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Enhancing Power Quality Issues in Distribution System Using D-STATCOM

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***Abstract*—** Power quality is becoming a major cause of distress in the area of electrical power system in the recent times. It causes many problems in the system such as voltage profile, sag, swell, interruption and noise which results in a failure of end-user equipment. To maintain a continuous voltage stability in electrical distribution system, different types of custom power devices such as Distribution Static Compensator (D-STATCOM) can be effectively used. This paper illustrates an analysis of voltage profile in distribution system by using the performances of D-STATCOM which are based on the VSC principle. The paper depicts the modelling and simulation of D-STATCOM in MATLAB/SIMULINK. Total Harmonics Distortion (THD) is also calculated for the distribution system with and without compensation. Simulation result shows the performance of D-STATCOM under various faults. The simulation result shows that by using D-STATCOM, one can achieve an improving power quality also to reduce the harmonic distortion in the system.

Keywords*— *POWER QUALITY, D-STATCOM, VSC, THD, TDD

I. INTRODUCTION

Power system contains of three levels, Generation – Transmission – Distribution of power. In earliest time the Power Transmission has been faced lots of challenges like voltage fluctuations during change in load and power transmission limitation because of reactive power unbalances. Load is very impulsive in nature it keeps changing with time and customer which make it even more difficult for prognosis. This arises a great need of improving power utilization methods in the present era. To obtaining optimum power system security and reliability in highly complicated & interconnected power system is one of the most difficult tasks. To achieve Optimum Power Quality, it needs perfect equilibrium between generated capacity and its demand. Power flow in the transmission line is affected due to under loading and overloading condition, as a result of this problems regarding Voltage profile and Power system stability will shoot up. Power quality issues is the results of inadequate voltage, current, or frequency that results in a mal-operation of end user equipment. The most common PQ events are voltage sag, harmonic distortion and low power factor [1].

Voltage dip is stimulated by a distortion in the distribution system. The distribution system can be defined as the part of power system which distributes electrical power to the consumer for utilization. As utilization of power is directly related to distribution system, power quality directly affects the end users or customers. Harmonic current in distribution system can generate harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can produce vibration and noise in device.

The advanced FACTS devices furnish a rapid and reliable, and increases power transfer capability control over the transmission invariable such as line impedance, voltage, and phase angle between the sending end voltage and receiving end voltage [2]. D-STATCOM is a custom power device its hereafter like it provides fast response, suitable for dynamic response or voltage regulation, to correct voltage surges or sags caused by reactive power requirements. Various PWM control strategy is executed for D-STATCOM control at the distribution level which will compensate reactive power and improve voltage regulation.

This paper illustrates, the composition and scheme of the D-STATCOM, VSC based PWM controller with LCL passive filter are tested. It is connected in shunt to the 11 kv test distribution system. D-STATCOM can be adequately employed to improve the power quality equipped to the customers. The MATLAB/SIMLINK software is used and to verify the result on the basis of performance under different faults voltage sag, total harmonic distortion(THD) and low power factor.

II. DISTRIBUTION STATIC SYNCHRONOUS COMPENSATOR (D-STATCOM)

A Distribution Static Compensator (DSTATCOM), a custom power device, connected in shunt with the load, compensates for the reactive power and unbalance caused by various loads in the distribution system. The 39 performance of the DSTATCOM depends on the control algorithm used for extracting the reference current components. In this paper, the working principle of a DSTATCOM is explained and its mathematical model is derived. The control techniques for voltage regulation, power factor improvement and compensation of unbalanced systems, for a DSTATCOM, are described. A DSTATCOM is a shunt compensation device that provides an effective solution for reactive power compensation and voltage regulation [3]. It comprises of a Voltage Source Converter (VSC), a DC capacitor, a coupling inductor or coupling transformer and a controller, as shown in Figure 2.1. The DSTATCOM, connected to the grid through the coupling inductor at the point of common coupling (PCC), is controlled in such a way that it exchanges only reactive power with the grid. This is achieved by injecting the current in quadrature with the grid voltage. If the magnitude of the DSTATCOM voltage V_c is greater than the grid voltage V_s (V_C>V_S), the DSTATCOM supplies reactive power to the grid, VSC Sensitive Load Interface Distribution 40 and the DSTATCOM is operating in the capacitive mode. If the grid voltage V_S is greater than the DSTATCOM voltage V_C (V_S>V_C), the DSTATCOM absorbs reactive power from the grid and the DSTATCOM is operating in the inductive mode. If the grid voltage V_S and the DSTATCOM voltage V_C of the same magnitude (V_S =V_C), there is no exchange of reactive power between the grid and the DSTATCOM and the DSTATCOM is operating in the floating state.

