LOAD BALANCING USING FACT DEVICES

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Abstract - Distribution system is mostly suffered from the load unbalanced condition. Load is differing at different time and location, which affects the system performance and efficiency. Distribution system having the efficiency approximates 50%. Proper operation of the system the load must be in under balance potion.

The load can be balanced by using the different types of the FACTS devices. variety of custom power devices are developed and successfully implemented to compensate various custom power devices are the D-STATCOM (distribution static compensator),DVR (dynamic voltage restorer), UPQC(unified power quality conditioner), the current related power quality problems are mitigated by a shunt connected device are called DSTATCOM

Index Terms- DSTATECOM, load balance, DVR, FACTS devices, distribution system.

I. INTRODUCTION

1.1 OVER VIEW

All the electrical and electronic equipments are affected by the power quality disturbances on uneven distribution of loads in the three phase there occurs the problem of load unbalancing and increase in the use of power electronic equipment results in increase of harmonic content in the power distribution system .A variety of custom power devices are developed and successfully implemented to compensate various custom power devices are the D-STATCOM (distribution static compensator),DVR (dynamic voltage restorer), UPQC(unified power quality conditioner), the current related power quality problems are mitigated by a shunt connected device are called DSTATCOM .the effectiveness OF D-STATCOM depends upon the control algorithm used to obtain the reference current the hysteresis controller is then used to generate the gate signals for firing the IGBT used in D-STATCOM[1].

A D-STATCOM is a device which is used in AC distribution system where harmonic current, reactive current compensation and load balancing are necessary the building block of a DSTATCOM is voltage source converter (VSC) consisting of self commutating semiconductor valves and a capacitor on a dc bus the device is shunt connected to the power distribution network through a coupling inductance. In general, the DSTATCOM can provide power factor correction, harmonic compensation and load balancing. the major advantages of DSTATCOM compared with a conventional static VAR compensator(SVC) include the ability to generate the rated current at virtually any network voltage . better dynamic response and the use of relatively small capacitor on the dc bus the size of the capacitor does not play an important role in steady state reactive power generation which results in a significant reduction of the overall compensator size and cost[2].

1.2 OBJECTIVE

The term power quality embraces all the aspects associated with amplitude ,phase and frequency of the voltage and current waveforms existing in the power circuit . Poor power quality may occur due to transient condition in the power circuit or from the installation of non-linear loads , there is an increasing use of sensitive loads , such as computers ,industrial drives communication and medical equipments .nowadays , power quality is a more complex problem than in the past because the new loads are not only sensitive to power quality , but also responsible for adversely affecting the quality of power supply . Although, the distribution power systems may have an impact on the quality of power. It becomes significantly worse at the point where the loads connected to the distribution grid [1]. A single customer may cause significant reduction in power quality for many other customers understanding power quality issues is a good starting point for solving any power quality problem.

2. PROBLEM IDENTIFICATION

In power generation or distribution the most important factor is quality of power which depends mostly on the respective voltage and current . the major sources of problems with power quality at the customer site is the arc welding the next group consists of uninterruptible power supply . variable speed dc and AC drives these equipment draw large amount of harmonic contents from the supply causing distortion of the voltage and overheating of the transmission system .In addition they draw currents at low power factor .various types of rectifiers used in these equipment mostly create the problems in addition the quality of utility power affects the performance of these power systems.

3. IDEAL- THREE PHASE SHUNT COMPENSATOR STRUCTURE

To illustrate the functions of shunt compensator ,(3p4w) distribution system shown in fig . All the currents and voltages that we indicated in this figure 1

Are instantaneous quantities , have a three phase balanced supply (V_{sa}, V_{sb}, V_{sc}) is connected across a star(Y) connected load .the load are such that the load

Currents (i_{sa}, i_{sb}, i_{sc}) may not be balanced .may contain harmonics and dc offset .In addition, the power factor of the load maybe zero-sequence current i_{Nn} flowing in the 4-wire i.e. in the path n-N as shown in fig. 1

