UNIFIED POWER FLOW CONTROLLER USING A POWER ELECTRONICS INTEGRATED TRANSFORMER

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ABSTRACT:

This paper presents a Unified Power Flow Controller (UPFC) application of the Custom Power Active Transformer (CPAT); a power electronics integrated transformer which provides services to the grid through its auxiliary windings. The CPAT structure integrates three single-phase transformers into one shunt-series combining transformer. This integration empowers a sub-station with the capability of dynamically regulating the terminal voltage and current of a transformer through isolated power electronics converters. This paper investigates the CPAT's capability to provide UPFC services which includes power flow control, reactive power compensation, voltage regulation and harmonics elimination. Moreover, the impact of the CPAT-UPFC during load perturbations on the power system is investigated to further validate its transient and steady-state response. Furthermore, an experimental prototype reveals the operation of the three-phase CPAT-UPFC confirming its stable operation according to the theoretical expectations.

Keywords - Power transformers, Magnetic circuits, Power control, Power transmission.

I INTRODUCTION

The increased demand for distributed generation to facilitate momentous contributions to the grid has faced several challenges and technical issues. Owing to the intermittent behavior of renewable generation and the ever growing need of electrical energy, the construction and operation of substations has undergone several developments to address these challenges [1]. To guarantee a reliable, sustainable and intelligent electric network, integration of monitoring and control functionalities throughout the power system have evolved to respond to such demands [2]. Such functionalities have been commissioned through power electronics converters that has proven several beneficial impacts on the distribution network [3-5] and transmission network [6-8]. Flexible AC Transmission Systems (FACTS) have proven their capability in providing services to effectively support the transmission and distribution systems, increasing their reliability, quality and stability [9]. Among such devices, the UPFC is considered the most versatile device to reduce line congestion and increase existing lines capacity. Connection of power electronics converters to provide UPFC services have either been achieved through bulky isolation transformers, complex multilevel topologies or back-to-back converters handling the rated line power . Transformer-less approaches involving multilevel topologies arises from the need of eliminating requirement of bulky isolation transformers. However, such topologies handle the full rated line voltage which typically requires a complex configuration. The use of transformers to connect shunt and series power electronic devices to the power system is an effective solution due to the isolation they provide. However, size, cost and footprint are another concern when considering high power compensation systems. To address such concerns, the integration of power electronic devices in a typical transformer has been observed in recent literature aiming for the use of off-the-shelf converters or construction of a power electronics-based transformer . However, these approaches have either addressed one type of compensation specific applications or require high power and complex architectures .

II POWER QUALITY AND ITS PROBLEMS

Electric systems and grids are complex dynamic systems. These systems suffer usually from unexpected or sudden changes of the currents and voltages. These changes are due mainly to the different types of linear and non-linear loads to which they are connected. In addition, to different types of accidents which can intervener into the grid. With the increasing use of power semiconductors in the most of industrial and domestic procedures, the electric grids are polluted with different harmonic currents and voltages. These harmonics affect the normal function of the most of the grid connected devices; in addition to considerable economic losses. Many classic and modern solutions have been proposed in the literary for the harmonic problems. In this chapter, the harmonic problem as one of the most common power quality problems will be presented. The different modern and traditional solutions will then be discussed.

Definition of Power Quality

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment." As appropriate as this description might seem, the limitation of power quality to "sensitive electronic equipment" might be subject to disagreement. Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

A simpler and perhaps more concise definition might state: "Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy." This definition embraces two things that we demand from an electrical device: performance and life expectancy. Any power-related problem that compromises either attribute is a power quality concern.

Power quality can also be defined as a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. Power distribution systems should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in power systems, especially the distribution systems have many nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the pure sinusoidal waveform is lost. This ends up producing many power quality problems.

Power Systems Distortion and Problems

In power systems, different voltage and current problems can be faced. The main voltage problems can be summarized in short duration variations, voltage interruption, frequency variation, voltage dips and harmonics. Harmonics represent the main problem of currents of power systems.

Voltage Variation for Short Duration

The short duration voltage variation is the result of the problems in the function of some systems or the start of many electric loads at the same time. The defaults can increase or decrease the amplitude of the voltage or even cancel it during a short period of time. The increase of voltage is a variation between 10-90% of the nominal voltage. It can hold from half of a period to 1 minute according to the IEEE 1159-1995. According to the same reference, the increase in voltage is defined when the amplitude of the voltage is about 110-180% of its nominal value.

