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Power Quality Enhancement With D-Statcom Under Different Fault Conditions

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ABSTRACT

Power quality problem mainly related to non-standard voltage, frequency, and current at the load side. In this paper an attempts has been to analyses the role of D-STATCOM (Distribution static compensator) and located at load side in the electrical distribution system. So in order to maintain the power system quality, the D-STATCOM will absorb and provide reactive power to mitigate the voltage sag occurred due to different causes. Utility distribution network, sensitive industrial load and critical commercial operation suffer from various type of outage and service interruption, which can cost significant financial losses. Here, in this paper the work has been carried out by various techniques with D-STATCOM to minimize the problem associated in distribution system such as voltage sag, voltage instability in power system with different fault conditions for LG, LLG fault. D-STATCOM used to supply the reactive power to maintain the power quality as well.

Keywords: D-STATCOM, Distribution System, Line Voltage, Voltage Stability, Voltage Source Converter.

1. INTRODUCTION:

To overcome the problem related to the power quality custom power device is introduced. A number of power quality problem solutions are provided by custom devices. At present, a wide range of flexible AC controller which is capitalized on newly available power electronic components are emerging for custom power application. Among these the distribution static compensator is used in the present work. The fast response of D-STATCOM makes it efficient solution for improving the power quality in distribution system. Here the D-STATCOM used with different controller such as PI to improve the power quality under different abnormal condition, which causes the power quality related problem.

A D-STATCOM basically VSC based FACTS controller sharing many similar concept with that of STATCOM used at transmission level. A STATCOM at transmission level handle only reactive power and provide voltage support. While a D-STATCOM is employed at distribution level or at load side also behaves as shunt active filter. It works as the IEEE-519 standard limit. Since the electrical power distribution system it is very important to balance the supply and demand of active and reactive power in the electrical power system. Incase if the balance is lost the frequency and voltage excursion may occur result in collapse of power system. So we can say that the voltage and reactive power control is the key of stable power system. The distribution system losses and power quality problem are increasing due to reactive power.

The main application of STATCOM is D-STATCOM exhibit high speed control of reactive power to provide voltage stabilization in power system. The D-STATCOM protect the distribution system from voltage sags, flicker caused by reactive current demand. The D-STATCOM provides:

2. VOLTAGE SOURCE CONVERTER (VSC):

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

3. Distribution Static Compensator (DSTATCOM):

A D-STATCOM (Distribution Static Compensator) is a shunt voltage controller, which is schematically depicted in Figure-1, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics.

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter.

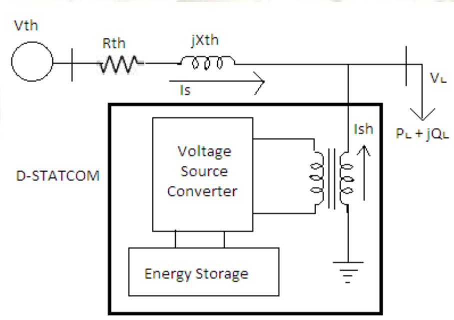

Fig.3.1 Schemetic Dig. Of D-STATCOM

The shunt injected current I_{sh} corrects the voltage sag by adjusting the voltage drop across the system impedance Z_{th}. The value of I_{sh} can be controlled by adjusting the output voltage of the converter.

The shunt injected current I_{sh} can be written as,

$$I_{sh} = I_L - I_S = I_L - \left(\frac{V_{Th} - V_L}{Z_{Th}}\right)$$

$$I_{sh}\angle\eta = I_L\angle -\theta - \frac{V_{th}}{Z_{th}}\angle(\delta - \beta) + \frac{V_L}{Z_{th}}\angle -\beta$$

The complex power injection of the D-STATCOM can be expressed as,

$$S_{sh} = V_L I^*_{sh}$$

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Z_{th} or fault level of the load bus. When the shunt injected current I_{sh} is kept in quadrature with V_L the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of I_{sh} is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system.

