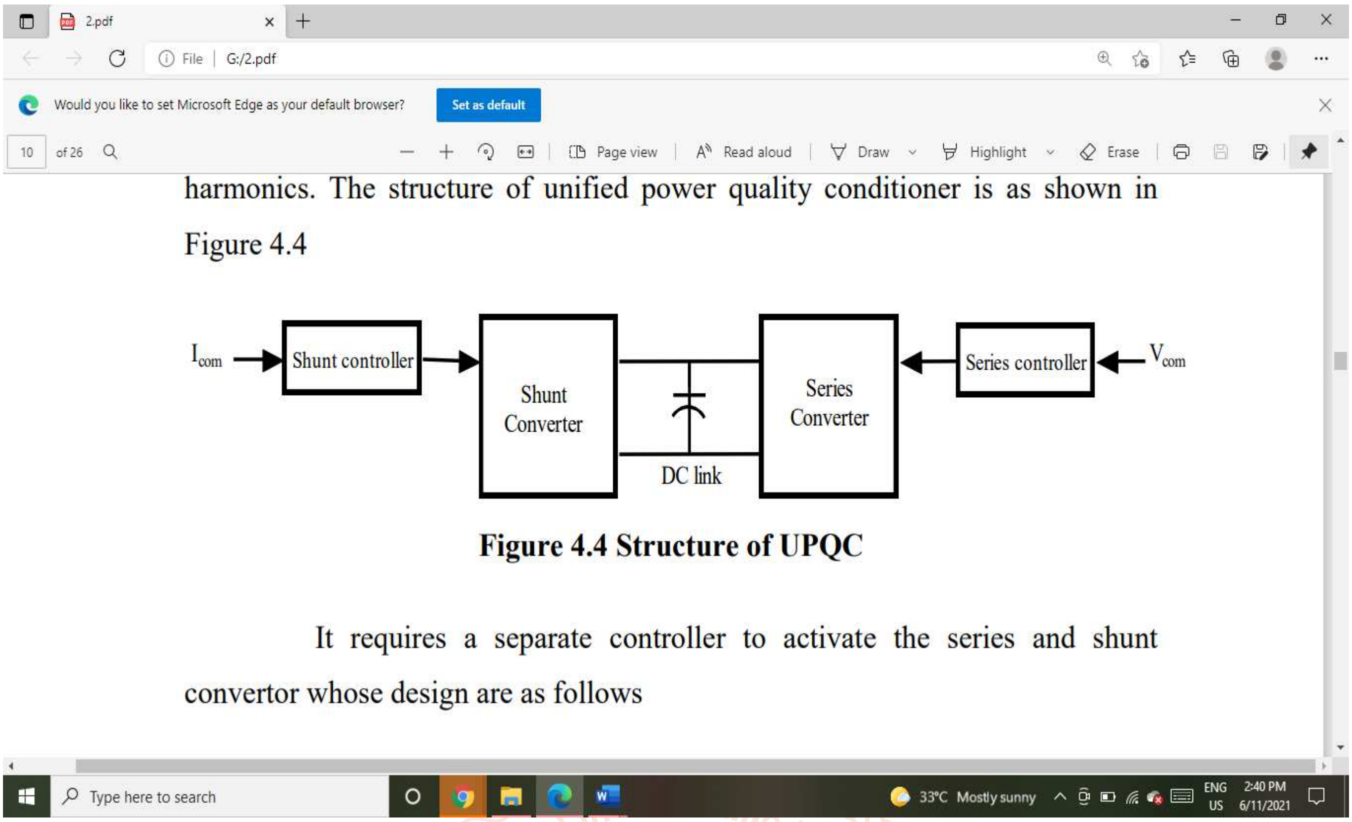

harmonics. The structure of unified power quality conditioner is as shown in Figure 4.4

Figure 4.4 Structure of UPQC

It requires a separate controller to activate the series and shunt convertor whose design are as follows

Figure 4.2 Structure of UPQC

5. RESULTS:

5.1. SIMULATION RESULTS ANDDISCUSSION

Simulation results are presented below for the system considered for study. The results obtained with and without implementation of UPQC are provided. Simulation has been performed under MATLAB/Simulink environment.TwotypeofcontrollersnamelyPIcontrollerandANFIScontrollers has been analyzed for the performance enhancement of UPQC for the considered operating condition. The MATLAB/Simulink diagram is shown in Figure5.1.

