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Power Quality Improvement Using Modern FACT's apparatus DPFC

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Abstract —*This paper demonstrate modern FACT'S apparatus, predicted as DPFC Distributed Power Flow Controller. Through avoiding the joint dc link among shunt and series converters from UPFC, the DPFC hold the D-FACT'S conception which is use multiple small-size single phase converters rather of the one large-size three-phase series converter in the UPFC. So the price of DPFC system is let down than the UPFC. inthis DPFC took as UPFC with voiding of dc link and applied to mitigate load current harmonic. This is modeled without DPFC and With DPFC in Matlab/Simulink on IEEE-6bus system and comparable outcomes will be shown.*

Keywords- *FACT'S, Power Quality,DPFC, Mitigation of load current harmonic, IEEE-6 Bus*

I. INTRODUCTION

Since the electrical power quality issue has been the main concern of power industrial revolution. So, industrially developed societies need an ever improving supply of electrical power. Very complex power system apparatus have been built to satisfy this power quality improving demand.FACT'Sthe flexible ac-transmission system that is determined by IEEE as "the FACT'S is a modern technology based on power electronic device which extend an opportunity to enhance controllability, power transfer capability and stability of AC transmission system"[1] power quality issues caused varying load, short circuit, motor starting upward. A harmonic is determined by "a harmonic is a signal or wave whose frequency is an integral (whole-number) multiple of the frequency of some reference signal or wave".

Now and then the FACT'S engineering has demonstrated strong possibilities in all aspects. Many examples of FACT'S apparatus and controllers are in procedure. The conception of FACT'S was brought as a category of power electronic apparatus which have issued for controlling and optimizing flow of electrical power in the transmission line.The unified power-flow controller UPFC is the most apparatus to control like the line impedance, the transmission angle, and bus voltage. The UPFC is the combing of a STATCOM and SSSC, which are paired via joint dc link, to allow bidirectional flowing of active power among the series output terminals of the SSSC and the shunt output terminals of theSTATCOM. As shown in figure 1.

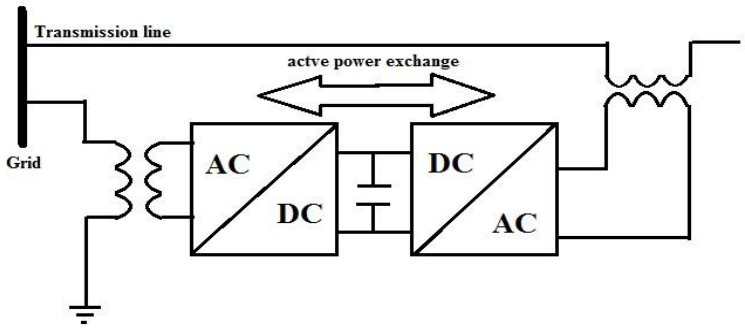

Figure 1 configuration of UPFC

The converter in series with the line appropriate the main function of the UPFC by injects a four-quadrant voltage with controllable magnitude and phase. The injected voltage basically acts as a synchronous ac voltage source, which is applied to change the transmission angle and line impedance, therefore independently controlling the active and reactive power flow through the line. The series voltageresults in active and reactive power injected or absorbwithin the series converter and thetransmission line. This reactive power is generatedinternally by the series converter and the active power is added by the shuntconverter that is back to back connected. The shuntconverter controls the voltage of the dc capacitor by absorbs or generating active power from the bus,hence, it behaves as a synchronous source in

parallelwithinthe system. Similar as STATCOM, the shuntconverter can also give reactive compensation forthe bus. The components of the UPFC hold thevoltages and currents with in high rating hence, thetotal price ofthe system is high. Due to the jointdc-link, a failure that happens at oneconverter will affect the whole system. Toattain the required reliability for power systems,bypass circuits and redundant backup's transformer are needed.Which on other hand,increase the price, so the UPFC has not usually applied still most versatile apparatus for reliable. This paper introduces modern conception, presented as DPFC distributed power-flow controller that is emerged from the UPFC. The same asthe UPFC, the DPFC is able to control all systemparameters. Within the DPFC voiding joint dclink withinthe shunt and series converters. The active power exchange between the shunt and theseries converter is through the transmission line at the 3rd harmonic frequencies. The series converter of theDPFC applied theD-FACT'S conception.

