Performance Analysis of Seven Level UPQC For Voltage Regulation

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Abstract-In emerging electric power systems, increased transactions often lead to the situations where the system no longer remains in secure operating region. The flexible Ac transmission system (FACTS) controllers can play an important role in the power system security enhancement. However, due to importance of quality of power, it is necessary to locate these controllers with much better THD in the power system. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics Multilevel configuration of converters in these can lead to control in line flow and maintain bus voltages in desired level with much better quality of wave-shapes and so improve voltage stability margins. This project proposes a control method for a MUTI LEVEL FACTS DEVICES to be installed. FACTS DEVICES model is incorporated by using SIMULINK modeling source.. Increasing the number of levels will further converge towards quality of wave shape but leads to increase cost and control complexity. A marginal solution is utilized depending on the application required.

Keywords: Voltage Stability, FACTS Devices, Series active filters, shunt active filters, 7-Level inverter

I. INTRODUCTION

The usage of power quality conditioners in the distribution system network has increased during the past years due to the steady increase of nonlinear loads connected to the electrical grid. The current drained by nonlinear loads has a high harmonic content, distorting the voltage at the utility grid and consequently affecting the operation of critical loads. By using a unified power quality conditioner (UPQC) it is possible to ensure a regulated voltage for the loads, balanced and with low harmonic distortion and at the same time draining undistorted currents from the utility grid, even if the grid voltage and the load current having harmonic contents.

The UPQC consists of two active filters, the series active filter (SAF) and the shunt or parallel active filter (PAF). The PAF is usually controlled as a non-sinusoidal current source, which is responsible for compensating the harmonic current of the load, while the SAF is controlled as a non sinusoidal voltage source, which is responsible for compensating the grid voltage. Both of them have a control reference with harmonic contents and usually these references might be obtained through complex methods.

Some works shows a control technique to the both shunt and SAFs with uses sinusoidal references without the need of harmonic extraction, in order to decrease the complexity of the reference generation for the UPQC. An interesting alternative for power quality conditioners was proposed in and was called Line Voltage Regulator/ Conditioner (LVRC). This conditioner consists of two single-phase current source inverters (CSI) where the SAF is controlled by a current loop and the PAF is controlled by a voltage loop. In this way, both grid current and load voltage are sinusoidal and therefore their references are also sinusoidal.

Some authors have applied this concept, using voltage source inverters (VSI) in Uninterruptable Power Supplies (UPS) [35], [36] and in UPQC [10], [25], [32]. In [10] this concept is called “dual topology of unified power quality conditioner” (iUPQC), and the control schemes use the pq theory requiring determination in real time of the positive sequence components of the voltages and the currents. The aim of this paper is to propose a simplified control technique for a dual three-phase topology of a unified power quality conditioner (iUPQC) to be used in the utility grid connection. The proposed control scheme is developed in ABC reference frame and allows the use of classical control theory without the need for coordinate transformers and digital control implementation. The references to both SAF and PAFs are sinusoidal dispensing the harmonic extraction of the grid current and load voltage.

The paper is organized as follows. In Section II the iUPQC circuit is presented and its operation is explained in detail. Section III shows the power circuit design of the converters. The analysis and design of the passive filters are presented in Section IV. The proposed control scheme and its design are shown in Section V while the power flow is analyzed in Section VI. Section VII presents the experimental results and finally conclusions are drawn.

II. LITERATURE SURVEY FACTS DEVICES

Power systems over the worldwide becoming complex day to day and continuous requirements are coming for stable, secured, controlled, economic and better quality power. These requirements become more essential when environment becoming more vital and important deregulation. Power transfer capacity in transmission system is limited due to various factor such as steady state stability limit, thermal limit, transient stability limit and system damping or even negative damping. The scenarios of the magnitude of various limits are given in figure1.

