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Adaptive Controllers for Voltage Sensitive Loads in a UPQC Configuration

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ABSTRACT
An open, unified photovoltaic-fed power quality conditioner with a new architecture aimed at voltage-sensitive loads is presented in this work. In order to meet end- user demand for a variety of power quality levels, To do this, it combines the benefits of both grid-connected photovoltaic (PV) systems and open Unified Power Quality Conditioner (UPQC).. Controllers for the adaptive compensators of the UPQC have been installed in the series and shunt compensators.The series compensator was managed using an enhanced SRF technique based on an adaptive notch filter. For the suggested system's shunt component, an adaptive logarithmic absolute algorithm was designed. The possibility of high and low frequency ripples has been overlooked in favour of using Moving Average Filter (MAF) rather than Low Pass Filter (LPF) for dc bus voltage control. There is now a feed-forward component to keep grid current stable even in the event of a power outage.. In the lab, a prototype of the proposed system is used to test the controllers. A variety of grid circumstances, including voltage dips, voltage swells, imbalance, harmonics, unexpected additions and subtractions of loads, and changes in solar irradiation, were all used to evaluate system performance.

Keywords: UPQC,MAF,Low Pass filter,Photovoltaic System,Shunt Controller.

I. INTRODUCTION

There are a number of undesired outcomes when non-linear loads are used in the operation of power systems.The most significant components are the harmonic components of current and voltage shapes. Passive filters were traditionally used to remove current line harmonics. But the resonance mechanism is introduced and tends to be large. Active power supplies are therefore more common than passive filters, because they simultaneously adjust for the harmonic and reactive power.

It is possible to connect the active power filter design in series with shunt or in parallel with shunt, respectively.Shunted active filters are more common than series active filters because current harmonic rectification is often needed in industrial applications. To enhance the electrical system, a variety of active filters were proposed. This is in accordance with the standards.

- ❖ The compensated system requires an assessment of power and a rapid response time.
- ❖ specified argument for the design
- ❖ An estimation method used to determine the reference voltage and current.

As a control method for active filtering, a voltage source inverter with current control may be used..As the percentage of small and medium-sized businesses utilising renewable energy increases, for example solar panels or wind turbines, a substantial proportion of them will be part of the electrical grid.

Since most grid interconnections include harmonic components that affect the quality of the energy, installing tiny renewable energy installations on the grid is a common challenge.

The growing usage of power-electronics-based non-linear loads in the industry also caused significant disruption issues in the power supply grids. In addition to excessive reactive energy consumption, frequent rise in harmonic emissions and current imbalances may also be seen. The passage of harmonic currents in the electrical grids may also generate harmonic voltage and perturbation. These harmonic currents may interact with a number of power systems, safety systems, and other harmonic loads. The energy distributors such as customers indicated substantial regulatory protection against the rise in the harmonic problem.

Many different approaches have been proposed to deal with the problem of harmonics. Other treatments, including the use of load modifications like single-phase and three-phase correction structures and PWM rectifiers, were used.

A significant amount of time and effort was put into researching and developing new, improved, and more efficient power quality solutions, such as harmonics problems, in order to resolve the harmonics issue. Active compensators and active power filters are both often referred to as active compensators or active power filters in the modern day. Harmonic and reactive power adjustment are the primary objectives of the APF.

Many kinds of APFs have been suggested and utilised to compensate harmonically. The APF series is used for compensating voltage harmonics. For present harmonics and reactive power correction, Shunt APF was suggested. It is possible to alter voltage, current harmonics, and reactive power in a shunt-to-series APF converter using the Unified Power Quality Filter or Conditioner.Even though there are various APF varieties, the Shunt APF remains the best known and most common APF type.

Grid harmonics may be reduced with the use of the Shunt Active Power Filter.Similar- sized harmonics are an objective of SAPF's.The non-linear charges are able to absorb grid non- sinuous currents. However, the SAPF current is produced in a way which maintains the grid current sinusoidal. The SAPF is checked as a linear resistive load with nonlinear load through the grid.

An Active Power Filter (APF) may be controlled directly or indirectly, with either structure being the primary control structure.The idea is to provide referral assistance for the filter current using the best methods that allow for manual control. After reference currents are produced, the resulting signals are compared to the APF current measurements. This error is useful in the generation of control signals from the filter. Better regulation of grid currents means better regulation of filter currents. Measurements of the grid currents are compared to the findings. After calculating the APF control signal, the error is transmitted to the control circuit for the APF.

Purpose of the thesis

I'm mainly aiming to include the APF features in the traditional inverter interface, i.e. the four leg voltage source inverter connecting the renewable energies, such as wind energy and the photovoltaic cell, with no extra hardware expenses. The grid interface inverter is used to fulfil the essential tasks as much as possible:

- ❖ To inject renewable energy sources into the AC grid for maximum available power.
- ❖ Active power supply for load.
- ❖ To make up for the burden PCC's current reactive power and harmonics.
- ❖ In 3-phase 4-wire systems to offset current unequal and neutral current.

A model of the AC gird, non-linear load, multi-niveau inverter and renewable energy sources in the MATLAB/SIMULINK 2009 software environment will be created for assessing the performance of the suggested method.

Method

Overview

In the same manner that opposing harmonics would sound, this active energy filter sounds like it. Shunt active power filter acts as a harmonic load injection source., but the filter 180 degrees out of phase with the power injection is responsible for shifting the phase. This term encompasses any kind of load that's described as a harmonic load. That is similar to the idea. Furthermore, in order to balance the power factor, an active power filter may be used. It has a fine-tuned resistor for non-linear loads and active power filters. This example illustrates the shunt active power filter's current compensation features, as seen in Figure 1.

