International Journal of Electrical, Electronics and Computer Engineering **2**(1): 59-64(2013)

ISSN No. (Online) : 2277-2626

A Review on the Control Strategies used for DSTATCOM and DVR

Reena Asati and Dr. N.R. Kulkarni
Department of Electrical Engineering,
P.E.S. Modern College of Engineering, Pune, (MS)

(Received 15 February, 2013 Accepted 10 March, 2013)

ABSTRACT: Presently many types of FACT controllers are available for the application of power system stability. This paper is only focusing on Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) and addressing the different controlling techniques available for the proper controlling of both devices. The paper provides the detail description and configuration of the recently introduced controlling methods for both the devices with their advantages, limitations applicable conditions.

Keywords: Power System Stability (PSS), Distribution Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR).

I. INTRODUCTION

Increased application of the sophisticated electronic devices like microcontrollers, FPGA, CPLD in industrial and home requires a smooth operational power supply and to maintain such supply the power company uses regulating equipments. Although all type of power quality problems are important but voltage dips occur more often and cause severe problems and economical losses. Voltage dips mainly have their origin in the higher voltage levels. Faults due to lightning, is one of the most common causes to voltage dips on overhead lines. Nowadays, various types of Custom Power Devices (CPD) such as D-STATCOM, Dynamic Voltage Restorer (DVR) and Static Transfer Switch (STS) are introduced and used as a mitigation device to improve power quality. The D-STATCOM and DVR are most effective Voltage Source Converter (VSC) based devices among other types of CPDs which are used for power quality improvement [6]. The working of both D-STATCOM and DVR are based on VSC. A DVR injects a voltage in series with the system voltage and a D-STATCOM injects a current into the system to correct the voltage sag, swell and interruption. The performance of these systems not only described by their topologies and components but greatly depends upon control algorithms they used and the modification of these algorithms can give us a cost effective improvement on the performance of the device. This paper presents operational details of these devices with brief review of some recent algorithms for enhancement and specialized operations of these devices.

II. VOLTAGE SOURCE CONVERTER (VSC)

Because both the devices based on VSC this section presents a brief explanation of this device.

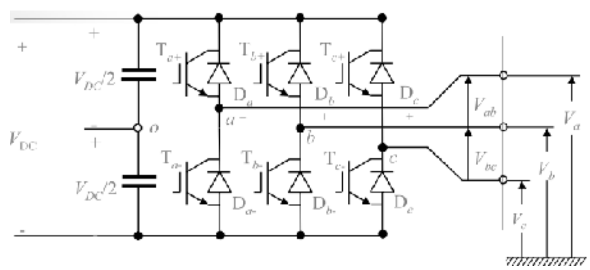

Fig. 1. The topology of a conventional two level VCS using IGBT switches.

Voltage Sourced Converters (VSCs) are six-pulse converters consisting of six power semiconductor switching devices and anti-parallel diodes. From a direct current (DC) voltage source, the VSC generates a set of controllable three-phase output voltages at the frequency of the system voltage. Pulse width modulation is used to control the firing of the semiconductor switching devices, generating an “average” sine wave. Pulse width modulation also helps mitigate the amount of harmonics [15].

III. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

When the STATCOM is applied in distribution system is called DSTACOM (Distribution-STACOM) and its configuration is the same, or with small modifications, oriented to a possible future amplification of its possibilities in the distribution network at low and medium voltage, implementing the function so that we can describe as flicker damping, harmonic filtering and long and short interruption compensation.

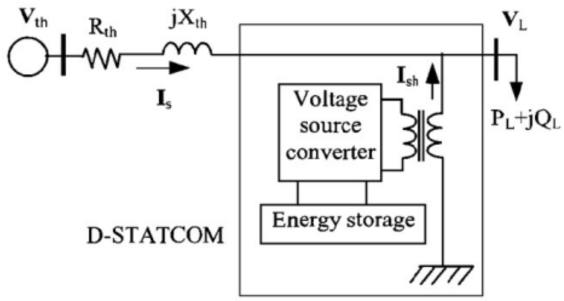

Fig. 2. Basic D-STATCOM Diagram.