In addition, the DSTATCOM can be operated to exchange real power with the grid by controlling the phase angle of the DSTATCOM's output voltage. In this thesis, the DSTATCOM operates in the reactive power compensation mode only. In this mode, the DSTATCOM operates in such a way that there is no phase angle difference between the DSTATCOM output voltages and the grid voltages. Hence, the DSTATCOM neither supplies nor absorbs real power.

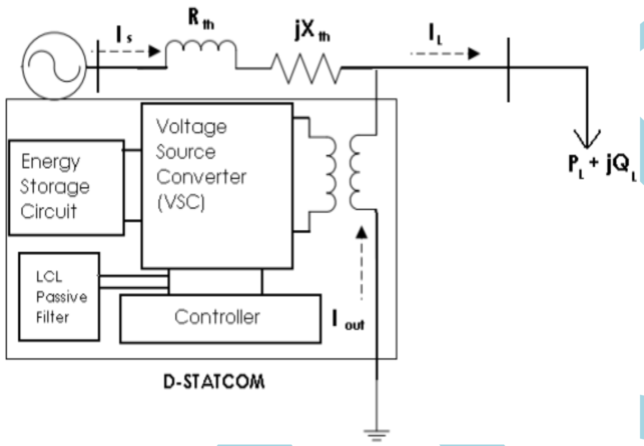

Fig. 2.1 Schematic Diagram of D-STATCOM

The VSC connected in parallel with the ac system provides a multifunctional topology which can be used for three quite distinct targets: [5]

1. Voltage control and compensation of reactive power
2. Power factor improvement.
3. Destruction of current harmonics

The shunt injected current Ish can be penned as:

$$Ish=IL-Is=IL-\left[\frac{V_{th}-V_L}{Z_{th}}\right]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

$$Ish<\eta=IL<(-\theta)-\left[\frac{V_{th}}{Z_{th}}\right]<(\delta-\beta)+\left[\frac{V_L}{Z_{th}}\right]<(-\beta)\ldots\ldots\ldots\quad (2.2)$$

The complex power injection of the DSTATCOM can be expressed as:

$$Ssh=V_L{}^*I^*sh\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

As per above equation the voltage sag is enhanced by current Ish which adjusting the voltage drop across the system impedance Zth. And the value of the Ish can be controlled by adjusting the output voltage of converter.

III. VOLTAGE SOURCE CONVERTER (VSC)

It can generate variable voltage variable frequency AC output from a constant voltage constant frequency AC input by two stage conversion process. It can produce a sinusoidal voltage with any desired magnitude, frequency and phase shift. Voltage source converters are generally used in ASDs. Moreover, it can be used to completely replace the voltage and to inject the missing voltage. The difference between the nominal voltage and actual voltage is termed as the "missing voltage". VSC converts the DC voltage across storage devices into a set of three phase AC output voltages [7]. D-STATCOM is also effient to generate or absorbs reactive power. D-STATCOM said to be a capacitive, when the output voltage of the VSC is greater than AC bus terminal voltage Due to this feature, D-STATCOM compensate the reactive power through AC system and coordinate missing voltages. The solid state electronic converter is switched to get desired output voltage [4]. Voltage source converters are used for power quality issues such as flicker, unbalance and harmonics.

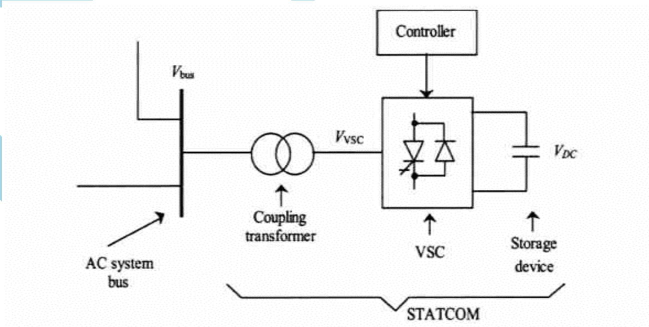

Fig 3.1 Basic diagram of VSC

IV. TOTAL HARMONIC DISTORTION (THD)

The Total Harmonic Distortion (THD) is defined as the RMS value of the waveform after removing the integral part, the measured part is the distorted leftover and also undesired (which is said as THD). The use of different non-linear load such as Variable Speed Drives (VSD), Compact Fluorescent Lamp (CFL), SMPS draws high current having harmonic components which leads to Distortion in waveform of the Fundamental frequency. The selection of the range for the rating most of the Electrical equipment is based on the ability of heat dissipation to avoid the overheating of bus bars, circuit breakers, neutral conductors, transformer windings or generator alternators. In general, the less distorted frequency gives the more desired operation.