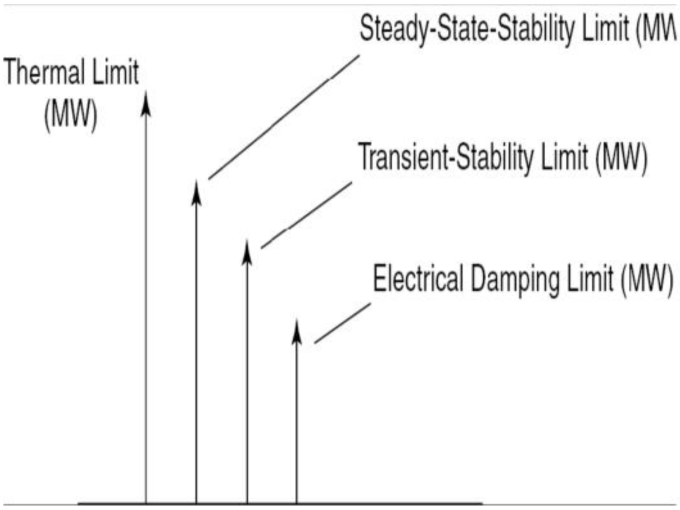


Fig.1.1 scenarios of the magnitude of various limits

The electrical damping of power system requires to be mitigate to stable oscillations free power transfer. Flexible AC Transmission System and Distributed Flexible AC Transmission System provides feasible and cost-effective solution to these problems and so these devices are required to use worldwide for improving performance of power system.

FACTS CONTROLLERS

FACTS as "Alternating current transmission systems incorporating power-electronic based and other static controllers to enhance controllability and increase power transfer capability ."

FACTS are used to fulfill the given objectives:

• To improve the transient stability limit of the line
• To enhance the damping of existing system
• To improve voltage stability
• To mitigate sub synchronous resonance
• To minimize short circuit currents
• To improve integrity of wind power generation
• To improve terminal performance of HVDC converter

An overview of nowadays available network controllers and FACTS-devices are as below.

A. Shunt Device
(1)Static Var Compensator:
(2)Static Synchronous Compensator (svc light/statcom)
(3)STATCOM
B. Series Device
(1) Thyristor Controlled Series Compensator (TCSC)
(2) Static Synchronous Series Compensator (SSSC, DVR,SVR)
(3) Fault Current Limiter (SC+FPD)
C. Hybrid device
(1) Dynamic Power Flow Controller (DFC)
(2) HVDC Light/HVDCLightB2B/UPFC

Thyristor based FACTS controllers are enough mature technology and SVC and TCSC are all ready been installed at many locations. Some new versatile FACTS controllers which more effectiveness are emerging in power system. These include Thyristor controlled phase shifting transformer (TCPST), inter phase power controller (IPC), Thyristor control breaking resistor (TCBR), Thyristor control voltage limiter (TCVL)[24,4],Battery energy storage system(BESS) and , superconducting magnetic energy storage system(SMES).

2.1: STATIC VAR COMPENSATOR

The SVC is a widely used FACTS controller, it is a shunt connected absorber or generator which exchange capacitive or inductive current to maintain/control specific parameter of power system.fig 2 shows SVC having controllable variable inductor with switchable capacitance.