Voltage Interruption

The cutoff of the voltage happens when the load voltage decreases until less than 10% of its nominal value for a short period of time less than 1 minute. The voltage interruption can be the effect of defaults in the electrical system, defaults in the connected equipment's or bad control systems. The main characteristic of the voltage interruption is the period over which it happens.

Frequency Variations

In the normal conditions the frequency of the distribution grid must be within the interval 50±1 Hz. The variations of the frequency of the grid can appears to the clients who are using auxiliary electric source (solar system, thermal station…etc.). These variations are rare and happen in the case of exceptional conditions like the defaults in the turbines.

Unbalance in Three Phase Systems

The three phase system is unbalanced when the currents and voltages are not identical in amplitude; or when the phase angle between each two phases is not 120°. In the ideal conditions, the three phase system is balanced with identical loads. In reality, the loads are not identical, in addition to the problems of the distribution grids which can interfere.

Voltage Dips

The voltage dips are periodic perturbations. They appear as a natural effect of the switching of the transistors. They are due also to the start of big loads like motors. Lifts, lights, heaters…etc. this phenomena causes bad functioning of the protection equipment's.

Harmonics

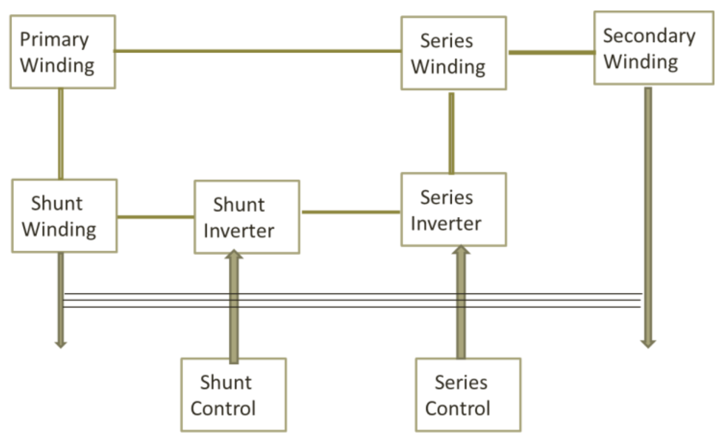
Power systems are designed to operate at frequencies of 50 or 60 Hz. However, certain types of loads produces currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These frequencies components are a form of electrical pollution known as harmonic distortion. There are two types of harmonics that can be encountered in a power system.

- ❖ Synchronous harmonics.
- ❖ Asynchronous harmonics.

Synchronous harmonics are sinusoids with frequencies which are multiples of the fundamental frequency. The multiplication factor is often referred to as the harmonic number. The synchronous harmonics can be subdivided into two categories.

- ❖ Sub-harmonics: when the harmonic frequency is less than the fundamental frequency.
- ❖ Super harmonics: when the harmonic frequency is more than the fundamental frequency.

III BLOCK DIAGRAM



IV UPFC

Overview

Shunt active power filter compensates current harmonics by injecting equal-but-opposite harmonic compensating currents into the grid. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non-linear load and the active power filter as an ideal resistor. The current compensation characteristics of the shunt active power filter is shown in Fig.

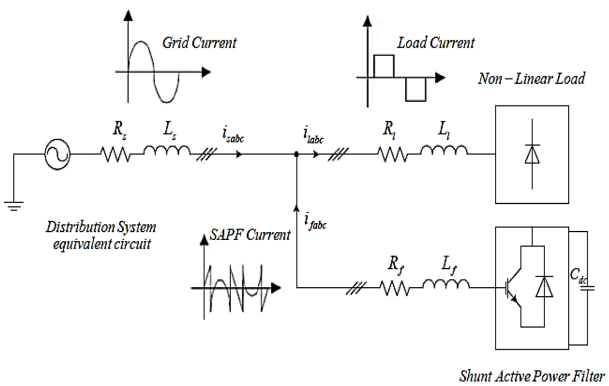


Fig. 1 Compensation Characteristic of Shunt Active Power Filter

Harmonic Current Extraction Methods

The aim of active power filtering is to compensate the harmonic currents produced by the non-linear loads, and to ensure the sinusoidal form of grid currents and voltages. The first step in active filtering is the harmonic currents extraction to be injected into the grid. The good extraction of harmonics is a keyword for a good active power filtering. Many extraction methods were proposed in literary. They can be divided into two families: the first family uses the Fast Fourier Transform (FFT) in the frequency domain to extract the current harmonics. The main disadvantages of this method are the bad results in transient, the heavy amount of calculations, and the use of considerable memory. In addition to a delay in the extraction of harmonics which can be at least one period.

