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Power Quality Improvement By Using SVPWM Based UPFC

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Abstract

With the increasing demand of electricity, at time , it is not possible to elevated new line to face the situation. Power system harmonic is one of the considerable problem in power system operation. If these harmonic can rise and decrease transmission capacity of the line which may cause interruption in energy supply. Therefore, FACTS devices are working to reduce this harmonic. The SVPWM based UPFC are used . SVPWM is perfect as compare to other PWM technique. It presents a amount of flexibility of space vector placing in a switching cycle. The main consideration of this project is to compare the performance of PWM based UPFC with SVPWM based UPFC on the bases of harmonic reduction. The proposed work is validated by using MATLAB software.

Keywords: FACTS, sample power system, harmonics, dynamic non-linear load, UPFC, SVPWM

I. INTRODUCTION

Present day industrial devices are worked on the electronic devices such as PLC and electronic drives. The electronic devices are appropriate unstable to interruption and become less opposition to power quality problems such as voltage swells, voltage sag and harmonics.

In current years, more demands have been placed on the transmission network and this demand will carry on increases day by day. While the generation of power and transmission of power has been extremely limited due to limited natural resources and environmental limit. With raised power condition, transient and dynamic stability is of raising importance for safe operation of electric power system. So, a more recent control method should be execute. FACTS controller such as static VAR compensator, static synchronous compensator, static synchronous series compensator, thyristor controlled series compensator are capable to performing changed the network parameter in a fast and effective way in order to carry out better system performance out of this, UPFC is the most flexible FACTS device proposed by Gyugyi in 1991. This device control simultaneously all three parameters such as impedance, voltage and phase angle of electric power system. These devices is a combination of two FACTS device such as STATCOM and SSSC. Practically, these devices are two VSC are such a way shunt inverter are connected shunt with the shunt transformer in transmission line and series inverter are connected series with series transformer in transmission line. These two devices connected each other by common dc link capacitor. The shunt inverter is used to voltage regulation at the point of connection, introduce reactive power flow into the line and to balance the active power flow returned between the series inverter on the transmission line. In this paper mainly focus on control of UPFC. There are so many PWM method to control the UPFC but SVPWM is perfect as compare to other PWM technique. It presents a amount of flexibility of space vector placing in a switching cycle. SVM is a digital modulation technique, to generate PWM load line voltage which is equal to given load line voltage. By correctly choosing the switching state of the inverter and the calculation of the suitable time period for each state. The advantages of space vector modulation as compare to PWM are

1. Lower order harmonic cannot be removed by filters. This harmonic can be remove by SVM technique.
2. In SVM technique, there is 15% rise in maximum voltage compared to PWM.
3. Space vector modulation provides excellent output performance.

The paper is arranged as follows. The second section provides basic of SVPWM based voltage source inverter. Third section is fundamental of unified power flow controller. Fourth section is detail information about two machine system with PWM and SVPWM firing base UPFC.

II. BASIC OF SPACE VECTOR MODULATION

SVPWM is arranged in such a manner that at the end only two independent variable will be there at three phase system . The adjacent co-ordinates in phasor diagram are mainly used to represent the three phase system voltage fig.1 comprise of total eight switching patterns (V0 to V7) as shown in table 1 which represent reference voltage (Vref.) because of vectors (V1 to V6). The plane is divided into six sectors. Each sector makes an angle of 60 deg. Vref. is the product of two zero vectors and two non zero vectors respectively.