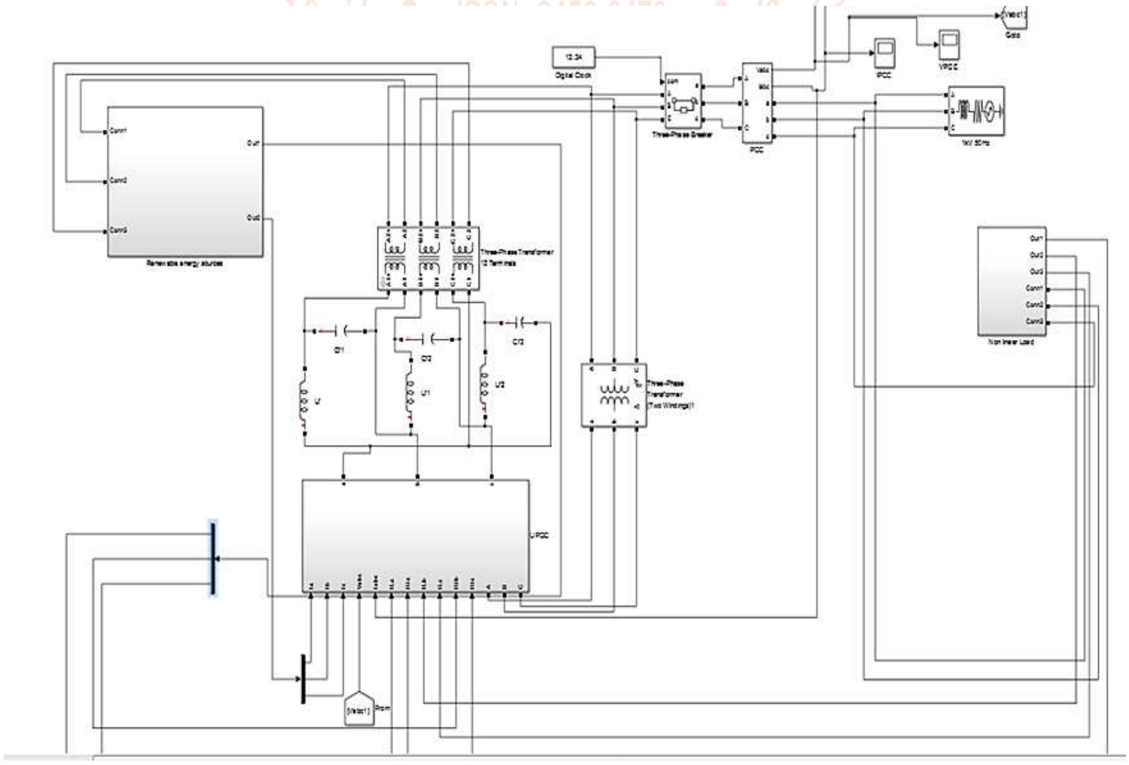


Figure 5.1 MATLAB /Simulink diagram of the proposed system for analysis

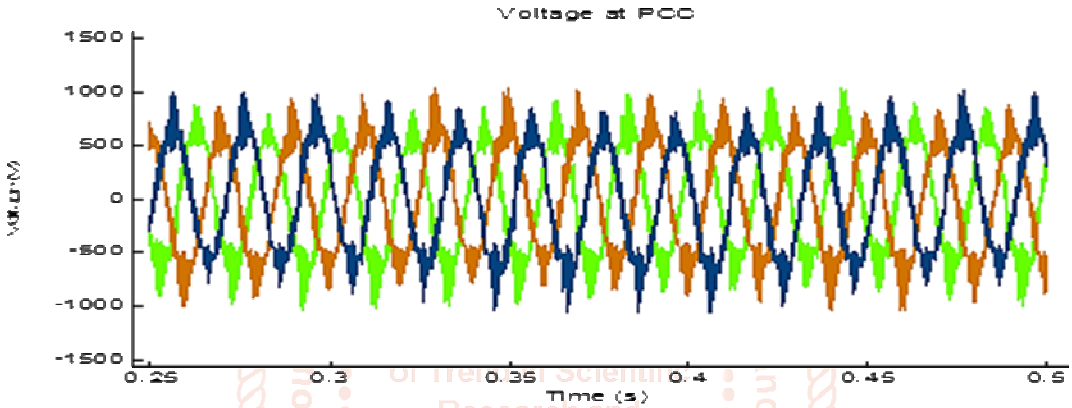
The Simulation Parameters for the above MATLAB/Simulink diagram is listed in Table5.1