The second family is based on the time domain calculations in the extraction of harmonics. Some of its methods are based on the instantaneous active and reactive power. Others are based on the calculation of direct and indirect current components. Recently, the neural networks and the adaptive linear neural networks have been used in the extraction of harmonic components of current and voltage.

Instantaneous Active and Reactive Power Theory

Most APFs have been designed on the basis of instantaneous active and reactive power theory (p-q), first proposed by Akagi et al in 1983. Initially, it was developed only for three-phase systems without neutral wire, being later worked by *Watanabe* and

Aredes for three-phase four wires power systems. The method uses the transformation of distorted currents from three phase frame *abc* into bi-phase stationary frame $\alpha\beta$. The basic idea is that the harmonic currents caused by nonlinear loads in the power system can be compensated with other nonlinear controlled loads. The p-q theory is based on a set of 31 instantaneous powers defined in the time domain. The three-phase supply voltages (u_a, u_b, u_c) and currents (i_a, i_b, i_c) are transformed using the Clarke (or α-β) transformation into a different coordinate system yielding instantaneous active and reactive power components. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame. The Clarke transformation for the voltage variables is given by

$$\begin{bmatrix} u_\propto \\ u_\beta \\ u_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad (1)$$

Similarly, this transform can be applied on the distorted load currents to give:

$$\begin{bmatrix} i_{l\propto} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (2)$$

The instantaneous active power *p(t)* is defined by:

$$p(t) = u_a i_{la} + u_b i_{lb} + u_c i_{lc} \quad (3)$$

This expression can be given in the stationary frame by:

$$\begin{cases} p(t) = u_\propto i_{l\propto} + u_\beta i_{l\beta} \\ p_o(t) = u_o i_{lo} \end{cases} \quad (4)$$

Where, *p(t)* is the instantaneous active power, *p0(t)* is the instantaneous homo-polar sequence power. Similarly the instantaneous reactive power can be given by:

$$q(t) = -\frac{1}{\sqrt{3}}[(u_a - u_b)i_{lc} + (u_b - u_c)i_{la} + (u_c - u_a)i_{lb}] = u_\propto i_{l\beta} - u_\beta i_{l\propto} \quad (5)$$

It is important to notice that the instantaneous reactive power *q(t)* signify more than the simple reactive power. The instantaneous reactive power take in consideration all the current and voltage harmonics, where as the habitual reactive power consider just the fundamentals of current and voltage.

From equations (4) and (5) the instantaneous active and reactive power can be given in matrix form by:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_{\propto} & u_{\beta} \\ -u_{\beta} & u_{\alpha} \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \qquad (6)$$

In general, each one of the active and reactive instantaneous power contains a direct component and an alternating component. The direct component of each presents the power of the fundamentals of current and voltage. The alternating term is the power of the harmonics of currents and voltages.

In order to separate the harmonics from the fundamentals of the load currents, it is enough to separate the direct term of the instantaneous power from the alternating one. A Low Pass Filter (LPF) with feed-forward effect can be used to accomplish this task. Fig. 2 shows the principle of this extraction filter.

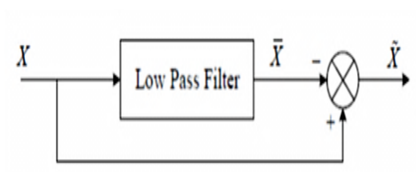


Fig. 2 Diagram of the Low Pass Filter with Feed-Forward.

After the separation of the direct and alternating terms of instantaneous power, the harmonic components of the load currents can be given using the inverse of equation (6) which gives:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{v_{s\propto}^2 + v_{s\beta}^2} \begin{bmatrix} v_{s\propto} & -v_{s\beta} \\ v_{s\beta} & v_{s\alpha} \end{bmatrix} \begin{bmatrix} \tilde{p}_l \\ \tilde{q}_l \end{bmatrix} \quad (7)$$

Where, the "$\sim$ "sign points to the alternating. The APF reference current can be then given by:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \tilde{\imath}_{l\alpha} \\ \tilde{\imath}_{l\beta} \end{bmatrix} \qquad (8)$$

Fig. 3. presents the principle of the active and reactive instantaneous power. This method offers the advantage of the possibility of harmonic compensation and/or reactive power compensation. In the case of reactive power compensation it is enough to send the reactive power q(t) directly to the reference current calculation bloc without the use of any extraction filter.