4. D-STATCOM Controller:

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

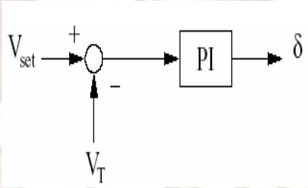

Fig.4.1 PI Controller

The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

5. Simulation Model of Test System With and Without D-STATCOM and its Operation:

In this test system we have a generating unit of 25kv, 50Hz. The test system employed to carry out simulations consisting the D-STATCOM actuation. The output from generating unit is fed to primary winding of the three winding transformer. Further two parallel feeder of 11kv each are drawn. In one of the feeder D-STATCOM is connected in shunt is followed by circuit breaker and other feeder is kept as it is. For this system a non-linear load is connected at the end of the feeder consisting of D-STATCOM. PI controller is used for the control section.

The simulation is carried out between time 0.4 to 0.9 sec. During which circuit breaker is not connected to the power system, such as CB2 is closed when D-STATCOM is not in operating mode.

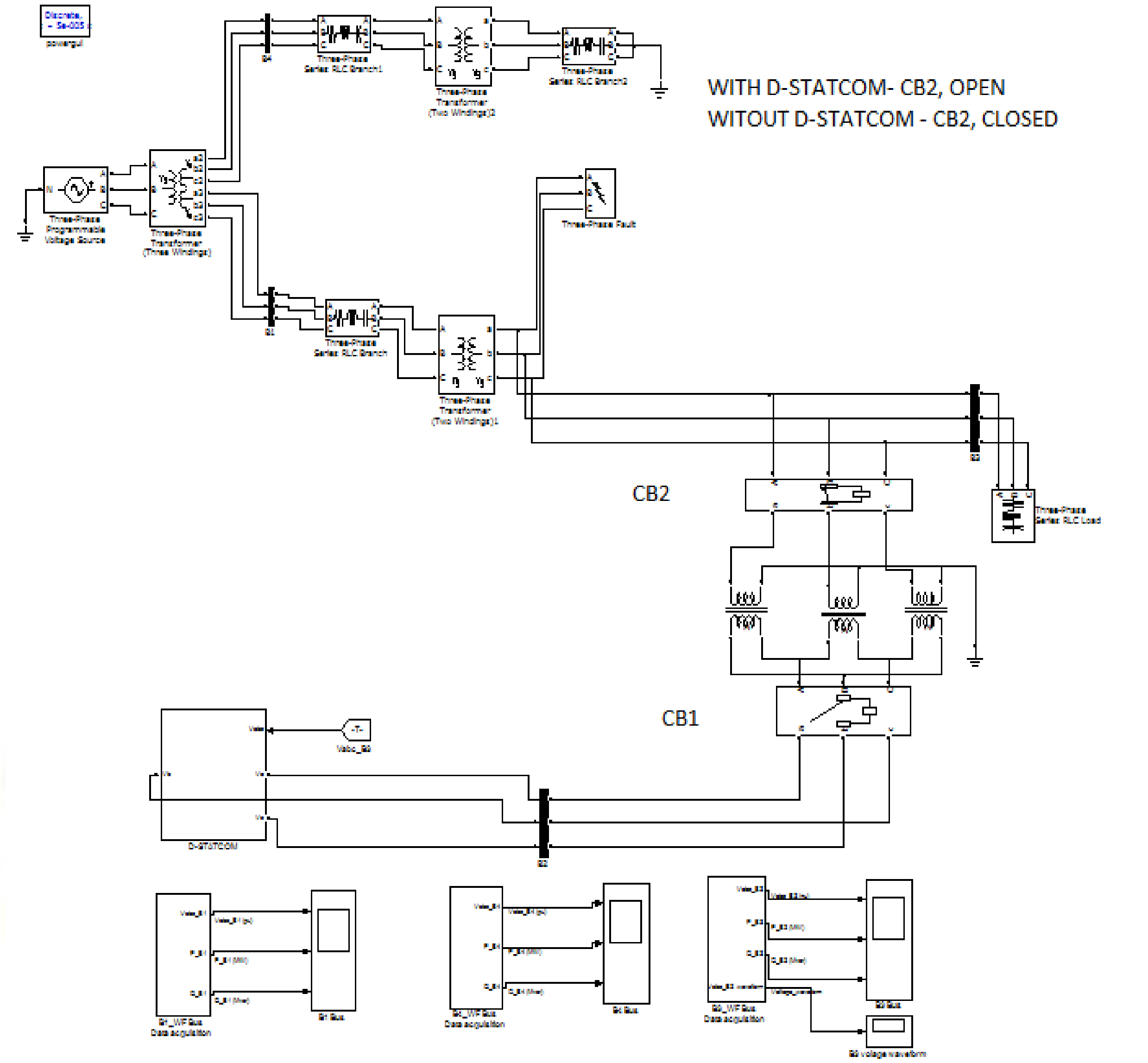

Fig.5.1 Simulation Diagram for Test Sytem

5.1. PARAMETER OF THE TEST SYSTEM:

The model system has been tested on different fault conditions with non-linear load. This system employed with three phase programmable voltage source with configuration of 25kv , 50 Hz. The source is feeding two transmission line through a three phase winding transformer with power rating 250MVA.