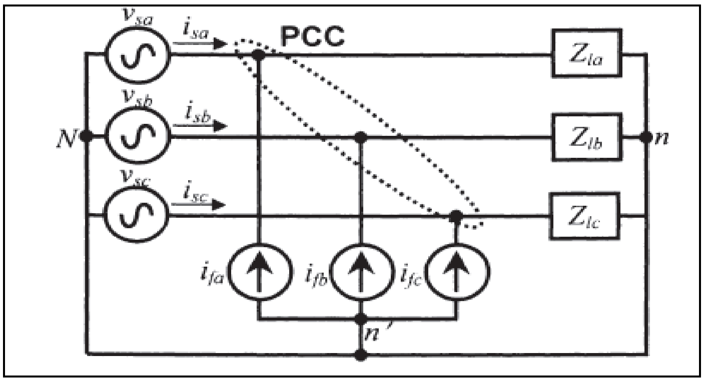


Fig.1 Schematic diagram of a shunt compensator for 3p-4w distribution system that is supplying a Y –connected load.

The shunt compensator is represented by three ideal current sources i_{fa}, i_{fb}, i_{fc} the point of common coupling (PCC) is encircled in fig(4.2). The current sources are connected inY-with their neutral n' being connected to the 4-wire system.

The purpose of the shunt compensator is to inject current in such a way that the source currents (i_{sa}, i_{sb}, i_{sc}) are harmonic free balanced sinusoids and their phase angle with respect to the source voltages (v_{sa}, v_{sb}, v_{sc}) has desired value

3.1 GENERATING REFERENCE CURRENTS USING INSTANTANEOUS P-Q THEORY

Hirofumi Akagi and his coworker desired an instantaneous method of generations reference currents for shunt compensator since then various interpretations of this method have been presented this method is applicable to a three phase four wire system . to begin with we transform the three phase voltages from a,b ,c frame to $\alpha - \beta - 0$ frame and vice versa using the following power invariant transformation

$$\begin{bmatrix}V_0\\V_\alpha\\V_\beta\end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix}\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}\\ 0 & \frac{-1}{2} & \frac{-1}{2}\\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2}\end{bmatrix}\begin{bmatrix}V_a\\V_b\\V_c\end{bmatrix} \quad (1)$$

$$\begin{bmatrix}V_a\\V_b\\V_c\end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix}\frac{1}{\sqrt{2}} & 1 & 0\\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2}\\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2}\end{bmatrix}\begin{bmatrix}V_0\\V_\beta\\V_\gamma\end{bmatrix} \quad (2)$$

The instatantaneous three phase is then givenby

$$P_{3\phi} = v_a i_a + v_b i_b + v_c i_c \quad (3)$$

$Where p$ is the total instantaneous real power in the three phase wires and $p_0 = v_0 i_0$ is the instantaneous power in the zero-sequence network defining the following variables

$$q = v_\alpha i_\beta - v_\beta i_\alpha \quad (4)$$

$$\frac{1}{\sqrt{3}}\{i_a(v_c - v_b) + i_b(v_a - v_c) + i_c(v_b - v_a)\}$$

Consider the following balanced three- phase voltages and currents

$$v_a = v_m \sin \omega t, \quad i_a = i_m \sin(\omega t - \phi) \quad (5)$$

$$v_b = v_m \sin(\omega t - 120)\, i_b = i_m \sin(\omega t - 120 - \phi) \quad (6)$$

$$v_c = v_m \sin(\omega t + 120)\, i_c = i_m \sin(\omega t + 120 - \phi) \quad (7)$$

It can then write

$$v_a - v_b = \sqrt{3} v_m \sin(\omega t + 30) \quad (8)$$

$$v_b - v_c = \sqrt{3} v_m \sin(\omega t - 90) \quad (9)$$

$$v_c - v_a = \sqrt{3} v_m \sin(\omega t + 150) \quad (10)$$

Using the above relation we get

$$i_a(v_b - v_c) = -\sqrt{3} v_m i_m \{\cos \omega t \sin(\omega t - \phi)\}$$

$$= \frac{\sqrt{3}}{2} v_m i_m \{\sin(2\omega t - \phi) - \sin \phi\} \quad (11)$$

$$i_b(v_c - v_a) = -\sqrt{3}v_m i_m\{\cos(\omega t - 120)\sin(\omega t - 120 - \phi)\} = \frac{-\sqrt{3}}{2}v_m i_m\{\sin(2\omega t - 240 - \phi) - \sin\phi\} \quad (12)$$

$$i_c(v_a - v_b) = \sqrt{3}v_m i_m\{\cos(\omega t + 120)\sin(\omega t + 120 - \emptyset)\} = \frac{-\sqrt{3}}{2}v_m i_m\{\sin(2\omega t + 240 - \phi) - \sin\phi\} \quad (13)$$

