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Enhancement of Power Quality in Distribution System Using D-STATCOM &Passive Filter

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ABSTRACT: This paper presents the enhancement of harmonic distortion, voltage sags and low power factor using Distribution Static Compensator (D-STATCOM) with LCL Passive Filter in distribution system. The D-STATCOM injects a current into the system to mitigate the voltage sags.LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB simulink version R2009a. A new PWM-based control scheme has been implemented to control the electronic valves in the DSTATCOM. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage. In this paper, the configuration and design of the DSTATCOM with LCL Passive Filter are analyzed. It also is design to enhance the power quality such as harmonic distortion, voltage sags and low power factor in distribution system.

KEYWORDS: DSTATCOM, Voltage Sag, THD, Voltage source converter

I. INTRODUCTION

Electrical power quality may be defined as a measure of how well electric power service can be utilized by customers or power quality is the quality of the electric power supplied to electrical equipment. In order to improve the power quality in distribution system, we have to use D-STATCOM and LCL passive filters. The D-STATCOM injects a current into the system to mitigate the voltage sags.LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor.

Voltage magnitude is one of the major factors that determine the quality of power supply [1]. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in voltage magnitude occur [4]. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min.

Voltage sags is caused by a fault in the distribution system, a fault within the customer's facility or a large increase of the load current, like starting a Induction motor or single phase or three phase transformer energizing [2,3]. Voltage sags are one of the most occurring power quality problems. For an industry voltage sags occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from loads as the main power quality problems [5].

Harmonic distortion in distribution system is because of harmonic current. Low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. The development of power electronics devices such as Flexible AC Transmission System (FACTS) and customs power devices have introduced and emerging branch of technology providing the power system with versatile new control capabilities. There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices.

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II. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

A D-STATCOM consists of a two-level VSC, a dc energy storage device, controller and a coupling transformer connected in shunt to the distribution network. Figure 1 shows the schematic diagram of D-STATCOM.

$I_{out}= I_L - I_s = I_L-(V_{th}-V_L)/Z_{th}$ 1

$I_{out}<\gamma = I_L<(-\theta) - V_{th}/Z_{th}<(\delta-\beta) + V_L/Z_{th}<(-\beta)$ 2

I_{out}=output current I_L= load current
I_s= source current V_{th}=thevenin voltage
V_L=load voltage Z_{th}=thevenin impedance

Referring to the equation 2, output current will correct the voltage sags by adjusting the voltage drop across the system impedance. It may be mention that the effectiveness of D-STATCOM in correcting voltage sags depends on:

a) The value of Impedance,
b) The fault level of the load bus

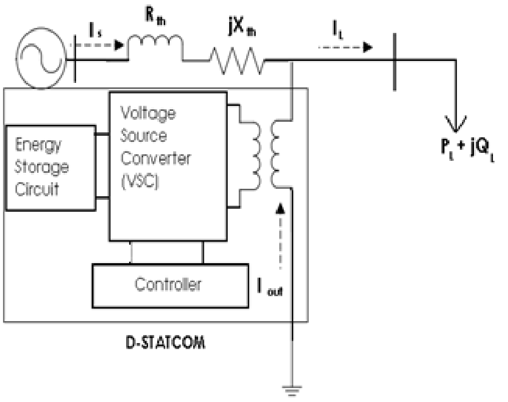

Fig 1 schematic diagram of D-STATCOM.

Voltage Source Converter (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC used to inject a voltage to augment the drop. It also converts the DC voltage across storage devices into a set of three phase AC output voltages [8, 9].

