Modeling, Simulation and Implementation of D-STATCOM for Improvement of Power Quality

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Abstract **- Since in today's era we deal with the power quality issue and multi level power conversion has become an increasing challenge while we deal with high power concepts and its application. The main application of the concept is that we need to have high voltage with low harmonics and this paper represents a unique way of the combination of the multi level D-STATCOM and DVR configuration consisting of a voltage source inverter . The D-STATCOM is one of the efficient and effective device through which we can have correct sag and swell by injecting the current into the system. The voltage source converter (VSC) is controlled by the help of SPWM. The proposed model has been design evaluated and simulated with the help of MATLAB/SIMULINK to obtain the result.**

Index Terms **— DSTATCOM, MATLAB/SIMULINK PWM, VSC, voltage sag and swell.**

INTRODUCTION

A standout amongst the most widely recognized power quality issues today is voltage plunges. A voltage plunge is a brief timeframe (10 ms to 1 minute) occasion amid which a decrease in r.m.s voltage extent happens. Usually set just by two parameters, profundity/greatness and length. The voltage plunge size is extended from 10% to 90% of ostensible voltage (which relates to 90% to 10% outstanding voltage) and with a length from a large portion of a cycle to 1 min. In a three-stage framework a voltage plunge is naturally a three-stage marvel, which influences both the stage to-ground and stage to-stage voltages. A voltage plunge is brought about by a blame in the utility framework, a blame inside the client's office or a substantial increment of the heap current, such as beginning an engine or transformer empowering. Normal deficiencies are single-stage or different stage short-circuits, which prompts high flows. The high current outcomes in a voltage drop over the system impedance. At the blame area the voltage in the blamed stages drops near zero, though in the non-blamed stages it stays pretty much unaltered [1, 2].

Voltage plunges are a standout amongst the most happening force quality issues. Off base, for an industry a blackout is more terrible, than a voltage plunge, however voltage plunges happen all the more regularly what's more, cause extreme issues and affordable misfortunes. Utilities regularly center around aggravations from end-client gear as the principle control quality issues. This is right for some unsettling influences, gleam, music, and so on., however voltage plunges for the most part have their source in the higher voltage levels. Shortcomings because of lightning, is a standout amongst the most widely recognized causes to voltage plunges on overhead lines. In the event that the efficient misfortunes due to voltage plunges are huge, moderation activities can be productive for the client and even now and again for the utility. Since there is no standard arrangement which will work for each site, every moderation activity must be cautiously arranged and assessed. There are diverse approaches to alleviate voltage plunges, swell and intrusions in transmission and appropriation frameworks. At present, a wide scope of very adaptable controllers, which profit by recently accessible control hardware segments, are rising for custom control applications [3, 4]. Among these, the appropriation static compensator and the dynamic voltage restorer are best gadgets, them two dependent on the VSC standard. STATCOM is frequently utilized in transmission framework. When it is utilized in appropriation framework, it is called DSTATCOM （ STATCOM in Distribution framework). DSTATCOM is a key FACTS controller and it uses control gadgets to tackle many power quality issues generally looked by dispersion frameworks. Potential uses of D-STATCOM incorporate power factor revision, voltage direction, stack adjusting and symphonious Decrease.

Contrasting and the SVC, the D-STATCOM has snappier reaction time and conservative structure. It is normal that the D-STATCOM will supplant the jobs of SVC in almost future D-STATCOM and STATCOM are distinctive in both structure and capacity, while the decision of control technique is identified with the principle circuit structure and primary The most important factor for any mitigation of the power is due to the increasing demand and unbalanced load and the power quality variations plays an important role while considering the increasing harmonic level of the power system. Most of the power

system now-a-days is connected to an transmission network which consists of an integrated system of variable loads which in fact due to its results in the failure of component. Many efforts has been taken into consideration to meet the PQ requirements and hence FACTS devices and custom made power devices are generally used to meet the demand of the electrical system to improve the PQ.

