A NEW HARMONICS ELIMINATION METHOD APPLIED TO A STATIC VAR COMPENSATOR

Ankush A. Kosare
Department of Electrical Engineering,
GNIT Nagpur, Maharashtra, INDIA, RTMN University Nagpur
ankushkosare@gmail.com

Abstract— *In this paper, the use of harmonics elimination method applied to a three level inverter which calculates the switching angles. Simulations results using MATLAB program are carried out to validate the mathematical model. Harmonics are generated in power system due to various reasons such as nonlinear loads, iron core devices, semiconductor switching devices etc. So, it is important to reduce harmonic content from output of Static VAR Compensator in order to avoid harmful effects of harmonics such as noise, overheating, voltage flicker, torque pulses etc. This project investigates an optimal strategy for harmonic reduction in the inverter based converters*

Keywords -- **GTO, SVC, PWM, FACTS, Inverter, Reactive Power Compensation, MATLAB.**

I. INTRODUCTION

As we knw that.recently the multilevel pulse width modulation (PWM) converter topology has drawn tremendous interest in the power industry since it can easily provide the high power required for high power applications and for that they uses static VAR compensation, active power filters, and so that large motors can also be controlled by high power adjustable frequency drives [1].

A Static VAR Compensator is a device which belongs to the family of FACTS devices where as FACTS stands for flexible AC transmission Systems are a family of devices which can be inserted into power grid in series, in shunt, and in some cases, both in series and shunt combination. With the help of FACTS devices, availability and efficiency of power grids are improved, for existing just as well as for new grids. Recent advances in the power handling capabilities of static switches have made the use of the voltage source inverters (VSI) feasible at both the transmission and distribution levels [1].

II. HARMONICS

A harmonic is a signal or wave whose frequency is an integral (whole-number) multiple of the frequency of some reference signal or wave. In a 50Hz system, the 3rd harmonic is at 150Hz, 5th at 250Hz, 7th at 350Hz and so on [2].

The troublesome harmonics for single phase loads are the 3rd and odd multiples of the 3rd i.e. the 9th, 15th etc. These harmonics are called “triplens harmonics”. The triplen harmonics on each phase are all in phase with each other which will cause them to add rather than cancel in the neutral conductor of a three phase four wire systems. This can overload the neutral if it is not sized to handle this type of load. On the other hand, three phase non linear loads generate primarily 5th and 7th current harmonics. And a small amount of 11th, 13th and higher orders. These types of loads do not generate triplen harmonics [2].

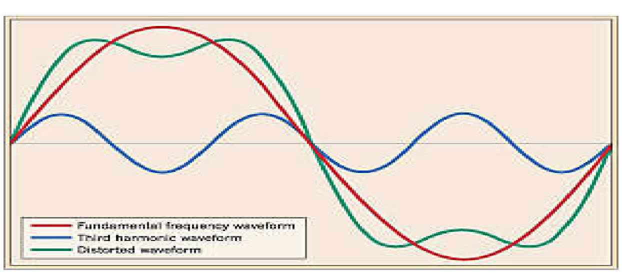


Fig.2.1 Waveform with harmonics

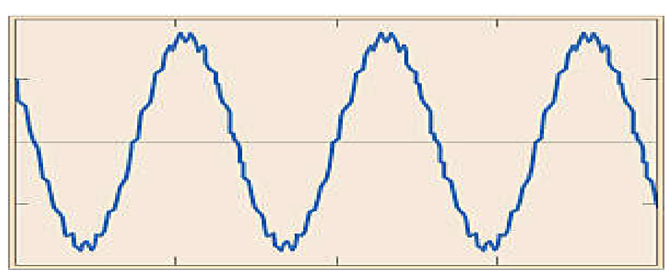


Fig.2.2 Fundamental waveform with 3rd harmonic content

III. THREE LEVEL INVERTER

The multilevel inverters can be developed neutral-point-clamped multilevel inverter as we seen in the fig 3.1. Using multiple 3-phase bridges or by increasing the number of switching devices per phase we can increase the number of levels. A multilevel converter achieves high power ratings as well as enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application [3].