From the definition of space vector

$$V = \frac{2}{3}[Va\,(t) + aVb\,(t) + a^2 Vc\,(t)] \;\dots\dots\dots\dots\dots\dots (1)$$

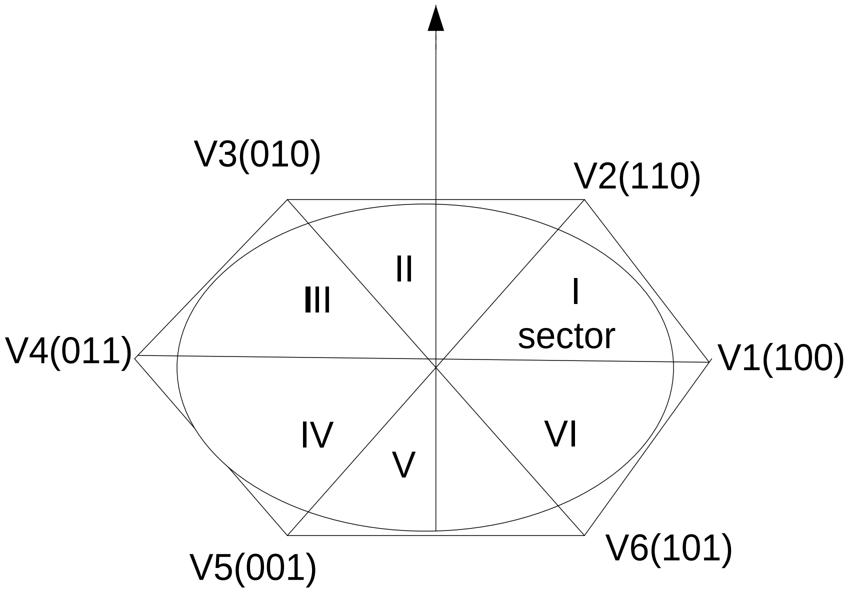

Fig.1. Switching vector of 2-level inverter

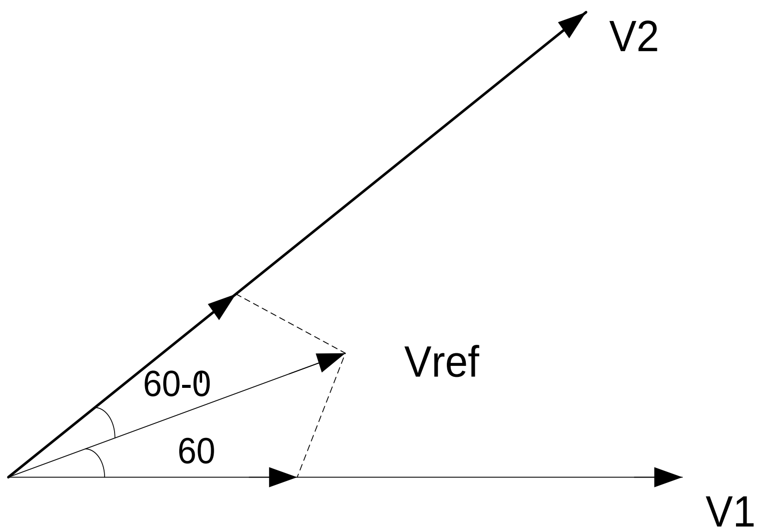

Fig.2. Reference vector

Table.1 : 2-level inverter voltage vector

S. No.	Sa	Sb	Sc	Van	Vbn	Vcn
1	1	0	0	Vdc	0	0
2	1	1	0	Vdc	Vdc	0
3	0	1	0	0	Vdc	0
4	0	1	1	0	Vdc	Vdc
5	0	0	1	0	0	Vdc
6	1	0	1	Vdc	0	Vdc
7	1	1	1	Vdc	Vdc	Vdc
8	0	0	0	0	0	0

+Vdc and –Vdc output line voltage are obtained from active state and null state does not contribute in 2-level inverter to obtain any output line voltage from table 1, “1” tends to ON state and “0” tends to OFF state of the switches respectively.

