IMPROVEMENT OF POWER QUALITY OF A DISTRIBUTED SYSTEM USING DSTATCOM FOR VARIOUS PHASE FAULTS

G. Sravani , Dr.A. Rajesh
Ph.D Scholar,
Department of Electronic and Electrical Engineering, Shri Jagdishprasad Jhabarmal Tibrewala University
Associate Professor,
Department of Electronics and Communication Engineering, CVR College of Engineering, Hyderabad, Telangana

Abstract : An increasing demand for good quality, reliable electrical power and increasing number of unbalanced loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. In this paper, a DSTATCOM is used for the compensation in presence of faults. The DSTATCOM is one of the most efficient and modern custom device used in distribution networks. The faults are introduced in different phases, also DSTATCOM is used for both voltage and power quality compensation. The MATLAB/Simulink model is used for results.

***IndexTerms* – DSTATCOM, Power Quality, Harmonic Distortion, Voltage Sags, Phase Faults, Distribution Network, Power Factor**

I.INTRODUCTION:

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occur. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min.

Voltage sags is caused by a fault in the utility system, a fault within the customer"s facility or a large increase of the load current, like starting a motor or transformer energizing. Voltage sags are one of the most occurring power quality problems. For an 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. 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.

The computer programs are used for the evaluation of risk factors or faults involved in production and transmission of electrical energy to distribution lines, which reduces risk and also cost involved in laying down of network. Many important factors and parameters which were previously considered neglected in complete process of production and distribution to end users are now calculated and analyzed in presence of evasive probable problems or faults using simulations in foundation phase. The two most important and common faults which arises in electrical power systems are short circuits and grounding faults. The probability of short circuit fault is very high. They can appear between the phases and as well as between the phases and the ground.

The short circuit faults can be broadly defined as: three phase short circuit faults, grounding faults and arc faults. The faults can arise due to many reasons and can be analysed using conventional methods or sign processing methods. The sign processing methods provide excellent results by providing the frequency domain analysis of fault.

The three phase and four wire distribution lines suffers from poor power quality problems like excessive of neutral current, unbalanced loading, and current harmonics resulting in voltage distortion. Also, there might be an increase or decrease in VAR demands due to drop or rise of load bus voltage which might result in voltage instability.

The DSTATCOM used a compensation device are used in such condition to limit the variation in voltage and also increases the operational capability of power lines while keeping the power supply reliability at same level. A D-STATCOM is used here to improve the power factor and to control the voltages at terminals, at the point of common coupling (PCC) it injects current as it is a shunt connected custom power device.

II.D-STATCOM (Distribution Static Compensator)

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. 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.

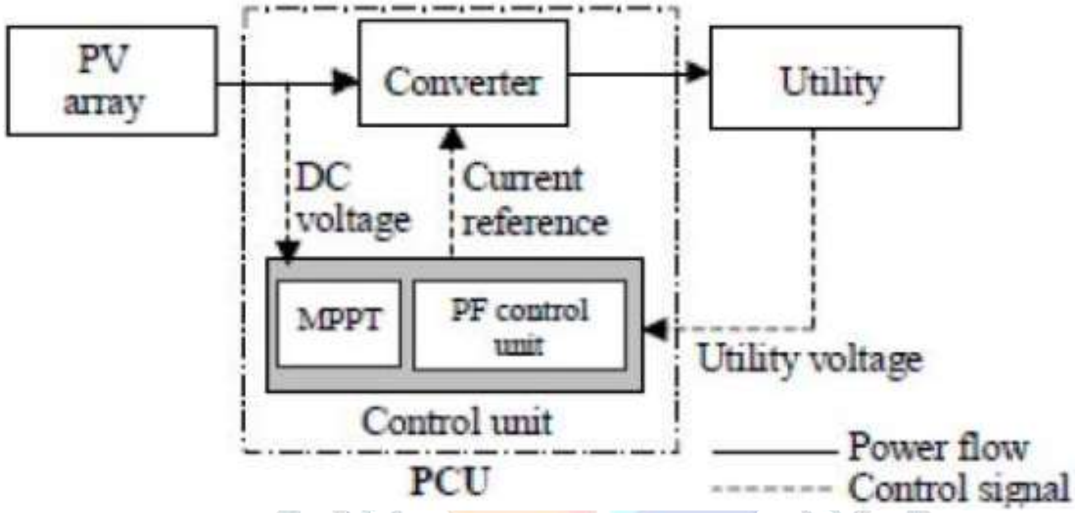

Figure: Single line diagram of D-STATCOM connected distribution system

III. DSTATCOM components:

DSTATCOM involves mainly three parts

(i) IGBT or GTO based dc-to-ac inverters: These inverters are used which create an output voltage wave that's controlled in magnitude and phase angle to produce either leading or lagging reactive current, depending on the compensation required.