Adding the above three terms together we get

$$i_a(v_b - v_c) + i_b(v_c - v_a) + i_c(v_a - v_b) = \frac{3\sqrt{3}}{2}v_m i_m \sin\phi = \sqrt{3}Q = -\sqrt{3} \quad (14)$$

Where Q is the reactive power required by the circuit We thus see that the quantity q given in (13) is the reactive power absorbed by a circuit when voltages and currents contain only the fundamental frequency akagi et al called this terms the instantaneous imaginary power we can write from (13) and (14)

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (15)$$

This is equivalent to writing

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} p \\ q \end{bmatrix}$$

$$\frac{1}{v_\alpha^2+v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\left\{\begin{bmatrix} p \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ q \end{bmatrix}\right\} \quad (16)$$

$$= \begin{bmatrix} i_{\alpha p} \\ i_{\beta p} \end{bmatrix} + \begin{bmatrix} i_{\alpha q} \\ i_{\beta q} \end{bmatrix}$$

The following components of current can then be defined from the above equation

α-axis instantaneous active power:

$$p_{\alpha p} = v_\alpha i_{\alpha p} \quad (17)$$

α -axis instantaneous reactive power:

$$p_{\alpha q} = v_\alpha i_{\alpha q} \quad (18)$$

β-axis instantaneous active power:

$$p_{\beta p} = v_\beta i_{\beta p} \quad (19)$$

β-axis instantaneous reactive power:

$$p_{\beta q} = v_\beta i_{\beta q} \quad (20)$$

Let's now expand these expressions

$$p_{\alpha p} = \frac{v_\alpha^2}{v_\alpha^2+v_\beta^2}p \ ,$$

$$p_{\beta q} = \frac{v_\alpha^2}{v_\alpha^2+v_\beta^2}p \quad (21)$$

Adding the above two expressions we get

$$p = p_{\alpha p} + p_{\beta p} \quad (22)$$

Similarly adding the reactive power components we get

$$p_{\alpha p} + p_{\beta q=0} \quad (23)$$

We can then conclude the following

The sum of $p_{\alpha p}$ and $p_{\beta q}$ is equal to the instantaneous real power

Therefore they referred to as instantaneous active powers. The instantaneous powers $p_{\alpha q}$ and $p_{\beta q}$ cancel each other and don't contribute to the real power, they are thus called instantaneous reactive powers the instantaneous three-phase power is then given by

$$P_{3\phi} = p_{\alpha p} + p_{\beta p} + p_0 \quad (24)$$

Let the following balanced three-phase voltages

$$v_a = V_m \sin\omega t,$$
$$v_b = V_m \sin(\omega t - 120), v_c = V_m \sin(\omega t + 120) \quad (25)$$

Be supplying a non lineare load. The load currents contain 3^{rd} and 5^{th} harmonics In addition to the fundamental .these currents are given by

$$i_a = \sum_{n=1,3,5}\frac{I_m}{n}\sin(n\omega t - \phi_n) \quad (26)$$

$$i_b = \sum_{n=1,3,5}\frac{I_m}{n}\sin\{(n\omega t - 120) - \phi_n\} \quad (27)$$

$$i_c = \sum_{n=1,3,5}\frac{I_m}{n}\sin\{(n\omega t + 120) - \phi_n\} \quad (28)$$

Transforming the voltages and currents into $\alpha - \beta - 0$ frame we get

$$v_0 = \frac{1}{\sqrt{3}}(v_a + v_b + v_c) = 0 \quad (29)$$

$$v_\alpha = \sqrt{\frac{2}{3}}\{v_a - \frac{1}{2}v_b - \frac{1}{2}v_c\} = \sqrt{\frac{2}{3}}v_a = \sqrt{\frac{2}{3}}V_m \sin\omega t \ v_\beta = \sqrt{\frac{1}{2}}\{v_b - v_c) = \frac{-2}{\sqrt{2}}V_m \cos\omega t \sin 120 = -\sqrt{\frac{3}{2}}V_m \cos\omega t \quad (30)$$

$$i_0 = \sqrt{\frac{1}{3}}\{i_a + i_b + i_c\}=\frac{I_m}{\sqrt{3}}\sin(3\omega t - \phi_3) \quad (31)$$