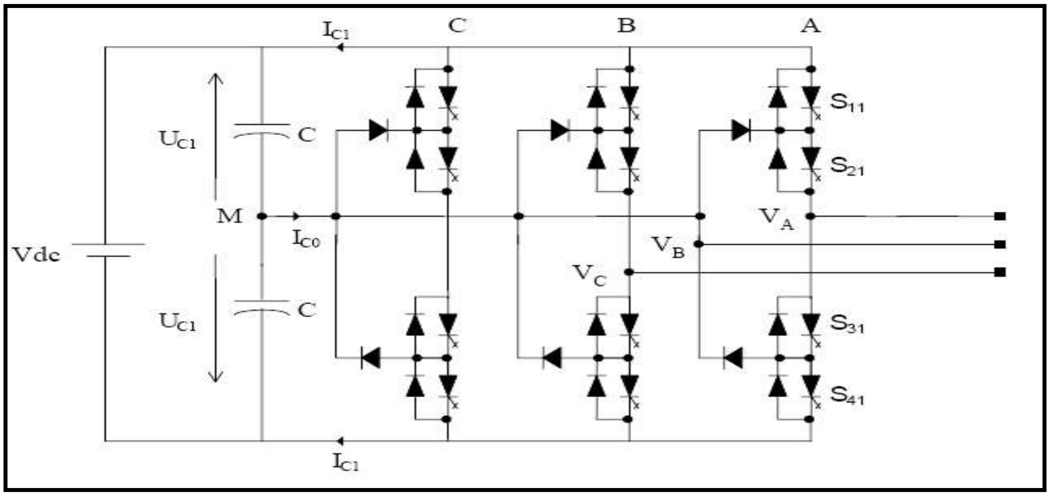


Fig.3.1 3-level (Multilevel) Inverter

IV. REACTIVE POWER COMPENSATION

FACTS devices have a lot to do with reactive power compensation which is used to be the term utilized for the technology in the old days. Reactive power appears in all electric power systems, due to the laws of nature and presence of inductive and capacitive elements. Contrary to active power, which is what we really want to transmit over our power system which performs real work, such as keeping a lamp lit or a motor running but as respect to reactive power,it does not perform any such work. Consequently, in a way one can say that the presence of reactive power in a grid makes it heavier for it to perform its task, i.e. transmit power from one end to other end, and consequently less efficient. We can also refer to Lenz´ law which formulated already in the nineteenth century stated as "Every change in an electrical system induces a counter-reaction opposing its origin"[4].

So, as a consequence, if we can minimize the flow of reactive power over the transmission system, we can make the system more efficient and put it to better and more economical use.

V. FLEXIBLE AC TRANSMISSION SYSTEM

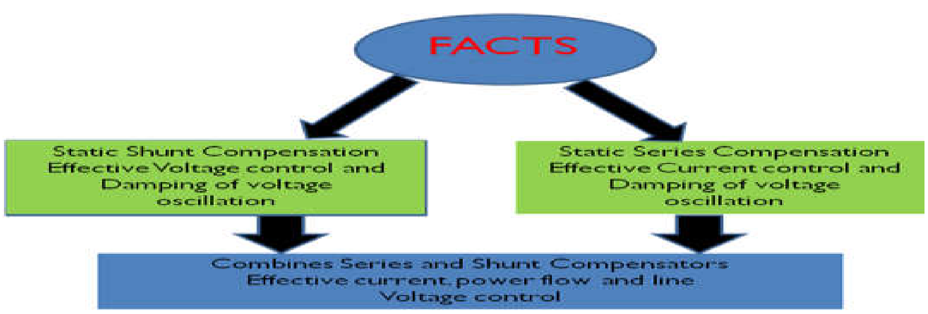


Fig.5. Breakdown of FACTS devices

The concept of a flexible AC transmission system (FACTS) is based on the operations of advanced power electronic controlled devices to effectively avoid power loss and extend the load ability of existing power transmission networks without changing the old ones. FACTS devices are able to influence the power flow in a transmission line by controlling one of the three system variables, namely, line reactance, magnitude, and phase angle difference of the voltages across the line. FACTS devices are able to provide both capacitive and inductive compensations required by the power system by implementing the appropriate power electronic controllers [5].

