Hybrid DSTATCOM Topology for Compensation of Reactive Power in Non-Linear Loads

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Abstract: *The DSTATCOM is used to mitigate the power quality issues such as transients, voltage sag, voltage swell, voltage fluctuation etc. The nonlinear loads such as computer, VFD, rectifier draws non-sinusoidal nature of current even though the supply voltage is sinusoidal. As the power quality issues highly affects the power rating, filter size, compensation performance, and power loss. The complete study includes the comparison of traditional topology with new improved hybrid DSTATCOM topology. The DSTATCOM model has been simulated in MATLAB Simulink software. The series capacitor along with LCL filter is used to minimize the size of passive component that eventually reduces the voltage rating to the front end of the VSI. The values of the LCL filter have been selected considering the power losses in the damping resistor. The reduction in the power loss in the damping resistor reduces the power rating of the VSI. This will reduced the dc link voltage and voltage across the shunt capacitor of the LCL filter. The results are validated by analyzing the reduction in power rating of DSTATCOM.The source current, PCC voltage, filter current is compared for all the topologies and best alternative has been presented comparing the size of filter inductor, reduction in the damping power loss, and current compensation. The compensation performance of LCL filter is analyzed by analyzing the harmonic ripples and percentage of total harmonic distortion.*

Keywords: *D-STATCOM, Power Quality, LCL filter, Hybrid Topology*

I. INTRODUCTION

Power quality plays an important role in productivity, per capita income and ultimately an economic growth of nation. To overcome power quality issues like power factor correction, power loss, long or short duration voltage variations the static capacitors and passive filters have been utilized in recent years. Consequently, these have problems like Ferranti effect, power loss, fixed compensation and resonance with line reactance. A Flexible AC transmission (FACT) controller termed as Distribution Static Compensator was introduced in literature to overcome these drawbacks. It injects the compensating component of load current to compensate reactive and nonlinear loads which makes the source currents balanced, sinusoidal, and in phase with the load voltages. The compensating performance of any FACT controller or active filters depends on voltage rating of DC link capacitors. For better and satisfactory compensation, the DC link voltage of DSTATCOM has to keep at much higher value than the maximum value of phase to neutral (in a three phase four wire system) or phase to phase (in a three phase three wire system). As the power rating of the DSTATCOM is directly proportional to DC link voltage the traditional DSTATCOM requires a high power rated Voltage source converter. This makes the VSC heavy with higher rated power electronic switches such as IGBT.

In this paper, we have attained a reduction in the dc-link voltage for reactive load compensation. However, the reduction in voltage is limited due to the use of an L-type interfacing filter. This also makes the filter bigger in size and has a lower slew rate for reference tracking.

An L-C-L filter has been planned as the front end of the VSI in the works to overwhelm the limitations of an L filter. It delivers improved reference tracking performance while using much lower value of passive components. This also reduces the cost, weight, and size of the passive component. However, the L-C-L filter uses a analogous DC-link voltage as that of DSTATCOM retaining an L filter. Hence, disadvantages due to high dc-link voltage are still present when the LCL filter is used. Another serious issue is resonance damping of the LCL filter, which may push the system towards instability.

II. LITERATURE SURVEY

Immense study has been done on the mitigation of power quality issues using voltage controlled DSTATCOM. Various power quality issues have been studied with respect to DSTATCOM and their effects on transmission system. The major problems such as power rating, filter size, compensation performance, and power loss are formulated and various DSTATCOM topologies were compared.The DSTATCOM is connected to point of common coupling i.e. PCC through the interfacing inductor. DSTATCOM topology uses L type filter to shape the injecting current. This L type filter uses large inductor which has low slew rate to track reference currents and produces large voltage drop across it. To address this voltage, drop and better compensation, the DC link voltage has to increase. Hence, the L filter adds to cost and power rating. For distortion, free compensation the DC link voltage should be greater than or equal to the 2.44 times the phase to neutral voltage. [1]