By means of three adjacent switching vector reference vector is obtained, likewise when Vref. drop into sector1 as shown in fig.2, it can be arrange by V1, V2 and V0. The switching time duration at any sector is

$$T_1 = \frac{\sqrt{3}.T_s|V_{ref.}|}{V_{dc}}\left\{\sin\left(\frac{\pi}{3} - \propto + \frac{n-1}{3}\pi\right)\right\} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$= \frac{\sqrt{3}.T_s|V_{ref.}|}{V_{dc}}\left\{\sin\frac{n}{3}\pi - \propto\right\} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$= \frac{\sqrt{3}.T_s|V_{ref.}|}{V_{dc}}\left\{\sin\frac{n}{3}\pi\ \cos\propto\ -\ \cos\frac{n}{3}\pi\ \sin\propto\right\} \ldots\ldots\ldots\ldots (4)$$

$$T_2 = \frac{\sqrt{3}.T_s|V_{ref.}|}{V_{dc}}\left\{\sin\left(\propto - \frac{n-1}{3}\pi\right)\right\} \ldots\ldots\ldots (5)$$

$$= \frac{\sqrt{3}.T_s|V_{ref.}|}{V_{dc}}\left\{-\cos\propto.\sin\frac{n-1}{3}\pi + \sin\propto.\cos\frac{n-1}{3}\pi\right\} \ldots\ldots\ldots (6)$$

$$T_0 = T_s - T_1 - T_2 \ldots\ldots\ldots\ldots\ldots (7)$$

Where Ts is the time period of switching cycle, T1 and T2 are switching time of the vector V1 and V2 similarly calculation is applied to sector II to IV.

The maximum value of Vref. is obtain when

$$max.V_{ref.} = \cos 30 \sqrt{\frac{2}{3}} V_{dc} \quad \text{.....................(8)}$$

III. UNIFIED POWER FLOW CONTROLLER

Fig.3 shows the layout of UPFC, which consists of two VSC, two coupling transformer and DC capacitor. The two VSC generates a balance set of voltage and current at the fundamental frequency with provide simultaneous control of the electric power system parameters like voltage, amplitude and phase angle.

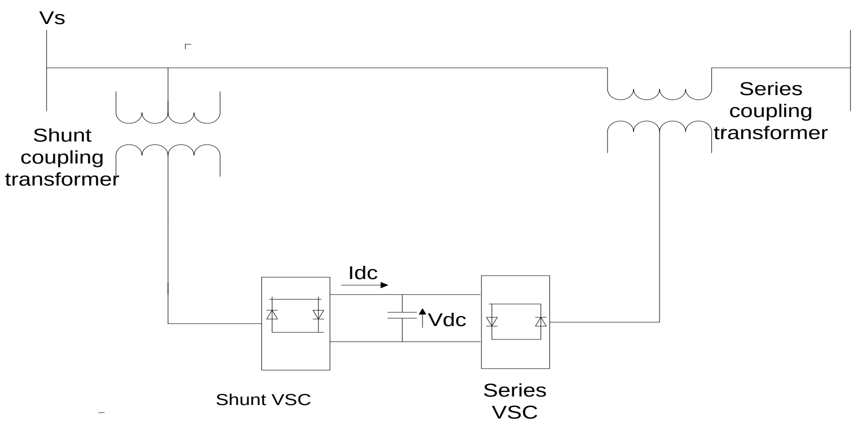

Fig.3. Unified power flow controller

The UPFC equivalent circuit is similar to two port network. Shunt VSC and series VSC are connected to two different ports respectively Vl is the final port voltage to manage real power and reactive power (i.e Apparent power) in the line Vp and Vr are introduced. The complex power (PL+jQL) is flow through VL is shown fig.4