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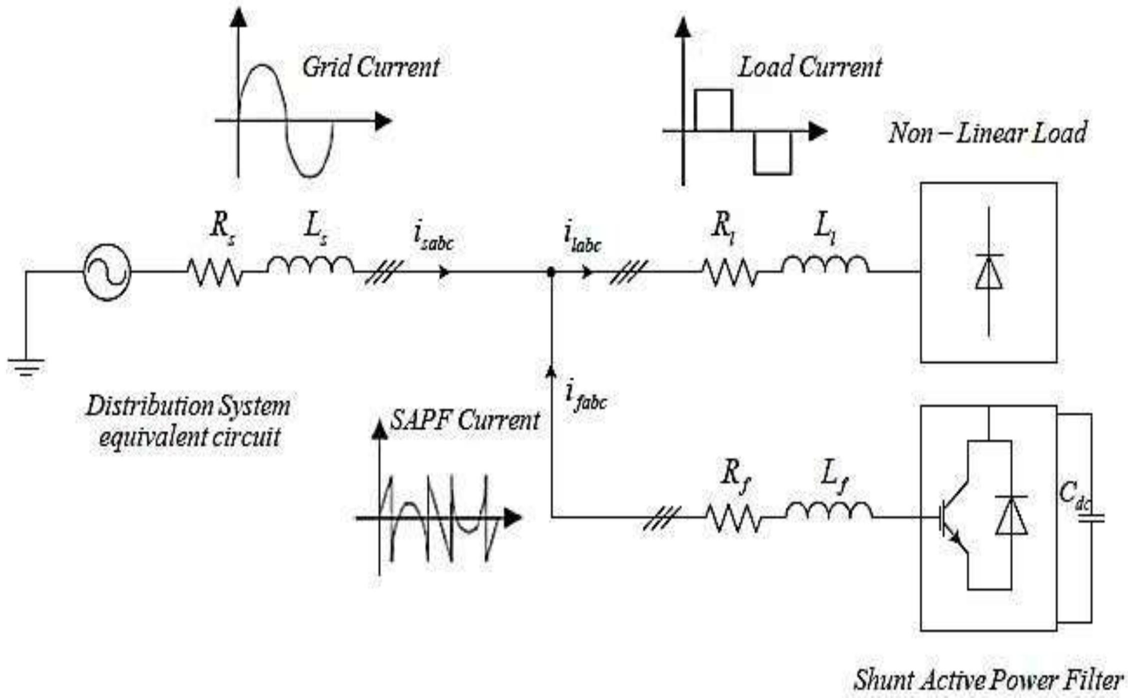

Fig. 1 Shunt Active Power Filter Compensation Feature

Current harmonic methods of extraction

Grid current and voltage harmonics are the primary goals of the active power filtering procedure. To get the filtered signals ready for processing, the first step is removing any harmonic signals from the grid. An good harmonic elimination is a watchword for efficient active power filtering. In literature, several extraction techniques were suggested. To better detect harmonics in the frequent domain, the first family utilises the Fast Fourier Transform (FFT). The two groups may be separated. The biggest limitations of this approach are its low output quality, the high computational costs, and the large memory requirements. Furthermore, because of the time it takes to extract harmonics, it may take longer than one time.

The second family is a set of techniques for extraction of harmonics on the basis of time domain calculations. The techniques used by this approach are immediately based on active and reactive power. The remaining elements are digital either on their own or by way of connections. The usage of neural networks and adaptive linear neural networks for the extraction of harmonic components has been widely utilised in recent months.

Active and reactive power theory instantaneously

Most APFs are based on the Akagi and colleagues' active and reactive power (p-q) model, which was originally introduced in 1983. The system was first designed exclusively for Watanabe and Aredes' four three-phase cable power systems, and afterwards it was adapted for three-phase systems with neutral cable. Three-phase bi-phasic current may be transformed from a stationary three-phase frame ABC to a three-phase current that has been warped.This concept may be seen as having two points: non-linear loads compensating for harmonic currents and non-linear loads reducing harmonic currents are two separate topics.. The p-q hypothesis is built on the premise that there are 31 direct power effects in the time domain. The transition from three phase voltages (a, ub, uc) and Ia, Ib, and Ic currents to an instantaneous active and reactive power system is accomplished by means of the Clarke (or α-β) transformation. 3-phase quantity projected on a fixed double-axis frame may be referred to as a projection. It is provided by the Clarke voltage variable.

$$\begin{bmatrix} v_\alpha \\ v_\beta \\ v_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1)$$

Similar to the distorted load currents, this transform may be performed to produce a more accurate representation:

$$\begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \\ i_{L0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (2)$$

The active power p(t) instantaneously is defined by:

$$p(t) = v_a i_{La} + v_b i_{Lb} + v_c i_{Lc} \quad (3)$$

In the stationary frame this equation may be provided by:

$$\begin{cases} p(t) = v_\alpha i_{L\alpha} + v_\beta i_{L\beta} \\ p_0(t) = v_0 i_{L0} \end{cases}$$

Where P(t) is the power active immediately, p0(t) is the homopolar power of an instantaneous sequence. Likewise, reactive power may be provided instantaneously:

$$q(t) = -\frac{1}{\sqrt{3}}\left[(v_a - v_b) i_{Lc} + (v_b - v_c) i_{La} + (v_c - v_a) i_{Lb}\right] = v_\alpha i_{L\beta} - v_\beta i_{L\alpha} \quad (5)$$

The reactive q(t) instantaneous capacity is greater than the reactive energy. All the harmonics of current and voltage, which only account for the fundamentals of voltage and current in the typical reactive power, are considered by immediate reactive power.

Active and reactive power in matrix form at the same time (3.4) and (3.5) may be obtained by:

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$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \quad (6)$$

There is a direct and an alternating instantaneous power for each active and reactive instantaneous power.The direct component displays the current power and voltage fundamentals. The alternating term is a strong harmonic of streams and tensions.

The immediate term of instantaneous power from alternating one is adequate in order to isolate the harmonics from the fundamental current of the loft.This task may be carried out by utilising a low-pass filter (LPF). The extraction filter shown in Figure 2 is based on this notion.

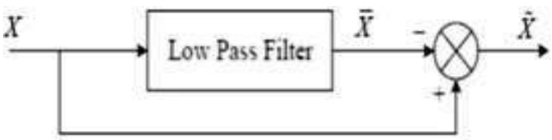

Fig. 2 Feed-forward low-pass filter schematic.

In order to determine the load current harmonic components, use the inverse equation:

$$\begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix}$$

Where, the "~ "sign points to the alternating. You may then provide the APF reference current:

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \quad (8)$$

Fig. 3 illustrates the active and reactive immediate power idea. This technique offers two possible advantages: harmonic compensation, and reactive power compensation. Using the reactive power q(t) in the reference current calculation block, you don't require an extract filter for reactive power compensation.

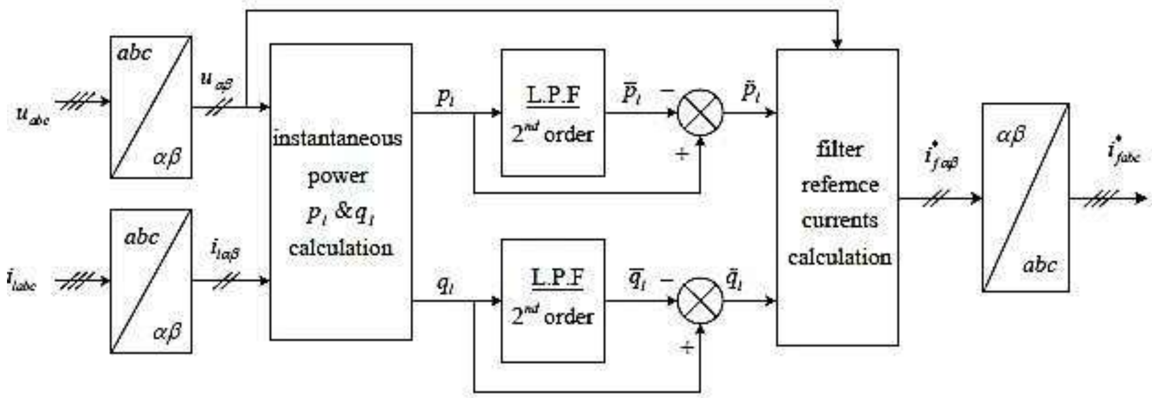

Fig. 3 Instantaneous theory of active and reactive power.