An important issue is resonance damping which is very serious because it tends the system towards instability. To overcome this two options are there either the use of active damping or passive damping. In active damping the digital or sensors are used which will adds extra circuitry they should be tuned for proper satisfactory performance. Another option is passive damping in which the damping resistor is inserted in shunt part of LCL filter. This results in the power loss in damping resistor. In literature, various hybrid and traditional DSTATCOM topology have been studied which deals with practical issues like higher DC link voltage, Power loss, higher cost, rating and size of passive and active components, low reference tracking performance, etc. The hybrid DSTATCOM topology is introduced by *S. Karanki*, with the consideration of an important aspect of DSTATCOM application. In this study, the DC link voltage is reduced and the better compensating results with less THD compared to traditional DSTATCOM was achieved. Though DC link voltage reduced in this literature but the DSATCOM uses same L type filter for interfacing. This also uses large size inductor and has low reference tracking performance. [2]

A VSC based DSTATCOM has been accepted as the most preferred solution for power quality improvement as power factor correction and to maintain rated PCC voltage. A three phase DSTATCOM has been implemented for compensation of nonlinear loads using BPT control algorithm to verify its effectiveness. The proposed BPT control algorithm has been used for extraction of reference source currents to generate the switching pulses for IGBTs of VSC of DSTATCOM. Various functions of DSTATCOM such as, harmonic elimination and load balancing have been demonstrated in PFC and ZVR modes with DC voltage regulation of DSTATCOM. [3]

A new control algorithm of DSTATCOM has been implemented for compensation of three phase linear and nonlinear loads. The performance of DSTATCOM and its control algorithm has been demonstrated for reactive power compensation, harmonics elimination, and load balancing in PFC and ZVR modes of operation under linear, nonlinear, and mixed loads. Test results have shown that the proposed control algorithm has a fast response for the extraction of fundamental components of load currents under noisy and distorted supply voltages. In all operating conditions, the THD of source current has been observed within an IEEE 519–1992 standard limit of 5%. [4]

A literature presents a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wire DG system. It has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid interfacing inverter with the proposed approach can be utilized to Inject real power generated from RES to the grid, and Operate as a shunt Active Power Filter (APF). [5]

The hybrid filter proposed in literature for motor drive application is connected in parallel with the converter tuned for seventh harmonic. But the design is for specific motor drive application and the reactive power compensation is not considered. [6]*O.Vodyakho* has introduced an LCL filter in front end of DSTATCOM. This makes the reduction in cost, size and rating of passive components with better tracking performance. But it uses same DC link voltage as that of traditional DSTATCOM keeping the same drawback of high DC link voltage. [7]

This paper projects a single-step non-iterative optimized algorithm for a three-phase four wire shunt active power filter under distorted and unbalanced supply conditions based on the investigation. The main objective of the proposed algorithm is to optimally determine the conductance factors to maximize the supply-side power factor subject to predefined source current total harmonic distortion (THD) limits and average power balance constraint. Unlike previous methods, the proposed algorithm is simple and fast as it does not incorporate complex iterative optimization techniques, hence making it more effective under dynamic load conditions. Moreover, separate limits on odd and even THDs have been considered. A mathematical expression for determining the optimal conductance factors is derived using the Lagrangian formulation. The effectiveness of the proposed single-step non-iterative optimized algorithm is evaluated through comparison with an iterative optimization-based control algorithm and then validated using a real-time hardware-in-the-loop experimental system. The real-time experimental results demonstrate that the proposed method is capable of providing load compensation under steady-state and dynamic load conditions, thus making it more effective for practical applications.

III. IMPLEMENTATION MODEL

A three-phase equivalent circuit diagram of the projectedD-STATCOM topology is displayed in figure 1. It is realized usinga three-phase four-wire two-level neutral-point-clamped VSI.The proposed scheme connects an L-C-L filter at the frontend of the VSI, which is followed by a series capacitor C_{se}.Introduction of the L-C-L filter significantly reduces the sizeof the passive component and improves the reference trackingperformance. Addition of the series capacitor reduces thedc-link voltage and, therefore, the power rating of the VSI.Here, R_1 and L_1 represent the resistance and inductance,respectively, at the VSI side; R_2 and L_2 represent the resistanceand inductance, respectively, at the load side; and C is the filtercapacitance forming the L-C-L filter part in all three phases. Adamping resistance R_d is used in series with C to damp outresonance and to provide passive damping to the overall system.

VSI and filter currents are i_{f1a} and i_{f2a}, respectively, in phase-aand similar for other phases. In addition, voltages across andcurrents through the shunt branch of the L-C-L filter in phase-aare given by v_{sha} and i_{sha}, respectively, and similarly for theother two phases.The voltages maintained across the dc-linkcapacitors are $V_{dc1} = V_{dc2} = V_{dcref}$.