Winding 1: V1rms (Ph-Ph) = 25kv, R1= 0.002(pu), L1 = 0.08002(pu)

Winding 2: V2rms (Ph-Ph) = 11kv, R2= 0.002(pu), L2 = 0.08002(pu)

Winding 3: V3rms (Ph-Ph) = 11kv, R3= 0.002(pu), L3 = 0.08002 (pu)

Inverter Parameter : IGBT based , 3arm , 6 pulse , carrier frequency = 1080Hz., sample time = 5µ sec.

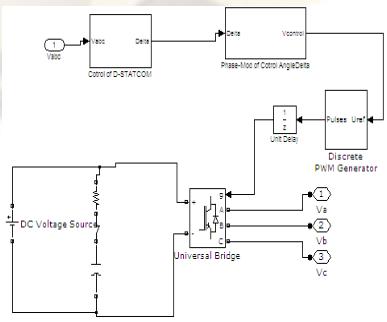

Fig.5.2 D-STATCOM Simulation Model

The D-STATCOM model which is incorporated in the transmission system for voltage regulation is as shown in Fig.

5.2. SIMULATON RESULTS: CASE 1. : SINGLE LINE TO GROUND FAULT (LG) CONDITION:

In this case single line to ground fault is considered for both the feeders. Here the fault resistance is 0.001 ohm and the ground resistance is 0.001ohm. The fault is created for the duration of 0.4s to 0.9s. The output waveform for LG fault is shown below.

5.3. RESULT WITHOUT D-STATCOM (LG Fault):

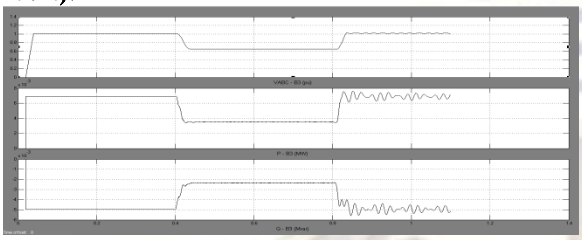

Fig.5.3 Three Phase Voltage(pu), Active Power and Reactive Power at Bus 3 Without D-STATCOM (LG Fault)

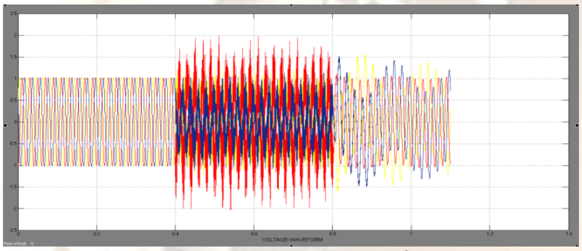

Fig.5.4 Three Phase Voltage Waveform Without D-STATCOM (LG Fault)

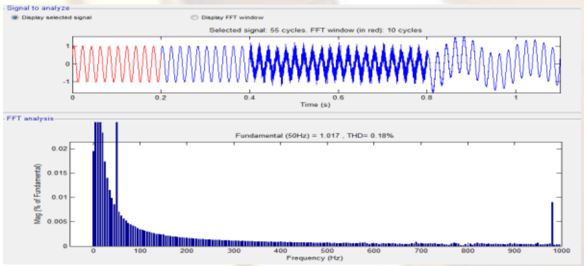

Fig.5.6 FFT Analysis Before Fault Without D-STATCOM (LG Fault)

