*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 7 July 2022

I_d – I_q Theory Based DSTATCOM for Compensation of Reactive Power and Harmonics

Authors: Garima Dixit; Imran Khan; Malik Rafi
*Azad Institute of Engineering & Technology, Lucknow (India)
(dixitgarima24@gmail.com, pe.imran@gmail.com , mali_rafi@rediffmail.com)

Abstract: This paper depicts DSTATCOM for reactive power and harmonic compensation in distribution system. A distribution static compensator (DSTATCOM) proves to be a viable solution for the mitigation of power quality problems. As the power demand raises every day and implication of non-linear loads increases power quality issues like reduction in reactive power and induction of harmonics. This problem in distribution system is addressed by employing DSTATCOM. By controlling DSTATCOM power quality issues can be addressed. I_d – I_q control theory is simple and can control DSTACOM for reactive power issues and to reduce harmonics. Conventional Id – Iq theory suffers from high switching losses due to high frequency harmonic current as reference. This paper depicts a novel current reference I_d – I_q theory for compensation of harmonics and reactive power reducing losses and thus system efficiency is increased. Reference signal is taken from the source current instead of conventional method of harmonic reference currents thus enabling the user to have complete control over the source parameters.

Keywords: DSTATCOM, DVR, harmonics, power quality, PWM approach

1. INTRODUCTION

In the early days of power transmission due to reactive power unbalances, the problems like voltage deviation during load changes and power transfer limitation were observed. Most of the AC loads are consuming reactive power due to presence of reactance. Power quality is getting poor due to heavy consumption of reactive power. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic configurations to be introduced to the tasks of power Transmission and load flow control. Over the transmission parameters, the FACTS devices offer a fast and reliable control. Most widely known custom power devices are SVC, STATCOM, IPC, DVR, UPFC, TCSC, TCPST and DSTATCOM. Among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system. DSTATCOM is capable to inject a current into the system to correct the power factor and reactive power compensation and harmonics reduction. The DSTATCOM applications are mainly for sensitive loads that may be drastically affected by fluctuations in the system voltage.

The presence of non-linearity in load makes power network to disturb. Use of more power electronic converters in this modern era induces harmonics in to the system to which they are connected as they constitute non-linear loads. Also loads consume reactive power due to the presence of reactance. Many researchers have studied to improve the power quality by using many techniques. Use of custom power devices can help effectively to deliver power with good quality. FACTS devices are a type of custom power devices which can regulate the voltage, line impedance, phase angle between sending end and receiving end voltage. Some of the FACTS devices are STATCOM (static compensator), UPQC (unified power quality conditioner), and DVR (dynamic voltage restorer). STATCOM used in distribution system can be termed as DSTATCOM (distribution static compensator). DSTATCOM [1-4] can effectively control reactive power flow in the system and also can contribute to nullification of harmonics.

DSTATCOM could be a voltage-source electrical converter (VSI) primarily based shunt device typically accustomed to compensate reactive-power and disturbances caused by non linear loads connected in distribution system. Performance of

DSTATCOM depends on the control strategy employed. For this there are many control techniques for DSTATCOM. Out of available control strategies and internal controls of a DSTATCOM play a very important role in the effectiveness of the DSTATCOM in maintaining the power quality at PCC (point of common coupling). For extraction of current reference parts varied management algorithms [5-9] are projected for the management of DSTATCOM like phase shift management, Decoupled current management (p - q theory), hysteresis control and current reference $I_d - I_q$ theory. In this paper a modified $I_d - I_q$ theory is used to control DSTATCOM [10-12] reducing losses. Reference currents are drawn from the fundamental component rather to reference harmonic current in conventional theory. With this, complete hold over source can be achieved and can be easily extended for integration of DG in distribution system through DSTATCOM. This paper deals with the planning of the management strategy for DSTATCOM. The distribution static synchronous compensator (DSTATCOM) with proposed control strategy is fundamental current reference Id - Iq theory is implemented for reactive power and harmonics compensation. The simulation model of a DSTATCOM has been build up with the help of MATLAB/SIMULINK; simulated results are compared with and without DSTSTCOM.

