Investigations on the Role of Distribution Static Compensator in Distribution Networks Under Fault Condition

Amrinder Kaur
Asst. Professor,
EEE Deptt.,
Manav Rachna International University
Faridabad, India
E-mail: amrinder.fet@mriu.edu.in

Leena G.
Professor
EEE Deptt.,
Manav Rachna International University
Faridabad, India
E-mail: leenag.fet@mriu.edu.in

Abstract: Power quality problem is an occurrence related to nonstandard voltage, current or frequency that results in a failure or a disoperation of end user equipments in power system. Nowadays in electrical distribution system, there has been a sudden increase of nonlinear loads, such as power supplies,rectifier equipment used in communication networks, domestic appliances, adjustable speed drives etc. With power quality problem utility distribution networks, industrial loads, sensitive loads etc. are suffered. As the power systems is restructured and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. A number of power quality solutions are provided by Custom power devices like Active and passive filters, capacitors as compensators. The fast response of the Distribution Static Compensator (DSTATCOM) makes it the efficient solution for improving power quality in distribution systems.. DSTATCOM can use with different types of controllers. The performance of a distribution network with DSTATCOM and PI controller is studied in this paper under different abnormal conditions like single line to ground fault, double line to ground fault and triple line to ground faults with static linear load.

Keywords: Distribution Static Compensator (DSTATCOM), power quality, voltage source converter (VSC), Harmonics, Unsymmetrical fault.

I. INTRODUCTION

Power Quality is defined in different ways by different people. Institute of Electrical and Electrical Engineers (IEEE) standard IEEE 1100 defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment."

What makes this power quality so important is that its effects are often not predictable until failure occurs. Even if failure does not occur, poor power quality and harmonics increase losses in power system and decrease the lifetime of power components and end-use devices.Poor powerfactor, load unbalancing, and high neutral current, harmonics injection due to penetration of power electronics based loads causes power quality problems inthe distribution system. To mitigate the power quality problems and to maintain reliability of the delivered power, tough power quality standards are practiced [1]. The power quality problems and different techniques adopted to reduce its effect is discussed in [2-4]. With the advance of power electronics various custom power devices [5-8] came into existence for improving the power quality problems like series compensator, static VAR compensators (SVC), Unified power quality conditioner (UPQC), dynamic voltage restorer (DVR), distribution static compensator (DSTATCOM). DSTATCOM is better compared to static capacitors and passive filters in improving power quality[3,5].A comparative study of various topologies of DSTATCOM and its potential application in power quality improvement is discussed in [9-10].

A DSTATCOM is normally a voltage source converter (VSC)-based shunt compensator, The DSTATCOM used toregulate voltage, is similar to a transmission STATCOM. However, the VSC used in a DSTATCOM is a Type 1 converter with PWM control over the magnitude of the injected AC voltage while maintaining a constant DC voltage across the capacitor. A DSTATCOM can be termed as a variable current source determined by the controller parameters. The different control techniques for DSTATCOM reported in literature are sliding mode control [11] instantaneous symmetrical component theory[12] and neural network theory [13-14].

In this paper a simulation study is conducted on a test model with DSTATCOM under different fault condition and how the power quality is improved is investigated. The test model is a transmission line of two feeders one with DSTATCOM and one without DSTATCOM.

II. TEST SYSTEMS AND ITS PARAMETERS

Adistribution network model with two different feeders connected to similar linear loads is considered. Feeder 1 is without DSTATCOM and feeder 2 is connected with DSTATCOM. This test system is modeled in Matlab/Simulink and analyzed under different unsymmetrical fault conditions with linear load. The control technique used is a PI controller which starts from the difference between the injected current (DSTATCOM current) and reference current (identified current) that determines the reference voltage of the inverter (modulating reference signal).

The various parameters of the test systemtaken are as follows:

The system is with three phase generation source of 25KV, 50 Hz. The source is feeding two transmission lines through a three phase, three windings transformer with power rating 250MVA, 50 Hz with a specification as.