Table 5.1 Simulation parameters of the proposed system for analysis

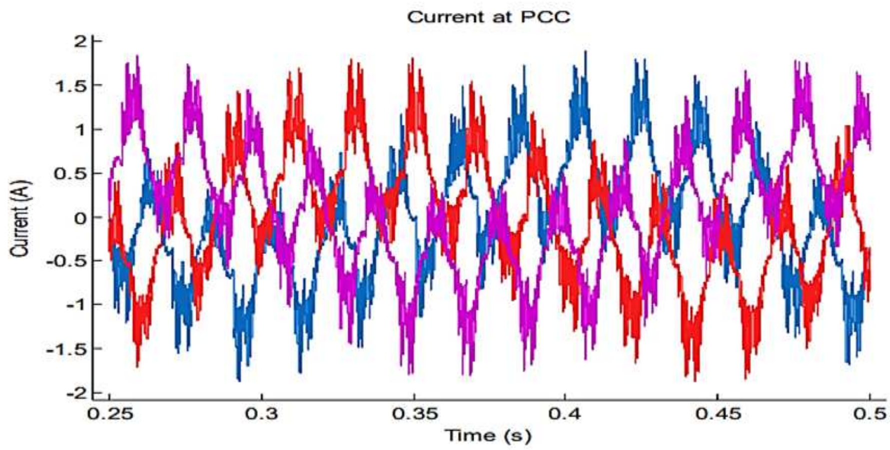
Simulation Parameters	Values	
Grid Voltage (Phase to Phase) in RMS	440V	
Grid Frequency	50 Hz	
Rating of the Coupling Transformer	3.3kVA, 1kV/440V	
Renewable Energy Source Voltage (Wind and Fuel cell)	200 V	
Non Linear Load	1000W, 100VAR	
Filters (LC type)	9.3mH, 4.2 μF	
PI Controller	K_p	K_i
Voltage	0.75	20
Current	0.6	16

5.1.1. System without UPQC

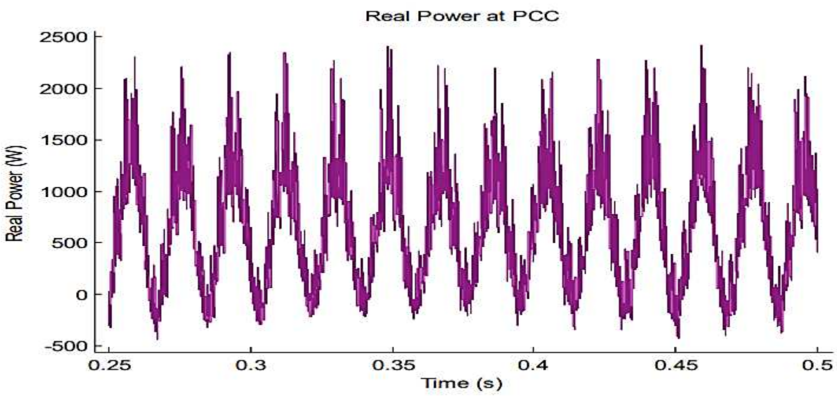
The renewable energy sources (Fuel cell, Wind energy system) were integrated into an electric grid along with a non-linear load without UPQC. The complete simulation diagram of the considered systems with UPQC is shown in Figure 5.1 the voltage, current and power (Real & Reactive) were as shown in Figure 5.2 (a-d).