2. D-STATCOM Operation

The shunt related Static Synchronous Compensator is a custom strength device and while it is placed within the utilization segment of electricity device then it's miles known as D-STATCOM.

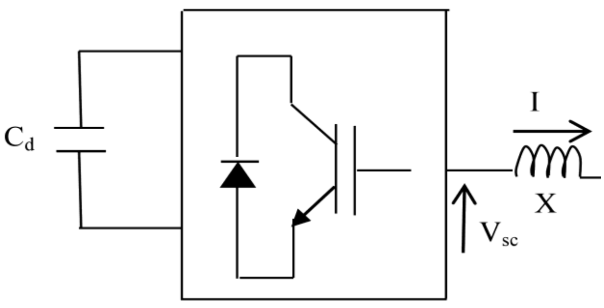

Fig. 1: Schematic of a Distribution STATCOM

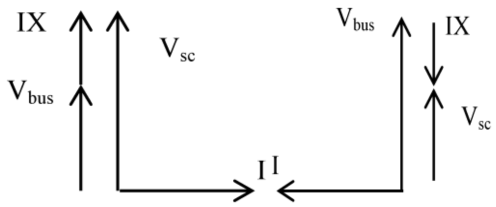

Fig. 2: Capacitive and Inductive operation

The D-STATCOM is a parallel-related device based totally on Voltage Source Converter (VSC), incorporating superior strength electronics to deliver power great solutions for software and for business or business programs. A schematic diagram and corresponding phasor diagram confirmed in Fig. 1 and 2 respectively. The converter may arrange to behave as a distribution STATCOM [7,8]. In its simplest implementation, a sine PWM approach has integrated to generate desired gate sign for IGBT. The electricity drift throughout the inductor has governed via equations:

$$I = \frac{Vc - Vac}{jX} \quad (1)$$

or in terms of real and imaginary power

$$P = \frac{Vc \times Vbus}{X} \sin \delta \quad (2)$$

$$Q = \frac{Vc \times Vbus}{X} \cos \delta - \frac{Vbus^2}{X} \quad (3)$$

Where: V_c– converter output voltage
V_{bus}-system voltage
X-coupling reactance
I-converter current
δ -angle between V_c and V_{bus}

The distribution STATCOM can perform in an equal manner to exchange actual and reactive electricity float with software bus with the aid of controlling perspective and voltage significance respectively between converter and bus [8-10]. The working feature of a distribution STATCOM in accordance with dc storage device is proven in Fig. 3. The flexibility supplied via the speedy switching of the IGBTs lets in extra sophisticated manage schemes, based totally on voltage space vector strategies. The compensator can manipulate big reactive modern along side brief when it operated in voltage law mode.

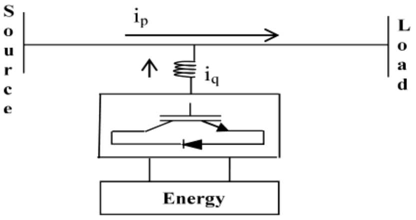

Fig. 3: Functions of D-STATCOM

The reactive cutting-edge will determine the voltage regulation at the reference voltage, Vref, with a purpose to relies upon on the minimum and most variety of present day injected by way of the converter [10- 14]. Its i-v feature has a slope indicated in Fig. Three. Four and a voltage stoop is typically used between zero.01-zero.04 at maximum reactive strength output. The regulated voltage is given by

$V_{ref} = V - X_s\ I$

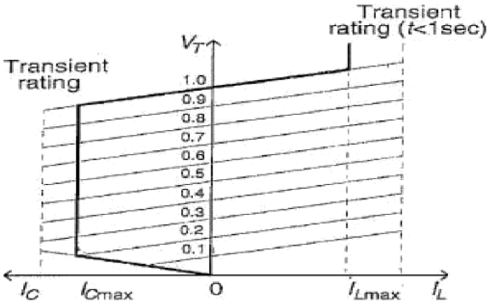

Fig. 4: i-v characteristics of STATCOM

4 Strategy For Voltage Compensation:

The voltage compensation using phasor algebra according to steady state analysis has described in detail [4]. In the circuit of Fig. 5, it can be find out by comparing the source voltage and line voltage [15-18], that the common coupling point voltage can expressed as

$$V \cong E[1 - \frac{Q_l - Q_c}{S_{sc}}] \qquad (4)$$

Where,

Ql : reactive component ofload

Q_c: injected reactive component

S_{SC}: short circuit level at common coupling point

The common coupling point voltage can be change according to the load magnitude of reactive power.

