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POWER QUALITY IMPROVEMENT IN DISTRIBUTION NETWORK USINGDSTATCOM WITH BATTERY ENERGY STORAGE SYSTEM

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***Abstract*— The distribution static compensator (DSTATCOM) provides fast control of active and reactive powers to enable load compensation, harmonics current elimination, voltage flicker mitigation, voltage and frequency regulation. This paper presents power quality improvement technique in the presence of grid disturbances and wind energy penetration using DSTATCOM with battery energy storage system. DSTATCOM control is provided based on synchronous reference frame theory. A modified IEEE 13 bus test feeder with DSTATCOM and wind generator is used for the study. Power quality events during grid disturbances such as feeder tripping and re-closing, voltage sag, swell and load switching have been studied in association with DSTATCOM. The power quality disturbances due to wind generator outage, synchronization and wind speed variations have also been investigated. The study has been carried out using MATLAB/SIMULINK and the simulation results are compared with real time results obtained by the use of real time digital simulator (RTDS) for validating the effectiveness of proposed methodology. The proposed method has been proved to be effective in improvement of power quality with all disturbances synchronization of renewable energy (RE) generator.**

Keywords—Power quality improvement, DSTATCOM, power factor correction, reactive power compensation, Total Harmonic Distortion(THD)*key words)***

I. INTRODUCTION

The sources of poor power quality can be categorized into two groups: (1) actual loads, equipment and components and (2) subsystems of transmission and distribution systems. Poor quality is normally caused by power line disturbances such as impulses, notches, voltage sag and swell, voltage and current unbalances, momentary interruption and harmonic distortions. The International Electro-Technical Commission (IEC) classification of power quality includes loss-of-balance as a source of disturbance. IEEE standard also includes this feature as a source of quality deterioration of electric power. The other major contributors to poor power quality are harmonics and reactive power. Solid state control of ac power using high speed switches are the main source of harmonics whereas different non-linear loads contribute to excessive drawn of reactive power from supply. It leads to catastrophic consequences such as long production downtimes, mal-function of devices and shortened equipment life [1]. IEEE standards determined power quality problems into seven problems according to wave form: Transients• Interruptions• Sag (dips) /under voltage• Swell/overvoltage• Waveform distortion• Voltage fluctuation• Frequency variations•

One of the most common power quality problems today is voltage sag (dips). A voltage dip is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration from half a cycle to 1 min. In a three-phase system a voltage dip is by nature a three phase phenomenon, which affects both the phase-to ground and phase-to-phase voltages. A voltage dip 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. Typical faults are single-phase or multiple-phase short circuits, which lead to high currents. The high current results in a voltage drop over the network impedance. At the fault location, the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged [2,3]. The Flexible AC Transmission System devices (FACTS) offer a fast and reliable control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand, the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are D-STATCOM, UPQC, DVR among them D-STATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system [4]. D-STATCOM is a fast response solid-state power electronic device provides shunt injected current at the point of connection for the distribution system to correct voltage sag. This value of the shunt injected current can be controlled by adjusting the output voltage of the converter to improve power quality. D-STATCOM can exchange both active and reactive power with the distribution system by changing the amplitude and phase angle of the converter with respect to the terminal voltage of the line.it can be used to provide voltage regulation, power factor correction, compensation of

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harmonics and during transient condition provides leading or lagging reactive power to active system stability.

II. D-STATCOM CONFIGURATION AND OPERATION

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a DSTATCOM are shown in Figure 1. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, and a control strategy

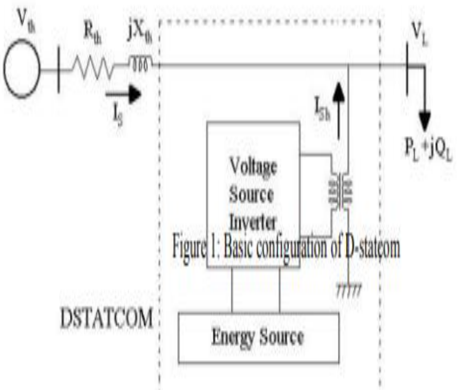

Fig.1 Block Diagram of Statcom

The main component block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage with desired magnitude and frequency algorithms