Winding 1: V_{1rms} (ph-ph) = 11 KV,
R_1 =0 .002 (pu), L_1=0 .08002 (pu).
Winding 2: V_{2rms}(ph-ph) = 11 KV,
R_2= 0.002 (pu), L_2= 0.08002 (pu).
Winding 3: V_{3rms} (ph-ph) = 11 KV,
R_3 = 0002 (pu), L_3= 0.08002 (pu).
The modeled system is shown in Fig. 1.

III. SIMULATION RESULTS

Three different unsymmetrical fault conditions are considered for testing the model, like single line to ground(L-G), double line to ground (LL-G) and three line to ground (LLL-G) fault. The results for each fault condition are given one by one.The results of simulations

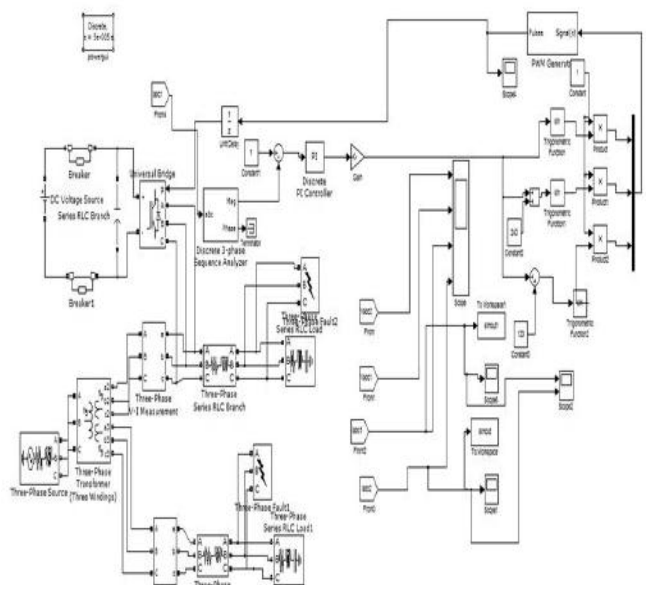

Fig. 1: Simulink Model of Test System

with linear load for the above three different fault conditions are shown below.

CASE 1-Single Line to Ground (L-G)Fault Condition

A single line to ground fault is considered for both the feeders. Here the fault resistance is 0.001 ohm and the ground resistance is 0.001 ohm. The fault is created for the duration of 0.3s to 0.5s in one phase. The output waveform of the load current in feeder 1without DSTATCOM and feeder 2 withDSTATCOM is shown in Fig. 2, Fig. 3 respectively.

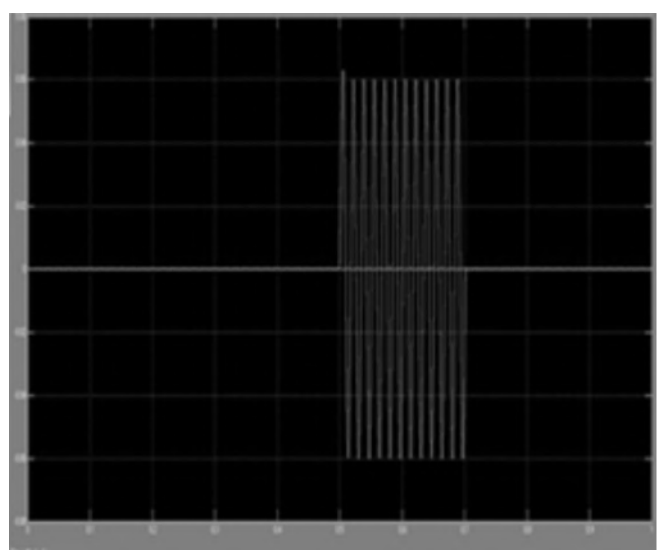

Fig. 2: Load current in feeder 1under LG fault (without DSTATCOM)

