A Review on UPQC Based one Feeder and Double Feeder Distribution System for Power Quality Improvement

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Abstract–This paper present an encyclopedic review on the unified power quality conditioner (UPQC) to improve electric power quality. This is proposed to present a generous overview on the one feeder and double feeder distribution system. For pulse width modulation based sinusoidal pulse width modulation technic are present to improve the electric power quality.
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Keywords *– FACTS, UPQC, PWM, SPWM, THD*

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I. INTRODUCTION

Over the past few years, the growth in the use of nonlinear power electronics loads, like static rectifiers, adjustable speed drives, dc/ac converter, has caused many power quality problems like high current harmonics, poor power factor and maximum neutral current, etc. problems caused by power quality can have an adverse economic impact on utilities and customers. These problems can be resolved by the use of unified power quality conditioners (UPQCs). The UPQC, which is combination of the series and shunt active filters, is able to mitigate most of the power quality problems. This project is to design a UPQC for improvement of power quality in a power distribution system. A new control using pulse width

The first name of UPQC was universal power quality conditioning modulation (PWM) technique will be designed to improve the power quality problems. System (UPQS) named after unified power quality conditioner (UPQC), which is extended by adding a shunt active filter at the load side[1].

In recent years, Power engineers are increasingly concerned over the quality of the electrical energy. In present-day industries, load appliances uses electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is depressed and may mal-operate in other ways if harmonic Distortion of the supply voltage is maximum. Most of this current load equipment uses electronic switching devices which can contribute to poor network voltage duality. The competition in electrical power supply has created greater commercial awareness of the issues of power quality while equipment is readily available to measure the quality of the voltage waveform and so quantify the problem.

Along with advance technology, the organization of the worldwide economy has evolved towards globalization and the profit margins of many activities tend to decays. The increased in sensitivity of the vast majorof processes such as (industrial, other services and even residential areas) to power quality disturbancesturn the availability of electric power with quality a crucial factor for competitiveness in each sector. The regular process industry and the information technology services are most difficult area. Due to some variation, a large amount of financial losses may occur, with the consequent loss of productivity and competitiveness.

Many efforts have been taken by utilities to fulfill customer's fulfillment and some consumers require a higher level of power quality than the level provided by modern network of electrical supply. This mentions that some measures must be taken so that higher levels of Power Quality can be obtained.

The FACTS devices and Custom power devices are introduced to electrical system to improve the power quality of the electrical power system network. DVR, DSTATCOM, ACTIVE POWER FILTERs and UPQC etc. are some of the equipment's used toimprove the power quality of the voltage profile and current profile. For using FACTS devices to reduce the problems related to power quality [2].

Although all devices can improve the power quality but in this the proposed is on Unified Power Quality Conditioner.UPQC is a custom power device consisting of both DVR and D-STATCOM, departed is connected in series and recent is connected in parallel to protect the sensitive load from all disturbances.

Reliability of supply and power quality (PQ) is two most important facets of any power delivery system today [3]. Not so long ago, the main concern of consumers of electricity was the required continuity of power supply. Forever now-days, consumers want not only continuity of supply, but the quality of power is very essential to them too. The power quality problems in distribution and transmission power systems are not new, but customer alertness of these problems has recently increased. The power quality at the point of common coupling (PCC) with the utility grid is governed by the various standards and the IEEE-519 standard is widely accepted.

Utilities and researchers all over the world have for decades worked on the improvement of power quality. There are sets of conventional solutions to the power quality problems, whichhave continue for a long time. For this conventional result use passive elements and do not always respond correctly as the nature of the power system conditions change. The increased

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power capabilities, ease of control, and reduced price of modern semiconductor devices have made power electronic converters affordable in a large number of uses. New adjustable solutions too many power quality problems have become possible with the aid of these power electronic converters [5].

The power electronic based power conditioning devices can be effectively utilized to improve the quality of power supplied to customers [3].One most effective solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC) [9], which was first presented in ***1995 by Hirofumi Akagi.*** Such a solution can compensate for different power quality phenomena, such as: sags, swells, voltage fluctuations, flicker, harmonics and reactive currents etc.