(ii) L-C filter: The LC filter is used which reduces harmonics and matches inverter output impedance to enable multiple parallel inverters to share current. The LC filter is chosen in accordance with the type of the system and the harmonics present at the output of the inverter.

(iii) Control block: Control block is used which switch Pure Wave DSTATCOM modules as required. They can control external devices such as mechanically switched capacitor banks too. These control blocks are designed based on the various control theories and algorithms like instantaneous PQ theory, synchronous frame theory etc.

Basic operating principle of a DSATCOM is similar to that of synchronous machine. The synchronous machine will provide lagging current when under excited and leading current when over excited. DSTATCOM can generate and absorb reactive power similar to that of synchronous machine and it can also exchange real power if provided with an external device DC source.
1) Exchange of reactive power:- if the output voltage of the voltage source converter is greater than the system voltage then the DSATCOM will act as capacitor and generate reactive power(i.e.. provide lagging current to the system.
2) Exchange of real power: as the switching devices are not loss less there is a need for the DC capacitor to provide the required real power to the switches. Hence there is a need for real power exchange with an AC system to make the capacitor voltage constant in case of direct voltage control. There is also a real power exchange with the AC system if DSTATCOM id provided with an external DC source to regulate the voltage incase of very low voltage in the distribution system or in case of faults. And if the VSC output voltage leads the system voltage then the real power from the capacitor or the DC source will be supplied to the AC system to regulate the system voltage to the =1p.u or to make the capacitor voltage constant. Hence the exchange of real power and reactive power of the voltage source converter with AC system is the major required phenomenon for the regulation in the transmission as well as in the distribution system. For reactive power compensation, DSTATCOM provides reactive power as needed by the load and therefore the source current remains at unity power factor (UPF). Since only real power is being supplied by the source, load balancing is achieved by making the source reference current balanced. The reference source current used to decide the switching of the DSTATCOM has real fundamental frequency component of the load current which is being extracted by these techniques.

A STATCOM at the transmission level handles only fundamental reactive power and provides voltage support while as a DSTATCOM is employed at the distribution level or at the load end for power factor improvement and voltage regulation. DSTATCOM can be one of the viable alternatives to SVC in a distribution network. Additionally, a DSTATCOM can also behave as a shunt active filter, to eliminate unbalance or distortions in the source current or the supply voltage as per the IEEE-519 standard limits. Since a DSTATCOM is such a multifunctional device, the main objective of any control algorithm should be to make it flexible and easy to implement in addition to exploiting its multi functionality to the maximum. The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement. The control algorithms of a DSTATCOM are mainly implemented in the following steps:

1. Measurements of system voltages and current and signal conditioning.
2. Calculation of compensating signals.
3. Generation of firing angles of switching devices.

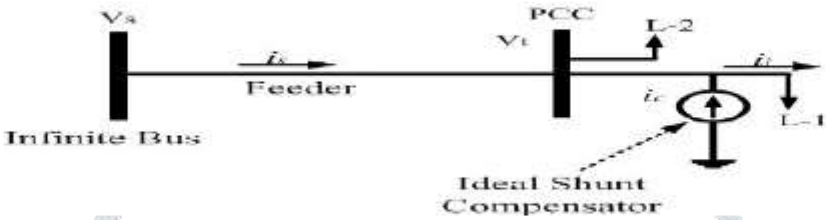

Figure: Single line diagram of DSTATCOM

DSTATCOM is employed to provide continuous voltage regulation using an indirectly controlled converter. In the Figure the shunt injected current Ish corrects the voltage sag by adjusting the voltage drop across the system impedance Zth. The value of Ish can be controlled by adjusting the output voltage of the converter.