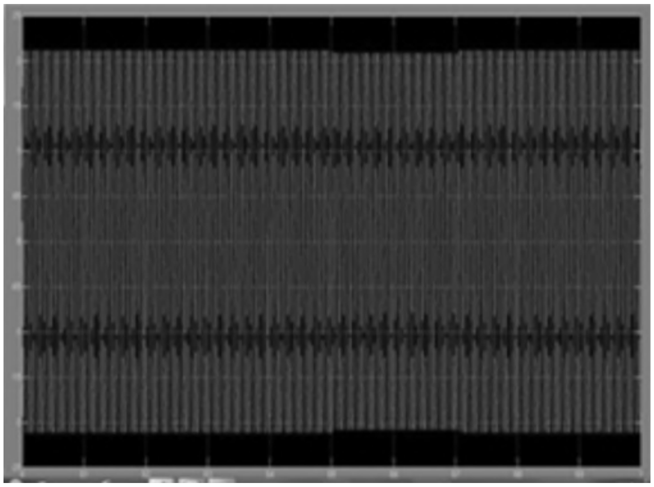

Fig. 3: Load current in feeder 2under L-G fault (with DSTATCOM)

It is to be noted that the output current waveform in the phase where fault is created is increasing during the fault duration in the uncompensated feeder. While the feeder in which DSTATCOM is connected the current is balanced which itself improves the power quality.

CASE 2- Double Line to Ground (LL-G) Fault Condition

In second case the fault considered is double line to ground faultis created for one of the phases of both the feeders. For this fault resistance and ground resistance is 0.001ohm and 0.001ohm respectively. And the time duration for this fault is 0.3 seconds to 0.5 seconds. The output wave form for the load current in feeder 1 without DSTATCOM and in feeder 2 with DSTATCOM is shown in Fig. 4 and Fig. 5 respectively.

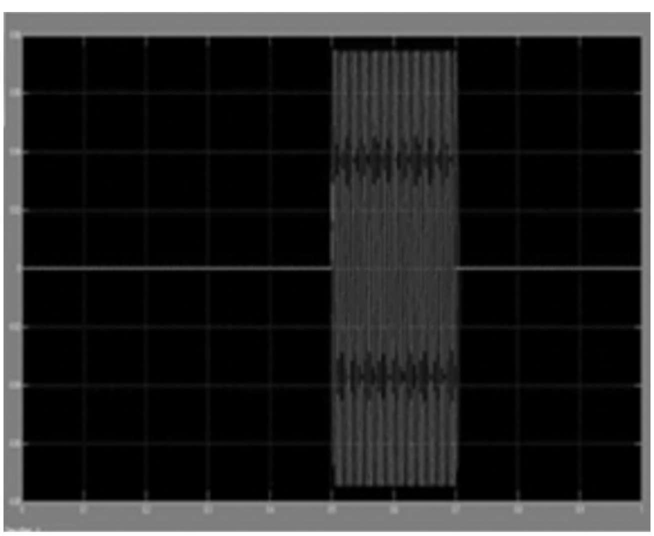

Fig. 4: Load current in feeder 1 under LL-G fault (without DSTATCOM)

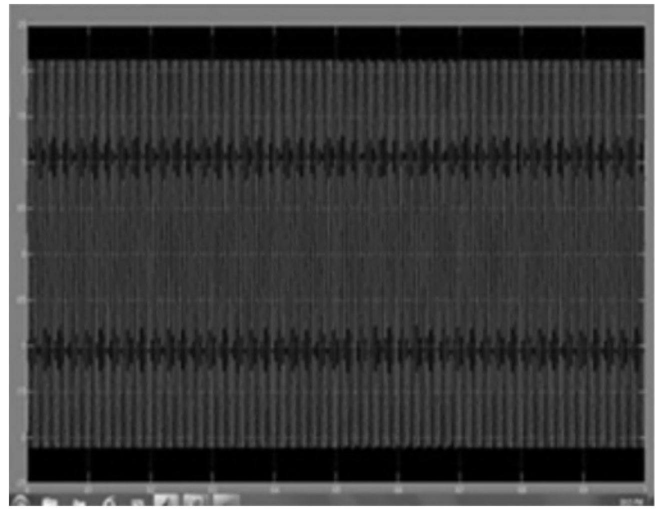

Fig. 5: Load current in feeder 2 under LL-G fault (with compensation)

The output wave form shows that the current in the phase where fault is created is increasing during the fault duration in the uncompensated feeder (refer Fig. 4), but in feeder 2 wherethe DSTATCOM is connected current unbalancing is reduced much as shown in Fig. 5.

