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Power Quality Improvement in case of Electrical faults using D-STATCOM

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ABSTRACT : *Since Power System has become more complex in nature, The phenomena of voltage stability led to blackout of the grid has become more challenging to utilities and researcher. A DSTATCOM is a distribution side device which is used to protect such failures in the system. In this paper, a Simulink model of DSTATCOM is developed in which faults are intentionally induced (LG, LLG, LLLG, LL and LLL) for the short period and the behavior of DSTATCOM is studied in 50Hz frequency supply. Total Harmonic Distortion (THD) is compared for different faults when DSTATCOM is not connected and connected. The behavior of load voltages is also figured in both the condition. This paper shows that the drastically reduced THD when power quality devices (DSTATCOM) is used in the system.*

KEYWORDS – *DSTATCOM, Electrical Faults, PI Controller, Power Quality, Total Harmonic distortion*

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I. INTRODUCTION

Since 18th century, energy demand has been increased exponentially risen in the whole world. New industrialization era which started in Europe in early 18 centuries, caught every country into its grasp for economic growth. Now economist give comparison of any country's economic growth to its energy demand. In the form of Electrical Energy, we started with simple DC power then AC power with small setup. Now our transmission and distribution network of electrical energy have become much more complex in last few decades. Now we use complex buses, feeders, different types of relays according to our need of transmission. We are much comfortable and confident with our generation and transmission side of network to put them into balanced condition. But we have to give more focus on balancing the distribution side of network which is an ideal case because of the different type of inductive loads and electronic types of loads. The term for this problem is called "Power Quality". Today's equipment are very sensitive to power quality. Thomas Key ,1978 [1] called increased sensitivity of equipment to voltage disturbance. This voltage disturbance i.e. bad power quality also reduces the profit margins of distribution companies. A article published by Jane Clemmesnsen of ERPI estimated $26 billion a year revenue loss of US companies due to bad power quality. To mitigate this power loss and to improve power quality, DSTATCOM which is a static voltage compensator is a powerful method. This method is related to distribution side management, connected in parallel to line to compensate the reactive power.

II. POWER QUALITY PROBLEMS

Deflection of voltage waveform and deflection of current waveform from its natural original wave is called Power Quality problems. These problems come under two main categories: voltage and current characteristics which deviation is also indicate deviation in frequency and power factor [1]. Sudden change in voltage or current due to events like fault, sag, swell etc. caused the voltage zero [2] which also impact to sudden inrush current which flows in the circuit. At the distribution end, load variation also caused such problems of sudden change of voltage and current. The supply voltage unable to maintain constant frequency due to power quality problems.[2]. Following table shows the reference standards [3] used for Power Quality Study:

Parameters	Reference limits	Reference Standard
Power Frequency	Mean value of fundamental measured over 10s: +/-2%for 99.5% of week	EN 50160
Voltage magnitude variation	+/- 10% for 95% of the week, mean 10min RMS values (LL/LN)	EN 50160
Rapid voltage changes	3% normal, 4% maximum	EN 61000-2-12
Voltage Swells/dips	LV: 10-50%	EN 0160

	Locally limited swells caused by load switching up to 30% of V-RMS and duration up to 10ms	EN 61000-6-1 & 6-2
Short interruption of supply voltage	95% reduction for 5 sec	EN 61000-6-1 & 6-2
Long interruption of supply voltage	LV-MV up to 3 min	EN 50160
Transient over-voltage	+/-2KV(LN), +/- 1KV(LL),1.2KV/50KA(8/20us)	EN 61000-6-1 & 6-2
Supply voltage unbalance	Positive, negative and zero sequence, 2% between L-L	EN 61000-2-12
Load unbalance	Positive, negative and zero sequence, leakage current<500Ma	EN 50160
Harmonics voltage	V-THD<5%, individual V*h<3%	IEEE 519
Harmonics current	I-THD% as defined by I(short circuit)/I(full load)IEEE 519	

Table 2.1: Reference standards used for Power Quality study

2.1.1 DSTATCOM

Distribution Static Compensator is connected in shunt with the load which compensate the reactive power and unbalanced loads. It is usually connected to distribution end. A DSTATCOM has voltage source inverter (VSC), a DC capacitor, a coupling inductor or coupling transformer and a controller shown in fig 2.1.