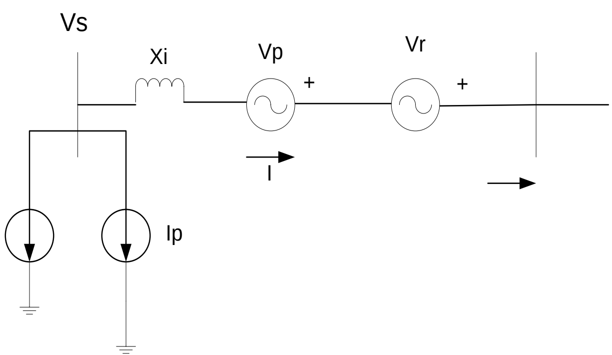

Fig.4. UPFC equivalent circuit

IV. SAMPLE POWER SYSTEM MODEL

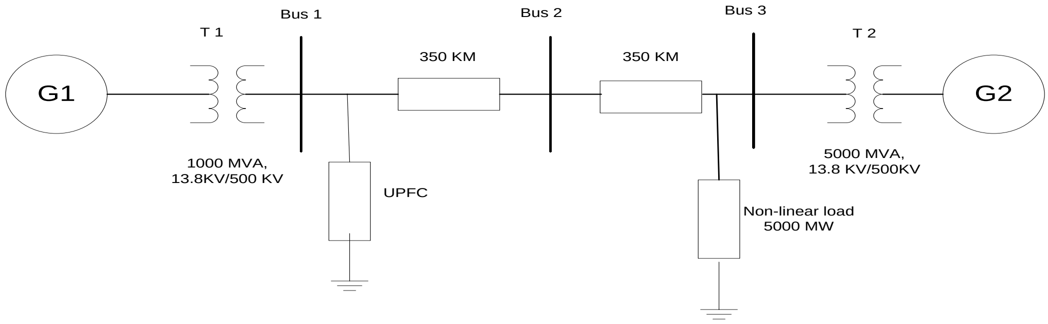

Fig.5. Single line diagram of sample power system model

Table 2. Data sheet of sample power system

Device	**Rating**
Generator1	10000MVA
Generator2	5000MVA
Transformer1	1000MVA, 13.8/500KV
Transformer2	5000MVA, 13.8/500KV
Transmission line1	350Km
Transmission line2	350Km
Three phase linear load	5000MW
Three phase dynamic non-linear load	5000MW

Sample power system model consist of two hydraulic generation plant is of 1000MVA and 5000MVA which is placed in the two end of the system. one is placed at sending end and other is placed at receiving end near with three phase transformer is of 13.8 KV to 500 KV which are connected by two transmission line of 350 km each. There are three buses which are connected with the help of two transmission line of 350 km each. The three phase dynamic non-linear load is connected which is 5000 MVA capacity.

The firing pulses of space vector pulse width modulation (SVPWM) based unified power flow controller is shown in fig.6 and fig.7 (i.e. shunt and series pulses)

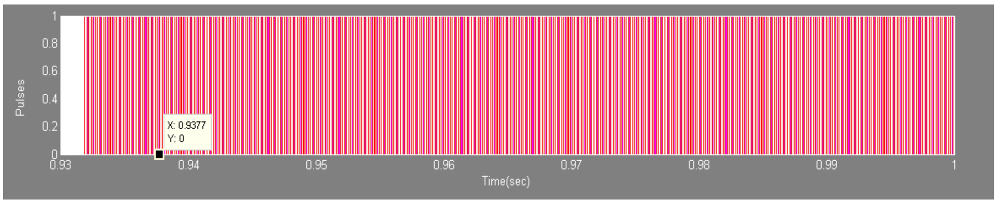

Fig.6. Pulses of shunt converter

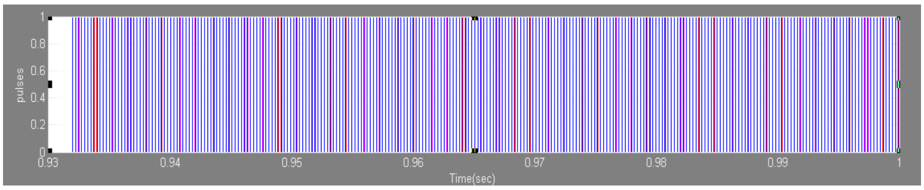

Fig.7. Pulses of series converter

V. SIMULATION RESULT

The simulation is done in MATLAB simulink software and observation is done under the different condition. The description of the system under the particular condition is observed which are explained below.

Case 1: Sample power system with PWM firing based UPFC and dynamic non-linear load.

