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CONTROL OF MULTILEVEL INVERTER BASED DSTATCOM USING SRF TECHNIQUE FOR POWER QUALITY ENHANCEMENT IN DISTRIBUTION SYSTEM

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Abstract:- ***In this paper design and implementation of Modulation index based Multi-level inverter based static synchronous compensator (DSTATCOM) has been carried out. It presents the enhancement of power quality problems, such as voltage sag and swell using Distribution Static Compensator (D-STATCOM) in distribution system. The model is based on Sinusoidal Pulse Width Modulation (SPWM) technique. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The Proposed Multilevel Inverter based Distribution STATCOM (MLI-DSTATCOM) with Synchronous Reference Frame based control for harmonic mitigation. A three phase four wire system with nonlinear, balanced/unbalanced load is designed and simulated in Matlab/Simulink for performance analysis of proposed MLI-DSTATCOM. Simulation result analysis carried out with different load conditions to analyze the superior performance of MLI-DSTATCOM controlled using SRF in Matlab Simulink. With the proposed control method, load currents, source currents and source voltages are measured. Total Harmonic Distortion (THD) of supply currents with conventional two-level DSTATCOM, three-level diode clamped and five-level diode clamped MLI-DSTATCOM is developed and analyzed in Matlab/Simulink software. This study has been expanded to active and reactive power flow analysis.***

Keywords:- SRF, D-STATCOM, VDC, PQ Isuues, MLI, THD, etc.

1. INTRODUCTION

The electrical power produced at the generating station is delivered to the consumers through a network of transmission and distribution systems. It is difficult to draw a line between the transmission and distribution systems of large power system. The transmission and distribution systems are similar to man's circulatory systems. The transmission systems may be compared with in the human body and distribution systems with capillaries. They serve the same purpose of supplying the ultimate consumer in the city with life giving blood of civilization electricity. An electric power system is a network of various electrical Components (equipment) installed for the generation, transmission, distribution and utilization of electrical power. Power system consists of alternators that are driven by prime movers, grid, substations, transformers, circuit breakers, bus bars, and other auxiliary devices, etc. that are used to transfer power from generating stations to load in most reliable, economical and efficient manner.

With the introduction of many non-linear loads at the consumer end, Power Quality problem is a serious threat to the Power System. As per IEEE, Power Quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment. Common Power Quality problems that can be observed in daily life are Voltage Sag, Voltage Swell, Voltage Flickering, Over-Voltage and Under-Voltage. Impulsive transients, Oscillatory transients and Harmonics are also Power Quality problems. For the Harmonic elimination, passive, active and hybrid power filters are used. At the distribution side, Custom Power devices are used which mainly include Unified Power Quality Conditioner (UPQC), Distribution Static Compensators (D-STATCOM) and Dynamic Voltage Restorer (DVR). D-STATCOM, a shunt linked Custom Power device employed for the reactive power compensation at the distribution side whereas STATCOM is also a shunt linked device employed in the transmission system for the power factor improvement and the voltage stability. Some of the power quality issues of electrical distribution systems influenced by the allocation of DSTATCOM with distribution generator are given in this paper. These devices are optimally sized and allocated in the radial distribution system by using a particle swarm optimization algorithm to compensate the reactive power for the reduction of power loss.

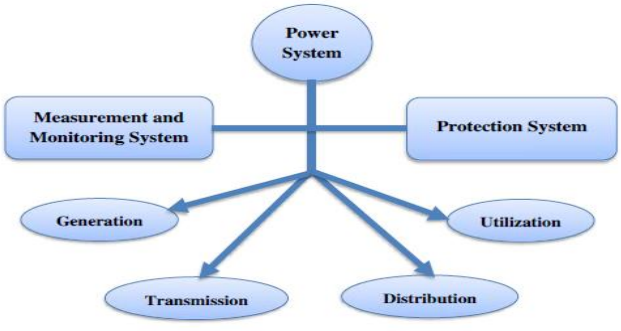

Figure.1: The block diagram of electric power system

Fig. 1 signifies the block diagram of electric power system. In the block diagram, it can be seen that the power system comprises the various stages of operations such as generation, transmission, distribution, and utilization along with the measurement of the monitoring system and protection system. The simple layout of the electric power system is shown in Fig.2.

