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Power Quality Improvement In Distribution System Using D-Statcom In Transmission Lines

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Abstract:-

A power quality issue is an incident that manifests as an abnormal voltage, current, or frequency, resulting in the failure or malfunction of end-user equipment. Various sorts of outages and service interruptions affect utility distribution networks, sensitive industrial loads, and important commercial operations, resulting in considerable financial losses. The issue of power quality will take on new dimensions when power systems are restructured and the trend toward distributed and dispersed generation shifts. In developing countries such as India, where variations in power frequency and other variables of power quality are a severe concern, it is critical to take meaningful advances in this area. The current study is to identify the major concerns in this area, and as a result, actions to improve power quality are advised.

This paper describes how to use a Distribution Static Compensator (D-STATCOM) to improve voltage sags/swells, harmonic distortion, and low power factor. The Voltage Source Converter (VSC) principle underpins the model. The D-STATCOM injects current into the system to reduce voltage sags and swells, as well as to improve harmonic distortion and power factor. The simulations were carried out using MATLAB SIMULINK R2009b.

Keyword:- D-STATCOM, Total harmonics Distortion (THD, Voltage Sag/swell, Voltage Source Converter (VSC).

1.INTRODUCTION

An electric distribution system connects the bulk power source or sources to the consumer's service switches in an electric system. Bulk power sources are either producing stations or power substations supplied via transmission lines and are located in or near the load region to be served by the distribution system.Sub transmission circuits, distribution substations, distribution or primary feeders, distribution transformers, secondary circuits or secondary's, and consumer's service connections and meters or consumer's services are the six components of distribution systems. Voltage sag/swell is one of the most common power quality issues nowadays. It is frequently determined by only two parameters: depth/magnitude and duration. The amount of the voltage sag/swell ranges from 10% to 90% of the normal voltage and the duration ranges from half a cycle to 1 minute. Voltage sag is a three-phase phenomena that affects both phase-to-ground and phase-to-phase voltages in a three-phase system. Voltage sag is produced by a malfunction in the utility system, a fault within the customer's facility, or a large rise in load current, such as starting a motor or energizing a transformer. Single-phase or multiple-phase short circuits, which result in high currents, are common defects. The high current causes a voltage drop across the network's impedance. The voltage in the faulted phases drops down to zero at the fault position, while it remains relatively constant in the non-faulted phases.

Voltage sags are one of the most common power quality issues. Voltage sags are more common in the business, causing severe issues and economic losses. Utilities frequently identify end-user equipment disruptions as the primary source of power quality issues.

Harmonic currents in the distribution system can generate harmonic distortion, low power factor, extra losses, and electrical equipment heating. It can also cause machine vibration and noise, as well as the malfunction of sensitive equipment.

There are various methods for improving power quality issues in transmission and distribution systems.

The D-STATCOM is one of the most effective of these devices. To regulate the electronic valves in the D-STATCOM, a novel PWM-based control method has been designed. The D-STATCOM can also maintain reactive current at low voltage and can be developed as a voltage and frequency support by substituting capacitors with batteries as energy storage. To improve power quality in distribution systems, such as voltage sags/swell, harmonic distortion, and poor power factor.

2. VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a type of power electronic equipment that can generate a sinusoidal voltage of any magnitude, frequency, and phase angle. Voltage source converters are commonly employed in variable-speed drives, but they can also be utilized to reduce voltage dips. The VSC is used to either totally replace or inject the "missing voltage." The'missing voltage' is the discrepancy between the nominal and actual voltage. The converter is often based on some type of energy storage that provides a DC voltage to the converter. The converter's solid-state electronics are then switched to get the desired output voltage. Normally, the VSC is employed not just for voltage sag/swell reduction, but also for other power quality issues such as flicker and noise.

3. ENERGY STORAGE CIRCUIT

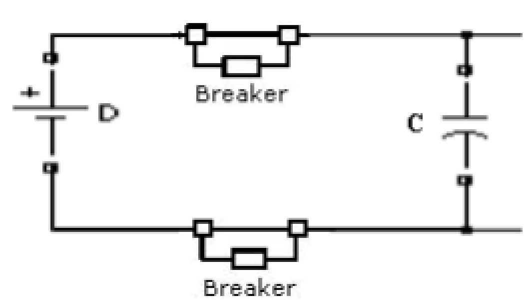


Fig.3.1.Circuit Diagram of DC Storage

Figure 3.1 shows a DC source linked in parallel with a DC capacitor. It transports the converter's input ripple current and serves as the primary reactive energy storage element. This DC capacitor could be charged by a battery or recharged by the converter itself.

4. CONTROLLER

Under system disruptions, the control scheme's goal is to maintain constant voltage magnitude at the point where a sensitive load is attached. The control system just measures the r.m.s voltage at the load point; no measurements of reactive power are necessary. The VSC switching approach is based on a sinusoidal PWM technology that is simple and responsive. Because bespoke power is a low-power application, PWM approaches are more flexible than the Fundamental Frequency Switching (FFS) methods used in FACTS applications. Furthermore, high switching frequencies can be used to improve converter efficiency without incurring considerable switching losses.

