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A Review on Improvement of Power Quality Using a Facts Device-DSTATCOM

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***Abstract*—** The term Electric Power quality has gained an increasing attention in power systems engineering in the recent years. At present there are many solutions to the power quality improvement, but this paper is based on a FACTS device- DSTATCOM. This paper focuses on Distribution Static Compensator (D-STATCOM) and addresses the different methodologies available for the improvement of power quality. The paper discusses detail description and configuration of the recently introduced methodologies using DSTATCOM.

***Keywords**-FACTS (Flexible AC Transmission Systems), Distribution Static Compensator (DSTATCOM), BESS (Battery Energy storage System), VSC (Voltage Source Converter), Point of Common Coupling (PCC), non-stiff source, LCL Filter.*

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I. INTRODUCTION

Generally the term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. However, there are many devices that distort the waveform for example non-linear loads. These distortions may propagate all over the electrical network. In recent years, there has been an increased use of non-linear loads which has resulted in an increased fraction of non-sinusoidal currents and voltages in Electric Networks. In earlier stages improvement was done by conventional devices such as tap-changing transformer, synchronous condensers, capacitor placement in shunt, etc. But with improvement of power electronic devices a new height has achieved [1]

Poor Power Quality can be explained as any event related to the electrical network that ultimately results in a financial loss. The main contributors for the low voltage and poor power quality may be reactive power, which unnecessarily loads up the supply system, load imbalance, fast voltage variations leading to flicker. Possible consequences of Poor Power Quality may be equipment failure or malfunctioning, increase of system losses, unexpected power supply failures, etc.

Electricity supply has a very important role in the technology advancement along with the economic development around the world. The power supply reliability and quality relates very closely to the economic growth of any country. But, lot of problems is created to achieve quality and reliable power supply. The reasons may be the power quality disturbances like voltage imbalance, swells, sags, harmonics, flickers, etc. To diminish these problems, power electronics based FACTS devices are used in the transmission and distribution systems.

The FACTS devices have been used to resolve the voltage stability problem and attain major power transfer. The FACTS devices can also be in effect for the power distribution systems to augment the quality and the reliability of power conveyed to the consumers.

Presently power electronic devices are utilized to great extent in industries and also for domestic purpose. These devices have significant impacts on the supplied voltage quality. If the power quality of the network is good, then the load (any linear/non-linear) connected to it will run efficiently and satisfactorily. On the other hand if it's not good, then loads connected to it will have a reduced lifetime, and there will be reduction in the efficiency of the electrical installation.

II. STATE OF THE ART-DSTATCOM

STATCOM is one of the vital FACTS Controllers. It can be based upon current-sourced or voltage sourced converter. A STATCOM (static synchronous compensator) is also called as a "static synchronous condenser". Basically it is a regulating device used on ac electricity transmission networks [2].

In general, a STATCOM is installed to support electricity networks that have often poor voltage regulation and a poor power factor. However there are other uses, out of which the voltage stability is the most common one. A STATCOM is actually a VSC (voltage source converter)-based device, provided with the voltage source behindhand a reactor. The voltage source is produced from a DC capacitor and hence a STATCOM has inadequate active power capability. However, increments in its active power capability can be brought by connecting an appropriate energy storage device across the DC capacitor. The amplitude of the voltage source is influenced by the reactive power of the STATCOM terminals.

The basic purpose of the load compensation is to inject currents in such a way that at the PCC (point of common coupling) the source currents and the PCC voltages are balanced and sinusoidal. When a STATCOM is employed at the distribution level (or at the load end) for power factor improvement and voltage regulation alone it is called DSTATCOM (Distribution Static Compensator).DSTATCOM is a shunt connected voltage source converter that is utilized to compensate bus voltages.

A. D-STATCOM Operation

A D-STATCOM is actually shunt device that regulates the system voltage by absorbing or producing reactive power at a PCC. Fig 1 shows a diagram of a DSTATCOM which is placed in shunt to the transmission/distribution line. It is connected to the distribution network through the impedance of the coupling transformer. A constant DC link voltage is provided by a DC-link capacitor.

