# VSC Based DSTATCOM & Pulse-width modulation for Power Quality Improvement

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*Abstract* - **We proposed voltage-sourced converter (VSC) with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. The proposed DSTATCOM is modeled and its performance is simulated and verified for power factor correction and voltage regulation along with neutral current compensation, harmonic elimination and load balancing with linear loads and non-linear loads. The three phase three wire Distribution Static Compensator (DSTATCOM) is proposed for power quality improvement. DSTATCOM is based on a three leg VSC and is controlled to compensate reactive power, harmonic current and unbalances in the load. IGBT based VSC is capacitor supported and is controlled for the required compensation of the load current.**

*Keywords* - **Distribution Static Compensator, Pulse-width modulation, voltage-sourced converter.**

## I. INTRODUCTION

In present day's power distribution systems is suffering from severe power quality problems. These power quality problems include high reactive power burden, harmonics currents, load unbalance, excessive neutral current etc. Some remedies to these power quality problems are reported in the literature. A group of controllers together called Custom Power Devices (CPD), which include the DSTATCOM (distribution static compensator), The DSTATCOM, is a shunt-connected device, which takes care of the power quality problems in the currents. Three-phase four-wire distribution systems are used to supply single-phase low voltage loads such as computer.

The voltage regulation is also poor in the distribution system due to the unplanned expansion and the installation of different types of loads in the existing distribution system. In order to control the power quality problems, There are mitigation techniques for power quality problems in the distribution system and the group of devices is known by the generic name of custom power devices (CPD) [1]. VSC, three-leg VSC with split capacitors [2], three-leg VSC with zig-zag transformer.

In this paper, We proposed A voltage-sourced converter (VSC) with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The voltage regulation in the distribution feeder is improved by installing a shunt compensator [3]. The proposed DSTATCOM is modeled and its performance is simulated and verified for power factor correction and voltage regulation along with neutral current compensation, harmonic elimination and load balancing with linear loads and non-linear loads.

## II. VOLTAGE SOURCE CONVERTERS (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 dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

A special gate unit and voltage divider across each IGBT maintain an even voltage distribution across the series connected IGBTs. The gate unit not only maintains proper voltage sharing within the valve during normal switching conditions but also during system disturbances and fault conditions. A reliable short circuit failure mode exists for individual IGBTs within each valve position.

Depending on the converter rating, series-connected IGBT valves are arranged in either a three-phase two-level or three-level bridge. In three-level converters, IGBT valves may also be used in place of diodes for neutral point clamping. Each IGBT position is individually controlled and monitored via fiber optics and equipped with integrated antiparallel, free-wheeling diodes. Each IGBT has a rated voltage of 2.5 kV with rated currents up to 1500 A. Each VSC station is built up with modular valve housings which are constructed to shield electromagnetic interference (EMI). The valves are cooled with circulating water and water to air heat exchangers. PWM switching frequencies for the VSC typically range between 1-2 kHz depending on the converter topology, system frequency and specific application.

2.1 Zig-Zag Transformer

The harmonic current will pollute the power system and result in the problems such as transformer overheats, rotary machine vibration, degrading voltage quality, damaging electric power components, medical facilities malfunction, etc. The third harmonic is most serious for the single-phase nonlinear loads. The current of the integer multiples $3^{rd}$ are regarded as the zero-sequence current. The unbalanced load currents contain zero-sequence components and also flow in the neutral conductor.

The Zig-Zag transformer has been used to attenuate the neutral current and zero-sequence harmonic currents on the utility sites. In recent years due to the advantage of low cost, high reliability and simplified circuit connection. The Zig-Zag transformer has also another application for avoiding iron losses.

What are Power Quality problems?

- It include all possible situations in which the waveforms of the supply voltage or load current deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three-phases of a three-phase system.
- Power quality disturbance covers sudden short duration deviation impulsive and oscillatory transients, voltage dips or sags, short interruptions, as well as steady-state deviations, such as harmonics and flicker.

## III. DISTRIBUTION STATIC COMPENSATOR

A voltage-sourced converter (VSC) with PWM provides a faster control that is required for flicker mitigation purpose. A PWM operated VSC utilizing IGBTs and connected in shunt is normally referred to as "STATCOM" or "D-STATCOM" [67]. A shunt-connected synchronous machine has some similarities with the STATCOM, but does not contain power electronics. The capability of the synchronous machine to supply large reactive currents enables this system to lift the voltage by 60% for at least 6 s. D-STATCOM has the same structure as that of an STATCOM. It can potentially be used in the context of FACTS at the transmission level [4], custom power controllers at the distribution level and in end users' electrical installations [5]. A typical configuration of a VSC based D-STATCOM is shown in Fig. 1 [6]. The DSTATCOM has emerged as a promising CPD to provide not only for voltage sag mitigation but a host of other PQ solutions. Important applications of it include voltage regulation, load balancing, power factor correction, harmonic filtering, and flicker mitigation [7].

