A Detailed Study of Power Enhancement using DSTATCOM

Vidhyavati Suryawanshi[1], Dr. Surbhi Gupta[2]
[1]Ph.D. Scholar, Electrical Engineering Department, Chandigarh University, India
[2]Associate Professor, Electrical Engineering Department, Chandigarh University, India
[1]vidhya_vs2003@yahoo.com

* Corresponding Author: Vidhyavati Suryawanshi

Abstract: *One of the most pressing concerns in today's power system is power quality. Non-linear loads, system failures, load fluctuations, intermittent loads, and arc furnaces are the most common sources of power quality problems. Many electrical disruptions occur as a result of this, including voltage surges, voltage dips etc. Different methods are used in advanced circuits, which lead to reduced voltage stability and reliability. Due to these sorts of issues, electric companies are receiving a high amount of customer complaints. To discover power quality issues in industry, business, municipal or residential establishments, a strategy is necessary. Thus, to improve power quality some methods are implemented knows as Facts (Flexible AC transmission system). It is of broadly two type's series Facts and Shunt Facts. In series facts the device is connected in series with the transmission line and Shunt it is connected in Parallel with the transmission line. With the aid of these FACTS devices we can reduce the difficulties associated with power quality. One of the best device out of all is D-Statcom. D-STATCOM is a shunt-connected solid-state device used to manage load-side disturbances at the distribution level. Because of its cheaper investment cost, superior dynamics, lack of static, and reduced operational cost, it has surpassed the conventional capacitor used to enhance .power quality. This paper discusses the types, Architecture, working, controllers and its link with AI*
Keywords:AI, FACT system, DSTATCOM, AC

I. Introduction

Production, transmission, and distribution are the three primary functional components of the electric power system. According to the dependability requirements in power systems, production units must create an appropriate quantity of electricity, transmission units must offer power output across large areas, and substantial power systems must distribute electric power to each customer's facilities. Because the distribution system is at the final point of the electricity network and connects straight to the consumers, the power quality is determined by the status of the distribution system. One cause seems to be that 80 per cent of the normal public's outages are caused by failures in the electrical distribution system. Therefore, when it comes to dependability, the distribution system is getting more attention these days.The capacity to transport AC power in a traditional AC transmission system is restricted by numerous variables such as temperature limitations, dynamic load restrictions, power limits, maximum voltage limits, and so on. These limitations specify the maximum amount of electric power that may be efficiently conveyed over a transmission line without causing harm to electronic systems or power lines. This is usually accomplished by altering the power system's architecture. This is not practical, and there is another approach to achieve optimum transfer efficiency and capability without modifying the power system structure. With the introduction of variable impedance devices like as inductance and capacitance, not many of the electrical energy from the supply is transmitted to the loads, but rather a portion is stored as reactive power in these components and returns to the supply. As a result, the active power, or the amount of power transmitted to the load, is always smaller than the perceived power, or the total power.

The active power(ACP) should be equal to the apparent power(APP) for optimal transmission. To put it another way, the power factor which is ACP/APP should be one. This is where a FACTS comes into play.
The term "flexible AC transmission system" describes a set that combines electronic power and power system devices to improve the distribution system's manoeuvrability and reliability, as well as its transmission capabilities. The advancement in power electronics devices known as FACTS controllers. By adding power electronic devices to provide highly inductor and capacitance power into the connection, the FACT system provides controllability and control abilityof the large electrical side of the network.
There are four types of Fact controllers:

1. Series Type Fact controller:
2. Shunt Type Fact controller:
3. Series- Shunt Type Fact controller
4. Series- series Type Fact controller

In series facts the device is connected in series with the transmission line and Shunt it is connected in Parallel with the transmission line. In a unified series controller two Fact devices are connected in parallel with the DC transmission. In coordinated series and unified series shunt controller separate devices are used to control voltage and current transmission as shown in Fig-1.
Advantages of shunt connected over other are as follows:

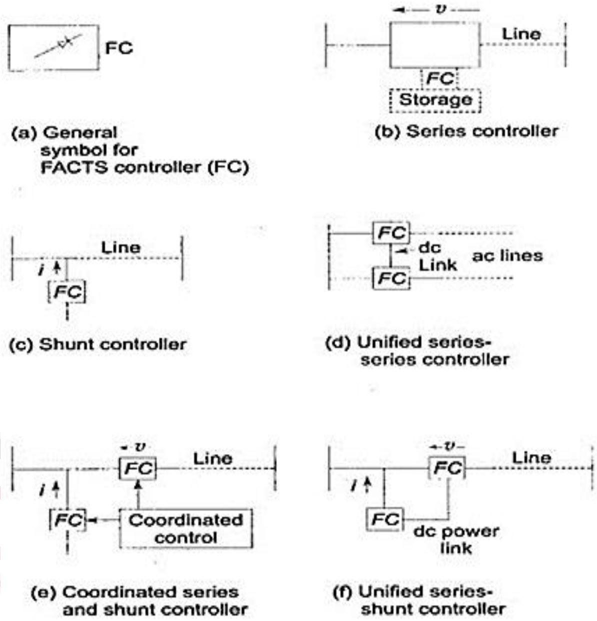

Fig.1 Types of FACT controller

1. It provides the continuous potential control
2. Better stability, no hysteresis, lower operating, installation, and maintenance costs as compared to series controllers.
3. Active power control is feasible with a D-StatCom, which aids in system stability control.
4. Over a wide voltage range, the maximum reactive current may be achieved.
5. It has very High productivity rate.

One of the common and widely used shunt controller is the distributor power static compensator used to solve various power quality problems like voltage dip, voltage sag etc. In 1999, the first DSTATCOM, an SVC with Voltage Source Converter, was used. Because of its cheaper investment cost, superior stability, lack of inertia, and reduced expenses, it has surpassed the various other types of the controllers. In ac networks, DSTATCOM is used to compensate for reactive power. Through the leaking reactance of a transformers, the voltage source converter regulates the transfer of reactive power from the Dc voltage storage device to the Electrical system.

II. Literature review

Sandeep Prajapatiet al. [1] in this research various quality improvement method of distribution system of a electrical transmission line is discussed. The quality improvement includes voltage sagging, voltage drips etc. The dstatcom usedthe vsc for voltage source converter it changes the direct voltage into 3-phase alternating voltage across the storing device. The amplitude and phase alignment of this power supply are adjusted to provide the appropriate leading or lagging reactive power for correction. Also different controls block is discussed in this paper. Also the matlab simulation and various harmonics is discussed.

Pallaviet al. [2] in this research work, power quality issues in power systems are mostly caused by pulsed loads, which degrade overall system performance over a short period of time is discussed. This article shows how dstatcom may be used to decrease the influence of pulsed loads on a bus voltage and therefore maintain it at a desirable level, hence improving power quality in a power system both during and after pulsed loads. The distribution static compensator (dstatcom) is a shunt compensation device based on a voltage-source inverter (vsi) that is commonly used to alleviate power quality concerns in distribution systems. N this document

Trupti et al. [3] in this research work, the control system and functioning of the d-statcom are described in this work, with the control approach for voltage being sinusoidal pulse width modulation and space vector pwm. Harmonics and their distruption in all power quality concerns with SPWM and SVPWM has been detected and improved as a result of project effort. D-statcom used the matlab/simulink tools to model and simulate the system.

Ktanujaet al. [4] this review paper examines the performance, analysis, and operating principles of a modern trend of enhanced brand equipment known as the distribution static compensator (DSTATCOM), which is aimed at ensuring the efficiency and durability of voltage control in low voltage distribution networks, as well as the computation of a d-STATCOM (distribution static compensator) used for voltage sag mitigation in transmission network.

III. DEVICE DESCRIPTION

A. Definition And Basic Introduction Of D-STATCOM

STATCOM, or Static Synchronous Compensator, is a voltage - controlled device that uses force shunt - connected devices such as IGBTs, GTOs, and other force shunt - connected devices to control the power flow through an electrical grid, thereby improving the network's reliability. STATCOM is a shunt device, which means it is linked to the line in a shunt configuration. A Static Synchronous Condenser is another name for a Static Synchronous Compensator It belongs to the FACTS (Flexible AC Transmission System) family of devices.The term "synchronized" in STATCOM refers to the ability to absorb or create reactive power in synchrony with need in order to keep the voltage and frequency grid stable.