a. **There are numerous ways to enhance the power quality problem in the transmission and distribution system and one of it is the D-STATCOM.**

b. **Harmonic currents are very well diluted in every power system in the transmission network. This harmonic current give rise to the harmonic distortion, low power factor and additional losses as well as destroying of the power electronics devices due to heating.**

c.**These harmonic current can be removed by using LCL passive filter and connected either in shunt or in series with the distribution system.**

I. VOLTAGE SOURCE CONVERTER (VSC)

Voltage-source converter is a power electronic gadget that associated in shunt or parallel to the framework. It can create a sinusoidal voltage with any required greatness, recurrence and stage edge. The VSC used to either totally supplant the voltage or to infuse the „missing voltage". The „missing voltage" is the contrast between the ostensible voltage and the real. It additionally changes over the DC voltage crosswise over capacity gadgets into a lot of three stage AC yield voltages. What's more, D-STATCOM is likewise skilled to produce or assimilates responsive power. On the off chance that the yield voltage of the VSC is more noteworthy than AC transport terminal voltages, D-STATCOM is said to be in capacitive mode. Thus, it will remunerate the responsive power through AC framework and manages missing voltages. These voltages are in stage and combined with the AC framework through the reactance of coupling transformers. Appropriate change of the stage and size of the DSTATCOM yield voltages permits effectives control of dynamic and receptive power trades between D-STATCOM and AC framework. In expansion, the converter is typically founded on some sort of vitality stockpiling, which will supply the converter with a DC voltage

The power disturbances occur generally in all the system. Power issues remains a vital problem while considering any electronics devices as its sensitivity will changes as the load changes, which impact to the power generation and transmission , distribution system. A power voltage spike can damage valuable components. Power quality encovers a wide range of disturbances mainly such as voltage sag, swells, flickers, harmonic distortion, interruption invariant transitions. In simple words we can say that PQ is the set of electrical boundaries that allows a part of the equipment to be work in an intended manner with any losses. Custom power devices mainly work on the better regulation with zero interruptions. This paper aims at the development of the diode-clamped multi-level D-STATCOM and DVR for power quality enhancement. A controller is used to provide better voltage stabilization, sag/swell suppression and power quality *factor*

II. Distributed static compensator [D-STATCOM]

A DSTATCOM is basically a two level voltage source converter (VSC), a DC energy storage device and a coupling transformer connected in shunt to the network with the AC system. The reactive power between the converter and the AC system is controlled by varying the amplitude of the three phase output voltage of the converter. The D-STATCOM is used to regulate the voltage at the point of the connection.

III. Voltage Sag and Swell: A major Concern

Voltage dip or sag is an important constraint while considering any power quality issue. If there is a dip or sag of 0.1 to 0.4 p.u. in rms voltage or current for an interval of one minute then rms voltage magnitude changes drastically. These sag occurs in the high current which is general give rise to the voltage drop over the network impedance. To avoid these we have to use the DVR, SSTS (SOLID STATE TRANSFER SWITCHES) or distribution level static compensator and the fault level of the sag depends on the load bus. Voltage swell is the opposite of the voltage sag. It momentary increases in voltage when a heavy load turns off in a power system. Swell means an increase in the rms voltage between 1.1 p.u. to 1.5 p.u. at an interval of one minute. These also can be avoided by the efficient use of the DVR and D-STATCOM. These voltage sag and swell may be instantaneous, momentary, temporary but cause severe harm to the electrical systems.

IV. Essential operating principle

Essential working standard of a DSATCOM is like that of synchronous machine. The synchronous machine will give slacking current when under energized and driving current when over energized. DSTATCOM can produce and assimilate responsive power like that of synchronous machine and it can likewise trade genuine power whenever gave an outside gadget DC source..

