POWER QUALITY IMPROVEMENT IN POWER DISTRIBUTION SYSTEM USING D-STATCOM

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***Abstract*-The STATCOM is the shunt connected FACTS devices that are useful for reactive power compensation and mitigation of power quality problems in transmission and distribution system perticulaly in smart grid environment. This paper has dealed with performance analysis of D-STATCOM that is used for voltage flicker control. The D-STATCOM has been used to regulate voltage on a 33-kV distribution network for the plant absorbing continuously changing currents, like an arc furnace, that produces voltage flicker. The variable load current magnitude has been modulated at a frequency of 5 Hz so that its apparent power varies significantly and fast. It will be observed the ability of the D-STATCOM to mitigate voltage flicker.**

***Index Term*- D-STATCOM, distribution system, line voltage, voltage stability, Power Quality, voltage source converter.**

I. INTRODUCTION

Power Transmission and distribution is a complex process, requiring the working of many factors of the power system in order to maximize the output. One of the major factors is to maintain the reactive power in the system. Following are the requirements of reactive power compensation:

(1) It is required to supply/absorb reactive power to maintain the rated voltage to deliver the active power through the long transmission lines. This Voltage support helps in (a) reduction of voltage fluctuation at a given terminal of the long transmission line. (b) An increase in transfer of active power through a long transmission line (c) increases the stability.
(2) Many Loads like motor loads require reactive power for their proper operation. This Load compensation helps in (a) improvement of power factor (b) balancing of real power drawn from the supply (c) better voltage regulation due to large fluctuating loads.
(3) The modern industries use electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is depressed and may mal-operate in other ways if changes of the supply voltage is excessive. Many of these modern load equipments itself uses electronic switching devices which then can contribute to poor network voltage quality [5]. With power quality problem utility distribution networks, industrial loads, sensitive load etc. are suffered.
(4) Along with advance technology, the organization of the worldwide economy has evolved towards globalization and the profit margins of many activities tend to decrease. The increased sensitivity of the vast majority of processes like (industrial services and even residential) to Power quality problems turns the availability of electric power with quality a crucial factor for competitiveness in every activity sector. The continuous process industry and the information technology services are most critical area due to disturbance a huge amount of financial losses may happen with the consequent loss of productivity and competitiveness.
(5) With the trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions.
(6) The introduction of competition into electrical energy supply has created greater commercial awareness of the issues of power quality while equipment is now readily available to measure the quality of the voltage waveform and so quantify the problem [1-3].

This implies that some measures must be taken in order to achieve higher level of power quality and power transfer capability [3]. STATCOM can do these jobs of absorbing or generating reactive power with a faster time response compare to SVC and capacitor banks. (1) The maximum capacitive power generated by a SVC is proportional to the square of the system voltage (constant susceptance) while the maximum capacitive power generated by a DSTATCOM decreases linearly with voltage decrease (constant current). (2) This ability to provide more capacitive power during a fault is one important advantage of the DSTATCOM over the SVC. (3) The DSTATCOM will normally exhibit a faster response than the SVC because with the voltage-sourced converter, the DSTATCOM has no delay associated with the thyristor firing (in the order of 4 ms for a SVC). (4) DSTATCOM provides fast acting dynamic reactive compensation for voltage support during contingency events which would otherwise depress the voltage for a significant length of time [2, 3].
(7) The fast response of the distribution static compensator (DSTATCOM) makes it the efficient solution for improving power quality in distribution systems [3-5].

II. DSTATCOM

The STATCOM mainly consists of DC voltage source behind IGBT based current controlled

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voltage source inverter. STATCOM has no long term energy support in the DC Side and can not exchange real power with the ac system; however it can exchange reactive power. Also, in principle, it can exchange harmonic power too. But when a STATCOM is designed to handle reactive power and harmonic currents together it is Shunt Active Power Filter but the STATCOM handles only fundamental reactive power exchange with the ac system. DSTATCOM controller is highly effective in improving the power quality at the distribution level by making the voltage stable. It is the shunt connected var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage).