CASE 3- Three Line to Ground (LLL-G) Fault Condition:

In third case the considered fault for both the feeders is three lines to ground fault. The fault is created for the duration of 0.3s to 0.5s in one of the phases of feeder 2. And fault resistance and ground resistance is 0.001ohm and 0.001ohm respectively. Figs.6 and 7

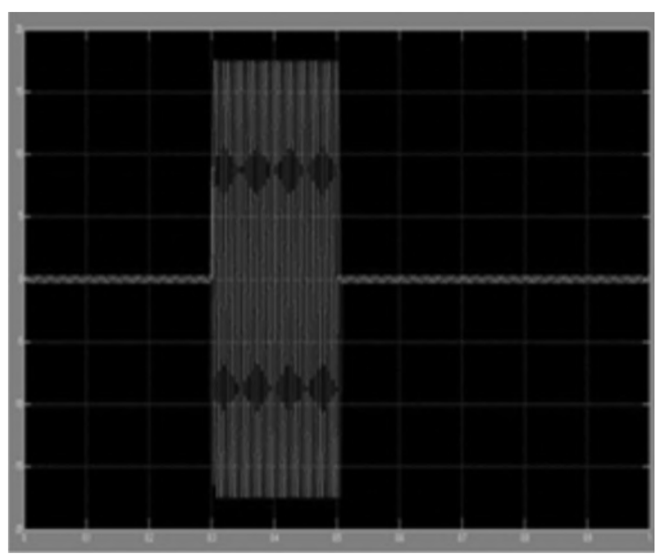

Fig. 6: Load current in feeder 1 under LLL-G fault condition (without DSTATCOM)

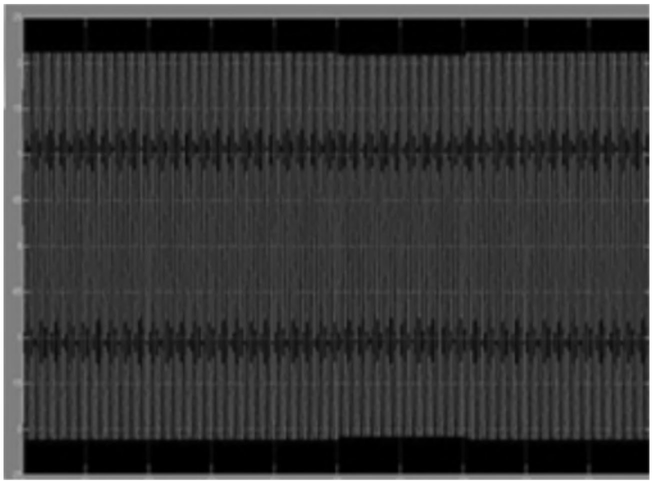

Fig. 7: Load current in feeder 2 under LLL-G fault condition (with DSTATCOM)

respectively shows the wave forms of the load current in the feeders where fault is created without DSTATCOM and with DSTATCOM. The voltage unbalancing is clearly reduced in the feeder 2 where DSTATCOM is connected.

Further THD (Total harmonics distortion) analysis is done on the output current wave form under different fault conditions and is shown in Figs. 8-13. The results are tabulated in Table 1.

From Table 1, it is to be noted that THD is reduced in the load current in feeder 2 where the DSTATCOM is connected compared to feeder 1 where the DSTATCOM is not connected under three different