1) Exchange of receptive power:- if the yield voltage of the voltage source converter is more noteworthy than the framework voltage then the DSATCOM will go about as capacitor and create receptive power(i.e.. give slacking current to the framework)

2) Exchange of genuine power: as the exchanging gadgets are not misfortune less there is a requirement for the DC capacitor to give the required genuine influence to the switches. Consequently there is a requirement for genuine power trade with an AC framework to make the capacitor voltage consistent if there should arise an occurrence of direct voltage control. There is additionally a genuine power trade with the AC framework if DSTATCOM id gave an outer DC source to manage the voltage incase of low voltage in the dispersion framework or if there should be an occurrence of flaws. Furthermore, on the off chance that the VSC yield voltage drives the framework voltage, the genuine power from the capacitor or the DC source will be provided to the AC framework to control the framework voltage to the =1p.u or to make the capacitor voltage consistent. Henceforth the trading of genuine power and receptive power of the voltage source converter with AC framework is the major required wonder for the direction in the transmission just as in the dissemination framework. For receptive power pay, DSTATCOM gives receptive power as required by the heap and along these lines the source current remains at solidarity control factor (UPF). Since just genuine power is being provided by the source, stack adjusting is accomplished by making the source reference current adjusted. The reference source current used to choose the exchanging of the DSTATCOM has genuine basic recurrence segment of the heap current which is being extricated by these methods. A STATCOM at the transmission level handles as it were crucial responsive power and gives voltage bolster while as a DSTATCOM is utilized at the conveyance level or at the heap end for power factor enhancement and voltage control. DSTATCOM can be one of the reasonable options to SVC in an appropriation organize. Also, a DSTATCOM can likewise carry on as a shunt dynamic channel, to wipe out unbalance or twists in the source current or the supply voltage according to the IEEE-519 standard points of confinement.

Since a DSTATCOM is such a multifunctional gadget, the principle target of any control calculation ought to be to make it adaptable and simple to actualize notwithstanding misusing its multi usefulness to the most extreme. The primary goal of any pay conspire is that it ought to have a quick reaction, adaptable and simple to execute. The control calculations of a DSTATCOM are chiefly executed in the accompanying advances:

- Measurements of framework voltages and current and
- flag molding
- Calculation of repaying signals
- Generation of terminating points of exchanging gadget

A. DSTATCOM parts:

DSTATCOM includes essentially three sections IGBT or GTO based dc-to-air conditioning inverters: These inverters are utilized which make a yield voltage wave that is controlled in size and stage edge to create either driving or slacking receptive current, contingent upon the remuneration required.

B. L-C channel:

The LC channel is utilized which decreases sounds and matches inverter yield impedance to empower various parallel inverters to share current. The LC channel is picked in agreement with the sort of the framework and the concept present at the yield of the inverter.

C. Control square:

Control square is utilized which switch Pure Wave DSTATCOM modules as required. They can control outside gadgets, for example, mechanically exchanged capacitor banks as well. These control squares are planned dependent on the different

control speculations and calculations like momentary PQ hypothesis, synchronous edge hypothesis and so forth.. All these diverse calculations

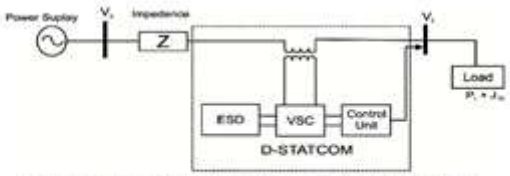


Figure 1 Schematic Representation of D-STATCOM [3].

V. PHASE SHIFT CONTROL

Sinusoidal PWM procedure is utilized which is basic and gives a decent reaction. The mistake flag acquired by contrasting the deliberate framework rms voltage and the reference voltage, is nourished to a PI controller which produces the point which chooses the fundamental stage move between the yield voltage of the VSC and the AC terminal voltage. This edge is summed with the stage point of the decent supply voltages, thought to be similarly separated at 120 degrees, to deliver the ideal synchronizing signal required to work the PWM generator. In this calculation the D.C. voltage is kept up consistent utilizing a different dc source."