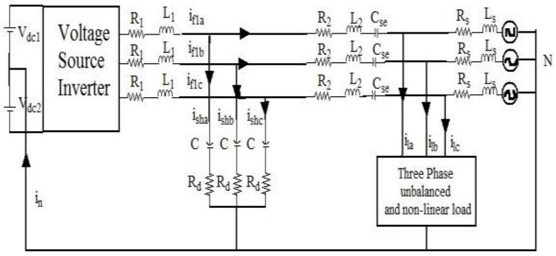

Figure 1- DSTATCOM topology to compensate Non-linear loads

IV. CONTROLOF DSTATCOM

The D-STATCOM is regimented, such that all source currents are balanced, sinusoidal, and in phase with the terminal voltage. In voltage source inverter (VSC), losses and load power are delivered by the source. Control diagram is as publicized in figure 2. Here, source is reflected, therefore the voltages are linked to calculate reference filter currents, which will not provide satisfactory operation with the direct use of terminal current. And hence the fundamental positive sequence component of three-phase voltages are used to spawn reference filter currents ($i_{f2a}{}^*$,$i_{f2b}{}^*$,$i_{f2c}{}^*$)established on symmetrical component theory. These currents are written as follows.

$$i_{f2a}{}^* = i_{la} - i_{sa}{}^* = i_{la} - \frac{v_{la1}{}^+}{\Delta_1{}^+}(P_{lavg} + P_{loss})$$

$$i_{f2b}{}^* = i_{lb} - i_{sb}{}^* = i_{lb} - \frac{v_{lb1}{}^+}{\Delta_1{}^+}(P_{lavg} + P_{loss})$$

$$i_{f2c}{}^* = i_{lc} - i_{sc}{}^* = i_{lc} - \frac{v_{lc1}{}^+}{\Delta_1{}^+}(P_{lavg} + P_{loss})$$

Where, $v_{la1}{}^+$, $v_{lb1}{}^+$ and $v_{lc1}{}^+$ are fundamental positive sequence voltages at respective phase load terminal, and

$$\Delta_1{}^+ = (v_{la1}{}^+)^2 + (v_{lb1}{}^+)^2 + (v_{lc1}{}^+)^2$$

The terms P_{lavg} and P_{loss} characterize the average load power and the total losses in the VSI, correspondingly. The average load power is premeditated using a moving average filter for improved performance during transients and can have a window width of half-cycle or full cycle depending upon the odd or odd and even harmonics, respectively, present in the load currents. At any arbitrary time t_1, it is computed as follows:

$$P_{lavg} = \frac{1}{T}\int_{t_1-T}^{t_1}(V_{la}i_{la} + V_{lb}i_{lb} + V_{lc}i_{lc})\,dt$$

$$P_{loss} = K_p e_{vdc} + K_i \int e_{vdc}\, dt$$

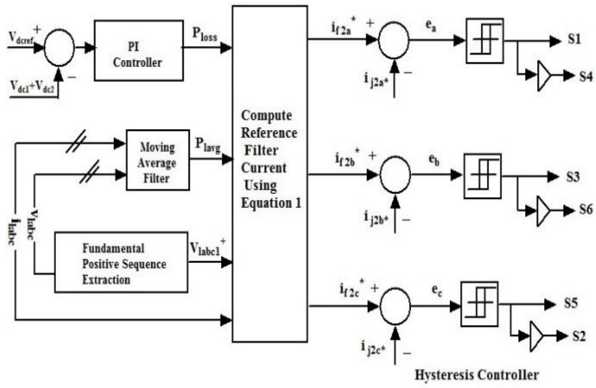

Figure 2- D-STATCOM Controller block diagram

Where,K_p,K_i, and $e_{vdc} = 2V_{dcref} - (v_{dc1} + v_{dc2})$ are the proportional gain, integral gain, and voltage error of the P-I controller, correspondingly. The current errore_{abc} is acquired by subtracting the definite filter currents from the position filter currents. The error is structuredabout a predefined hysteresis band h using the hysteresis current controller (HCC), and IGBT switching pulses are engendered.