VI. STATIC VAR COMPENSATOR

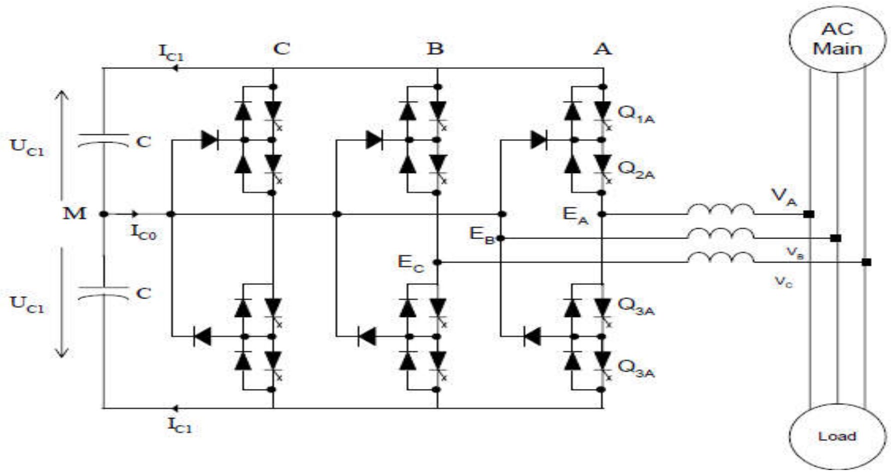


Fig.6 Power circuit of svc

High Power SVCs of this type essentially consist of a three phase PWM Inverter using GTOs, Thyristors or IGBTs, a D.C. side capacitor which provides the D.C. voltage required by the inverter, filter components to filter out the high frequency components of inverter output voltage, a link inductor which links the inverter output to the AC supply side, interface magnetic as well as related control blocks. The Inverter generates a three-phase voltage, which is synchronized with the AC supply from the D.C. side capacitor and the link inductance links up this voltage to the AC source. The current drawn by the inverter from the AC supply is controlled to be mainly reactive which is leading or lagging as per requirement with a small active component needed to supply the losses in the inverter and link inductor .The D.C. side capacitor voltage is maintained constant or allowed to vary with a definite relationship maintained between its value and the reactive power to be delivered by the inverter by controlling this small active current component [5].

VII. OPERATION OF STATIC VAR COMPENSATOR

The magnitude of the reactive power absorbed or supplied by the SVC depends on the DC side capacitor voltage and hence by controlling the phase angle 'α' of the inverter, the dc capacitors voltage levels can be changed. The dc voltage increases when the SVC delivers increasing lagging VAr and it decreases when SVC delivers leading Vars.When the reactive power reference changes, it causes a change in value of α. The residual voltage across link inductor changer resulting in more active power flow into/out of the inverter. Increased active power flow into/out of the inverter results in increase /decrease in the energy storage in the DC side capacitor resulting in an increase/decrease in the dc side voltage. With a fixed modulation index, the increase or decrease in the DC voltage is straight away passed on to inverter output voltage. Change in the inverter output voltage results in desired reactive power change [6].

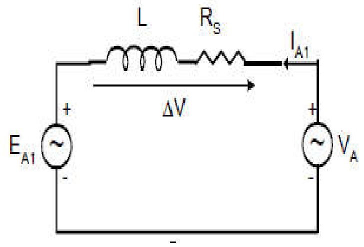


Fig.7.1 Per phase equivalent diagram of svc

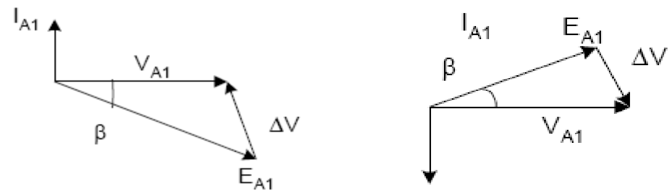


Fig.7.2 Phasor diagrams for leading and lagging mode

In this figure (7.2), EA1 is the ac mains voltage source. IA1 and VA are the fundamental components of the output current and voltage of the inverter supply respectively.

VIII. PULSE WIDTH MODULATION TECHNIQUE (PWM)

Pulse Width Modulation (PWM) techniques are extensively used for eliminating harmful low-order harmonics in input and output voltage and current of static power converter. PWM does not reduce the total distortion factor of the current or the voltage, but the non-zero harmonics are of high order. This results in low design values for the inductor and capacitor components of the output filter which gives overall reduction in the filter size. In PWM control, the converter switches are turned on and off several times during a half cycle and the output voltage is controlled by varying the pulse widths. In this section, the discussion is mainly focused on the application of PWM techniques for harmonic elimination in voltage-source inverters, as this is relevant to the paper.

IX. SIMULATION SYSTEM

The entire simulated system of this paper is divided into two parts i.e. Simulation of three level inverter and Simulation of power system.