VI. DECOUPLED CURRENT CONTROL (P-Q THEORY)

Use this algorithm requires the measurement of instantaneous values of three phase voltage and current. The compensation is achieved by the control of id and iq. Using the definition of the instantaneous reactive power theory for a balanced three phase three wire system, the quadrature component of the voltage is always zero, the real (p) and the reactive power (q) injected into the system by the DSTATCOM can be expressed under the dq reference frame as:

p=vd id+vq iq

q=vq id-vd iq

Since vq=0, id and iq completely describe the instantaneous value of real and reactive powers produced by the DSTATCOM when the system voltage remains constant. Therefore the instantaneous three phase current measured is transformed by abc to dqo transformation. The decoupled d-axis component id and q axis component iq are regulated by two separate PI regulator

VII. THE DESIGN

The different attributes of voltage lists experienced by clients inside mechanical conveyance frameworks. Extraordinary accentuation is paid to the impact of the acceptance engine stack on the portrayal of voltage lists. Amid a blame, an acceptance engine works as a generator for a brief time frame and causes an expansion in hang extent. Its re acceleration after the results in an all-inclusive post-blame voltage list. The impact of the enlistment engine on the imbalanced droops brought about by single line-to-ground shortcomings (SLGF's) and line-to-line deficiencies (LLF's) has been broke down in detail. For an imbalanced blame, the enlistment engine current contains just positive-and negative-succession segments. Acceptance engines make a low impedance way for the negative-grouping voltage because of an imbalanced blame. This causes a little continued nonzero voltage with vast stage edge hop in the blamed stage and a voltage drop in the non blamed stages with a little stage edge hop. The symmetrical parts of the enlistment engine amid the imbalanced hangs have been examined. The outcomes appear that acceptance engine conduct is controlled by positive-and negative-grouping voltages amid the imbalanced list. The strategies of redressing the supply voltage hang in a dissemination framework by two power hardware based gadgets called DVR and D-STATCOM. A DVR infuses a voltage in arrangement with the framework voltage and a D-STATCOM infuses a current into the framework to address the voltage list. The consistent state execution of both DVR and D-STATCOM is resolved and looked at for different estimations of voltage droop, framework blame dimension and load level. The base obvious power infusion required to right a given voltage list by these gadgets is likewise decided and looked at. The most extreme voltage hang that can be adjusted without infusing any dynamic power into the framework is likewise decided. Reproduction results

demonstrated that a DVR can address voltage droop with significantly less infused evident power contrasted with that of a D-STATCOM.

Another and far reaching symphonious space model of a three-stage, six-beat PWM STATCOM. The model takes appropriate record of the DC capacitor impact

Proportional-integral controller (PI Controller) is a feedback controller which drives the system to be controlled with a weighted sum of the error signal (difference between the output and desired set point) and the integral of that value. In this case, PI controller will process the error signal to zero. The load r.m.s voltage is brought back to the reference voltage by comparing the reference voltage with the r.m.s voltages that had been measured at the load point. It also is used to control the flow of reactive power from the DC capacitor storage circuit. PWM generator is the device that generates the Sinusoidal PWM waveform or signal. To operate PWM generator, the angle is summed with the phase angle of the balance supply voltages equally at 120 degrees. Therefore, it can produce the desired synchronizing signal that required. PWM generator also received the error signal angle from PI controller

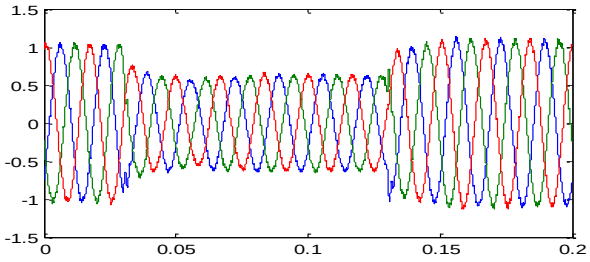
VIII. REGULATION OF AC BUS AND DC LINK VOLTAGE

This remuneration plot is multifunctional and can be adequately utilized for load adjusting and consonant concealment in expansion to control factor rectification and dynamic voltage direction. Three stage supply voltages and DC connect voltage is detected and bolstered r two PI controller , the yields of which choose the sufficiency of the reference receptive and dynamic current to be created by the DSTATCOM. Demonstrates the square chart of the actualized plan. Duplication of these amplitudes with the in stage and quadrature voltage unit vectors yields the separate segment of reference flows. While applying the calculation for power factor amendment and symphonious end the quadrature segment of the reference current is made zero. The summed direct and quadrature pivot reference flows and the detected line flows are bolstered to transporter less hysteresis controller which is utilized for following control. The converter exchanging activities are created from a hysteresis controller which includes a hysteresis band +/ - h around the determined reference current. these formats along with the manuscript.

