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A D-STATCOM for Power Quality Improvement Under Different Fault Conditions

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Abstract: D-STATCOM has been used to improve the power quality problems, such as voltage sags, voltage swells for different fault conditions. In order to improve the power factor and reduce the harmonic distortions, LCL passive filter is used along with D-STATCOM. The aim of this paper is to compensate the voltage sag and harmonic distortions by designing the D-STATCOM with LCL passive filter across the distribution system. The simulations were performed by using MATLAB/SIMULINK.

Key words: D-STATCOM, LCL passive filter, Total Harmonic Distortions (THD), voltage sag.

I. INTRODUCTION

Voltage sag or dip is a reduction in rms voltage, which occurs for a short duration of time [1]. In case of a three phase system, due to the voltage sag both phase to phase and phase to ground voltages will be affected [4]. The definition of voltage sag is set by two parameters such as magnitude/depth and duration.

This paper is organized as follows. D-STATCOM and its operation explained in section II, types of electrical faults are explained in section III, simulation model explained in section IV, and conclusion explained in section V.

Causes of voltage dip:

i. Due to short circuit faults.
ii. Switching action.
iii. Sudden addition and removal of loads.
iv. Due to transformer energizing.
v. Starting of electric motors

Effect of Voltage Sag on Different Distribution side Loads:

- Due to voltage sag, the light intensity of a fluorescent lamp will reduce.
- For digital alarm clock radios, when a sag depth is 60%, then there exists severe audio quality loss.
- In case of computers, when sag depth is greater than 30%, computer will restart again. For
- For televisions, the television will switched off for 50% sag depth and duration of 30 cycles.
- DVD and CD players was largely unaffected by sags, except for flickering of the electronic timer displays.
- In case of Air conditioners, when sag is greater than 50%, the motor speed decreased.

In this paper voltage dip occurred due to different faults exist in the distribution system such as, Triple Line to Ground (TPG) fault, Double Line to Ground (DLG) fault, Single Line to Ground (SLG) fault, Line to Line (LL) fault.

In order to avoid all these problems a D-STATCOM is used [5].A PWM control method and PI controller technique has been used to operate the switches of the D-STATCOM.

Due to the usage of power electronic components, harmonic currents are present in the distribution system. These harmonic currents create a noise and disturbance in the system. So the performance, reliability and efficiency of a distribution system may reduce. So to avoid all these problems a LCL passive filter is added.[3].

II. D-STATCOM

D-STATCOM is one of the FACTS controllers, which connected in parallel or shunt to the distribution system. D-STATCOM consists of voltage source converter (VSC), a set of coupling reactors and a controller. Fig.2.1 shows the block diagram of a D-STATCOM.

Generally, voltage quality problem occurred at the customer side. That's why the D-STATCOM is connected at the load side [2, 5].

D-STATCOM contains an inverter, Dc link capacitor (C), coupling inductor (L) and controller. Dc link capacitor is used as an energy storage device and which provides a dc voltage to the inverter. Coupling inductor is used as a current filter. Control unit generates a PWM signals for the switches of invert

VSC:

VSC is one of the shunt connected power electronic device. VSC generates a sinusoidal voltage and used to replace the missing voltage.

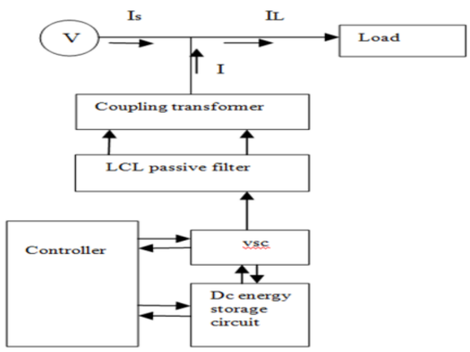

Fig 2.1: Block diagram of D-STATCOM

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D-STATCOM is used to absorb and generate reactive power. The exchanging of the reactive power between the D-STATCOM and distribution system depends on the output voltage of an inverter. When the VSC output voltage is larger than AC bus terminal voltage, D-STATCOM changed to capacitive mode and regulates the missing voltages by controlling the reactive power [3].