3. Results and discussion

A Distribution Static Synchronous Compensator (D- STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and a couple of km) transmit electricity to masses connected at buses wide variety of B2 and B3. A shunt capacitor is used for electricity issue correction on the bus B2. The 600-V load is connected to the bus B3 via a 25kV/600V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, accordingly generating voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz in order that its obvious power varies approximately among 1 MVA and five.2 MVA, while maintaining a 0.9 lagging electricity aspect. This load version will permit you to observe the potential of the D- STATCOM to mitigate voltage flicker.

The D- STATCOM regulates bus B3 voltage via absorbing or producing reactive electricity. This reactive electricity transfer is finished via the leakage reactance of the coupling transformer by means of producing a secondary voltage in phase with the primary voltage (network facet). This voltage is supplied with the aid of a voltage-sourced PWM inverter. When the secondary voltage is decrease 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 producing reactive power.

The D-STATCOM consists of the following components:

- a 25kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network.
- a voltage-sourced PWM inverter. In this example, the PWM inverter is replaced on the AC side with three equivalent voltage sources averaged over one cycle of the switching frequency (1.68 kHz). Harmonics generated by the inverter are therefore not visible with this average model. On the DC side, the inverter is modeled by a current source charging the DC capacitor. The DC current Idc is computed so that the instantaneous power at the AC inputs of the inverter remains equal the instantaneous power at the DC output (Va*Ia + Vb*Ib + Vc*Ic = Vdc*Idc).
- LC damped filters connected at the inverter output. Resistances connected in series with capacitors provide a quality factor of 40 at 60 Hz.
- a 10000-microfarad capacitor acting as a DC voltage source for the inverter
- a voltage regulator that controls voltage at bus B3
- anti-aliasing filters used for voltage and current acquisition.

The D-STATCOM controller consists of several functional blocks:

- a Phase Locked Loop (PLL). The PLL is synchronized to the fundamental of the transformer primary voltages.
- two measurement systems. Vmeas and Imeas blocks compute the d-axis and q-axis components of the voltages and currents by executing an abc-dq transformation in the synchronous reference determined by sin(wt) and cos(wt) provided by the PLL.
- an inner current regulation loop. This loop consists of two proportional-integral (PI) controllers that control the d-axis and q-axis currents. The controllers outputs are the Vd and Vq voltages that the PWM inverter has to generate. The Vd and Vq voltages are converted into phase voltages Va, Vb, Vc which are used to synthesize the PWM voltages. The Iq reference comes from the outer voltage regulation loop (in automatic mode) or from a reference imposed by Qref (in manual mode). The Id reference comes from the DC-link voltage regulator.
- an outer voltage regulation loop. In automatic mode (regulated voltage), a PI controller maintains the primary voltage equal to the reference value defined in the control system dialog box.
- a DC voltage controller which keeps the DC link voltage constant to its nominal value (Vdc=2.4 kV).

The electrical circuit is discretized using a sample time Ts=40 microseconds. The controller uses a larger sample time (4*Ts=160 microseconds).