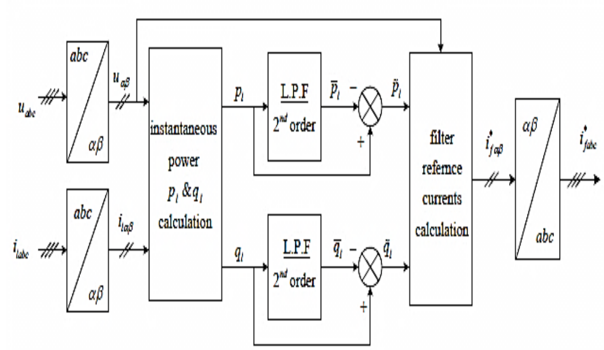


Fig. 3 Principle of Instantaneous Active and Reactive Power Theory.

Voltage Source Inverter

Voltage source inverters (VSI) are one of the most important applications of power electronics. The main purpose of these devices is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. The important development of VSI is a result, from the one hand to the development of fast, controllable, powerful, and robust semi-conductors, from the other hand to the use of the so-called pulse width modulation (PWM) techniques. In the high power applications, the three level VSIs are the most adopted in comparison with two levels ones. Because the THD of the output voltage and current of the three levels VSI is clearly lower.

The standard three-phase VSI topology is shown in Fig. It is composed of three legs with current reversible switches, controlled for the open and close. These switches are realized by controlled switches (GTO or IGBT) with anti-parallel diodes to allow the flow of the free-wheeling currents.

The switches of any leg of the inverter (T1 and T4, T2 and T5, T3 and T6) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity.

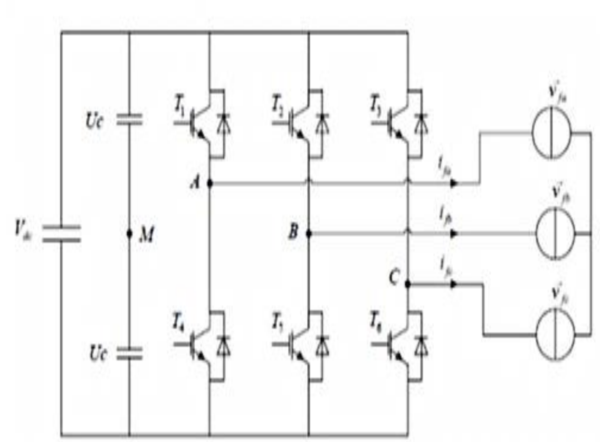


Fig. 4 Three-phase Two Levels VSI Topology

(A) Modeling of Voltage Source Inverter

The output of the VSI which is shown in Fig. 3.4 can take two levels of voltage ($+V_{dc}$, $-V_{dc}$) dependent on the dc source voltage and the switches states. Actually, the control of the two switches on the same leg is complementary: the conduction of one of them implies the blocking of the other.

The state of each one of the switches is defined by the control signals (S_a, S_b and S_c) as follow:

$$S_a = \begin{cases} 1 \; if \; T_1 close \, , T_4 open \\ 0 \; if \; T_1 open \, , T_4 close \end{cases}$$

$$S_b = \begin{cases} 1 \; if \; T_2 close \, , T_5 open \\ 0 \; if \; T_2 open \, , T_5 close \end{cases}$$

$$S_c = \begin{cases} 1 \; if \; T_3 close \, , T_6 open \\ 0 \; if \; T_3 open \, , T_6 close \end{cases}$$

B) Modeling of Active Power Filter

The connection of the shunt active power filter to the point of common coupling of the grid is done mostly by the mean of a RL low pass filter as shown in Fig. 1. The voltage equation for each phase can be given by:

$$v_{sk} = v_{fk} - v_{L_{fk}} - v_{R_{fk}}$$

$$v_{fk} - L_f \frac{di_{fk}}{dt} - R_f i_{fk} \text{ , k=a,b,c} \quad (9)$$

The three phase equations are then given by:

$$L_f \frac{d}{dt} \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} = -R_f \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} + \begin{bmatrix} v_{fa} \\ v_{fb} \\ v_{fc} \end{bmatrix} - \begin{bmatrix} s_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \quad (10)$$

