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Mitigation of Power Quality Issues in Distribution System by Using D-Statcom

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Abstract – Power Quality issues occur in the power system due to the non-standard voltage, current and frequency. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction. The goal of this project is to show how the enhancement of voltage sags, harmonic distortion and low power factor by using D-STATCOM (Distribution static compensator) in distribution system with LCL passive filter. The model is based on the Voltage Source Converter (VSC) principle. A modified instantaneous power control scheme of D-STATCOM (Distribution static compensator) is used for reduction of reactive power, power factor correction and harmonic compensation. 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 R2010b.

Index Terms – D-STATCOM, VSC (voltage source converter), Controller, LCL passive filter.

1. INTRODUCTION

Now a day there is an increases the need of electric energy. Due to these there is an increasing the generation and distribution. so that there is required high quality of electric power it means that the disturbances occur in case of generation and distribution get less. The disturbances in power quality are voltage sag, voltage swell, harmonic distortion, low power factor. Due to these disturbances the working ability of the equipment get reduce. So that we must awareness about power quality at the customer side and utility.

Compared to other power quality problems affecting industrial and commercial end users, voltage sags occur most frequently. They reduce the energy being delivered to the end user and cause computers to fail, adjustable-speed drives to shut down, and motors to stall and overheat. The voltage sag means voltage dips. The duration of voltage sag is less than 1min but more than 8milisecond.The magnitude of reduction is between 10 percent and 90 percent of the normal root mean square (rms) voltage at 50Hz.

There is a harmonic current in the system produced the harmonic distortion. The harmonic distortion is the major source of sine waveform distortion.Harmonics are integral multiples of the fundamental frequency of the sine wave. The causes harmonic currents are usually caused by nonlinear loads, like adjustable speed drives, solid-state heating controls, electronic ballasts for fluorescent lighting, switched-mode power supplies in computers, static UPS systems, electronic and medical test equipment, rectifiers, filters, and electronic office machines. Nonlinear loads cause harmonic currents to change from a sinusoidal current to a non-sinusoidal current by drawing short bursts of current each cycle or interrupting the current during a cycle. Due to these power factor get decreases.

In some of the electric power consumers, such as the telecommunications industry, power-electronics drive applications, etc., there is a constraint for ac as well as dc loads. The telecommunication industry uses several parallel-connected switch-mode rectifiers to support dc bus voltage. Such an arrangement draws nonlinear load currents from the utility. This causes reduced power factor, more losses and less efficiency. Obviously, there are Power Quality issues, such as unbalance, poor power factor, and harmonics produced by telecom equipment in power distribution networks. Therefore, the functionalities of the conventional DSTATCOM should be increased to mitigate the abovementioned PQ problems and to supply the dc loads from its DC Link as well.

For reducing these issues the development of power electronic device such as FACTS (Flexiable AC Transmission system). In that case the D-STATCOM is used at the distribution level. It connect at load side and by injecting the current it can reduce the power quality problem. The D-STATCOM has additional properties to sustain reactive current at low voltage and can be developed as a voltage and frequency support by replacing capacitor with batteries as energy storage.

In these paper, there is the study of D-STATCOM with LCL passive filter and enhancement of the power quality such as voltage sags, harmonic distortion and low power factor in distribution system.

2. BASIC CONCEPTS OF DSTATCOM

A distribution static compensator is a voltage source converter based power electronic device. Usually, this device is supported by short term energy stored in a dc capacitor. The DSTATCOM filters load current such that it meets the specifications for utility connection. The DSTATCOM can fulfill the following points.

1. The result of poor load power factor such that the current drawn from the supply has a near unity power factor.

2. The result of harmonic contents in loads such that current drawn from the supply is sinusoidal.

3. The result of unbalanced loads such that the current drawn from the supply is balanced.

4.The dc offset in loads such that the current drawn from the supply has no offset.

