Direct and Indirect Control Strategies of DSTATCOM Power Factor Controller

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ABSTRACT

The device analyzed in this paper is Distribution STATic COMpensator (DSTATCOM). The objective is to focus on the power factor control with the two different control strategies i.e., Indirect and Direct Control Strategies. This paper presents a study about the control strategies of DSTATCOM device and their impact on the dynamic performance of distribution network. Simulation results were presented to illustrate and understand the reliability and robustness of these control strategies in the system response to load variations.

Keywords – **Distribution Static Compensator, Power Factor, Indirect Control Strategy and Direct Control Strategy.**

I. INTRODUCTION

Quality power supply is essential for proper operation of industrial processes which contain critical and sensitive loads. For Power Quality improvement, the developments of power electronics devices such as FACTS and Custom Power Devices have introduced an emerging branch of technology providing the power system with versatile new control capabilities. The recent growth in the use of non-linear loads caused many Power Quality Problems. In general, FACTS devices are used in transmission control where as Custom Power Devices are used for distribution control. As FACTS equipment is more common on transmission network, its derivatives (e.g. DSTATCOM and DVR) on the distribution network are gaining importance. Voltage sags and swells in the medium and low voltage grid are considered to be the most frequent type of Power Quality problems. Their impact on sensitive loads is severe. Different solutions have been developed to protect sensitive loads against such disturbances. Among these, DSATCOM and DVR are most effective devices. Both of them are based on VSC principle. A DVR injects a voltage in series with the system voltage and DSTATCOM injects a current into the system to correct the voltage sag and swell.

II. CUSTOM POWER DEVICES

The new technology known as Custom Power, using power electronics-based concepts have been developed to provide protection from power quality problems in distribution systems. FACTS use power electronic devices and methods to control the high-voltage side of the network for improving the power flow. Custom Power is for low-voltage distribution, and improving the poor power quality and reliability. At present, a wide range of flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Some of these Custom Power Devices are: Series-connected compensator like DSTATCOM (Distribution Static Compensator), DVR (Dynamic Voltage Restorer), Shunt-connected compensator like Series and shunt compensator like UPQC (Unified Power Quality Conditioner) and SSTS (Solid State Transfer Switch). The DSTATCOM is based on the VSC principle can deal with voltage sags and swells which are considered to have a severe impact on manufacturing places such as semiconductors and plastic products, food processing places and paper mills.

III. DISTRIBUTION STATIC SYNCHRONOUS COMPENSATOR (DSTATCOM)

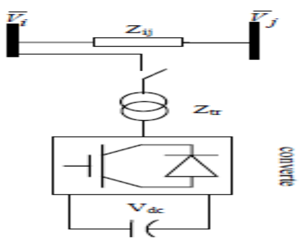

Fig.1: Structure of DSTATCOM

Distribution Static Synchronous Compensator (DSTATCOM), which is schematically depicted in Fig.1, consists of a voltage source converter connected in shunt to distribution network through a coupling transformer. The DSTATCOM has emerged as a promising device to provide not only for voltage sag/swell mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, **power factor correction** and harmonic control. It can exchange reactive power with the distribution system varying the amplitude and phase angle of an internal voltage source with respect to the line terminal voltage, resulting in controlled current flow through the coupling transformer. It can effectively replace conventional voltage and VAR control elements, load tap changing transformers, voltage regulators and switched capacitors used in distribution systems.