Generally, the D-STATCOM configuration consists of a typical 12 pulse inverter arrangement, a dc energy storage device; a coupling transformer connected in shunt with ac system, and associated control circuits, as shown in Figure 2. The voltage source inverter converts an input dc voltage into a three phase output voltage at fundamental frequency. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer [7].

A. The Control Methods for the D-STATCOM

This section presents some recent approaches for controlling of D-STATCOM

(i) PWM based Control with only Voltage Measurement: Hojat Hatami *et al* [2] presented a new PWM based control scheme has been proposed that only requires voltage measurements and no reactive power measurements are required. The proposed control system only measures the rms voltage at the load point *i.e.*, no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Because distribution network is a relatively low-power application, PWM methods offer a more flexible option than the fundamental frequency switching methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses. The simulations carried out showed that the D-STATCOM provide excellent voltage regulation capabilities.

(ii) Adaptive Control Strategy for DSTATCOM: A novel adaptive control strategy for the DSTATCOM based on Artificial Immune System (AIS) is presented by Mitra and Venayagamoorthy [3]. In their proposed system optimal parameters of the controller are obtained first using the particle swarm optimization algorithm. This provides a sort of innate immunity (robustness) to common system disturbances. For unknown and random system disturbances, the controller parameters are modified online, thus providing adaptive immunity to the control system.

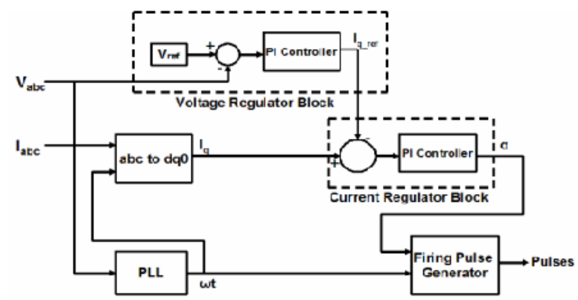

Fig. 3. Control structure for the DSTATCOM [3].

The control strategy employed in [3] contains a GTO based square wave voltage source converter (VSC) is used to generate the alternating voltage from the DC bus. In this type of inverters, the fundamental component of the inverter output voltage is proportional to the DC bus voltage. So, the control objective is to regulate VDC as per requirement. Also, the phase angle should be maintained so that the AC generated voltage is in phase with the bus voltage. The schematic diagram of the control circuit is shown in Fig. 3.

(iii) Flexible DSTATCOM operation in voltage or current control mode: Ledwich and Ghosh [4] discussed the topology and control of a distribution static compensator (DSTATCOM) that can be operated flexibly in the voltage or current control mode.

In the voltage control mode, the DSTATCOM can force the voltage of a distribution bus to be balanced sinusoids. In the current control mode, it can cancel distortion caused by the load, such that current drawn by the compensated load is pure balanced sinusoid. The proposed algorithm works properly irrespective of unbalance and harmonic distortions in load currents or source voltages.

(iv) The Lookup Table and Super capacitor energy storage system based DSTATCOM controlling: Amin Nazarloo *et al* [5] proposed a new method in which firstly the D-STATCOM and Super-capacitor energy storage system are integrated and secondly, a feedback from out of the PI controller is situated for detecting the suitable proportional gain for any specific fault that is shown in Fig. 4. The Lookup Table arrangement in feedback is based on qualitative testing by individual parameter alterations. The proposed feedback improves the speed of dynamic response of controller system and mitigates the transient states, quickly.

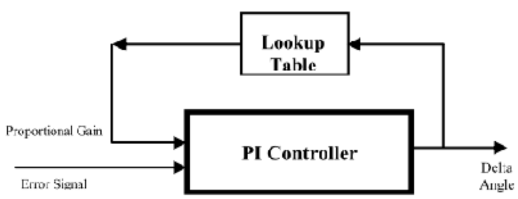

Fig. 4. Feedback for improving the dynamic response.