$$i_\alpha = \sqrt{\frac{2}{3}}\{i_a - \frac{1}{2}i_b - \frac{1}{2}i_c\}=$$

$$\sqrt{\frac{3}{2}}I_m \sin(\omega t - \phi_1) + \sqrt{\frac{3}{2}}\frac{I_m}{5}\sin(5\omega t - \phi_5) \quad (32)$$

$$i_\beta=\frac{1}{\sqrt{2}}(i_b - i_c)=-\sqrt{\frac{3}{2}}I_m \cos(\omega t - \phi_1)$$

$$+\sqrt{\frac{3}{2}}\frac{I_m}{5}\cos(5\omega t - \phi_5) \quad (33)$$

It can be seen from the above expression that the 3^{rd} harmonic current is persent only in the zero –sequence furthermore ,the zero- sequence power is given by $p_0 = v_0 i_0 = 0$

We can then get from(1.20)

$$p=v_\alpha i_\alpha + v_\beta i_\beta=\frac{3}{2}V_m I_m\{\cos\phi_1 - \frac{1}{5}\cos(6\omega t - \phi_5)\}$$
(34)

$$q=v_\alpha i_\beta - v_\beta i_\alpha=\frac{-3}{2}V_m I_m \{\sin\phi_1 - \frac{1}{5}\sin(6\omega t - \phi_5)\}$$
(35)

the above result example clearly demonstrates that there are two components

of real and reactive power present in a system when the load contains harmonics . we can then write

$$p=p_{av} + p_{osc} \quad (36)$$

$$q=q_{av} + q_{osc} \quad (37)$$

4. CONTROL CIRCUIT:

In control ckt different types of ckts are there

Clarke's transformation ckt three terminal voltage V_{ta},V_{tb} and V_{tc} is connected and generate the V_{alpha} and V_{beta} voltage

Clarke's transformation ckt for source current these three source current generate the current I_{alpha} and I_{beta} in similar manner

V_{alpha} ,V_{beta} and I_{alpha},I_{beta} with product block generate the rective power (P)

V_{apha} , V_{beta} and I_{beta} ,I_{alpha} with prtoduct block generate the reactive power (Q)

V_{alpha} , V_{alpha} and V_{beta} ,V_{beta} product block after summing block generate the D (denominator term)

5. SIMULATION MODEL

Simulation model are presented in this chapter simulink diagram (2) is been shown that with a proposed control method the load unbalancing is been reduced considerably and also the THD that is the total marmonic distortion has been reduced considerably the waveform obtained with a and without compensator.

Simulation results indicate that this method is effective and DSTATCOM has good performance to balance the load and mitigate harmonic components of current.

It has three phase supply provides which unbalance & non-linear.6-IGBT has connected which is working as a Dstatcom. It is used to unbalance & non-linear loads to the balance & linear load. In simulation model has 230volt supply voltage ,nominal frequency has 50 hz,IGBT resistance is 0.001 ohm snubber resistance is 500 ohm, snubber capacitance is 250*10^(-9) F.

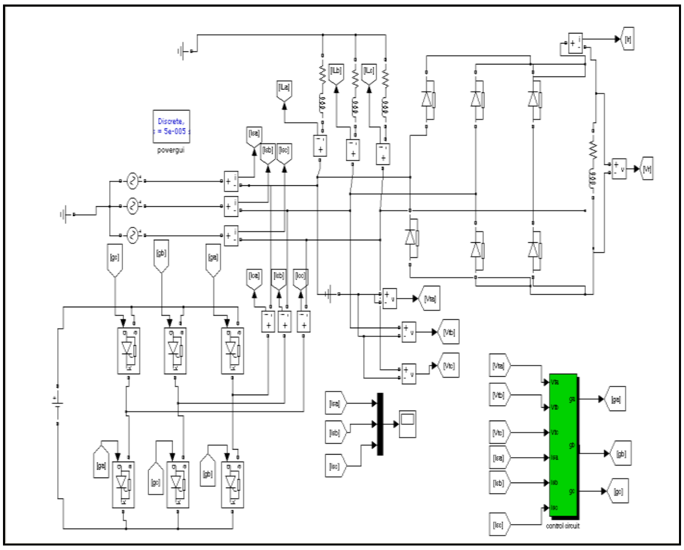
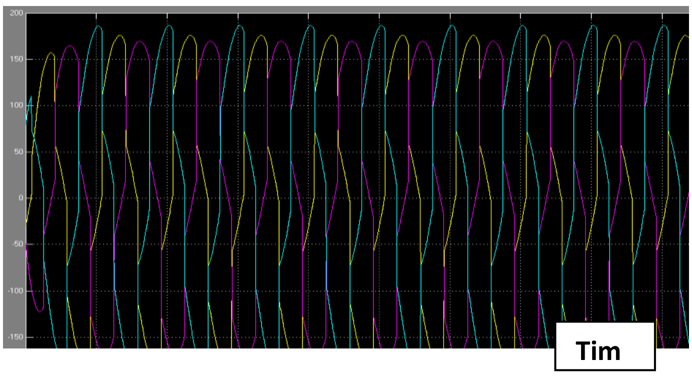