And for the dc side:

$$C_{dc} . \frac{dV_{dc}}{dt} = S_a i_{fa} + S_b i_b + S_c i_f \quad (11)$$

The equation system defining the SAPF in the three phase frame is then given by:

$$\begin{cases} L_f \frac{di_{fa}}{dt} = -R_f i_{fa} + v_{fa} - v_{sa} \\ L_f \frac{di_{fb}}{dt} = -R_f i_{fb} + v_{fb} - v_{sb} \\ L_f \frac{di_{fc}}{dt} = -R_f i_{fc} + v_{fc} - v_{sc} \end{cases} \quad (12)$$

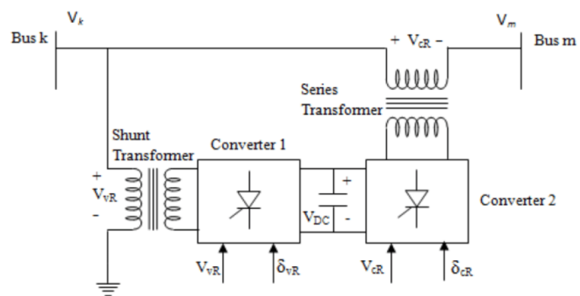


Fig. 5 Unified Power Flow Controller

C) Control Methods of VSI

The aim of the control of the VSC is to force the output currents of the inverter to follow their predefined reference currents. The main principle is based on the comparison between the actual current of the filter with the reference currents generated by the different extraction methods. In the next section, we are going to discuss some different methods in VSC control.

D) Hysteresis Control Method

The current control strategy plays an important role in fast response current controlled inverters such as the active power filters. The hysteresis current control method is the most commonly proposed control method in time domain. This method provides instantaneous current corrective response, good accuracy and unconditioned stability to the system. Besides that, this technique is said to be the most suitable solution for current controlled inverters.
Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current waveform.

The basic structure of PWM voltage source inverter with hysteresis controller is shown in Fig. 6. The hysteresis control strategy aims to keep the controlled current inside a defined rejoin around the desired reference current. The status of the switches is determined according to the error. When the current is increasing and the error exceeds a certain positive value, the status of the switches changes and the current begins to decrease until the error reaches a certain negative value, then the switches status changes again.

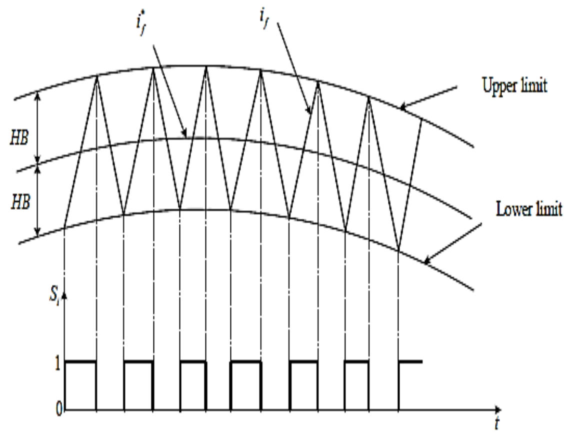


Fig. 6 Hysteresis Control Principle

In the fix hysteresis band control of the VSI, the switching frequency is a function of the derivative of the output current. This one depends on the value of the inductance of the decoupling filter and the voltage drop around it. It is important to notice that the coupling filter affects the switching frequency and the dynamic behavior of the active filter. The simple implementation procedure is the main advantage of this control method. However, the variable switching frequency is the major draw-back of this method. This variable frequency affects mainly the function of power electronic elements which can’t support high switching frequency in high power applications. In order to solve the problem of variable switching frequency, a new hysteresis control strategies like “modulated hysteresis control” and “variable hysteresis band” were proposed. In the modulated hysteresis control it is difficult to define the hysteresis band width. Over more, the fix switching frequency achieved using this method affects the rapidity obtained by hysteresis control.

E) Sinusoidal Pulse Width Modulation (SPWM) Control

The control techniques based on the PWM solve the problem of switching frequency of the VSI. They use a fix switching frequency which makes it easier to cancel the switching harmonics. The PWM can be realized using different techniques such as carrier based PWM, PWM with harmonics minimization, and space vector PWM. The carrier PWM can be natural PWM, symmetric PWM, and asymmetric PWM.