A D-StatCom is identical to a STATCOM, except that STATCOM is used at at the transmission end to regulate basic reactive power and provide potential support, whereas a D-StatCom is utilised at the distribution level for voltage regulation and reactive power compensation. Total harmonic distortions, voltage sags, and swells may all be eliminated with D-StatCom. Furthermore, a D-StatCom may be used as a shunt boost converter to minimise supply power or supply voltage imbalance or instabilities. Figure 1.2 shows the basic structure of D-statcom where the power generating or distribution hub is connected with non-linear loads like houses, offices etc with a d stat com connected in parallel with a transmission line.

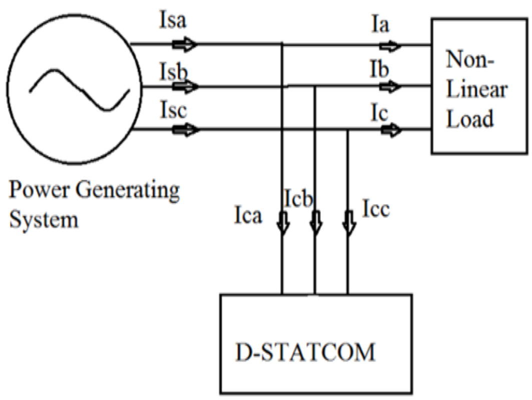

Fig. 2 Basic structure of D-STATCOM

IV. ARCHITECTURE

The major architecture of a DSTATCOM consist of the following things:

1. VSC
2. Line Filters like inductive, capacitive or L-C filter
3. Transformer
4. Energy storing device
5. Control scheme block

VSC: The VSC stands for voltage source converter it changes the direct voltage into 3-phase alternating voltage across the storing device. The amplitude and phase alignment of this power supply are adjusted to provide the appropriate leading or lagging reactive power for correction. A Voltage source converter might be three-phase, three-wire or three-phase, four-wire. A two-level converter or a 3-level converter can be used. It is 3 phase , 2 level power converter which provides the best simulation results in terms ofvoltage. It is made with a diodes and a pulse width modulator.

Two of the common VSC types are as below.

A) Square-wave Inverters using Gate Turn-Off Thyristors: In this type of VSC, output AC voltage is controlled by changing the DC capacitor input voltage, as the fundamental component of the converter output voltage is proportional to the DC voltage.

B) PWM Inverters using Insulated Gate Bipolar Transistors (IGBT): It uses Pulse Width Modulation (PWM) technique to create a sinusoidal waveform from a DC voltage source with a typical chopping frequency of a few kHz. In contrast to the GTO-based type, the IGBT-based VSC utilizes a fixed DC voltage and varies its output AC voltage by changing the modulation index of the PWM modulator.

Harmonic or Line filters: On the basis of the input input voltage the various type of harmonic or line filters are used in the Dstatcom. The type of LC filter to use is determined by the type of device and the occurrence of overtones at the output voltage. The LC filter is used to remove overtones and balance the power output of the converter.

Inductive Reactance or Transformer: The voltage source converter and the line filters works on the DC voltage. To match the type of voltage the output of the VSC after the filtering is connected with the coupling transformer whih converts the DC voltage into required AC voltage connected with the line distribution.
Energy storing device: Its primary purpose is to create the injected voltage by supplying energy to VSC through a dc connection. The energy storing device i.e.DC capacitor and the direct current source are linked in a parallel. It's the main component that stores reactive energy and transports input ripple current. This storage device may be powered by a battery or a converter.

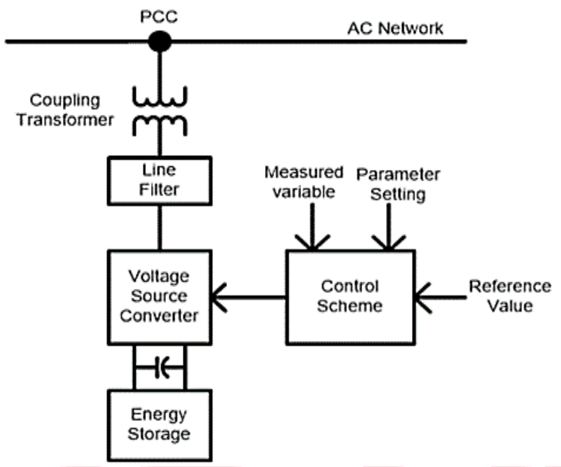

Fig-3 shows the architecture of the D-STATCOM.