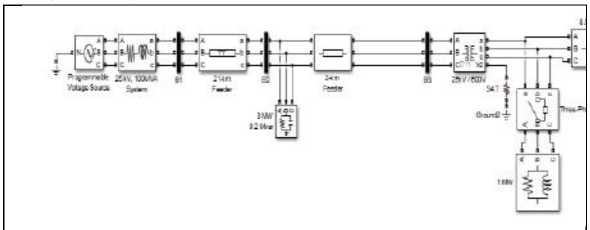

Figure 6:Power system model with variable load and voltage fluctuation

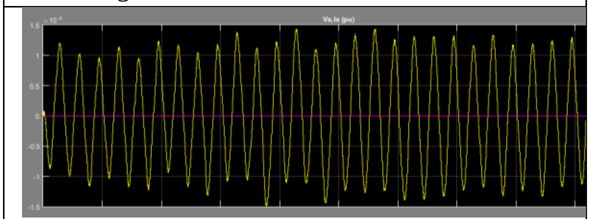

Figure 7: Voltage waveform without connection of D STATCOM

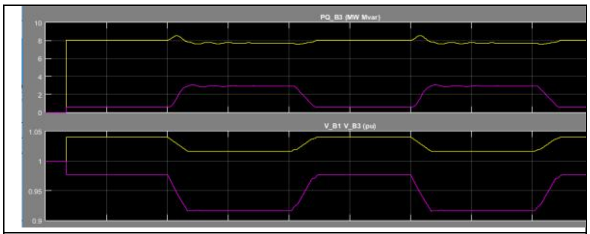

Figure 8:Power and voltage wavefor representing voltage sag due to inductive load.

Figure 8 shows that how the source voltage inserted at the 1 puvoltage the drop in values are: [0.97 0.91 0.97 0.91 0.97]pu at time instants [0.05 0.15 0.25 0.35 0.45] seconds. Here a constant active load is connected.

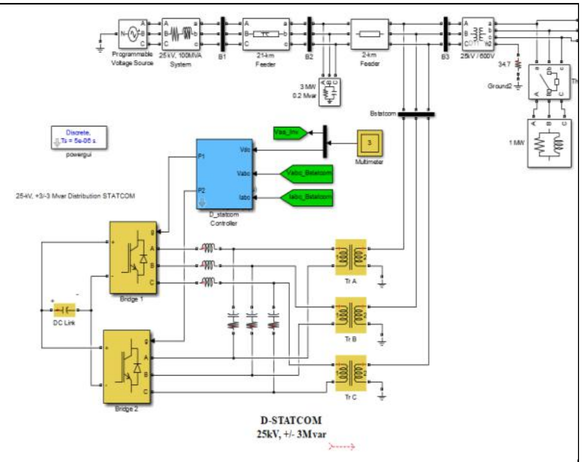

Figure 9:Power system with variable load for sag compensation with DSTATCOM

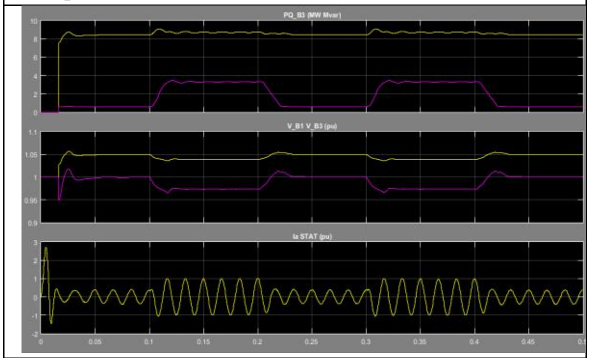

Figure 10 :Minimization of voltage sag with D-STATCOM

Sag origination and mitigation

An additional 1 MW, 3MVAR load is connected to the existing one for two different short duration of time. This load is switching on for 0.1 second ranging 0.1 to 0.2 second and again for 0.1 second ranging 0.3 to 0.4 second duration using a circuit breaker. The voltage waveform and the magnitude are shown in the Fig.4.3. The voltage magnitude during the inductive load 'switching on' period is found out to be 0.9160 pu. Hence, voltage sag is created and can be mitigated by placing a D-STATCOM. The compensated voltage waveform and its magnitude are found to be 0.9731 pu which is shown in Fig.10.

