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POWER QUALITY ENHANCEMENT USING FUZZY CONTROL BASED DVR

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Abstract - *In the present scenario, power quality plays a vital role in affecting power quality harmonics. With the introduction of novel devices this issue has become more sensitive. Custom power devices, such as FACTS devices have come into existence for enhancement of power quality. Of these, UPFC (Unified Power Flow Controller) and DVR (Dynamic voltage Restorer) leads a key role in mitigating power quality issues. In this paper, UPFC is employed to the IEEE 14 bus system and the voltage improvement is observed. In the similar way, DVR with PI control and Fuzzy control is employed on a simple test system and harmonic distortion values are noted.*

Key Words: Power quality, Harmonics, Unified Power Flow Controller (UPFC), Dynamic Voltage Restorer (DVR).

1. INTRODUCTION

In the last few decades, the word power quality [1] has become one of the most concerned area to electric utilities as well as end users. Moreover complaints related to PQ disturbances are also increasing. An equipment performing without significant loss and having good efficiency can be termed as an achievement of power quality. Of all the factors affecting power quality, harmonics play a crucial role.

All periodical non sinusoidal waveform can be represented as sum of sine waves whose frequencies are integer multiples of fundamental frequency, which we call harmonics. Here we shall discuss the harmonics occurred due to disturbances in IEEE 14 bus system.

2. IEEE 14 BUS SYSTEM:

The IEEE 14 bus system is shown in fig-1. Out of the 14 buses, 5 are generators, 3 are transformers and 11 are loads. Harmonic analysis is performed on this system by considering all the impedance parameters and calculating harmonic currents as well as harmonic impedances.

For performing harmonic analysis, we make use of Newton Raphson method of load flow studies and get the values of real and reactive power generated at different buses and line losses. By using this data, Harmonic analysis for IEEE 14 bus system is done. Now, If we employ a converter with 5000kw & 0.85pf lag at bus 5, the harmonics calculated at different buses for different harmonic values are given in results section in fig.6 to fig.10. By those results we get an idea of how the harmonic voltages are varying with change in harmonic values.

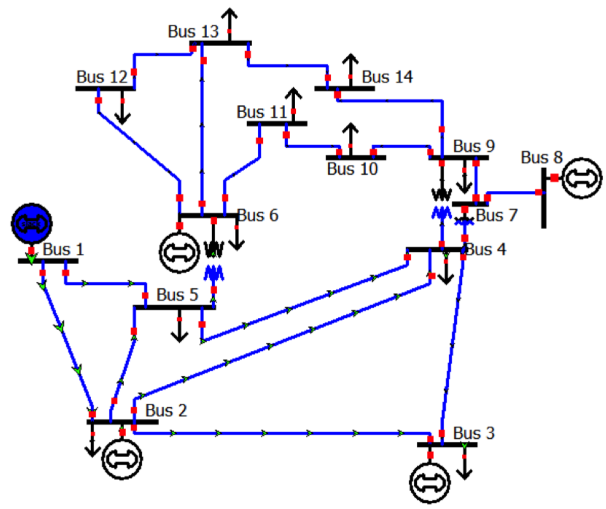

Fig -1: Single line diagram of IEEE 14 bus system

To reduce harmonics and to improve Power Quality, two types of FACTS devices namely UPFC and DVR are employed.

2.1 UPFC Control:

FACTS technology [2] allows a greater control of power flow. Since these devices provide very fast power swing damping, the power transmission lines can be securely loaded up to their thermal limits.

Unified Power Flow Controller (UPFC) is "A combination of Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC) which are coupled via a common D.C link to allow bi-directional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM".

UPFC which is the one of the most powerful FACTS device [3] can simultaneously control all the parameters of the system: the line impedance, the transmission angle, and bus voltage.

The UPFC schematic diagram is shown in fig-2 and it consists of two voltage-sourced converters, which operate from a common D.C. Circuit consisting of a storage capacitor.