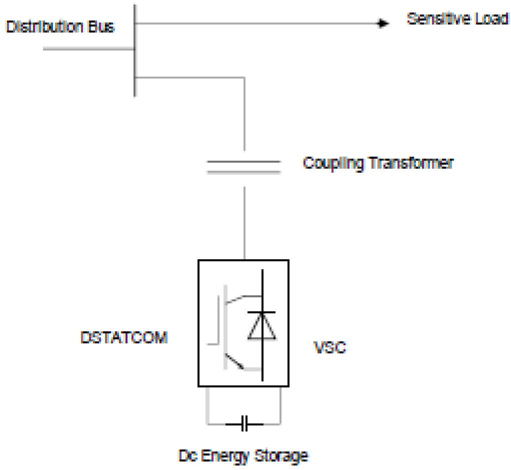

Figure 1.D-STATCOM- basic diagram.

The output voltage of the D-STATCOM is generated by a VSC (voltage source converter) functioned from an energy storage capacitor. The dc input voltage to the DSTATOM is obtained from a charged capacitor. A set of controllable 3-Φ output voltages are produced b this input voltage (dc) at a frequency that of the ac power system.

The output voltages are in phase with the corresponding ac voltage and are coupled through the coupling reactance. The reactive power exchange between the D-STATCOM and an AC system can be controlled by varying the magnitude of these output voltages. The increase in magnitude of the output voltage above the system voltage enhances the converter to generate the reactive power for the system and vice versa.

III. DSTATCOM CONFIGURATIONS

In this section the various methodologies of load compensation or power quality improvement using modification in dstatcom topologies are discussed.

A. Load Compensation using DSTATCOM and BESS.

Alka Singh and Suman Bhowmick [3] presented the modeling and control of two custom power devices-DSTATCOM (Distribution Static Compensator) and BESS (Battery Energy Storage Systems). They mainly discussed the configurations of BESS and DSTATCOM, their control strategies, modeling of the system in the Matlab and their performance. DSTATCOM configured as two-level voltage source converter, dc energy storage device and a coupling transformer. On the other hand BESS configuration mainly consists of a battery at the dc link. The dc battery has a linked small series resistor (R1) connected in a parallel combination of a resistance (R2) and a large capacitor (C2). Also a dc link capacitor is added to this circuit in parallel. The control strategy used for controlling both BESS and DSTATCOM is a Synchronous Reference Frame Theory. This theory is based on the current transformation in synchronously rotating d-q frame. The Test System -single line diagram is shown below in fig.2.

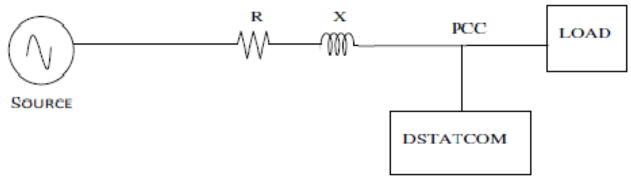

Figure 2. Single line diagram for the test system.

The above system is modeled in Matlab. The performances for the above test model for DSTATCOM and BESS have been carried out. The DSTATCOM is performed for linear and non-linear load (including RL and RLC loads connected at end of diode rectifier). On the other hand BESS is performed for two cases viz. equal sharing of active power and constant source power. The DSTATCOM regulates the PCC voltage for both linear and non-linear loads. Also the THD level of supply is improved for the non-linear loads. For BESS, it also maintains the PCC voltage and dc link voltages at their reference values and the additional power that loads requires is also equally shared. The BESS maintains the active power delivered at a constant value. Thus, DSTATCOM performance for linear and non-linear loads are found satisfactory and also the BESS design is modelled, controlled and simulated and can have a huge scope for power quality improvement

B. Load Compensation by means of DSTATCOM Hybrid Filter.

Srinivas Karanki and Mahesh Mishra [4] proposed a new DSTATCOM topology. Basically they made some modifications in the conventional DSTATCOM topology. The conventional topology for DSTATCOM is shown below in Fig.3. The modification is addition of a series capacitor along with an interfacing inductor and a shunt capacitor in parallel to the active filter. The series capacitor enhances reduction in dc-link voltage along with the reactive power (that load requires) compensation. The shunt capacitor with help of the control feedback algorithm enables to maintain the terminal voltage to the desired value. They carried out the simulation study of the proposed topology (Fig.4) using PSCAD (Power Systems Computer-Aided Design) simulator and also carried out experimental studies to verify it. They preferred a system with a non-stiff source and with considering the feeder impedance and mainly focused on the conventional and proposed topology comparison, VSI parameters design, Cf and Csh (hybrid filter) detail design aspects, state feedback control, generation of reference currents and the simulation results.

