IMPROVEMENT OF POWER QUALITY USING DISTRIBUTED STATIC COMPENSATOR (DSTATCOM)

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Abstract— **The objective of this project is to compensate various problems in power quality; such as voltage sag, voltage swell and interruptions. FACTS devices like SVC, STATCOM, IPFC, UPFC, DVR, DSTATCOM can be used. The fact device used in this project is DSTATCOM. DSTATCOM is a custom power device based on VSC principle; which is installed in parallel with distribution system; it is a compensating device which is used to control the flow of reactive power in distribution system. A DSTATCOM injects a current into the system to correct the voltage sag, swell and interruptions. PI Controller was used to detect error and compensate. The simulations were performed using MATLAB/SIMULINK.**

Index Terms— **D-STATCOM, Voltage source converter, voltage sag/swell.**

I. INTRODUCTION

Most of the ac loads are consuming reactive power due to the presence of reactance. Heavy consumption of reactive power causes poor voltage quality. The most common power quality problems today are voltage sag, swell and interruptions.

Voltage sags are one of the most occurring power quality problem. Voltage sags is caused by fault in the utility system, utilities often focus on disturbances from end-users equipment as the main power quality problems.

Harmonic current in distribution system can cause the harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It can also 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 has have introduced and emerging branch of technology providing the power system with versatile new control capabilities.

There are different ways to mitigate power quality problems in transmission and distribution systems. Among these, the DSTATCOM is one of the most effective devices. The DSTATCOM protects the utility transmission or distribution system from voltage sags or flicker caused by rapidly varying reactive current demand. In utility applications, a DSTATCOM provides leading or lagging reactive power to achieve system stability during transient conditions.

A new PWM based control scheme has been implemented to control the electronic valves in the DSTATCOM. The DSTATCOM 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.

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II. DISTRIBUTION STATIC COMPENSATOR (DSTATCOM)

A DSTATCOM consists of a two level VSC ,a dc energy storage device , controller and a coupling transformer connected in shunt to the distribution network; shown in fig 1. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable 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.

$$I_{out} = I_L - I_S = I_L - \frac{V_{th} - V_L}{Z_{th}} \quad (2.1)$$

$$I_{out} < \gamma = I_L < (-\theta) - \frac{V_{th}}{Z_{th}} < (\delta - \beta) + \frac{V_L}{Z_{th}} < (-\beta) \quad (2.2)$$

I_{out} = output current I_L = load current
I_S = source current V_{th} = Thevenin Voltage
V_L = load voltage Z_{th} = impedance

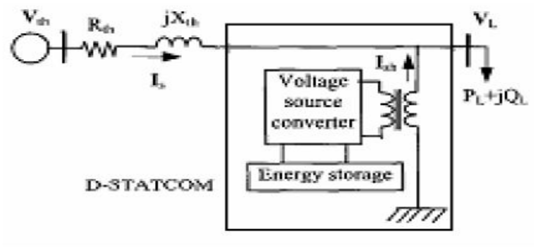


Fig:1 The schematic diagram of a DSTATCOM

III. CONTROLLER

The main aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected under system disturbances; shown in figure 2. The control system only measures the r.m.s voltage at load point. The VSC switching strategy based on sinusoidal PWM technique which offers simplicity and good response.

The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller the output is the angle, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously, an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e, the rms voltage is brought back to the reference voltage.

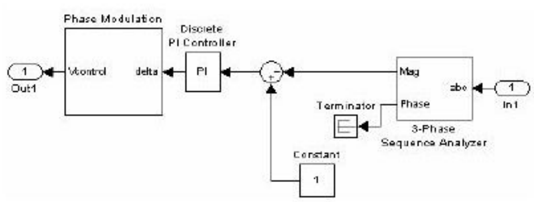


Fig :2 Simulink model of D-STATCOM Controller

IV. VOLTAGE SOURCE CONVERTER (VSC)

A Voltage source converter is a power electronic device that connected in parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

V. ENERGY STORAGE CIRCUIT

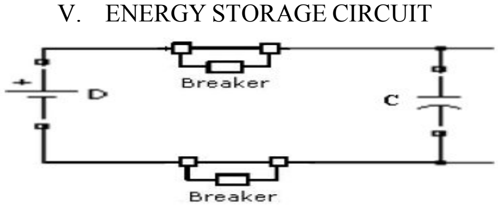


Fig:3 Energy storage circuit

DC source is connected in parallel with the DC capacitor; shown in fig 3. It carries the input ripple current of the converter and it is the main reactive energy storage element. This DC capacitor could be charged by a battery source or could be recharged by the converter itself.