X. SIMULATION OF THREE LEVEL INVERTER

Fig.10.1 shows the simulated diagram of a three level inverter using twelve IGBTs. Each IGBT is connected to a pulse generator wherein appropriate switching instances are mentioned to obtain a controlled output. The dc side of inverter is connected to a dc voltage source and two capacitors. The ac side is connected to load. Scopes and other measurement blocks are connected for analysis of result.

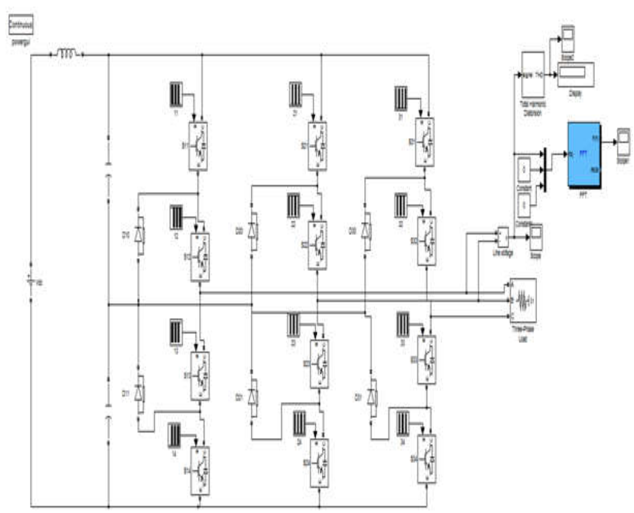


Fig.10.1 Simulation of three level inverter

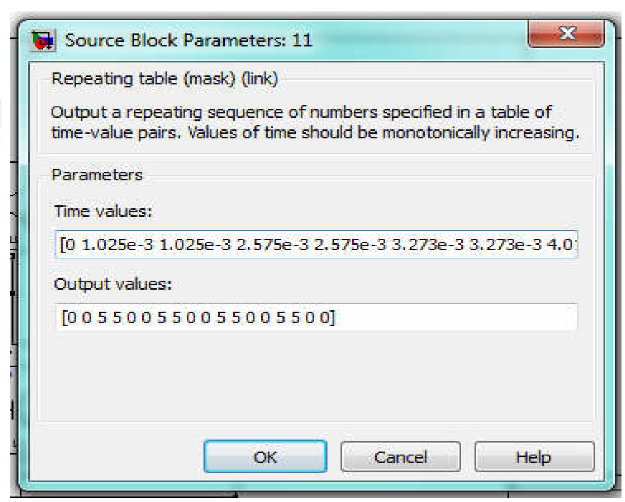
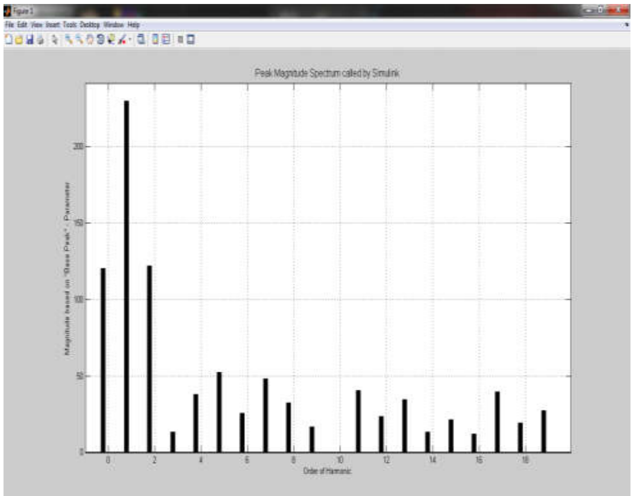


Fig.10.2 Repeating sequence pulse block

Fig.10.2 shows the repeating pulse block used for generation of pulses. The block needs two input parameters, time values and respective output values.