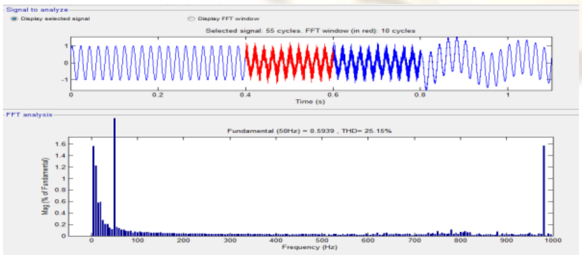

Fig.5.7 FFT Analysis During Fault Without D-STATCOM (LG Fault)

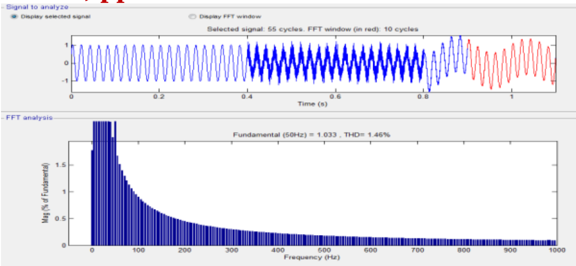

Fig.5.8FFT Analysis After Fault Without D-STATCOM (LG Fault)

5.4. RESULT WITH D-STATCOM (LG Fault):

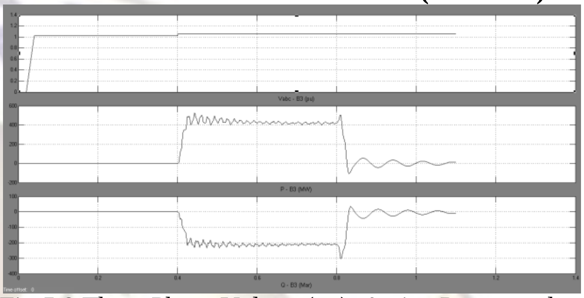

Fig.5.9 Three Phase Voltage(pu), Active Power and Reactive Power at Bus 3 With D-STATCOM (LG Fault)

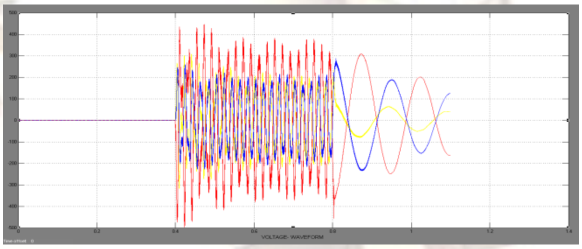

Fig.5.10 Three Phase Voltage Waveform With D-STATCOM (LG Fault)

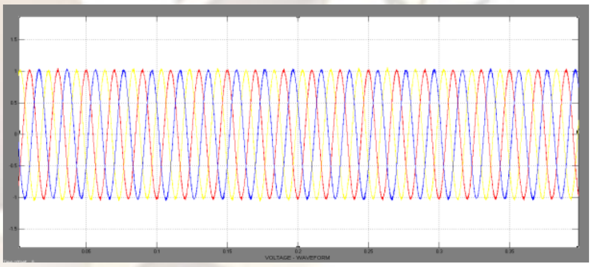

Fig.5.11 Three Phase Voltage Waveform Before Fault With D-STATCOM (LG Fault)

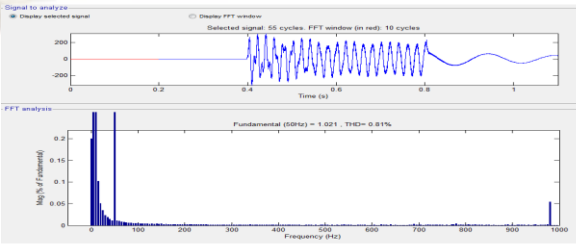

Fig.5.12 FFT Analysis Before Fault With D-STATCOM (LG Fault)