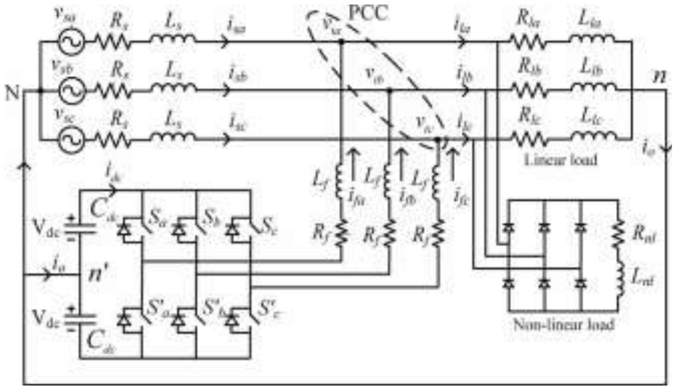

Figure.3 Equivalent circuit of the neutral clamped VSI topology-based DSTATCOM. (Conventional topology)

The conventional topology consists of neutral-clamped VSI topology-based DSTATCOM as shown in Fig.3.

The proposed topology consists of addition of series capacitor (Cf) along with an interfacing inductor and the shunt capacitor (Csh). Fig.4. shows the equivalent circuit diagram of the proposed topology. They discussed in detail designing of the VSI parameters and also design of Cf and Csh. For the feedback control strategy they designed a PSO (particle swarm optimization)-based state feedback control [5].They generated reference compensator currents under distorted and unbalanced voltages and even though obtained the balanced source currents. The values of Cf and Csh designed were 65μF and 50μF respectively.

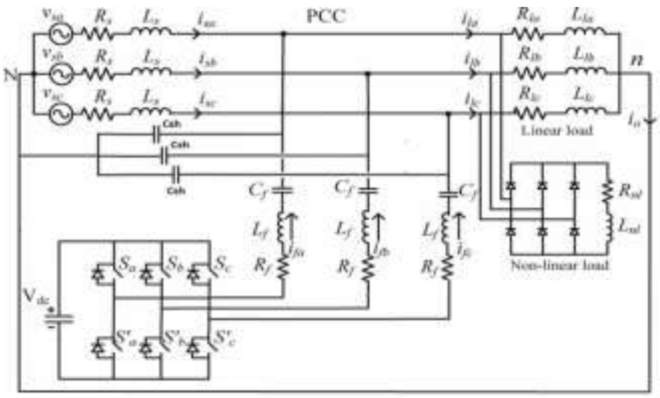

Figure.4. Equivalent circuit of the proposed neutral clamped VSI topology-based DSTATCOM (hybrid filter).

They validated the proposed topology by simulating it in PSCAD software and found that the topology enhances load compensating capacity at a reduced dc-link voltage, less total harmonic distortions in the source currents and less average switching frequency as compared to the conventional topology (Fig.3) of DSTATCOM.

C. A Hybrid topology for reducing dc-link voltage rating.

S B Karanki and Nagesh G [6] proposed a hybrid topology for DSTATCOM (Distribution Static Compensator) applications. The dc-link voltage is mainly responsible for the compensating capability of the DSTATCOM. In their proposed topology a series capacitor along with the interfacing inductor is used. The proposed topology enhances reduction in dc link voltage without the compromising the performance. Also it enables to reduce the average switching frequency of the VSC of the DSTATCOM. They mainly discussed the detail design of this series capacitor utilized for the hybrid filter and carried out simulation using PSCAD, graphic-driven simulation software and presented the results. They compared the conventional and the proposed topologies and discussed the detail design aspects of VSI parameters, Cf for proposed topology by generating reference currents but without state feedback control.

The conventional topology is a neutral clamped VSI based DSTATCOM topology (same as for [4]) as shown in Fig.3. The proposed topology is a neutral clamped VSI based DSTATCOM topology- a hybrid filter as shown in Fig.5 below.