The UPFC [4] could be described as consisting of a parallel and series branch. Each converter can independently generate or absorb reactive power. This arrangement enables free flow of active in either direction between the A.C. terminals of the two converters.

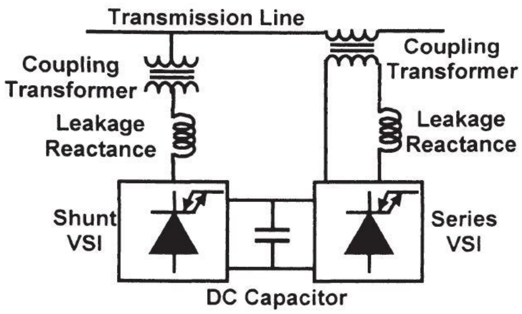

Fig -2: Schematic diagram of UPFC

The IEEE 14 bus system shown in fig 1 is implemented using simulink and a shunt converter with parameters 5000kw and 0.85pf is inserted at bus 5 and the voltage waveform is as given in fig 11. Now, the implementation of UPFC [5] is done using simulink for the same system and the voltage improvement is obtained. The corresponding waveforms obtained are shown in fig 12.

2.2 DVR Control:

DVR is one of the most effective and efficient FACTS device which injects voltage into the system dynamically in order to reduce the harmonic voltages and to bring a balance into the system.

Here we consider a simple test system shown in fig-3, which has 2 feeders drawn from same supply using 3 winding transformer. One of the feeder is uncompensated whereas the other is compensated using DVR [6]. For this we make use of different control strategies. Here we are going to discuss about PI control and Fuzzy control methods.

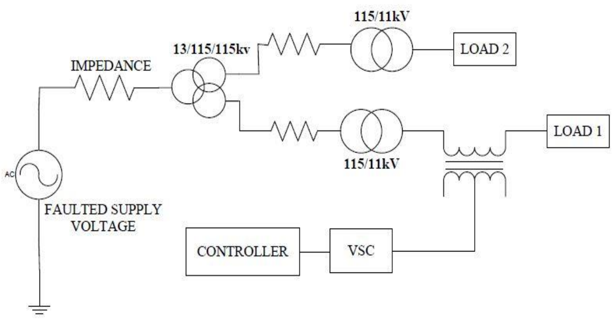

Fig -3: Single line diagram of test system.

2.2.1 DVR with PI control:

PI controller is shown in fig-4. This is a linear technique. It is a feedback controller which uses weighted sum of error & integral value to perform control operation. The response can be adjusted by multiplying error by constant K_p, called proportional gain. The integral term is proportional to both magnitude of error and duration of error. The error is first multiplied by integral gain K_i and then integrated to give an accumulated offset. Linear PI adjusts its K_p and K_i to reduce the steady state error to zero for step input.

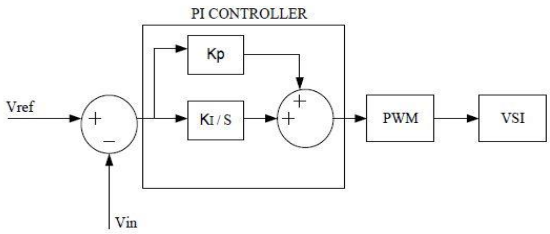

Fig -4: PI controller

The results obtained by making use of this DVR control with PI is shown in fig. 13

Table -1: DVR system parameters

S.no	System Quantities	System parameters
1	Source	3-phase 13KV, 50Hz
2	Inverter parameters	IGBT, 3 arms, 6 pulse, carrier frequency=1080Hz, sample time=50μsec
3	PI controller	Kp=0.5, Ki=50, sample time=50 μsec
4	Three winding transformer	Y / Δ/Δ 13/115/115 KV
5	Two winding transformer	Δ/Y 115/11 KV

PI controller gives faster response and zero steady state error can be achieved. Both the steady state and transient responses can be improved.