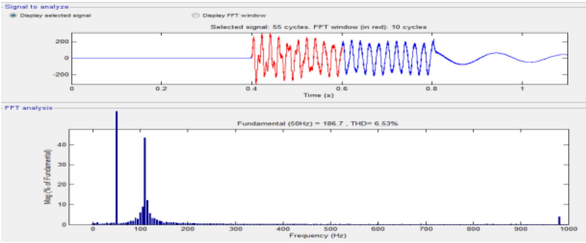

Fig.5.13 FFT Analysis During Fault With D-STATCOM (LG Fault)

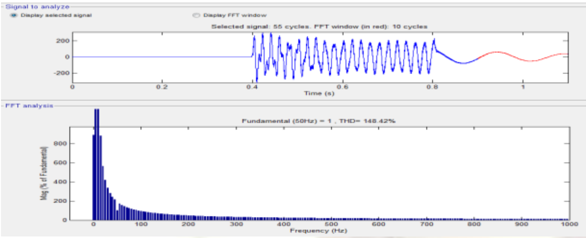

Fig.5.14 FFT Analysis After Fault With D-STATCOM (LG Fault)

5.5. CASE 2. : DOUBLE LINE TO GROUND FAULT (LLG) CONDITION:

In this case Double line to ground fault is considered for both the feeders. Here the fault resistance is 0.001 ohm and the ground resistance is 0.001ohm. The fault is created for the duration of 0.4s to 0.9s. The output waveform for LG fault is shown below.

5.6. RESULT WITHOUT D-STATCOM (LLG Fault):

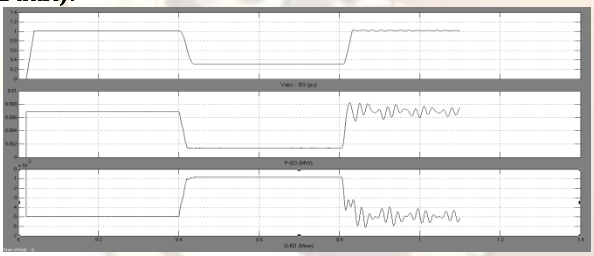

Fig.5.15 Three Phase Voltage(pu), Active Power and Reactive Power at Bus 3 Without D-STATCOM (LLG Fault)

5.7. RESULT WITH D-STATCOM (LLG Fault):

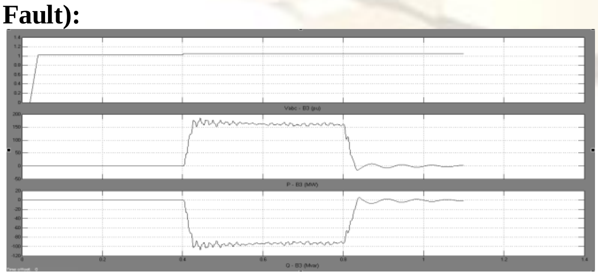

Fig.5.19 Three Phase voltage(pu), Active Power and Reactive Power at Bus 3 With D-STATCOM (LLG Fault)

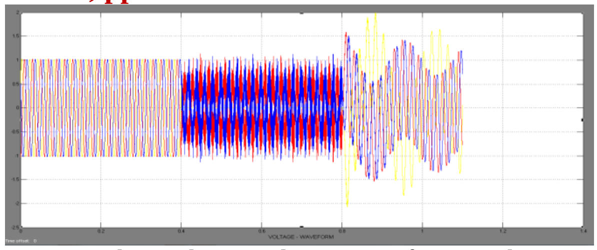

Fig.5.16 Three Phase Voltage Waveform Without D-STATCOM (LLG Fault)

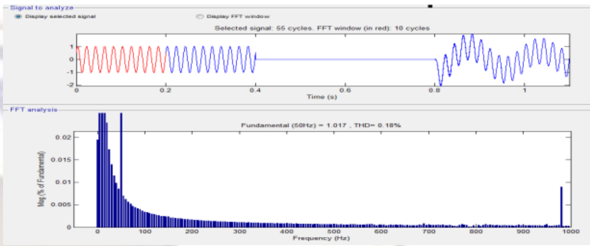

Fig.5.17 FFT Analysis Before Fault Without D-STATCOM (LLG Fault)