V. SIMULATION AND RESULTS

Here fig.5.1 shows the test system implemented in MATLAB SIMULINK. The test system consists of a 230 kv, 50 Hz transmission system which is now fed into the primary side of transformer connected in Y/Y/Y, 230/11/11 kv. A two-level DSTATCOM is connected to the 11 kv tertiary winding to provide instantaneous voltage support at the load point. A 750μF capacitor on dc side provides the DSTATCOM energy storage capability. Simulation were carried out with and without DSTATCOM connected to the system, to show the effectiveness of this controller. The DSTATCOM model which is connected in the transmission system for voltage regulation and it shows an VSC with its PWM controller.

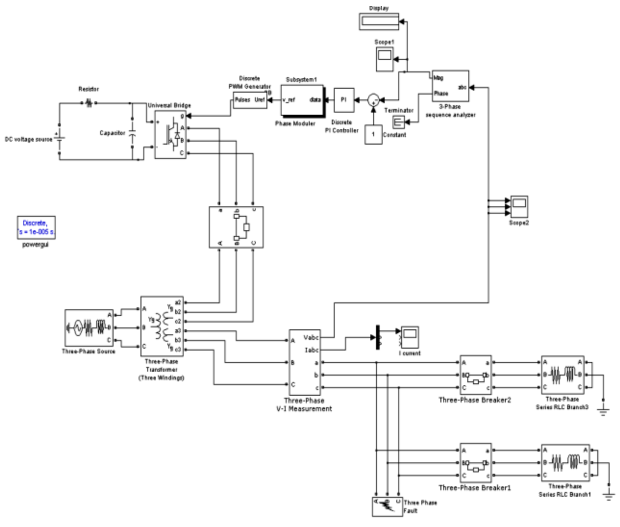

Fig.5.1 Simulation Model of DSTATCOM test system

To create distortion and unbalance in distribution system, injected 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).

(A) Results of Sag without DSTATCOM

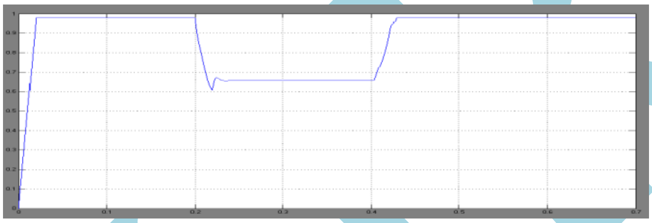

Fig. 5.2(a) Voltage sag at load point is 0.6578 p.u using TPG fault

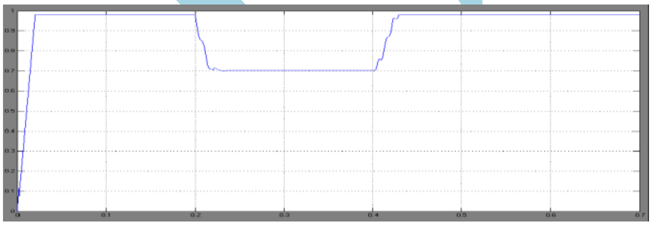

Fig. 5.2(b) Voltage sag at load point is 0.7024 p.u using DLG fault

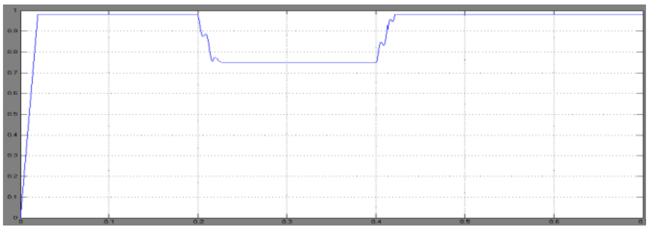

Fig. 5.2 (c) voltage sag at load point is 0.7518 p.u using LL fault

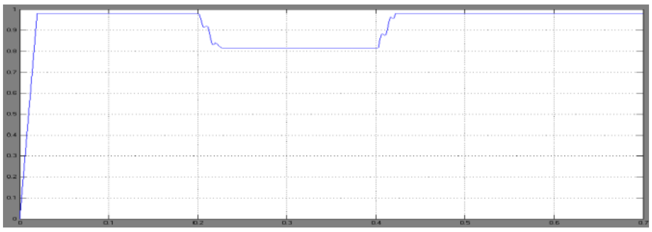

Fig. 5.2(d) voltage sag at load point is 0.8173 p.u using SLG fault

Figure 5.2(a) to 5.2(d) shows the simulation result of voltage sags of the test system for different faults without DSTATCOM with fault resistance R_f = 0.66Ω.