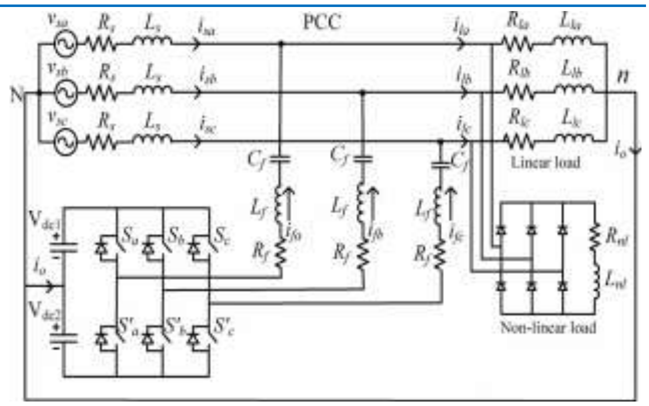

Figure.5. Equivalent circuit of proposed neutral clamped YSI topology based DSTATCOM (Hybrid filter)

The basic difference in the conventional and the proposed topologies is only the addition of a series capacitor accompanied by an interfacing inductor. The value of this capacitor (Cf) is found to be 280μF. They simulated the proposed topology using this value of Cf in PSCAD simulator and presented the results and concluded that this hybrid DSTATCOM topology has the load compensating capability at a lower dc link storage capacity. Also the proposed topology enables less THD and average switching frequency than the conventional one.

D. Modified DSTATCOM Topology with reduced filter size and VSI Rating.

Two important concerns while employing DSTATCOM are the rating of VSI (Voltage Source Inverter) and size of Lf (Interfacing Inductor). Chandan Kumar, Mahesh K. Mishra [7] proposed a new DSTATCOM topology that concurrently reduces interfacing filter size and VSI rating as well with improved current compensation abilities. To reduce dc link voltage a capacitor is placed in series with an interfacing filter. And an LCL filter has been used to reduce the interfacing filter size. This LCL enhances using considerably smaller value of inductor as that in the conventional L filter and also provides exceptional switching harmonics removal capability. The smaller value of inductance will affect a small voltage drop across it and this in turn further reduces the dc bus voltage size and ultimately the VSI rating. They presented detailed design aspects of LCL filter parameters and the series capacitor, VSI parameters of DSTATCM and generating the reference currents. They performed the simulation on PSCAD/EMTDC and presented the results.

The traditional topology considered in their research is a 3-Φ, 4-wire, 2-level, neutral point clamped VSI. It is the same system as shown in Fig.3. The proposed work of C Kumar and M Mishra is the modification in the traditional topology. Their proposed topology consists of the DSTATCOM conventional topology with front end inductor L exchanged by the LCL filter, followed by a Cse (series capacitor) as shown in Fig. 6. below.

The authors briefly discussed the detail designing of the VSI parameters for the proposed topology and found the following values Vdc=110V, Cdc=3000μF, L1= 3Mh, L2= 0.6Mh, Cfc= 10μF, R1=R2= 0.05Ω and presented the simulation results performed on PSCAD/EMTDC.

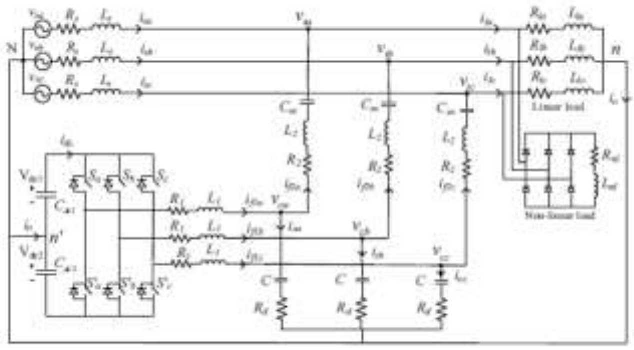

Figure.6. Proposed DSTATCOM topology consisting of LCL filter and Cse.

They found that the proposed DSTATCOM topology offers superior current compensation at a reasonably lower dc link value as compared to the traditional topology. The LCL filter provides excellent switching harmonics removal capability thus leading to low cost, reduced weight, size and rating of the DSTATCOM as compared to the conventional topology.

IV. CONCLUSION

This paper presented a brief overview of the functionalities and various topologies of DSTATCOM (also BESS). The paper also presents review of different modifications for the same DSTATCOM topology. The content presented in paper can be used for deciding the proper methods for particular conditions like for example lower dc link voltage, maintaining active power delivered, reducing average switching frequency, obtaining less THD, etc.

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