Control Block: The voltage from the distribution end faces the different errors or we can say faults in a line. All this type of faults like lagging, voltage dips, non-uniform voltages, noises are corrected in the control block of the Dstatcom. The controls are broadly divide into two parts master control and slave control made with inverters and Pulse width modulator. The control blocks also have impact on external devices like power electronic switching, capacitor banks. These control blocks are built using a variety of control hypotheses and methodologies, such as synchronous park,s theory and synchronous frame theory, among others.
Fig-4 shows the connection of the D-STATCOM with the distribution network, Transmission line with various loads and supply voltages. As illustrated in Figure 3.4, the D-STATCOM is in parallel with the transmission system. In this diagram, 3 different lines are being examined. Different loads such as houses, offices, industries are fed by these lines. When any fault arises owing to these loads in the distribution end, D-StatCom is linked at the point of connection to introduce current into the system and cancel out that faults.

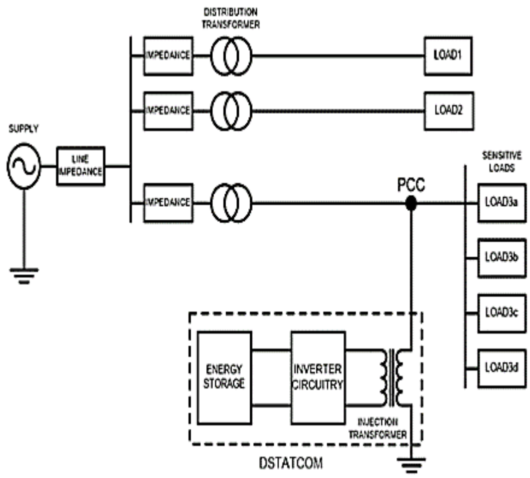

Fig. 4 shows the connection of the D-STATCOM with the transmission line or distribution network.

A. Principle and Working ofaD-STATCOM

The D-stat com consist of the transformer, capacitor to store energy and control blocks. Whenever at the distribution site the current or voltage generated is lagging it provides the energy to the system, whenever the the current or voltage generated is leading it absorbs the energy of the system.
The transmission control protocolall of the required voltages and currents and compares them to the commands. After that, the device provides feedback control and creates a series of switching pulses to operate the power supply. A single line schematic of a DSTATCOM is shown in Figure-5

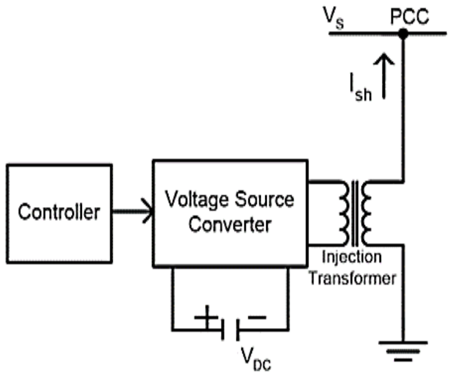

Fig. 5 single line schematic of a DSTATCOM converter

The VSC, which is based on Thermistors, converts DC power into a series of 3-phase ac o/p voltages. These outputs are in phase and connected to the AC system via the coupling transformer's reactance. The phase and magnitude of DSTATCOM o/p voltages are adjusted appropriately to efficiently regulate active and reactive power transfer between the DSTATCOM and the main grid.

B. Exchange Of Reactive Power:

The reactive power transfer of the DSTATCOM with the Alternating source system is controlled by the changeable amplitude of the DSTATCOM output power. The DSTATCOM's reactive power is calculated as follows:

$$QP = \frac{(V0 - Vs).Vs}{Z}$$

Where QP is the reactive power. The DSTATCOM output voltage is called VO
The value of the system voltage is Vs. Between DSTATCOM and the system, Z is the total resistance offered by capacitor, resistor and inductors if any.
The following scenarios describe the reactive power exchange between DSTATCOM and the AC system:
Case I: The reactive current is zero and the DSTATCOM does not absorb reactive power if the amplitudes of the DSTATCOM output voltage Vi and the AC system voltage Vs are equal as shown in Fig 6

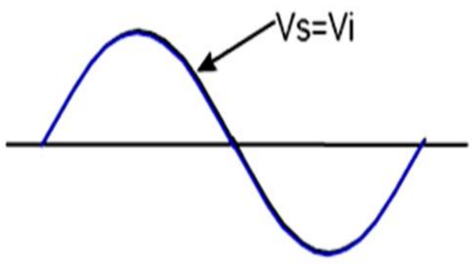

Fig. 6 Output and source voltage is in phase

(ii) When the amplitude of the DSTATCOM output voltage is greater than the amplitude of the AC PD power system, the lag current flows from the DSTATCOM to the AC system through the transformer reactance, causing the device to generate capacitive reactive power. Figure 7 depicts this.