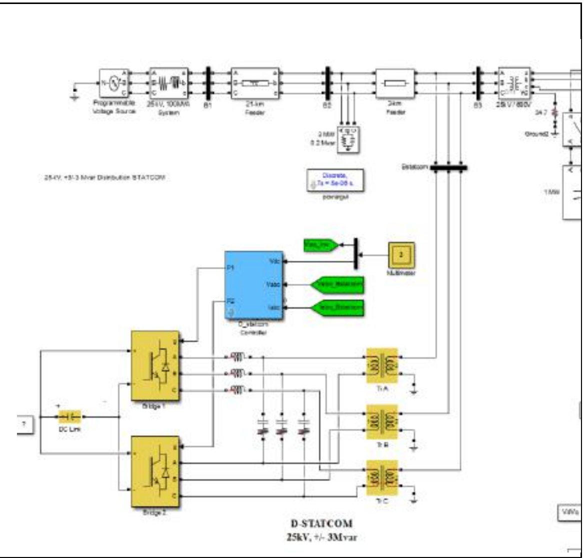

Figure 11:Power system with load variation with capacitive load for insertion of swell.

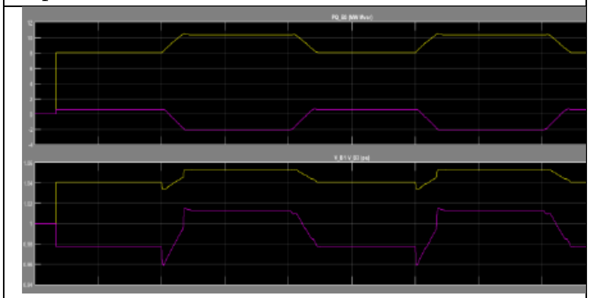

Figure 12:Power and voltage waveform showing swell in voltage without DSTATCOM

Swell origination and mitigation

Figure 12 shows that the capacitive load of 3MVAR is connected in parallel with 8.5MW resistive load by circuit breaker.This load is introduced at 0.1 to 0.2 second and 0.3 to 0.4 sec. On insertion of this load swell is produced in the voltage waveform shown in figure 4.8. and during these periods the voltage magnitude is found to be 1.0127 puIn figure13. It can be seen that the voltage swell is completely removed and the voltage has reached to given source voltage value i.e.1.000 pu.by using D-STATCOM.

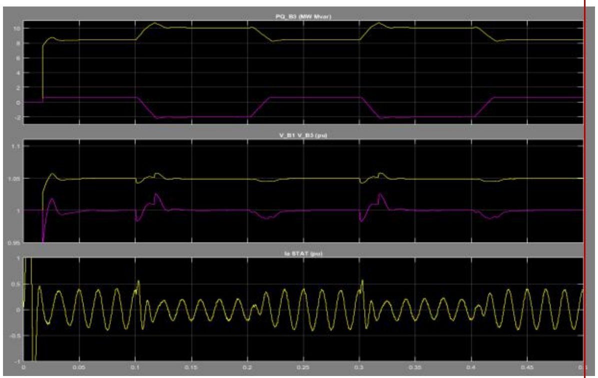

Figure 13: Minimization of swell using DTATCOM.

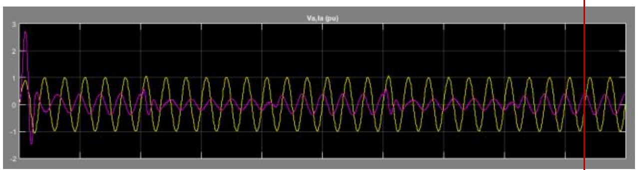

Figure 14: Phase voltage and current with DSTATCOM for system having swell due to capacitive load.

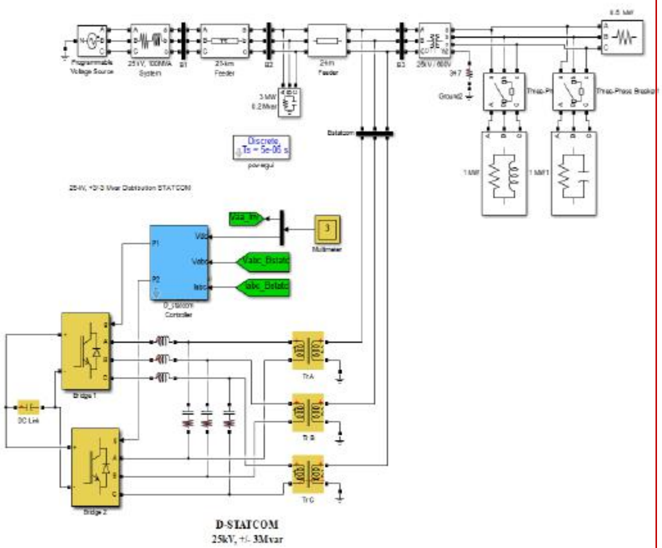

Fig. 15: Simulink diagram representing the network with voltage fluctuation.