LCL Passive Filter:

LCL Passive filter is more effective on reducing harmonics distortion. To design it, equations 3,4 and 5 are needed.

$$L_g = \frac{E_n}{2\sqrt{6} i_{rippm} . f_{sw}}$$ 3

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$$L_c = \frac{L_g}{2} \qquad 4$$

$$C_f = \frac{L + L_g}{LL_g (2\pi f_{res})^2} \qquad 5$$

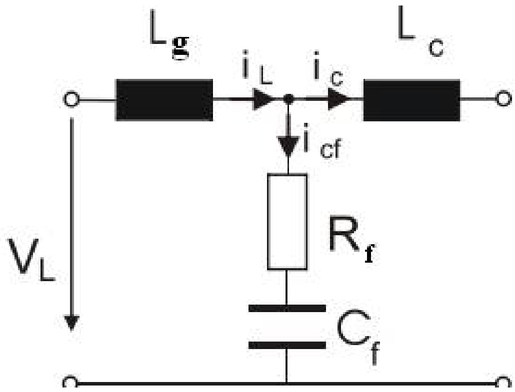

Fig 2. Circuit diagram for single phase LCL Passive filter

TABLE 1. LIST OF VALUE OF PARAMETERS OF LCL PASSIVE FILTER

Symbol	Name	Quantity Value
En	RMS value of grid voltage	19kv(rms)
Lg	Grid-side filter inductance	1630 mH
Lc	Converter side filter inductance	815 mH
Cf	Filter Capacitance	0.0017uf
Fsw	Switching frequency	20 kHz

III. METHODOLOGY

To enhance the performance of distribution system, DSTATCOM was connected to the distribution system. DSTATCOM was designed using MATLAB simulink version R2009a. Figure 3 below shows the flowchart for the methodology:

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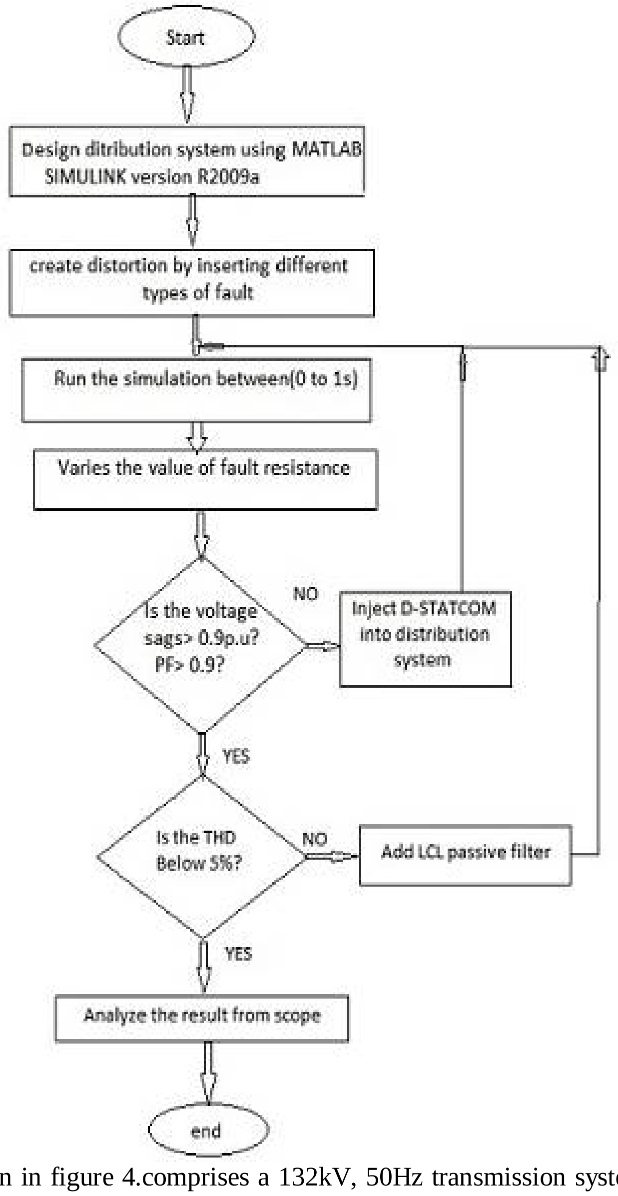

The test system shown in figure 4.comprises a 132kV, 50Hz transmission system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer connected in Y/Y/Y, 132/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point. A 750 µF capacitor on the dc side provides the D-STATCOM energy storage capabilities. Breaker 1 is used to control the period of operation of the D-STATCOM and breaker 2 is used to control the connection of load 1 to the system.