The shunt injected current Ish can be written as,

Ish= IL- IS= IL- (Vth − VL)/Zth ----------------------(1)

Ish^η= IL^ -θ - (Vth/Zth) ^(δ-β) + (Vth/Zth) ^- β ------------(2)

The complex power injection of the D-STATCOM can be expressed as,

Ssh=VL Ish*

It may be mentioned that the effectiveness of the DSTATCOM in correcting voltage sag depends on the value of Zth or fault level of the load bus. When the shunt injected current Ish is kept in quadrature with VL, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of Ish is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system. The control scheme for the DSTATCOM follows the same principle as for DVR. The switching frequency is set at 475 Hz.

IV. CONTROL STRATEGY:

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 rms 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.

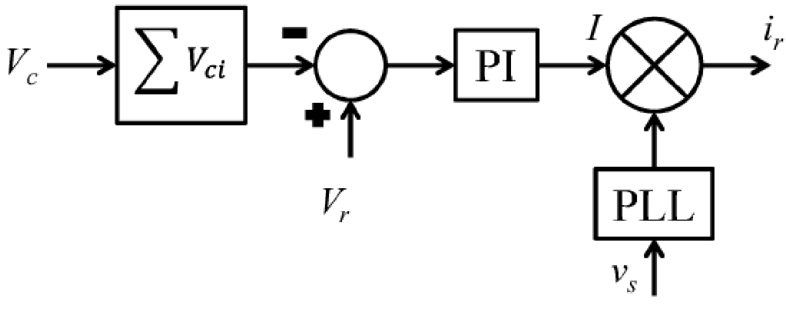

Figure: Indirect Controller

Above figure shows that 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 and the output is the angle d, 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 and generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

V. WORKING PRINCIPLE AND SIMULATION PARAMETERS:

A Distribution Static Synchronous Compensator (D-STATCOM) is utilized to compensate voltage on a 25-kV distribution line. Two feeders are connected to the transmission line between buses B2 and B3. At the bus B2 a shunt capacitor is utilized for power factor correction. The varying load will allow D-STATCOM to mitigate voltage flicker problem. A three phase fault is connected in parallel between transformer of 25kV/600V and bus B3.

Two modes of operations are used in D-STATCOM namely: voltage regulation and Q regulation. The injected reactive current which is modulated at 5 Hz is on trace 3 of scope 3.

