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PERFORMANCE ANALYSIS OF ADAPTIVE PI CONTROLLER BASED STATCOM FOR DYNAMIC LOADING

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ABSTRACT

Power quality is an important issue for distribution network companies. For safe and stable operation of powersystems, the control for voltage regulation is studied in this paper. This is generally achieved by adaptive PI control of STATCOM with non-linear loading condition. In traditional PI control methods, the control gains in these controllers are tuned for a case-by-case study or trial-and-error approach which is time consuming and not suitable for dynamic condition. By this adaptive PI control method, the PI control parameters can be self-adjusted automatically and dynamically under different operating conditions. Simulation result verifies the performance of the proposed control strategy for dynamic loading condition.

Keywords- FACTS, proportional-integral(PI) controller, STATCOM, voltage regulation.

I. INTRODUCTION

Voltage stability is the ability of a power system to remain steady voltages at all busesin the system when it is subject to a disturbance from a given initial operating condition. The capability to maintain the equilibrium between the load demand and supply in power systems will determine the voltage stability [10]. Voltage instability will result in the loss of load in some areas, tripping of transmission lines and other elements by the protective systems, and even a large-scale cascading blackout.

Voltage stability is an important consideration for secure operation and reliability of power supply systems. Flexible ac transmission systems (FACTS) technology is an 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[1].

In the past different control methods have been proposed for STATCOM control. References [5]–[6] 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 [3]–[4], 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 [7], a new STATCOM state feedback design is introduced based on a zero set concept. Similar to [3]–[4], the final gains of the STATCOM state feedback controller still depend on the designer’s choice.

In a power system, to obtain satisfactory dynamic responsesProportional-integral (PI) controllers have been designed forSTATCOM [2]. In traditional PI control methods, the control gains in these controllers are tuned for a case-by-case study or trial-and-error approach. It is a time-consuming job for utility engineers to perform trial-and-error studies to find suitable parameters. Further, conventional PI controllers with fixed control gains are designed for one specific operating condition. A fixed controller, optimal in one specific operating condition may not be suitable in another operation condition and large oscillations may occur in the power system.

The purpose of this work is to propose a control method that can ensure a quick and consistent desired response when the system operation condition varies. In other words, the objective is to avoid negative impacts, such as slower response, overshoot, or instability to the system performance when external conditions change.

Based on this fundamental goal, an adaptive PI control of STATCOM for voltage regulation is presented. The PI control parameters can be self-adjusted automatically and dynamically under different disturbances in a power systemby this adaptive PI control method. When a disturbance occurs in the system, the PI control parameters for STATCOM can be computed automatically in every sampling time period and can be adjusted in real time to track the reference voltage. Different from other control methods, this method will not be affected by the initial gain settings, changes of 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 a fast, dynamic performance of STATCOM in various operating conditions.

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. DYNAMIC MODELING OF STATCOM

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.

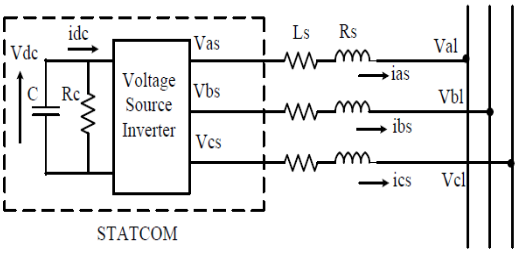

Fig.1 Equivalent circuit of STATCOM

The equivalent circuit of the STATCOM is shown in Fig.1. In this power system, the resistance R_s in series with the voltage source inverter represents the sum of the transformer winding resistance losses and the inverter conduction losses. The inductance $L_s$represents the leakage inductance of the transformer. The resistance R_c in shunt with the capacitor *C* represents the sum of the switching losses of the inverter and the power losses in the capacitor. In Fig.1 V_{as},V_{bs}, and$V_{cs}$are the three-phase STATCOM output voltages;V_{al}, V_{bl}, and V_{cl} are the three phase bus voltages; andi_{as}, i_{bs}, and $i_{cs}$are the three-phase STATCOM output currents [3].

The output phase voltages of VSI are given by V_{as}, $V_{bs}$and V_{cs}. The phase voltages at the PCC are denoted as V_{al}, V_{bl} and V_{cl} . Then:

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

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

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

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

In order to conveniently analyze the balanced three-phase system, the three-phasevoltages and currents are converted to synchronous rotating frame by abc/dq transformation. By this rotation, the control problem is greatly simplified since the system variables become DC values under the balanced condition. Further, multiple control variables are decoupled, permitting the use of the classic control method. The transformation from phase variables to *d* and *q* coordinates is given as follows:

$$\begin{bmatrix} i_{ds} \\ i_{qs} \\ o \end{bmatrix} = [C] \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} V_{ds} \\ V_{qs} \\ o \end{bmatrix} = [C] \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} \quad (6)$$

where$i_{ds}$and $i_{qs}$are the *d* and *q* currents corresponding toi_{as},i_{bs} and i_{cs}; $V_{ds}$and V_{qs}represent the *d* and *q* voltages corresponding to V_{as}, V_{bs}, and V_{cs}.