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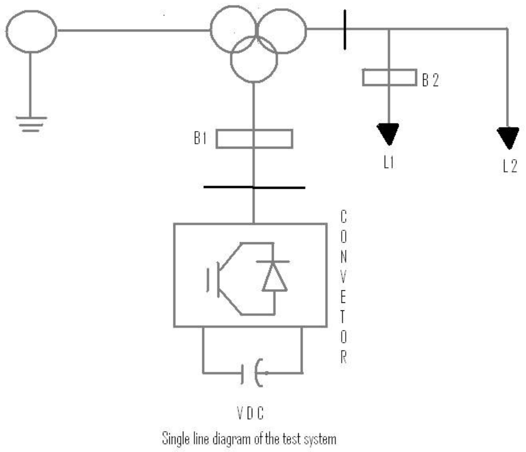
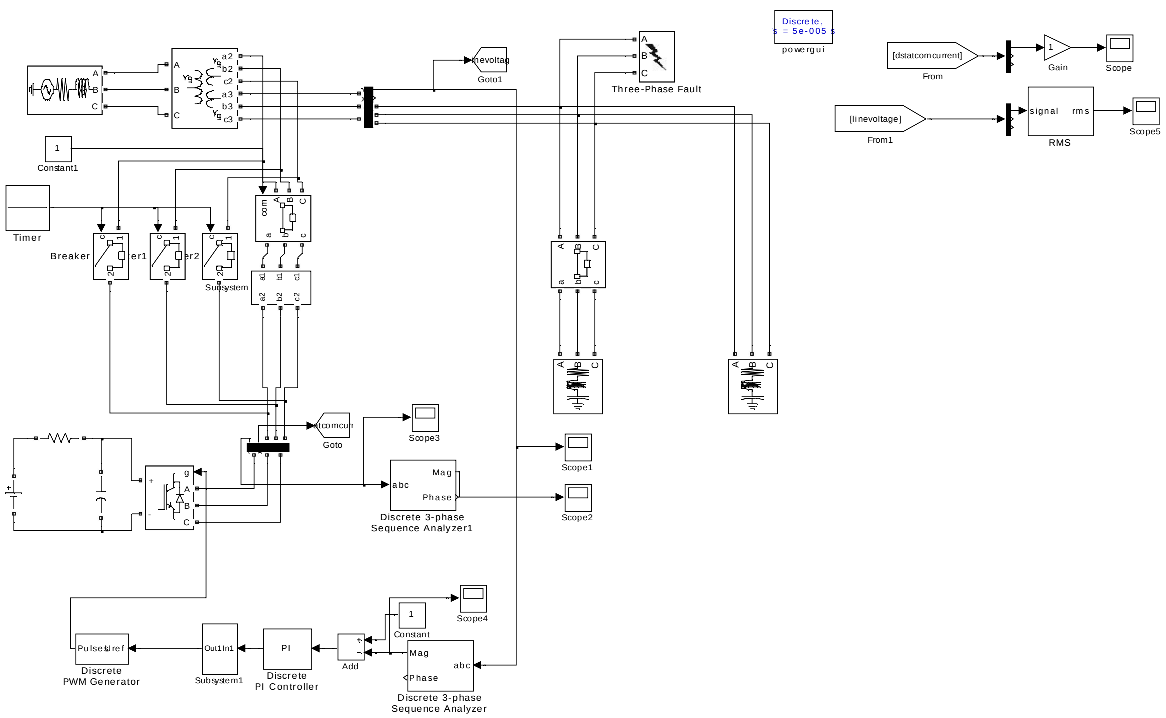


Fig 4 The test system

IV. MATLAB DESIGN OF CASE STUDY

Diagram of the test system



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V. RESULTS AND DISCUSSION

To create disturbance in the distribution system, different types of faults such as Three Phase to Ground (TPG), Double Line to Ground (DLG), Line to Line (LL), and Single Line to Ground (SLG) are injected.