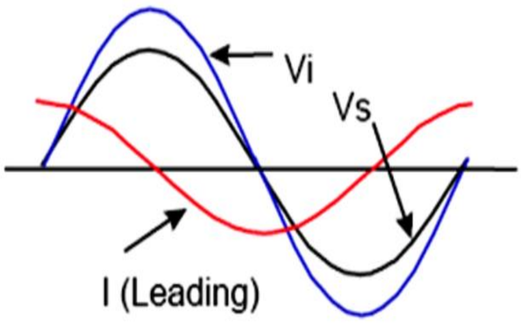

Fig. 7 Capacitive operation

(iii) The leading current flows from the AC system to the when the amplitude of the output voltage is reduced to a level below that of the AC system, and the device produces inductive reactive power. Figure 8 depicts this.

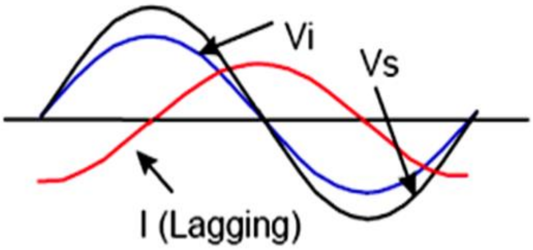

Fig. 8 Inductive operation

Because more switching devices are used, the Direct source condensor is necessary to provide actual power to the switches. In the case of direct voltage control, genuine power exchange is necessary to keep the capacitor voltage constant. Figure 9 depicts the DSTATCOM's V-I characteristic. The DSTATCOM smoothly and continuously controls the voltage from V1 to V2.

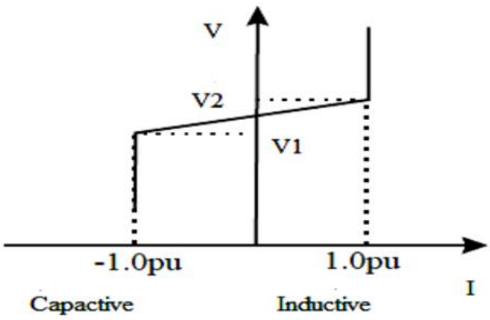

Fig. 9 V-I characteristics of DSTACOM

If DSTATCOM is equipped with an outside Dc voltage to control the voltage, there is a genuine power transfer with the AC system in the event of extremely low voltage in the power grid or in the event of failures. If the VSC output voltage is higher than the power system, the AC system will receive actual power from the capacitor or a DC source to keep the system voltage at 1p.u or keep the capacitor voltage constant.

C. Load Compensation in DSTACOM

The input voltage line of the DSTATCOM gives distorted signal if the load are not linear or unbalanced. For this a compensator is required, to regulate the voltage. To reduce this effect the DSTATCOM produce current to make the distorted current from line or load positive or in phase. This method is called load compensation. The compensator provides the power factor almost equal to 1.

If the I_l is the load current, I_d is the distorted current and I_{ds} is the STACOM current then the load compensator current equation at any node for DSTATCOM and load is given by the KCL equation as:

$$I_c - I_{ds} = I_l$$

So it is concluded that the load compensator balance the current I_l for any disturbances and noises.

V. Operations Performed By DSTATCOM

DSTATCOMS used to correct the following type of inputs:
Sagging: Voltage sag is described as a reduction in the typical supply voltage between 10% and 90% of the conventional root mean square voltage at the higher frequencies over periods ranging from 0. 5 to 1 minute.