III.1Basic Principle of DSTATCOM

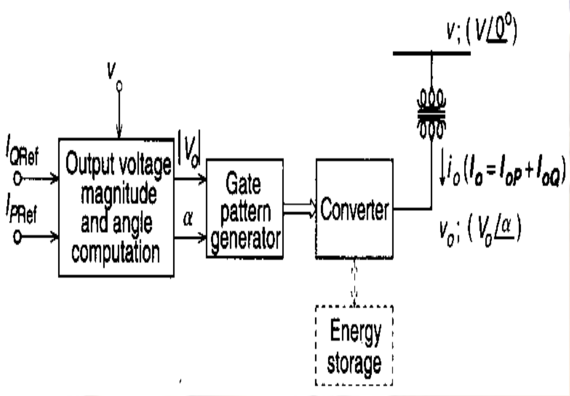

Fig.2: Basic control model of DSTATCOM

The basic control scheme of DSTATCOM is shown in Fig.2. The reactive current drawn by compensator is given by

$$I = \frac{V - V_o}{X} \quad \text{----- (1)}$$

Where V = System voltage

V_o = Output voltage of IGBT-based Inverter

X = Total circuit reactance.

If Vo is equal to V, then no reactive power is delivered to the system. If V_o is greater than V, a leading reactive power flows in capacitive mode of DSTATCOM. If V_o is lower than V, a lagging reactive power flows in inductive mode of DSTATCOM. The quantity of the reactive power flow is proportional to the difference V and Vo.

The basic control scheme of DSTATCOM is shown in Fig.2. The reactive current drawn by compensator is given by The DSTTATCOM comprises a large number of gate-controlled semiconductor power switches. The gating commands for these devices are generated by internal converter control in response to the demand for reactive power reference signal.

III.2. Voltage Sourced Converter

Converters presently employed in FACTS controllers are the Voltage Sourced Converters (VSC) type rather than Current Sourced type converters. The most dominant converters needed in FACTS controllers are the voltage sourced converters. Such Converters are based on devices with gate turn-off capability. A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any magnitude, frequency and phase angle. In distribution voltage level, usually, the employed switching element is the Integrated Gate Bipolar Transistor (IGBT), due to its lower switching losses and reduced size. As the converter rating employed in these devices is relatively low, hence the output voltage control can be executed through Pulse Width Modulation (PWM) switching pattern. In this work converter is directly controlled (i.e., both the angular position and the magnitude of the output voltage are controllable by appropriate on/off signals)[5].The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of coupling transformer.

IV. CONTROL STRATEGY

The controller continuously monitors the load voltage and current to determine the right amount of compensation required by the system and the less response time should be viable alternative. The aim of control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbance. In this paper, the proposed control strategies are indirect and direct methods. Prior to the incorporation of controller, the choice of converter is an important criterion. The two converter configurations are VSC or CSC in addition to the passive storage elements either a capacitor or a inductor. Normally VSCs are preferred due to their smaller size, less heat dissipation and less cost of the capacitor, as compared to an inductor for the same rating. The VSC converts the DC voltage across the storing device into a set of three-phase AC output voltages. These voltages are in phase and couples with the AC system through the reactance of coupling transformer.

IV.1 Indirect Control Scheme

The indirect control scheme for power factor improvement is shown in fig. 3 and indirect controller investigated here is shown in Fig. 4. Here reactive power reference Q* is set to zero in order to minimize the reactive power drawn from the supply i.e., unity power factor operation. In indirect controller the controller input is an error signal obtained from the reference reactive power and the reactive power measured. Such error is processed by a PI controller and this output is the angle δ which is provided to the PWM signal generator. The PWM generator then generates the pulse signals to the IGBT gates of Voltage Source Converter (VSC). It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously. In this, V_{ABC} are the three-phase terminal voltages, V_{RMS} is the Root Mean Square (RMS) terminal voltage. Finally, V^*_{abc} are the three-phase voltages desired at the converter output. The indirect control strategy implemented with DSTATCOM is as shown in fig. 5.