One of the main features of DSTATCOM is the generation of the reference compensator currents. The compensator, when it tracks these reference currents, injects three-phase currents in the ac system to cancel out disturbances caused by the load. Therefore, the generation of reference currents from the measurements of local variables has fascinated wide attention. These methods carry an inherent assumption that the source is stiff (i.e., the voltage at the point of common coupling is tightly regulated and cannot be influenced by the currents injected by the shunt device). This however is not a valid assumption and the concert of the compensator will reduce considerably with high impedance ac supplies. The operation of VSC is supported by a dc storage capacitor with appropriate dc the transient response of the voltage across it. The transient response of the DSTATCOM is very significant while compensating AC and DC loads.

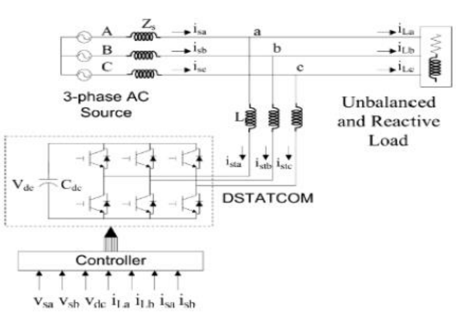

Fig.1.1 Basic Circuit Diagram of the DSTATCOM System.

A static synchronous compensator (STATCOM) is one of the most operative solutions to regulate the line voltage. The STATCOM consists of a voltage source converter connected in shunt with the power system and permits to control a leading or lagging reactive power by means of correcting its ac voltage. A STATCOM for installation on a distribution power system called DSTATCOM, has been researched to clear voltage fluctuations and voltage flickers. A shunt active filter intended for installation on a power distribution system, with emphasis on voltage regulation capability. Theharmonic damping has the capability to improve the stability of voltage regulation. Thus, modification of the feedback gains makes it possible to decrease voltage fluctuation in transient states, when the active filter has the function of combined harmonic damping and voltage regulation.

3. D-STATCOM(Distribution Static Compensator)

It is a FACTS device which is installed for the support of electricity networks which have poor power factor and voltage regulation also, commonly it is use for the stabilization of voltage and to improve power factor of that network. It is a voltage source converter based device, which can work as reactive power source. The D-STATCOM, in which the dc storage battery also connected with the device to charge in case of over voltage and to discharge in case of under voltage in this way by withdrawing and supplying the reactive power it can compensate the reactive power. Therefore it can improve the power factor and reduce the harmonics in the system. The D-STATCOM proposed here maintains the voltage magnitude within the limits by eliminating the voltage sags and swells in the system.

4. OPERATION OF D-STATCOM

D-STATCOM consists of following component:

A. Voltage source converter
B. Energy storage circuit
C. LCL passive filter
D. controller.

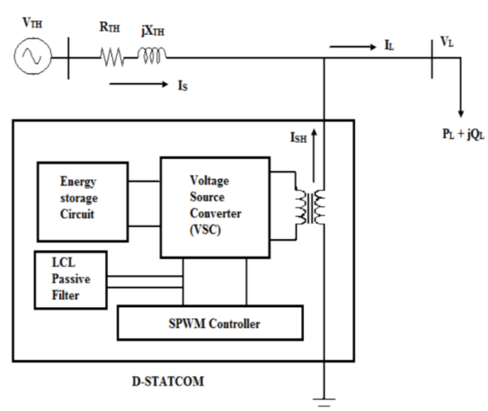

Fig. 4: Schematic diagram of a D-STATCOM

A) Voltage Source Converter

The voltage source converter have a dc input voltage source provided by capacitor C_s, the converter produce set of controllable three phase output voltages with the frequency of the ac power system. Each output voltage in phase with, and coupled to the corresponding ac system voltage via relatively small the per phase leakage inductance of the coupling transformer. By varying the amplitude of a output voltage produced, the reactive power exchange between converter and ac system .If the amplitude of a output voltage is increases above the ac system voltage then the current flows through the leakage inductance from the converter to ac system, and the converter generates reactive power (capacitive) power for the ac system. If the amplitude of a output voltage is decreases above the ac system voltage then the current flows through the leakage inductance from the ac system to converter, and the converter absorb reactive power (inductive). If the amplitude of a output voltage is equal to the ac system voltage, the reactive power exchange is zero. VSC-based unit utilizes several important Technological developments:

i. High voltage valves with series-connected MOSFETs

ii. Compact, dry, high-voltage dc capacitors

iii. High capacity control system

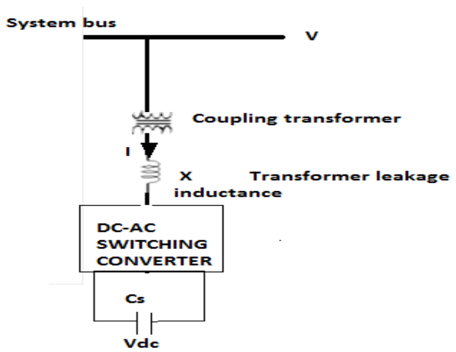

Fig.4(A): Operation mode of Voltage Source Converter

B) Energy storage circuit

This connected to the VSC(voltage source converter),energy storage circuit consists of capacitor which is parallel to the DC source. The capacitor is charged by battery and discharged by converter.

C) Controller

Figure shows the block diagram of controller system. The controller system is important part of distribution system. Here use a PI controller for minimizing the error in the system. PI controller is a feedback controller. In this case, PI controller will process the error signal to zero. Transmission line voltage or load r.m.s. voltage is given to the abc_to_dq0 transformation. Function of these transformation block is to convert abc phases to dq0 for simplification of the system.

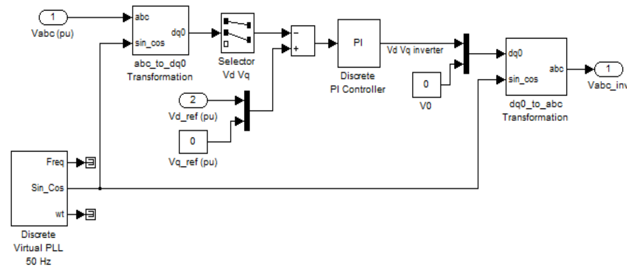

Fig.4(C): Block Diagram of Controller System

Transmission line voltage is brought back to the reference voltage with the r.m.s. voltages that measured at the load voltages. In controller block also maintain the angle of three phases. PI controller output is given to the dq0_to_abc transformation. These block convert the dq0 to abc phases and it is given to PWM generator.

D) LCL passive filter

In passive filter inductor and capacitor are used. The high order LCL filter using space of conventional L-filter for smoothing the output current. It's saves large amount of cost and reduce the rate and size as the reduce in component. It has been used in grid connected inverter and pulse width modulated rectifier, because the minimize the current distortion injected to utility grid. Also it is used in reduction of harmonic distortion.

This LCL filter will introduce resonance frequency into the system. The harmonic resonance current is reduce by adding passive damping circuit to the filter. This damping circuit can be purely resistive causing relatively high losses or a more complex solution consisting of combination of resistor, capacitor and inductor.

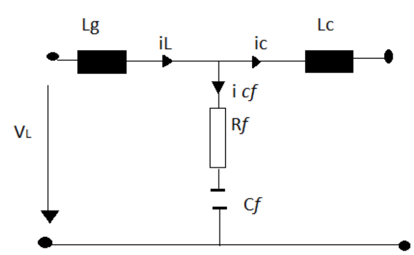

Fig.4(D):LCL Passive Filter

LCL filter is more effective on reducing harmonic distortion. To design it, these equation are used

$$L_g = \frac{E_n}{2\sqrt{6} i_{rpm} f_{sw}} \quad \text{………… (1)}$$

$$L_c = \frac{L_g}{2} \quad \text{……….. (2)}$$

$$C_f = \frac{L + L_g}{L L_g (2\pi f_{res})} \quad \text{………… (3)}$$

To design a LCL passive filter make sure that,

$$10 f_n \leq f_{res} \leq 0.5 f_{sw}$$

Where;

E_n = RMS value of grid voltage,

L_g = Grid side filter inductance,

L_c = Converter side filter inductance,

C_f = Filter capacitance,

i_{rpm}=Peak value fundamental harmonic current,

f_{sw} = Switching frequency,

f_{res}= Resonance frequency

5. APPLICATIONS

1. It is used in wind energy.
2. It is used in solar energy.
3. It is used in ship.

6. RESULT

6.1: Without insertion of D-STATCOM

Result of voltage sag for different types fault without insertion of

D-SATCOM

Fault Resistance $R_{f,\Omega}$	**Voltage Sags for LLLG fault(p.u)**	**Voltage Sags for LLG fault(p.u)**	**Voltage Sags for LL fault (p.u)**	**Voltage Sags for SLG fault(p.u)**
0.66	0.51	0.77	0.73	0.82