Voltage Source Inverter

Voltage Source Inverters are a key application of power electronics.(VSI). These devices have the primary function of providing a three-phase source of voltage that should always regulate the amplitude, phasing and frequency of the voltages. VSI's significant growth comes, on one hand, from the development by the so-called pulse wide modulation (PWM) methods of quick, controlled, powerful and sturdy semiconductors. The three level VSIs are the most often used in high-powered applications compared to two levels. Due to a noticeable reduced THD of the three-level VSI output voltage and current.

Fig. 4 shows the typical 3-phase architecture of the VSI. It has three legs and is operated for open and shut using the current reversible switches. The interrupts are regulated by GTO or IGBT buttons for passage of free-running currents using anti-parallel diodes.

On any inverter leg (T1, T4, T2, and T5), In order to turn the switches on, you must short off the dc power supply.Similarly, the switches on any leg of an inversor cannot be turned off simultaneously in order to prevent undefined VSI statuses and therefore undefined ac output line voltages, since they would result in voltages which rely on the corresponding line current polarity.

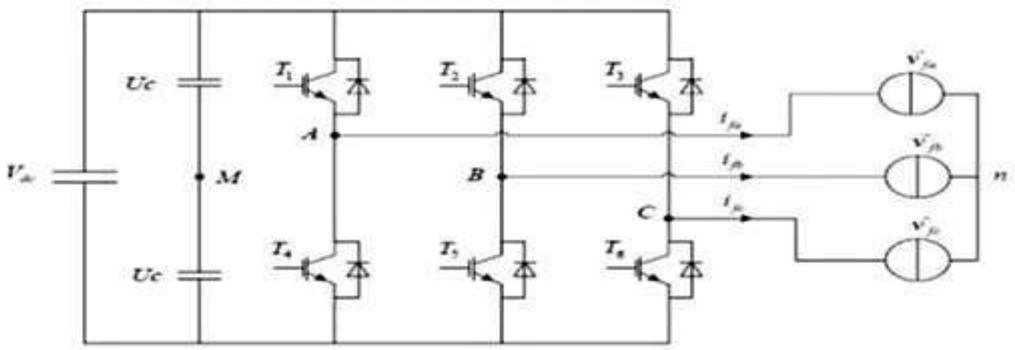

Fig. 4 Two-level VSI Topology three-level

Voltage Source inverter modelling

Two levels (+Vdc, - Vdc) may be used for the VSI output illustrated in Fig. 3.4, according to the source tension and the switches. In fact, both switches have a complimentary control on the same leg. The control of one of them means that the other is blocked.

The control signals (Sa, Sb and Sc) determine the status of each switch accordingly:

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$$\square_{\square} = 1 \square\square\ \square_1\square\square\square\square\square,\ \square_4\square\square\square\square\ 0\ \square\square \quad \{ \square_1\square\square\square\square,\ \square_4\square\square\square\square\square$$

$$\square_{\square} = 1\{ \square\square\ \square_2\square\square\square\square\square,\ \square_5\square\square\square\square\ 0\ \square\square \quad \square_2\square\square\square\square,\ \square_5\square\square\square\square\square$$

$$\square_{\square} = 1\{ \square\square\ \square_3\square\square\square\square\square,\ \square_6\square\square\square\square\ 0\ \square\square \quad \square_3\square\square\square\square,\ \square_6\square\square\square\square\square$$

Active power filter modelling

As shown in Fig. 1, Connecting the active power filters to the grid's common connection is the primary function of a R L low-pass filter. For each phase the voltage equation may be determined by:

$$\square_{\square\square} = \square_{\square\square} - \square_{\square\square\square} - \square_{\square\square\square}$$

$$\square_{\square\square} - \square_{\square} \frac{\square\square\square\square}{\square_{\square\square}} - \square_{\square\ \square\square}, k=a,b,c \tag{9}$$

Then are provided the three phase equations:

$$\square_{\square} \frac{-}{\square\square} |\square\square\square| = \square_{\square} [\square\square\square] + [\square\square\square] - [\square\square\square] \tag{10}$$

And for the dc side:

$$\square_{\square} . \frac{\square\square\square\square}{\square_{\square}} = \square_{\square\square} + \square_{\square} + \square_{\square\ \square\square} \tag{11}$$

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In the three-phaseframe, the SAPF equation system is then providedby:

[illegible] (12)

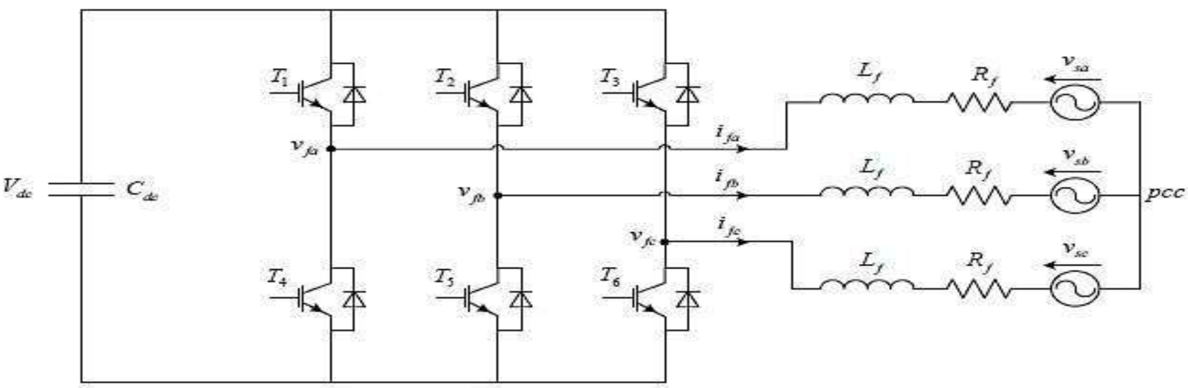

Fig. 5 SAPF PCC connection

VSI methods of control

The VSC controller sets a reference current that tries to limit the output currents of the inverter. This premise holds that the actual filter current is measured, together with the various extraction method-generated referral currents. A variety of VSC control strategies will be explored in this section.