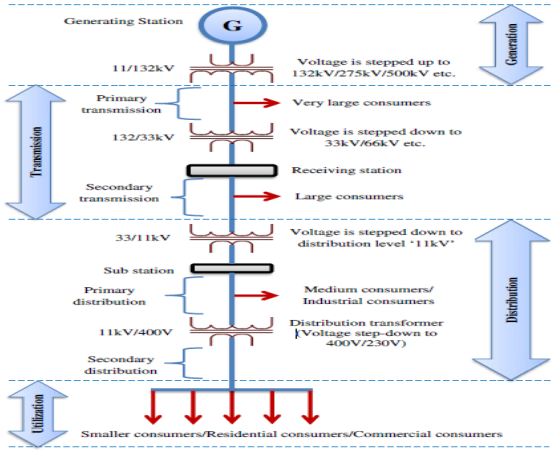

Figure.2: A simple layout of electric power system

2. PROBLEM STATEMENT

In a distribution system, there may be several different compensating devices. However, in a radial distribution system, the voltage profile of a particular bus can be poor or distorted or unbalanced if the demand is increased suddenly or loads in any part of the system are nonlinear or unbalanced. The power quality problems in the DS usually originate from voltage disturbances and power loss.

In DS the maximum amount of power gets consumed by the reactive loads, as a result there is increase in lagging power factor current drawn by these loads. Hence, the demand of excessive reactive power increases, which causes the reduction in the capability of active power flow, increase in power loss and poor voltage profile. Therefore, in recent days the voltage profile and power loss predominantly play vital role in the planning and operation of DS. Thus, the main reason of poor voltage profile and power loss in DS is the excessive demand of reactive power and increase in load. The DSTATCOM, which belongs to the family of DFACTS devices can compensates the reactive power statically in the DS to minimize the power loss and improve the voltage profile.

Research Objectives

- The main objective of this paper is to represents the Instantaneous power control and Power factor correction using FACTS device D-STATCOM.
- In this paper design and implementation of Modulation index based multilevel inverter based static synchronous compensator (DSTATCOM) has been carried out.
- In this Paper we are going to represents the working of the D-STATCOM using MATLAB simulation for our objective and also analysis the performance of device using the simulation results.
- Simulation result analysis carried out with different load conditions to analyze the superior performance of MLI-DSTATCOM controlled using SRF in Matlab Simulink.

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3. POWER QUALITY & FACTS DEVICES

Power System is a subsystem of Electrical Engineering which composes of the generating, transmitting and distributing sections of the electric power. It is the chief duty of Power System engineers is to meet the consumer's electric power demand. Rated voltage and rated frequency supply should be supplied to the end user. With the advance need of energy, Renewable energy is included in the subsisting Power System. With the beginning of the Power Electronics into the subsisting system, the consumer demand is fulfilled up to a certain extent but the Power Quality problem is now one of the chief concerns of Power engineers. Power quality is defined as a capability of system or an equipment to function satisfactorily in its electromagnetic environment with circuit introducing intolerable electromagnetic disturbance to anything in that environment. Power quality is a set of electrical boundaries that allows a piece of equipment to function in its manner with circuit significant loss of performance.

Power Quality Problems

- The major types of power quality problems are:
- Interruption
- Voltage sag
- Voltage swell
- Transient
- Waveform distortion
- Harmonics

Interruption:-
An interruption is define as complete loss of supply voltage or load current.

Voltage sag:-
RMS reduction in the AC voltage at power frequency from half of a cycle to a several seconds duration.

Voltage swell:-
RMS increase in the AC voltage at power frequency from half of a cycle to a several seconds duration.

Transient:-
Transient are defined as when there is a sudden change in voltage or current in a power system at that time transient are occurred.

Waveform distortion:-
Voltage or current waveforms assume non sinusoidal called

the distorted wave. It is define as steady state deviation from an ideal sine wave due to harmonics.

Harmonics:-

Harmonics component in A.C system is defined as a sinusoidal component of a periodic waveform that has a frequency equal to integer multiple of the fundamental frequency of the system. Sinusoidal component of a periodic wave having a frequency that an integral multiple of the fundamental frequency. If the fundamental frequency is 50 Hz that the third harmonic is a sinusoidal wave of 150 Hz.