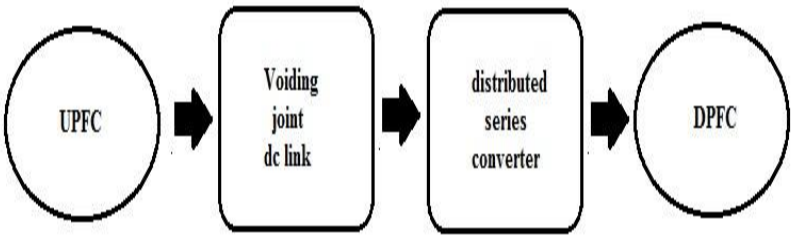

Figure 2 Flow-Diagrams from Unified Power Flow Controller to Distributed Power Flow Controller

The primary aim, distributed power flow Controller DPFC presented as modern FACTS apparatus is applied To mitigate load current harmonic to improve power quality. The DPFC configuration is emerged from the UPFC configuration that is include one shunt converter and several small independent series converters. The DPFC has similar capability as UPFC to maintain the line parameters, like as line impedance, transmission angle, and bus voltage magnitude. As shown in figure 3 below.[2]

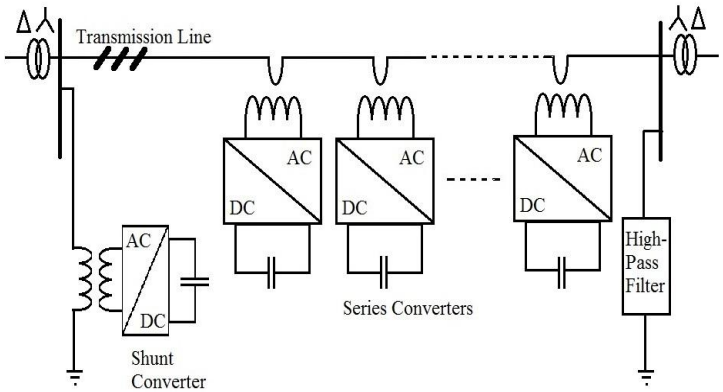

Figure 3 configuration DPFC

II. PRINCIPAL OF DPFC

The There are two basic approaches that applied to the UPFC for simulating of DPFC as below.

A. Active Power Exchange between Voiding dc-link

Throughout simulating of Distributed Power Flow Controller consisting the AC terminal at series converter side and DC terminal shunt converter side this connection are applied on transmission line. Rather of power exchanging within the converters through applying dc link. The power theory for non-sinusoidal part is established in DPFC [1] established of sinusoidal parts from different frequency is being from voltage or current. The active power is provide from the product part of voltage and current, afterward differently frequency is zero for integral within some condition. Mathematically the active power equation is as below.