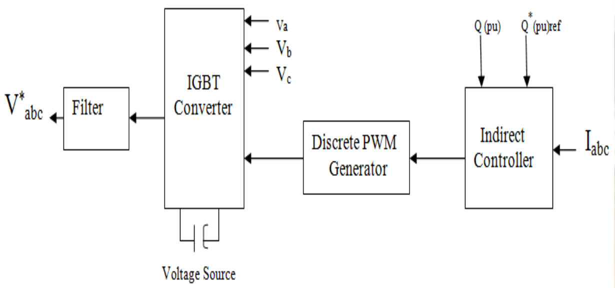

Fig. 3 Indirect control Scheme for PF improvement

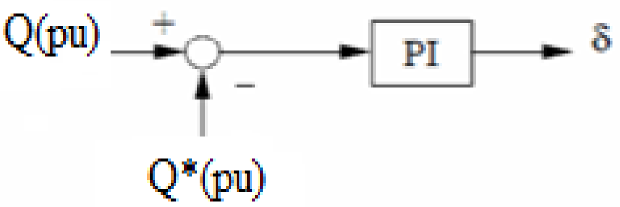

Fig. 4 Indirect control for PF improvement

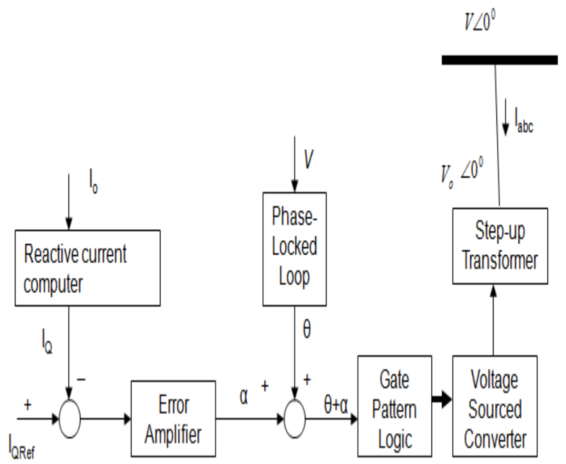

Fig. 5. Indirect Control Scheme of DSTATCOM

IV.2 Direct Control Scheme

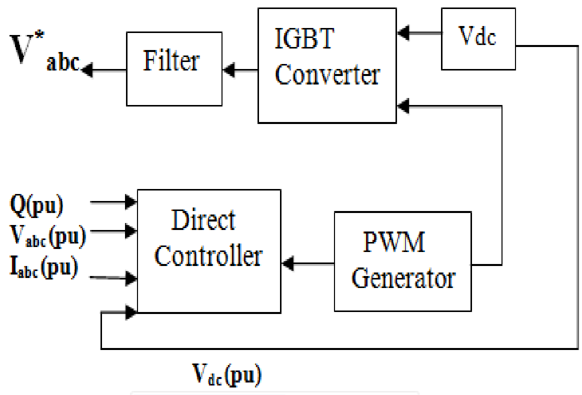

Fig. 6 Direct control Scheme for PF improvement

In direct controller, both the angular position and the magnitude of the output voltage are controlled by appropriate on/off signals . The direct control scheme for power factor improvement is shown in fig. 6 and the direct controller analyzed in this paper is exhibited in fig. 7, which employs the dqo rotating reference frame, a PLL and four Proportional Integral (PI) regulators. The first one is responsible for controlling the terminal voltage through the reactive power exchange with AC network. This PI regulator provides the reactive current reference I_q^*, which is limited +1p.u. capacitive and -1 p.u inductive. Another PI regulator is responsible for keeping the DC voltage constant through a small active power loss in the transformer and inverter. This PI regulator provides the active current reference I_d*. The other two PI regulators determine voltage reference V_d^* and V_q^*, which are sent to the PWM signal generator of the converter, after a dq0-to-abc transformation. The direct control strategy implemented with DSTATCOM is as shown in fig. 8.