Introduction to FACTS

FACTS gives solution to the problems and limits which are introduce in power system with the introduce of power electronics based control for reactive power. It is defined as "Alternating current transmission systems incorporating power electronics based and other static controllers to enhance control capability and increase power transfer capability." FACTS is term for a group of technologies that increases the transmission capacity of the electricity network maintain voltage reliability and grid capability and reduce overall power losses. With the introduction of many non-linear loads at the consumer end, Power Quality problem is a serious threat to the Power System. As per IEEE, Power Quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment.

Common Power Quality problems that can be observed in daily life are Voltage Sag, Voltage Swell, Voltage Flickering, Over-Voltage and Under-Voltage. Impulsive transients, Oscillatory transients and Harmonics are also Power Quality problems. For the Harmonic elimination, passive, active and hybrid power filters are used. At the distribution side, Custom Power devices are used which mainly include Unified Power Quality Conditioner (UPQC), Distribution Static Compensators (D-STATCOM) and Dynamic Voltage Restorer (DVR). The FACTS making use of power electronics promote the control of transmission line. It is increases load on the line up to the thermal limits with circuit having compromise with capability. The line capacity is increases which improves the capability of the system. There is a maximum utilization of available equipment and additional bulk transformer are possible. This is avoid of the construction of the new transmission line which is time consuming process

4. D-STATCOM

STATCOM is Static synchronous compensator. The STATCOM is a shunt connected reactive power compensation device that is capable of generating and absorbing reactive power and control of circuit input parameter. A DSTATCOM is a distributed static VAR compensator where a voltage source converter is used the controllable reactors and switched capacitors.

Working Principle of DSTATCOM

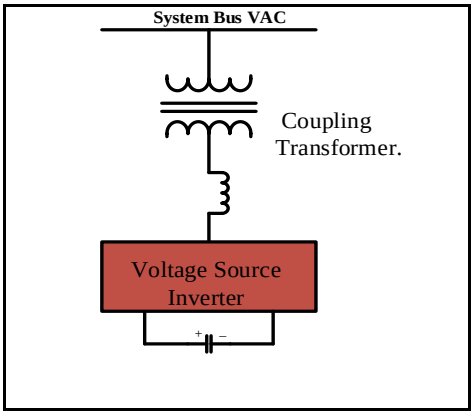

Fig.3 Schematic Diagram of DSTATCOM

A Distribution STACOM is a shunt linked device similar to Transmission STATCOM coupled with the help of a coupling transformer with the system. It is a Custom Power device which can give or take reactive power to\from the system. A simple schematic plan of a DSATCOM is shown in Figure 3.

The main components of D-STATCOM are Coupling Transformer, LC Filter, Voltage Source Converter (VSC) and DC energy storage system. The flow of Reactive power depends on the voltage conditions at PCC and at the inverter output.

- When voltage level at PCC is equal to the inverter output voltage, no reactive power transfer is there.
- When voltage level at PCC is greater than the inverter output voltage, the reactive power transfers from the system to the D-STATCOM i.e. D-STATCOM acts as an inductor and consumes reactive power
- When voltage level at PCC is less than the inverter output voltage, the reactive power transfers from D-STATCOM to the system i.e. D-STATCOM acts as a capacitor and supplies reactive power.

The voltage is compared with the ac bus voltage system, when ac bus voltage magnitude is above that of the VSI magnitude. The ac system the DSTATCOM as inductance connected to its terminal. It is an absorb reactive power. If the VSI voltage magnitude is above that of the ac bus voltage magnitude the ac system sees the DSTATCOM as injecting reactive power. If the VSI voltage magnitude and ac bus voltage magnitude is equal to so, there is no transfer means not absorbing or generating reactive power. When phase angle of the ac power system leads the VSI phase angle the DSTATCOM absorbs the real power from the ac system, if the phase angle of the ac power system lags the VSI phase angle the DSTATCOM supplies real power to ac system.