$$P = \sum_{i=1}^{\infty} V_i \, I_i \cos\phi_i$$

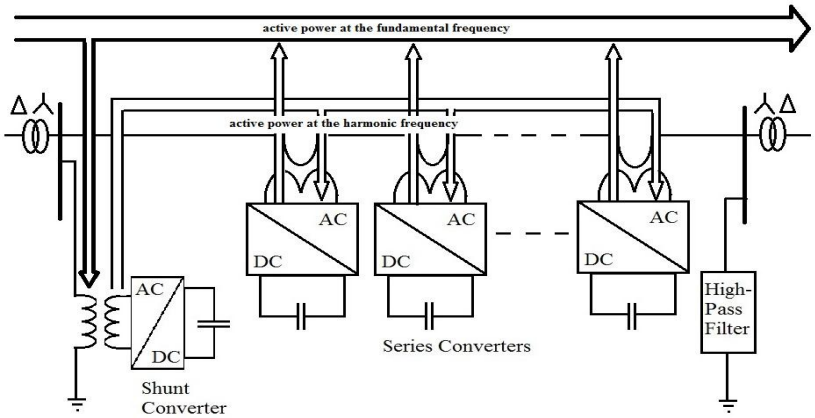

Figure 4 Active Power Exchange within DPFC

The ϕi is the angle amongst same frequency for current and voltage. Similarly VI is the voltage and Ii current is at the ITH harmonic. The active power through other frequency has not act upon by current and voltage for different frequency. Afterward going for above concept to for DPFC, the harmonic frequencies from the grid power come in that and the active power from fundamental frequencies is accepted among shunt converter as shown in figure 4. The transmission line bear dual power one at fundamental frequency and other at 3rd harmonic frequency, applying Superposition theorem both power can be achieved. The high pass filter in the DPFC structure blocks the fundamental frequency components and allows for the harmonic components to pass in ground, thereby allowing for a return way for the harmonic components. The series and shunt converters, the ground, and the high-pass filter form the closed loop for the harmonic current. Due to the unique Qualities of 3rd harmonic frequency components, it is taken to exchange the active power between series and shunt convertors in the DPFC.

B. Distributed Series Converters Concept

This system consisting lower cost and high reliability, the D-FACTS is the concept to use multiple low- power converters connected to the transmission line by individual transformer. There is no requiring of pricy high voltage isolation because on transmission line converters are hanged. The distributed series converters take the active power at 3rd harmonic frequency from transmission line and inject it back into the line at fundamental frequency as per disturbances.

C. DPFC Rewards

The DPFC can be takenas a UPFC thatApplied the D-FACT'S conception and the conception of exchanging power through harmonic. Hence, theDPFC has all the reward of the UPFC andthe D-FACT'S, as below

High control capability

The DPFC can control all the parameters of the power system, the line impedance, the transmission angle, and the bus voltage. The Joint dc link enables separated installation of the DPFC converters. The shunt and series converters can be placed at the most effectivelylocation. Due to the high control capability, [2] theDPFC can also be applied improve the power qualityand system stability, such as low-frequency poweroscillation damping, voltage sag restoration, or balancing asymmetry.

High reliability

The redundancy of the series converter gives animproved reliability. The shunt and seriesconverters are independent, and the failure at oneplace will not affect the other converters. When adecline occurs in the series converter, the converterwill be short-circuited by bypass protection, therebyhaving little influence to the network. In the case ofthe shunt converter decline, the shunt converter willtrip and the series converter will stop providingactive compensation and will act as the D-FACT'Scontroller

Low price

The single-phase series converters rating arelower than one three-phase converter. Hence,the series converters do not required of any high voltageisolation in transmission line connecting; single-turntransformers can be used to hang the seriesconverters.

III. CONTROL OF DPFC

The DPFC comprises with central control, series control and shunt control as mentioned in figure 5. From the power system point the function of DPFC are handled by the central control. For converter parameter the shunt converter and series converter control are place for converter parameter.

Central Control

The central control generating the reference signals for both the shunt and series converters of the DPFC. Its control function has depends on the specifics of the DPFC application at the power system level, such as power flow control, low frequency power oscillation damping and balancing of asymmetrical components. According to the system requirements, the central control gives corresponding voltage reference signals for the series converters and reactive current signal for the shunt converter, all the reference signals generated by the central control concern the fundamental frequency components.[3]DPFC control block diagram as shown figure 5 as below.