UPQC is a combination of series and shunt active filters connected in cascade via a common dc link capacitor. The series active filter injects a voltage, which is added at the point of the common coupling (PCC) such that the load ends voltage remains unaffected by any voltage disturbance. The main objectives of the shunt active filter are: to compensate for the load reactive power demand and fluctuations', to cancel the harmonics from the supply current, and to regulate the common dc link voltage [6].

A unified power quality conditioner (UPQC) [2], is another mitigating device that is similar in construction to a unified power flow controller (UPFC). A UPFC is employed in power transmission system where as a UPQC is employed in a power distribution power system, to perform the shunt and series compensation together. But a UPFC only require providing balance shunt and/or series compensation, since an electrical power transmission system generally operates with balanced, distortion free environment. The primary objective of a UPFC is to control the flow of power at fundamental frequency only. On the other hand, a power distribution system may contain dc components, distortion, and unbalance. Therefore, a UPQC must operate under these environments while performing shunt and/or series compensation.

Quality of power supply has become an important issue with the increasing demand of distributed generation systems either connected to the conventional grid, smart grid or micro-grid. Power quality has become a research topic in power distribution system due to a significant increase of harmonic pollution caused by proliferation of nonlinear loads, use of rectifiers, switching power supplies and other line connected power converters. So to improve the voltage profile, stability of system, improvement of power quality, reduction in THD and reliability of power *etc.* The various ductile alternating currenttransmission systems (FACTS) are come in electrical network. The FACTS based application of power electronic devices effective for the power distribution systems to enhance the quality and the reliability of power delivered to the consumers [9].

II. SYSTEM DEVELOPMENT

2.1 Single Line Diagram of the UPQC for One Feeder System

A multi-level converter is proposed to increase the converter operation voltage, avoiding the series connection of switching elements. However, the multilevel converter is complex to Form the output voltage and requires an excessive number of back-connection diodes or flying capacitors or cascade converter. A basic form of multi-level UPQC is shown in Fig.2.1.

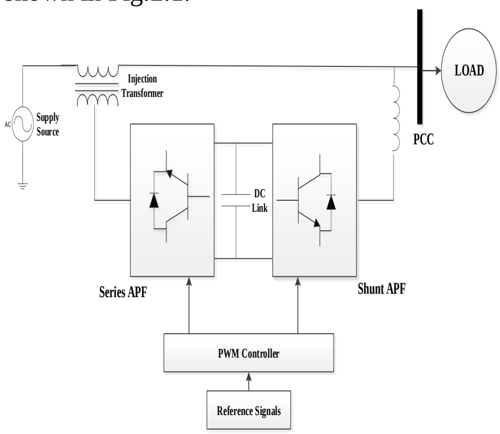

Fig.2.1: UPQC with controller arrangement

The multi converter UPQC consists of two VSC's. The two voltage source converters are connected with a commutation reactor and high-pass output filter to prevent the flow of switching harmonics in to the supply. The voltage source converters are controlled by pulse width modulation (PWM) techniques.

2.2 Single Line Diagram of the UPQC for Double Feeder System

In the two feeder distribution power system, it consists of two different substation supplies the loads L1 and L2. In two feeders UPQC consist of three VSCs which are connected in series with BUS1 and VSC2 is connected in shunt with load L1 at the end of feeder one. The VSC3 is connected series with BUS2 at the feeder two ends. In double feeder system three voltage source converters are connected with a commutation reactor and high-pass output filter are used to prevent the flow of switching harmonics in to the supply.

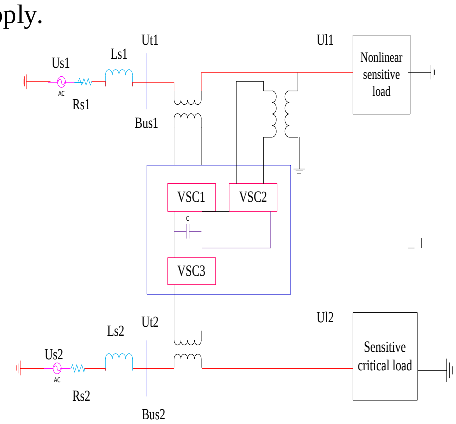

Fig.2.2: Double feeder UPQC System

The two feeder UPQC system are used

- To regulate the load voltage against sag/swell and disturbances in the system to protect the nonlinear/sensitive load L1 and L2.
- To compensate for the reactive and harmonics components of nonlinear load current.