VI. METHODOLOGY

To enhance the performance of distribution system , D-STATCO was connected to the distribution system. D-STATCOM was designed using MATLAB simulink ; shown in fig,4. The test system shown comprises a 230KV, 50 Hz transmission system represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer in Y/Y/Y, 230/11/11KV.A varying load is connected to the 11Kv, 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 750μF capacitor on the dc side provides the DSTATCOM energy storage capabilities. Circuit Breaker is used to control the period of operation of the D-STATCOM.

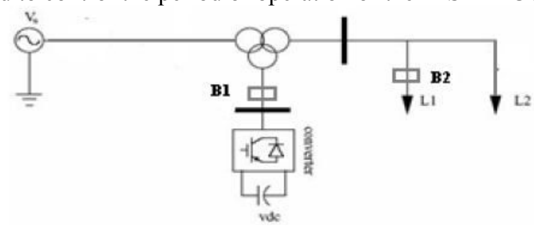
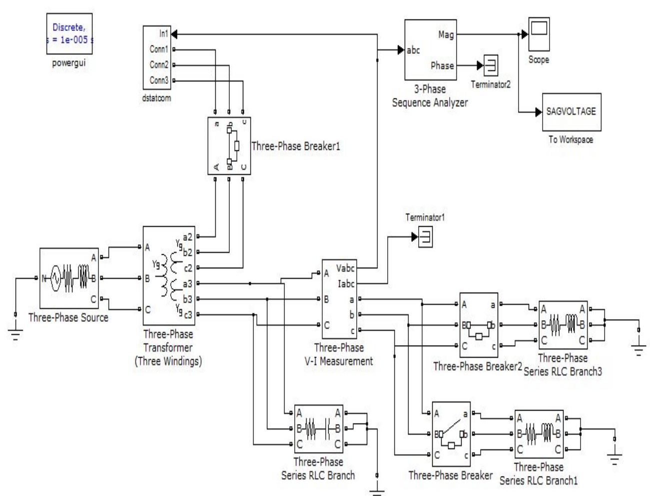


Fig:4 Single line diagram of the test system.

VII. SIMULINK MODEL FOR THE TEST SYSTEM



VIII. SIMULATION RESULTS

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.5.1. with a time period of 500ms-
900ms.

From the fig.5.2. the voltage sag is mitigated
with an energy storage of 18.2kv, when the DSTATCOM is connected to the system.

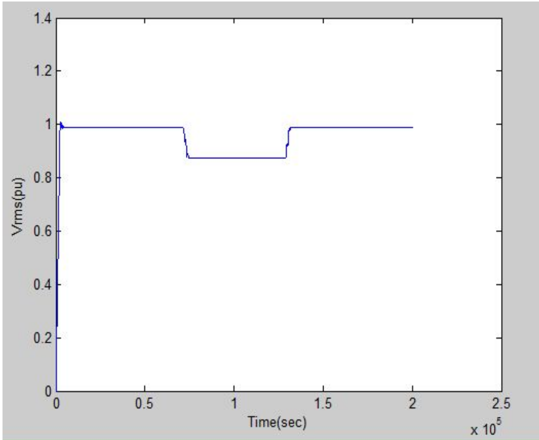


Fig.5.1.Voltage Vrms at load point without DSTATCOM

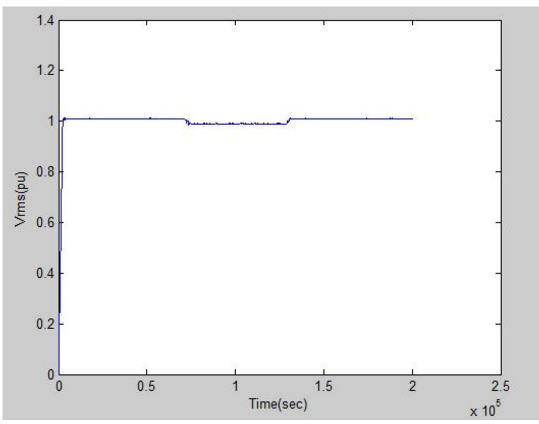


Fig.5.2.Voltage Vrms at load point with DSTATCOM

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 0.96Ω.The voltage sag is shown in fig 5.3, with a time period of 500ms-900ms.