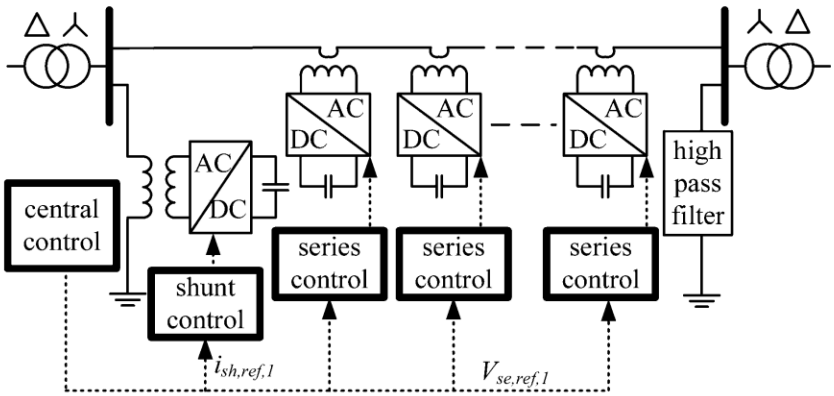

Figure 5 DPFC control confirguration

Series Control in Matlab/Simulink

Within each series converter has its own series control. The controller is used to maintain the capacitor DC voltage of its own converter, using third harmonic frequency components, in addition to generating series voltage at the fundamental frequency as required by the central control

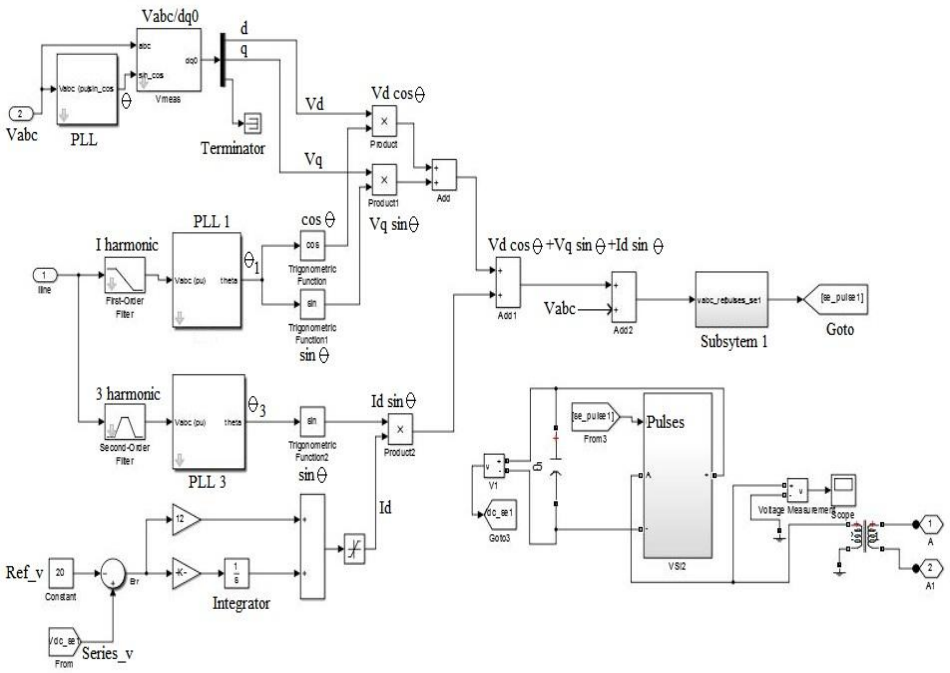

Figure 6 Series Converter control on Matlab/Simulink

Shunt Control in Matlab/Simulink

The main objective of shunt control is to inject a constant 3rd harmonic current into the line to supply active power for the series converters, At the same time, it maintains the capacitor DC voltage of the shunt converter at a constant value by absorbing active power from the grid at fundamental frequencies and inject the required reactive current at the fundamental frequency in to the grid.