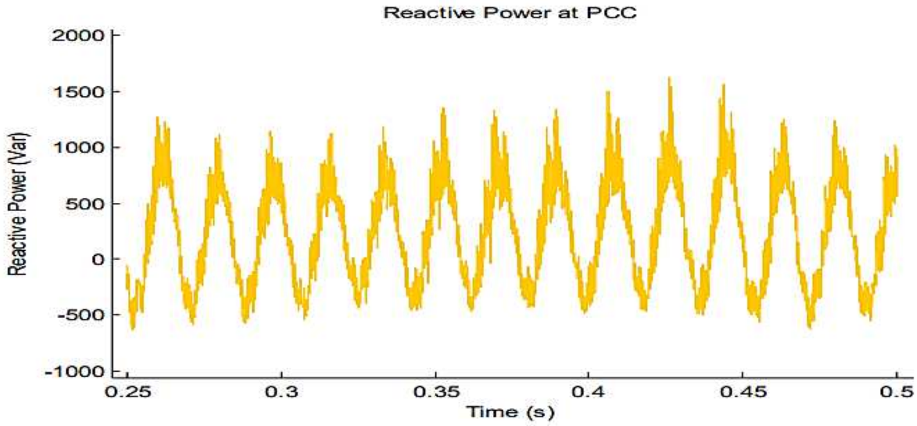
(a)



(b)



(c)



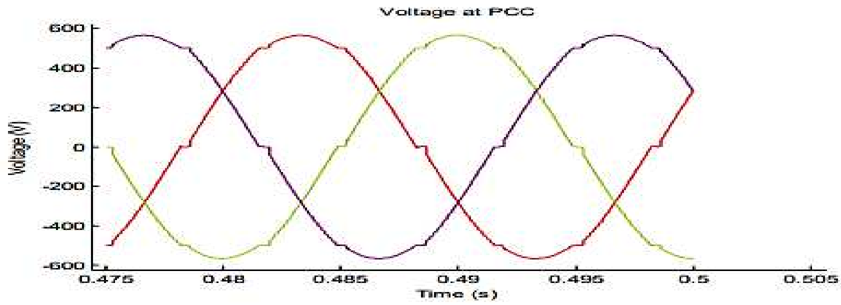
(d)

Figure 5.2 (a) Voltage at PCC without UPQC, (b) Current at PCC without UPQC, (c) Instantaneous real power at PCC without UPQC and (d) Instantaneous reactive power at PCC withoutUPQC

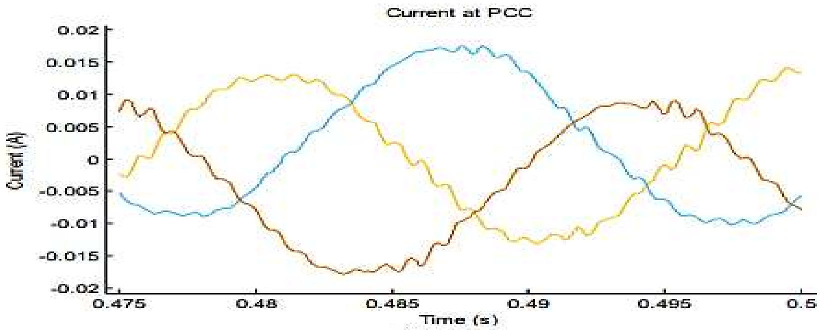
From the above Figures it is clear that due to the presence of the nonlinear load and the renewable energy sources at the PCC the voltages and current waveforms are distorted.

5.1.2. System with PI Controlled UPQC

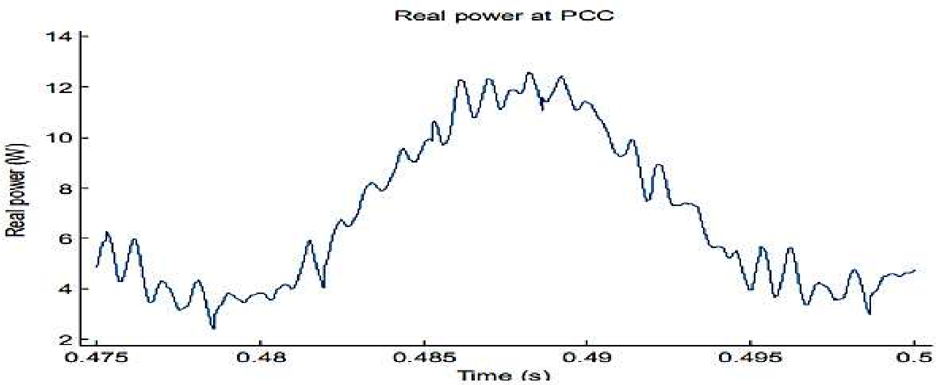
The renewable energy sources (Fuel cell, Wind energy system) were integrated into an electric grid along with a non-linear load with PI Controlled UPQC. The K_p and K_i values of the PI Controller were generated using trial and error method. The voltage, current and power (Real & Reactive) were as shown in Figure 5.3 (a-d).