CASE 1. Three phase to Ground (LLLG) fault condition Without D-STATCOM

Voltage sag is caused by fault in the utility system. A fault with in the customer's facility or a large increase of the load current. By the applying different types of fault's and also measured voltage at load point where the sag is formed. These cases not use any FACTS devices like D-STATCOM**.**

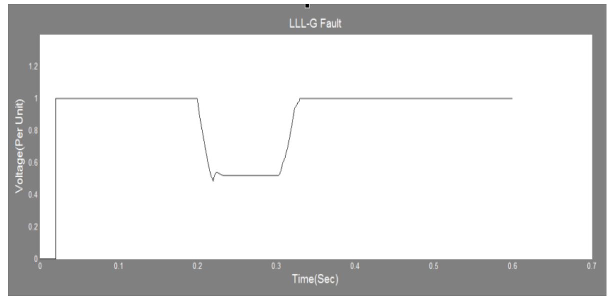

Fig 6.1: Voltage at load point 0.51 p.u

CASE 2. Double line to Ground (DLG) fault condition Without D-STATCOM

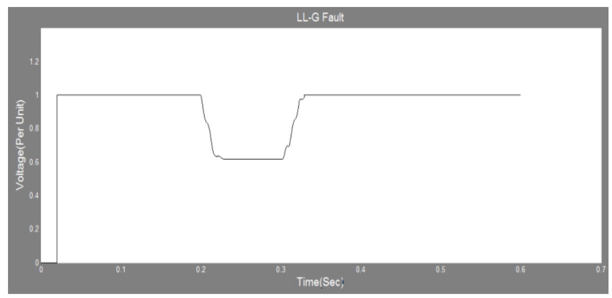

Fig 6.2(b):Voltage at load point is 0.77p.u.

6.2: With insertion of D-STATCOM

Table 6.2:Result of voltage sag for different types fault with insertion of

D-SATCOM

Fault Resistance R_f, Ω	**Voltage Sags for LLLG fault(p.u)**	**Voltage Sags for LLG fault(p.u)**	**Voltage Sags for LL fault(p.u)**	**Voltage Sags for SLG fault(p.u)**
0.66	0.900	0.980	1.02	0.982

Table 6.2 shows the overall result of voltage sags in p.u with different types of fault. With the insertion of D-STATCOM measured different fault resistances of different voltage sags fault conditions From the table, it can be observed that voltage sags improved with insertion of D-STATCOM. If the fault resistance is increased parallel the voltage sag of different fault conditions also increased. The overall results of voltage sags in p.u with different types of fault. It can be observed that when DSTATCOM is connected in the system, voltage sag improved and the value of voltage sag is creates in between 0.9 to 1.01.

CASE 1. Three phase to Ground (LLLG) fault condition With D-STATCOM

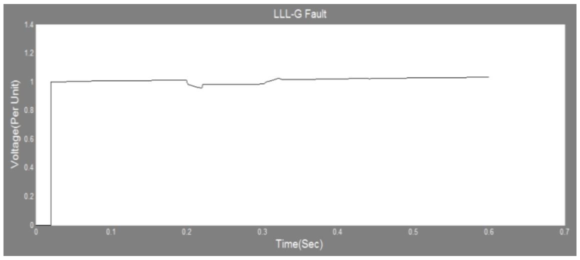

Fig.6.2(a): Voltage at load point is 0.900

CASE 2. Double line to Ground (DLG) fault condition Without D-STATCOM

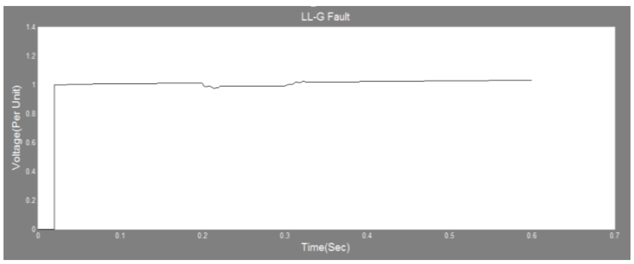

Fig6.2(b): Voltage at load point is 0.980 p.u.

