AN ENERGY STORAGE OF PODC CHARACTERISTICS BY STATCOM

Y.Rajesh[1]

[1](Dept of EEE, Global College of Engineering & Technology, Kadapa, A.P, INDIA)

Abstract— *An interline dynamic voltage restorer (IDVR) is a new device for sag mitigation which is made of several dynamic voltage restorers (DVRs) with a common dc link, where each DVR is connected in series with a distribution feeder. During the sag period, active power can be transferred from a feeder to another one and voltage sags with long durations can be mitigated. IDVR compensation capacity, however, depends greatly on the load power factor, and a higher load power factor causes lower performance of IDVR. To overcome this limitation, a new idea is presented in this paper which enables reducing the load power factor under sag conditions and, therefore, the compensation capacity is increased. The proposed IDVR employs two cascaded H-bridge multilevel converters to inject ac voltage with lower total harmonic distortion and eliminates the necessity to low-frequency isolation transformers in one side. Then, experimental results on a scaled-down IDVR are presented to confirm the simulation results.*

Keywords— Back-to-Back Converter; Cascaded H-Bridge; Interline Dynamic Voltage Restorer (IDVR); Minimum Energy; Power Quality (PQ); Voltage Sag

1. INTRODUCTION

STATIC synchronous compensator (STATCOM) is a key device for reinforcement of the stability in an ac power system. This device has been applied both at distribution level to mitigate power quality phenomena and at transmission level for voltage control and power oscillation damping (POD) [1]–[3]. Although typically used for reactive power injection only, by equipping the STATCOM with an energy storage connected to the dc-link of the converter, a more flexible control of the transmission system can be achieved [4], [5]. An installation of a STATCOM with energy storage is already found in the U.K. for power flow management and voltage control [6]. The introduction of wind energy and other distributed generation will pave the way for more energy storage into the power system and auxiliary stability enhancement function is possible from the energy sources [7]. Because injection of active power is used temporarily during transient, incorporating the stability enhancement function in systems where active power injection is primarily used for other purposes [8] could be attractive. Low-frequency electromechanical oscillations (typically in the range of 0.2 to 2 Hz) are common in the power system and are a cause for concern regarding secure system operation, especially in a weak transmission system [9]. In this regard, FACTS controllers, both in shunt and series configuration, have been widely used to enhance stability of the power system [1]. In the specific case of shunt connected FACTS controllers [STATCOM and static var compensator (SVC)], first swing stability and POD can be achieved by modulating the voltage at the point of common coupling (PCC) using reactive power injection. However, one drawback of the shunt configuration for this kind of applications is that the PCC voltage must be regulated within specific limits (typically between 10% of the rated voltage), and this reduces the amount of damping that can be provided by the compensator. Moreover, the amount of injected reactive power needed to modulate the PCC voltage depends on the short circuit impedance of the grid seen at the connection point. Injection of active power, on the other hand, affects the PCC-voltage angle (transmission lines are effectively reactive) without varying the voltage magnitude significantly. The control of STATCOM with energy storage (named hereafter as E-STATCOM) for power system stability enhancement has been discussed in the literature.

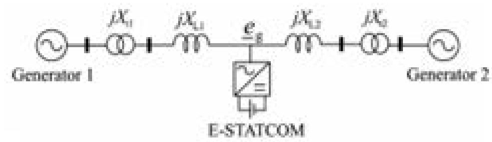

Fig. 1. Simplified two-machine system with E-STATCOM.

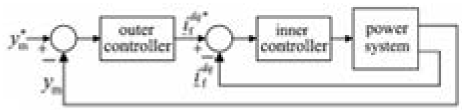

Fig. 2. Block diagram of the control of E-STATCOM.

However, the impact of the location of the E-STATCOM on its dynamic performance is typically not treated. When active power injection is used for POD, the location of the E-STATCOM has a significant impact on its dynamic performance. Moreover, the typical control strategy of the device for POD available in the literature is similar to the one utilized for power system stabilizer (PSS) [9], where a series of wash-out and lead-lag filter links are used to generate the control input signals. This kind of control strategy is effective only at the operating point where the design of the filter links is optimized, and its speed of response is limited by the frequency of the electromechanical oscillations. In this paper, a control strategy for the E-STATCOM when used for POD will be investigated. Thanks to the selected local signal quantities measured in the system, the control strategy optimizes the injection of active and reactive power to provide uniform damping at various locations in the power system. It will be shown that the implemented control algorithm is robust against system parameter uncertainties. For this, a modified recursive least square (RLS)-based estimation algorithm as described in [13], [14] will be used to extract the required control signals from locally measured signals. Finally, the effectiveness of the proposed control strategy will be validated via simulation and experimental verification.

2. POWER STEBILITY

Voltage sag as described by IEEE Standard 1159-1995, IEEE suggested carryout for Monitoring Electric Power Quality, as a reduce in voltage of RMS at the power frequency of span from 0.5 cycles to 1 minute, conveyed as the residual voltage.