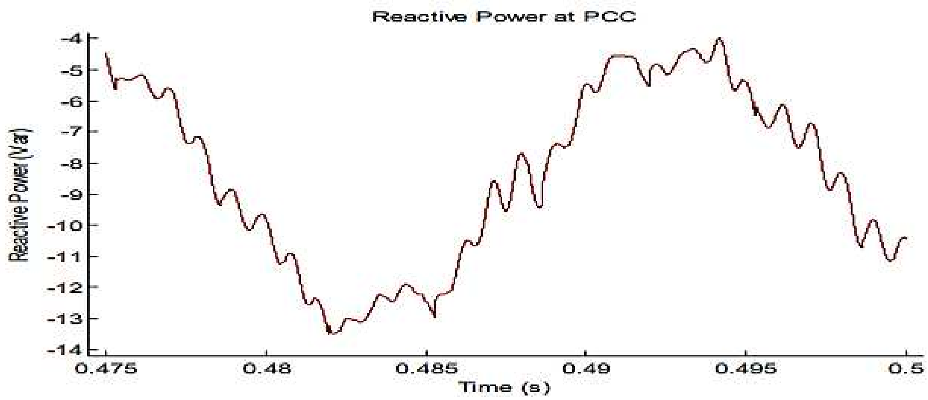
(a)



(b)



(c)



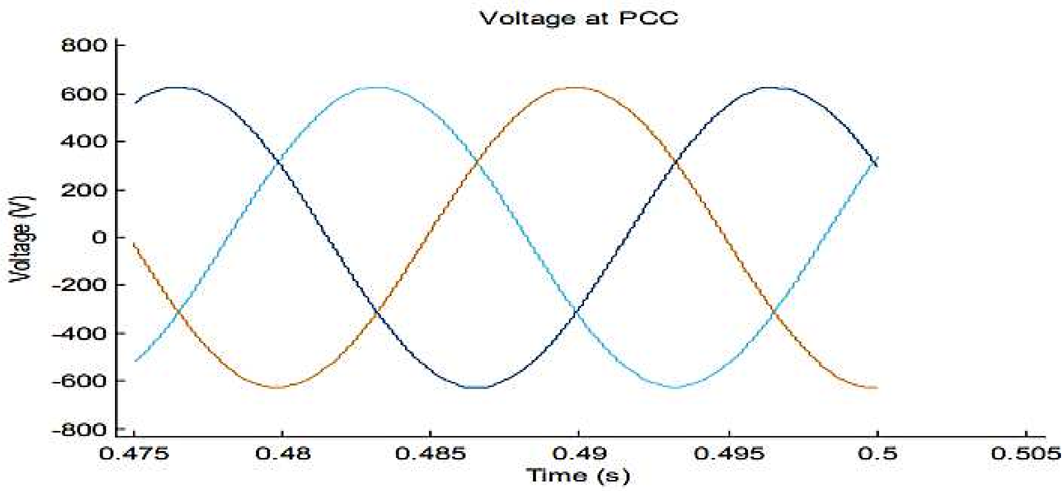
(d)

Figure 5.3 (a) Voltage at PCC with PI controlled UPQC, (b) Current at PCC with PI controlled UPQC, (c) Instantaneous real power at PCC with PI controlled UPQC and (d) Instantaneous reactive power at PCC with PI controlledUPQC