The most simple and well known PWM technique is the sinusoidal PWM. This technique uses a controller which determines the voltage reference of the inverter from the error between the measured current and its reference. This reference voltage is then compared with a triangular carrier signal (with high frequency defining the switching frequency). The output of this comparison gives the switching function of the VSI. The choice of the ratio between the frequency of the reference signal and the frequency of the carrier signal is very important in the case of symmetric and periodic reference. As a consequence, in the case of sinusoidal reference, the ratio between the two frequencies must be integer to synchronize the carrier with the reference. Over more, it is preferable that the carrier frequency be odd to conserve the reference symmetry. In all cases this ratio must be sufficiently high to ensure the fast switching and to take the switching harmonics away from the fundamental produced by the inverter.

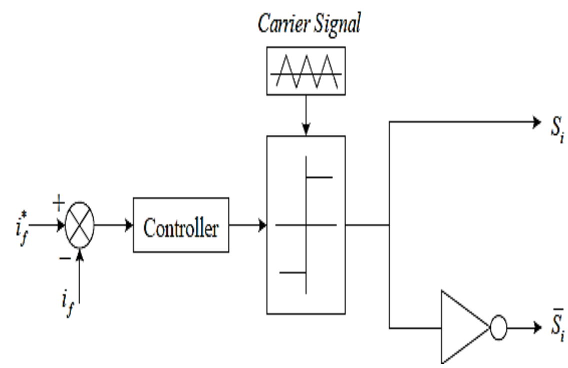


Fig. 7 The Principle of Sinusoidal PWM Control Method

Recently, new control techniques called space vector PWM were implemented. The difference between this technique and the sinusoidal technique is that it doesn't use carrier signal to define switching orders.

F) Space Vector PWM Control (SVPWM)

Space vector modulation technique was first introduced by German researchers in the mid of 1980s. This technique showed several advantages over the traditional PWM technique and has been proven to inherently generate superior PWM waveforms. By implementing the SVM technique, the number of switching is reduced to about 30% at the same carrier frequency of the sinusoidal pulse width modulation (SPWM) method. It offers better DC bus utilizations with lower THD in the AC current and reduces of switching losses too. The maximum modulation index for the SPWM method is 0.785 with the sinusoidal waveform between the phase and the neutral current of the system. However, the modulation index can be increased to 0.907 for the SVPWM.

The basic principle of the SVM technique is that it treats the inverter as a whole unit, which is different when compared to PWM technique. This technique is based on the decomposition of a reference voltage vector into voltage vector realizable on a six pulse inverter.

The SVPWM technique is widely used in inverter and rectifier controls. Compared to the sinusoidal pulse width modulation (SPWM), SVPWM is more suitable for digital implementation and can increase the obtainable maximum output voltage with maximum line voltage approaching 70.7% of the DC link voltage (compared to SPWM's 61.2%) in the linear modulation range. Moreover, it can obtain a better voltage total harmonic distortion factor. There are different algorithms for using SVPWM to modulate the inverter or rectifier. Many SVPWM schemes have been investigated extensively in literatures. The goal in each modulation strategy is to lower the switching losses, maximize bus utilization, reduce harmonic content, and still achieve precise control.

In the SVPWM scheme, the 3-phase output voltage is represented by a reference vector which rotates at an angular speed of $\omega = 2\pi f$. The task of SVM is to use the combinations of switching states to approximate the reference vector. To approximate the locus of this vector, the eight possible switching states of the inverter are represented as 2 null vectors and 6 active vectors.