Controller:

PI controller is one of the feedback controllers to make the error signal to zero. It compares the load r.m.s voltage and reference voltage. This error signal is given to the PWM generator. This PWM generator generates a sinusoidal PWM signals by comparing the modulated signals and triangle signals. Fig 2.2 shows the block diagram of a controller.

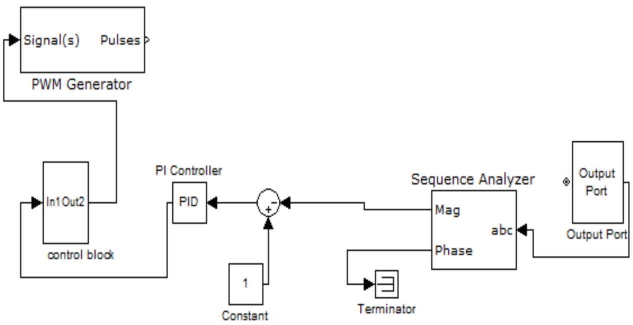

Fig 2.2: Block diagram of controller

LCL passive filter:

LCL passive filter remove unwanted frequency components from the applied signal and enhances the required signal. LCL passive filter has compensating bandwidth and variable frequency modulations. So the power losses in the damping resistor will reduce.

III. FAULTS

Generally a fault in a system creates a noise, disturbance in the system. So the performance and efficiency of the equipments may reduce. In three phase systems, a fault may occur one or more phases and ground, or may occur only between phases.

The types of faults are:

i. Symmetrical faults.
ii. Asymmetrical faults.

Symmetrical faults:

Symmetrical or balanced faults affect the three phases equally in a three phase system. The examples of symmetrical faults are LLL (line-line-line) fault and TPG fault. When compared to the total system faults, the symmetrical faults are in the range of 2 to 5 percent. If any symmetrical fault occurs in a distribution system, it creates a severe damage to the equipments even though the system remains in balanced condition.

Asymmetrical faults:

Asymmetrical or unbalanced faults do not affect the three phases equally in a three phase system. The examples of the asymmetrical faults are LL fault, SLG fault and DLG fault. The most occurring fault is SLG fault. Roughly 65% to 70% of faults are asymmetric SLG faults, 5% to 10% are asymmetric line to line faults and 15% to 20% are asymmetric DLG faults. The analysis of these types of faults is very complicated .so these types of faults are simplified by using symmetrical components.

IV. SIMULATION MODEL

Simulation Model With D-Statcom And Lcl Passive Filter

To provide an instantaneous voltage support, a D-STATCOM is added at the load side of the 11kv distribution system.

To provide D-STATCOM energy capabilities a 750μF capacitor connected on the dc side. For controlling the operating period of the D-STATCOM, breaker 1 is used and breaker 2 is used to control the load.