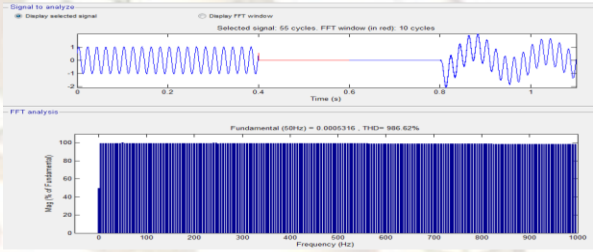

Fig.5.18 FFT Analysis During Fault Without D-STATCOM (LLG Fault)

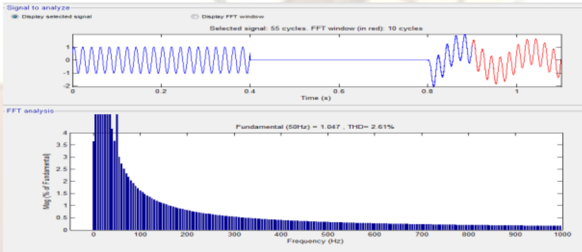

Fig.5.21 FFT Analysis After Fault With D-STATCOM

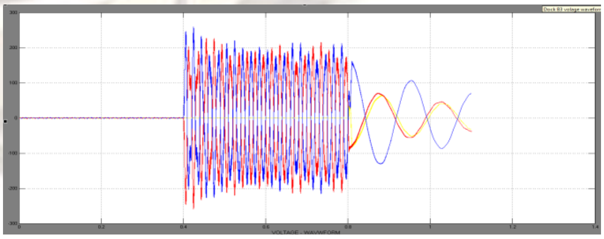

Fig.5.20 Three Phase Voltage Waveform With D-STATCOM (LLG Fault)

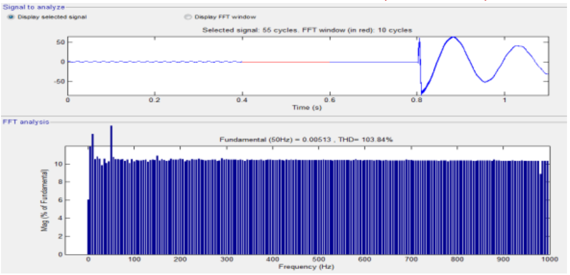
Fig.5.22 FFT Analysis During Fault (LLG Fault)

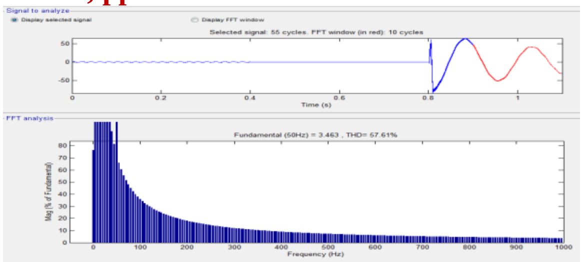
Fig.5.23 FFT Analysis After Fault (LLG Fault)

6. THD Comparison:

S.No.	Type Of Fault	With D-STATCOM (CB_2 -Closed)			With D-STATCOM (CB_2 – Open)		
		Before Fault	During Fault	After Fault	Before Fault	During Fault	After Fault
1.	LG	0.18%	25.15%	1.46%	0.18%	6.53%	48.42%
2.	LLG	0.18%	986.62%	2.61%	0.81%	103.84%	57.61%

Tabble 6.1 THD Comparison Under Different Condition

7. CONCLUSIONS

This paper has presented the power quality problems such as voltage dips, interruptions. The objective of this work is to study the performance of D-STATCOM for mitigating voltage sag (dip) and to improve the power quality in distribution network with non-linear load. The investigation is made on different fault condition for non-linear load. In this work the investigation is composed of power system distribution network with and without D-STATCOM.

THD comparison of different fault condition is also carried out during fault, before fault and after fault condition. So it can be concluded that D-STATCOM effectively improves the power quality in distribution network with non-linear load.

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