In order to achieve the goals VSC1 and VSC3 operates as a voltage controller and VSC2 operates as a current controller.

2.3 Control Strategies of UPQC

Control strategy play very important role in performance of systems. For the control strategy of UPQC are classify in three stages:

1) Voltage and current signal are sensed
2) Voltage and current levels are derived in terms of compensating commands
3) The gating signals for semiconductor switches of UPQC are generated using PWM based control techniques.

In this project use the third method for control method of UPQC in time domain are based on instantaneous derivation of compensating commands in form of either voltage or current signal [45]. There are mainly two widely used times domain control technique of UPQC are:

- The instantaneous active and reactive power or p-q theory, and
- Synchronous reference frame method or d-q theory.

In p-q theory instantaneous active and reactive powers are derive, while, the d-q theory related with current independent of the supply voltage. Both method transform voltage and current from abc frame to stationary reference frame (p-q theory) or synchronously rotating frame (d-q theory) to separate the fundamental and harmonics quantities. In this method the gating signal for semiconductor switches of UPQC based on derive compensating commands in terms of voltage or current. Then, these compensating commands are given to PWM control technique. In this project synchronous reference frame theory are used to abc-dq0 transformation are describe below:

In electrical engineering, direct–quadrature–zero (or dq0 or dq0) transformation or zero–direct–quadrature (or 0dq or 0dq) transformation is a mathematical transformation that rotates the reference frame of three-phase systems in an effort to simplify the analysis of three-phase circuits. The dq0 transform presented here is exceedingly similar to the transform first proposed in 1929 by Robert H. Park. In fact, the dq0 transform is often referred to as Park's transformation. In the case of balanced three-phase circuits, application of the dq0 transform reduces the three AC quantities to two DC quantities. Simplified calculations can then be carried out on these DC quantities before performing the inverse transform to recover the actual three-phase AC results. It is often used in order to simplify the analysis of three-phase synchronous machines or to simplify calculations for the control of three-phase inverters. In analysis of three-phase synchronous machines the transformation transfers three-phase stator and rotor quantities into a single rotating reference frame to eliminate the effect of time varying inductance.

Following steps are carried out to perform the synchronous reference frame theory:

Step.1. Transformation of stationary Three phase a,b,c to stationary two phase i.eα β

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$i_\alpha = \sqrt{\frac{2}{3}}\left[i_a + \left(\frac{-1}{2}\right) i_b + \left(\frac{-1}{2}\right) i_c\right]$$

$$i_\beta = \sqrt{\frac{2}{3}}\left[0 + \left(\frac{\sqrt{3}}{2}\right) i_b + \left(\frac{-\sqrt{3}}{2}\right) i_c\right]$$

Step.2. Transformation of stationary two phase i.e. α-β to Rotating two phase i.e d-q frame.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

$$i_d = [\cos\theta\, i_\alpha + \sin\theta\, i_\beta]$$

$$i_q = [-\sin\theta\ i_\alpha + \cos\theta i_\beta]$$

Step.3. After determination of d-q current, the d-q current consist AC and DC parts. DC part represent Fundamental component and AC represent harmonics component. This harmonics component can be extracted by Low Pass Filter.

Step.4. Conversion ofrotating d-q frame to stationary α-β. Here inverse Transformation is used.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} cos\,\theta & -sin\,\theta \\ sin\,\theta & cos\,\theta \end{bmatrix} \begin{bmatrix} i_{dh} \\ i_q \end{bmatrix}$$

$$i_\alpha = [\cos\theta\, i_{dh} - \sin\theta\, i_q]$$

$$i_\beta = [\sin\theta\ i_{dh} + \cos\theta i_q]$$

Step.5. Conversion of stationary two phase to the stationary three phase a-b-c to get the reference current.

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = [T_{abc}] \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix}$$

$$[T_{abc}] = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

$$i_{ca}^* = \sqrt{\frac{2}{3}}\left[i_\alpha + (0) i_\beta + \left(\frac{1}{\sqrt{2}}\right) i_0\right]$$

$$i_{cb}^* = \sqrt{\frac{2}{3}}\left[\left(\frac{-1}{2}\right) i_\alpha + \left(\frac{\sqrt{3}}{2}\right) i_\beta + \left(\frac{1}{\sqrt{2}}\right) i_0\right]$$

$$i_{cc}^* = \sqrt{\frac{2}{3}}\left[\left(\frac{-1}{2}\right) i_\alpha + \left(\frac{-\sqrt{3}}{2}\right) i_\beta + \left(\frac{1}{\sqrt{2}}\right) i_0\right]$$

According to control objective of the multi converter UPQC, to maintain the load voltage for sinusoidal in nature with constant amplitude even for the bus voltage is disturbed.