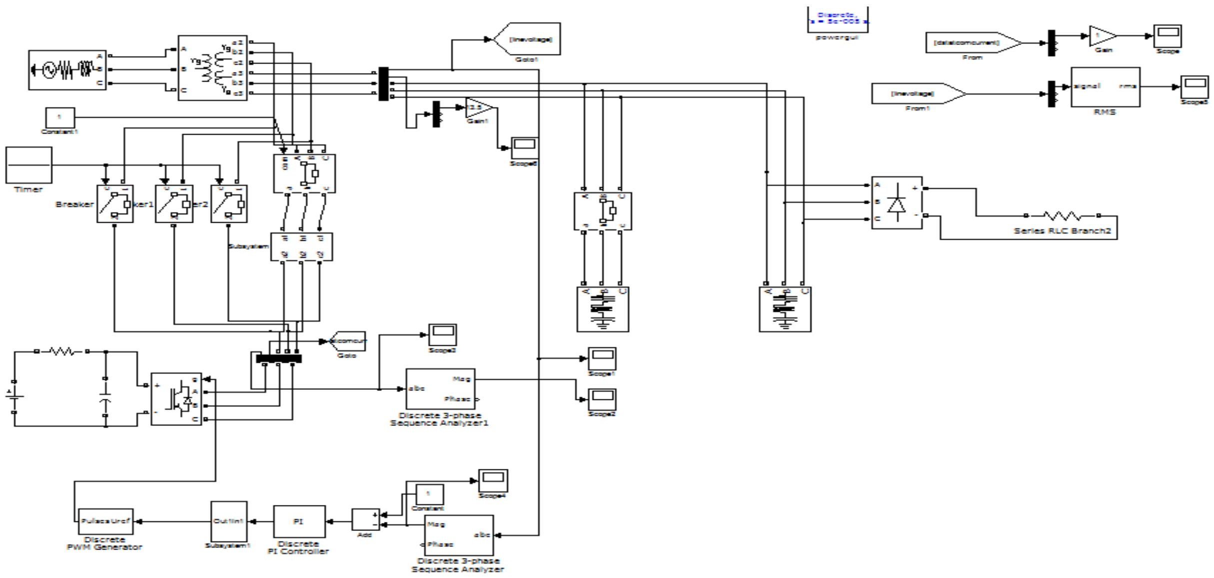

Fig 4.1: Simulink diagram

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V. SIMULATION RESULTS

A. Output Voltage Waveforms Without D- Statcom

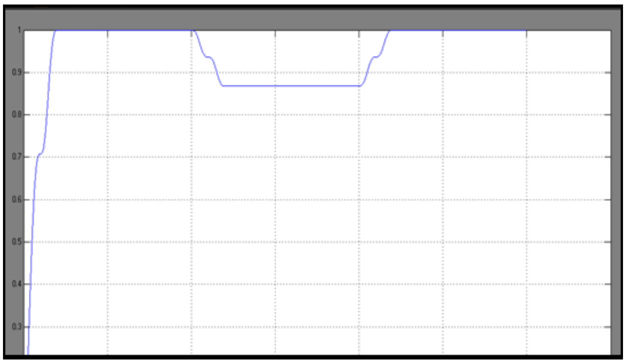

Fig 5.1(a): Voltage-time; Load voltage is 0.85 p.u for SLG.