The first condition we have taken is when the PWM firing based UPFC put in the sample power system model and dynamic non-linear load then fast fourier transformation (FFT) analysis of the sample power system and find the harmonic across each three buses voltage. The total harmonic distortion (THD) of dynamic non-linear load is 79.66% as shown in fig.8

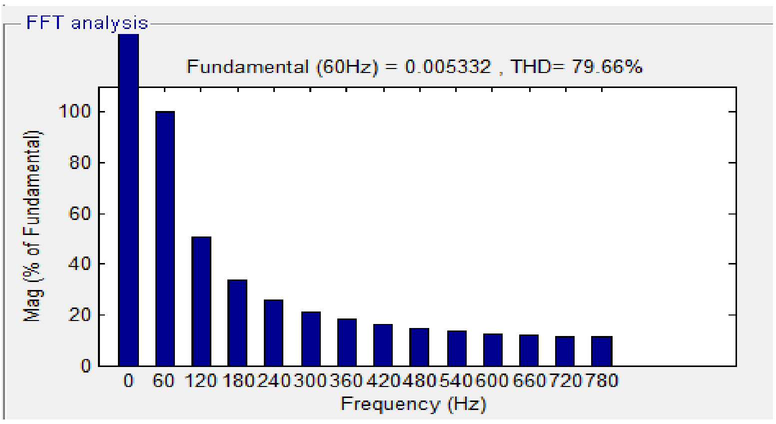

Fig.8. Simulation result of harmonic with PWM firing based UPFC

The percentage of odd harmonic table and bar diagram is shown in table.3 and fig.9 and the percentage of even harmonic table and bar diagram is shown in table.4 and fig.10

Table 3. Percentage of odd harmonic with PWM based UPFC

Harmonic	Frequency	PWM firing
Fund.	60Hz	100%
H3	180Hz	33.98%
H5	300Hz	20.88%
H7	420Hz	15.97%
H9	540Hz	13.32%
H11	660Hz	11.94%
H13	780Hz	11.34%

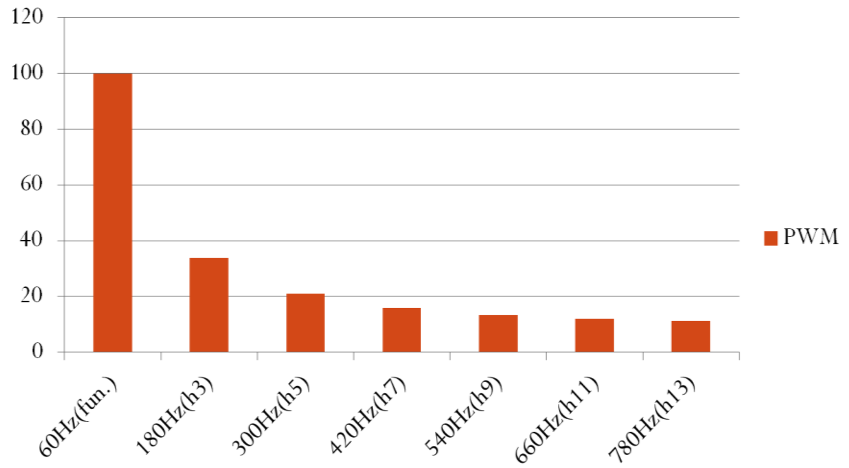

Fig.9. Bar diagram of odd harmonic percentage with PWM firing based UPFC

Table 4. Percentage of even harmonic with PWM based UPFC

Harmonic	Frequency	PWM firing
H2	120Hz	50.59%
H4	240Hz	25.77%
H6	360Hz	18.16%
H8	480Hz	14.43%
H10	600Hz	12.51%
H12	720Hz	11.56%