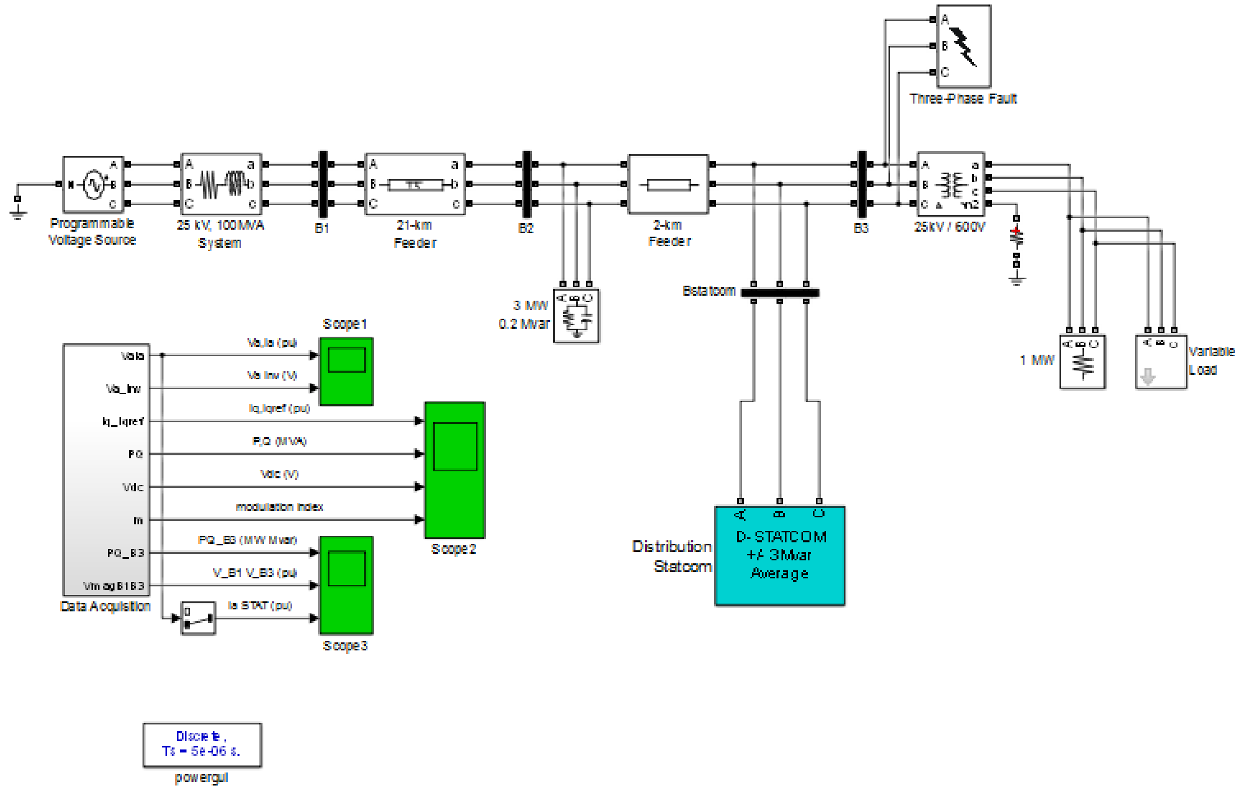

Figure: Distribution line with D-STATCOM and Three-phase fault.

VI. SIMULATION AND RESULTS:

A. Fault

- *Voltage Regulation:* The D-STATCOM controller is set to regulating voltage. The active power (P) and reactive power varies for time t=0.05 to t=1s and becomes constant after that at 3.8pu ad 1.5pu respectively. Voltages at bus B1 and B3 varies for time t=0.2 s to t=0.45s which is regulated by supplying injected current from D-STATCOM as shown in Figure below.
- *Reactive power(Q) Regulation:* The D-STATCOM controller is to regulating reactive power(Q). The active power (P) and reactive power varies for time t=0.05 to t=4.25s and becomes constant after that at 3.8pu ad 1.5pu respectively. Voltages at bus B1 and B3 varies for time t=0.05 to t=4.50s which bring regulation in Q as shown in Figure below.

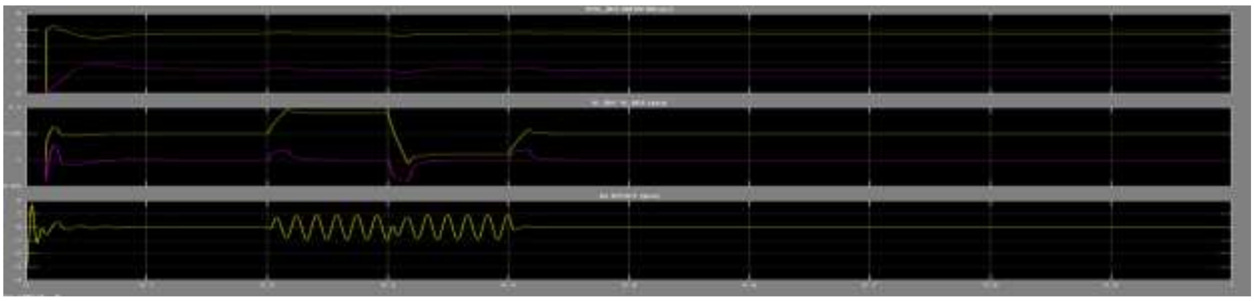

Figure: No fault appeared with voltage regulation .