Voltage fluctuation : The voltage variation is formed by varying capacitive and inductive load with the help of three phase circuit breaker shown in Figure 15, as its a phenomenon of repetitive and random variation of supply voltage from a nominal value for certain period of time. The voltage magnitude is decreases below 1 pu for duration of 0.1 to 0.2 seconds and 0.3 to 0.4 seconds, during which voltage magnitude is 0.9161pu. Similarly, it increases above 1 pu for period of 0.2 to 0.3 seconds and 0.4 to 0.45 seconds and magnitude of voltage is found to be 1.0127 pu. As shown in figure 16.Figure 17 shows that after compensating voltage magnitudes are 0.973 and 1.000 pu in the category of under voltage & over voltage respectively.

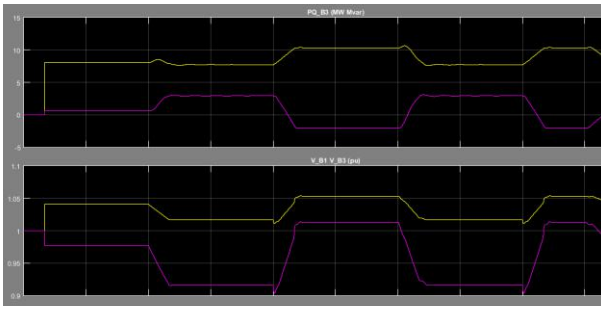

Figure 16:Power and voltage waveform showing voltage fluctuation without DSTATCOM.

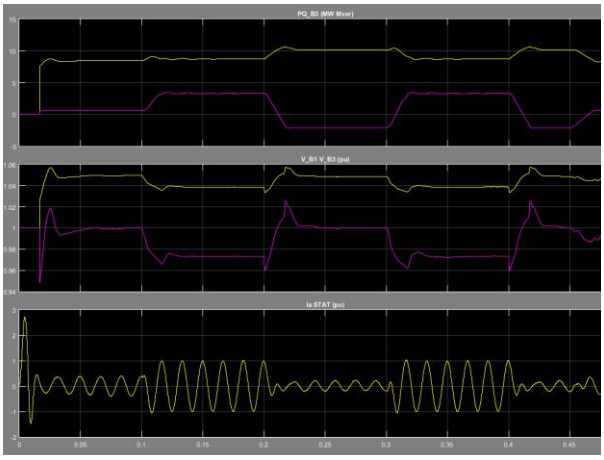

Figure 17: Minimization of voltage fluctuation using DSTATCOM.

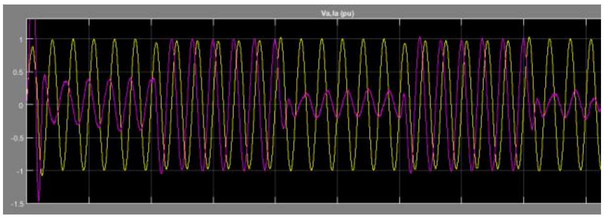

Figure 18: Phase voltage and current with DSTACOM for system having voltage fluctuation due to inductive and capacitive load.

Conclusion and Future Scope

This paper illustrates the power first-class development components in distribution device by DSTATCOM based on d-q-0 reference body. The utilities like home, commercial and industrial are facing severa PQ problems inside the shape of voltage dip, swell and voltage variations or fluctuations. The contributions of these strength exceptional problems are intense in our current electric systems in recent times. In this paintings the estimation and mitigation of voltage sag, voltage swell, voltage fluctuation and reactive electricity restricting for distinct loading condition in software through using Custom Power Devices. The D-STATCOM has taken as a compensating device, because it recognized for its flexibleness, easy implementation, dynamic load reimbursement & multifunctional operation. The version of D-STATCOM connected in shunt with a 3-phase supply feeding a steady and a variable load, that is develop the use of Simulink. The Simulated end result demonstrates that D-STATCOM can take into account as a possible solution for solving voltage dip, swell and fluctuation issues.