V. SIMULATION RESULTS

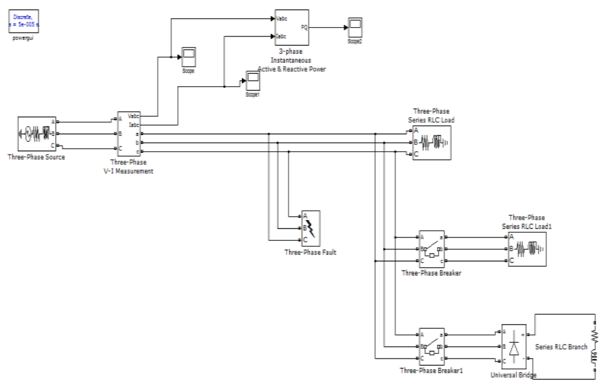


Fig .8 proposed circuit without UPFC

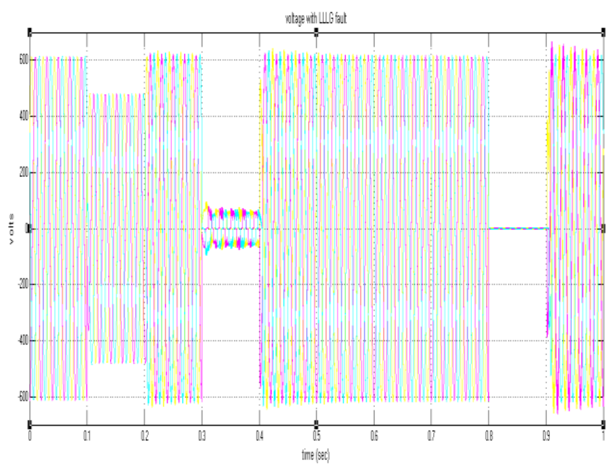


Fig .9 Output voltage without UPFC

The system without UPFC experiences a voltage disturbance when a LLLG fault occurred this effects the system power quality.

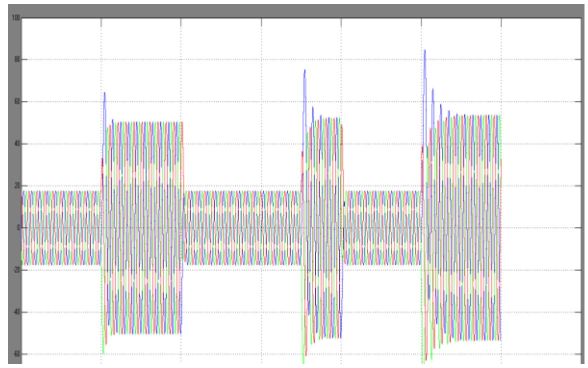


Fig .10 Output current waveform

A high current is observed under LLLG fault condition to the circuit with PI controller. This increases the system loses and effects the quality of power supply.

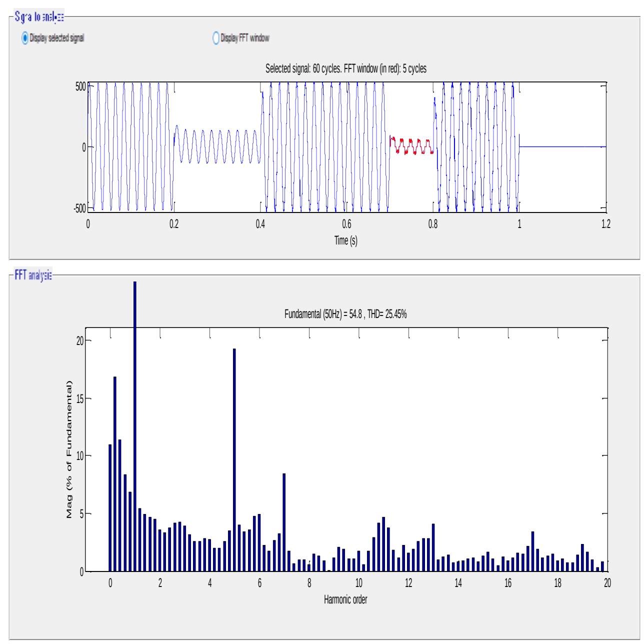


Fig .11 THD with PI controller

The above graph clearly describes the THD of the system with PI controller. It is observed a total harmonic distortion of 25.45%.