The output voltage of the STATCOM can be expressed as:

$$V_{ds} = KV_{dc}\cos(\alpha) \quad (7)$$

$$V_{ds} = KV_{dc}\sin(\alpha) \quad (8)$$

Where*K* is a factor that relates the DC voltage to the peak phase-to-neutral voltage on theAC side; $V_{dc}$is the DC-side voltage; α is the phase angle which the STATCOM output voltage leads the bus voltage.

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

$$\frac{d}{dt}\begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} = \begin{bmatrix} \frac{-R_s}{L_s} & \omega & \frac{K}{L_s}\cos\alpha \\ -\omega & \frac{-R_s}{L_s} & \frac{-R_s}{L_s}\sin\alpha \\ \frac{-3K}{2C}\cos\alpha & \frac{-3K}{2C}\sin\alpha & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} - \frac{1}{L_s}\begin{bmatrix} V_{dl} \\ V_{ql} \\ 0 \end{bmatrix} \quad (9)$$

where ω is the synchronously rotating angle speed of the voltage vector; $V_{dl}$and V_{ql}represent the *d* and*q*axis voltage corresponding to V_{al}, V_{bl} , and V_{cl}. Since V_{ql}=0, based onthe instantaneous active and reactive power definition, (10) and (11) can be obtained asfollows [8] [9]:

$$p_l = \frac{3}{2}V_{dl}\,i_{ds} \quad (10)$$

$$q_l = \frac{3}{2}V_{dl}\,i_{qs} \quad (11)$$

III. ADAPTIVE PI CONTROL SCHEME

Adaptive Controlcovers a set of techniques which provide a systematic approach for automatic adjustment of controllers in *real time*, in order to achieve or to maintain a desired level of control system performance when the parameters of the plant dynamic model are unknown and/or change in time.

Now consider the case when the parameters of the dynamic model of the plant change unpredictably in time. These situations occur either because the environmental conditions change (ex: the dynamical characteristics of a robot arm or of a mechanical transmission depend upon the load; in a DC-DC converter the dynamic characteristics depend upon the load) or because we have considered simplified linear models for nonlinear systems (a change in operation condition will lead to a different linearized model). These situations may also occur simply because the parameters of the system are slowly time-varying (in a wiring machine the inertia of the spool is time-varying). In order to achieve and to maintain an acceptable level of control system performance when large and unknown changes in model parameters occur, anadaptive control approach has to be considered. In such cases, the adaptation will operate most of the time and the term *non-vanishing adaptation* fully characterizes this type of operation (also called *continuous adaptation*).

Further insight into the operation of an adaptive control system can be gained if one considers the design and tuning procedure of the “good” controller illustrated in Fig.2. In order to design and tune a good controller, one needs to:

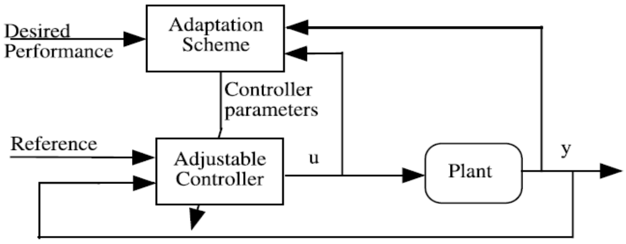

Fig.2 An adaptive control system

1) Specify the desired control loop performances.
2) Know the dynamic model of the plant to be controlled.
3) Possess a suitable controller design method making it possible to achieve the desired performance for the corresponding plant model.

The dynamic model of the plant can be identified from input/output plant measurements obtained under an experimental protocol in open or in closed loop. One can say that the design and tuning of the controller is done from data collected on the system. An adaptive control system can be viewed as an implementation of the above design and tuning procedure in real time. The tuning of the controller will be done in real time from data collected in real time on the system. The corresponding adaptive control scheme is shown in Fig.2.

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 SimPower Systems. In this model of power system a substation of 4.16kV, 50Hz capacity is utilized for voltage regulation. And the values of proportional and integral gain components are as $K_p = 1$ and $K_i = 10$ respectively.