Hysteresis Control Method

In rapid response current controlled converters like the active power filter plays a significant part in the current control approach. The most commonly recommended time domain control approach for hysteresis is the current control technique. Instant remedial reaction, excellent precision and unconditional stability are provided with this technique. Moreover, the best option for current inverters regulated is considered to be this technology.

Hysteresis Curring is a means of regulating a voltage source inverter in order to produce a power output that follows a waveform of the reference current.

Fig. 6 illustrates the fundamental construction of the hysteresis controller PWM voltage source inverter. The control technique of hysteresis is designed to maintain the regulated current within the specified reference current. The switch status should be determined by error. In order to minimise the frequency of errors, When the error exceeds a particular threshold, the switches are modified to a lower value, and the current decreases until a certain negative value of the error is achieved.

International Journal of Advances in Engineering and Management (IJAEM)
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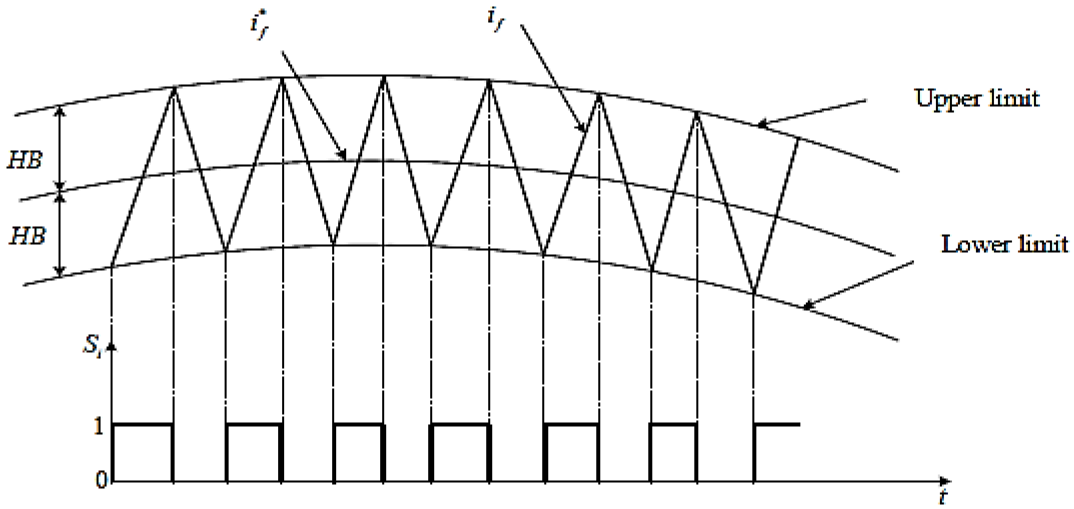
Fig. 6 Control Principle of Hysteresis



When the VSI is under control by the fixed hysteresis band, the switching frequency relies on the output current derivative. This relationship is defined by this formula: the inductance value, and the voltage drop in the disconnecting filter. Particularly relevant is the coupling filter's influence on the active filter's switching frequency and dynamic behaviour. There is a major advantage to this method in that it is quite simple to implement.The main drawback of this technique is nevertheless the changeable switching frequency. The function of power electronic components that cannot handle high frequency switching in high power applications is mostly affected by this changing frequency. A novel hysteresis control methods such as "modulated hysteresis control" and "variable hysteresis strip" To address the problem of a variable switching frequency, they were created. The hysteresis band width cannot easily be defined in the modulated hysteresis control. In addition, the fixed frequency of switching produced by this technique influences the speed of hysteresis control.

Pulse Width Control for Sinusoidal Pulsing (SPWM)

The VSI frequency changing problem is addressed using PWM-based control techniques. The harmonics may be cancelled using a set frequency. The PWM may be performed by various ways, such as PWM, harmonic PWM reduction, and PWM space vector. It is possible to use natural PWM, symmetrical PWM and asymmetric PWM. Carrier of PWM.

Sinusoidal PWM is the most well-known and simplest approach. To calculate an error between the current and the reference, the method utilises an inverter voltage reference controller. A reference voltage is then compared to a triangle transmission signal (When specifying the switching frequency, the term "high frequency" is used.). The VSI switching feature is set by this comparison output. In the case of a symmetrical and periodical reference, a ratio between the reference signal frequency and the carrier signal frequency should be selected. Thus, when a sinusoidal reference synchronises the carrier with the reference, the relationship between these two frequencies must be integer. In addition, it is better to preserve the reference symmetry at the carrier frequency. This ratio needs in all instances to be high enough to provide quick switching and to remove the switching harmonics from the inverter's basic result.

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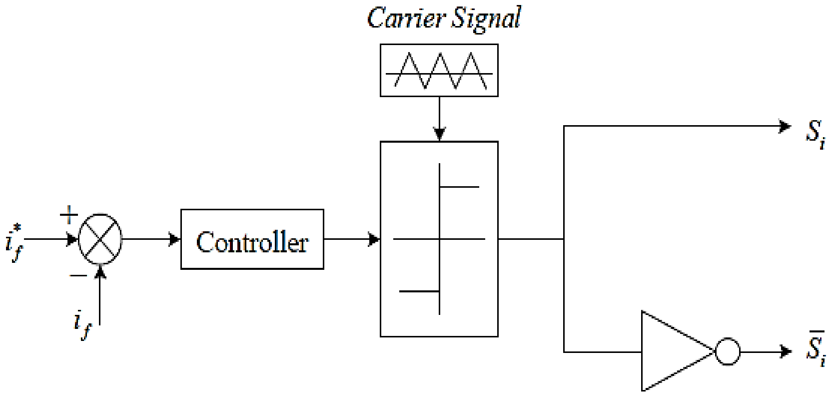


Fig. 7 Method of Control for sinusoidal PWM

New techniques of control known as the space vector PWM have recently been created. The distinguishing feature of this technology is that the carrier signal does not serve the definition of instructions.

PWM Control Space Vector (SVPWM)

In the mid-1980s, German researchers developed space-vector modulation method for the first time. It demonstrated many benefits over the conventional PWM technology and has been shown that better PWM waveforms are naturally generated. The number of switches at the same carrier frequency as the SPWM procedure is decreased by applying the SVM approach, to about 30 percent. The AC power system provides improved DC bus use with reduced THD and also lowers switching losses. A sinusoidal waveform results in the greatest modulation index when using the SPWM technique: 0.785. SVPWM allows modulation indices of 0.907 to be used.

The SVM technique's main concept is that the inverter is treated as a whole unit, which is distinct from PWM. This method is based on a voltage vector breakdown of a six-pulse inverter.