III. LITERATURE SURVEY

Saeed Mohammad [1] is represent a paper which show a power quality is a major issue in distribution system. In the distribution system problem will be occurs regarding reactive power due to the large power angle with voltage magnitude gradient. The D-STATCOM is used in FACTS devices to compensate the reactive power. D-STATCOM is 3-phase VSC used to compensate the voltage and make the system stable by absorbing and generating the reactive power. The model of D-STATCOM was analyzed and developed for use in Simulink. D-STATCOM also control reactive power and regulate voltage. D-STATCOM also improve power system performance. Bhim Singh, Sabha Raj Arya[2] represent the paper in which –phase D-STATCOM design. The control algorithm based on correlation and cross correlation function approach the quality improvement during non-linear and linear distribution system. In this paper, the functional active and reactive power compensation on load current. The D-STATCOM is make under non-linear and linear loads. The performance of the system in MATLAB Simulink and SPS toolbox. The designed and control model of D-STATCOM is used in 3- phase distribution system. The control algorithm under correlation and cross correlation function. Which is used to generating switching signals for D-STATCOM in 3-phase system. D-STATCOM is used to reduce THD, reactive power compensation and also load balancing. The dc bus voltage of D-STATCOM can be regulate without overshoot. Mr. Vaishali P Kuralkar[3] Doing in this paper the FACTS devices is a devices which is capable to control the voltage, transmission line, devices STATCOM and UPFC are analyzed in this paper. Analysis of the standard 5 bus system done static and dynamic with the help of MATLAB. Result of network using UPFC and STATCOM are compared in terms of active and reactive power flow in line. The performance of injected voltage, injected phase and phase distortion are show in dig and graph. This paper shows the simulation methods which are required for FACTS devices UPFC and STATCOM. UPFC is able to control voltage that affects the power flow in the transmission line. Kyungsoo LEE, Hirotaka KOIZUMI and Kosuke KUROKAWA [4] Here, D-UPFC is used to control the distribution system voltage during voltage sages and swells. In the DUPFC concepts single phase. Converters generate power which are using switching outline when voltage variation occurs. A transformer in series is used to compensate voltage to the load. In this paper simulation are used for testing the voltage sag and swell . Zang Dongling, Li Guoxin [5] In this paper the circuit of D-STATCOM. The model of D-STATCOM is based on the 3-level voltage inverter. Which build by lead in switch function. In this research main focus on the control method of D-STATCOM. The main purpose of this dissertation to detect the reactive power. The PWM controller used to find the current technology achieve to direct control. The result of D-STATCOM shows in Matlab Simulink. The need of VAR compensation to improve the voltage regulation. That's by we study on the D-STATCOM. The switching functions build with the help of mathematical expression. The simulation is done with the help of Matlab Simulink. The result shows to compensating reactive power. Kyungsoo LEE, Kenichiro Yamaguchi, Hirotaka KOIZUMI and Kosuke KUROKAW[6] Controlling over-voltage condition in the distribution system are the problems so far has been faced and it is discussed and eliminated in this paper. The voltage controller is also called the distribution-unified power flow controller (D-UPFC). At high voltage level and power consumption is feed into the system . Sourabh Kothari, Rahul Agrawal, Dr. Surendra Kumar Bharadwaj [7] Is done in this paper presents a review on the enhancement of voltage stability margin by employing FACTS controllers. Due to the sharp increase in power demand, voltage instability & line overloading has become challenging problems for the power engineers. In case of heavily loaded transmission line, reactive power may be insufficient causing voltage drops at various buses. This results in voltage collapse, unexpected line & generator outages which lead to total blackouts of the whole systems. Reactive power unbalancing is the major cause of voltage instability. Therefore to improve & enhance the voltage profile & the stability margin of a power system, FACTS controllers are the alternative solution. Under the contingency conditions, the conventional methods and artificial intelligent techniques 14 are required for handling the complex problems in power system. The authors strongly believe that this paper will be helpful to the researchers. Chintan R Patel, Sanjay N Patel and Dr. Axay J Mehta[8] Done in this paper a transmission line needs controllable compensation for power flow control and voltage regulation. This can be achieved by FACTS controllers. Static Synchronous Series Compensator (SSSC) is a series connected FACTS controller, which is capable of providing reactive power compensation to a power system. The output of an SSSC is series injected voltage, which leads or lags line current by 90°, thus emulating a controllable inductive or capacitive reactance. SSSC can be used to reduce the equivalent line impedance and enhance the active power transfer capability of the line. In this paper, series compensation provided by an SSSC is considered. It can also inject fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. The SSSC can also damp out the oscillations of the system . B.Sharath Kumar and MD.Yaseen [9] Dynamic voltage restorer (DVR) and a unified power flow controller (UPFC) for the compensation of voltage sag is discussed in this paper. A Unified Power Flow Controller (UPFC) is an electrical device for providing fastacting reactive power compensation on voltage electricity networks. The modeling of Zsource based dynamic voltage restorer and UPFC is carried out component wise and their performances are analyzed using MATLAB software. Control of the flow of power over the transmission line has been investigated and simulated on the control circuits.s.energy;