Here, the examine of shunt related Converter working as a D-STATCOM accomplished to enhance the voltage profile in distribution network with static linear load. The power pleasant troubles like voltage sag, swell and fluctuation are analysed for a nine.6 MW and 3 MVAR variable loads and consequences have been offered. The Simulation result suggests that due

to unexpected switching on of load & sudden off of load, the Voltage Dip, Swell and Voltage Variation are created, which go to pot the systems electricity high-quality. The deteriorated voltage profile of the device can carry returned to its authentic one by means of putting a parallel-connected Converter, which is likewise able to enhance its best of energy via limiting the gadget electricity component in a targeted limit.

The fee of THD is likewise determined be minimized in all case of sag swell and voltage fluctuation. The THD data in any respect time is recorded in each situation this is in presence and shortage of D-STACOM and the plots are observed. It is determined that the DSTATCOM is very efficient in minimizing the THD. It is justified with the aid of calculating common THD in both situations with and without DSTACOM and for presence of sag and swell the average THD is found to be dropped. Thus it may be concluded that DTATCOM is helpful in minimizing sag, swell and voltage fluctuation due to variable load as well as it reduces the THD.

References

1. G. Hingoranai Narain and GYugyi Laszlo “Understanding Facts A JOHN WILEY & SONS” in 2000 Inc. publication.

2. R. C. Dugan M. F. McGranaghan and H.W. Beaty “Electrical power system quality” in Vol. 1, 1996 McGraw-Hill c1996.

3. K. Padiyar FACTS Controllers in Power Transmission and Distribution 2007 New Age International

4. Kundur Prabha “Power system Stability and Control” in 1994 McGraw-Hill.

5. S. P. Gopal and D. R. Patil, “Hysteresis Band Current Controller for voltage regulation and harmonic mitigation using DSTATCOM,” 2016 International Conference on Computation of Power, Energy Information and Commuincation (ICCPEIC), Chennai, 2016, pp. 707-712

6. S. Arya; B. Singh; R. Niwas; A. Chandra; K. Al Haddad, “Power Quality Enhancement Using DSTATCOM in Distributed Power Generation System,” in IEEE Transactions on Industry Applications, Vol. PP, No. 99, pp.1-1.

7. S. S. Pawar, A. P. Deshpande and M. Murali, “Modelling and simulation of DSTATCOM for power quality improvement in distribution system using MATLAB SIMULINK tool,” 2015 International Conference on Energy Systems and Applications, Pune, 2015, pp. 224-227.

8. F. Shahnia, “Application and control of a DSTATCOM to couple neighboring low voltage feeders,” 2016 IEEE International Conference on Industrial Technology (ICIT), Taipei, 2016, pp. 476-481.

9. K. Kant, S. R. Arya and B. Singh, “Current sensorless control algorithm of DSTATCOM for power quality improvement,” 2015 Annual IEEE India Conference (INDICON), New Delhi, 2015, pp. 1-5.

10. M. Angulo D. A. Ruiz-Caballero J. Lago M. L. Heldwein and S. A. Mussa “Active power filter control strategy with implicit closed-loop current control and resonant controller” IEEE Transactions on Industrial Electronics, Vol. 60, No. 7, pp. 2721-2730 July 2013.

11. P. Lohia M. K. Mishra K. Karthikeyan and K. Vasudevan “A minimally switched control algorithm for three-phase fourleg VSI topology to compensate unbalanced and nonlinear load”, IEEE Trans. on Power Electronics, Vol. 23, No. 4, pp. 1935-1944 July 2008.

12. A. Ghosh and G. Ledwich “Load compensating DSTATCOM in weak AC systems” IEEE Transactions on Power Delivery, Vol. 18, No. 4, pp. 1302-1309 Oct. 2003.