III. STATIC OF ART

The D-STATCOM is three phase shunt connected power electronics based device. It is connected near the load at the distribution system as shown in fig 1. It is also a one type of the voltage-source converter, which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system.

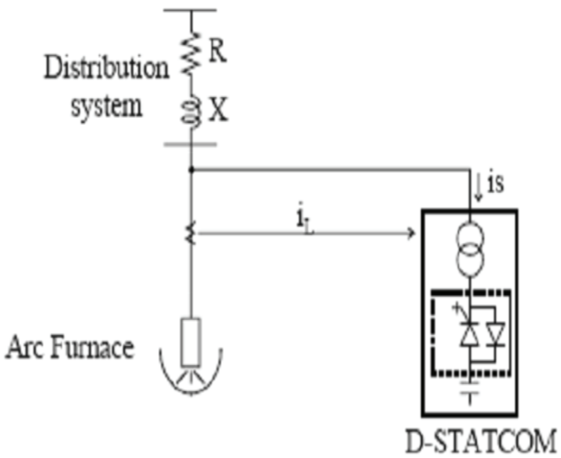


Figure 1 system configuration of DSTATCOM

A voltage Source converter is connected to bus via three phase transformer. A voltage source converter is a power electronics device, which can generate sinusoidal voltage with required magnitude frequency and phase angle. A 5000 µF capacitor is used as a dc voltage source for the inverter. PCC is the point of common coupling at which the generation or absorption of reactive Power takes Place to and from the system and the device. At the distribution voltage level, the switching device is generally the IGBT due to its lower switching losses and reduced size. Figure 2 shows a simplified diagram of a STATCOM connected to a typical distribution network represented by an equivalent network.[2]

1) Control System Block Diagram of DSTATCOM

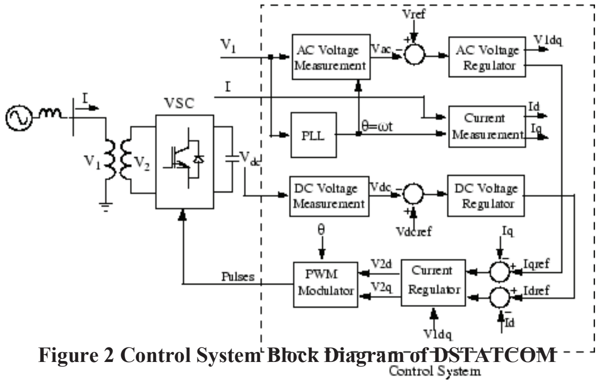


Figure 2 Control System Block Diagram of DSTATCOM

The control system consists of:

a) A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the three-phase primary voltage V1. The output of the PLL is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltage and currents (labelled as V_d, V_q or Id, I_q on the diagram).

b) Measurement systems measuring the d and q components of AC positive sequence voltage and currents to be controlled as well as the DC voltage V_{dc}.

c) An outer regulation loop consisting of an AC voltage regulator and a DC voltage regulator. The output of the AC voltage regulator is the reference current I_{qref} for the current regulator (I_q = current in quadrature with voltage which controls reactive power flow). The output of the DC voltage regulator is the reference current I_{dref} for the current regulator (I_d = current in phase with voltage which controls active power flow).

d) An inner current regulation loop consisting of a current regulator. The current regulatory controls the magnitude and phase of the voltage generated by the PWM converter (V_{2d} V_{2q})from the I_{dref} and I_{qref} reference currents produced respectively by the DC voltage regulator and the AC voltage regulator (in voltage control mode). The current regulator is assisted by a feed forward type regulator which predicts the V_2 voltage output (V_{2d} V_{2q}) from the V_1 measurement (V_{1d} V_{1q}) and the transformer leakage reactance.

IV. SIMULATION RESULTS AND DISCUSSION

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 33-kV distribution network. Two feeders (30 km and 7.5 km) transmit power to loads connected at buses B2 and B3 as shown in fig 3 and 4.