The measurement of voltage sag is affirmed as a proportion of the supposed voltage; it is a dimension of the residual voltage and is affirmed as sag to a fraction value. Hence a voltage sag to 60% is equivalent to 60% of supposed voltage, otherwise 288 volts for a nominal 480 Volt system.

At present the interest for power is rising wonderfully particularly in creating nation like india. this determined interest is prompting operation of the force framework at its farthest point. on top of this the requirement for dependable, steady and quality force is additionally on the ascent because of electric force touchy commercial ventures like data innovation, correspondence, gadgets and so on. in this situation, taking care of the electric force demand is not by any means the only criteria additionally it is the obligation of the force framework specialists to give a steady and quality energy to the shoppers. these issues highlight the need of comprehension the force framework solidness. in this course we will attempt to see how to assess the soundness of a force framework, how to enhance the security lastly how to counteract framework getting to be unsteady. power framework steadiness is the capacity of an electric force framework, for a given introductory working condition, to recover a condition of working balance subsequent to being subjected to a physical aggravation, with the greater part of the framework variables limited so that for all intents and purposes the whole framework stays in place. the unsettling influences said in the definition could be blames, burden changes, generator blackouts, line blackouts, voltage breakdown or some mix of these. power framework strength can be extensively ordered into rotor point, voltage and recurrence dependability. each of these three dependable qualities can be further arranged into extensive unsettling influence or little aggravation, transient or long haul.

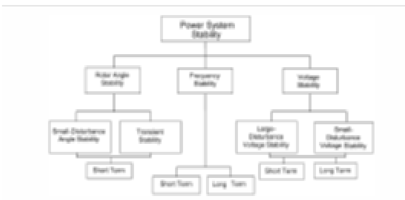

fig.3. classification of power system stability

3. PROPOSED SYSTEM

The equivalent circuit of the STATCOM is shown in Fig.1.In this power system, the resistance Rs in series with the voltage source inverter represents the sum of the transformer winding resistance losses and the inverter conduction losses. The inductance Ls represents the leakage inductance of the transformer. The resistance Rs in shunt with the capacitor represents the sum of the switching losses of the inverter and the power losses in the capacitor. In Fig.1 Vas, Vbs and Vcs are the three phase STATCOM output voltages; Val, Vbl and Vcl are the three-phase bus voltages; Ial, Ibl and Icl are the three-phase STATCOM output currents.

3.1.1 STATCOM Dynamic Model:

The tree-phase mathematical expressions of the STATCOM can be written in the following from:

$$L_s \frac{di_{as}}{dt} = -R_s i_{as} + V_{as} - V_{al} \quad (1)$$

$$L_s \frac{di_{bs}}{dt} = -R_s i_{bs} + V_{bs} - V_{bl} \quad (2)$$

$$L_s \frac{di_{cs}}{dt} = -R_s i_{cs} + V_{cs} - V_{cl} \quad (3)$$

$$\frac{d}{dt}\left(\frac{1}{2}CV_{dc}^2(t)\right) = -[V_{as}i_{as} + V_{bs}i_{bs} + V_{cs}i_{cs}] - \frac{V_{dc}^2(t)}{R_c}. \quad (4)$$

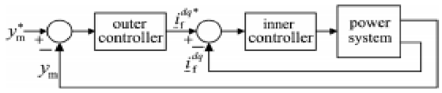

Fig.4: Traditional E-STATCOM control block diagram

By using the abc/dq transformation, the equations from (1) to (4) can be rewritten as

$$\frac{d}{dt}\begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L_s} & \omega & \frac{K}{L_s}\cos\alpha \\ -\omega & -\frac{R_s}{L_s} & \frac{K}{L_s}\sin\alpha \\ -\frac{3K}{2C}\cos\alpha & -\frac{3K}{2C}\sin\alpha & -\frac{1}{R_c C} \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} - \frac{1}{L_s}\begin{bmatrix} V_{dl} \\ V_{ql} \\ 0 \end{bmatrix} \quad (5)$$

where Ids and Iqs are the d and q currents corresponding to ias, ibs and ics; K is a factor that relates the dc voltage to the peak phase-to-neutral voltage on the ac side; Vdc is the dc-side voltage; α is the phase angle at which the STATCOM output voltage leads the bus voltage; ω is the synchronously rotating angle speed of the voltage vector; and Vdl and Vql represent the d and q axis voltage corresponding to Val, Vbl and Vcl. Since Vql = 0, based on the instantaneous active and reactive power definition, (6) and (7) can be obtained as follows.

$$P_l = \frac{3}{2} V_{dl} I_{ds} \quad (6)$$

$$q_l = \frac{3}{2} V_{dl} I_{qs} \quad (7)$$

Based on the above equations, the traditional control strategy can be obtained, and the STATCOM control block diagram is shown in Fig. 2 [10], [11], [25].

As shown in Fig. 2, the phase-locked loop (PLL) provides the basic synchronizing signal which is the reference angle to the measurement system. Measured bus line voltage Vm is compared with the reference voltage Vref, and the voltage regulator provides the required reactive reference current Iqref. The droop factor Kd is defined as the allowable voltage error at the rated reactive current flow through the STATCOM. The STATCOM reactive current Iq is compared with Iqref, and the output of the current regulator is the angle phase shift of the inverter voltage with regard to the system voltage. The limiter is the limit imposed on the value of control while considering the maximum reactive power capability of the STATCOM.