The SVPWM technology uses substantially inverter controls and rectifier controls. In comparison with the modulation of pulse width, SVPWM is more suitable for digital use (SPWM).The maximum output voltage of the DC connector (compared with 61.2 percent) may be increased in the linear modulation range by a maximum line voltage of 70.7 percent. Moreover, a total harmonic distortion factor of superior voltage may be achieved. SVPWM may be used to modulate the inverter or correcter utilising many methods. In literature, several SVPWM programmes have been thoroughly studied. Each modelling approach aims to minimise the switching losses, optimise the use of buses, reduce harmonic contents and accomplish accurate checks.

The SVPWM is defined by a rotationally invariant reference vector that spins at an angular velocity of 2 f in the three-phase output voltage. SVM's aim is to utilise the changing values of the reference vector as a switching state. 2 null vectors and 6 active vectors with 8 potential switching scenarios are found at about the vector locus.

Active power filter control control

In the development of new control processes aiming to improve performance with different non-linear loads, the researchers are constantly on the verge of improved methods for controlling SAPF, either in terms of improving disruption extraction procedures, improved dynamic regimes, lowered THD value, etc.. Compensation of harmonic currents is primarily based on two methods.

Method of direct control

It measures the loading currents and derives harmonics from the loading currents.The direct control technique diagram is shown in Fig. 8. The SAPF injects harmonic currents using this technique without information on grid streams. In the grid current all system errors are shown as unfiltered harmonical contents, including the uncertainty of the parameter, measurement or control errors. System stability is the primary benefit of this approach. However, with a high number of sensors, this approach requires an extended control algorithm.

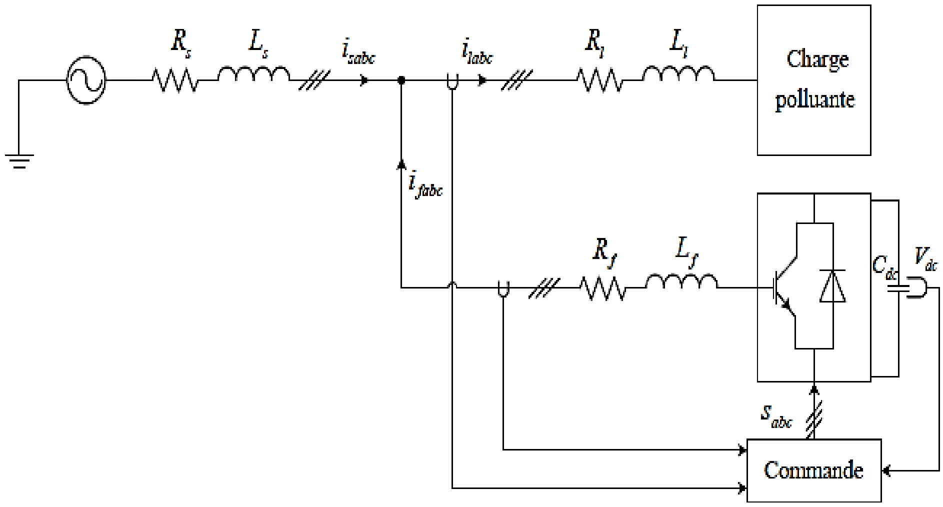


Fig. 8 Direct Method of Control Chart

Indirect Control Method

This technique bases on measuring the source currents, which are then imposed onto these currents by the sinusoidal shape. The control algorithm is less complex than the direct control and requires less sensors. The indirect control technique diagram for the SAPF shown in Fig. 3.9.

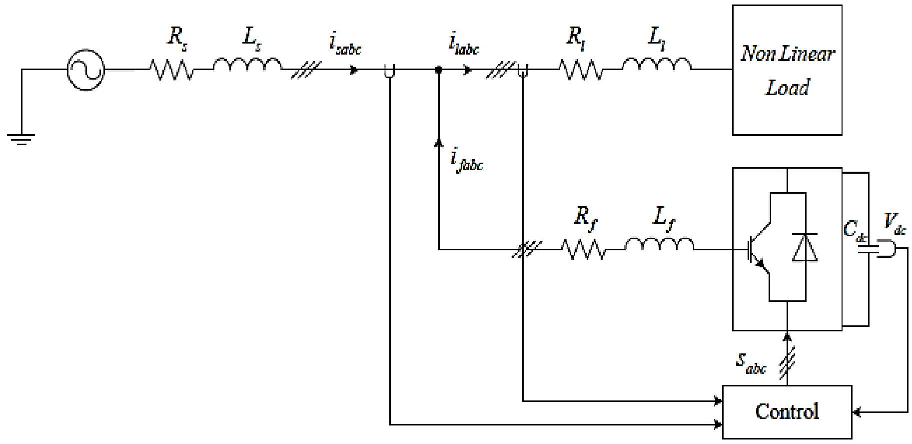
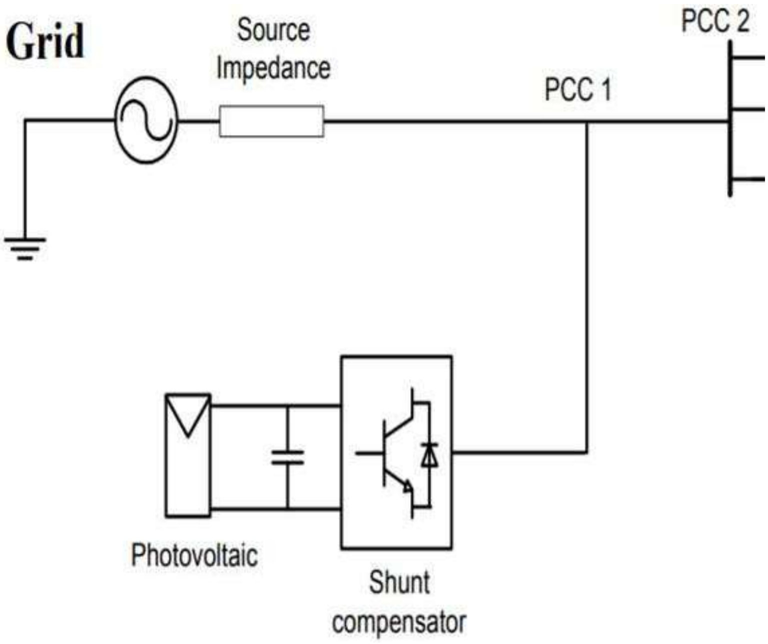


Fig. 9 Method diagram for Indirect Control

Schematic Diagram of UPQC Configuration

Controls for compensators must be more robust in order to protect voltage sensitive loads from any potentially dangerous grid conditions at the distribution level.. It has therefore been possible to build newer and more robust controllers in the current article. The suggested system has been tested in the laboratory using a developed prototype. Vulnerability-sensitive loads have been shielded from grid voltage fluctuations. As a result, existing quality concerns are also addressed for different distribution network load unbalancing scenarios. The effect of shifting solar irradiations on the system was also investigated.