Basic Arrangement of DSTATCOM

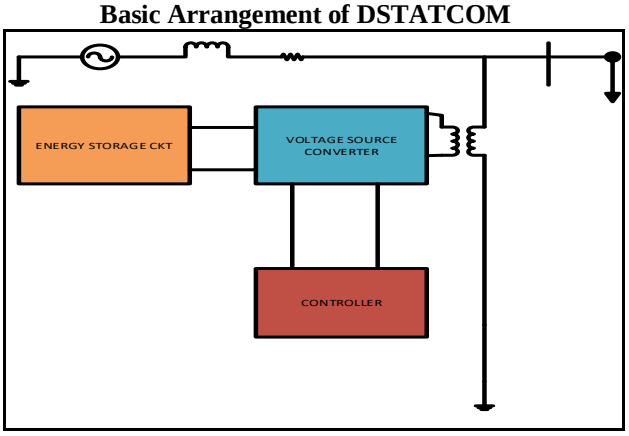

Fig.4 DSTATCOM model

Voltage Source Converter

Voltage source converter converted dc voltage to ac voltage. When ac bus voltage system greater then Et, generate capacitive reactive power for the system. When Es less than Et, absorb reactive power of the system. Voltage source converter generate a square voltage waveform as it switches the direct voltage source on and off. The main object of a VSC is produce a sinusoidal AC voltage with minimum harmonic distortion from a DC voltage.

Energy Storage Circuit

Energy storage circuit is connected in parallel with capacitor. A capacitor can be charge by the battery source. Capacitor connect parallel to circuit to maintain balance voltage.

Controller

When line voltage value feedback to the DSTATCOM strategy. The given to sequence analyzer and measure sequence of 3phase power supply R,Y,B phase to positive, negative and zero phase sequence voltage compare with add block. Maintain regulated signal to the PI controller generate error signal occur operating waveform and reference value. Then after PWM compare circuit input waveform in the triangular carrier signal waveform the different of pulses generate to given IGBT and IGBT triggering for pulses circuit input value constant.