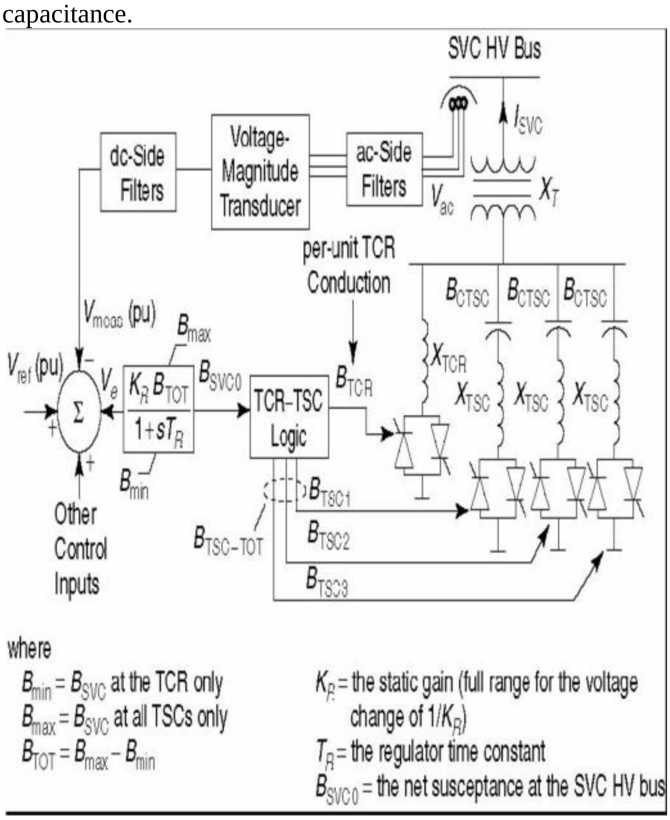


Fig. 2.1 SVC controllable variable inductor with switchable capacitance

svc may be of(a)Thyristor control Reactor(TCR)(b)Thyristor Switched Capacitor (c) combination of (a)and (b) (c)Fixed capacitor-TCR(d)TCR-Mechanically Switched Capacitor(TCR-MCR)[2] here the high voltage system bus voltage measured ,filtered and compared with reference voltage and the error voltage is processed and through gain time constant controller to provide a desired susceptance for SVC. This susceptance is now implemented by logic control to select no of TSCs or to determine firing angle for the TCR.

The modeling and simulation of TSR based SVC and TCR based SVC are investigated using Mat lab fuzzy logic controller. Effect of both Thyristor switched Based Reactor and Thyristor Controlled Capacitor based VAR compensator on load voltage in a single machine infinite bus system is analyzed.

The three modeling of SVC generator fixed susceptance model, total susceptance model and firing model are compared. The dimension under which comparison done was voltage at regulated bus, equivalent SVC susceptance at the fundamental frequency, and load flow convergence rate when SVC is operating both with in and on the limit Two modified models are also proposed to improve SVC regulated voltage under static condition and better convergence rate gas been achieved.

2.2: STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

The Static Synchronous Series Compensator (SSSC) is a device that belongs to the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve power oscillation damping on power grids. The SSSC injects a voltage in series with the transmission line where it is connected. The SSSC contains a solid-state voltage source inverter connected in series with the transmission line through an insertion transformer. This connection enables the SSSC to control power flow in the line for a wide range of system conditions.

APPLICATIONS:

Static synchronous series compensator (SSSC) uses a voltage source converter to inject a controllable voltage in quadrature with the line current of a power network. Such a device is able to rapidly provide both capacitive and inductive impedance compensation independent of the power line current. Moreover, an SSSC with a suitably designed external damping controller can also be used to improve the damping of the low-frequency power oscillations in a power network.

2.3: STATCOM

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on electricity transmission networks. It is based on a voltage-source converter and can act as either a source or sink of reactive to an electricity network. If connected to a source of power it can also provide active. It is a member of the family of devices. It is inherently modular and electable.

USES

Usually a STATCOM is installed to support electricity networks that have a poor and often poor . There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).

2.4: SIMILAR DEVICES

A SVC can also be used for voltage stability. However, a STATCOM has better characteristics than a SVC. When the system voltage drops sufficiently to force the STATCOM output current to its ceiling, its maximum reactive output current will not be affected by the voltage magnitude. Therefore, it exhibits constant current characteristics when the voltage is low under the limit. In contrast the SVC's reactive output is proportional to the square of the voltage magnitude. This makes the provided reactive power decrease rapidly when voltage decreases, thus reducing its stability. In addition, the speed of response of a STATCOM is faster than that of an SVC and the harmonic emission is lower. On the other hand STATCOMs typically exhibit higher losses and may be more expensive than SVCs, so the (older) SVC technology is still widespread.