XI. SIMULATION RESULT FOR THREE LEVEL INVERTER



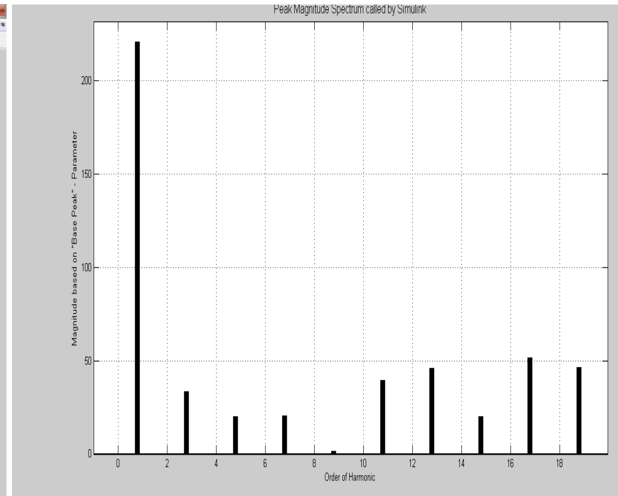
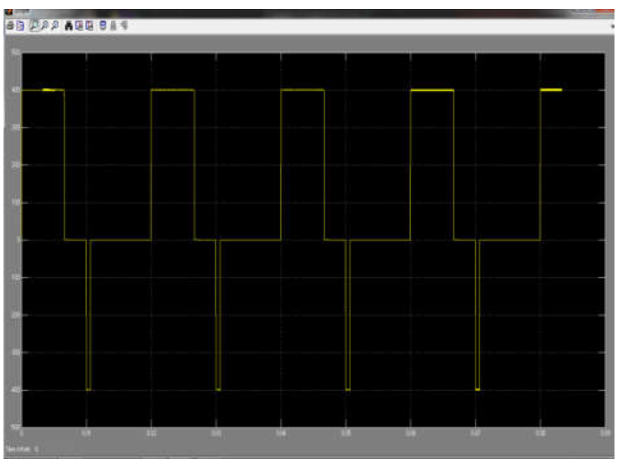


Fig.11.1 Harmonic spectrum without PWM

Fig.11.2 Harmonic spectrum after applying programmed PWM



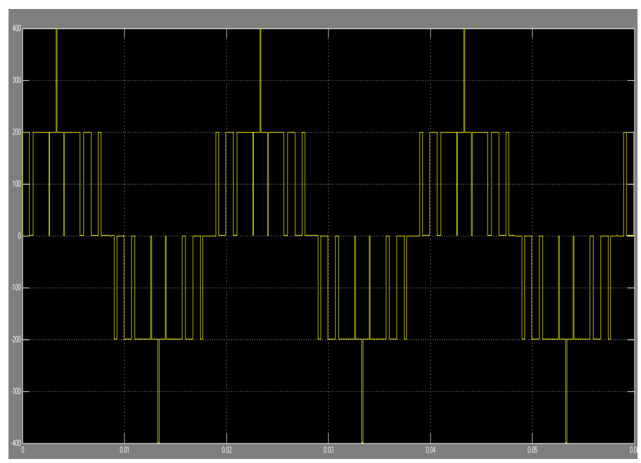
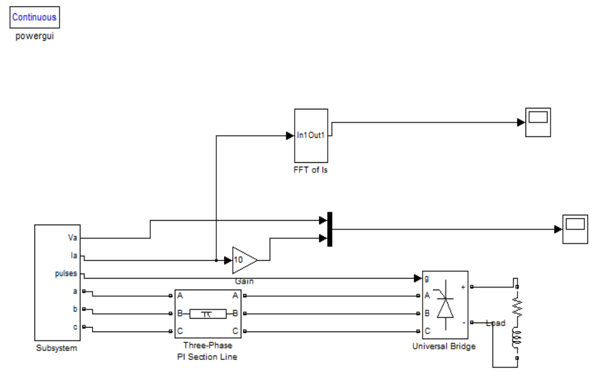


Fig.11.3 Line voltage of inverter without harmonic elimination

Fig.11.4 Line voltage for a three level inverter

Hence, we can observe that there is considerable reduction in harmonic content in the output of inverter using the programmed harmonic elimination technique. Also, the waveform for line voltage verifies the operation as a three level inverter.