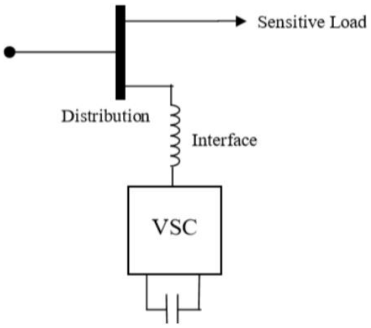


Fig2.1: Basic structure of DSTSATECOM

A simplified single line diagram of DSTATCOM is shown as

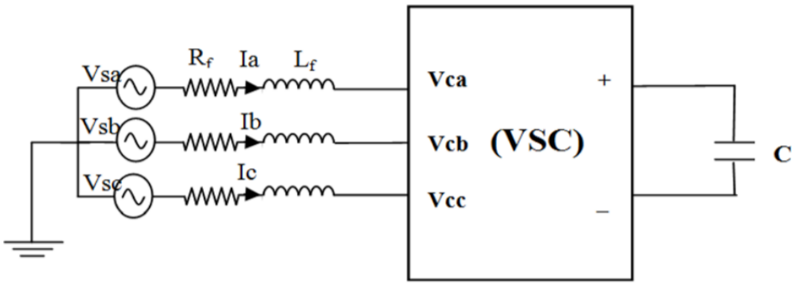


Fig 2.2: Single line Diagram of DSTATCOM

In which three phase instantaneous voltage is given as

$$\begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} = \sqrt{\frac{2}{3}} V_s \begin{bmatrix} \sin\omega t \\ \sin\left(\omega t - \frac{2\pi}{3}\right) \\ \sin\left(\omega t + \frac{2\pi}{3}\right) \end{bmatrix}$$

$$\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} -R_f/L_f & 0 & 0 \\ 0 & -R_f/L_f & 0 \\ 0 & 0 & -R_f/L_f \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{1}{L_f} \begin{bmatrix} V_{sa} - V_{ca} \\ V_{sb} - V_{cb} \\ V_{sc} - V_{cc} \end{bmatrix}$$

III. SIMULATION WORK

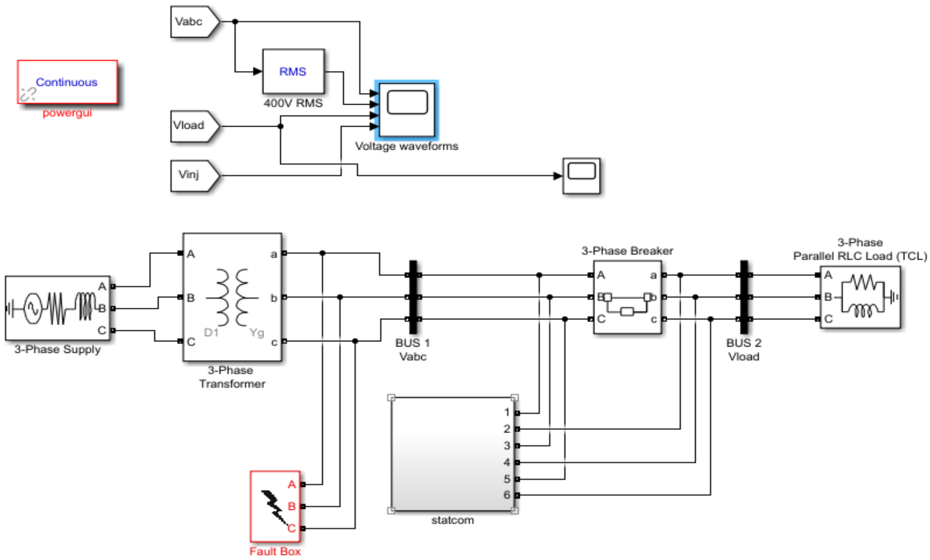


Fig 3.1 Simulation model of DSTATCOM

In fig 3.1, A 3-phase power supply which output is a 3-phase balanced voltage is driven to a 3-phase transformer. The output of transformer is connected to a bus and then to a 3-phase parallel RLC load. A 3 phase Breaker is also introduced between the BUS1 and BUS2 in which BUS 1 is connected to input. Then Bus1 is connected to store the voltage and current values so that it can use at those points where it will be needed with the help of tags Vabc and Iabc. So as fault occurs the circuit breaker operates and disconnect the load side. Now the voltage distorted due to fault is fed in D-STATCOM and then D-STATCOM inject required voltage to make the load voltage again balanced and sinusoidal. Aa soon as fault is removed the circuit breaker again reset and system is again in normal operation. Then Bus-2 is connected to store the values voltage and current so that we can use them where we want to use with the help of tags Vload and Iload. and then a three-phase load is connected. To see the waveforms, scopes are connected. Here used tags as V_{abc}, V_{load} , V_{inj} whose waveforms are observed on scopes.