III. PROPOSED METHOD AND RESULTS

This project presents iUPQC, a Unified Power Quality Conditioner in which the series converter emulates a sinusoidal current source and the shunt converter emulates a sinusoidal voltage source. This methodology gives circuitous power quality pay of the heap voltage and the source current. Latest studies have recommended that the iUPQC has specialized points of interest in correlation with the traditional UPQC because of its lessened switching frequency trademark. This is used to control the power flow in the transmission system by controlling the impedance , voltage magnitude and phase angle. Unique in relation to an ordinary UPQC, the iUPQC has the series converter controlled as a sinusoidal current source and the shunt converter controlled as a sinusoidal voltage source. By expanding no. of levels in the converters, injected voltages or currents gets closer to sinusoidals in this manner we accomplishes better THD esteem.

NEED FOR EXTENSION

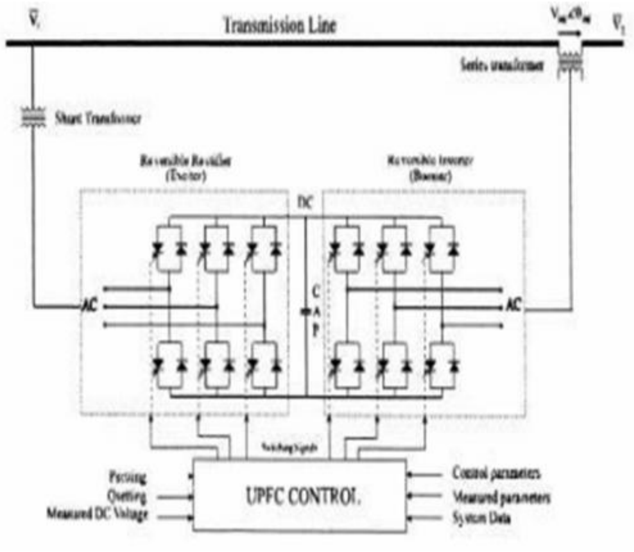
The technology of power system utilities around the world has rapidly evolved with considerable changes in the technology along with improvements in power system structures and operation. The ongoing expansions and growth in the technology, demand a more optimal and profitable operation of a power system with respect to generation, transmission and distribution systems. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive equipment and non-linear loads are commonplace in both the industrial and the domestic environment; because of this a heightened awareness of power quality is developing [2]. The sources of problems that can disturb the power quality are: power electronic devices, arcing devices, load switching, large motor starting, embedded generation, sensitive equipment, storm and environment related damage, network equipment and design. The solution to improve the energy quality (PQ-Power

Quality) at the load side is of great important when the production processes get more complicated and require a bigger liability level, which includes aims like to provide energy without interruption, without harmonic distortion and with tension regulation between very narrow margins [3].

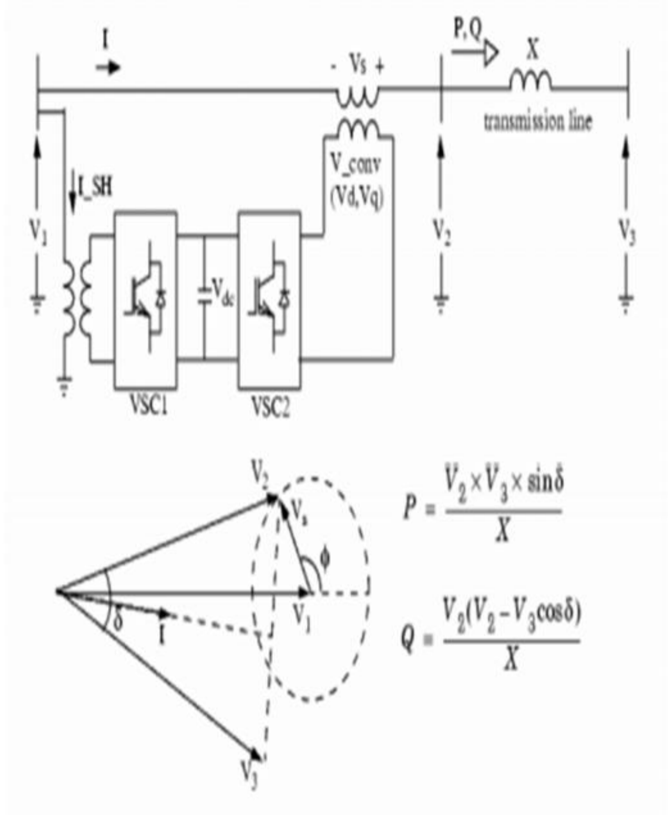
In the present scenario, most of the power systems in the developing countries with large interconnected networks share the generation reserves to increase the reliability of the power system. However, the increasing complexities of large interconnected networks had fluctuations in reliability of power supply, which resulted in system instability, difficult to control the power flow and security problems that resulted large number blackouts in different parts of the world. The reasons behind the above fault sequences may be due to the systematical errors in planning and operation, weak interconnection of the power system, lack of maintenance or due to overload of the network. In order to overcome these consequences and to provide the desired power flow along with system stability and reliability, installations of new transmission lines are required. However, installation of new transmission lines with the large interconnected power system are limited to some of the factors like economic cost, environment related issues. These complexities in installing new transmission lines in a power system challenges the power engineers to research on the ways to increase the power flow with the existing transmission line without reduction in system stability and security.