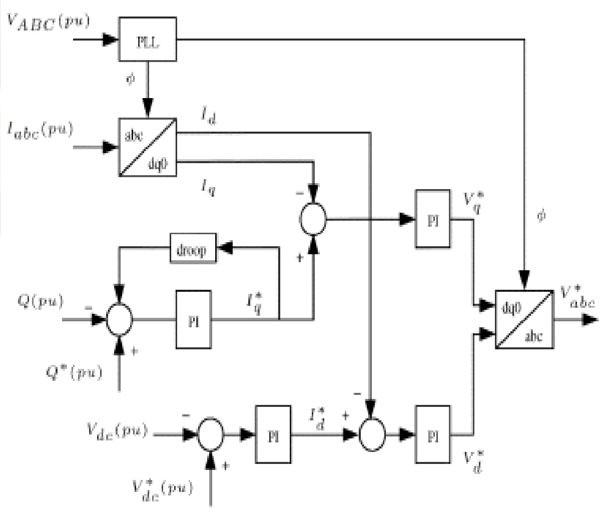

Fig. 7 Direct Controller for PF improvement

K. Sandhya, Dr. A. Jaya Laxmi, Dr. M.P. Soni / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 1, January -February 2013, pp.1970-1975

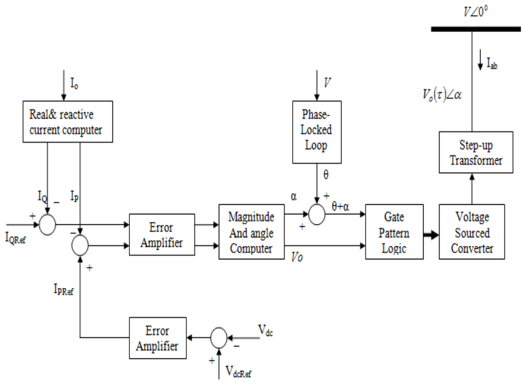

Fig. 8 Direct Control Scheme of DSTATCOM

V. Results

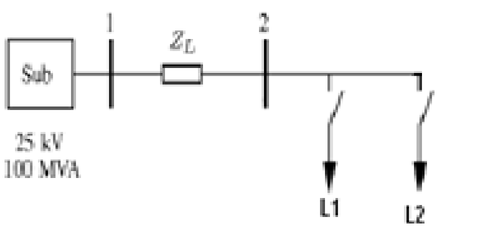

Fig . 9 Test system for PF control

Single line diagram of the test system for Power Factor (PF) control is shown in fig. 9 and load description is shown in Table I.

Table I

Load Description

Load at Bus2	P (MW)	Q (MVAR)
Inductive Load(L1)	5	2
Inductive Load(L2)	10	5

For the test system shown in Fig.9, an inductive load (L1) is connected at bus 2 at t =0.1 sec. T he load power factor varies from 1.0 (unity) to 0.928 due to the introduction of inductive load. Then at t=0.5 sec. another inductive load (L2) is connected and the power factor of load becomes 0.906 as shown in fig. 9 (a). The above events are again carried out with indirect and direct control DSTATCOM power factor controllers. The simulation results are shown in fig.10 (a) and fig.10 (b).

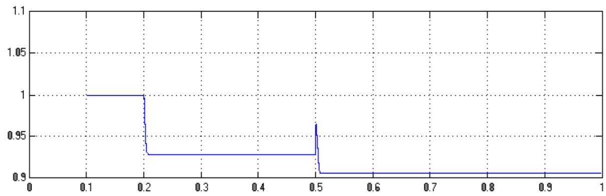

Fig. 9(a) Power Factor without DSTATCOM.