In fig 3.2, This is Single line to ground fault where first graph shows the Bus-1 Voltage. Here we have introduced single line to ground fault in phase A for a duration from 0.02 sec to 0.08 sec. Now as fault impedance is zero so it makes voltage of phase A zero but if we have a finite fault impedance the voltage of phase A will be some finite value.

The second graph is of RMS value of voltages as for a pure sinusoidal wave rms value is constant value $\frac{Vm}{\sqrt{2}}$ so rms of B and C phase is 222.73 volts. But RMS of phase A is zero. Then the third graph is of load voltage with D-STATCOM which is made sinusoidal again by injecting the required voltage and the voltage of injected voltage is shown in graph 4.

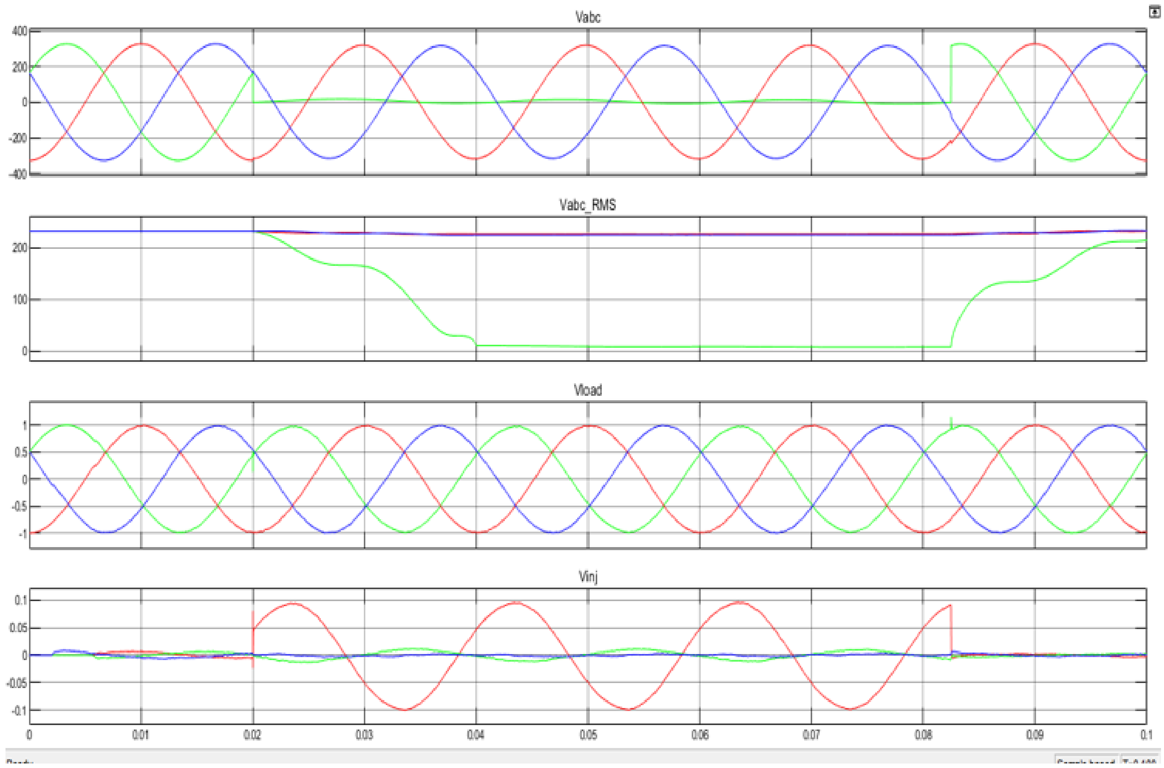


Fig 3.2: Result of simulation model

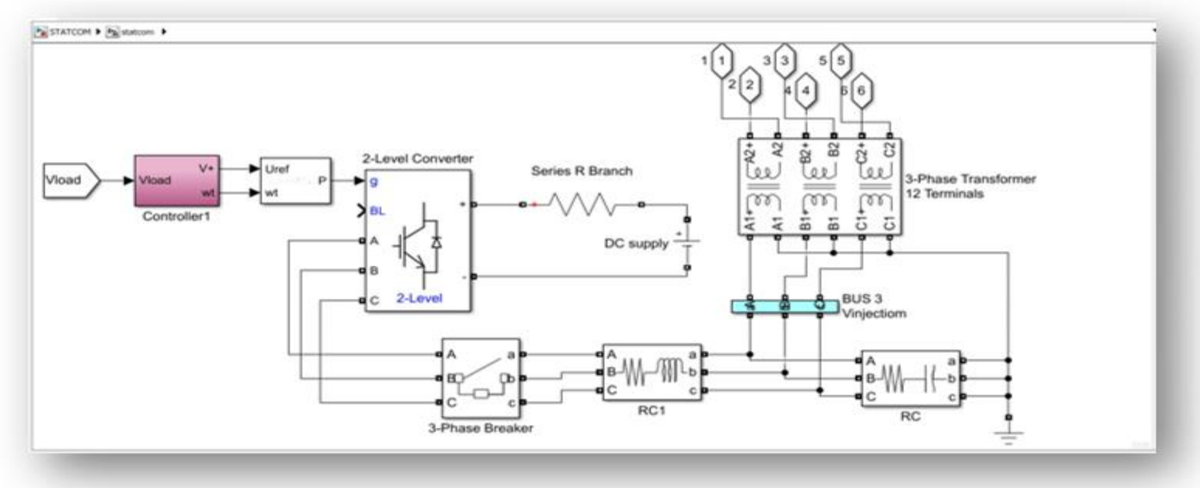


Fig 3.3 Inside of DSTATCOM box on simulation model

We have connected controller which is used for the proper functioning of the STATCOM. The load voltage is sensed and then it is passed through a sequence analyzer. The magnitude of the load voltage is compared with the reference voltage. Pulse width modulation technique is used for the switching of inverter so as to generate a three-phase sinusoidal voltage at the load terminals. The frequency of three phase sinusoidal voltage is 50 Hz. The Chopping frequency is set in around few KHz. We have used PI controller with the IGBT inverter so that 1p.u. voltage is maintained at the load terminals. The input of the controller is an actuating signal. This actuating signal is difference of Reference voltage and Actual voltage. The advantage of using PI controller is that the integral term makes the steady-state error zero for a step input. The output of the controller block is in form of an angle that establishes an additional phase-lag/lead to three-phase sinusoidal voltage.