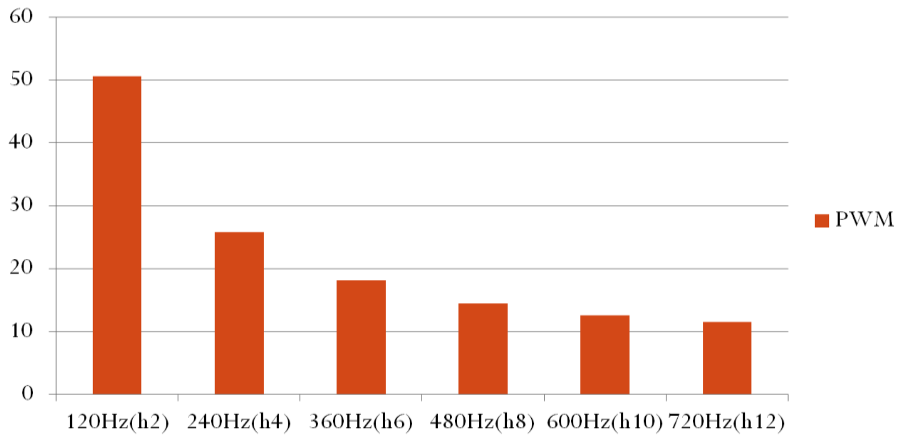

Fig.10. Bar diagram of even harmonic percentage with PWM firing based UPFC

Case 2: Sample power system with SVPWM firing based UPFC and dynamic non-linear load.

In second condition we have taken is when the space vector pulse width modulation (SVPWM) firing based UPFC put in the sample power system model and dynamic non-linear load then fast fourier transformation (FFT) analysis of the system and find the harmonic across each three buses voltage. At that time the total harmonic distortion (THD) is less as compare to the PWM firing based UPFC (i.e THD is 59.32%) harmonic of the system may get reduce using SVPWM firing based UPFC shown in fig.11

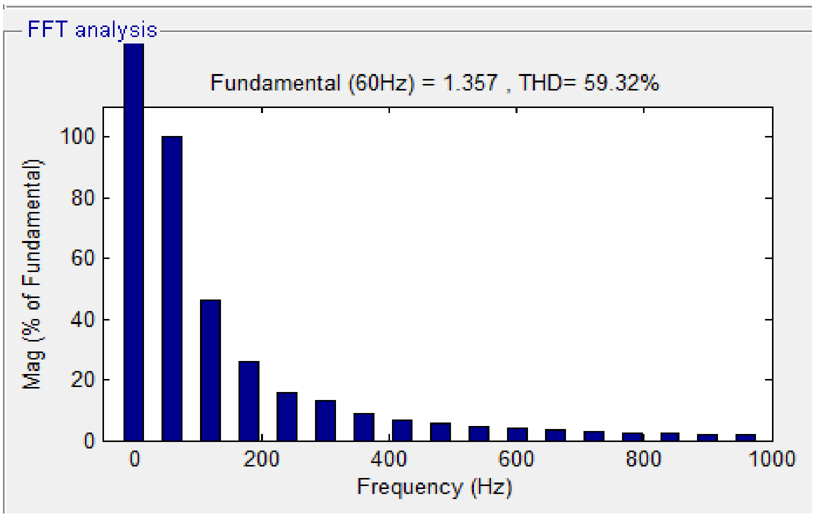

Fig.11. Simulation result of harmonic with SVPWM firing based UPFC

The percentage of odd and even harmonic in the system is shown in fig.12,13 and table.5,6

Table 5. Percentage of odd harmonic with SVPWM based UPFC

Harmonic	Frequency	SVPWM firing
Fund.	60Hz	100%
H3	180Hz	25.71%
H5	300Hz	13.19%
H7	420Hz	6.49%
H9	540Hz	4.36%
H11	660Hz	3.25%
H13	780Hz	2.55%
H15	900Hz	2.07%