XII. SIMULATON OF POWER SYSTEM



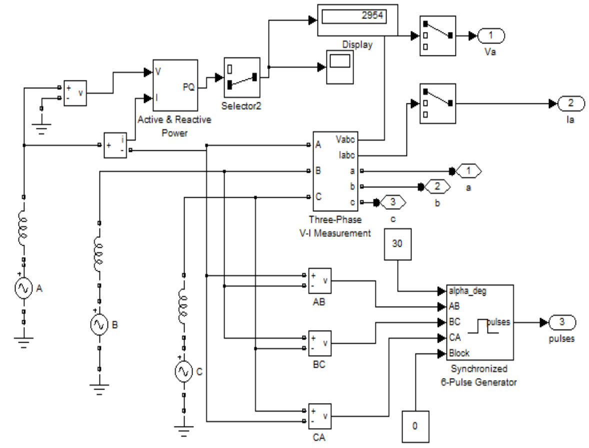
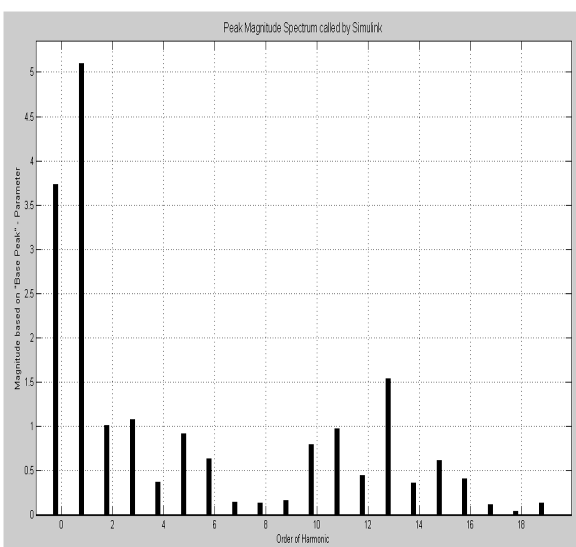


Fig.12.1 Simulation of power system

Fig.12.2 Subsystem containing voltage source and pulse generator for universal bridge.

The fig.12.1. shows the simulation diagram of the power system. Fig.12.2 shows the subsystem which contains the three phase voltage source and the pulse generator circuit to provide gate pulses to the universal bridge. In the model of power system a three phase voltage source is connected to a pi section model of transmission line. A universal bridge is connected as a non linear load which introduces harmonics in the system. System parameters are observed via the measurement and display devices connected to the line. Here, initially the SVC is not connected to the system and various parameters are observed .Then, the SVC with PWM is connected to the system and changes in the parameters are observed.

Case 1:- When SVC is not connected to the system



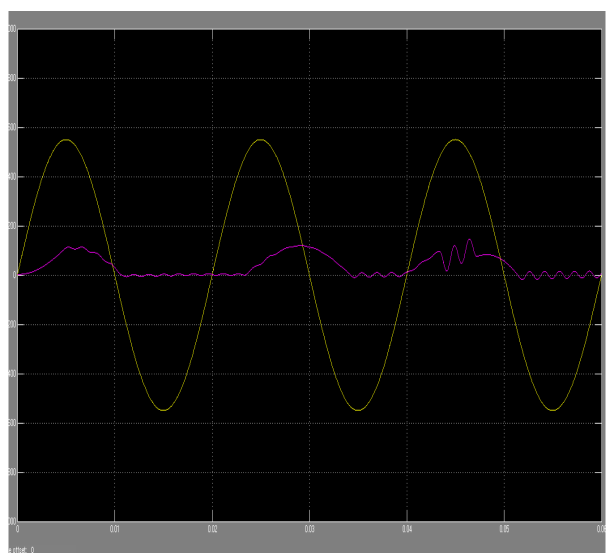


Fig12.1.1 Harmonic Spectrum

Fig.12.1.2 Waveform for voltage and current with harmonics

The fig.12.1.1 and 12.1.2 shows the waveform for harmonic spectrum, voltage and current waveform of the system without an SVC

