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To Study and Implement Power Quality Improvement Technique using VSC Based DSTATCOM (Distribution Static Compensator)

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ABSTRACT

A power quality issue is an incident that manifests as a nonstandard voltage, current, or frequency, resulting in a failure or mis-operation of end-user equipment. Utility distribution networks, sensitive industrial loads, and important commercial activities all suffer from different sorts of outages and service disruptions, which may result in severe financial losses. With the reorganisation of power networks and the transition toward distributed and scattered generation, the problem of power quality will take on new dimensions. In developing nations like 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 effort aims to identify the most pressing issues in this area, and as a result, recommendations for steps to improve power quality are made. This paper presents the enhancement of voltage sags/swell; harmonic distortion and low power factor using Distribution Static Compensator (D-STATCOM). The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags/swell. to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2019a.

KEYWORDS:Harmonics, Load balancing, Weights, Power Quality Improvement,D-Statcom, VSC, Voltage Dips, Swells.

1. INTRODUCTION

An electric distribution system is a component of an electric system that connects the bulk power source or sources to the consumer's service switches. Bulk power sources are situated in or near the load region to be serviced by the distribution system and may be either producing stations or power substations supplied through transmission lines. In general, distribution systems are split into six sections: sub transmission circuits, distribution substations, distribution or main feeders, distribution transformers, secondary circuits or secondary's, and consumer's service connections and metres or consumer's services. Voltage sag/swell is one of today's most frequent power quality issues. It is often limited to two parameters: depth/magnitude and duration. The amount of the voltage sag/swell ranges from 10% to 90% of the normal voltage, with durations ranging from half a cycle to 1 minute. Voltage sag is three-phase phenomena that affects both the phase-to-ground and phase-to-phase voltages in a three-phase system. Voltage sag is produced by a problem in the utility system, a malfunction inside the customer's facility, or a significant rise in load current, such as starting a motor or transformer energising. Single-phase or multiple-phase short circuits, which result in high currents, are typical problems. The high current causes a voltage drop across the network impedance. The voltage in the faulty phases decreases down to zero at the fault point, but it stays more or less constant in the non-faulted phases. Voltage sags are one of the most occurring power quality problems. For industry voltage sags occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems.[2] Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices. A new PWM-based control scheme has been implemented to control the electronic valves in the D-STATCOM. The D-STATCOM 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. To enhance the power quality such as voltage sags/swell, harmonic distortion and low power factor in distribution system.

VSC:A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the 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 sag/swell mitigation, but also for other power quality issues, e.g. flicker and harmonics.

CONTROLLER: The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response.Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.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 δ, 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 load rms voltage is brought back to the reference voltage.

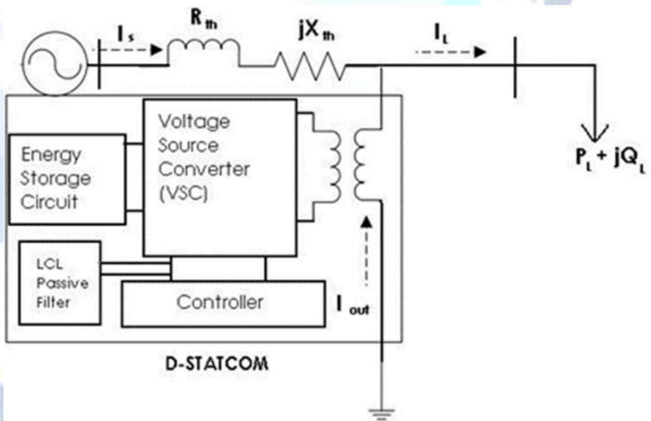

Fig 1. Schematic diagram of VSC based DSTATCOM

2. METHODOLOGY

There are many techniques to mitigate the voltage sag. Among them the best way is to use a device at the point of interest to regulate the voltage. The devices used for this purpose are already discussed along with their control techniques in the before part. These control strategies are simulated in MATLAB SIMULINK for a three phase two level distribution static compensator (DSTATCOM) to perform the functions such as harmonic mitigation, power factor correction under reactive loads, which further reduces the DC link voltage across the self-supported capacitor of voltage source converter (VSC). The weighted values of fundamental active and reactive components of load currents are extracted using the proposed control technique to generate the reference source currents. Furthermore, these currents are used to trigger the VSC of the DSTATCOM. The effectiveness of this control technique is demonstrated through simulation using MATLAB/SIMULINK and sim power system tool boxes.