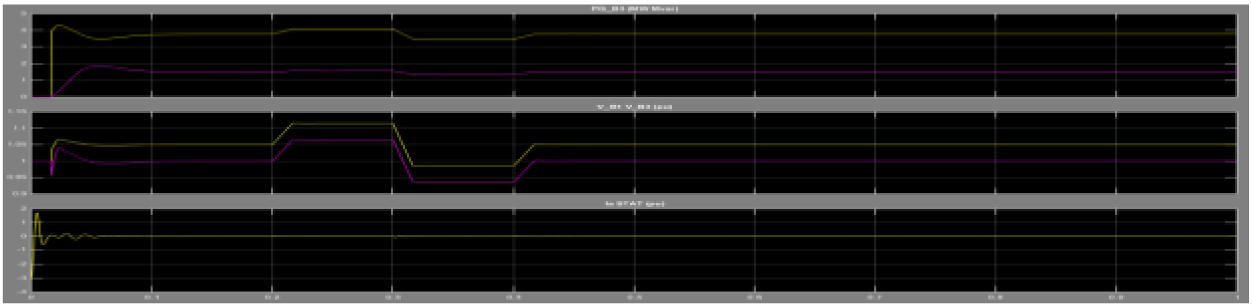

Figure: No fault appeared with reactive power (Q) regulation

B. Fault in phase A, B and C

- *Voltage Regulation:* The D-STATCOM controller is set to regulating voltage. The active power (P) and reactive power varies between 0 to12 pu for time t=0.05 to t=1s and becomes constant after that at 4pu ad 1pu respectively. Voltages at bus B1 and B3 varies for time t=0.5 s to t=1s below 1pu which is regulated by supplying injected current from D-STATCOM of varied amplitude. For time t=1s to 4 s, the variation in voltages at B1 and B3 is less than 0.5pu and therefore D-STATCOM injected current amplitude is also same as shown in Fig.

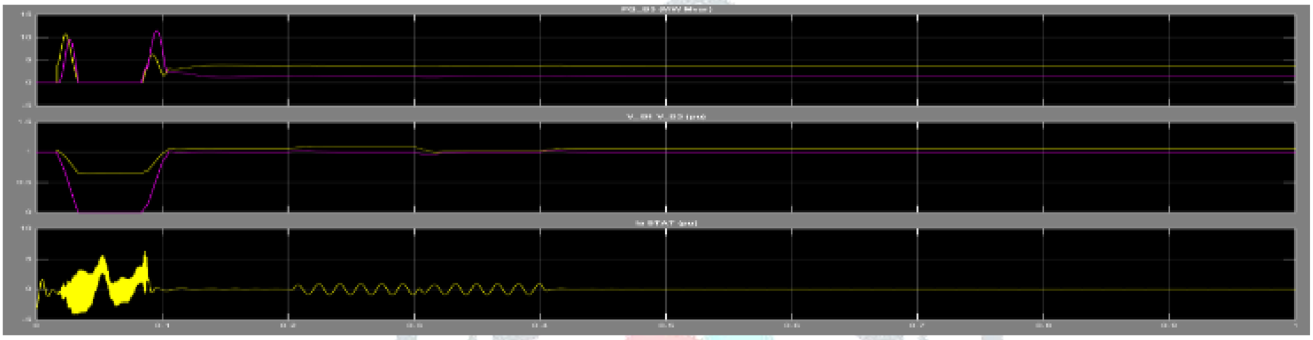

Figure: Voltage Regulation when Fault appeared on all phases A, B and C .

- Q Regulation: The D-STATCOM controller is to regulating reactive power Q. It follows almost the same pattern as for voltage regulation, the difference is in variation of the active power (P) and reactive power, they variation is higher between time t=0.05 to t=0.07 as shown in Fig.

