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VOLTAGE REGULATION OF POWER SYSTEM BY ADAPTIVE PI CONTROL OF STATCOM

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ABSTRACT

One of the most important requirements of a power system is to maintain a constant voltage within a permissible set of ranges. According to ever increasing load demand and secure operation of power system the voltage regulation of power system plays an very important role. In this paper, voltage regulation of power system is carried out by using an Adaptive PI control of STATCOM which will automatically adjust controller gains. By utilizing this method desired response of the system is achieved during disturbances. Performance of designed controller is verified for non-linear load.

Keywords: FACTS, Proportional-Integral(PI) Controller, STATCOM, Voltage Regulation.

I. INTRODUCTION

In the recent years, electrical power system is widely interconnected to achieve the advantage over a long distance transmission. And we need these interconnections are used not only for power delivery but to fulfill the advantages like variety of load, sharing of sources, operating cost, improvement in reliability, availability of sources, reduce fuel price [1].Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity. Recently, with the growth of nonlinear loads in industrial manufactures, the electric power quality plays major role in power transmission.

Voltage stability is an important consideration for secure operation and reliability of power supply systems. Flexible ac transmission systems (FACTS) technology is a appropriate solution that can change natural electrical characteristics of the power systems to provide better ability of power transmission, power flow control, oscillation damping. In transmission and distribution system, the important function of a static synchronous compensator (STATCOM) is to regulate the voltages at the point of common coupling (PCC). The main application of STATCOM is to provide dynamic reactive power compensation and to regulate the voltage at the interconnecting bus within acceptable limits. The static synchronous compensators are smaller in size because they do not require large energy storage units and which leads to faster response speed and better robustness properties.

In the past different control methods have been proposed for STATCOM control. References [4]–[5] mainly concentrated on the control design rather than exploring how to set proportional integral (PI) control gains. In many STATCOM models, the control logic is implemented with the PI controllers. The control parameters or gains are main key factor in STATCOM performance. Presently, few studies have been carried out in the control parameter settings. For instance, in [2]–[3], linear optimal controls based on the linear quadratic regular (LQR) control are proposed. This control depends on the designer's experience to obtain optimal parameters. In [6], a new STATCOM state feedback design is introduced based on a zero set concept. Similar to [2]–[3], the final gains of the STATCOM state feedback controller still depend on the designer's choice.

Conventionally PI controllers have been use for regulation of STATCOM. Conventional PI controller has limitations over its operating range. It is highly inefficient during nonlinear operations. Voltage regulation of power system by adaptive PI control of STATCOM is presented in this paper. With this adaptive PI control method, the PI control parameters can be self-adjusted automatically and dynamically under different disturbances in a power system. The PI control parameters for STATCOM can be computed automatically when a disturbance occurs in the system.

Therefore, STATCOM may consider as an effective solution to the problem of voltage stability. Fig.1 shows the basic structure of

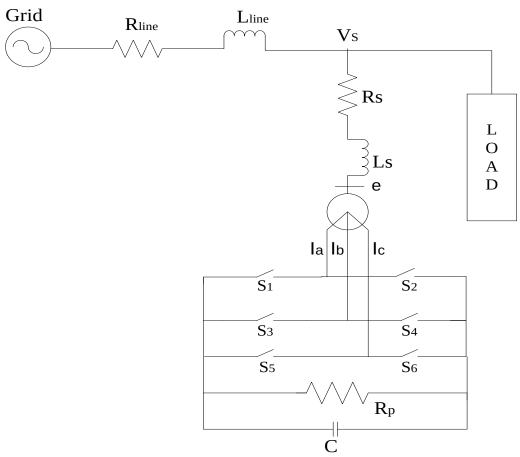

Fig.1.Basic Structure of STATCOM.

STATCOM. It is a shunt connected device which is connected to the grid through a series reactance.Different from other control methods, it is will not be influenced by the initial gain settings, and different system conditions, and the limits of human experience and judgment. This will make the STATCOM a "plug-and-play" device. In addition, this research work demonstrates fast, efficient performance of the STATCOM.

This paper is arranged as follows. Section II illustrates the system configuration and dynamic model of STATCOM. Section III presents the adaptive PI control method. Section IV presents the simulation results of adaptive PI control system. Finally, sections V conclude this paper.

II. MODELING OF STATCOM CONNECTED TO A GRID

In all FACTS devices STATCOM is an advanced device that utilizes no physical inductor or capacitor for reactive power support unlike SVC. STATCOM supplies reactive power by exchanging the instantaneous reactive power among phases of the AC system. STATCOM uses IGBT, IGCT or GTO as switching devices. In these switches, both switching ON and switching OFF events can be controlled. So this gives two degrees of freedom compared to one degree of freedom given by thyristors in SVCs. This makes it faster and more effectively controllable.