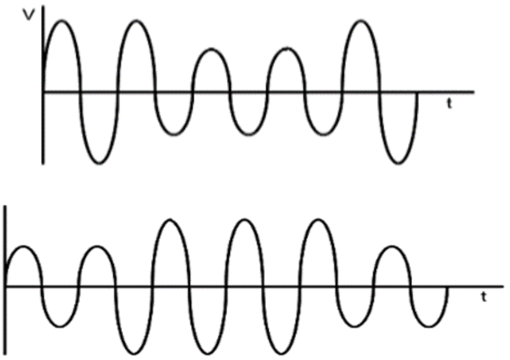

Fig-10a and b shows voltage sag and swells

The magnitude of voltage is reduced when voltage sag occurs, as seen in Figure 10. The major causes of voltage sag are the attachment of high loads, the setup of big motors, and defects in the user's system. Starting big motor drives can cause a voltage drop since the motor draws up to 10 times the maximum load current at the start. Disconnection and decrease in productivity in motorized mechanical systems and failure of information systems equipment, such as microcomputer control systems, are all effects of voltage sag.

A. Voltage Swells

Voltage swell is described as a brief rise in voltage at the power frequency that occurs outside of normal limits, lasts more than one cycle, and usually lasts less than a few seconds. Figure depicts the magnitude increase in voltage owing to voltage swell

Line failures, poorly dimensioned power sources, and improper tap settings in tap changers in substations can contribute to voltage swell. A voltage surge in the healthy phases might be caused by an SLG failure. Empowering a big capacitor bank might also cause in swell. Voltage surges cause illumination to flicker, data to disappear, and critical structures to halt or be damaged.

B. Interruptions

An interruption occurs when there is a brief but total cessation of supply. When the supply voltage drops by less than 10% from its initial value for a duration of only about one minute, an interruption occurs. The amount of supply interruptions also raises voltage sag, which need adequate reduction. Interruption can be of various type like short r long interruptions

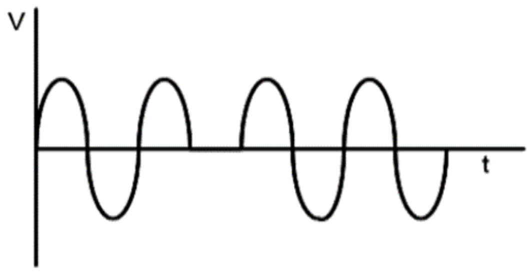

Fig. 11 showsinterruptions

C. Transients

Transients are sudden changes in voltage levels that last anywhere from a few microseconds to a few milliseconds. Even at low voltage, these fluctuations can reach hundreds of volts. There are two sorts of transients, which are described below: A brief linear voltage difference, current, or both on a power line is known as an impetuous transient. On a power line, an oscillatory transient is a small bidirectional change in voltage, current, or both. These transients are caused by power factor correction capacitors, inductive load switching, and transformer ferro-resonance.

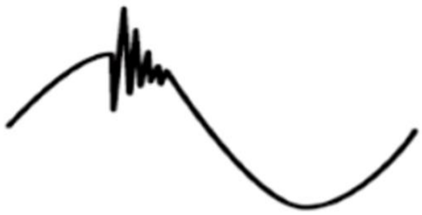

Fig-12 shows voltage transients

D. Distortion of Harmonics

The difference between the ideal sinusoidal waveform and the waveform of the supply voltage is known as harmonic distortion. It's created by the interplay of distorted customer loads and supply network impedance. The heating of induction motors, amplifiers, and capacitors, as well as the overloading of neutrals, are the most serious side effects.

Control of Dstacom:

The control system is at the basis of the D-STACOM utilised for power system adjustments, and its reaction to variable load changes is determined by the technique employed for control. In most cases, the regulation of the D-STATCOM power circuit is accomplished in three phases.

1. Phase shift control:The control strategy for phase shift is straightforward. The goal is to keep the voltage at the output port consistent. The control algorithm creates a phase shift in the terminal voltage of the VSC with reference to the AC series connection by exerting a voltage angle control. When the measured PCC voltage is compared to the intended voltage, an error signal is created.
2. Carrier based PWM control: For carrier-based PWM control, the switch of the VSC, a constant power carrier based sinusoidal PWM is utilised to generate the switching pulses. This method is predicated on the concept of instantaneously reactive power. The system's instantaneous voltage and current, as well as the loads, are monitored.
3. Carrier less hysteresis control: The terminal voltage is used to calculate the in-phase and quadrature unit vectors. This compensation system is quite flexible, and it has been used for improving the power factor, voltage control, load balancing, harmonic suppressing, and load levelling, among other applications. The amount of the reference active and reactive current generated by the D- STATCOM may be determined using a variety of ways, according to the authors.