4. SIMULATION RESULTS

The POD controller described in Section III is here verified via PSCAD/EMTDC simulation using the well-known two-area four-machine system in Fig. 4.1 the implemented system is rated 20/230 kV, 900 MVA and the parameters for the generators and transmission system together with the loading of the system are given in detail in [9]. The system is initially operating in steady state with a transmitted active power, 400 MW from area 1 to area 2. A three-phase fault is applied to the system on one of the transmission lines between bus 7 and bus 8. The fault is cleared after 120ms by disconnecting the faulted line. Due to the applied disturbance, a poorly damped oscillation is obtained after the fault clearing. With the POD controller structure described in Fig. 6.1, the performance of the E-STATCOM following the fault at three different locations is shown in Fig. 4.2 As described in the small-signal analysis for two-machine system in chapter 6, when moving closer to the generator units, a better damping With respect to reactive power injection, maximum damping action is provided when the E-STATCOM is connected close to the electrical midpoint of the line and the level of damping decreases when moving away from it (see Fig. 8, gray solid plots). Because of a good choice of signals for controlling both active and reactive power injection, effective power oscillation damping is provided by the E-STATCOM irrespective of its location in the line (see Fig. 8, black dashed plots)

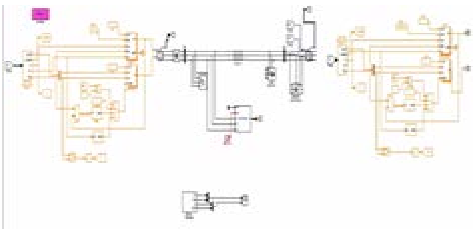

Fig 4.1 Simulink Diagram of E-STATCOM connected between Two Area System

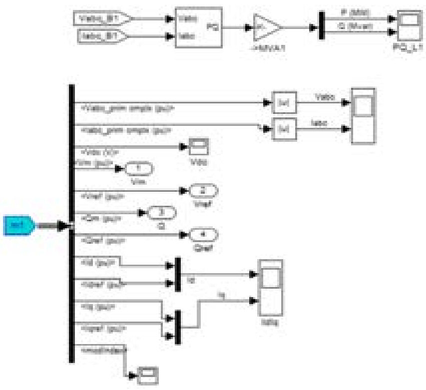

Fig 4.2 Simulink model of E-STATCOM.

5. SIMULATIONS RESULT

POD CONTROLLER WITH E-STATCOM

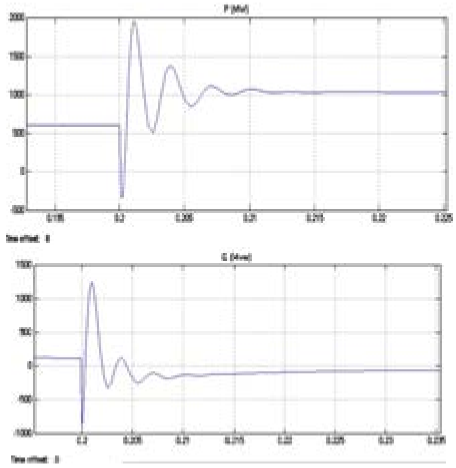

Fig 4.2.1 E-STATCOM for The Reactive And Active Power Injection

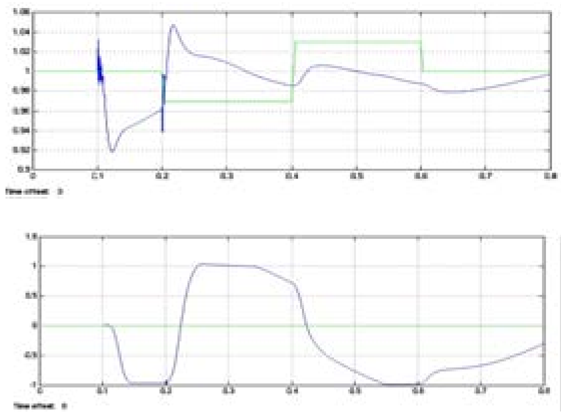

Fig 4.2.2 Measured Generator Power Output For Three-Phase Fault With E-Statcom

6. CONCLUSION

Design of an adaptive POD controller by E-STATCOM has been developed in this project. For this, a modified RLS algorithm has been used for estimation of the low-frequency electromechanical oscillation components from locally measured signals during power system disturbances. The estimator enables a fast, selective and adaptive estimation of signal components at the power oscillation frequency. The dynamic performance of the POD controller to provide effective damping at various connection points of the E-STATCOM has been validated through simulation. The robustness of the control algorithm against system parameter changes has also been proven through experimental tests. Furthermore, using the frequency variation at the E-STATCOM connection point as the input signal for the active power modulation, it has been shown that active power injection is minimized at points in the power system where its impact on POD is negligible. This results in an optimal use of the available energy source.

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