UPFC CONSTRUCTION & OPERATION

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common dc link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter or Static Synchronous Compensator (STATCOM) is used to provide reactive power to the ac system, beside that, it will provide the dc power required for both inverter. Each of the branches consists of a transformer and power electronic converter. These two voltage source converters shared a common dc capacitor [5]. The energy storing capacity of this dc capacitor is generally small. Therefore, active power drawn by the shunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. Figure3.2.1 shows the schematic diagram of the three phase UPFC connected to the transmission line



Control of power flow is achieved by adding the series voltage, VS with a certain amplitude, VS and phase shift, φ to V1. This will gives a new line voltage V2 with different magnitude and phase shift. As the angle φ varies, the phase shift δ between V2 and V3 also varies. Figure 2 shows the single line diagram of the UPFC and phasor diagram of voltage and current.



SIMULINK MODEL

Simulink design of Seven-Level Dual UPQC for Voltage Regulation

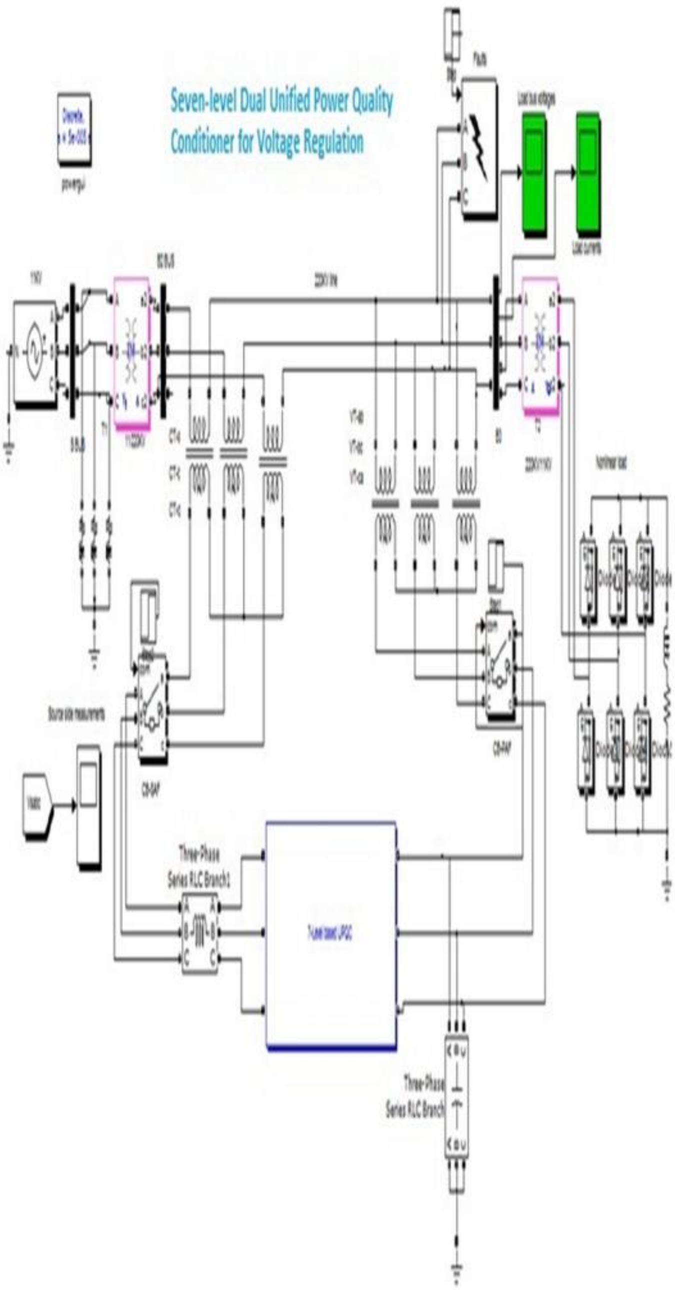


Fig1 Simulink design of Seven-Level Dual Unified Power Quality Conditioner for Voltage Regulation