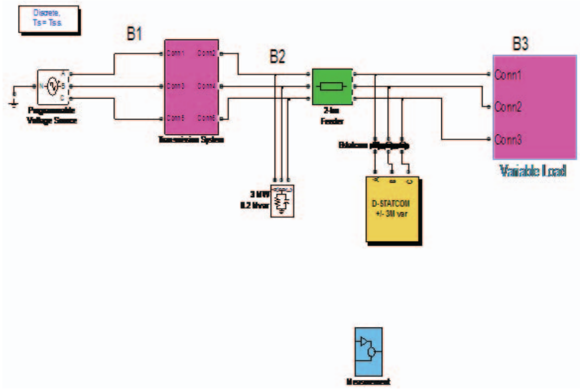


Figure 3 33-kV distributions System for simulation

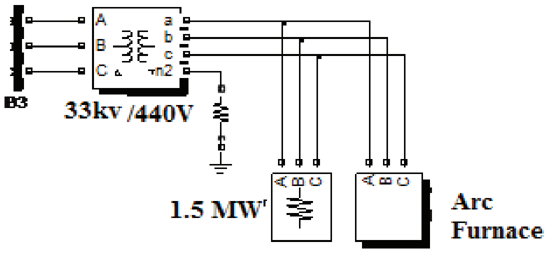


Figure 4 an arc furnace Load at bus B3

A shunt capacitor is used for power factor correction at bus B2. The 440-V load connected to bus B3 through a 33kV/440V transformer represents an arc furnace, that producing voltage flicker. The variable load current magnitude is represented at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 4.5 MVA, while keeping a 0.85 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker.

The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

The D-STATCOM consists of the following components:

A 33kV/1.25kV coupling transformer which ensures makes coupling between the PWM inverter and the network.

A voltage-sourced PWM inverter consisting of two IGBT bridges. This twin inverter configuration produces fewer harmonic than a single bridge, resulting in smaller filters and improved dynamic response as shown in fig 6 and 7.. In this case, the inverter modulation frequency is 28*50=1.40 kHz.

LC damped filters connected at the inverter output. Resistances connected in series with capacitors provide a quality factor of 40 at 60 as in fig 5.

A 5000-microfarad capacitor acting as a DC voltage source for the inverter.

A voltage regulator that controls voltage at bus B3.

A PWM pulse generator using a modulation frequency of 1.68 kHz

Anti-aliasing filters used for voltage and current acquisition.