5. SIMULATION & RESULTS

Matlab Simulation of D-STATCOM with PQ Transformation Controlling

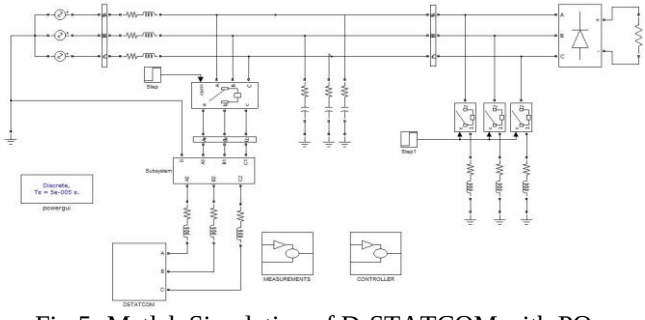

Fig 5- Matlab Simulation of D-STATCOM with PQ Transformation Controlling

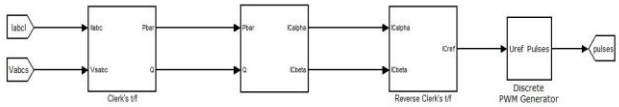

Fig 6- PQ Transformation Controlling subsystem

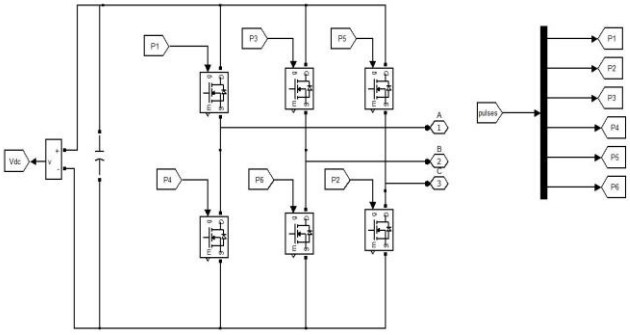

Fig 7- D-STATCOM subsystem of VSC Converter

Simulation Results

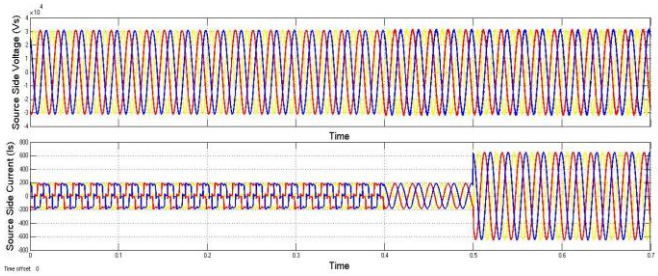

Fig 8- Source Side Voltage and Current Waveform with D-STATCOM

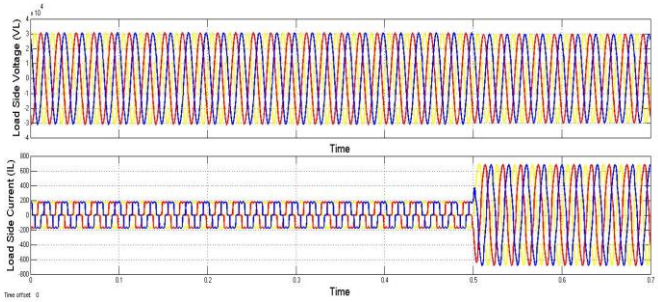

Fig 9- Load Side Voltage and Current Waveform with D-STATCOM

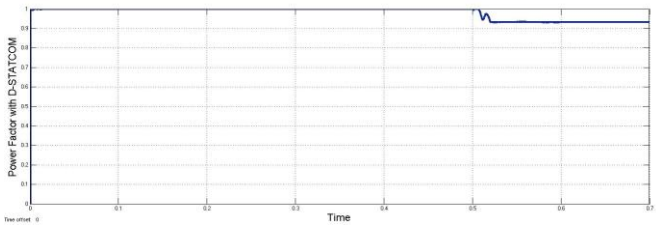

Fig 10- Power Factor Improvement with D-STATCOM

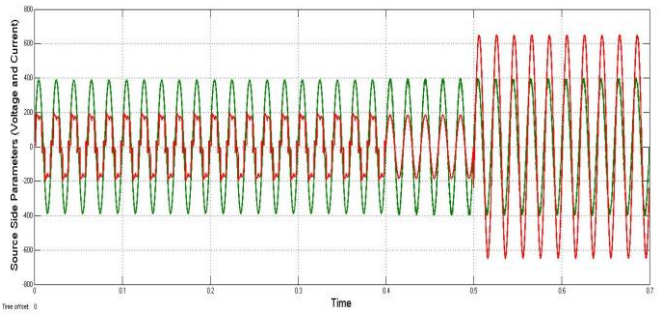

Fig 11- Source Voltage and Current Waveform with D-STATCOM

Matlab Simulation VSI Fed D-STATCOM

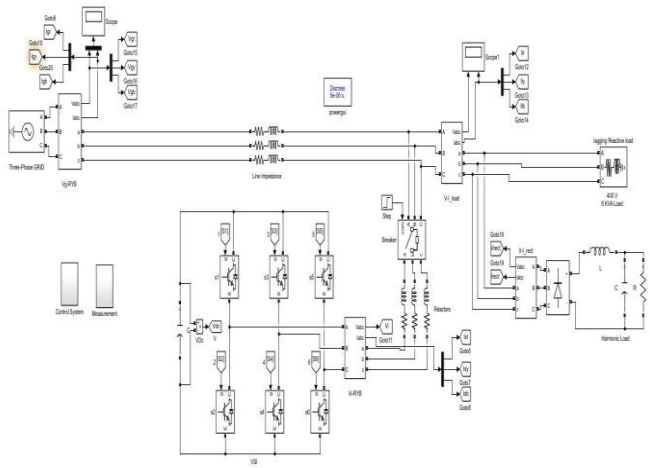

Fig 12- Matlab Simulation of Cascaded VSI Fed D-STATCOM

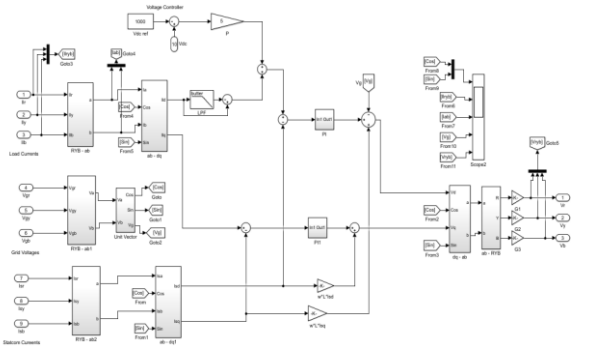

Fig 13- Controlling System of STATCOM

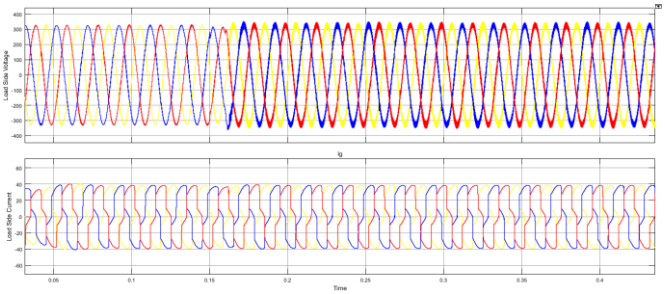

Fig 14- Load Side Output Voltage and Current Waveform

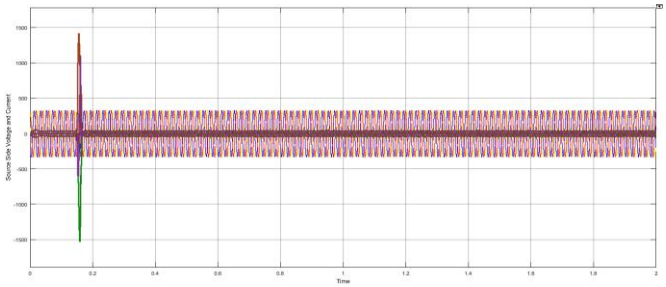

Fig 15- Source Side Input Voltage and Current

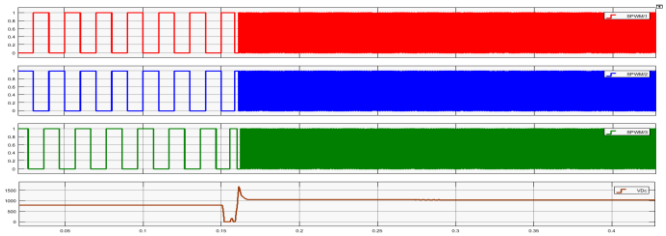

Fig 16- Triggering Pulses of Inverter and Vdc Voltage

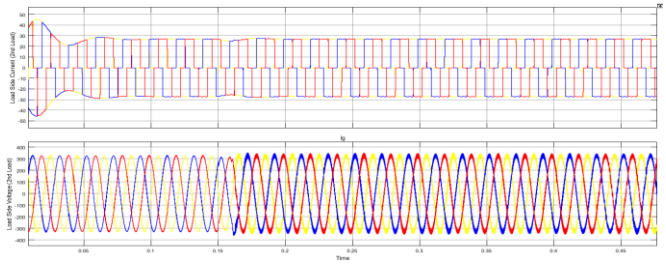

Fig 17- Second Load Output Voltage and Current

Comparison of Different Control Topologies for D-STATCOM

Sr. No.	System Parameter Name	D-STATCOM with PI Control	D-STATCOM with PQ-Transformation Control	D-STATCOM with SRF Control