From simulation the active power, reactive power and STATCOM dc link voltage are given below:

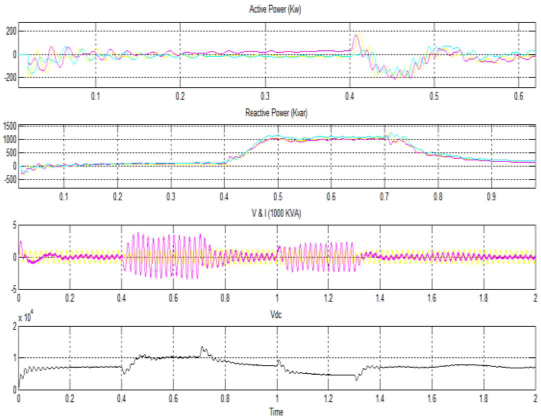

Fig.3 Results of STATCOM Active power, Reactive power, DC link voltage (V_{dc}).

In this simulation results are taken across dynamic loading of power system. In which three phase load is applied across bus 634 and 675 respectively, while single phase load is applied across bus 645 and 646 respectively.

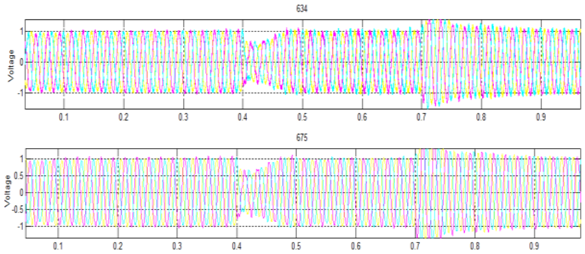

Fig.4 Three Phase Load Voltage (B634, B675).

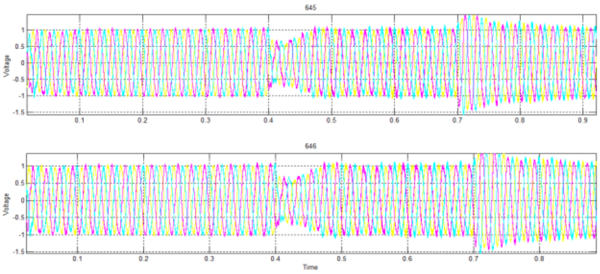

Fig.5 Single Phase Voltage (B645, B646).

V. CONCLUSION

In this paper, Adaptive PI control method is used for performance improvement of STATCOM for dynamic loading condition, which can automatically adjust the control gains dynamically during disturbances so that the performance always matches a desired response. In contrast, theconventional STATCOM control with fixed PI gains may perform acceptable in the original system, but with the change in system conditions may not perform as efficiently as the proposed control method.

REFERENCES

[1] G. Hingorani and L. Gyugyi, “Understanding FACTS, Concepts, and Technology of Flexible AC Transmission Systems”, Piscataway, NJ: IEEE Press, 2000.

[2] C.-H. Liu and Y.-Y. Hsu, “Design of a self-tuning PI controller for a STATCOM using particle swarm optimization,” *IEEE Trans. Ind. Electron.*, vol. 57, no. 2, pp. 702–715, Feb. 2010.

[3] P. Rao, M. L. Crow, and Z. Yang, “STATCOM control for power system voltage control applications,” *IEEE Trans. Power Del.*, vol. 15, no. 4, pp. 1311–1317, Oct. 2000.

[4] W. L. Chen and Y. Y. Hsu, “Controller design for an induction generatordriven by a variable speed wind turbine,” *IEEE Trans. Energy Convers.*, vol. 21, no. 3, pp. 625–635, Sep. 2006.

[5] Jain, K. Joshi, A. Behal, and N. Mohan, “Voltage regulation with STATCOMs: Modeling, control and results,” IEEE Trans. Power Del., vol. 21, no. 2, pp. 726–735, Apr. 2006.

[6] Y. Han, Y. O. Lee, and C. C. Chung, “Modified non-linear damping of internal dynamics via feedback linearization for static synchronous compensator,” IET Gen. Transm. Distrib., vol. 5, no. 9, pp. 930–940, 2011.

[7] V. Spitsa, A. Alexandrovitz, and E. Zeheb, “Design of a robust state feedback controller for a STATCOM using a zero set concept,” *IEEETrans. Power Del.*, vol. 25, no. 1, pp. 456–467, Jan. 2010.

[8] Wang, H.F., “Phillips-Heffron model of power systems installed with STATCOM and applications,” *IEE Proc.-Gener. Transmi. Distib.*, vol. 146, no 5, pp. 521-527,Sep. 1999.

[9] H.F. Wang, "Applications of damping torque analysis to statcom control", *I. J. of Elec. Pwr& Energy Sys.*, vol. 22, pp. 197-204, 2000.

[10] P. Kundur, *Power System Stability and Control*. New York: McGraw-Hill, 1994.