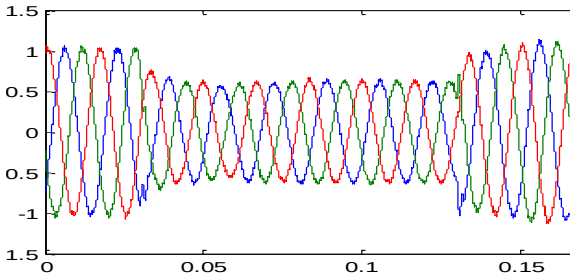
Fundamentally, the STATCOM framework is contained three fundamental parts: a VSC, a lot of coupling reactors or a step up transformer, and a controller. In a high-voltage framework, the spillage inductances of the progression up power transformers can work as coupling reactors. The principle motivation behind the coupling inductors is to sift through the current symphonious segments that are produced mostly by the throbbing yield voltage of the power converters. The STATCOM is associated with the power systems at a PCC, where the voltage-quality issue is a worry. All required voltages and flows are estimated and are encouraged into the controller to be contrasted and the directions. The controller at that point performs criticism control and yields a set of changing signs to drive the principle semiconductor switches of the power converter in like manner.

IX. RESULTS

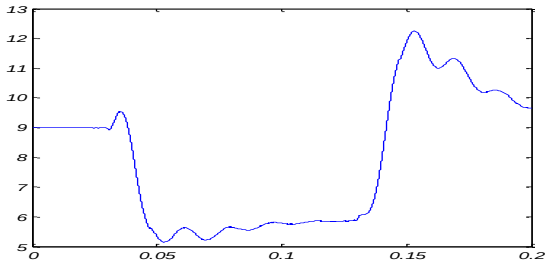
Scope 1: Vabc



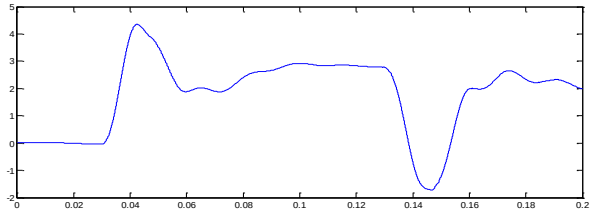
Scope 2:Iabc



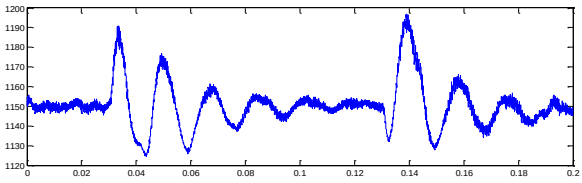
Scope 3: P(MW)



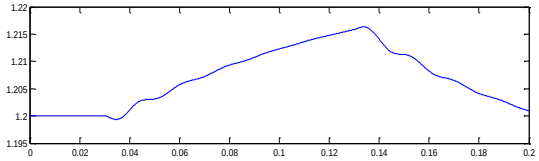
Scope 4:Q(MVAR)



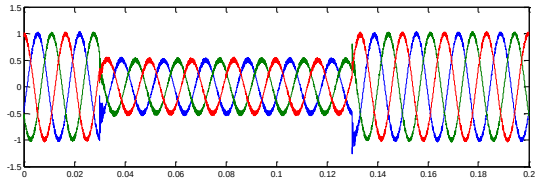
Scope 5: Q(Vdc)



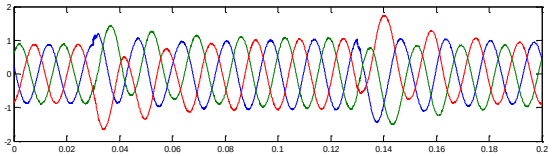
Scope 6 : wr (pu)



Scope 7 :Vabc_b25(pu)



Scope 8 :Iabc_b25(pu)



A: *Results Explained:*

Case 1: (an inductive load is applied .1seconds after the start of the simulation) Initially there is a fixed inductive load is connected to the line. After .1 second the circuit breaker .is closed and the terminal voltage is decreased to.8pu. The top window shows the change in the three phase voltage waveforms, the second window shows the changes in the currents when the inductive load is applied after .1seconds and the bottom window shows the magnitude of the voltage. This simulation is shown in Fig.