IV. PRINCIPLE DSTATCOM AND ITS COMPONENTS DESCRIPTION

The DSTATCOM is a three-phase and shunt connected power electronic devices. It is connected near the load of the distribution systems. The major components of a DSTATCOM are shown in Figure 1.. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control technique. The basic electronic block of the DSTATCOM is the voltage-sourced convertor that converts an input dc voltage into a three-phase ac output voltage at fundamental frequency in capacitive mode and it converts three phase ac voltage to dc voltage in inductive mode

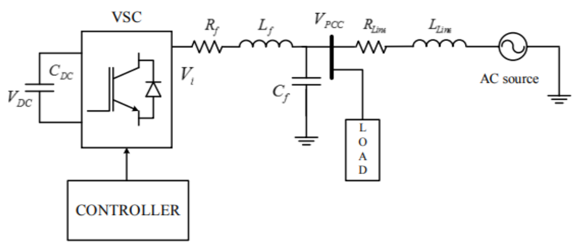

Fig.2: Basic building blocks of the DSTATCOM

DSTATCOM uses an inverter to convert the DC link voltage VDC on the capacitor to a voltage source of amendable magnitude and phase. Therefore the DSTATCOM can be treated as a voltage-controlled source. The DSTATCOM can also be seen as a current controlled source. Figure 3.1 shows the inductance Lf and resistance Rf which represent the equivalent circuit elements of the step-down transformer and the inverter is the main component of the DSTATCOM. The voltage Vi is the effective output voltage of the DSTATCOM and δ is the power angle. The reactive power output of the DSTATCOM can be either inductive or capacitive depending on the operation mode of the DSTATCOM. The controller of the DSTATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the DSTATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the IGBT-based inverter, , can be controlled in the same way as the distribution system voltage, Vs . Figure 3.2 shows the three basic operation modes of the DSTATCOM output current (I), which varies depending upon voltage . If Vi is equal to system voltage , the reactive power is zero and the DSTATCOM does not generate or absorb reactive power. When Vi is greater than , the DSTATCOM acts as an inductive reactance connected at its terminal. The current, I, flows through the transformer reactance from the DSTATCOM to the ac system, and the device generates capacitive reactive power. If Vs is greater than Vi the DSTATCOM acts as a capacitive reactance connected to its terminal. Then the current flows from the ac system to the DSTATCOM, resulting in the device to absorb inductive reactive power

The level of voltage causes the events of large disturbances which do not ensure the stability of the power systems. D-STATCOM for reactive power, voltages and power transfer capability for power systems. Similarly, compensate reactive power, voltage injected and increased power transfer capability. The THD reduction in source current is more in the case of DSTATCOM. Power factor improvement is comparatively better in DSTATCOM system.

V. PROPOSED DSTATCOM AND CONTROL

The controller for VSC of the DSTATCOM generates reference source currents using SRF theory with carrier based pulse width modulation (PWM) technique as shown in

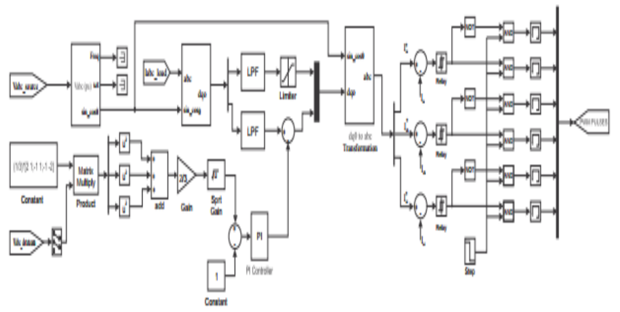

Fig. 3. SRF theory based controller involves the sensing of line voltages and load currents. The Clark's transformation is used to convert three-phase instantaneous load currents (ILa; ILb; ILc) into two phase currents (Ia; Ib) in stationary frame using the following relation.

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 1 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{La} \\ I_{Lb} \\ I_{Lc} \end{bmatrix}$$

The park's transformation is used to convert currents in stationary frame to synchronously rotating frame known as d q components (Id; Iq) as given by the following relation.