Power quality and multiple power quality levels may be addressed by this study, the main feeder of common coupling-1, particularly when a PV-fed compensator of UPQC is positioned at the primary feeder point, where voltage-sensitive loads are present (PCC1)



Fig;10:Schematic Diagram of UPQC Configuration

Open UPQC and PV-features UPQC's are inherited by the proposed design for very voltage sensitive loads Figure 11 depicts the present setup, with the DVR near the sensitive load and the DSTATCOM near the principal source of power. There is no dc connection between the series and shunt compensators in this configuration.

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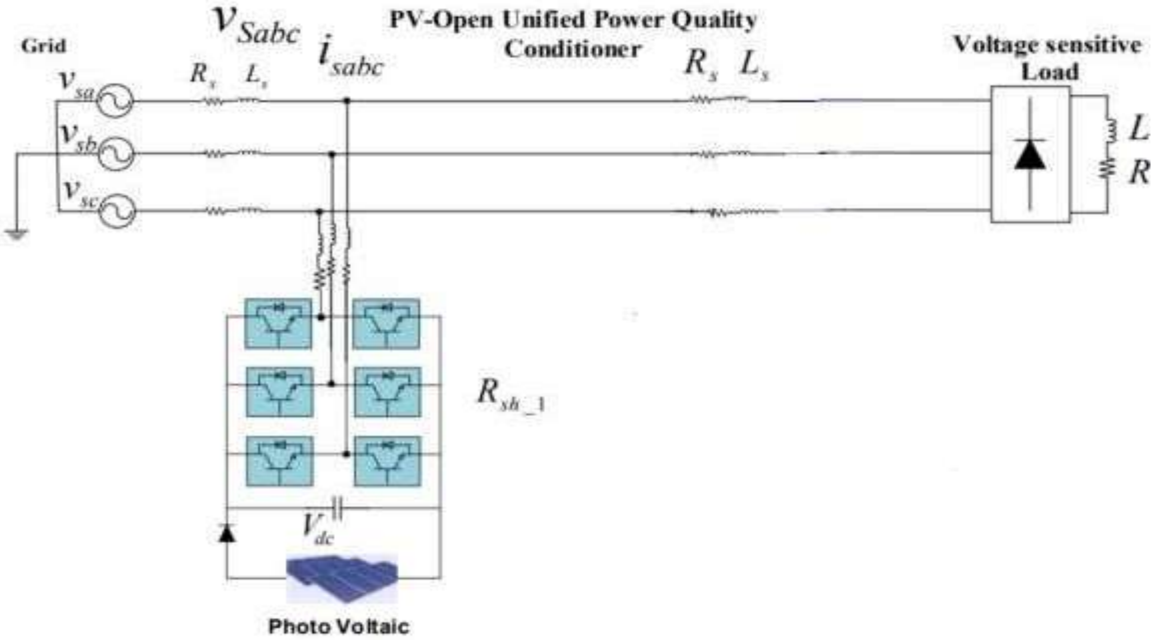

Fig;12:Proposed topology of UPQC Configuration

Software used in Execution

Simulink modifies the status and outputs of blocks in a model just once, which results in a model that varies from time to time.throughout a simulation. Consequently, the sequence in which blocks will be updated is essential for the outcomes. In particular, when the outputs of a block function at the moment, the block must be updated after the blocks which drive the inputs. The outputs of the block are invalid otherwise. As a model file, the order in which blocks are stored is not necessarily the order in which the simulations must be changed. As a result, Simulink places blocks in the correct order during the model's initialization phase.

A valid update order is generated by Simulink by classifying blocks according to their output- to-input connection. All of the current outputs of direct feed-through blocks may be traced back to their current inputs. Otherwise known as "blocks without direct feed," they are all the rest. Direct feeds may be seen in the blocks Gain, Product, and Sum. Non-direct block feeders include the Integratory (which only provides a state function as an output) and Constant (which does not receive any input) blocks, as well as the Memory block (Prior to that, its output is influenced by input.).Simulink enables you to prioritise blocks for the update. Simulink updates higher priority blocks prior to lower blocks of priority. Only when Simulink complies with its block sorting criteria will its priorities be honoured.

II. RESULT

Simulation Result Analysis Proposed System without UPQC

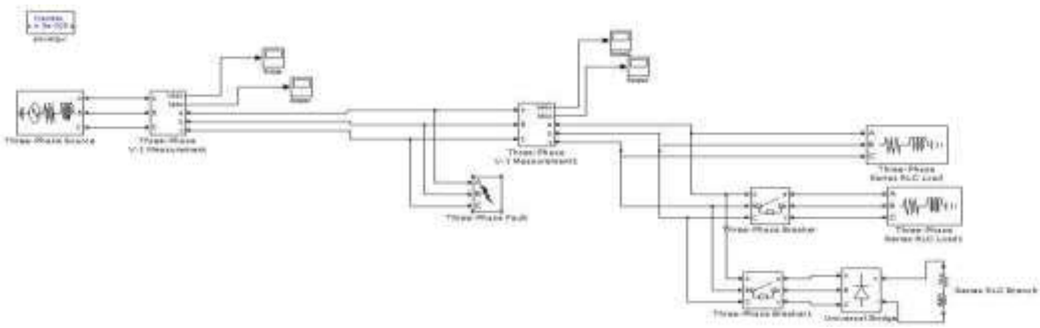

Fig 13 proposed circuit without UPQC

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 3 Mar 2022, pp: 1102-1119 www.ijaem.net ISSN: 2395-5252

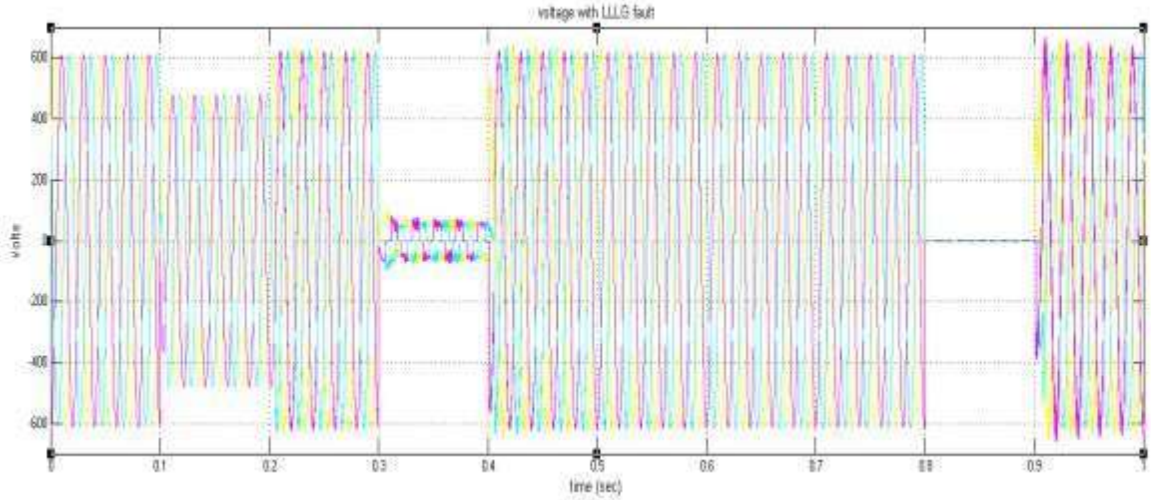

Fig 14 Output voltage without UPQC

When an LLLG error occurs, the system without UPQC is disturbed by the voltage, which affects system power quality.