The controller input is an error signal derived from the reference voltage and the measured terminal voltage value rms. Such an error is processed by a PI controller, the output of which is the angle, which is fed into the PWM signal generator. It is important to note that in this scenario, the indirectly controlled converter exchanges active and reactive power with the network at the same time: an error signal is derived by comparing the reference voltage with the rms voltage measured at the load point. The PI controller processes the error signal and generates the necessary angle to drive the error to zero, bringing the load rms voltage back to the reference voltage.

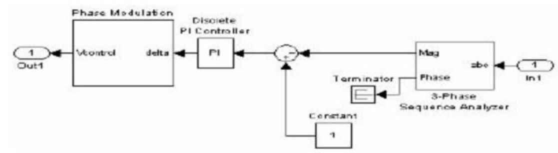


Fig.4.1. Simulink Model of D-STATCOM Controller

5. Distribution Static Compensator (DSTATCOM)

A D-STATCOM (Distribution Static Compensator), as shown schematically in Figure-5.1, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, and a coupling transformer linked in shunt to the distribution network.

The VSC transforms the dc voltage across the storage device into a collection of three-phase alternating current output voltages.

These voltages are in phase and are related to the alternating current system via the coupling transformer's reactance. The effective regulation of active and reactive power exchanges between the D-STATCOM and the ac system is enabled by appropriate modification of the phase and magnitude of the D-STATCOM output voltages. A device in this design can absorb or generate regulated active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes: 1. Voltage regulation and compensation of reactive power. 2. Correction of power factor and 3. Elimination of current harmonics. The value of Ish can be controlled by adjusting the output voltage of the converter. The shunt injected current Ish can be written as,

$$I_{sh} = I_L - I_S = I_L - \frac{V_{th} - V_L}{Z_{th}} \quad (5.1)$$

$$I_{sh}\angle\eta = I_L\angle-\theta - \frac{V_{th}}{Z_{th}}\angle(\delta-\beta) + \frac{V_L}{Z_{th}}\angle-\beta \quad (5.2)$$

I_{out} = output current I_L = load current

I_S = source current V_{th} = thevenin voltage

V_L = load voltage Z_{th} = impedence

Referring to the equation 5.2, output current, will correct the voltage sags by adjusting the voltage drop across the system impedance,

(Z th = R + jX).

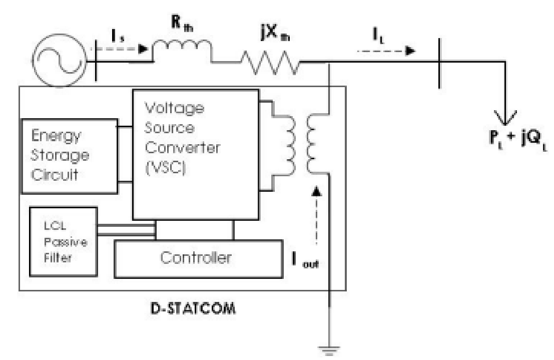


Fig.5.1. Schematic Diagram of D-STATCOM

6. METHODOLOG

D-STATCOM was attached to the distribution system to improve distribution system performance. D-STATCOM was created with MATLAB simulink R2009b.

Figure 6.1 depicts a 230kV, 50Hz transmission line, represented by a Thevenin equivalent, flowing into the primary side of a three-winding transformer linked in Y/Y/Y, 230/11/11 kV. A variable load is linked to the transformer's 11 kV secondary side. To provide instantaneous voltage support at the load point, a two-level D-STATCOM is linked to the 11 kV tertiary winding. The DSTATCOM energy storage capabilities are provided by a 750 F capacitor on the dc side. The D-STATCOM's operating period is controlled by a circuit breaker.

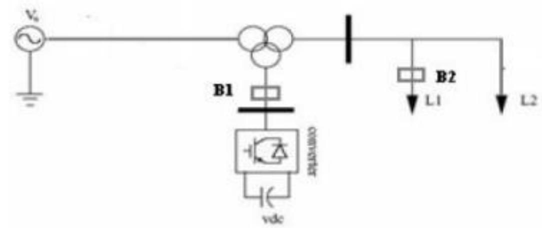
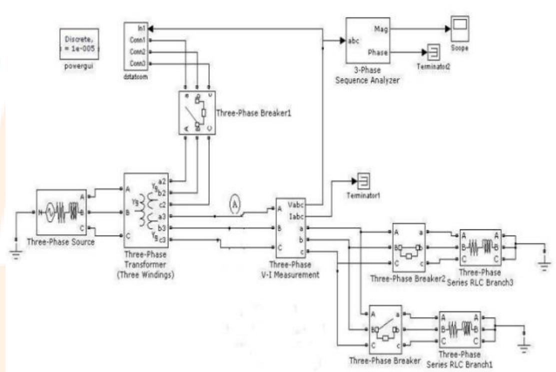