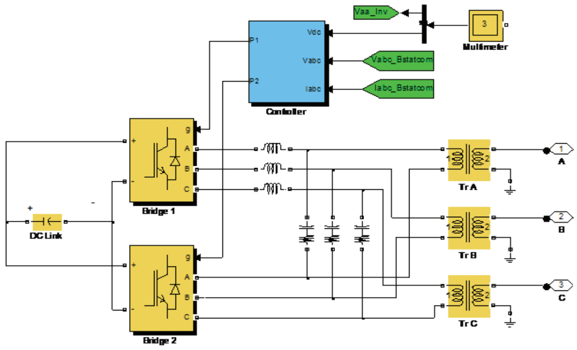


Figure 5 D-STATCOM 33KV, +/- 3Mvar

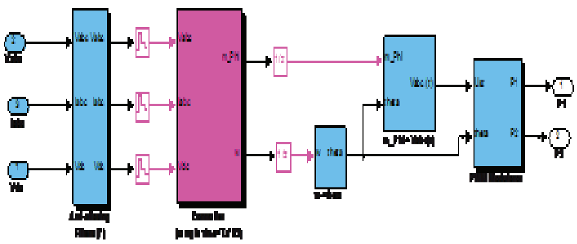


Figure 6 The D-STATCOM controller functional blocks

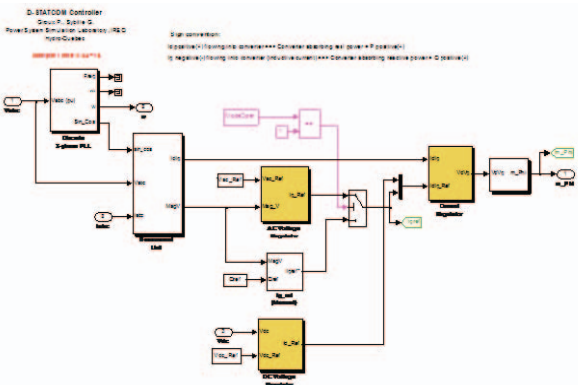


Figure 7 DSTATCOM Firing Control

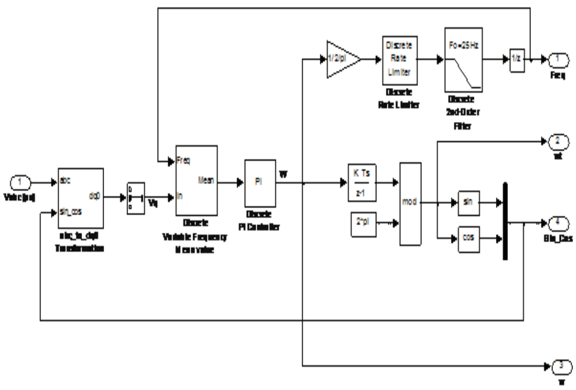
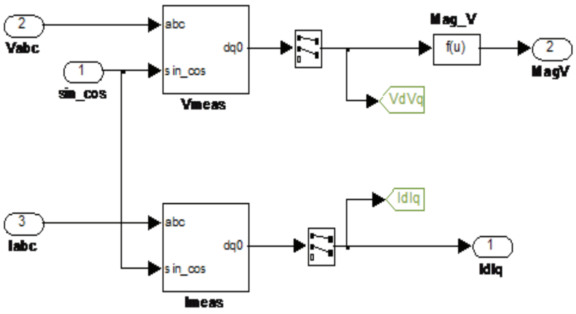
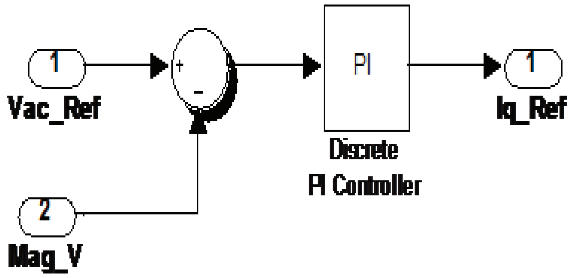
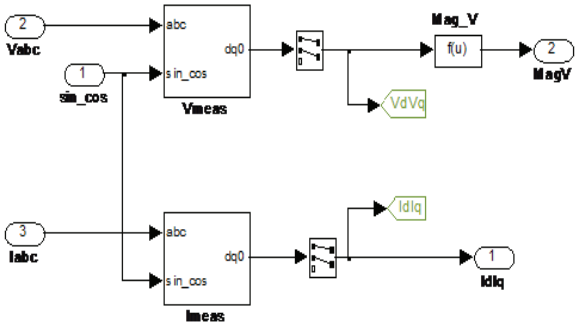