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

where h is transformation angle. The cos h and sin h are obtained from phase voltages using phase locked loop (PLL)

technique. The dq components of current are passed through the low pass filter
to extract the dc components (Iddc; Iqdc). The active power component of fundamental reference source current ðI

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ddcÞ is generated by limiting the active power component between 85% and 100% of the rated load DSTATCOM supplies real power when load becomes more than rated load (100%) and it absorbs the same when load becomes less than 85% of the rated value. In the presence of the power drawn by the test system is less than 85% of rated value which results in the power absorbed by the DSTATCOM.
The phase voltages at PCC are calculated from any two line voltages by the following relation
The phase voltages are used to calculate the amplitude of instantaneous terminal voltage at PCC using the following relation

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & 1 \\ -1 & 1 \\ -1 & -2 \end{bmatrix}\begin{bmatrix} V_{AB} \\ V_{BC} \end{bmatrix}$$

$$V_t = \sqrt{\frac{2}{3}\left(V_A^2 + V_B^2 + V_C^2\right)}$$

The voltage error input to the PI controller is given as Verror

$$V_{error} = V_{tref} - V_t$$

where V tref is the reference terminal voltage which is taken as 1 pu in this study.
Reactive power component of fundamental reference source current is generated by subtracting reactive power component from output of the PI controller. These active and reactive power components of fundamental reference source currents are used to generate three-phase fundamental reference source currents The active and reactive power components of fundamental
reference source currents are used to generate the three-phase reference source currents using inverse Park's and Clark's transformation as given in Eqs.

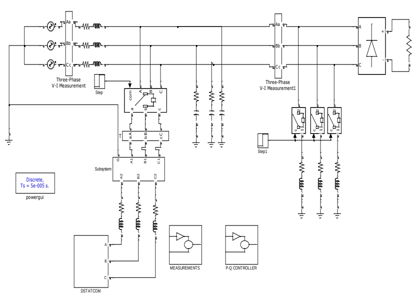
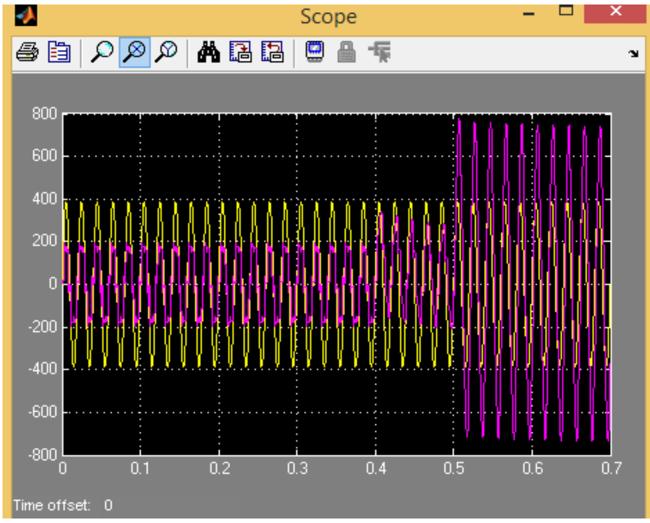


Fig.4 . System Daigram
This section presents the MATLAB/Simulink based simulation results. The power injected by the utility grid and consumed by the load are considered as positive. The DSTATCOM is considered as source of active and reactive powers if power flows out of the DSTATCOM whereas it acts as load if power is absorbed. The real power supplied by the DSTATCOM Pd can be expressed in terms of utility grid power Ps and load power Plby the following relation
Pd =Pl - Ps
The Pd is considered positive for power flows from DSTATCOM to the load and vice versa. Similarly, the reactive power supplied by the DSTATCOM Qd can be expressed in terms of reactive powers of utility grid Qs and load Ql by the relation
Qd= Ql - Qs
For reactive power flow from DSTATCOM to the grid, Qd is positive and vice versa.
The DSTATCOM exchanges no active and reactive powers in the absence of generation and with the rated load connected to the network. Power exchange is observed in the event of load changes and wind generation. Voltage for the proposed study has been captured.
Grid disturbances
Investigations have been made in the events such as feeder tripping and re-closing, voltage sag, swell, and load switching with and without DSTATCOM. The active power, reactive power
and harmonic compensations have been analyzed in these investigations.