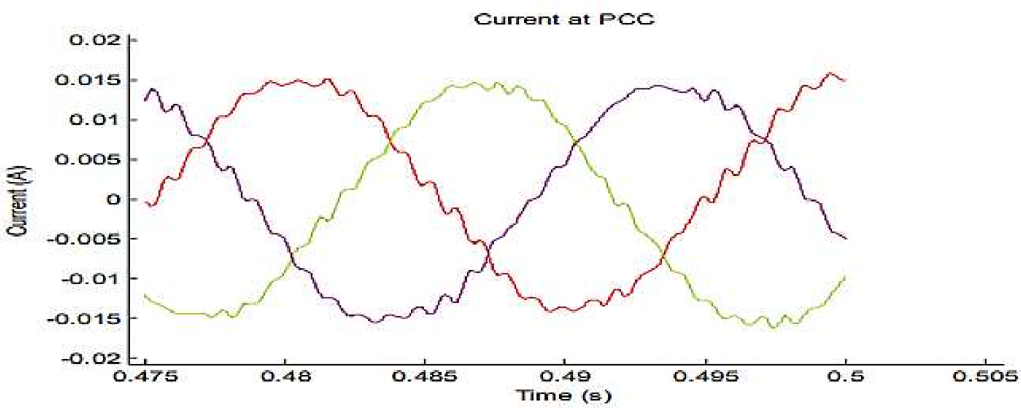
After installing the PI Controlled UPQC at the PCC the voltage and current distortions were reduced to some extent. It is evident that the installed PI Controlled UPQC is mitigating the power qualityevents.

5.1.3. System with ANFIS Controlled(UPQC)

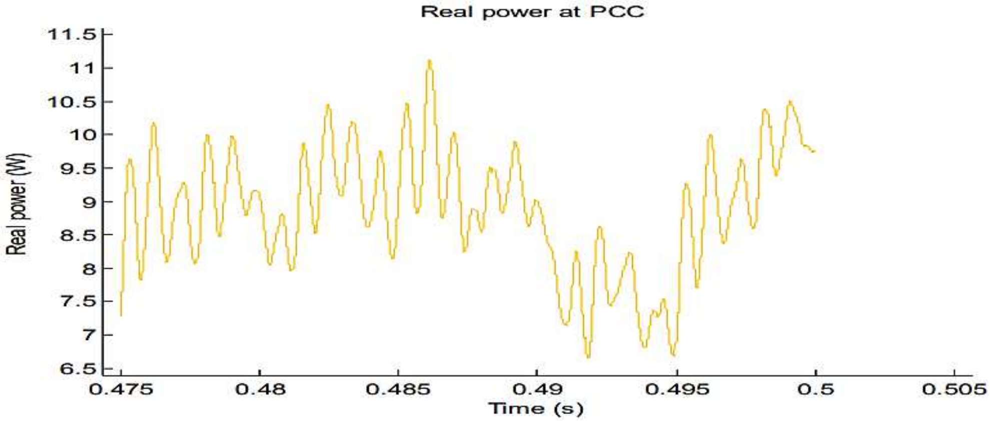
The renewable energy sources (Fuel cell, Wind energy system) were integrated into an electric grid along with a non-linear load with ANFIS Controlled UPQC. The voltage, current and power (Real & Reactive) were as shown in Figure 5.4 (a-d).



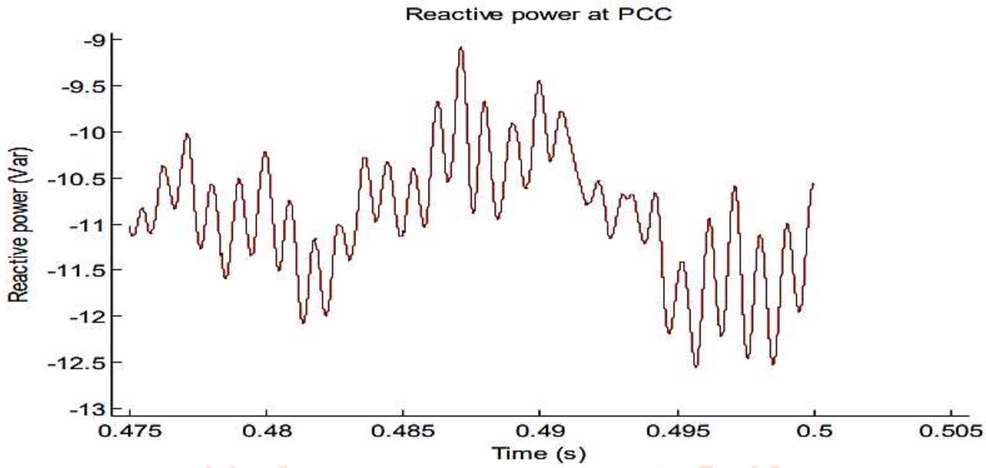
(a)