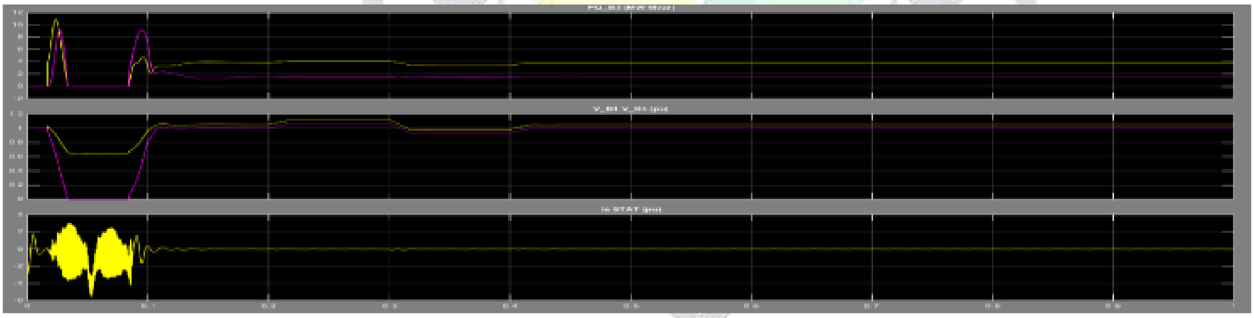

Figure: Reactive power Regulation when Fault appeared on all phases A, B and C

C. Fault in phase A

- Voltage Regulation: The D-STATCOM controller is set to regulating voltage. The active power (P) and reactive power varies for time t=0.05 to t=1s. The reactive power varies at higher rate as compare to active power. The variation in reactive power is from 0 to 12 pu and voltage at B3 varies between 0.1 pu to 1pu. The variation in voltage at B3 is due to introduced fault near B3. The voltage is regulated by injecting current of larger amplitudes from D-STATCOM, varying from -12 pu to 12 pu as shown in Fig.

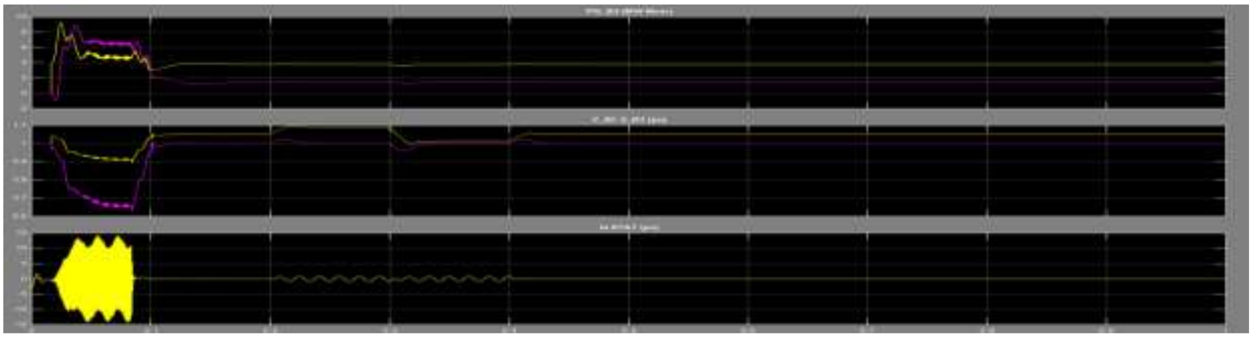

Figure: Voltage Regulation when Fault appeared on Phase A only.

- Q Regulation: The D-STATCOM controller is set to regulating reactive power(Q). The pattern is same as for voltage regulation as shown in Fig.

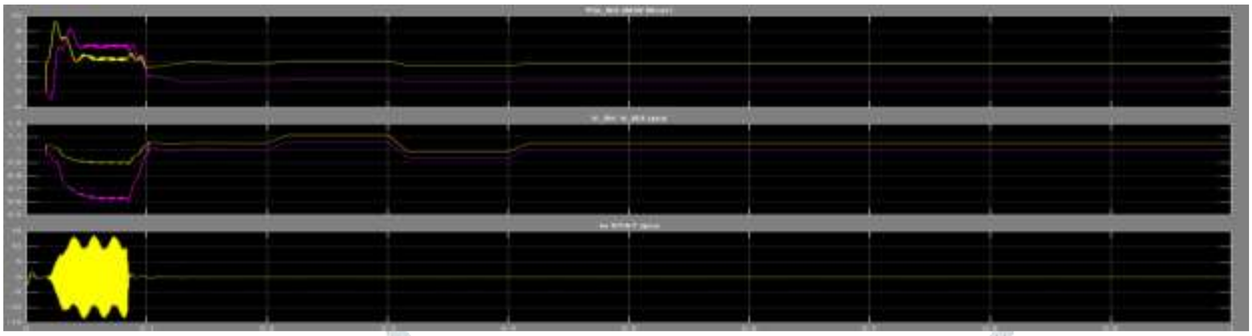

Figure: Reactive power regulation when the fault occurs on Phase A only.

VII. CONCLUSION

In order to supply uninterrupted supply of power to end users domestic or industrial with good power quality The paper introduces faults near a load B3. The loads are introduced in all phases, combination of two and one phase. The D-STATCOM is used for compensation in presence of faults. The MATLAB/Simulink model is used to generate results of a 25kV/100MV. The results show that when faults are introduced there is variation in active power, reactive power and voltages at B3 which is compensated by D-STATCOM by injecting current parallel close to B3 feeder.

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