WITH OUT INSERTION OF D-STATCOM:

TABLE 1. RESULTS OF VOLTAGE SAGS FOR DIFFERENT TYPES OF FAULT:

Fault Resistance(Rf) (p.u)	Voltage Sags For TPG Fault(pu)	Voltage Sags For DLG Fault(pu)	Voltage Sags For LL Fault(pu)	Voltage Sags For LG Fault(pu)
0.66	0.6610	0.7071	0.7586	0.8257
0.76	0.7109	0.7488	0.7919	0.8488
0.86	0.7516	0.7832	0.8211	0.8678

Table 1 shows the overall results of voltage sags in p.u for different types (TPG, DLG, LL, SLG) of faults. From the table, it can be observed that when the value of fault resistance is increase, the voltage sags will also increased for different types of faults

Voltage at load point for LG fault:

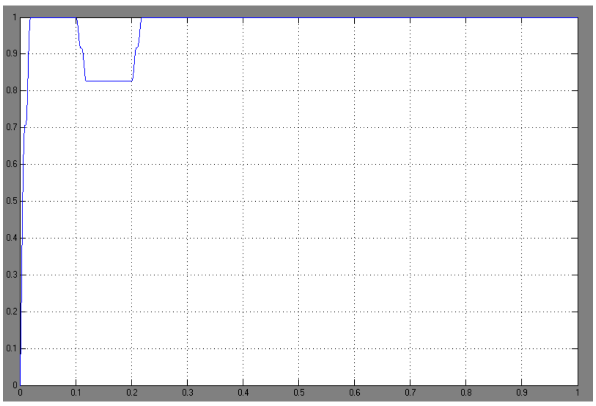

Fig 5 voltage at load point for SLG Fault

Voltage at load point for LLG fault:

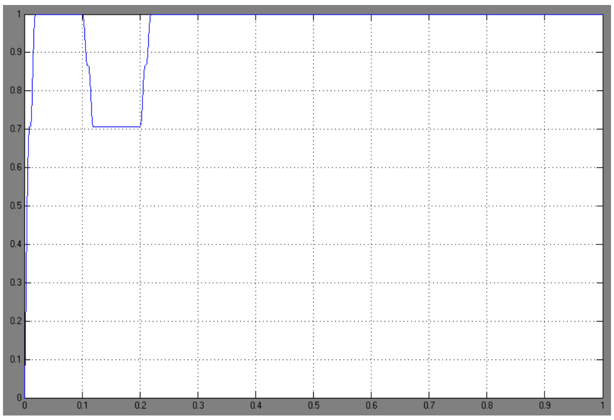

Fig 6 voltage at load point for DLG Fault

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Voltage at load point for LLLG fault

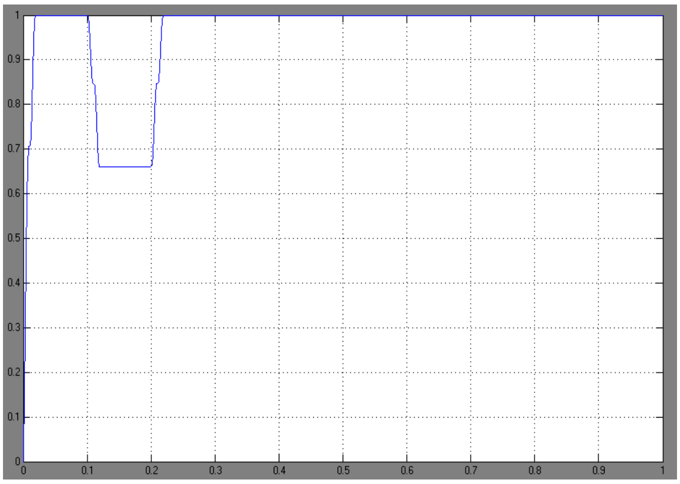

Fig 7 voltage at load point for TPG Fault

Figure 5 to 7 show the simulation results of the test system for different types of fault. The fault occurs during (100-200ms) when the fault resistance is 0.66 Ω.