(b)



(c)

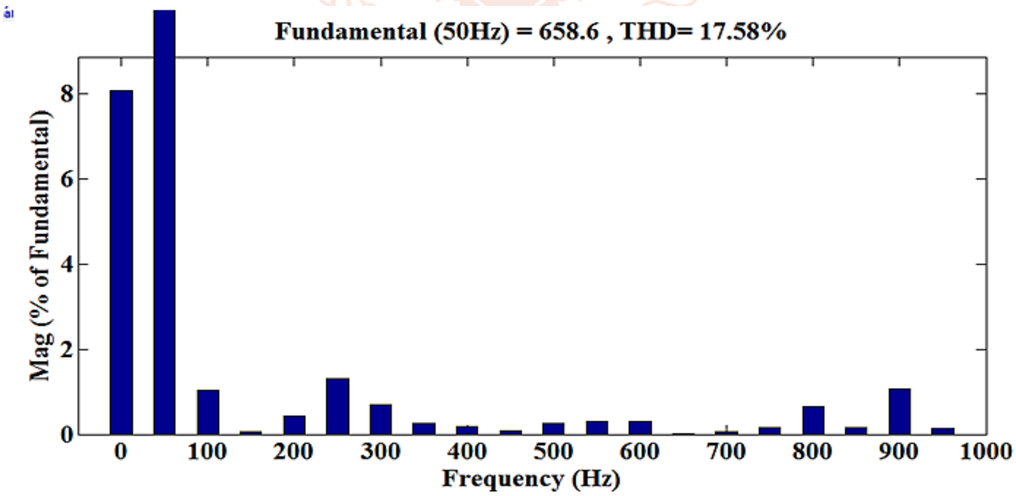


(d)

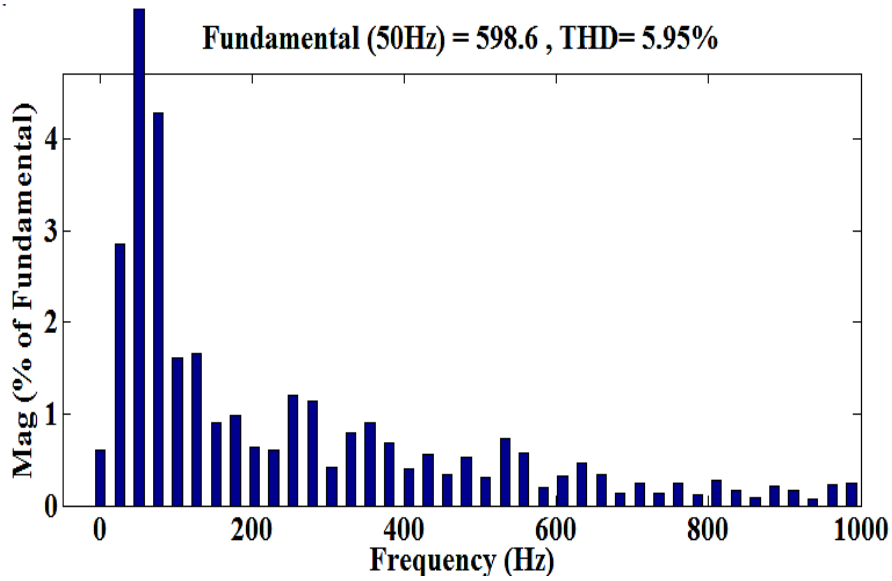
Figure 5.4 (a) Voltage at PCC with ANFIS Controlled UPQC, (b) Current at PCC with ANFIS Controlled UPQC, (c) Instantaneous Real Power at PCC with ANFIS Controlled UPQC and Instantaneous Reactive Power at PCC with ANFIS Controlled UPQC