Where the load voltage in the abc reference frame is

$$u_{l-abc}^{exp} = \begin{bmatrix} U_m \cos(wt) \\ U_m \cos(wt - \frac{2\pi}{3}) \\ U_m \cos(wt + \frac{2\pi}{3}) \end{bmatrix}$$

For the compensating reference voltage is transferred back into the abc reference frame.

For the measured load current are transformed into synchronous dq0 reference frame where the transformation matrix is

$$[F_{dq0}] = T_{dq0}(\mathrm{wt})[F_{abc}]$$

$$T_{abc}^{dq0} = \frac{2}{3}\begin{bmatrix} \cos(wt) & \cos(wt - \frac{2\pi}{3}) & \cos(wt + \frac{2\pi}{3}) \\ -\sin(wt) & -\sin(wt - \frac{2\pi}{3}) & -\sin(wt + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

By this transform, for the positive-sequence fundamental component, which is transformed into dc quantities in the d and q axes, can be easily extracted by low-pass filter. For the above equation it is clear that there are no harmonics and reactive components in the feeder current. It can be shown that for the inverse transformation we can write

$$[F_{abc}] = T_{dq0}(wt^{-1})[F_{abc}]$$

Where the inverse of park's transformation matrix is given by

$$T_{dq0}(wt^{-1}) = \begin{bmatrix} \cos(wt) & \sin(wt) & 1 \\ \cos(wt - \frac{2\pi}{3}) & \sin(wt - \frac{2\pi}{3}) & 1 \\ \cos(wt + \frac{2\pi}{3}) & \sin(wt + \frac{2\pi}{3}) & 1 \end{bmatrix}$$

2.4 Pulse Width Modulation

In Pulse Width Modulation (PWM) technique the switching signal [4] is generated by comparing fundamental reference signal with a carrier wave of required switching frequency. The frequency of reference signal determines the frequency of fundamental output wave and its peak amplitude controls the modulation index. The switching signal generation using carrier-PWM (sine PWM) technique is shown in Fig.

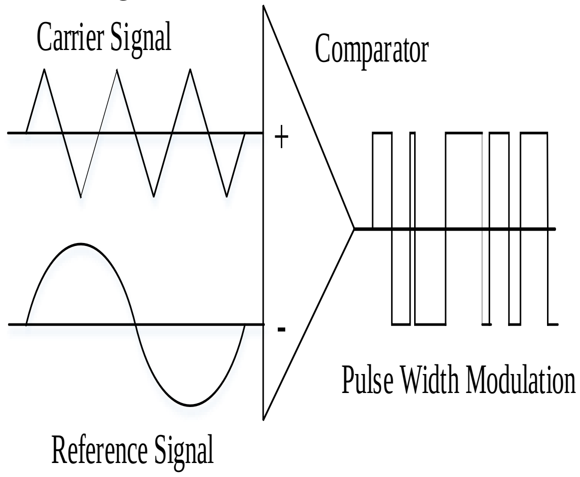

Fig. 2.4: Principle of PWM Generation

2.5 Sinusoidal Pulse Width Modulation

The pulse width modulation technique is classified as according to multilevel modulation and switching frequency such as:

- SPWM
- Space Vector PWM

From the above mentioned PWM control methods, the sinusoidal pulse width modulation (SPWM) is applied in the proposed system since it has various advantages over other techniques. Sinusoidal PWM inverters provide an easy way to control amplitude, frequency and harmonics contents of the output voltage.