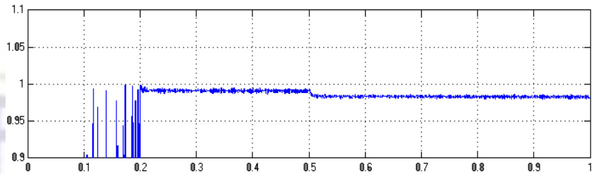

Fig.10(a) Improved Power Factor with indirect control DSTATCOM

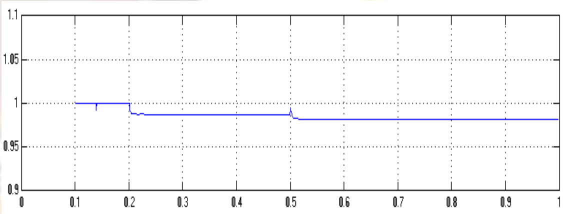

Fig.10 (b) Improved Power Factor with direct DSTATCOM

Initially without DSTATCOM the power factor was 0.928 at t=0.2 sec., with inductive load (L1) and 0.906 at t=0.5 with both inductive loads (L1 and L2) respectively . The power factor improved to 0.98 at t=0.2sec. and 0.975 at t=0.5 sec. with the indirect DSTATCOM power factor controller. With the direct DSTATCOM power factor controller, the power factor is improved to 0.985 at t=0.2 sec. and 0.981 at t=0.5 sec. It is clear from simulation results that direct control DSTATCOM power factor controller is effective than the indirect control DSTATCOM power factor controller. Table II gives the comparison of power factors.

TABLE II
COMPARISON OF POWER FACTORS

Time in sec	Without DSTATCOM	With Indirect Control Control of DSTATCOM	With Direct Control of DSTATC
T=0.2	0.928	0.98	0.985
T=0.5	0.906	0.975	0.981

Conclusion

This paper has presented PWM based indirect and direct control schemes implemented to control the VSC. DSTATCOM was analyzed as power factor controller. The direct control DSTATCOM can improve power factor better than that of indirect control DSTATCOM. Although a direct controller is more difficult and expensive, it gives superior dynamic performance.

References

[1] N.G. Hingorani and L. Gyuyi,Understanding FACTS- Concepts and Technology of Flexible AC Transmission Systems. (Ist edition,IEEE Press,2001).
[2] Walmir Freitas, Andre Morelato, Wilsun Xu and Fujio Sato, Impact of AC Generators and DSTATCOM Devices on the Dynamic Performance of Distribution Systems, *IEEE Transactions on Power Delivery, Vol. 20(***No. 2***):1493-1501, April 2005*.
[3] E. Acha, V.G. Agelidis, O. Anaya – Lara and T.J. Miller, Power Electronics Control in Electrical Systems. (Ist edition, Newnws,2002).
[4] O. Anaya-Lara, E. Acha, Modeling and Analysisof Custom Power System by PSCAD/EMTDC, *IEEE Transactions on Power Delivery, Vol. 17***(No. 1***):266-272, 2005.*
[5] N.G. Hingorani, Introducing Custom Power, *EEE Spectrum. Vol.31*: 41-48, 1995.
[6] Chris Fitzer, Mike Barnes and Peter Gree, Voltage Sag Detection Technique for a Dynamic Voltage Restorer, *IEEE Trans. Power Electronics, Vol. 22*,(No.2): 626-635, *March* 2007.
[7] H.K.Al-Hadidi, A.M.Gole, David A.Jacobson, A Novel Configuration for a Cascade Inverter – Based Dynamic Voltage Restorer with Reduced Energy Storage Requirements, *IEEE Transactions on Power Delivery, Vol. 23(*No. 2), *April* 2008.
[8] C. Benachaiba and B. Ferdi,,Power Quality Improvement Using DVR, *American Journal of Applied Sciences, Vol. 6*(No. 3): 396-400, 2009.
[9] Koen J.P.Macken, Math H.J.Bollen, Ronnie J.M.Belmans , Mitigation of Voltage Dips Through Distributed Generation Systems, *IEEE Transactions on Industry Applications, Vol. 40(*No. 6): 1686-1693, *November/December* 2004.
[10] M. A. Hannan and Azah Mohamed, PSCAD/EMTDC Simulation Of Unified Series, Shunt Compensator for Power Quality Improvement, *IEEE Transactions on power delivery*, *Vol.20(*No. 2): 1650-1656, *April* 2005.

VI. Authors' information

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