VI. ADVANTAGES OF DSTATCOM:

The following are the main advantages of utilising DSTATCOM:

A DSTATCOM has a high dynamic and rapid step response of 8 to 30 milliseconds, which aids in system stability management. Active power control is also feasible with a DSTATCOM, which aids in system stability control. High efficiency and maximum reactive current across a wide voltage range. Synchronous condenser has better dynamics, no inertia, reduced operating, investment, and maintenance costs. Voltage control that is both constant and dynamic. Allows complete grid control.

VII. APPLICATION OF DSTATCOM

DSTATCOM is identical to STATCOM, except STATCOM is used at the transmission level to regulate basic reactive power and provide voltage support, whereas DSTATCOM is used at the distribution level for voltage regulation and power factor correction.

The following are some of DSTATCOM's many applications:

Due to changing reactive current demand, DSTATCOM protects the utility distribution system against voltage sags and flicker. To achieve system stability, a DSTATCOM supply leading or lagging reactive power.To adjust for voltage, the DSTATCOM enables high-speed control over reactive power.

VIII. CONCLUSION

The detailed study on DSTATCOM is discussed in this review paper and it was concluded that the DSTATCOM can reduce the size of the compensation system necessary to manage transient events by utilising its critical short-term transient overload capabilities. For intervals of 1 to 3 seconds, the short-term overload capability is up to 325 percent. On both a transient and steady state basis, the DSTATCOM regulates physically shifted capacitors to achieve the best possible adjustment. DSTATCOM can also be used by utilities that have weak grid knots or reactive loads that fluctuate. It can transport imbalanced loads (such as arc welding operations, automobile crushers and shredders, and so on.

REFERENCES

[1] Sandeep Prajapati,ShivaniJohri, "Power Quality Improvement using D-Statcom," International Journal of Emerging Technologies and Innovative Research,ISSN:2349-5162,Vol1,Issue 5,page no pp371-379,October 2014

[2] Pallavi S, A Novel Adaptive Control for DSTATCOM by using ANN international Journal for Research in Engineering Application & Management (IJREAM) ISSN : 2494-9150 Vol-01, Issue 12, MAR 2016

[3] Trupti P. Gulhane1, SVPWM Technique based D-STATCOM to Improve Power Quality in Distribution System International Research Journal of Engineering and Technology (IRJET) e Volume: 07 Issue: 01 | Jan 2020

[4] K. TANUJA1 Enhancement of Power Quality in Distribution System using D-Statcom ISSN 2348–2370 Vol.09,Issue.10, September-2017, Pages:1689-1694

[5] N.Ravendra1, V.Madhusudhan2, A.Jaya Laxmi3 “Modeling and Simulation of DSTATCOM for Power Quality Enhancement in Distribution System” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 5, Issue 6, June 2016.

[6] PrabhirRanjanKasari ; Nanish Paul “Analysis of D-STATCOM for power quality enhancement in distributed network” TENCON 2017-2017 IEEE Region 10 Conference,Penang,2017,pp. 1421-1426

[7] M. G. Molina and P. E. Mercado, Dynamic Modelling and Control Design of DSTATCOM with Ultra-Capacitor Energy Storage for Power Quality Improvements, Conference on Transmission and Distribution conference and Exposition: Latin America, IEEE/PES, pp. 1 8, 2008.

[8] Virulkar, V, and Aware, M, Analysis of DSTATCOM with BESS for mitigation of flicker, International Conference on Control, Automation, Communication and Energy Conservation, 2009. INCACEC 2009, 4-6 June 2009.

[9] Sepulveda, C.A, Espinoza, J.R., Landaeta, L.M., and Baier, C.R. Operating Regions Comparison of VSC-based Custom Power Devices, 32nd Annual Conference on IEEE Industrial Electronics, IECON 2006, 6-10 Nov. 2006.

[10] NaetiladdanonSumate, Voltage Sag Compensation Performance by DSTATCOM with Series Inductor and Energy Storage, 7th International Conference on Power Electronics and Drive Systems, 2007. PEDS '07, 27-30 Nov. 2007.

[11] Aodsup, K., Boonchiam, P.N., Sode-Yome, A., Kongsuk, P. and Mithulananthan, N. Response of DSTATCOM under Voltage Flicker in Farm Wind, 7th International Conference on Power Electronics and Drive Systems, 2007. PEDS '07, 27-30 Nov. 2007