The SPWM technique is further classified as PD, POD and APOD. These methods generate similar ac-side phase and line voltage wave-forms. However, the PD technique generates a relatively lower total harmonic distortion. The carriers have the same frequency f_c and the same peak to peak amplitude A_c. Gating signals are generated by comparing the sinusoidal waveform with carrier waveform. The SPWM techniques are the most widely used technique in industrial application

2.5.1 Phase Disposition (PD)

The carrier based pulse width modulation scheme, namely phase disposition (PD) are presented. This technique takes advantages of special properties available in inverter to mitigate total harmonics distortion (THD) and increase output voltage. The PD control scheme is represented in Fig.Gating signals for each phase is generated by comparing the sinusoidal waveform with carrier waveforms. The phase disposition, where all carrier are in phase. Fig. 2.5 shows a waveform of SPWM control scheme with Phase Disposition (PD) carrier waves. The nature of inverter output voltage along with carrier and fundamental wave is shown in Fig.6.6 for SPWM with PD.

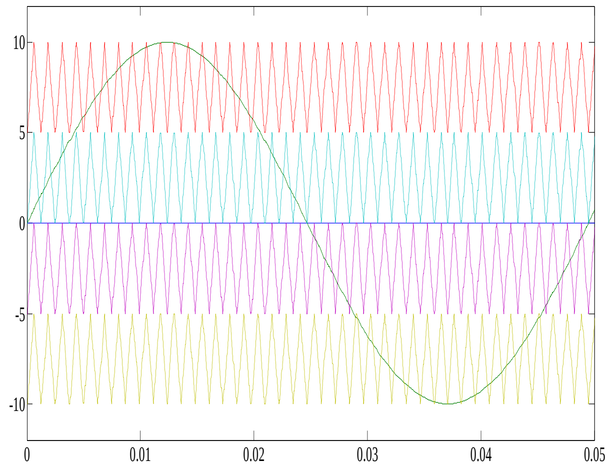

Fig.2.5: SPWM PD Control Scheme

III. CONTROLLER OF UPQC

The controller of Unified Power Quality Conditioner are describe the how to generate signals for both series and shunt part of UPQC. Fig. shows the reference signal generation using synchronous reference theory. The synchronous reference theory is most commonly used time domain control technique is synchronously rotating reference frame (SRF) or d-q theory. In this theory the fundamental quantities are converted into dc quantities and the oscillating component which represent the harmonics content. The following model are develop in mat lab Simulink are shows the SRF theory and inverse transformation are explain in previous point.

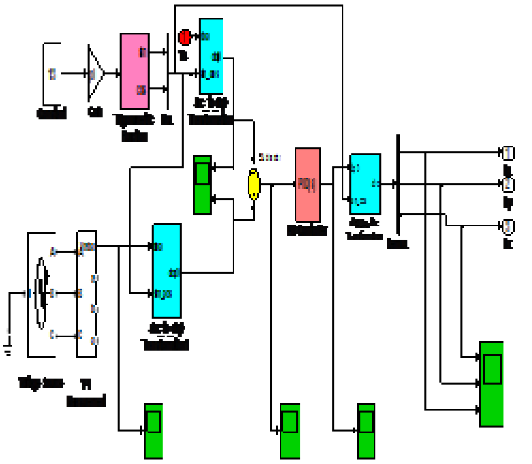

Fig. 3.1: Reference Signal Generation using Synchronous Reference Theory

3.1 Gate Signal Generation using PWM Technique

Fig. shows the control scheme algorithm for sinusoidal pulse width modulation (SPWM) Technique is used for gate signal generation using PWM technique. In this reference signals are compare with carrier signals to generate gate pulses for multi-level inverter. In which sinusoidal reference voltage waveform signal from transformation comparison scheme with repeating sequence triangular wave block compare with relational operator and generated the pulses output. This model is developing in mat lab Simulink and subsystem of controller.