2.2.2 DVR with FUZZY control:

Fuzzy controller is a nonlinear technique unlike the linear PI controller [9]. By changing the system parameters & operating conditions, the required results can be obtained. Mathematical modeling & calculations are not necessary for this system and both the transient and steady state analysis can be performed using this technique. The control strategy of fuzzy controller is as shown in fig-5. And the rule base for this system is as shown in table-2.

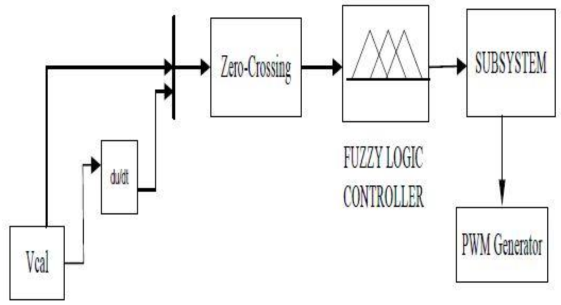

Fig 5: Control Strategy of fuzzy controller.

Table 2: Fuzzy rule base system

	NL	NM	NS	Z	PS	PM	PL
NL	L	L	L	M	Z	S	Z
NM	L	L	M	Z	Z	Z	S
NS	L	M	S	Z	Z	S	S
Z	M	S	S	Z	S	S	M
PS	S	S	Z	Z	S	M	L
PM	S	Z	Z	Z	M	L	L
PL	Z	S	Z	M	L	L	L

By using this fuzzy rule base, mamdani interference mechanism and centroid method of Defuzzification, this DVR control[10] is performed and the obtained results are shown in fig-14 and the Total Harmonic Distortion values are presented in the form of bar graph in fig-15.

3. RESULTS:

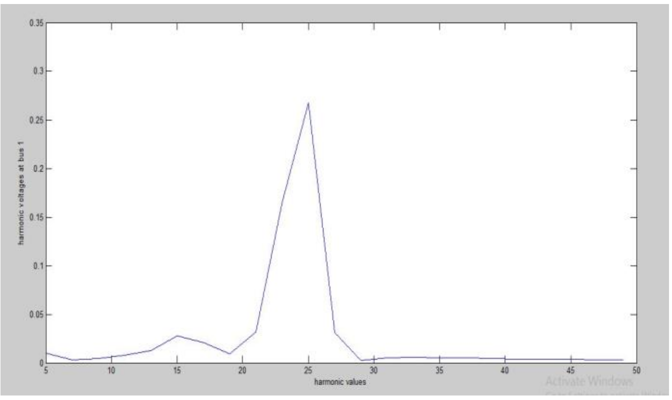

Fig 6: Harmonic voltages at different harmonics for bus 1

It can be observed from fig. 6 that harmonic voltage of bus 1 at 25th harmonic value is amplified due to impedance resonance.

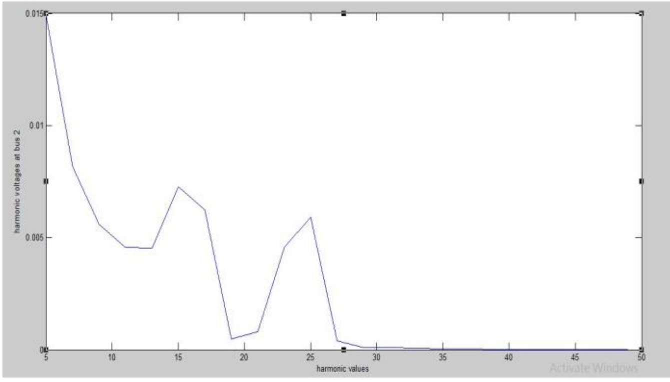

Fig 7: Harmonic voltages at different harmonics for bus 2

It can be observed from fig. 7 that harmonic voltage of bus 2 at 5th harmonic value is amplified due to impedance resonance.