Fig. 2 simulink model (Three phase load balancing)

5.1 Source And Load Current With & Without Compensator



In fig. (3) if we use three phase non linear source current, without using compensator , then we can find the non-linear Waveform of three phase source current. It creates the unwanted harmonics and power system becomes unbalance. The power system isn't smoothly run. To avoid these problems we connected the distribution compensator. In given model the control circuit has generates the gate pulses , this gate pulses are going to the dstatcom & reduces the unwanted Harmonics and the system becomes stable and balanced. Source voltage generating the current I_{sa},I_{sb},I_{sc} then load current become non-linear

And unbalance bridge rectifier generating the harmonics. the power system has not running properly. On it power quality problem is occurred to avoid this problem Dstatcom is connected

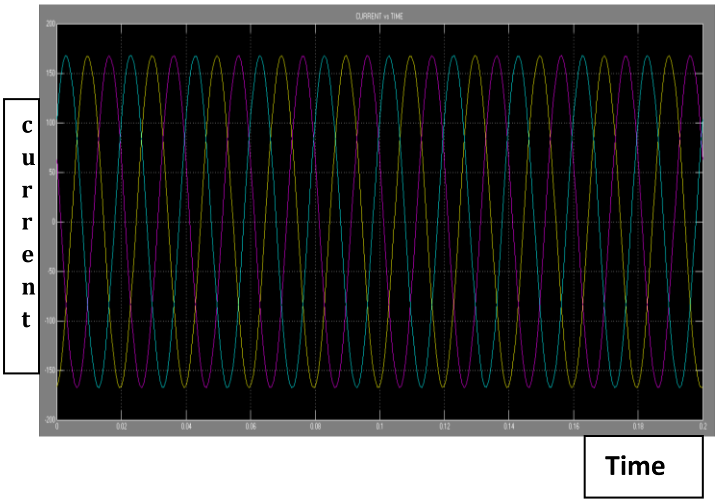


Fig. 4 Three phase load current with compensator

In case when Dstatcom is connected with combination of terminal voltage (V_{ta} V_{tb} V_{tc}) and source current I_{sa},I_{sb} and I_{sc} generating the gate pulse these gate pulses are injecting on the IGBT (insulated gate bipolar transistor) it become fired and working as the inverter it changes the dc to ac with reference current and actual current it generating the actual current which requires . suppose the source current are 10.5 ,0 when compensator is disconnected that is unbalance For the balancing Dstatcom is connected with the system it gives or generate the actual current 5,10,15 which is all 15 so these currents are compensator current Which requires to balance the load or system .it is FACT device which is used distribution network for supplying and absorbing reactive power it can also exchange real power if provides with an active dc sources.

5.2 THD ANALYSIS

The value of current after firing increases because the compensator generating the actual current. These current and source current by KCL produced the total current which is balance and linear. THD reduces to 0.04%. x-axis representing the number of cycles and y-axis representing the current