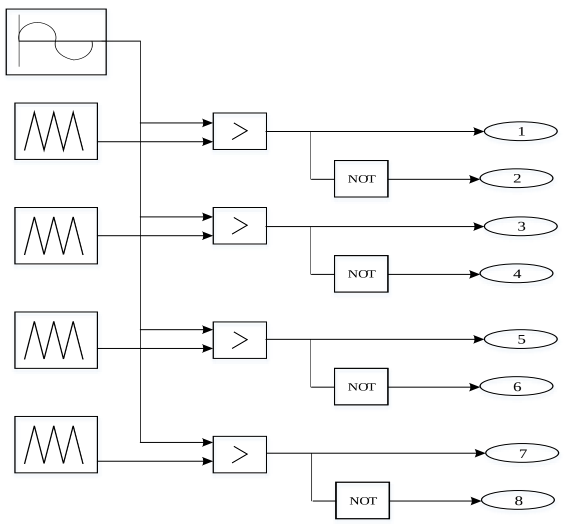

Fig. 3.2: Gate Signal Generation using PWM Technique

3.2 IGBT Based Voltage Source Inverter

The Insulated Gate Bipolar Transistor (IGBT) is power electronics device which has minority-carrier device with high input impedance and large bipolar current-carrying capability. It is also called as voltage-controlled bipolar device because many designers view IGBT as a device with MOS input characteristics and bipolar output characteristic. To make use of the advantages of both power MOSFET and BJT, the IGBT has been introduced. The IGBT is suitable for much application in power electronics, especially in Pulse Width Modulation (PWM) servo and three-phase drives requiring high dynamic range control and low noise. The IGBT improve dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuit. For IGBT is available for both low conduction loss and low switching loss.

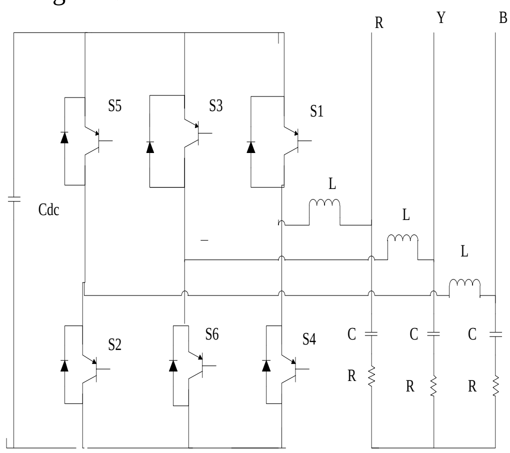

Fig. 3.3: Schematic structure of a VSC

Following is design propose model of IGBT based voltage source inverter in mat lab Simulink using above concept. The inverter parameter are designed IGBT based, 3-arm, 6-pulse and carrier frequency are 2 KHZ.

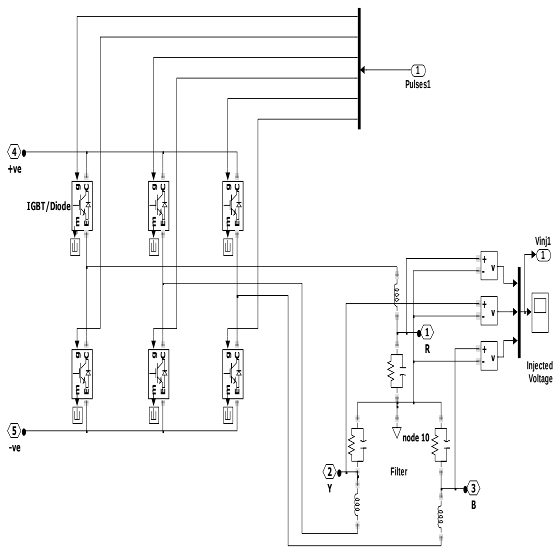

Fig. 3.4: VSI in mat lab Simulink

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IV. SYSTEM PARAMETER

Table 4.1: System Parameter of Unified Power Quality Conditioner

Sr.No.	System Quantities	Standards
1	Source	3-phase, 33 KV, 50 Hz
2	Source Impedance	R = 4 Ohm, L = 1.0001×10^{-6} H Z = 0.1 Ohm, wt = 5.730×10^{-4}
3	Inverter Parameter	IGBT Based, 3-arm, 6-pulse, Carrier Frequency = 2 KHz
4	PID Controller	K_P = 0.20, K_i = 0.02, K_d= 0.032
5	Transformer 1	10 MVA, 33 KV,50 Hz
6	Transformer 2	10 MVA, 33 KV/66 KV, 50 Hz
7	Line Impedance	R = 4 Ohm, L = 110×10^{-6} Z = 4.00 Ohm, wt = 1.575×10^{-3}
8	RL Load	R = 500 Ohm, L = 800×10^{-3} H

CONCLUSION

After this review we realized that the sinusoidal pulse width modulation control technique are very promising solution for reference current and voltage signal generation for series active filter and shunt active power filter. The UPQC is one of custom power device to compensate supply voltage power quality issues such as sags, swells, unbalance, flicker, harmonics and for load current power quality problems such as harmonics, unbalance, reactive current etc.

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BIOGRAPHIES

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