10.2 Circuit of Seven-Level Inverter for Series and Shunt Active Filters

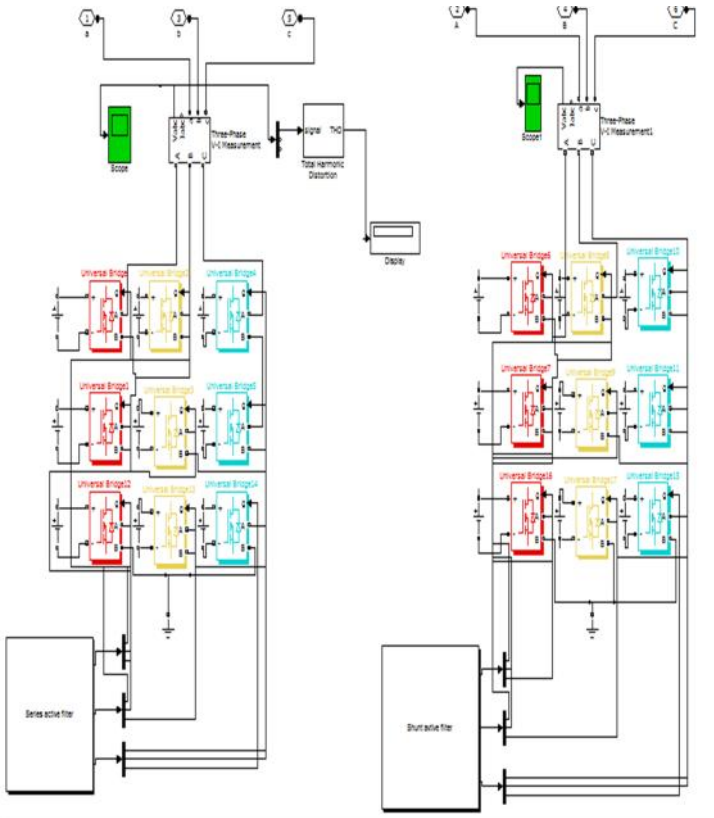


Fig 2 Circuit of Seven-Level Inverter for Series and Shunt Active Filters

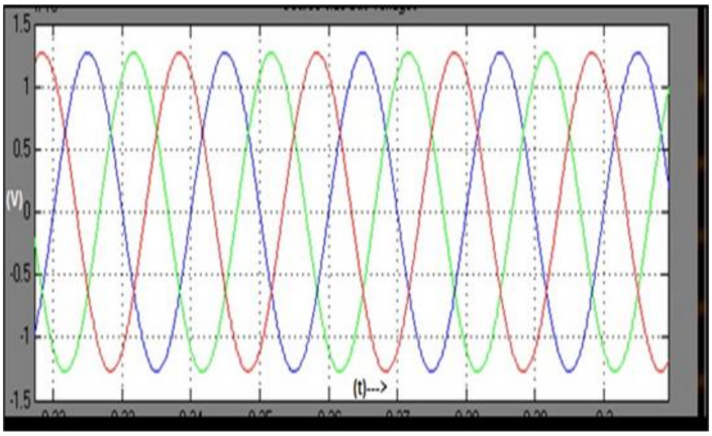


Fig 3. Source voltage

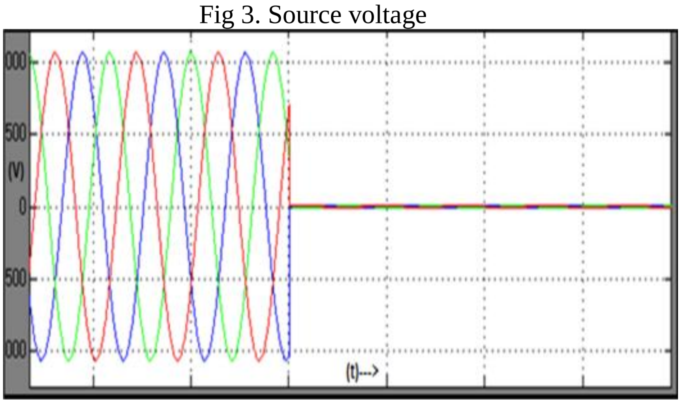


Fig 4 Load side voltages without iUPQC into the system

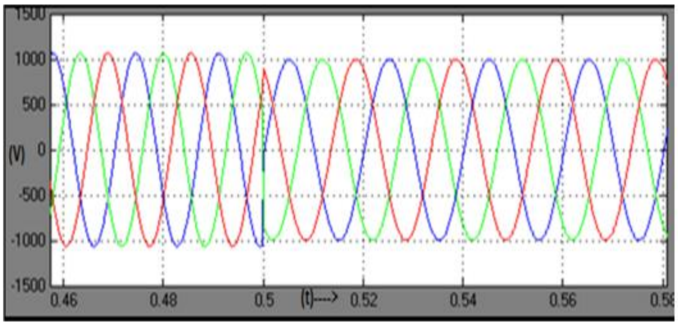


Fig 5 Load side voltages-With iUPQC

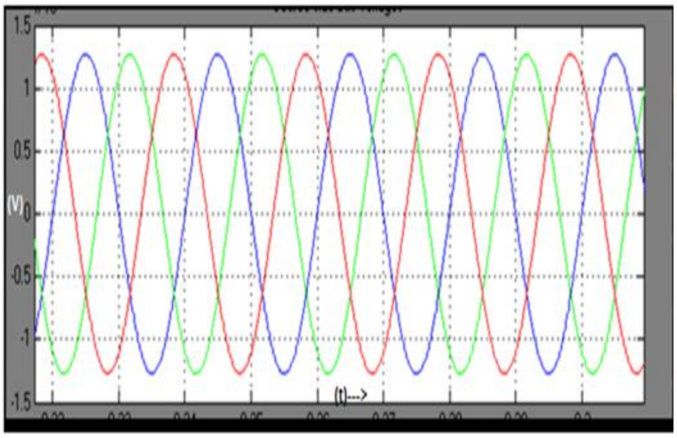


Fig 6 Voltage injected by seven-level iUPQC

CONCLUSION

The results obtained with the iUPQC confirms that the proposed ABC reference frame control works very well and was able to compensating the nonlinear load currents and also ensure the sinusoidal voltage for the load in all three phases. The control also had a great performance during the load steps and voltage disturbances at the source. The main advantages of this proposed control in relation to other proposed schemes were the utilization of sinusoidal references for both series and shunt active filters controls without the need for complex calculations or coordinate transformations.

The iUPQC references do not have harmonic contents and the only requirement is the synchronism with the grid voltage. Another positive aspect of the iUPQC in low voltage applications (distribution system network) is the non-interference of the leakage impedance voltage of the SAF connection transformer in the load voltage compensation, because the load voltage is directly controlled by the PAF. For other hand, the leakage impedance interferes in the current loop bandwidth, decreasing its frequency response under distorted grid voltages.

The results validate the proposed iUPQC control scheme proving that the power quality can be meaningfully better with a simple control method which uses only synchronized sinusoidal references.

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