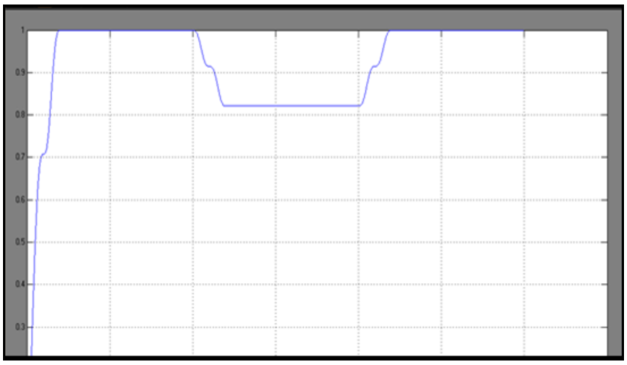

Fig 5.1(b): Voltage-time; Load voltage is 0.81 p.u for LL

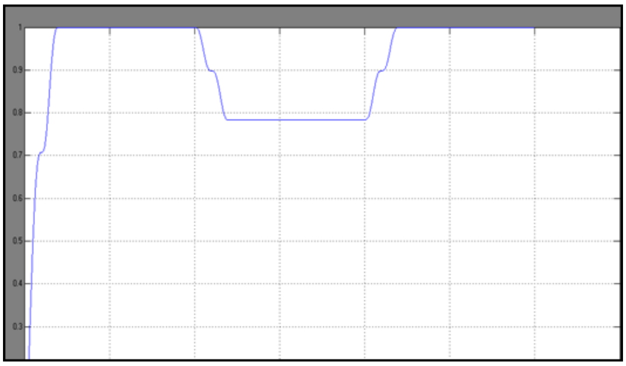

Fig 5.1(c): Voltage-time; Voltage is 0.77 p.u for DLG

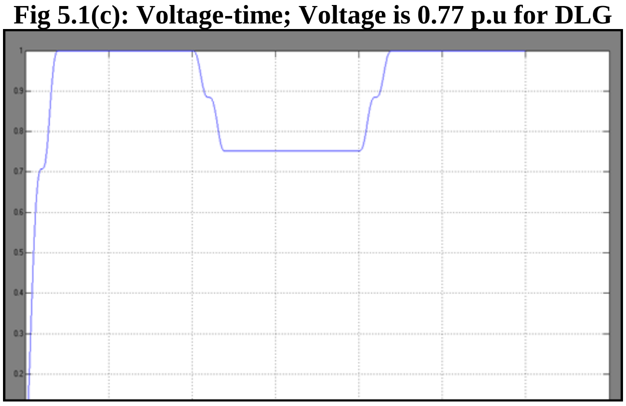

Fig 5.1(d): Voltage-time; Voltage is 0.73 p.u for TPG

Fault resistance (Rf) =0.660 Ω .

Fault duration time=500ms to 700ms.