TABLE 2. RESULTS FOR DIFFERENT TYPES OF FAULT BEFORE AND AFTER INSERT D-STATCOM WHEN Rf= 0.66Ω

Types of faults	Without DSTATCOM (P.u)	With DSTATCOM (P.u)	Percentageof improvement
TPG	0.6600	0.9367	27.67
DPG	0.7070	0.9800	27.30
LL	0.7587	1.0168	25.81
SLG	0.8259	0.9837	15.78

WITH INSERTION OF D-STATCOM:

TABLE 3. RESULTS OF VOLTAGE SAGS FOR DIFFERENT TYPES OF FAULT**:**

Fault Resistance(Rf) (p.u)	Voltage Sags For TPG Fault(pu)	Voltage Sags For DLG Fault(pu)	Voltage Sags For LL Fault(pu)	Voltage Sags For LG Fault(pu)
0.66	0.9367	0.9800	1.0168	0.9837
0.76	0.9450	0.9806	1.0142	0.9817
0.86	0.9543	0.9858	1.0152	0.9863

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Table 3 shows the overall results of voltage sags in p.u with different types of fault. From the table, it can be observed that voltage sags improved with insertion of D-STATCOM. The value of voltage sags is between (0.9 to 1.02 p.u.)

Voltage at load point for LG fault:

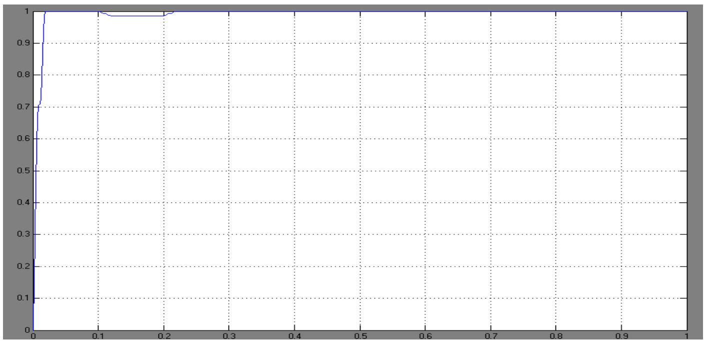

Fig 8 voltage at load point for SLG Fault with d- statcom

Voltage at load point for LLG fault:

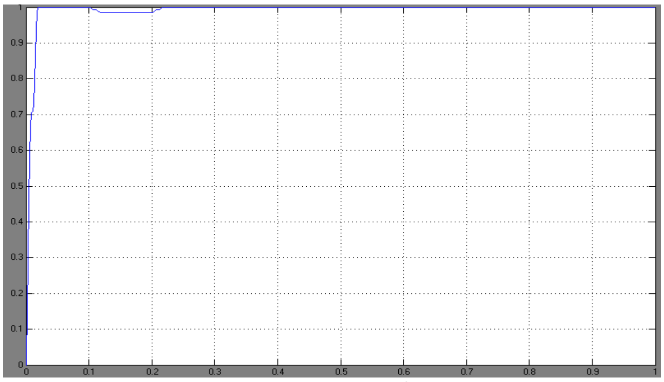

Fig 9 voltage at load point for DLG Fault

Voltage at load point for LLLG fault:

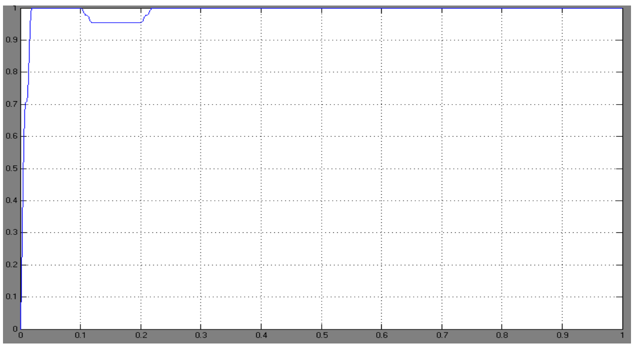

Fig 10 voltage at load point for TPG Fault

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WITHOUT LCL PASSIVE FILTER:

Table 4 Result current harmonic for different types of fault without LCL passive filter:

Number of harmonic spectrum	Harmonic distortion of TPG Fault %	Harmonic distortion of DPG Fault %	Harmonic distortion of LL Fault %	Harmonic distortion of SLG Fault %
1st	100.00	100.00	100.00	100.00
3rd	62.00	86.00	42.74	47.00
5th	2.00	2.00	1.00	2.00
7th	13.00	17.00	10.00	8.00
9th	6.00	9.00	5.01	4.00
11th	1.00	3.00	2.10	1.00
13th	5.00	7.00	3.56	3.00
15th	1.00	1.00	1.00	1.00
17th	2.00	3.00	1.72	1.00
19th	2.00	3.00	1.34	1.00
THD	63.65	88.68	44.56	48.26
Power Factor	84.49	74.79	91.34	90.00

THE THD SPECTRUM OF OUTPUT CURRENT OF D-STATCOM WITH AND WITHOUT LCL PASSIVE FILTER:

Without LCL passive filter:

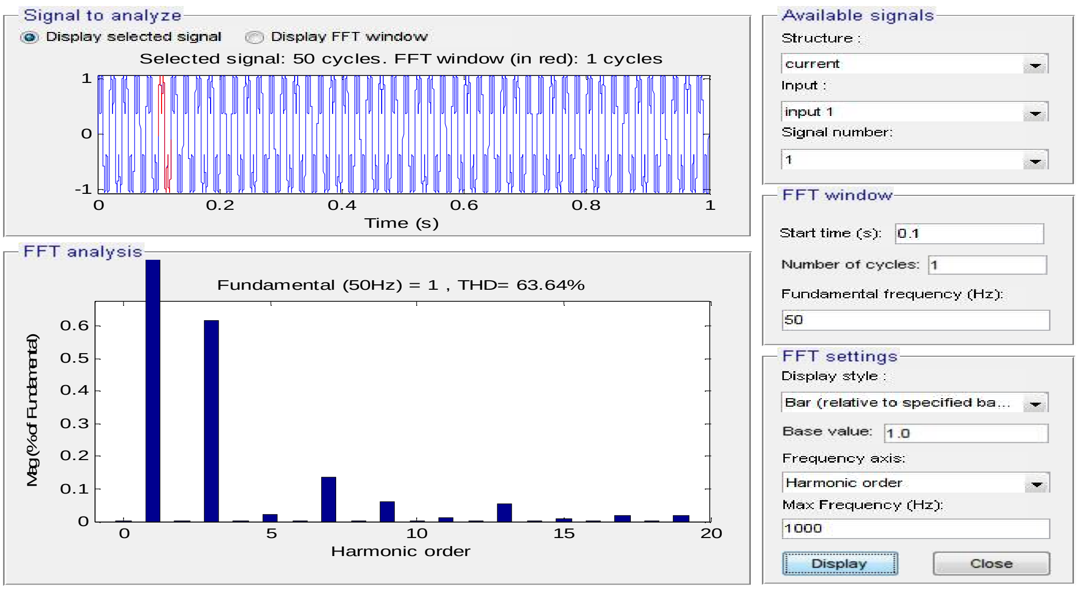

Fig 11 The THD Spectrum Of output current of D-statcom

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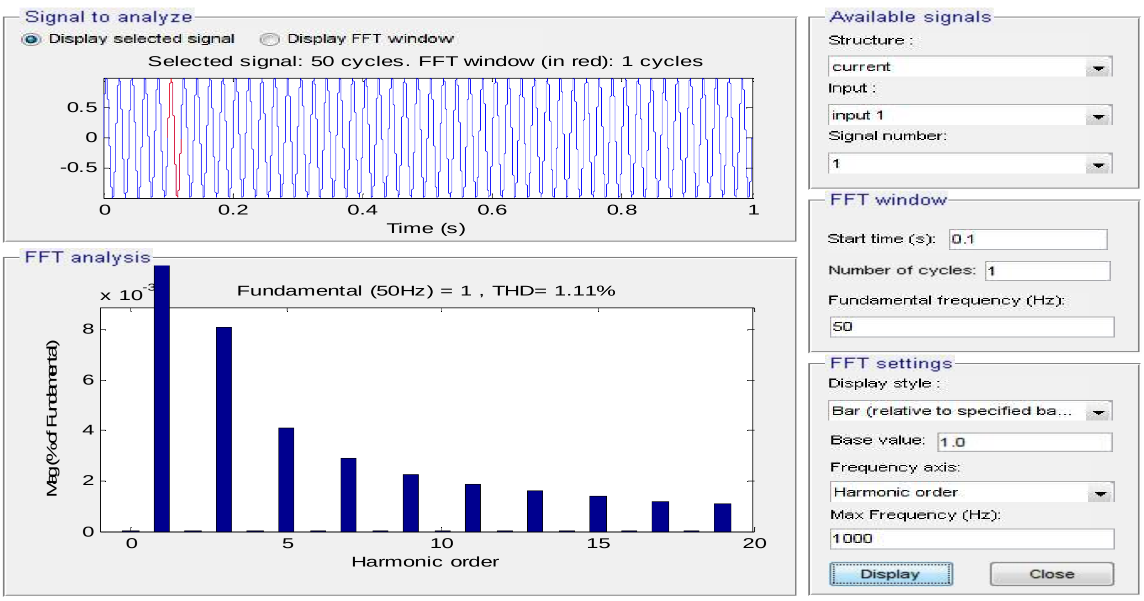
TABLE 5 RESULT CURRENT HARMONIC FOR DIFFERENTTYPES OF FAULT WITH LCL PASSIVE FILTER:

Number of harmonic spectrum	Harmonic distortion of TPG Fault %	Harmonic distortion of DPG Fault %	Harmonic distortion of LL Fault %	Harmonic distortion of SLG Fault %
1st	100.00	100.00	100.00	100.00
3rd	1.00	1.00	0.43	1.00
5th	0.00	0.00	0.16	0.00
7th	0.00	0.00	0.13	0.00
9th	0.00	0.00	0.13	0.00
11th	0.00	0.00	0.08	0.00
13th	0.00	0.00	0.07	0.00
15th	0.00	0.00	0.05	0.00
17th	0.00	0.00	0.05	0.00
19th	0.00	0.00	0.04	0.00
THD	1.11	1.12	0.72	1.14