1	Voltage Regulation	Good	Good	Very Good
2	Active and Reactive Power Control	Not Effective	Possible	Effective Control
3	System Response	Fast	Fast	Very Fast
4	Accuracy	Less	More	Very high
5	Reactive Power Compensation	Not Provided	Provide	Effectively Possible
6	PWM Pulse Control	Easy	Simply Done	Simply Done
7	THD Level	Less	Less	Very Less
8	Load Parameter Control	Good	Good	Very Good
9	Controller Design	Simple	Little complex	Complex
10	Controller operation and Results	Simple	Good	Very Good

6. CONCLUSION

This paper presents a modified control scheme to compensate a distribution feeder loading with non-linear loads. The D-STATCOM operation consists of three main objectives that are regulation of real powers delivering to loads, regulation of DC link voltage to ensure PWM converter operation Correction of Voltage Profile. In this Paper Control strategy of star VSI fed cascaded D-STATCOM is studied and analyzed to maintain the power quality at grid side in order to

limit the harmonic distortion and improve the voltage quantity. Further simulation for control strategy of cascaded D-STATCOM will be enhanced to check the more efficacy of the system. The Matlab Simulation of PQ Transformation based control and VSI fed SRF control Topology D-STATCOM device has been successfully developed using Matlab Simulink. The Simulation results gives the effective performance for Power Quality enhancement. The comparative analysis for different control topologies for operation D-STATCOM is carried out in this paper.