Fig.1 illustrates a schematic diagram of STATCOM connected to power system. The network consists of a grid connected to load through a transmission line. As to provide reactive power support to load, STATCOM a VSI (voltage source inverter) is connected with a capacitor in DC link. VSI is constituted of electrical switches (S1-S6) such as IGBTs or GTOs and series inductance (or a transformer). In this figure, $R_p$represents the switching losses in the inverter and power loss in capacitor, R_s represents inverter and transformerconduction losses and L_s is the leakage reactance of transformer or smoothing reactor or a combination of both. I_a, $I_b$and I_c are the phase currents flowing out of STATCOM in the Fig. 1. PCC voltage and VSI output voltage are denoted by *'V_s'* and *'e'* respectively.

The output phase voltages of VSI are given by e_a, e_b and e_c. The phase voltages at the PCC are denoted as V_a, V_b and V_c . Then:

$$e_a - V_a = R_s I_a + L_s \frac{dI_a}{dt} \quad (1)$$

$$e_b - V_b = R_s I_b + L_s \frac{dI_b}{dt} \quad (2)$$

$$e_c - V_c = R_s I_c + L_s \frac{dI_c}{dt} \quad (3)$$

$$\frac{d}{dt}\left(\frac{1}{2} C V_{dc}^2(t)\right) = -[e_a I_a + e_b I_b + e_c I_c] - \frac{V_{dc}^2(t)}{R_p} \qquad (4)$$

Applying transformation from *abc* reference frame to synchronously rotating *dq* reference frame from (1) to (4):

$$\frac{d}{dt}\begin{bmatrix} I_d \\ I_q \\ V_{dc} \end{bmatrix} = \begin{bmatrix} \frac{-R_s}{L_s} & \omega & \frac{K}{L_s}\cos\alpha \\ -\omega & \frac{-R_s}{L_s} & \frac{-R_s}{L_s}\sin\alpha \\ \frac{-3K}{2C}\cos\alpha & \frac{-3K}{2C}\sin\alpha & -\frac{1}{RpC} \end{bmatrix}\begin{bmatrix} I_d \\ I_q \\ V_{dc} \end{bmatrix} - \frac{1}{L_s}\begin{bmatrix} V_d \\ V_q \\ 0 \end{bmatrix}$$

where $I_d$and I_q are the *d* and q currents corresponding to I_a,I_b,and I_c;*K* is a factor that relates the dc voltage to the peak phase-to-neutral voltage on the ac side; $V_{dc}$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 V_d and V_q represent the *d* and *q* axis voltage corresponding to V_a, V_b, and V_c. Since $V_q = 0$, based on the instantaneous active and reactive power definition, (5) and (6) can be obtained as follows [7],[8]:

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$$p = \frac{3}{2} V_d I_d \qquad (5)$$

$$q = \frac{3}{2} V_d I_q \qquad (6)$$

III. ADAPTIVE PI CONTROL FOR STATCOM

The STATCOM with fixed PI control parameters may not reach the desired and acceptable response in the power system when the power system operating condition (e.g., loads or transmissions) changes. An adaptive PI control method is presented in this section in order to obtain the desired response and to avoid performing trial-and-error studies to find suitable parameters for PI controllers when a new STATCOM is installed in a power system. With this adaptive PI control method, the dynamical self-adjustment of PI control parameters can be realized.

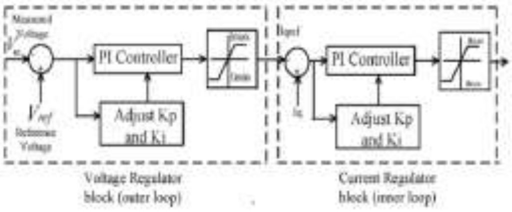

Fig3.1Adaptive PI Control Block for STATCOM.

An adaptive PI control block for STATCOM is shown in Fig.2. In Fig.2, the measured voltage $V_m(t)$ and the reference voltage $V_{\mathrm{ref}}(t)$, and the q-axis reference current $I_{q\mathrm{ref}}$and the q-axis current I_q are in per–unit values. The proportional and integral parts of the voltage regulator gains are denoted by $K_{p_V}$and K_{i_V}, respectively. Similarly, the gains K_{p_I} and K_{i_I}represent the proportional and integral parts, respectively, of the current regulator. In this control system, the allowable voltage error $K_d$is set to 0. The K_{p_V}, K_{i_V} , K_{p_I} , and K_{i_I}can be set to an arbitrary initial value such as simply 1.0. One exemplary desired curve is an exponential curve in terms of the voltage growth, shown in Fig.3, which is set as the reference voltage in the outer loop. Other curves may also be used than the depicted exponential curve as long as the measured voltage returns to the desired steady-state voltage in desired time duration. The process of the adaptive voltage-control method for STATCOM is described as follows.

- The bus voltage $V_m(t)$ is measured in real time.
- When the measured bus voltage over time $V_m(t) \neq V_{ss}$, the target steady-state voltage, which is set to 1.0 per unit (p.u.) in the discussion and examples, $V_m(t)$ is compared with V_{ss}. Based on the desired reference voltage curve, $K_{p_V}$and $K_{i_V}$are dynamically adjusted in order to make the measured voltage match the desired reference voltage, and the q-axis reference current $I_{q\mathrm{ref}}$can be obtained.
- In the inner loop, $I_{q\mathrm{ref}}$is compared with the q-axis current I_q. Using the similar control method like the one for the outer loop, the parameters $K_{p_I}$and K_{i_I}can be adjusted basedon the error. Then, a suitable angle can

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be found and eventually the dc voltage in STATCOM can be modified such that STATCOM provides the exact amount of reactive power injected into the system to keep the bus voltage at the desired value.