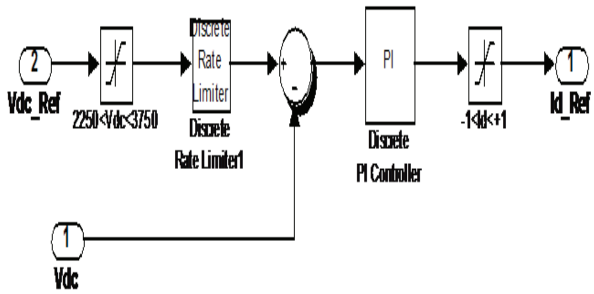
Figure 8 discrete 3-phase PLL

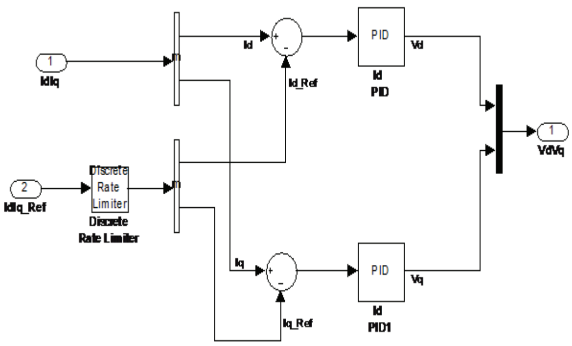
Figure 11 Current Regulator











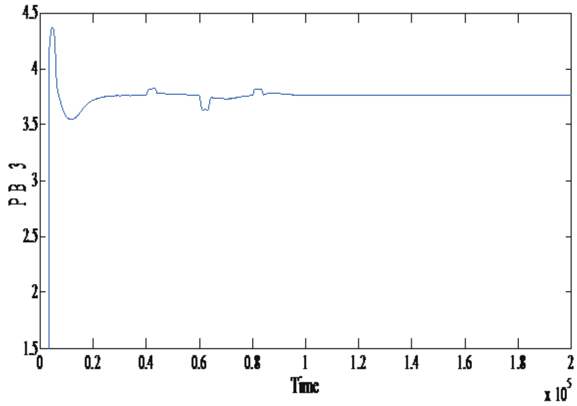


Figure 14 Active Power demand at Bus 3

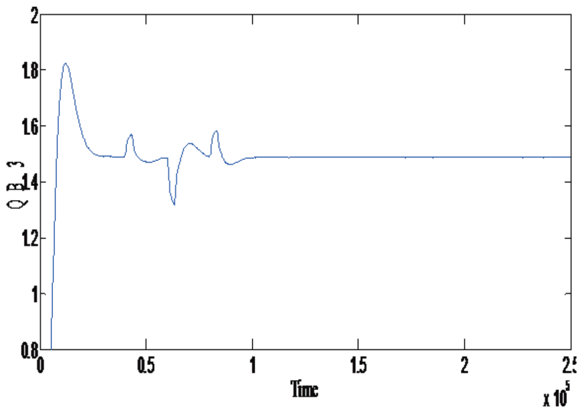


Figure 15 Reactive Power demand at Bus 3

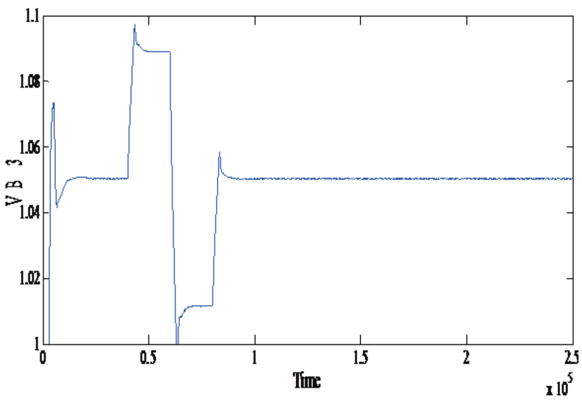


Figure 16 Voltage change at bus B3 due to change in load of Induction Furnace

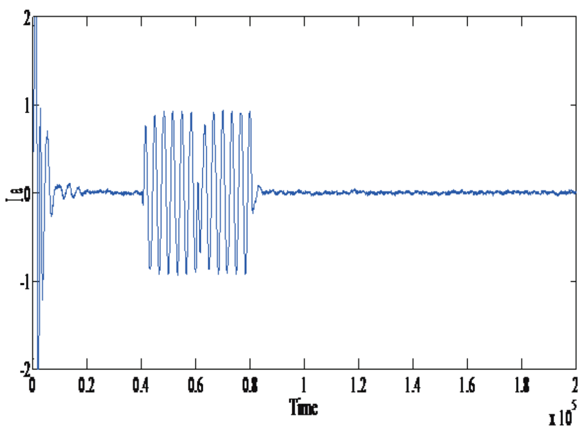


Figure 17 D-STATCOM Current to respond the change in voltage atbus B3

- Initially, the source voltage is such that the D-STATCOM is inactive. It does not absorb nor provide reactive power to the network.
- At t = 0.2 s, the source voltage is increased by 10%. The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network (Q=+3 Mvar on trace 2 of Scope2).
- At t = 0.3 s, the source voltage is decreased by 10% from the value corresponding to Q = 0. The D-STATCOM must generate reactive power to maintain a 1 pu voltage (Q changes from +3 MVAR to -3.1 MVAR).
- When the D-STATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter is increased from 0.6 to 0.92 it is due to a proportional increase in inverter voltage. Reversing of reactive power is very fast, about one cycle, as observed on D-STATCOM current as in fig 19.