REFERENCES

[1] Venkata Reddy Kota and Sudheer Vinnakoti, "Synchronous Reference Frame Based Control of MLI-STATCOM in Power Distribution Network", 978-1-5090-0261-0/16/©2016 IEEE.

[2] Khushaboo Rani Shandilya and Uma Shankar Patel, "Mitigation of Total Harmonic Distortion using Cascaded MLI-DSTATCOM in Distribution Network", IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI-2017), 978-1-5386-0814-2/17/©2017 IEEE.

[3] T. Rakesh, V. Madhusudhan, M. Sushama "Design of Modulation Index Persistent MLI DSTATCOM for Voltage Quality Enhancement in Electrical Distribution System", 2016 2nd International Conference on Next Generation Computing Technologies (NGCT-2016) Dehradun, India 14-16 October 2016, 978-1-5090-3257-0/16/©2016 IEEE.

[4] Ramyani Chakrabarty and Ravindranath Adda, "Reduced Switch Single DC Source Cascaded H-bridge Multilevel Inverter based DSTATCOM", 978-1-7281-4878-6/19/©2019 IEEE.

[5] K. Anuradha, B. P. Muni and A. D. RajKumar, "Cascaded Multilevel Converter Based DSTATCOM using p-q theory with DC Link Voltage Balancing", 978-1-4577-1510-5/11/©2011 IEEE.

[6] Akula N V V Rajasekhar, Mamidi. Naveen Babu, "Mitigation of Flicker Sources & Power Quality Improvement by Using Cascaded Multi-Level Converter Based DSTATCOM", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016, 978-1-4673-9939-5/16/ ©2016 IEEE.

[7] D.Mohan Reddy and T.Gowrimanohar, "Optimal Hybrid Modulation Scheme for 11-Level CMC Based DSTATCOM for Power Quality Improvement", 2nd International Conference on Current Trends in Engineering and Technology, ICCTET'14, IEEE.

[8] A Pranay Kumar, G Siva Kumar, D. Sreenivasarao, "Model Predictive Control of Four Level NNPC DSTATCOM for Power Quality Improvement in Distribution System", 978-1-7281-4878-6/19/ ©2019 IEEE.

[9] L.A.Moran, J.W. Dixon, and R.Wallace, A Three Phase Active Power Filter with fixed Switching Frequency for Reactive Power and Current Harmonics Compensation, IEEE Trans. On Industrial Electronics. Volume 42, PP: 402-8, August 1995.

[10] L.T. Moran, P.D Ziogas, and G.Joos, Analysis and Design of Three Phase Current source solid State Var Compensator, IEEE Trans, on Indutry Applications. Volume 25, No.2, 1989, PP: 356-65.

[11] Sung-Min Woo; Dae-Wook Kang; et all," The distribution STATCOM for reducing the effect of voltage sag and swell" Industrial Electronics Society, 2001. IECON '01. The 27th Annual Conference of the IEEE, Volume: 2, 29 Nov.-2 Dec. 2001 Pages: 1132-1137.

[12] Ghosh, A.; Ledwich, G.;" Load compensating DSTATCOM in weak AC systems" Power Delivery, IEEE Transactions on, Volume: 18, Issue: 4, Oct. 2003 Pages: 1302-1309.

[13] Papic, I.," Power quality improvement using distribution static compensator with energy storage system", Proceedings. Ninth International Conference on. Harmonics and Quality of Power Volume: 3, 1-4 Oct. 2000 Pages: 916-920.

[14] Jalali, "Series voltage injection for voltage sag mitigation," IEEE Summer Power Meeting, Power Quality Panel Session, July 1998, San Diego, USA.

[15] A. Campos, G. Joos, P. D. Ziogas^and J. F. Lindsay, "Analysis and design of a series voltage unbalance compensation of a three-phase VSI operating with unbalanced switching function) IEEE Wans. Electron. vol. 9, pp. 269-274, May 1994.