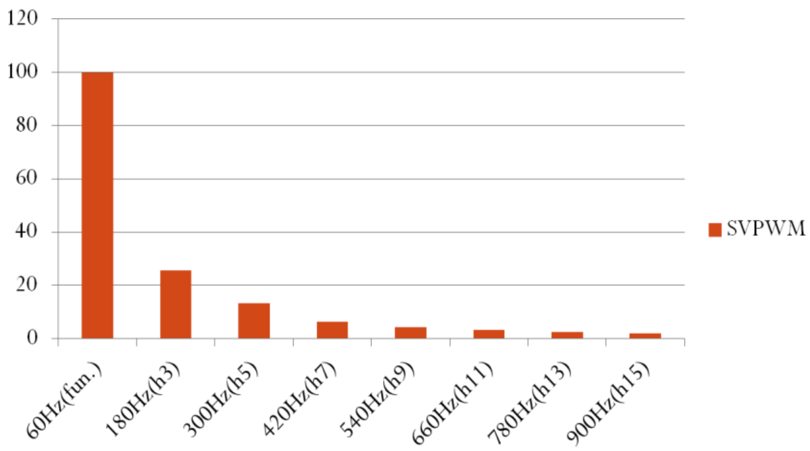

Fig.12. Bar diagram of odd harmonic percentage with SVPWM firing based UPFC

Table 6. Percentage of even harmonic with SVPWM based UPFC

Harmonic	Frequency	SVPWM firing
H2	120Hz	46.06%
H4	240Hz	15.77%
H6	360Hz	8.94%
H8	480Hz	5.37%
H10	600Hz	3.79%
H12	720Hz	2.82%
H14	840Hz	2.24%
H16	960Hz	1.89%

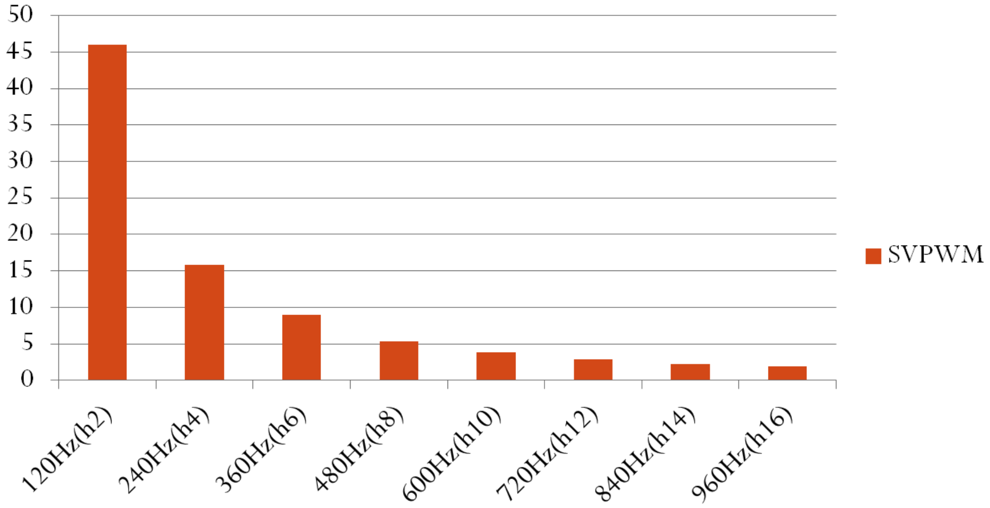

Fig.13. Bar diagram of even harmonic percentage with SVPWM firing based UPFC

The comparison between the PWM firing based UPFC and SVPWM firing based UPFC odd and even harmonic of system shown in table.7 and 8. you clarify the harmonic of SVPWM firing is less as compare to the PWM firing based UPFC and comparison bar diagram is shown in fig.14 and 15

Table.7. Comparison of odd harmonic with PWM and SVPWM firing

Harmonic	**Frequency**	**PWM firing**	**SVPWM firing**
Fund.	60Hz	100%	100%
H3	180Hz	33.98%	25.71%
H5	300Hz	20.88%	13.19%
H7	420Hz	15.97%	6.49%
H9	540Hz	13.32%	4.36%
H10	660Hz	11.94%	3.25%
H13	780Hz	11.34%	2.55%
H15	900Hz		2.07%