Power Factor	99.99	99.99	99.99	99.99

Table 5, shows that with LCL Passive filter, the percentage of THD has reduced. Now the THD is within the IEEE STD 519-1992. The power factor increases close to unity.

With LCL passive filter:



VI. CONCLUSION

The simulation results show that the voltage sags can be mitigate by inserting D-STATCOM to the distribution system. By adding LCL Passive filter to D-STATCOM, the THD reduced within the IEEE STD 519-1992. The power factors also increase close to unity. Thus, it can be concluded that by adding D-STATCOM with LCL filter the power quality is improved.

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BIOGRAPHY

Kothuri Ramakrishna completed his Bachelor of Engineering (B.E.) from Gulbarga University in the year 1998 and Master of Technology (M.Tech.) from J.N.T.U Hyderabad in 2001. He also completed Master of Business Administration (MBA) from Annamalai University in 2013. Presently, he is pursuing Ph.D from J.N.T.U. Hyderabad. Right now, he has around 16 years of teaching experience. His research interest includes Power Electronics, Power Quality, Power System Analysis, Power System Dynamics, etc. He has published several National and International Journals and Conferences. Have professional society memberships in IEEE (M), IETE (M), ISTE (LM), IE (AM), SESI (LM), IAENG (M), NIQR (M), SSI (LM), SPE (LM), IAENG (LM), IACSIT (LM), and C.Eng.