V. CONCLUSION

For compensation of reactive and harmonic loads, and exalted hybrid property D-STATCOM topology has been designed and operation of same is recommended. The hybrid interfacing filter used here consists of an *L*-*C*-*L* filter followed by a series capacitor. This topology make available with improved load current compensation capabilities while using reduced dc-link voltage and interfacing filter inductance. Moreover, the current through the shunt capacitor and the damping power losses are significantly reduced compared with the *LCL* filter-based DSTATCOM topology. The percentage THD's in three phase source current and PCC voltage are considerably very less in the proposed topology compare to traditional topology & from this thesis report confirm that dc-link voltage is reduced which sufficient for the DSTATCOM to achieve its current compensation performance.

REFERENCES

[1] C. Kumar, M. K. Mishra, "An Improved Hybrid DSTATCOM Topology to Compensate Reactive and Nonlinear Loads", IEEE Transactions On Industrial Electronics, Vol. 61, No. 12, pp. 6517-6527 December 2014

[2] S. Karanki, N. Geddada, M. K. Mishra, and B. Kumar,"A DSTATCOM Topology With Reduced DC-Link Voltage Rating For Load Compensation With Non-stiff Source", by, IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1201–1211, Mar. 2012.

[3] S. Arya ,B. Singh, "Back-propagation control algorithm for power quality improvement using DSTATCOM", IEEE Trans. Ind. Electron., vol. 61, no. 3, pp. 1204–1212, Mar. 2014.

[4] B. Singh, S. Arya, "Implementation of single-phase enhanced phase locked loop-based control algorithm for three-phase DSTATCOM", IEEE Trans. Power Del., vol. 28, no. 3, pp. 1516–1524, Jul. 2013.

[5] M. Singh, V. Khadkikar, A. Chandra, and R. Varma, "Grid interconnection of renewable energy sources at the distribution level with power quality improvement features", IEEE Trans. Power Del., vol. 26, no. 1, pp. 307–315, Jan. 2011.

[6] R. Inzunza, H. Akagi, "A 6.6-kv transformerless shunt hybrid active filter for installation on a power distribution system", IEEE Trans. PowerElectron., vol. 20, no. 4, pp. 893–900, Jul. 2005.

[7] B. Singh, S. Sharma, "Design and implementation of four-leg voltage source-converter-based VFC for autonomous wind energy conversion system",IEEE Trans. Ind. Electron., vol. 59, no. 12, pp. 4694–4703, Dec. 2012.

[8] Oleg Vodyakho, Chris C. Mi, "Three-Level Inverter-Based Shunt Active Power Filter in Three Phase Three-Wire and Four-Wire Systems", , IEEE Transactions on Industrial Electronics, Vol. 24, No. 5, May 2009.

[9] Mahesh K. Mishra, K. Karthikeyan, "An Investigation On Design And Switching Dynamics of a Voltage Source Inverter To Compensate Unbalanced and Nonlinear Loads", IEEE Transactions on Industrial Electronics, Vol. 56, No. 8, August 2009.

[10] U. Koteswara Rao, Mahesh K. Mishra, Arindam Ghosh, "Control Strategies for Load Compensation Using Instantaneous Symmetrical Component Theory Under Different Supply Voltages", IEEE Transactions on Industrial Electronics, Vol. 23, No. 4, October 2008.

[11] Tzung-Lin Lee, Shang-Hung Hu and Yu-Hung Chan, "D-STATCOM With Positive-Sequence Admittance and Negative Sequence Conductance to Mitigate Voltage Fluctuations in High-Level Penetration of Distributed-Generation Systems", , IEEE Transactions On Industrial Electronics, Vol. 60, No. 4, April 2013.

[12] P. Kanjiya, V. Khadkikar, and H. Zeineldin, "A noniterative optimized algorithm for shunt active power filter under distorted and unbalanced supply voltages", IEEE Trans. Ind. Electron., vol. 60, no. 12, pp. 5376–5390, Dec. 2013.

[13] Mukhtiar Singh, Vinod Khadkikar, Ambrish Chandraand Rajiv K. Varma,"Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features", , IEEE Transactions On Power Delivery, Vol. 26, No. 1, January 2011.

[14] X Chen, Baichao Chen, Cuihua Tian, Jiaxin Yuan and Yaozhong Liu, "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features", IEEE Transactions On Industrial Electronics, Vol. 59, No. 7, July 2012.