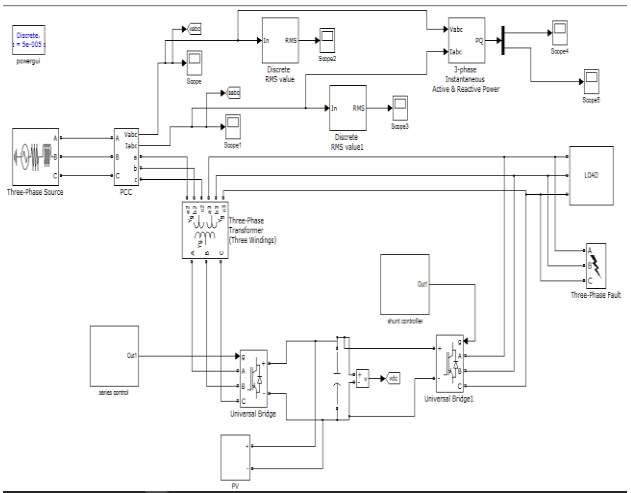


Fig .12 Simulation circuit with UPFC

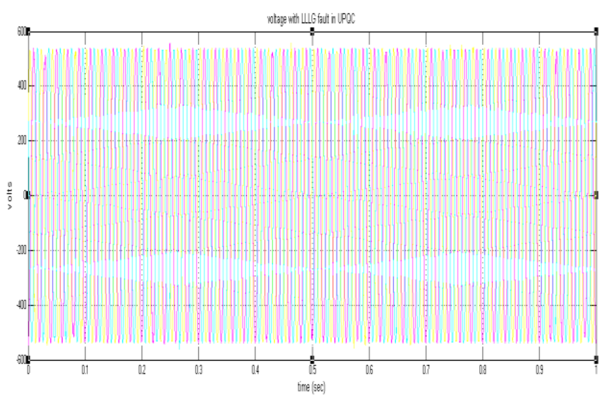


Fig .13 Output voltage waveform

The system with UPFC has generated a stabilized output voltage waveform without any distortions maintained during the LLLG fault condition.

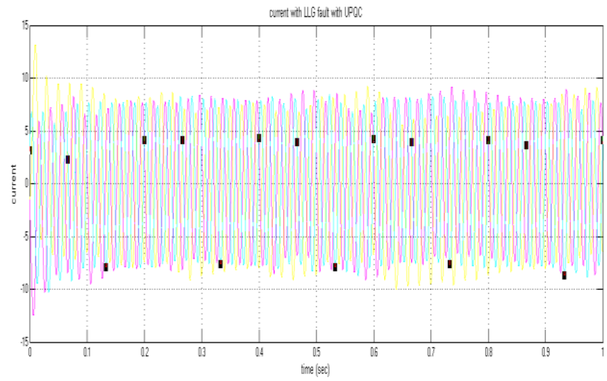


Fig .14 Output current waveform

The current waveform is still have some distortions under LLLG fault condition with UPFC Controller. This effects the system parameters.

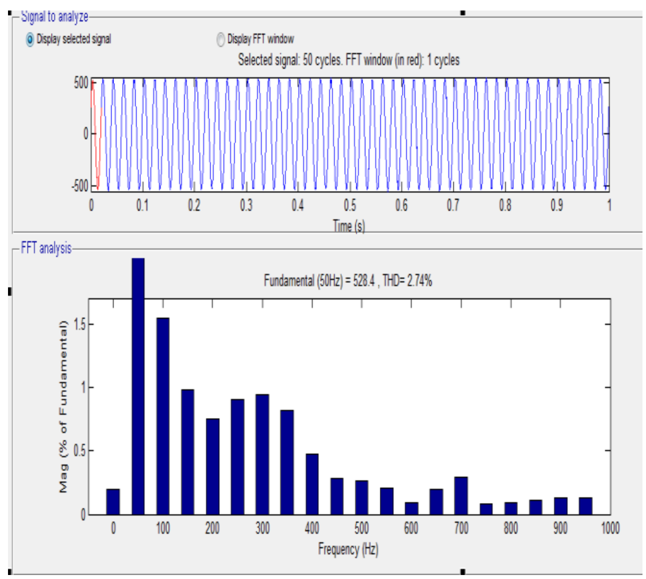


Fig .15 THD with UPFC

The THD of the system with UPFC controller has reduced the THD of 25.45% to 2.74%. this clearly shows that UPFC has achieved high efficiency when compared to the PI controller.

VI.CONCLUSION

A noticeable trend in distribution systems is the emergence of distributed harmonic producing loads. These loads typically have comparable sizes and are distributed all over an electric network. There is a need to develop new techniques to assess harmonic distortions for systems with distributred harmonic sources. The objective of the project is to minimize the power quality problems with the implementation of power quality enhancement device UPFC. This device has the capacity to improve the power quality at the point of installation. Without UPFC the system voltage and currents are unbalanced undar fault condition with THD of 25.45%. When we applied UPFC with PI controller the vooutput voltage is balanced and still some distortions observed in current waveforms under fault conditions the THD isss reduced to 0.02%. Hence the analysis proves that the proposed Hybrid controller with UPFC achieved better results when compared to the existing models.

VII. REFERENCES

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