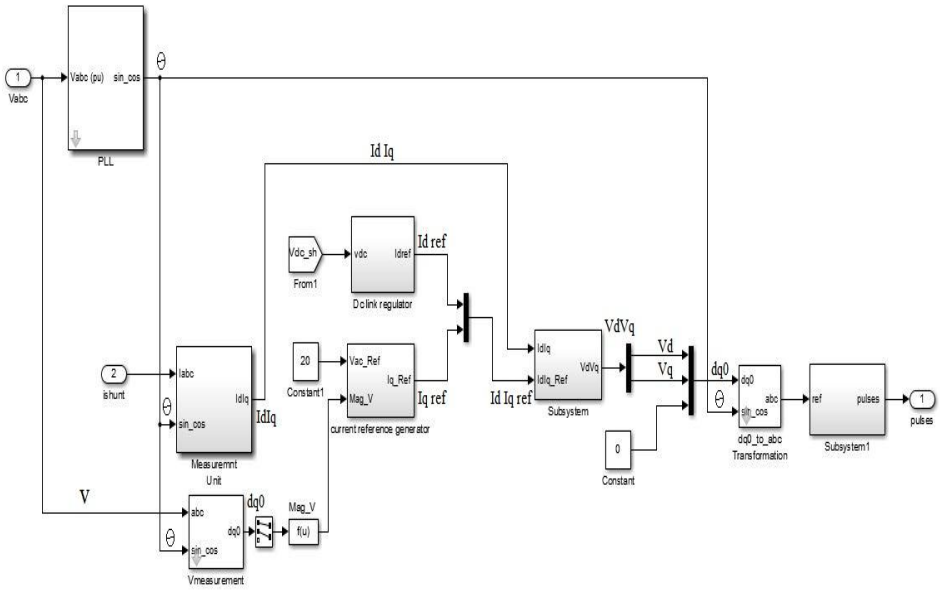

Figure 7 shunt converter control in Matlab/Simulink

IV. POWER QUALITY IMPROVEMENT IN MATLAB/SIMULINK

To simulate design model for harmonic in IEEE-6 bus system three phase diode and R-L are considered as non-linear load. In this simulation the scope indicate non-sinusoidal waveform of current that generated by three phase diode and R-L load shown in figure 7 as below.

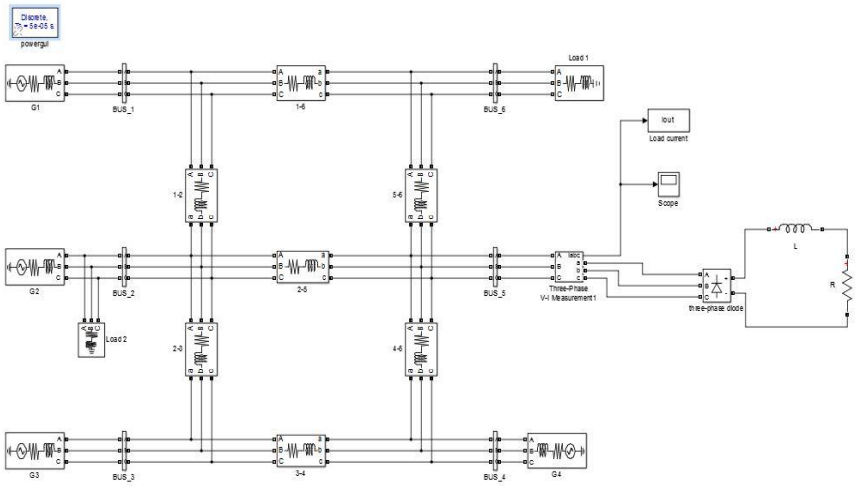

Figure 8 IEEE-6 bus systems for Load Current Harmonic without DPFC

The load current harmonic analysis without presence of DPFC is shown in figure 9. Three phase diode and R-L load generate non sinusoidal harmonic waveform. In system the even harmonics are eliminated, the odd harmonics are reduced within acceptable limits, and total harmonic distortion of current is minimized after adding DPFC to system.