Considering this fact that all types of fault may occur in distribution system, controller system must be able to mitigate any types of voltage sags. The integration and control of energy storage systems, such as super capacitor energy storage system (SCESS) into a D-STATCOM is developed to mitigate such problems, enhance power quality and improve distribution system reliability.

(v) Battery energy storage system (BESS) based D-STATCOM controlling: Ch. Siva Koti Reddy and Dr. P.Linga Reddy [8] presented a BESS based control strategy for wind energy system. In their proposed scheme distribution static compensator (DSTATCOM) is connected with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power.

IV. DYNAMIC VOLTAGE RESTORER (DVR)

The Dynamic Voltage Restorer (DVR) is a series compensating device. It is used for protecting a sensitive load that is connected downstream from sag/swell etc. It can also regulate the bus voltage at the load terminal. The DVR is connected in series with the critical load. During sags and swells, the VSI synthesizes a voltage waveform of controlled magnitude, frequency, and shape. The series insertion transformer "adds" and scales this synthesized waveform and superimposes it upon the line voltage. The DVR reacts to voltage sags and swells within 1/4 of a cycle.

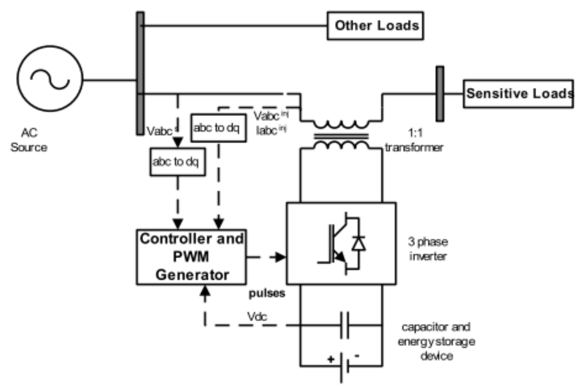

Fig. 5. Schematic diagram of DVR System.

The DVR uses DC capacitors to store the energy required to boost or buck the line voltage. During a sag or swell, the capacitors provide DC to the power transistors in the inverter, which synthesizes an AC voltage of the magnitude, waveform, phase angle, and duration needed to compensate for the event. Energy is not drawn from the system during the event. The capacitors are subsequently recharged through the inverter, which converts the line voltage to DC.

A. The Control Methods for the DVR

(i) Voltage unbalanced compensation using d-q-o transformation technique: Rosli Omar and N.A. Rahim [10] discuss the design and development of Dynamic Voltage Restorer (DVR) controller for voltage unbalanced compensation using d-q-o transformation technique. The controller in d-q-o coordinates has better performance than conventional controllers. The controlled variables in d-q-o coordinates are then inversely transformed to the original voltages which produced reference voltages to a DVR.

(ii) Feed forward pre-sag/swell voltage control method: Sanjay A Deokar *et al* [11] presents the feed forward pre-sag/swell voltage control method to regulate the output voltage of pulse width modulated (PWM) voltage source converter (VSC). The proposed controller maintains a constant load voltage under the multiple balanced/unbalanced dynamic PQ disturbances. The proposed DVR control scheme based on park's transformation is a simpler, lower cost. It is able to compensate multiple sag/swell accurately and can achieve fast response under dynamic load conditions.

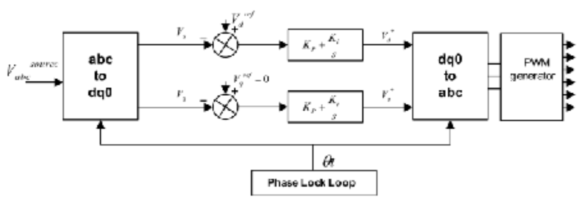

Fig. 6. Control scheme for PWM inverter [11].

This control system only measures the RMS voltage at supply side or load side and no reactive power tracking is required. The open-loop feed forward pre sag/swell voltage control method is used to restore the load voltage.

(iii) Repetitive Controller for DVR: Pedro Roncero Sánchez *et al* [13] presents a control system based on a repetitive controller to compensate for key power-quality disturbances, namely voltage sags, harmonic voltages, and voltage imbalances, using a dynamic voltage restorer (DVR). The control scheme deals with all three disturbances simultaneously within a bandwidth. The control structure is quite simple and yet very robust; it contains a feed-forward term to improve the transient response and a feedback term to enable zero error in steady state.