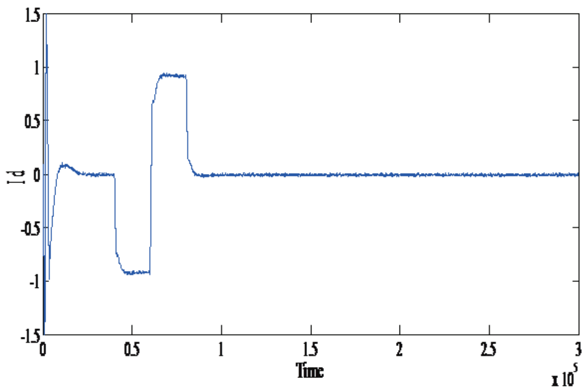


Figure 18 D-STATCOM d axis current

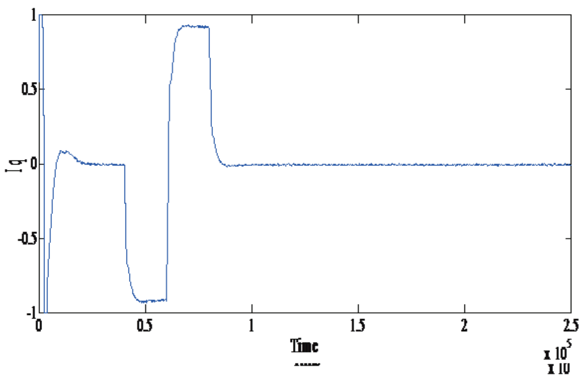


Figure 19 D-STATCOM q axis current

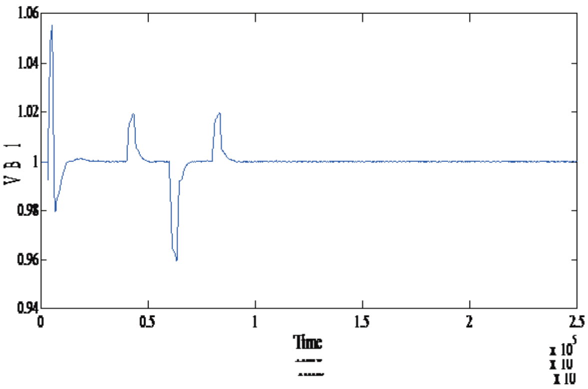


Figure 20 Change of voltage at bus B1

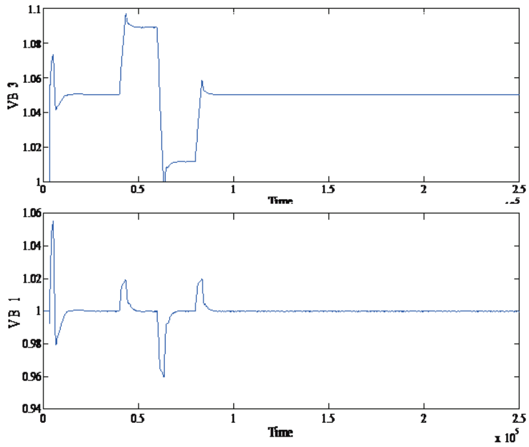


Figure 21 Comparison of voltage at bus B3 and B1

By using DSTATCOM we can see that the change in bus voltage 3 is more than bus voltage 1 due to change in DSTATCOM current as fig 20 and 21.

V. CONCLUSION

The power quality improvement by using DSTATCOM has been presented in this paper. The model of a D-STATCOM has been analyzed and developed for use in simulink environment with power system block sets. Here a control system is designed in MATLAB simulink. So DSTATCOM provides fast acting dynamic reactive compensation for voltage support during voltage flicker events .

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