Fig.6.1. Single line Diagram of Test System

7. SIMULINK MODEL FOR THE TEST SYSTEM



8. RESULTS

8.1 Simulation results of voltage sag during single line to ground fault

In this case, D-STATCOM is not connected and a single line to ground fault is applied at a point ‘A’ with a fault resistance of 1.06 Ω. The voltage sag is shown in fig.8.1. with a time period of 500ms900ms. From the fig.8.2. the voltage sag is mitigated with an energy storage of 18.2 kv, when the DSTATCOM is connected to the system.

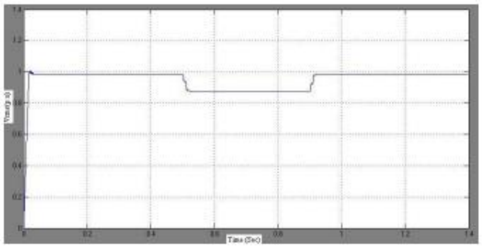


Fig.8.1.Voltage Vrms at the load point without DSTATCOM

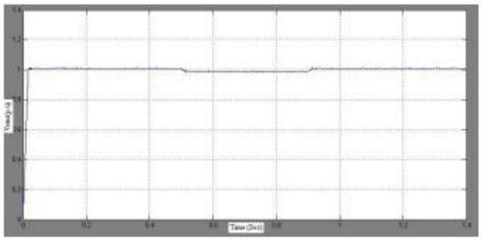


Fig.8.2.Voltage Vrms at the load point with DSTATCOM: with energy storage of 18.2 kv.

8.2 Simulation results of Voltage Interruption during Three-Phase fault

In this case, D-STATCOM is not connected and a three-phase fault is applied at a point ‘A’ with a fault resistance of 0.96 Ω. The voltage sag is shown in fig.8.3. with a time period of 500ms-900ms. As the simulation is carried out with a DSTATCOM connection as shown in the fig.8.4. The voltage sag is mitigated with energy storage of 18.2 kv,

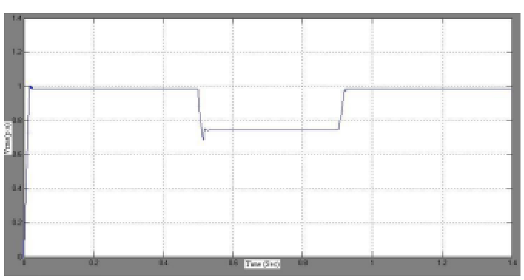


Fig.8.3.Voltage Vrms at the Load point without DSTATCOM.

8.3 Simulation results of Voltage swell

D-STATCOM is not connected in this scenario, and a capacitive load is applied at point 'A'. Figure 8.5 depicts the voltage swell throughout a time period of 500ms-900ms.

As illustrated in fig.8.6, the simulation is carried out via a DSTATCOM connection. The voltage swell is reduced by 13.2 kv of energy storage.

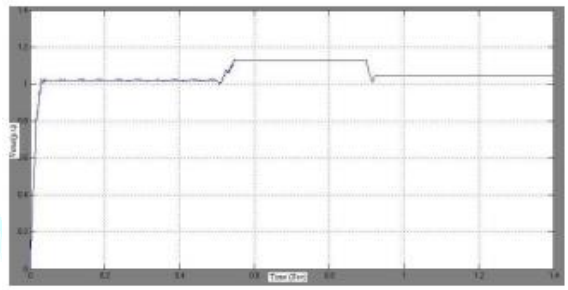


Fig. 8.5.Voltage V_{rms} at the load point without D-STATCOM

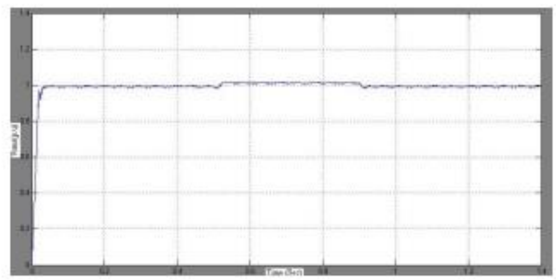


Fig.8.6. Voltage Vrms at the load point with DSTATCOM: with Energy storage of 13.2 kv.

V.CONCLUSION

At various inductive and capacitive loads, a single-phase to ground fault, three-phase fault, and voltage swell occurred in a time span of 500ms-900ms. D-STATCOM is created by combining two-level VSC and PWM-based control. The voltage measurement is regulated by a PWM controller in this case. So, by applying D-STATCOM, circumstances are alleviated by 13% sag, 25% interruption, and 11% swell.

9. REFERENCES

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