A Voltage source inverter consist of a storage device and switching devices, which generate a three-phase sinusoidal voltage of required magnitude, frequency and phase angle. It could be either 3 phase -3 wire voltage source inverter or 3 phase - 4 wire voltage source inverter. We can use either two level inverter or a three-level inverter. For STATCOM application, the voltage source inverter is used to generate the part of supply voltage which is absent. The main function of storage device is to supply required energy to voltage source inverter via a dc link. Here we have used capacitor as energy storage devices. DC charging circuit is used after the fault compensation event so that the energy source can be charged again. To maintain dc link voltage at the nominal dc link voltage we are using this charging circuit.

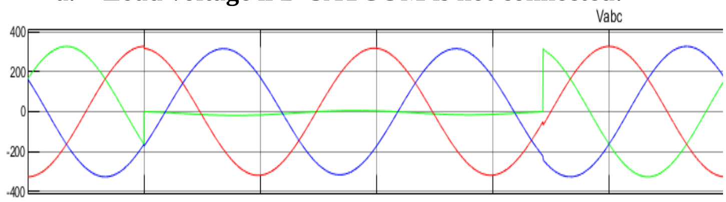
There are three single phase transformers which are connected in series with distribution feeder so that to couple voltage source inverter which is at lower voltage level to the distribution which is at the higher voltage level. It connects the STATCOM system to distribution network through High voltage windings and it couples the compensating injected voltages which is generated by the VSI to the incoming supply.

As SATCOM consist of large no of power electronic devices, so there is the possibility of generation self-harmonics so we have used harmonic filter. The main function of harmonic filter is to keep the harmonic voltage which is generated by the voltage source converter to the acceptable level.

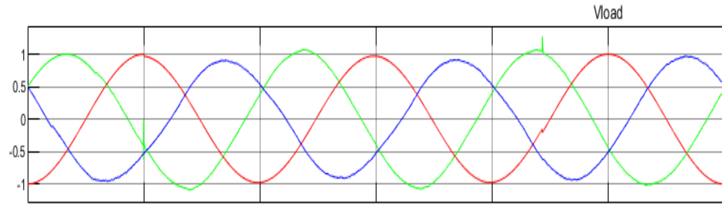
IV. EXPERIMENTAL RESULTS

4.1. Single line to ground fault : A single line to ground fault is the one in which one phase is connected to ground and the fault current is only due to that phase only . Let fault occurs at phase A this means fault current is equal to the line current of phase A. Here single line to ground fault is applied to the system by fault box for a duration from 0.01 sec to 0.04 sec.