3. SIMULATION RESULTS

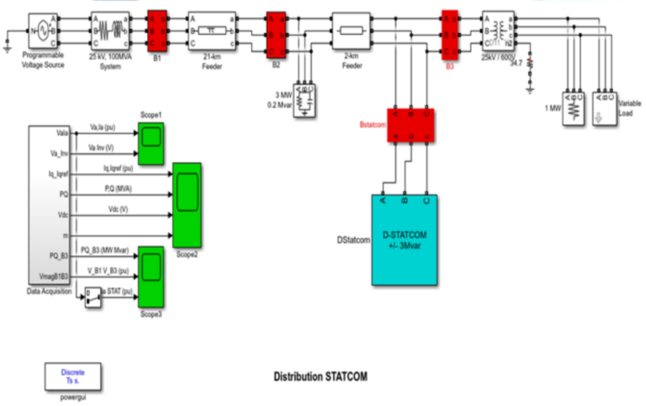

Fig 2. Simulink Model of VSC Based D-Statcom

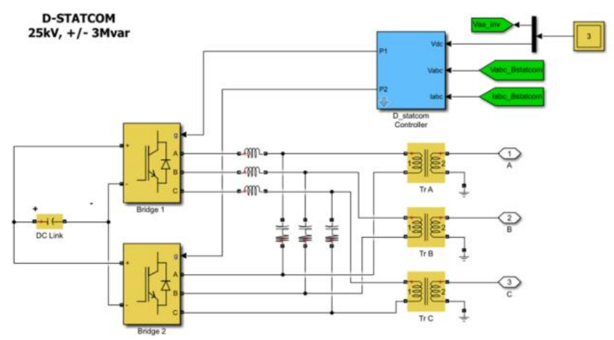

Fig 3. DSTATCOM

Results and Discussion

Results under load condition

nominal load [3000 0.9] [current (RMS) power factor]

modulation [2000 5] [amplitude current (RMS) frequency (Hz)]

nominal voltage 600 [volts (RMS)Phase to phase]

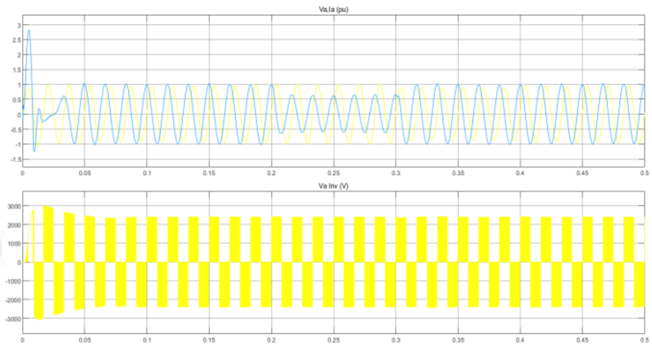

Fig 4.

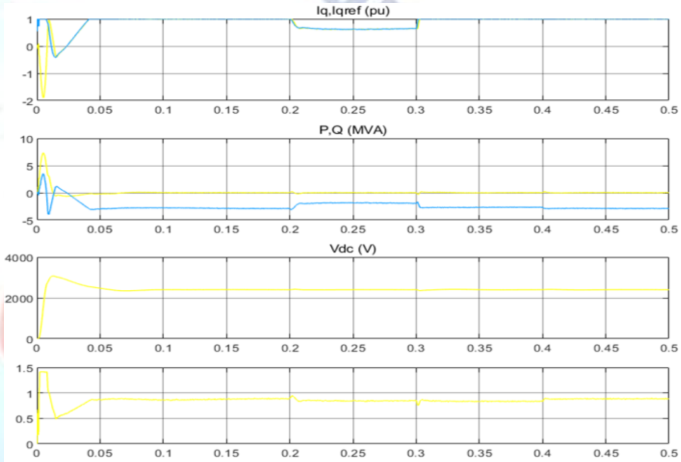

Fig 5.