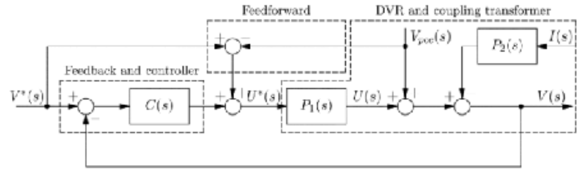

Fig. 7. Closed-loop control scheme [13].

The whole control system is depicted in Figure 7 where C(s) represents the controller. If the switching frequency is high enough, the DVR can be modeled as a linear amplifier with a pure delay $P_1(s)$. This delay is the sum of one-sample-period plus the time delay of the inverter due to PWM switching. The former applies in cases of microprocessor based implementations and the latter can be taken to be half the switching period. The transfer function $P_2(s)$ is equal to is the reference voltage V(s) for the load U(s), is the control output, whereas U(s) is the output voltage of the DVR and V(s) is the load voltage. The inputs and stand for the grid voltage and the current through the load, respectively. Both inputs $V_{pcc}(s)$ are I(s) assumed to be measurable. The model may be extended with ease to three phase applications.

(iv) Dynamic control scheme for capacitor-supported single phase dynamic voltage restorer (DVR): Carl N.M. Ho and Henry S.H. Chung [14] presented a fast dynamic control scheme for the capacitor-supported single phase dynamic voltage restorer (DVR). The scheme consists of two main control loops as inner and outer control loops. The inner loop is used to dictate the gate signals for the switches in the DVR. It is based on the boundary control method with the second order switching surface. The load voltage can ideally be reverted to the steady state in two switching actions during a supply voltage dip. The outer loop is used to generate the DVR output reference for the first loop. It has three control modes for achieving two different functions, including output regulation and output restoration. The first mode is for regulating the capacitor voltage on the dc side of the inverter, so that the output of the DVR is regulated at the nominal voltage.

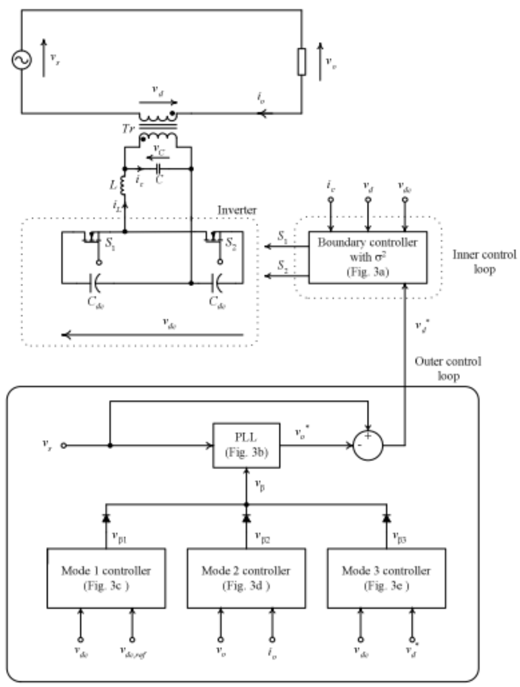

Fig. 8. Functional block diagram of the DVR [14].

The second mode is for restoring the output with the near minimum energy injection by the DVR during a voltage dip. The third mode serves for the same purpose as the second mode.

V. CONCLUSION

This paper presented a brief overview of the functionality, topologies and applications of D-STATCOM and DVR. The paper also presents review of the recent control algorithms used to enhance the performance or for specialized operation of D-STATCOM and DVR. The content presented in paper can be used for deciding the proper control methods for these devices for a particular condition or operation. It also establish that the control algorithm is a key aspect for proper utilization of resources used in these devices.

REFERENCES

[1]. S.V. Ravi Kumar and S. Siva Nagaraju “Simulation of D-STATCOM and DVR In Power Systems”, *ARPN Journal of Engineering and Applied Sciences,* Vol. **2**, NO. 3, JUNE 2007.