5.2. TOTAL HARMONICDISTORTION

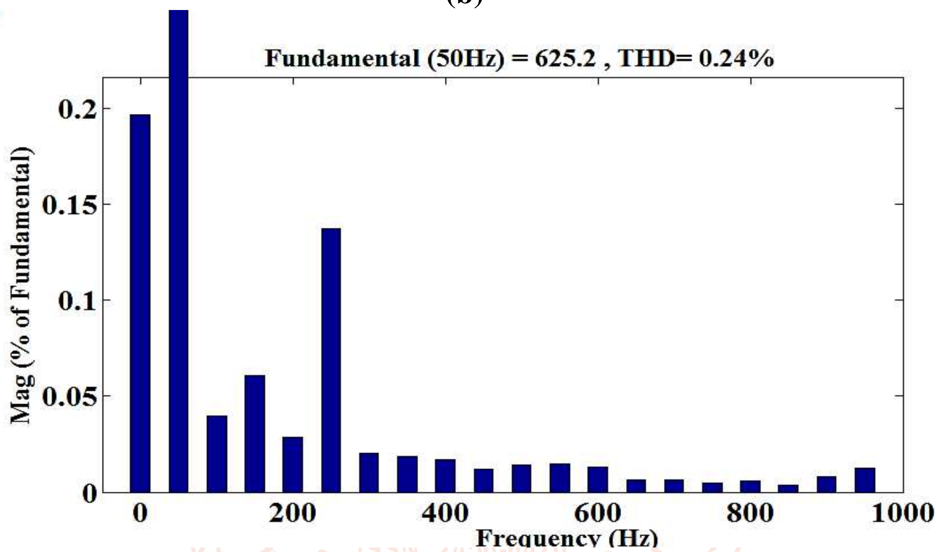
The Fast Fourier Transformation (FFT) is used to calculate the total harmonic distortion in three different scenarios for one complete cycle at 0.48 S. The representation of the FFT analysis for Phase A is as shown in Figure 5.5(a-c).



(a)



(b)



(c)

Figure 5.5 (a) FFT Representation of THD at PCC for Phase A without UPQC, (b) FFT Representation of THD at PCC for Phase A with PI Controlled UPQC and (c) FFT Representation of THD at PCC for Phase A with ANFIS Controlled UPQC

The THD levels is measured up to a frequency level of 1000 Hz. The values of THD for the other phases is listed in Table 5.2.

Table 5.2 THD in Voltage at PCC

Phases	Total Harmonic Distortion (%)		
	System without UPQC	System with PI Controlled (UPQC)	System with ANFIS Controlled (UPQC)
A	17.58	5.96	0.24
B	17.43	5.95	0.21
C	16.92	5.93	0.26

Effectiveness of the PI and ANFIS controller for the UPQC has been analyzed for mitigating power quality problem like wave form distortions, voltage unbalance, and total harmonic distortion are studied. It is clear that, ANFIS controlled UPQC out performs PI controlled UPQC in all aspects. Voltage unbalances are easily corrected and waveform are found to be clear and more or less sinusoidal. Total harmonic distortions is also very much reduced. as per the standard IEC 61000-3-2.

6. CONCLUSIONS AND FUTURE WORK

The main focus of this research is to provide a method for detection, classification of power quality events. It also offers a controller that suits to mitigate the power quality events that may rise due to the introduction of the renewable energy source and the nonlinear loads.

The important contributions of this research work are briefed as follows.

- The Proposed expert system offers a better classification in the power quality issues. Hence it is concluded that the expert system has a minimum training and testing error in detecting the power quality events to validate the effectiveness.
- The ANFIS controlled UPQC offers a solution to power quality problems like voltage imbalances and total harmonic distortion at the point of common coupling. It helps to integrate the renewable energy sources effectively with a minimum power quality impact.

FUTURESCOPE

Research is a constant process and opens other venue to continue the work. The Further research work may be continued in the following areas.

- The other transformation methods like linear, Walsh and coordinate methods can be implemented for pre-processing stage in expert system. It can be applied for any industries that require power quality monitoring system.
- Various evolutionary algorithm can be implemented for the tuning process of the controller implemented in the custom power devices.
- At micro grids, the Power quality issues can be assessed and mitigated using various energy storage systems.
- Energy storage system like super capacitors, fly wheel storage systems can be implemented in custom power devices to have a better performance.

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