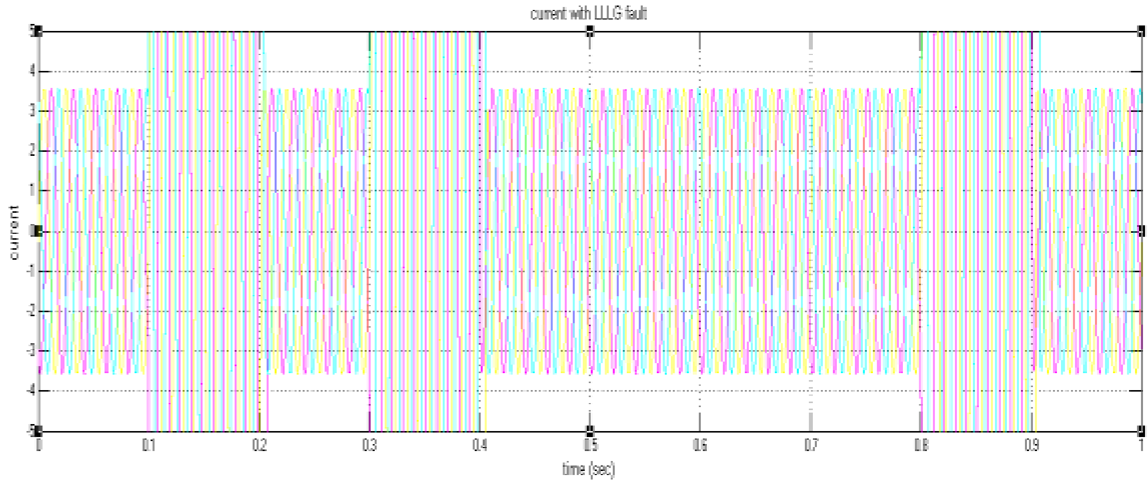

Fig 15 Output current waveform

The circuit with PI controller has a large current under LLLG fault conditions. This raises the loss of the system and enhances the power supply quality.

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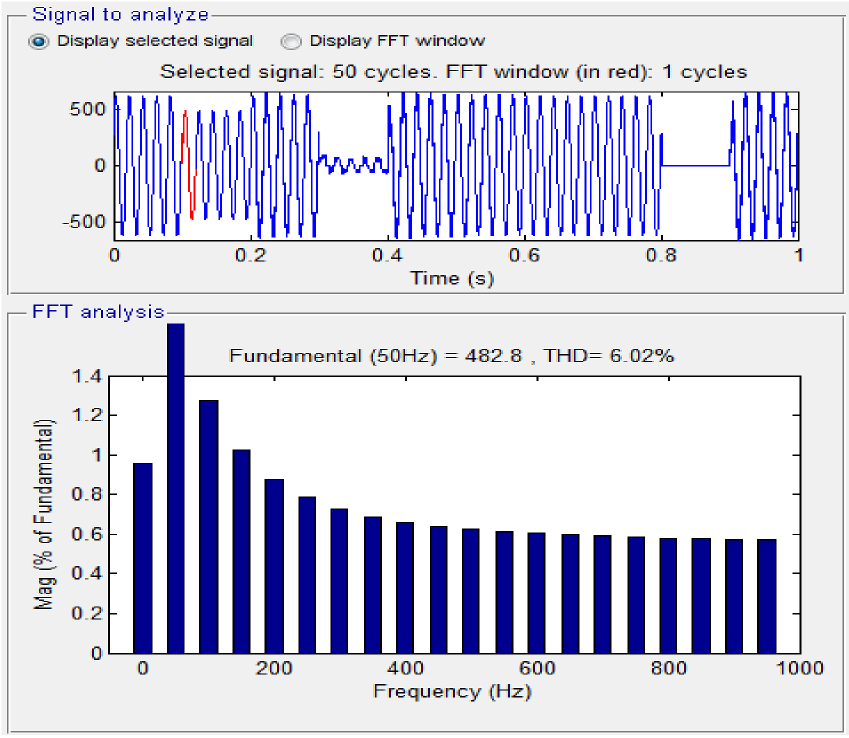

Fig 16 THD with PI controller

The diagram above illustrates clearly the THD of the PI controller system. A total harmonic distortion of 6.02% is found.

Proposed System with UPQC

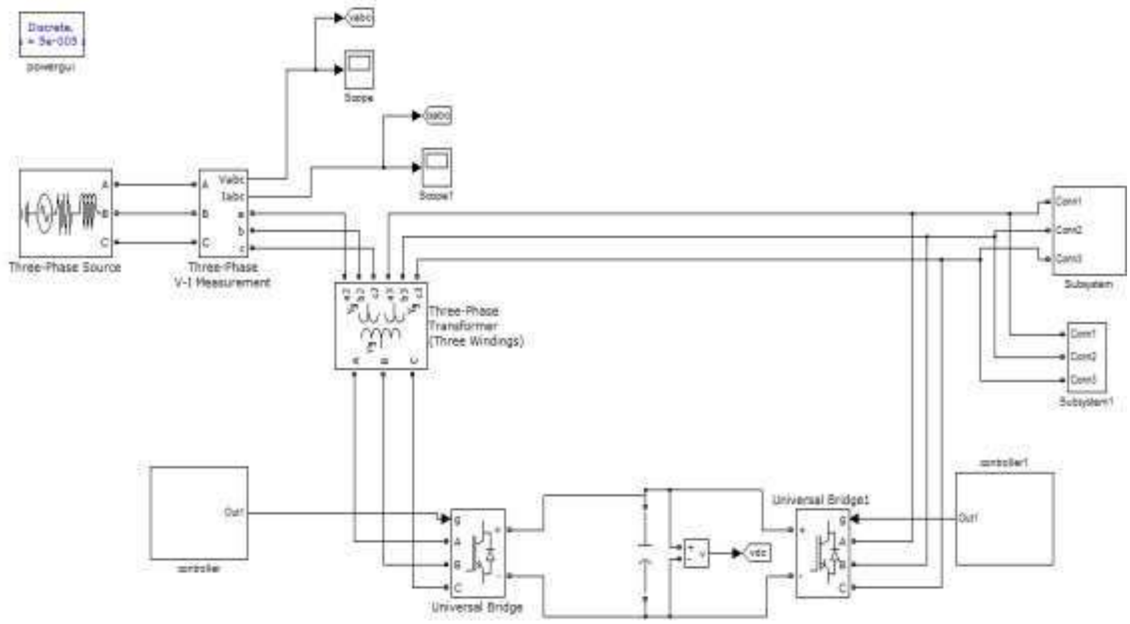

Fig 17 Simulation circuit with UPQC

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 3 Mar 2022, pp: 1102-1119 www.ijaem.net ISSN: 2395-5252