[2]. Hojat Hatami, Farhad Shahnia, Afshin Pashaei, S.H. Hosseini “Investigation on D-STATCOM and DVR Operation for Voltage Control in Distribution Networks with a New Control Strategy”, Power Tech, *2007 IEEE Lausanne*, 1-5 July 2007.

[3]. Pinaki Mitra, and Ganesh K. Venayagamoorthy “An Adaptive Control Strategy for DSTATCOM Applications in an Electric Ship Power System”, Power Electronics, *IEEE Transactions* on Jan. 2010.

[4]. G. Ledwich and A. Ghosh “A flexible DSTATCOM operating in voltage or current control mode”, *IEE Proc.-Gener. Trunsm. Disrrib*. Vol. **149**, No. 2, Murch 2002

[5]. Amin Nazarloo, Seyed Hossein Hosseini, Ebrahim Babaei and Mohammad Bagher Bannae Sharifian ” Compensation of Voltage Sags with New Control Method for D-STATCOM Used in 13-Bus Distribution Network”, *The Computing Science And Technology International Journal*, Vol. **2**, No. 2, JUNE, 2012.

[6]. Abdollah Shokri, Hussain Shareef, Azah Mohamed, Hadi Zayandehroodi and Masoud Farhoodnea “Effect of Network Parameters on the Injection Current Requirement of D-STATCOM Designed to Mitigate Voltage Sag”, *Research Journal of Applied Sciences, Engineering and Technology,* **5**(1): 161-166, 2013.

[7]. Amin Nazarloo, Seyed Hossein Hosseini, Ebrahim Babaei and Mohammad Bagher Bannae Sharifian ” Integrated D-STATCOM with Supercapacitor Used in IEEE Industrial Distribution System”, *ECTI Transactions on Electrical Eng., Electronics, and Communications* Vol.**10,** No.1 February 2012.

[8]. Ch. Siva Koti Reddy and Dr. P.Linga Reddy ” A DSTATCOM-Control Scheme for Power Quality Improvement of Grid Connected Wind Energy System for Balanced and Unbalanced Non linear Loads”, *International Journal of Modern Engineering Research (IJMER)* Vol. **2**, Issue.3, May-June 2012 pp-661-666.

[9]. S. Deepa and Dr. S. Rajapandian “Voltage Sag Mitigation Using Dynamic Voltage Restorer System”, *International Journal of Computer and Electrical Engineering*, Vol. **2**, No. 5, October, 2010.

[10]. Rosli Omar and N.A. Rahim “Voltage Disturbances Mitigation in Low Voltage Distribution System Using New Configuration of Dynamic Voltage Restorer (DVR)”, *World Applied Sciences Journal*, **10**(12): 1480-1489, 2010.

[11]. Sanjay A Deokar, Laxman M Waghmare “DVR Control Strategy for Dynamic Power Quality Disturbance Mitigation”, *International Journal of Scientific and Research Publications*, Volume **2**, Issue 11, November 2012.

[12]. Shazly A. Mohammed, Aurelio G. Cerrada, Abdel-Moamen M. A and B. Hasanin "Dynamic Voltage Restorer (DVR) System for Compensation of Voltage Sags, State-of-the-Art Review", *International Journal Of Computational Engineering Research* (ijceronline.com) Vol. **3** Issue. 1. Jan 2013.

[13]. Pedro Roncero-Sánchez, Enrique Acha, Jose Enrique Ortega-Calderon, Vicente Feliu and Aurelio García-Cerrada "A Versatile Control Scheme for a Dynamic Voltage Restorer for Power-Quality Improvement", *IEEE Transactions On Power Delivery*, Vol. **24**, NO. 1, JANUARY 2009.

[14]. Carl N.M. Ho and Henry S.H. Chung "Fast Transient Control of Single-Phase Dynamic Voltage Restorer (DVR) Without External DC Source", 37th *IEEE Power Electronics Specialists Conference* / June 18 - 22, 2006, Jeju, Korea.

[15]. http://www.donsion.org/calidad/cc8/c8-6.pdf.