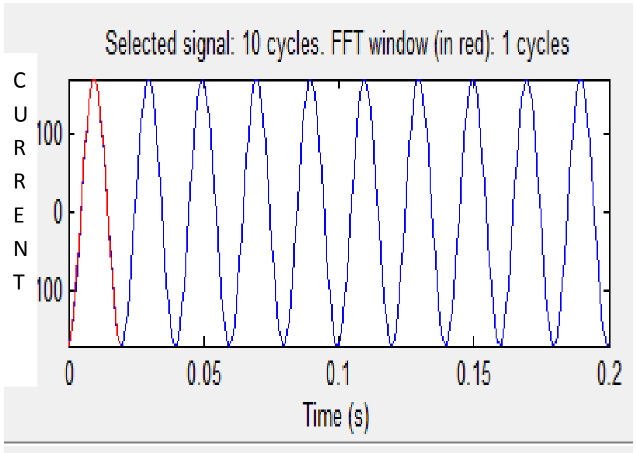


Fig 5 waveform of phase-1 current

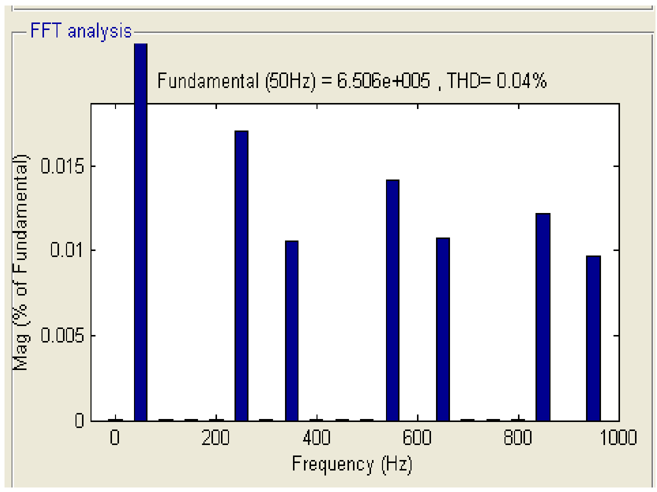


Fig. 6 Graph of THD v/s Freq.(Hz)

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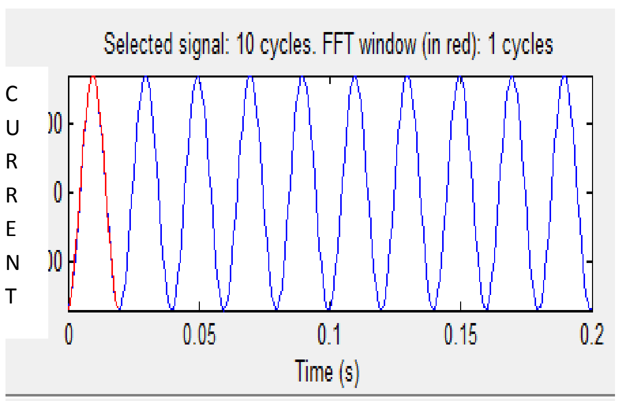

Fig. 7 waveform of phase-1current

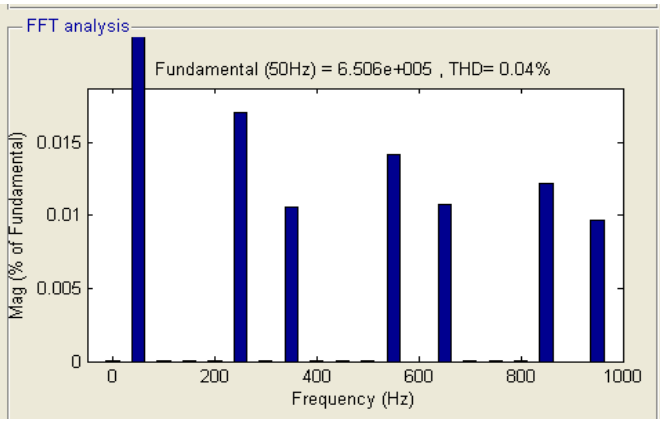

Fig. 8 Graph of THD v/s Freq. (Hz)

6. CONCLUSION

The number of non linear load in power distribution system especially due to advancement in power electronics technology. Non linear load causes interruption such as voltage sag swell and harmonics so reducing this problem using DSTATCOM. This making power system linear and balanced. DSTATCOM continuously monitors the line at primary terminals and compares the reference signal. In THD analysis before DSTATCOM disconnected is 20.20%. after connecting DSTATCOM THD becomes 0.04%.

In the above result we can say that for balancing and linearity DSTATCOM is a best switching device. Much more used in power system.

7. SCOPE FOR FUTURE WORK

Although this research has covered most of the interesting issues and challenges of the advanced STATCOM and several aspects of the integration of ESS into STATCOM, there are certain aspects that might be interesting for future investigation ,Due to the excessive number of semiconductor devices and passive components fault protection scheme to enhance the ride-though capability in various faults scenarios remains as an important challenge

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