The Block diagram of the D-SATCOM shows that phase-locked loop (PLL) technique is used for voltage sag detection and mitigation. However, this technique provides good results only if voltage sag is not coupled with phase-angle jump.

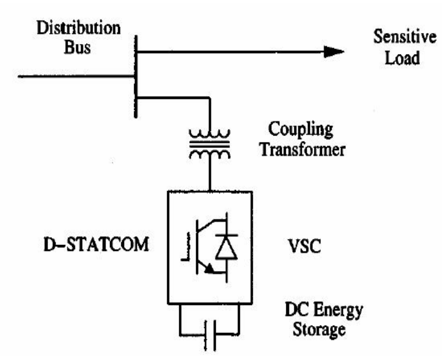


Fig. 1 Schematic representation of the D-STATCOM as a custom power Device [6].

The reactive power control strategy for the D-STATCOM has been employed for load compensation. PI controller is used to control the flow of reactive power to and from the DC capacitor. Phase-locked loop (PLL) has been used to generate the switching signals for the VSC. The DSTATCOM has been developed using DSP controller to achieve excellent overall performance. Simulation results show that the designed D-STATCOM is capable of mitigating voltage sag caused by three phase balanced fault. However, as PLL is used for detection and mitigation of sag in the control strategy, it provides good results only if sag is not accompanied by phase jumps.

### 3.1 Overview of Distribution Static Compensator (Dstatcom)

The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator that is used for the correction of line currents. Connection (shunt) to the distribution network is via a standard power distribution transformer. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations. The major components of a DSTATCOM are shown in Fig.2. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage, and a PWM control strategy. In this DSTATCOM implementation, a voltage-source inverter converts a dc voltage into a three-phase ac current that is synchronized with, and connected to, the ac line through a small tie reactor and capacitor (ac filter).

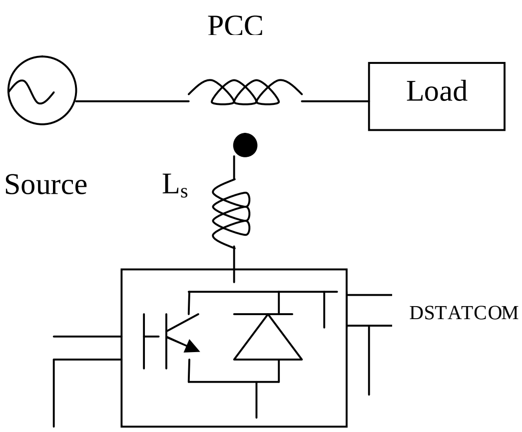


Fig. 2. Block diagram of DSTATCOM circuit

3.2 Application of DSTATCOM for Reactive Power compensation and Voltage Regulation

Initial application of DSTATCOM (using IGBT devices) was primarily for the control of (Fundamental Frequency) reactive power control and voltage regulation. SVCs have been applied for this purpose earlier. A major advantage relates to the improved speed of response, capacity for transient overload (upto one second) in addition to the improved performance at reduced voltages.

- Limiting voltage swells caused by capacitor switching.
- Reduction of voltage sags due to common feeder faults.
- Controlling the voltage fluctuations caused by customer load variations. It was found 2.5% to 0.2% with DSTATCOM. This reduces voltage flicker substantially.
- Based on the control algorithm, the frequency of mechanical switching operations (involving load tap changing (LTC) transformers and mechanically switched capacitors) is reduced that is beneficial for maintenance.
- Increase in the maximum load ability of the system (in particular, increase in the induction motor load that can remain stable through a major disturbance, such as a loss of primary infeed).

The controller of DSTATCOM suggested in has three levels given below:

- Fast voltage regulator.
- Fast current limiter and overload management control.
- Slow reset control.

The voltage regulator has a response time of few cycles. The second level of control allows the inherent short-term overload capability of DSTATCOM to be utilized for better performance while protecting the equipment. The third level of control involving slow reset ensures that the DSTATCOM does not remain near limits over an extended period of time. The objective is to ensure that the DSTATCOM remains ready to respond quickly to subsequent disturbances. The reset control acts on the voltage reference (with in limits) and works with a delay (of typically 2 minutes). The output of DSTATCOM is ramped ba DSTATCOM pecified dead band of +1.2 or -1.2MVA VAR per minute. The control is co-coordinated with existing mechanically switched devices.

The voltage flicker can be reduced by 50% from applying a DSTATCOM in comparison with a SVC. The controller design of a DSTATCOM based on analytical model is present and the predictions on the performance are validated by experimental results. A unified control to mitigate voltage say and flicker is presented, based on kalman filter.

## IV. CONCLUSION

The performance of voltage-sourced converter (VSC) with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. We proposed DSTATCOM is modeled and its performance is verified for power factor correction and voltage regulation along with neutral current compensation, harmonic elimination and load balancing with linear loads and non-linear loads.

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