B. Output Voltage Waveforms With D-Statcom

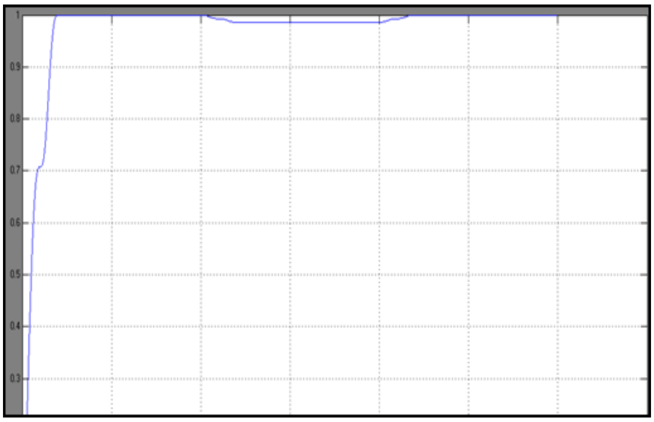

Fig 5.2(a): Voltage-time; Load voltage is 0.99 p.u for SLG

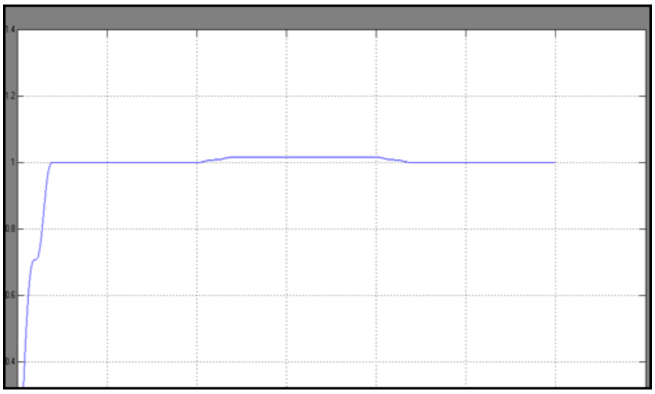

Fig 5.2(b): Voltage-time; Voltage is 1.05 p.u for LL

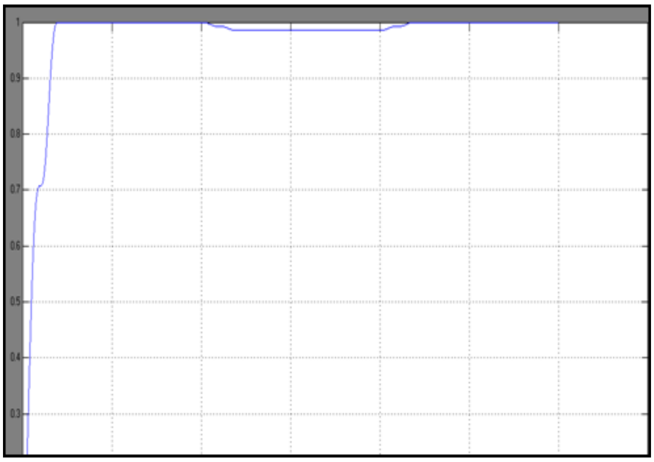

Fig 5.2(c): Voltage-time; Voltage is 0.99 p.u for DLG

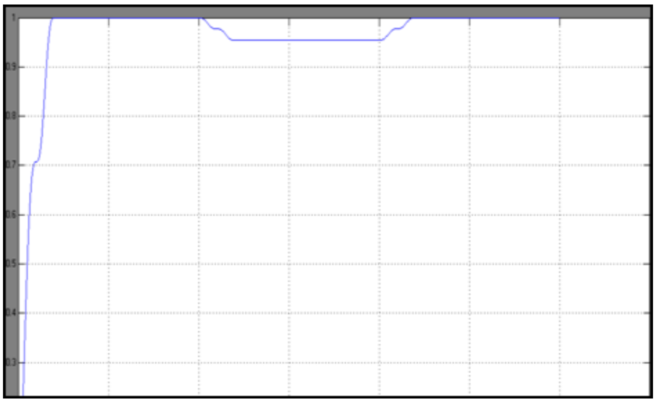

Fig 5.2(d): Voltage-time; Voltage is 0.95 p.u for TPG

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Fig 5.1(a) to fig 5.1(d) and Fig 5.2(a) to Fig 5.2(d) shows the simulation results of output without D-STATCOM and with D-STATCOM respectively for different types of faults.

C.Output Current Waveform Without Lcl Passive Filter.

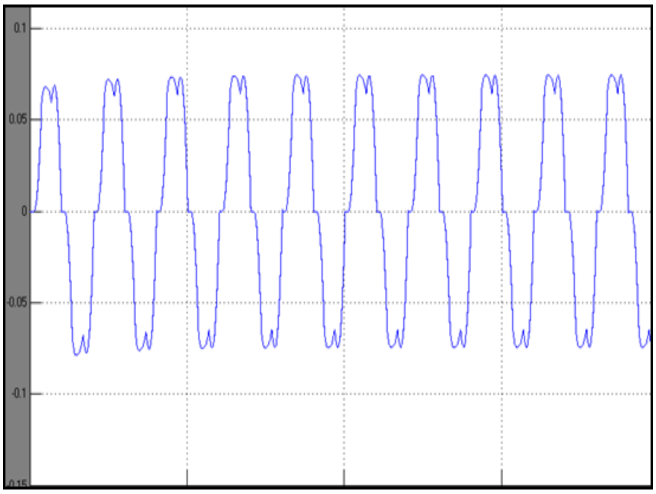
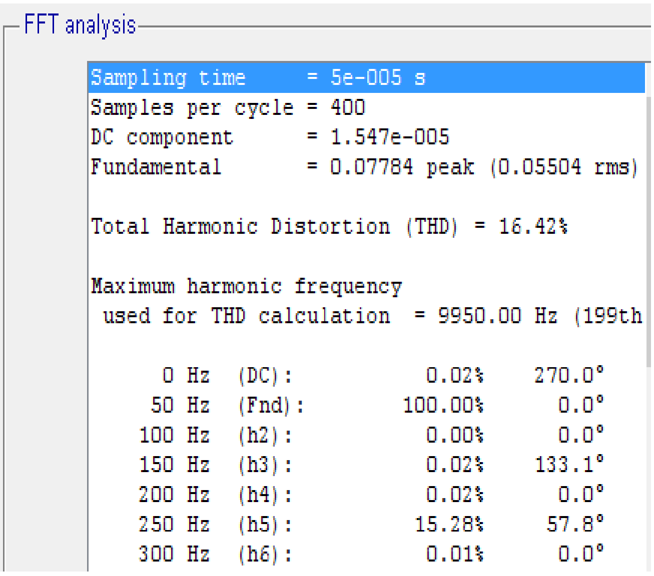