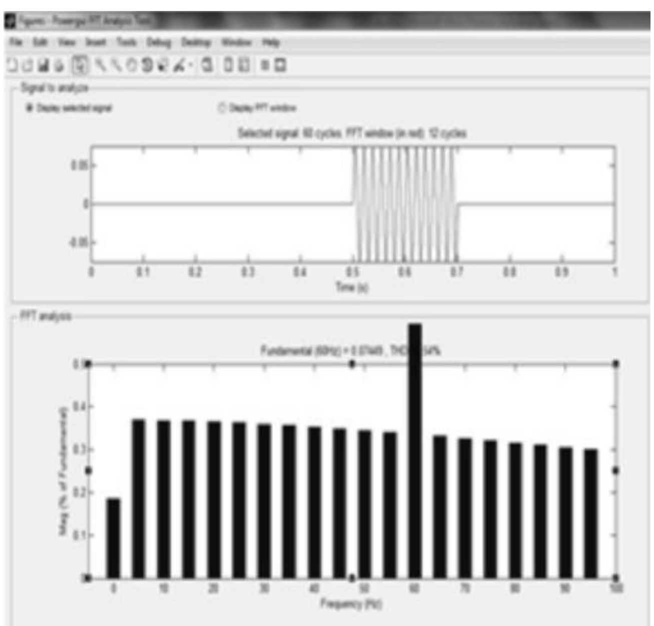

Fig. 8: THD (in feeder 1) under LG fault

unsymmetrical fault conditions. Hence it can be is stated that power quality is improved with the use of DSTATCOM.