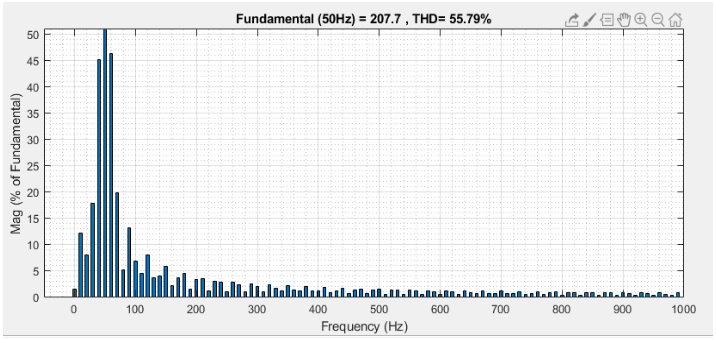
a. Load voltage if D-SATCOM is not connected:



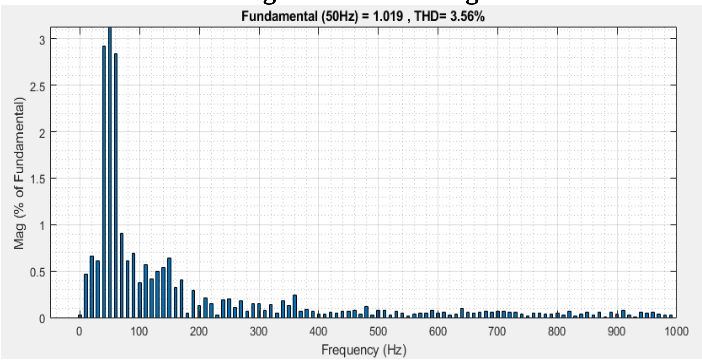
b. Load voltage After connecting D-STATCOM:



c. THD in Load voltage if D-STATCOM is not connected:



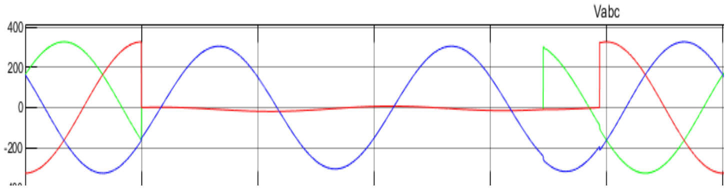
d. THD in Load voltage after connecting D-STATCOM:



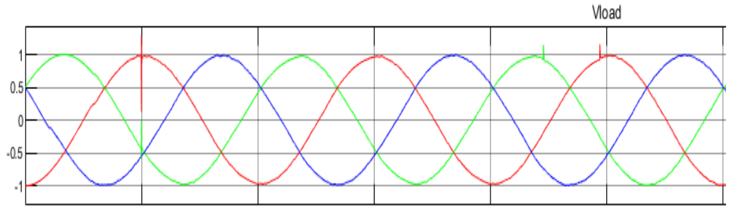
From graph it is known that THD in load before connecting D-STATCOM is 55.79% and after connecting D-STATCOM the THD in load is only 3.56%.

4.2 Double line to ground fault: A double line to ground fault is the one in which two phases are connected to each other first and then connected to ground and here fault current is due to both phases. This fault involves short-circuiting of phase B and C and ground this means fault current is equal to the sum of line current of phase B and C. Here double line to ground fault is applied to the system by fault box for a duration from 0.01 sec to 0.04 sec.

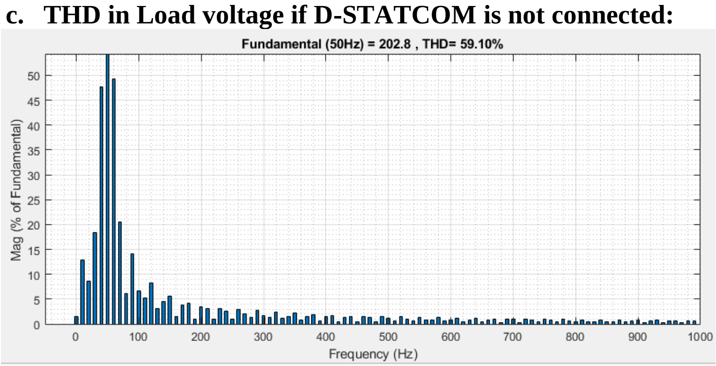
a. Load voltage if D-SATCOM is not connected:



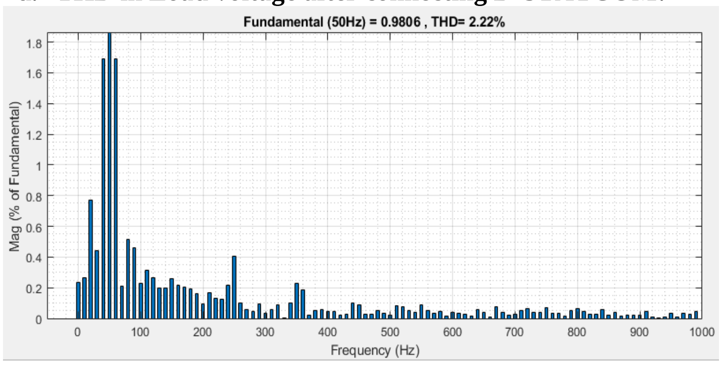
b. Load voltage After connecting D-STATCOM:



c. THD in Load voltage if D-STATCOM is not connected:



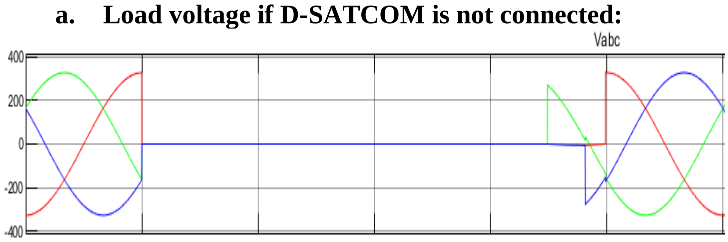
d. THD in Load voltage after connecting D-STATCOM:



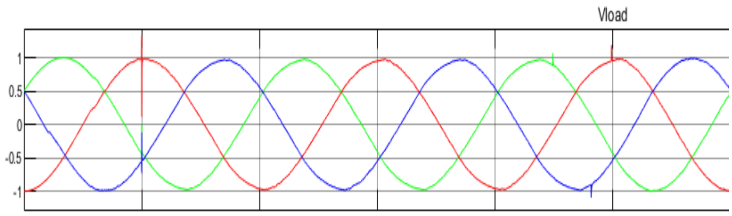
From graph it is known that THD in load before connecting D-STATCOM is 59.10% and after connecting D-STATCOM the THD in load is only 2.22%.

4.3 Triple line to ground fault: A triple line to ground fault is the one in which three phases are connected to each other first and then connected to ground and here fault current is due to all the phases. This fault involves short-circuiting of phases A, B and C and ground this means fault current is equal to the sum of line current of phase A, B and C. Here triple line to ground fault is applied to the system by fault box for a duration from 0.01 sec to 0.04 sec.

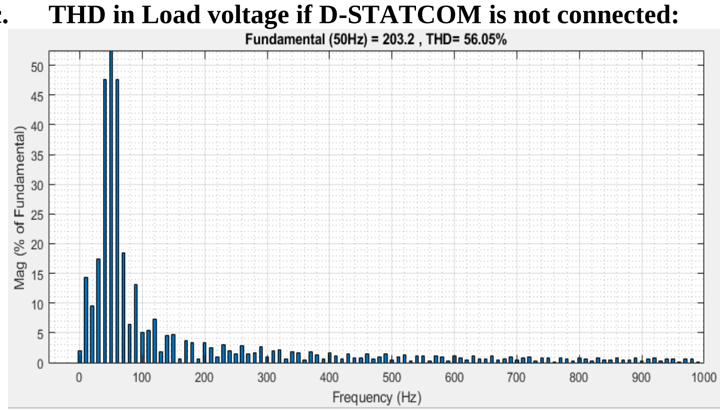
a. Load voltage if D-SATCOM is not connected:



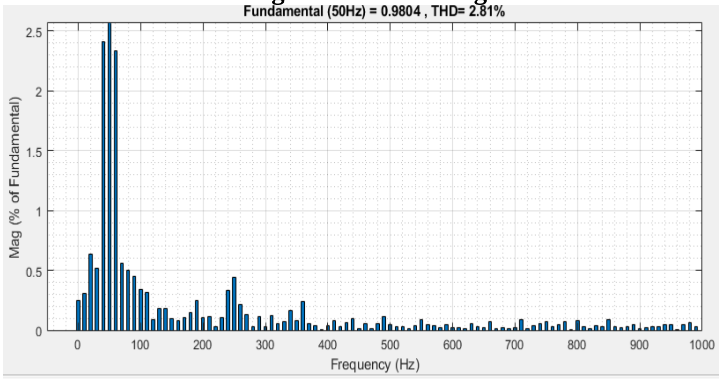
b. Load voltage After connecting D-STATCOM:



c. THD in Load voltage if D-STATCOM is not connected:



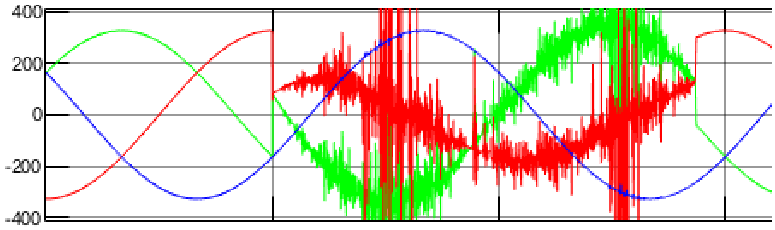
d. THD in Load voltage after connecting D-STATCOM:



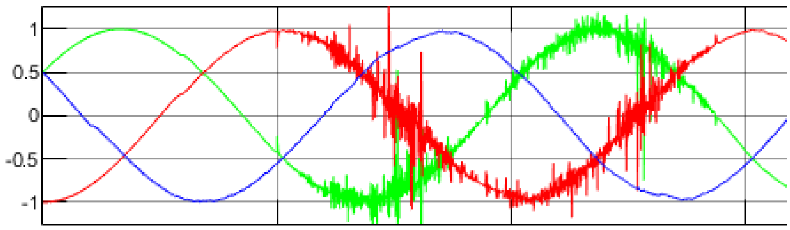
From graph it is known that THD in load before connecting D-STATCOM is 56.05% and after connecting D-STATCOM the THD in load is only 2.81%.

4.4 Line to Line fault: A line to line fault occurs when two conductors are short circuited also called unsymmetrical fault. A 3-phase system with a L-L fault phases b and c. The fault impedance is assumed to be Z_f. Here double line fault is applied to the system by fault box for a duration from 0.01 sec to 0.04 sec.

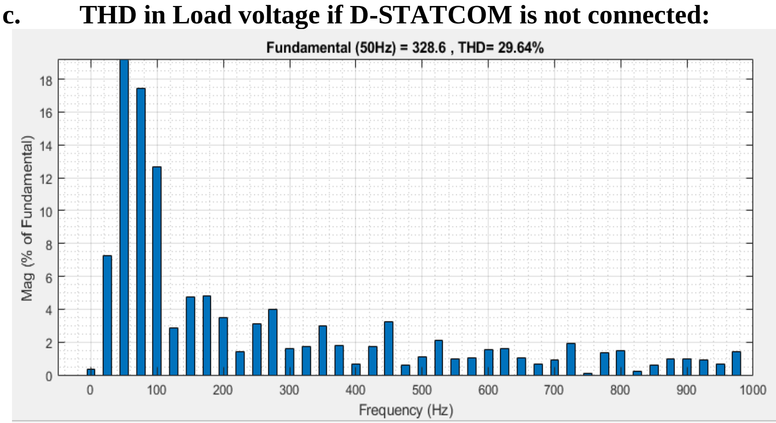
a. Load voltage if D-SATCOM is not connected:



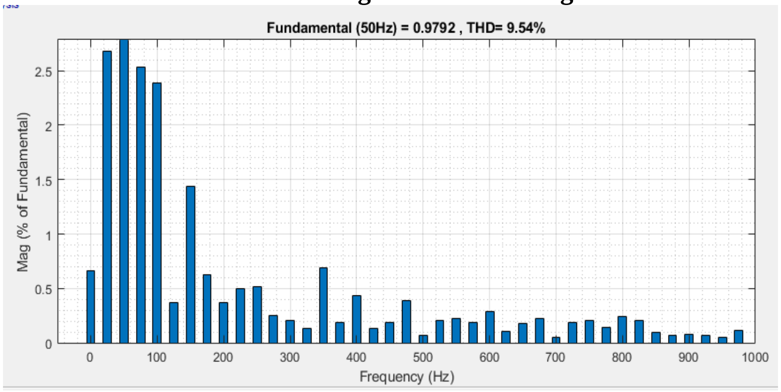
b. Load voltage After connecting D-STATCOM:



c. THD in Load voltage if D-STATCOM is not connected:



d. THD in Load voltage after connecting D-STATCOM:

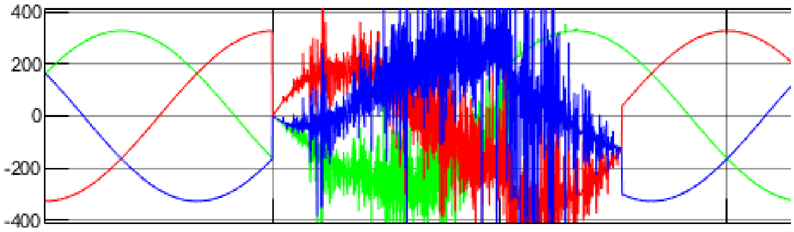


From graph it is known that THD in load before connecting D-STATCOM is 29.64% and after connecting D-STATCOM the THD in load is only 9.54%. The reason of getting very low THD even in case of before connecting D-STATCOM because we have selected only one cycle in FFT setting.