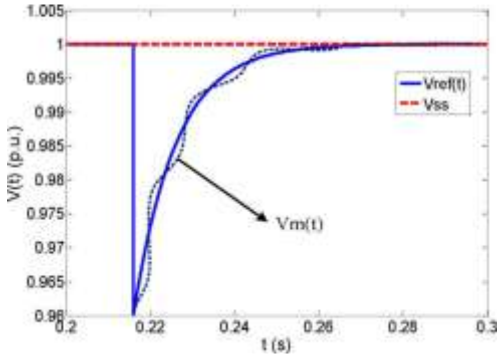

Fig3.2. Reference Voltage Curve

IV. SIMULATION RESULTS

In the detailed model, the switching elements–IGBTs/diodes, the PWM signal generator and the dc capacitor are explicitly represented. Here, a STATCOM model is implemented using MATLAB Sim Power Systems. In this model of power system a grid of 100V, 50Hz capacity is utilized for voltage regulation. And the values of proportional and integral gain components are as $K_p = 0.2$ and $K_i = 1.5$ respectively.

The three phase components source input is converted into two phase *dq* components using Clark's Transformation. A change of variables is often used to reduce the complexities in the voltage equations.

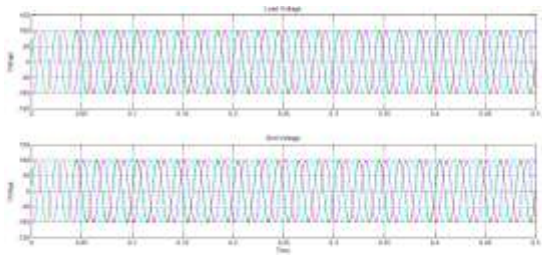

Fig.4.1 Load Voltage, Grid Voltage.

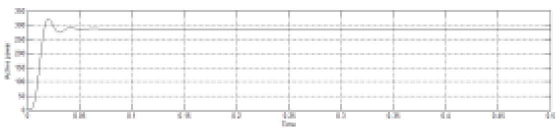

Fig.4.2.Active Power.

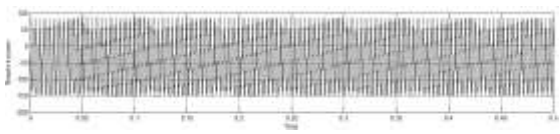

Fig.4.3.Reactive Power

As given in the above simulation results in Fig.4the load side voltage is similar as on the grid side voltage without any disturbances and Fig.5 and 0Fig.6 shows STATCOM active and reactive power respectively

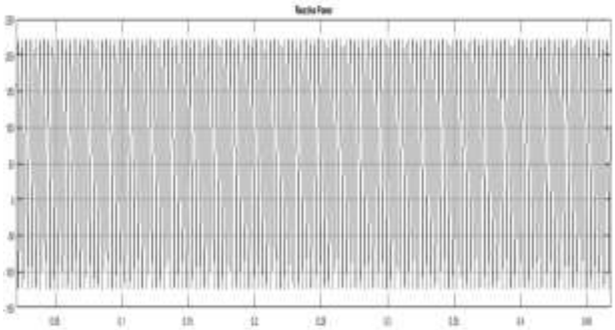

Fig.4.4.Reactive Power before Compensation

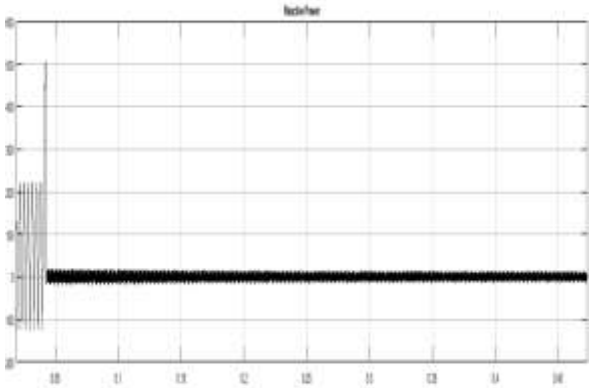

Fig.4.5.Reactive Power after Compensation.

As shown on Fig.7 and Fig.8 are the Reactive Power of Transmission line on the source side before and after compensation respectively. From these results it is observed that the reactive power after compensation is absorbed by the STATCOM.

V. CONCLUSION AND FUTURE WORK

In this paper, Adaptive PI control method is used to control STATCOM for voltage regulation, which can self-adjust the control gains dynamically during disturbances so that the performance always matches a desired response. Since the adjustment is autonomous this gives the "plug-and-play" capability for STATCOM operation.

In future work the performance of the STATCOM can be further improved by using the advanced fuzzy logic controller.

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