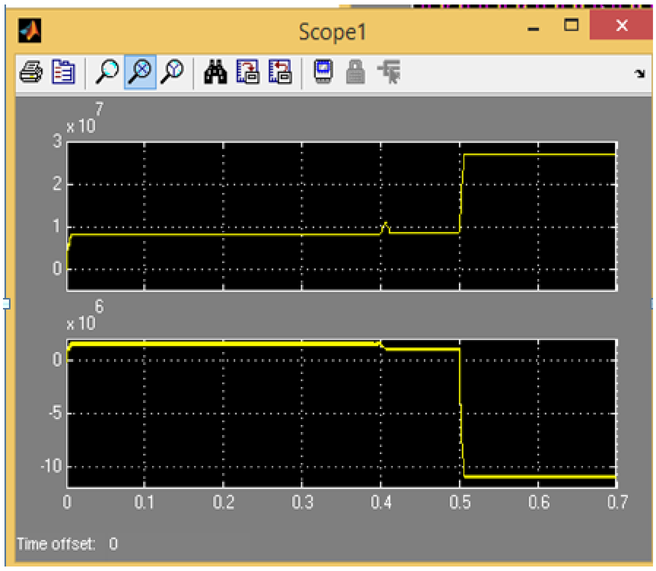


Fig. 4. Feeder tripping and re-closing t DSTATCOM in the network (a) RMS voltage at bus 632, (b) active power flow and (c) reactive power

VI. CONCLUSION

The proposed research work investigates into PQ events associated with distribution network due to grid disturbances such as voltage sag, swell, load switching, feeder tripping and re-closing. The DSTATCOM has been proposed to improve the power quality in the above events. The proposed DSTATCOM with SRF based control has been proved to be effective in improving the power quality in these events at grid level. The power quality events associated with grid synchronization of generator and improved by the use of proposed DSTATCOM in the distribution network. From, these studies it has been established that the DSTATCOM can effectively be used to improve the power quality in the distribution network with wind generation and during grid disturbances. The results have been validated

REFERENCES

[1] Saeed Mohammad (Impacts of D-STATCOM on voltage stability) Indian J. Edu. Inf. Manage., Vol. 1, No. 9 (Sep 2012)

[2] Bhim Singh, Sabha Raj Arya(Design and control of a DSTATCOM for power quality improvement using cross correlation function approach) International Journal of Engineering, Science and TechnologyVol. 4, No. 1, 2012, pp. 74-86

[3] Vaishali P Kuralkar(Power system control through statcom and upfc) International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 2, Issue 12, December 2012)

[4] Kyungsoo Lee, Kenichiro Yamaguchi, Hirotaka Koizumi, and Kosuke Kurokawa(D-UPFC as a Voltage Regulator in the Distribution System) Tokyo University of Agriculture and Technology, 2-24- 16 Naka-cho, Koganei, Tokyo, 184-8588 Japan

[5] GYUGYI, “Static Synchronous Series Compensator: A solid state approach to the series compensation of the transmission line”, IEEE Trans., 1997, PD-12.

[6] Kyungsoo Lee, Kenichiro Yamaguchi, Hirotaka Koizumi, and Kosuke Kurokawa, “D-UPFC as a Voltage Regulator in the Distribution System”, RENEWABLE ENERGY 2006 Proceedings 2012.

[7] Sourabh Kothari, Rahul Agrawal, Dr. Surendra Kumar Bharadwaj, “Contributions to Security of Electric Power Systems”, 2011.

[8] Chintan R Patel, Sanjay N Patel and Dr. Axay J Mehta,” Introduction to FACTS Controllers: A Technological Literature Survey”, International Journal of Automation and Power Engineering Volume 1 Issue 9, 2011.

[9] B.Sharath Kumar and MD.Yaseen,”Voltage Quality Improvement by using Facts Devices”, International Journal of Current Engineering and Technology, 2012. 35

[10] ISMAIL MUSIRIN, NUR DIANAH MOHD. RADZI, MUHAMMAD MURTADHA OTHMAN, MOHAMAD KHAYAT IDRIS and TITIK KHAWA ABDUL RAHMAN, “Voltage Profile Improvement Using Unified Power Flow Controller via Artificial Immune System”, 2010.

[11] Akhilesh A. Nimje, Chinmoy Kumar Panigrahi and Ajaya Kumar Mohanty, “Enhanced power transfer capability by using SSSC”, 2011.

[12] Saidi Amara and Hadj Abdallah Hsan,”Power system stability improvement by FACTS devices:.