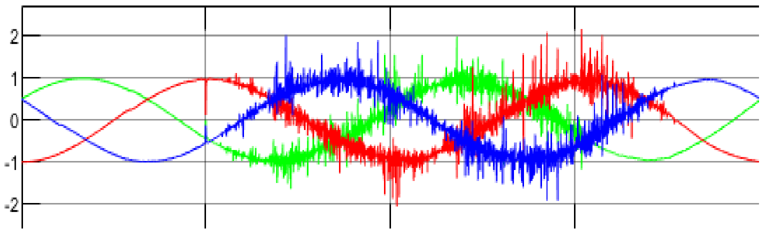
4.5 Triple line fault –The three phase faults occur when you have A, B and C phases are shorted together but ground is not involved.

Here triple line fault is applied to the system by fault box for a duration from 0.01 sec to 0.03 sec. Note in this condition we have selected a fault impedance of 0.04 ohms.

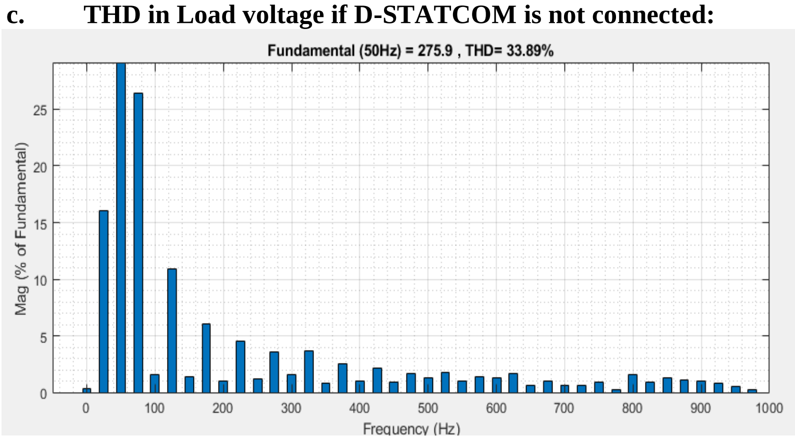
a. Load voltage if D-SATCOM is not connected:



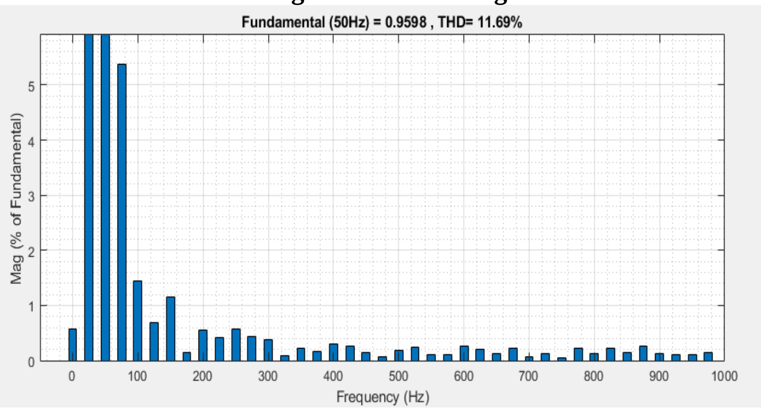
b. Load voltage After connecting D-STATCOM:



c. THD in Load voltage if D-STATCOM is not connected:



d. THD in Load voltage after connecting D-STATCOM:



From graph it is known that THD in load before connecting D-STATCOM is 33.89% and after connecting D-STATCOM the THD in load is only 11.69%. The reason of getting very low THD even in case of before connecting D-STATCOM because we have selected only one cycle in FFT setting.

V. CONCLUSION

After introducing different faults (SLG, LLG, LLLG, LL and LLL) in proposed Simulink model of DSTATCOM following comparative results have been found given in table 5.1:

S.No.	Fault Name	Total Harmonic Distortion (THD) before DSTATCOM	THD after DSTATCOM
1	Single Line to Ground Fault	55.79%	3.56%
2	Double Line to Ground Fault (LLG)	59.1%	2.22%
3	Triple Line to Ground Fault (LLLG)	56.05%	2.81%
4	Line to Line Fault (LL)	29.64%	9.54%
5	Triple Line Fault (LLL)	33.89%	11.69%

Table 5.1: THD comparison of different faults

Above table shown that the reactive compensation like DSTATCOM is very much needed to control the THD during faults. A significant amount is controlled in all the faults.

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