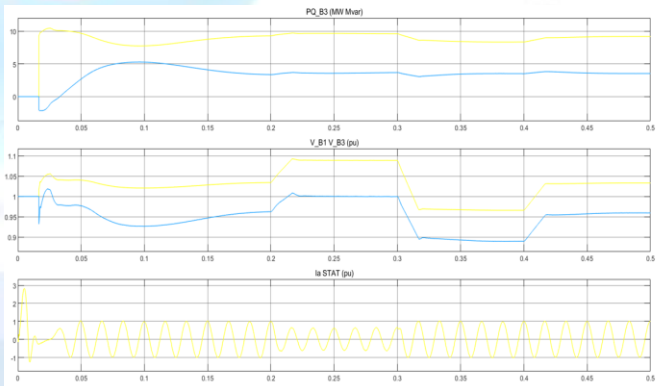

Fig 6.

MORE SIMULATION RESULTS USING D-STATCOM:

The system parameters used for simulation using D-STATCOM are given in Table - 1.

Main Supply Voltage	415V
Coupling Transformer Voltage	200V
Coupling Transformer Turns Ratio	1:1
DC Bus Voltage	200V
Capacitance	750F
Load Active Power	20KW
Line Frequency	60HZ

As in the case of DVR, voltage sag is created for simulation with D-STATCOM by connecting an extra load in the circuit. The resultant dip in the voltage at the PCC in per unit is shown in Fig. 7 (a). Now the control circuit of the D-STATCOM gets activated. As it is a shunt connected device, it generates compensating current which is injected into the system. Based on the magnitude of this compensation current reactive powerexchange takes place between the D-STATCOM and the transmission line. Based on this the load bus voltage is regulated. The waveform of the compensation current is shown in Fig. 7 (b) and the waveform shows that the compensation current is not balanced. This affects the voltage at PCC and increases its harmonic content. The final voltage at the load bus after compensation is shown in Fig. 7 (c). The THD of the load bus voltage is shown in Fig. 7 (d). As said earlier, the THD is more due to the imbalanced nature of compensating current.

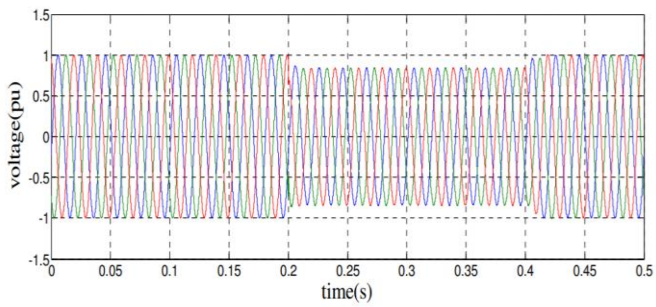

Fig 7 (A)

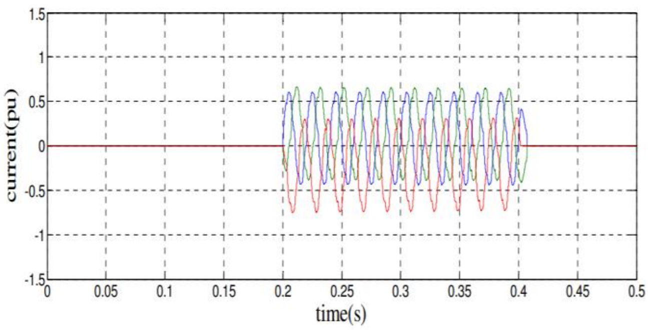

Fig 7 (B)