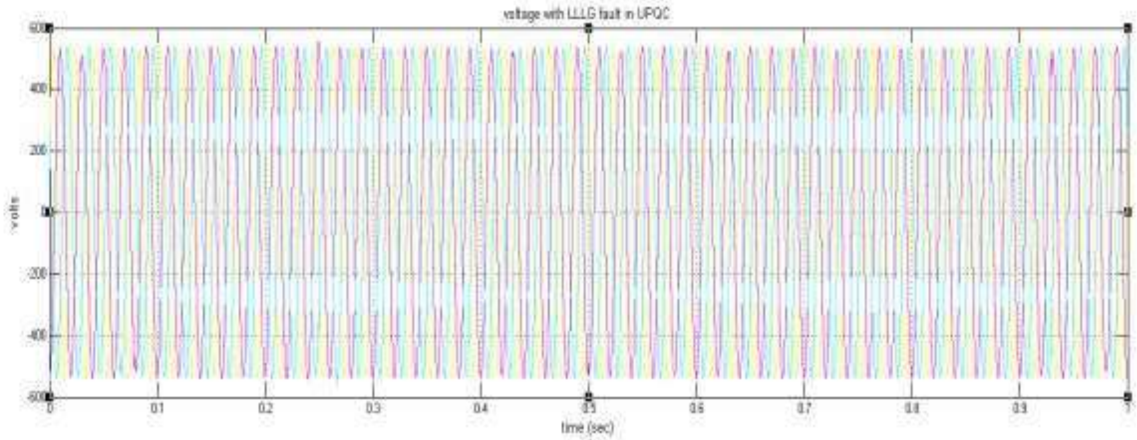

Fig 18 Output voltage waveform

A stabilised output voltage waveform has been created using UPQC without any distortion while the LLLG failure is being maintained.

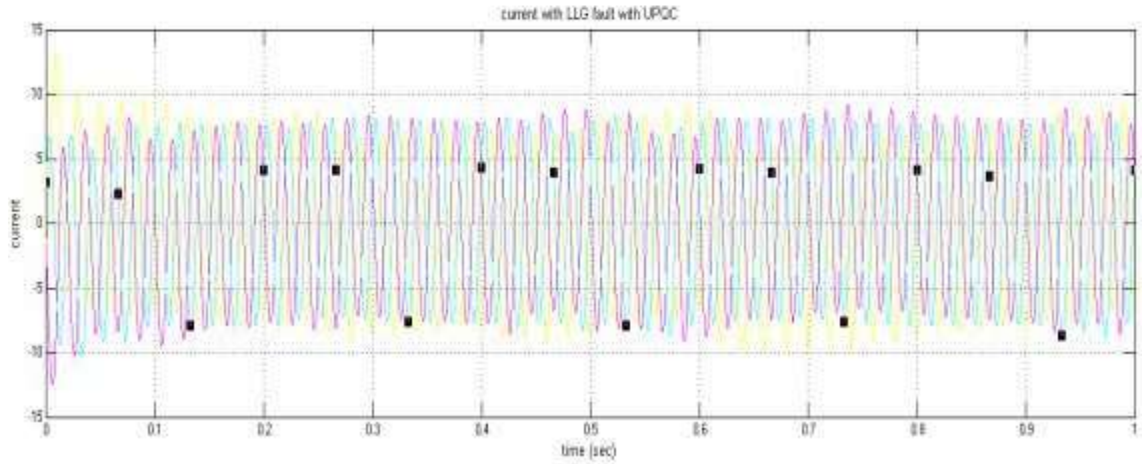

Fig 19 Output current waveform

In LLLG failure situation with UPQC controller, the present waveform still has certain defects. The system parameters are affected.

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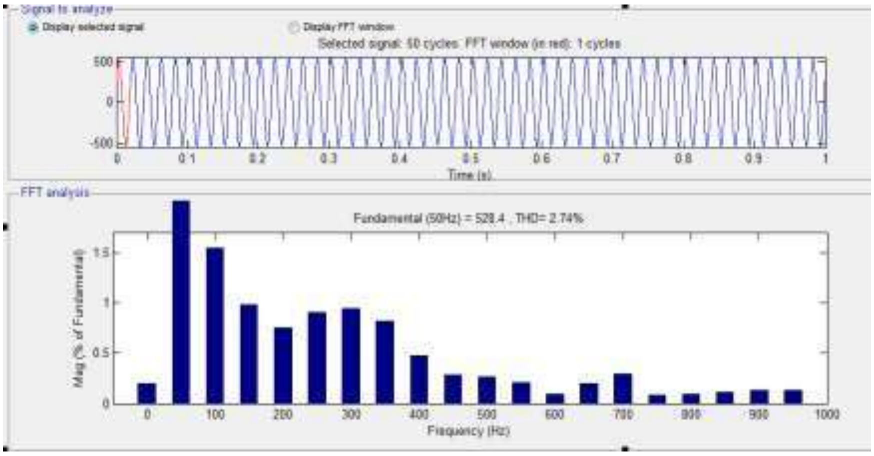

Fig 20 THD with UPQC

The THD of the UPQC controller system decreased the THD from 6.02% to 2.74%. It demonstrates clearly that as compared to the PI controller, UPQC achieved great efficiency.

III. CONCLUSION

The development of distributed harmonic production loads is a notable trend in distribution networks. Typically, these loads have similar proportions and are spread across a power grid. New methods are needed to evaluate harmonic distortions in systems with harmonic sources distributed. The goal of the project is to reduce the issues in power quality with the UPQC power improvement device installation. At the time of installation the gadget is capable of improving the power quality. Unwanted undar defect with THD of 6.02 percent is the system voltage and currents without UPQC. When using the UPQC with a PI controller, the voutput voltage remains balanced and minor distortions are still seen during fault situations in current waveforms, THD emits are decreased to 2.74%. The system's output voltage and currents are balance without distortion utilising the suggested hybrid controller with UPQC, and the THD is ultimately decreased to 0.08%. The study thus confirms that, in comparison to current models, the suggested UPQC hybrid controller produced superior outcomes.

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