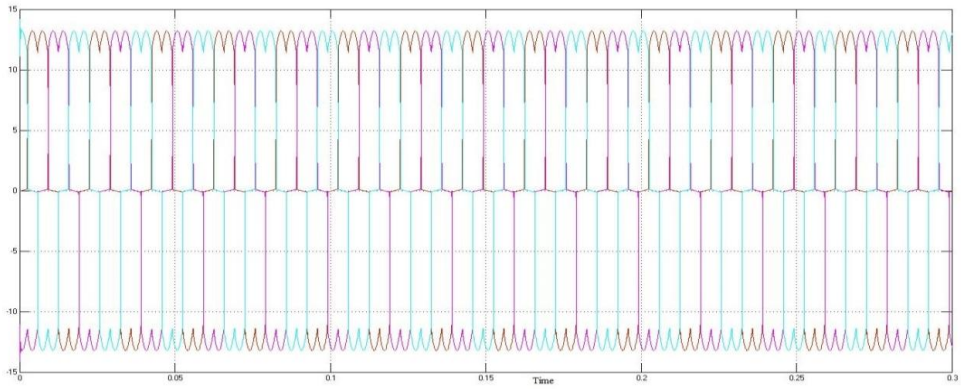

Figure 9 three-phase Load Current Harmonics Waveform

The FFT analysis result of Harmonic within the fundamental frequency of 50Hz and indication of the signal window of total harmonic distortion as below figure 10.

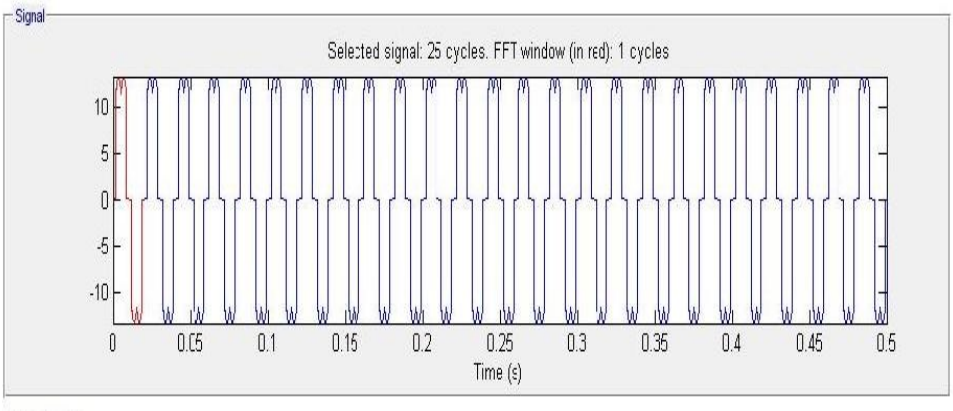

Figure 10 Three Phase Load Current Signal Selected for Calculating (THD)

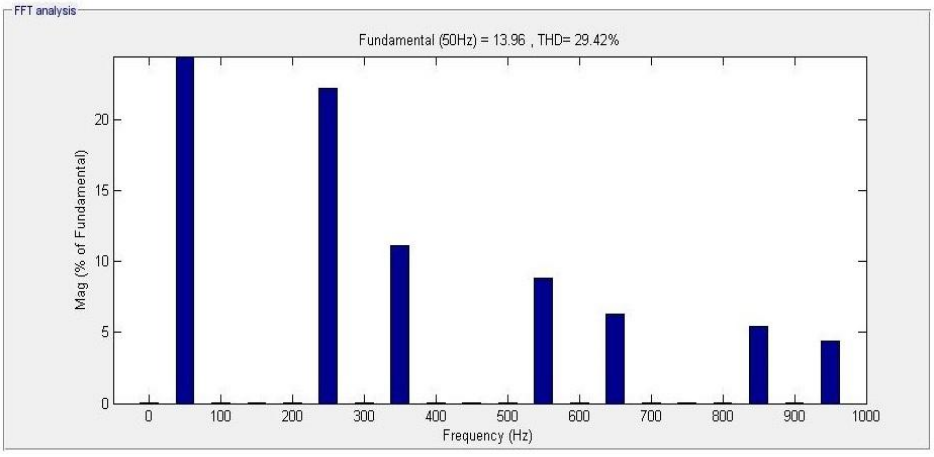

Figure 11 (THD) of Load Current Harmonic without DPFC

The case study, considering Harmonic in IEEE-6 bus system and analyzed waveform results are as above figure 11. The fundamental frequency (50Hz), and total harmonic distortions THD=29.42%, after adding the DPFC harmonic can be mitigated.