Table 1: THD under different fault condition for the two feeders

	LG	LLG	LLLG
Feeder 1	1.54	0.96	0.54
Feeder 2 with DSTATCOM	.02	.01	.02

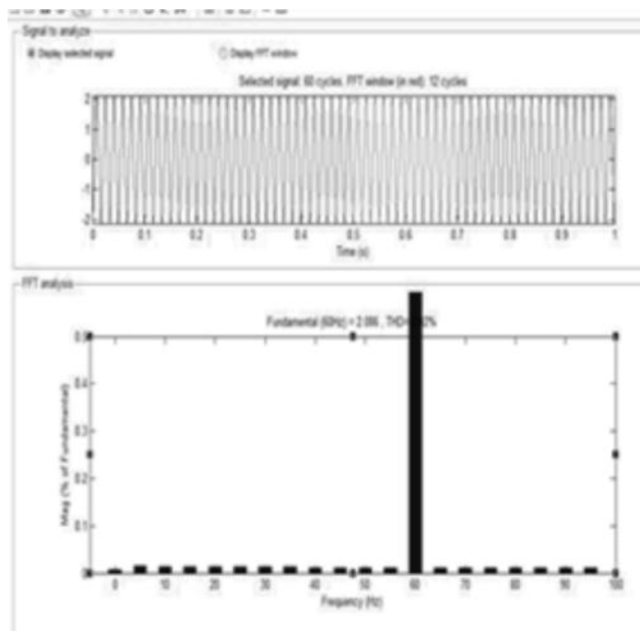

Fig. 9: THD in feeder 2 under L-G fault

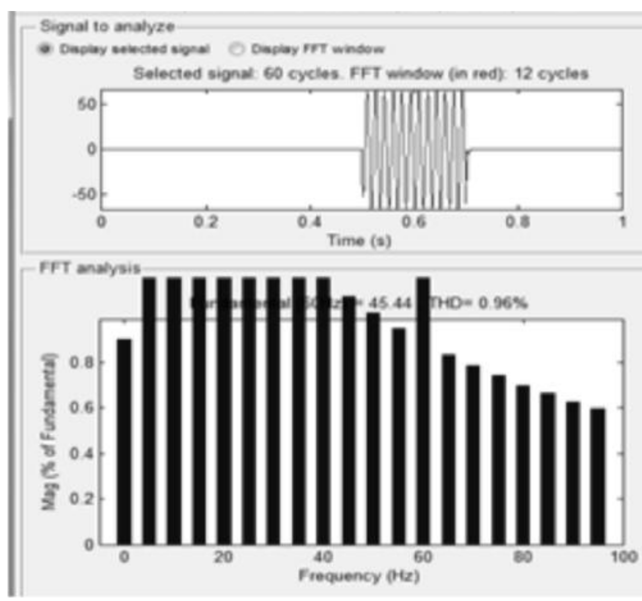

Fig. 10: THD (in feeder 1) under LLG fault

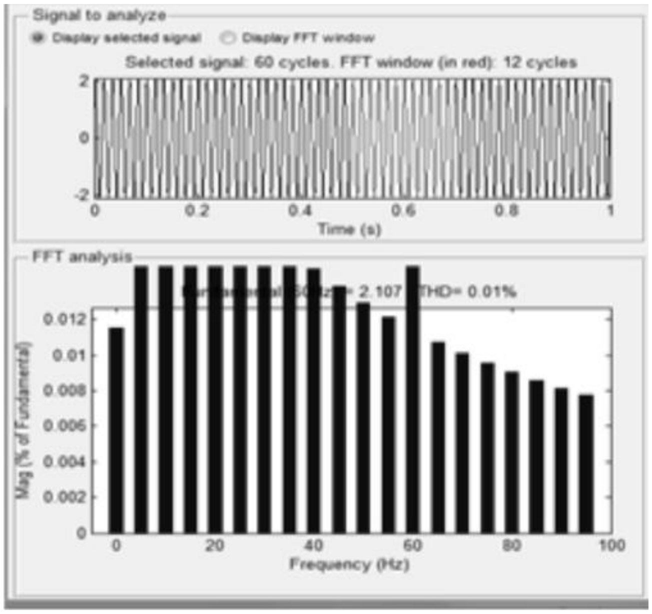

Fig. 11: THD (in feeder 2) under LLG fault

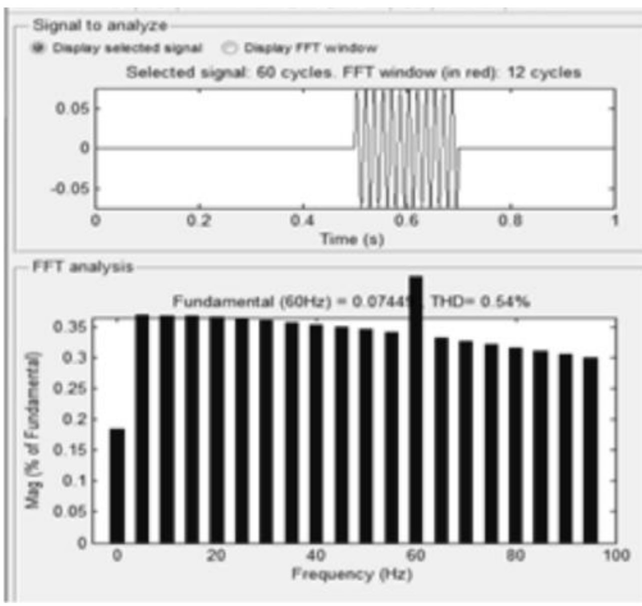

Fig. 12: THD (in feeder 1) under LLLG fault

IV. CONCLUSIONS

In this work, the investigation on the role of DSTATCOM to improve the power quality in distribution networks with static linear load under three fault conditions is studied. PI controller is used with the device to enhance its performance. The result shows that with DSTATCOM the load unbalancing is very much reduced under different fault conditions. It can be concluded that DSTATCOM effectively improves the

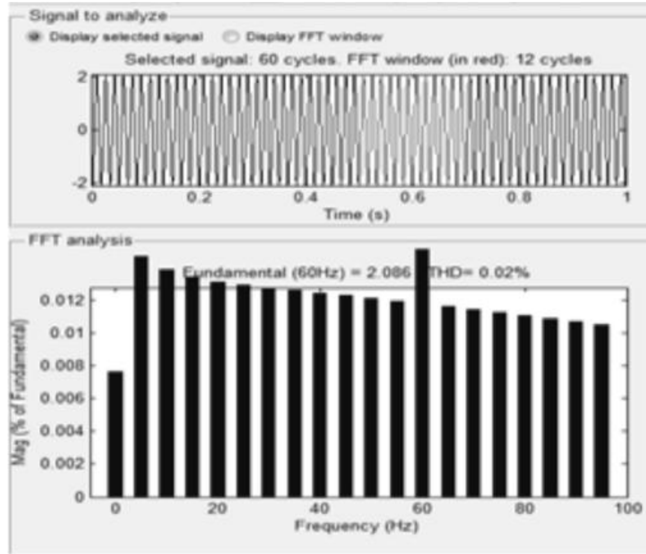

Fig. 13: THD (in feeder 2) under LLLG fault

power quality in distribution networks with static linear loadeven under different fault conditions.

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