Case 2:- When SVC is connected to the system

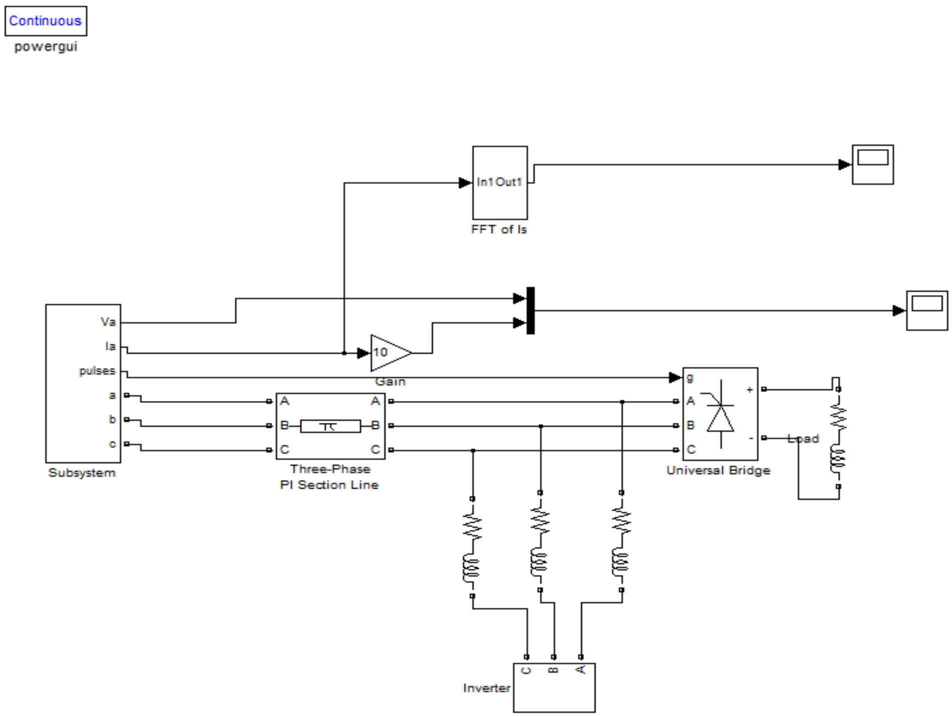
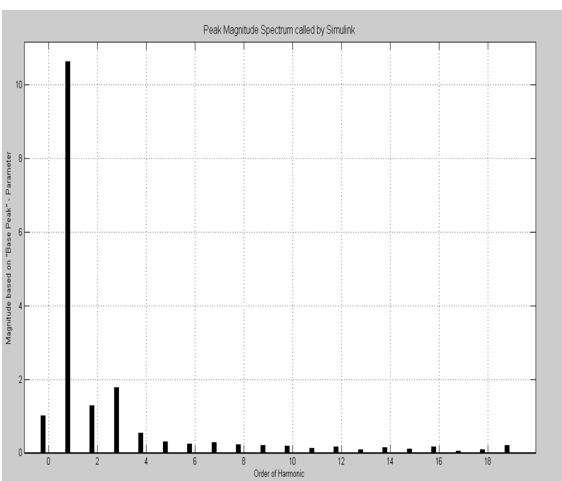


Fig.12.3 Power system with svc



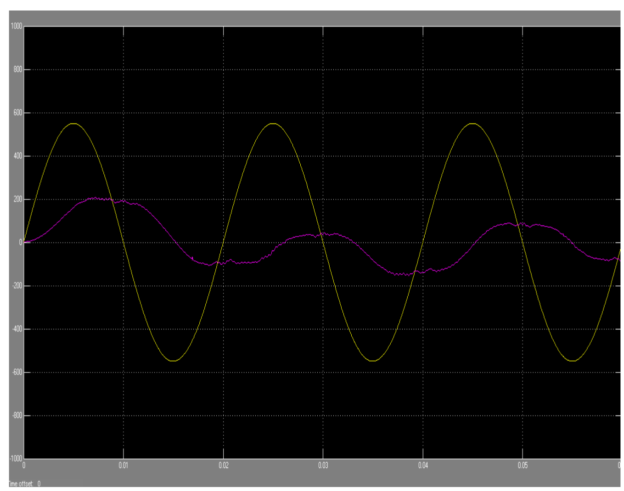


Fig.12.3.1 Harmonic Spectrum

Fig.12.3.2 Waveform for voltage and current with SVC

Fig.7.3.5 shows the previously shown power system with an SVC connected. Various wave forms are as shown in fig.7.3.6 and 7.3.7.After connecting the SVC to the system there is considerable reduction in the harmonic level of the system along with reactive power compensation. Improvement in current waveform due to elimination of harmonics is clearly visible.

XIII. CONCLUSIONS

In this paper, a new static var compensator (SVC) using three-level inverter is proposed for high voltage and high power applications. The general and simple model for the proposed SVC is obtained and analyzed. Using this model, a new control method which controls the phase angle and modulation index simultaneously in the switching pattern is suggested to achieve fast response of SVC system without using additional voltage source. The logic of the modeling, analysis and control method of the proposed SVC system is proved by the computer simulation by using MATLAB software. The behavior of the system depends on the operating modes. The dc voltage fluctuation causes apparition of eliminated harmonics. The proposed inverter circuitry has a low component count with twelve GTO, clamping diodes and link inductance. Both the cost and size are reduced, there by presenting a more reliable and more economic design, reduces switching transient power losses and contributes to efficiency improvement.

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