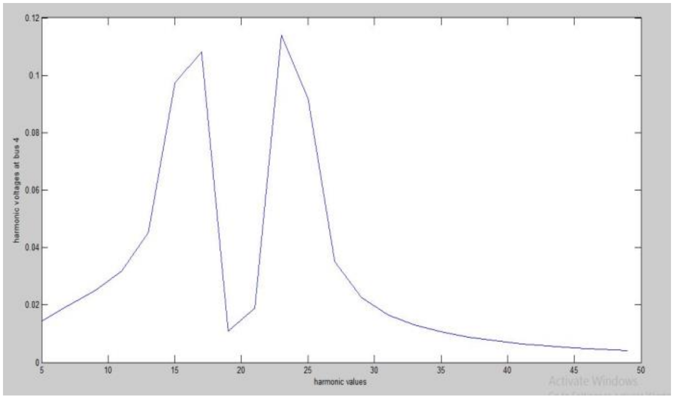

Fig 8: Harmonic voltages at different harmonics for bus 4

It can be observed from fig. 8 that harmonic voltages of bus 4 at 15th and 23rd harmonic values are amplified due to impedance resonance.

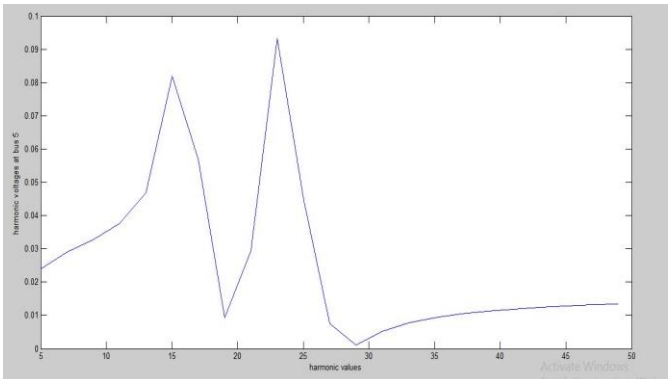

Fig 9: Harmonic voltages at different harmonics for bus 5

It can be observed from fig. 9 that harmonic voltages of bus 5 at 15th and 25th harmonic values are amplified due to impedance resonance.

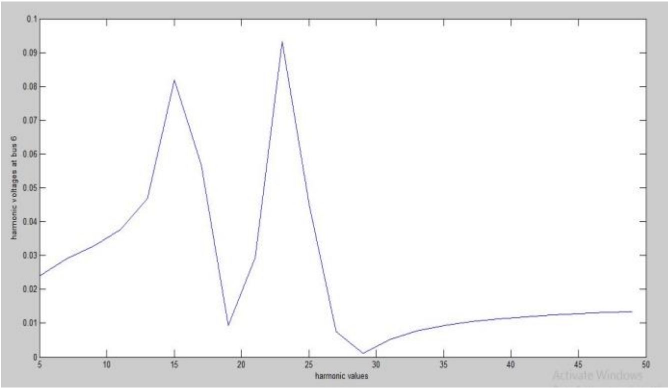

Fig 10: Harmonic voltages at different harmonics for bus 6

It can be observed from fig. 10 that harmonic voltages of bus 6 at 13th and 23rd harmonic values are amplified due to impedance resonance.

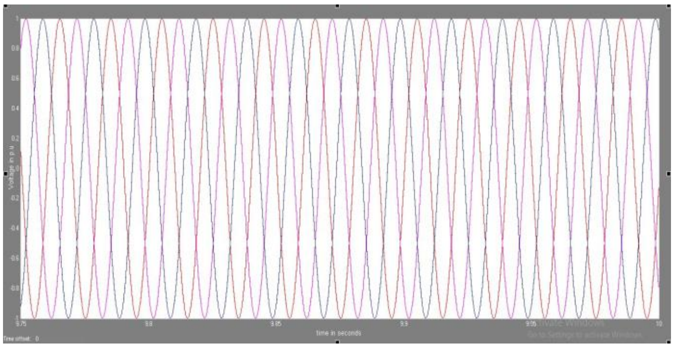

Fig 11: Load voltage waveform after creating disturbances in IEEE 14 bus system at bus 5.