TABLE 5.1 RESULTS OF VOLTAGE SAGS FOR DIFFERENT TYPE OF FAULTS

FAULT RESISTANCE RΩ	VOLTAGE SAG FOR TPG FAULT	VOLTAGE SAG FOR DLG FAULT	VOLTAGE SAG FOR LL FAULT	VOLTAGE SAG FOR SLG FAULT
0.6600	0.6578	0.7024	0.7518	0.8173
0.7600	0.7069	0.7435	0.7846	0.8397
0.8600	0.7469	0.7774	0.8119	0.8586

Table 5.1 shows the overall faults of voltage sag in p.u for different types of fault. From the table it can be observed that when fault resistance is increase, the voltage sag also will increase.

(B) Results of Sag with DSTATCOM

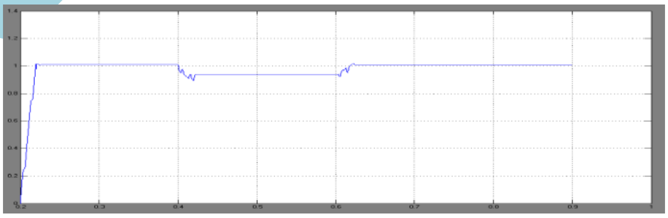

Fig. 5.3(a) Voltage sag at load point is 0.9344 p.u using TPG fault.

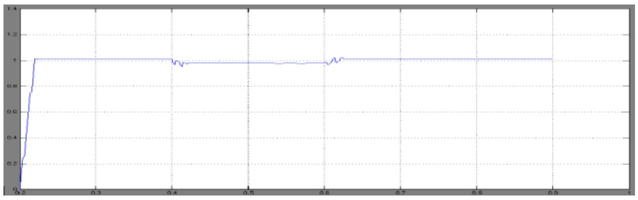

Fig 5.3(b) Voltage sag at load point is 0.9760 p.u using DLG fault

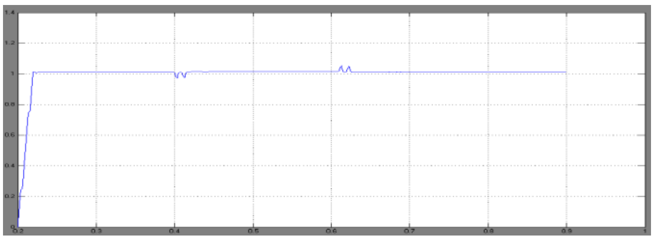

Fig. 5.3(c) Voltage sag at load point is 1.014 p.u using LL fault

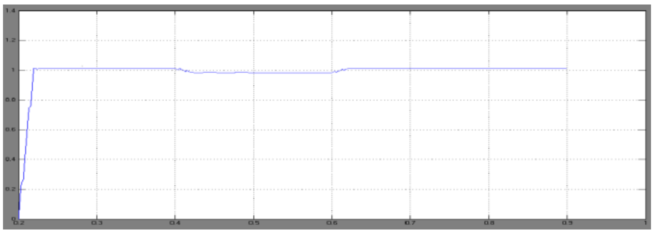

Fig. 5.3(d) Voltage sag at load point is 0.9825 p.u using SLG fault

Figure 5.3(a) to 5.3(d) represents the simulation results of voltage sags of the different fault with DSTATCOM with fault resistance $R_f = 0.66\Omega$.

TABLE 5.2 RESULTS OF VOLTAGE SAG FOR DIFFERENT TYPES OF FAULTS

FAULT RESISTANCE RΩ	VOLTAGE SAG FOR TPG FAULT	VOLTAGE SAG FOR DLG FAULT	VOLTAGE SAG FOR LL FAULT	VOLTAGE SAG FOR SLG FAULT
0.6600	0.9344	0.9760	1.0140	0.9825
0.7600	0.9490	0.9843	1.0168	0.9876
0.8600	0.9576	0.9890	1.0180	0.9912

Table 5.2 displays the overall results of voltage sags in p.u with different types of fault. It can be noticed that when DSTATCOM is connected in the system, voltage sag enhanced and the value of voltage sag is creating in between 0.9 to 1.01.

TABLE 5.3 RESULTS FOR DIFFERENT TYPES OF FAULT WITH AND WITHOUT DSTATCOM WHEN *RF* = 0.66Ω

TYPES OF FAULT	WITHOUT DSTATCOM (p.u)	WITHOUT DSTATCOM (p.u)	PERSENTAGE OF IMPROVEMENT (%)
TPG	0.6578	0.9344	27.66%
DLG	0.7024	0.976	27.36%
LL	0.7518	1.014	26.22%
SLG	0.8173	0.9825	16.52%

From table 5.3 shows the voltage sag improved in percentage for different types of fault with and without insert D-STATCOM in the system, it can be seen that with D-STATCOM the voltage sags improved close to 1.0 p.u.

CONCLUSION

The custom power device DSTATCOM is connected in parallel with distribution system to improve the power quality. The simulation result shows that the voltage sag can be mitigated by connecting DSTATCOM to the distribution system. PWM control scheme only required for voltage measurement.

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