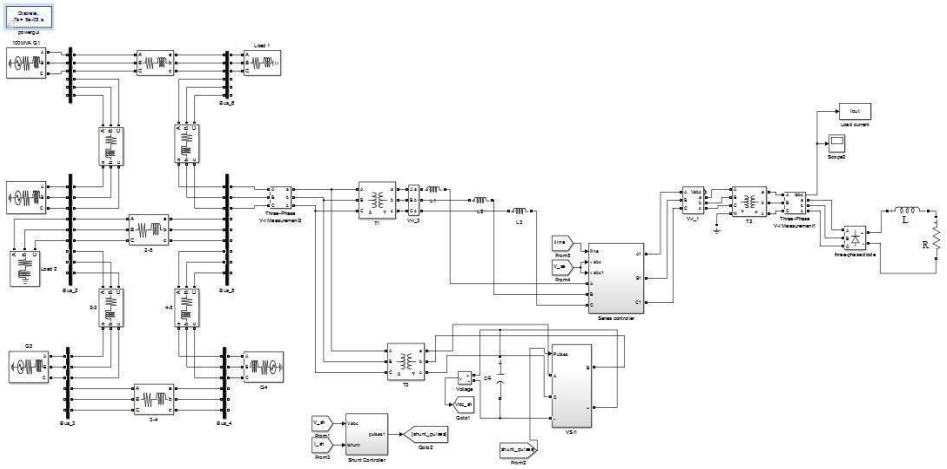

Figure 12 Mitigation of Load Current Harmonic with DPFC in Matlab/ Simulink

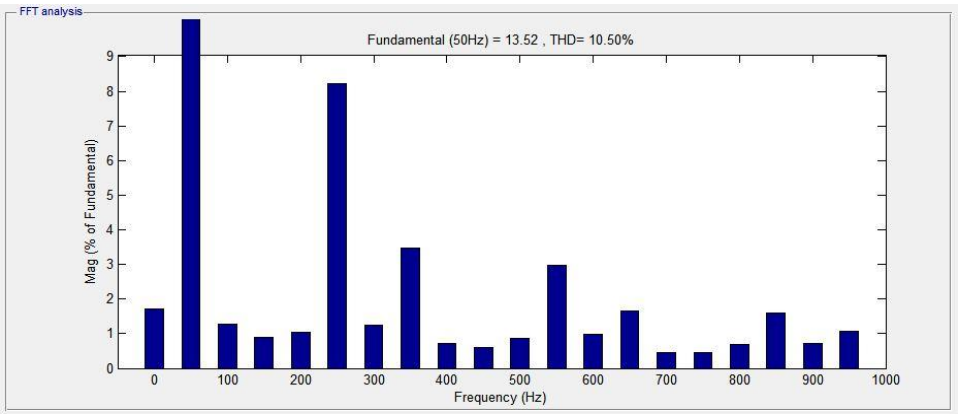

Figure 13 (THD) Load Current Harmonic with DPFC

The design model for load current harmonic is exhibited in Figure 8. In this the system modeled with a Load current Harmonic R, L load that behaves as non-linear load. The load current harmonics are analyzed with DPFC is exhibited at figure 12. After implementing DPFC in IEEE-6 bus system. The THD of load current harmonic are reduced from 29.42 to 10.50 percentages in figure 13.

V. CONCLUSION

This paper introduced a modern conception called DPFC. Which is emerged from UPFC offers the same contarlablity as UPFC at reduce price. The joint dc link voiding within the shunt and series converter and distributing the series converters so the no high voltage isolation is need so total cost is less. The DPFC is modeled with IEEE-6 bus system without DPFC and with DPFC, It demonstrate that DPFC give acceptable performance in power quality mitigation of load current harmonic on IEEE-6 bus system.

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