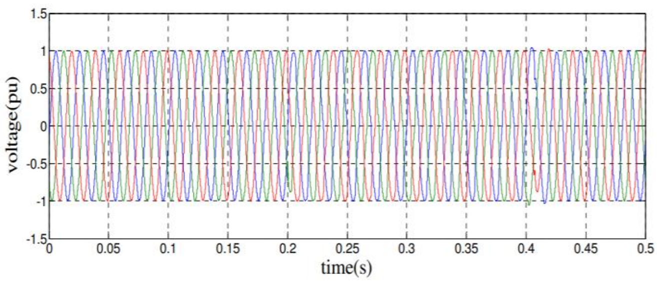

Fig 7 (C)

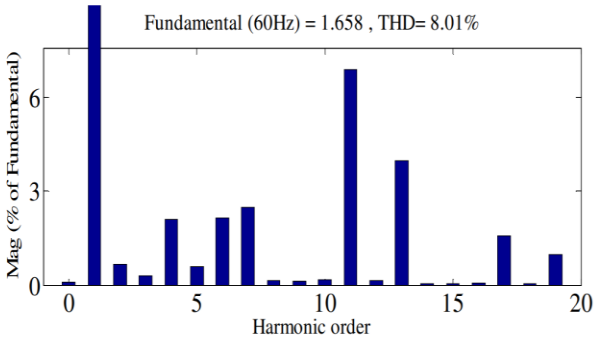

Fig 7 (D) Simulation Results Using D-STATCOM (a) Voltage Sag (b) Compensation Current generated by D-STATCOM (c) Load Voltage after Compensation (d) THD of Load Voltage after Compensation, D-STATCOM is better in terms of harmonic reduction. Though D-STATCOM acts faster.

Table -2 Comparative Study

Phases	Total Harmonic Distortion (%)	
	System without D-STATCOM	System with proposed control concept of D-STATCOM (THD of Load Voltage)
A	12.62	8.01%

4. CONCLUSION

Using this work, the investigation on the role of DSTATCOM is carried out to improve the power quality in distribution networks with static linear and non-linear loads. PI controller is used with the device to enhance its performance. Test system is analyzed and results are presented in the previous chapter. DSTATCOM in the distribution networks under different fault conditions and it can be concluded that DSTATCOM effectively improves the power quality in distribution networks with static linear.

The demand for electric power is increasing at an exponential rate and at the same time the quality of power delivered became the most prominent issue in the power sector. Thus, to maintain the quality of power the problems affecting the power quality should be treated efficiently. Among the different power quality problems, voltage sag is one of the major one affecting the performance of the end user appliances. In this project the methods to mitigate the voltage sag are presented. From this project, the following conclusions are made-

- Among the different methods to mitigate the voltage sag, the use of FACT devices is the best method.
- The FACT devices like DVR, D-STATCOM are helpful in overcoming the voltage unbalance problems in power system.
- D-STATCOM is a shunt connected device and injects current into the system.
- These devices are connected to the power network at the point of interest to protect the critical loads.
- These devices also have other advantages like harmonic reduction, power factor correction.
- The amount of apparent power infusion required by D-STATCOM is higher than that of DVR for a given voltage sag.
- Both DVR and D-STATCOM require a greater number of power electronic switches and storage devices for their operation.
- Here the number of switches required are less and hence the switching losses are also reduced.

5. FUTURE SCOPE

- These algorithms can be extended for custom power devices incorporated in three phase four wire distribution system to mitigate power quality problems.
- Various other time domain and frequency domain, approach based control algorithms can be developed to achieve desired response of DSTATCOM.
- The developed control algorithms can be applied in isolated power generating systems such as wind, solar and micro-hydro based generation for power transfer to the loads, voltage regulation and compensation of power quality problems.

Experimental verification of grid connected solar photovoltaic system with the proposed control algorithms can also be extended for power transfer to the grid along with compensation of power quality problems.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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