Fig 5.3(a): Current -Time; Output current waveform without LCL filter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FFT analysis
Sampling time       = 5e-005 s
Samples per cycle = 400
DC component        = 1.547e-005
Fundamental         = 0.07784 peak (0.05504 rms)

Total Harmonic Distortion (THD) = 16.42%

Maximum harmonic frequency
 used for THD calculation  = 9950.00 Hz (199th

   0 Hz  (DC):         0.02%    270.0°
  50 Hz  (Fnd):      100.00%      0.0°
 100 Hz  (h2):         0.00%      0.0°
 150 Hz  (h3):         0.02%    133.1°
 200 Hz  (h4):         0.02%      0.0°
 250 Hz  (h5):        15.28%     57.8°
 300 Hz  (h6):         0.01%      0.0°
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Fig 5.3(b): THD value without LCL filter.

D.Output Current Waveform With Lcl Passive Filter

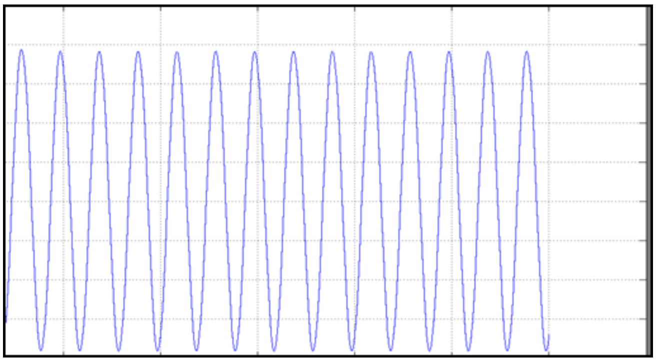
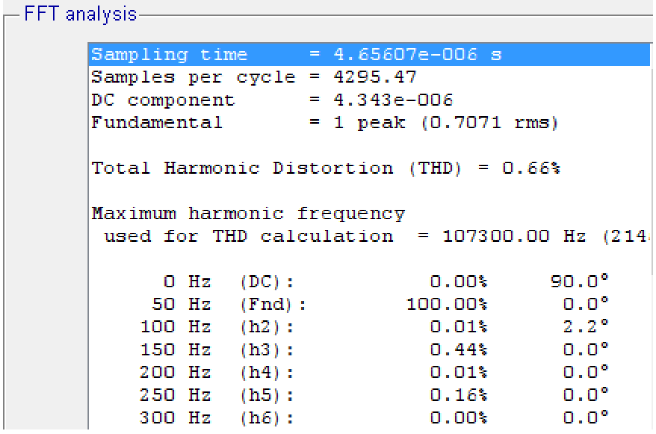


Fig 5.4(a) Current –Time; output current waveform with LCL filter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FFT analysis
Sampling time       = 4.65607e-006 s
Samples per cycle = 4295.47
DC component        = 4.343e-006
Fundamental         = 1 peak (0.7071 rms)

Total Harmonic Distortion (THD) = 0.66%

Maximum harmonic frequency
 used for THD calculation  = 107300.00 Hz (214

   0 Hz  (DC):         0.00%     90.0°
  50 Hz  (Fnd):      100.00%      0.0°
 100 Hz  (h2):         0.01%      2.2°
 150 Hz  (h3):         0.44%      0.0°
 200 Hz  (h4):         0.01%      0.0°
 250 Hz  (h5):         0.16%      0.0°
 300 Hz  (h6):         0.00%      0.0°
```

Fig 5.4(b) THD value with LCL filter

Fig 5.3(a) shows the distorted output current waveform. This distorted waveform can be compensated by adding a LCL passive filter. Fig 5.4(a) shows the sinusoidal output current. By inserting a LCL filter, THD can be reduced, which showed in fig 5.4(b).

VI. CONCLUSION

The simulation results shows that, by connecting a D-STATCOM in parallel to the distribution system, voltage sag can be improved by 14% in SLG fault, 24% in LL fault, 22% in DLG fault and 22% in TPG fault. Harmonic distortions will be reduced to 0.66% by connecting a LCL filter with D-STATCOM. Finally power quality can be enhanced.

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