From fig. 11 it can be observed that there is a change in voltage waveform obtained due to the disturbance created through a converter of 5000kw and o.85 power factor lag.

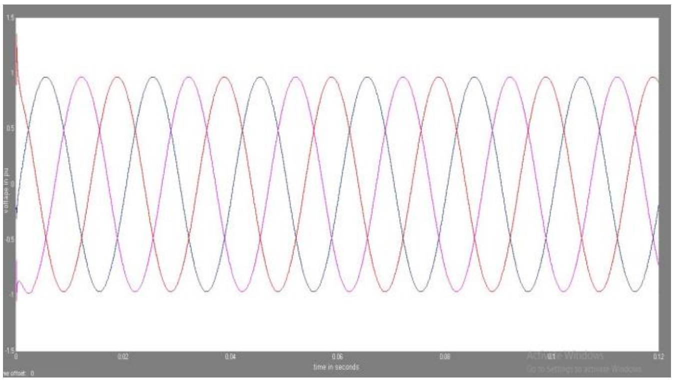

Fig 12: Load voltage waveform after employing UPFC at bus 5 in IEEE 14 bus system.

From fig. 12 the improvised waveform for voltage by using the FACTS device UPFC can be observed (Unified Power Flow Controller).

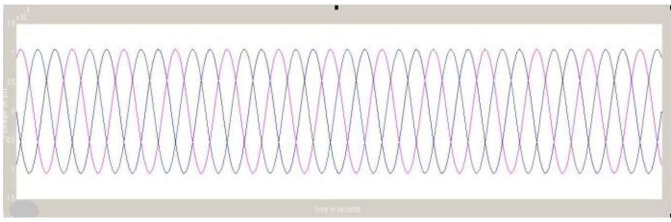

Fig 13: Load voltage waveform for PI control of DVR.

By using PI controller based DVR, we obtained a THD value of 23.70%.

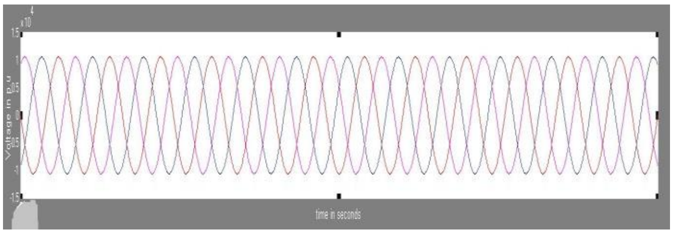

Fig 14: Load voltage waveform for Fuzzy control of DVR.

Without any controller being employed into the system we got 32.6% THD value. By using Fuzzy controller based DVR, we obtained a THD value of 17.49% which is better than that obtained through linear PI control strategy.

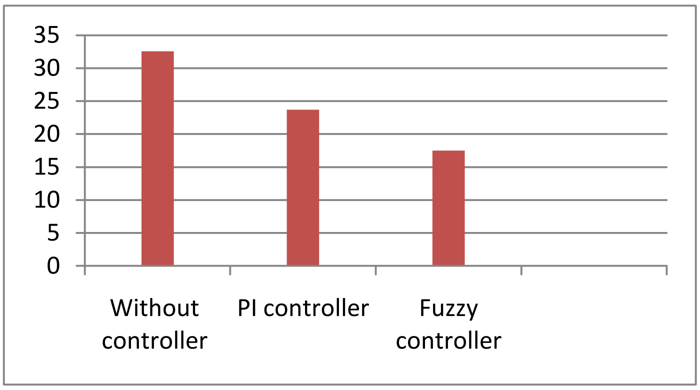

Fig. 15: Bar graph showing the variations in THD values for different controllers.

5. CONCLUSIONS

This paper has presented one of the main Power Quality problems i.e., harmonic variations. Harmonic analysis is done on IEEE 14 bus system and with the implementation of custom power devices such as UPFC and DVR, the power quality is improved. With further implementation of different control strategies for DVR such as PI and Fuzzy control, the percentage of total Harmonic Distortion is reduced, which results in enhancement of Power Quality.

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