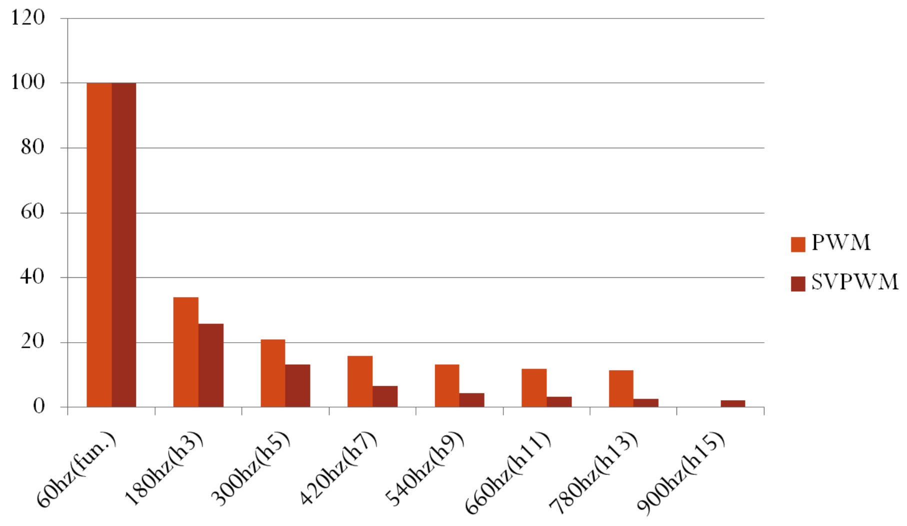

Fig.14 Comparison bar diagram of odd harmonic percentage with PWM and SVPWM firing based UPFC

Table 8. Comparison of even harmonic with PWM and SVPWM firing

Harmonic	Frequency	PWM firing	SVPWM firing
H2	120Hz	50.59%	46.06%
H4	240Hz	25.77%	15.77%
H6	360Hz	18.16%	8.94%
H8	480Hz	14.43%	5.37%
H10	600Hz	12.51%	3.79%
H12	720Hz	11.56%	2.82%
H14	840Hz		2.42%
H16	960Hz		1.89%

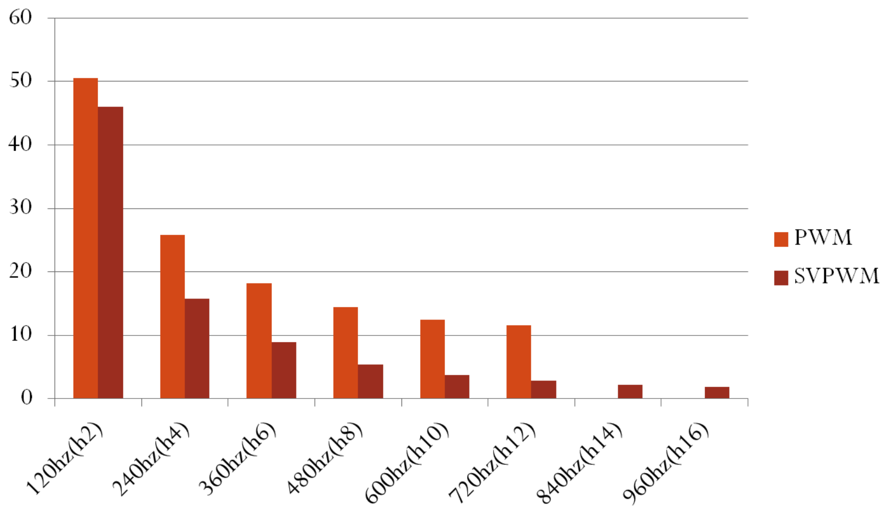

Fig.15. Comparison bar diagram of even harmonic percentage with PWM and SVPWM firing based UPFC

VI. CONCLUSION

This paper presents the power quality improvement of the system with UPFC. The MATLAB simulink environment is used to simulate sample power system with PWM firing based UPFC and SVPWM firing based UPFC and check the harmonic of the system. According to what mentioned in the simulation results, harmonic of the sample power system with PWM firing based UPFC is more as compare to the SVPWM firing based UPFC. using SVPWM firing harmonic of the system is reduce and power quality of the system may increased.

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