As the simulation is carried out with a DSTATCOM connection as shown in 5.4. The
voltage sag is mitigated with energy storage of 18.2

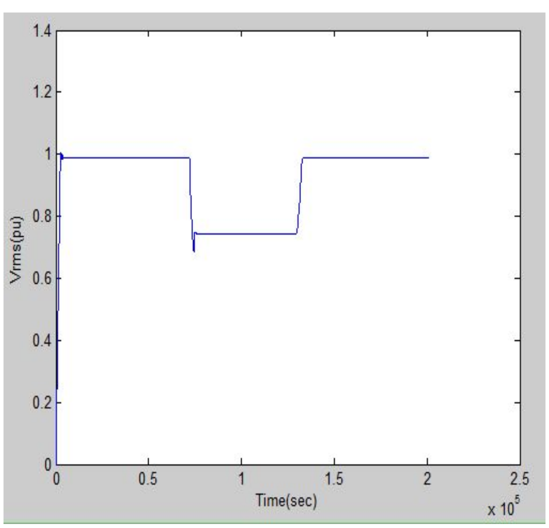


Fig.5.3. Voltage Vrms at load point without DSTATCOM

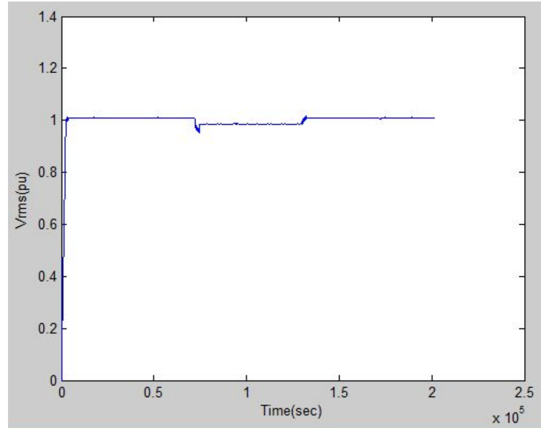


Fig.5.4. Voltage Vrms at load point with DSTATCOM

Simulation results of Voltage swell

In this case, DSTATCO M is not connected and a capacitive load is applied at a point 'A' .The voltage swell is shown in fig 5.5.

As the simulation is carried out with a DSTATCOM as shown in fig 5.6.

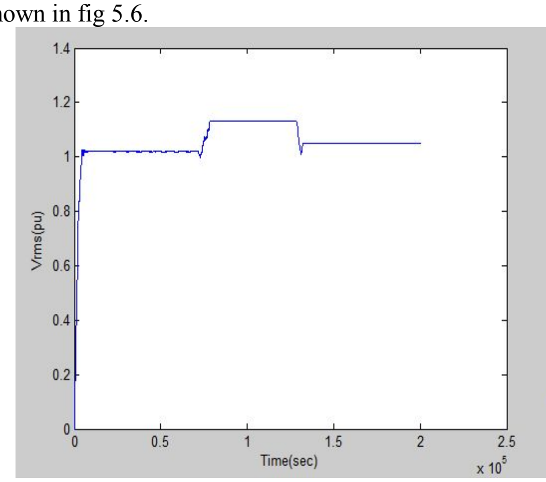


Fig.5.5. Voltage Vrms at load point without DSTATCOM

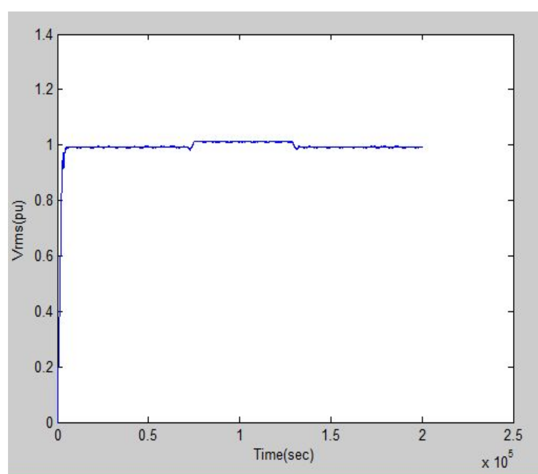


Fig.5.6.Voltage Vrms at load point with DSTATCOM

CONCLUSION

A single-phase to ground fault, Three – phase fault and voltage swell are occurred in a time period of 500ms -900ms at different inductive and capacitive loads. DTATCOM is designed by the combination of two- level VSC and PWM-based control. Here the voltage measurement is controlled by PWM controller. So by using DSTATCOM sag of 13%, interruption of 25% and swell of 11% conditions are mitigated.

FUTURE EXPANSION

In this project work, it is shown that the D-STATCOM can mitigate the voltage sag and swell conditions. The work can be extended to reduce the source voltage and source current harmonics supplied due to the non-linear loads.

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