6.3: Without insertion of LCL Passive Filter:

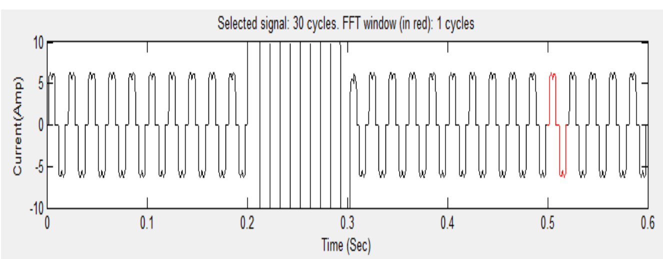

Fig.6.3(a): Waveform of distortion output current without LCL Passive Filter

Figure 6.3(a), shows the waveform of distortion output current and figure 6.3(b) shows the spectrum of distortion output current.

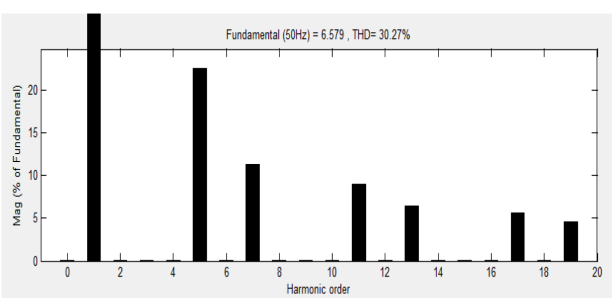

Fig.6.3(b): Harmonic spectrum of distortion output current without LCL Passive FilterTypes

6.4: With insertion of LCL Passive Filter:

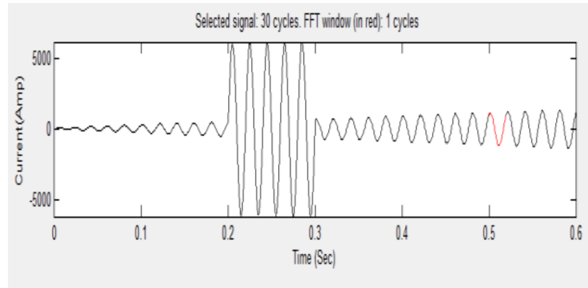

Fig.6.4(a): Waveform of output current with LCL Passive Filter

Fig.6.4(a) shows the waveforms of output current. It is sinusoidal with LCL Passive filter was connected to the D-STATCOM. Fig.6.4(b) shows the spectrum of output current.

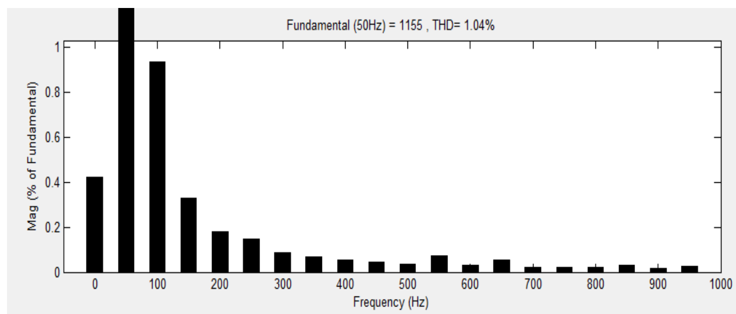

Fig.6.4(b): Harmonic spectrum of output current with LCL Passive Filter

7. CONCLUSION

D-STATCOM in system the power quality and voltage profile is improved. The power factors also increase close to unity. Thus by adding D-STATCOM with LCL filter the harmonic distortion get reduced. , it can be concluded that by adding D-STATCOM the voltage and current are improved that in addition to complete reactive power compensation, power factor correction and voltage regulation and harmonics are also checked, and for achieving improved power quality levels at the distribution end.

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