Case 2: (An capacitive load is applied at .2seconds after the start of the simulation) Initially there is a fixed inductive load is connected to the line. After 0.2seconds start of the simulation the circuit breaker is closed. The top window shows the changes in the three phase voltage waveform, the second window shows the changes in the currents when the capacitive load is applied after 0.2seconds and the bottom window shows the magnitude of the voltage. T

Case 3: (a capacitive load is applied .1seconds after the start of the simulation and an inductive load is applied at .2seconds after the start of the simulation). In this simulation we observe the variations in the terminal voltage. When a capacitive load is applied then the terminal voltage rises, this condition is known as swell. When the inductive capacitive load is applied then the terminal voltage drops, i.e. this condition is known as sag. Initially there is a fixed inductive load is connected to the line. After 0.1seconds start of the simulation a capacitive load is applied, and at 0.2seconds start of the simulation a indutivee load is applied. The top window shows the changes in the three phase voltage waveform, the second window shows the changes in the currents when the inductive and capacitive loads are applied after 0.1and0.2seconds respectively after the start of the simulation and the bottom window shows the magnitude of the voltage.

Case 5: Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed a capacitive load is applied, but in both the cases we observe that there is no rise in the terminal voltage due to the absorption of reactive power by the Dstatcom.

Case 6: Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed an inductive load is applied, but in both the cases we observe that there is no drop in the terminal voltage due to the injection of reactive power by the DSTATCOM

Case 7 and 8: Therefore the load is maintained at unity power factor. The top window shows that there is no change in the voltage waveform and it is maintained at unity power factor. The second window shows the variations in the currents when inductive loads are applied at different instances of the simulation

X. Conclusions

Custom Power (CP) gadgets can be utilized, at sensible expense, to give high power quality and progressed control benefit. displaying is introduced and results are talked about with various contextual analyses. These Custom Power gadgets give answers for power quality at the medium voltage dissemination arrange level. This undertaking presents the demonstrating of one of the custom power items, DSTATCOM is exhibited utilizing prompt PQ hypothesis, utilized for the control of DSTATCOM are talked about. These control calculations are depicted with the help of reenactment results under direct loads. The control plot keeps up the power balance at the PCC to control the dc capacitor voltages. PWM control plot as it were requires voltage estimations. This trademark makes it in a perfect world appropriate for low-voltage custom power applications.

THE CONTROL CONSPIRE WAS TRIED UNDER A WIDE SCOPE OF WORKING CONDITIONS, AND IT WAS SEEN TO BE EXTREMELY HEARTY FOR EACH SITUATION. BROAD REPRODUCTIONS WERE LED TO PICK UP KNOWLEDGE INTO THE EFFECT OF CAPACITOR MEASURE ON DSTATCOM CONSONANT AGE, SPEED OF REACTION OF THE PWM CONTROL ALSO, TRANSIENT OVERSHOOTING. IT WAS SEEN THAT AN UNDERSIZED CAPACITOR CORRUPTS EVERY ONE OF THE THREE ANGLES. ON THE OTHER HAND, A LARGER THAN USUAL CAPACITOR MAY LIKEWISE PROMPT A PWM CONTROL WITH A DROWSY REACTION HOWEVER IT WILL LESSEN DSTATCOM SYMPHONIOUS AGE AND TRANSIENT OVERSHOOTING. IT IS REASONED THAT A DSTATCOM HOWEVER IS THEORETICALLY LIKE A STATCOM AT THE TRANSMISSION LEVEL; ITS CONTROL PLAN OUGHT TO BE TO SUCH AN EXTENT THAT NOTWITHSTANDING COMPLETE RECEPTIVE POWER REMUNERATION, CONTROL FACTOR REDRESS AND VOLTAGE DIRECTION THE SOUNDS ARE TOO CHECKED, AND FOR ACCOMPLISHING ENHANCED POWER QUALITY DIMENSIONS AT THE DISPERSION END

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