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Voltage Regulation by Adaptive PI Control of STATCOM

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Abstract— **To Maintain Voltage Regulation A STATCOM Provides The Fast And Efficient Reactive Power. In order to understand various STATCOM control methods are discussed in the literature. But in those methods they use the trail and error approach methods so the performance is trade off. so at different operating points the control parameters may not be effective for the optimal performance. In order to overcome this problem an adaptive control technique came in to picture, in which the control gains automatically self adjusted as per our desired response even with the change of operating condition that's why we named as autonomous adjustment. In the simulation test, the adaptive PI control shows consistent excellence under various operating conditions, such as different initial control gains, different load levels, change of transmission network, consecutive disturbances, and a severe disturbance. when there is a change of system conditions the conventional STATCOM control with tuned, fixed PI gains usually perform fine in the original system, but may not perform as efficient as the proposed control method.**

Index Terms— **STATCOM, Voltage Regulation**

I. Introduction

In order to maintain security and reliability vloltage stability is a critical Consideration of power system.. for improving power system stability The static power system static compensator (STATCOM), a popular device based on gate turnoff (GTO) thyristors, for reactive power control has gained much interest in the last decade .

In the past, various control methods, mainly focus on the control design instead of how to set propor-tional-integral (PI) control gains .

The pi controllers implement the control logic. The statcom pefformance entirely depends upon these control parameters or gains. Earlier The case-by case or trail and error approach methods are carried out to design the control parameters but with less efficiency or trade off performance. for utility engineers it is not feasible, to perform thse methods inorder to find the suitable parameters if the new statcom is placed in the system. perfor-mance may be disappointing even if the control gains been tuned to fit the projected scenarios, because if any disturbance occurred in a system like upgraded or retires from service the control parameters are fixed to their intial values only and does not change to as per our need.so finallu we would like to say the statcom performance is not good with fixed values of the pi controller gains.

In order to maintaining the time and to obtain the better voltage stability A few, but limited previous works in the literature discussed.those are like linear quadratic regular (LQR), a new STATCOM state feedback design based on a zero set concept and a fuzzy PI control method , the population-based search technique but with these methods highly efficient results may not be always achievable under a specific operating condition besause they needs a long running time to calculate the controller gains, and the variety of operation conditions still has to be made during the designer's decision-making process.

Different from these previous works, the motivation of this paper is does not have slower response, over-shoot, or even instability to the performance even though , the change of the external condition so that can ensure a quick and consistent desired respone.

The PI control parameters for STATCOM can be computed automatically,When a disturbance occurs in the system.i.e PI control parame-ters can be self-adjusted automatically and dynamically.

Based on this fundamental motivation, an adaptive PI control of STATCOM for voltage regulation is came in to picture.

This method will not be affected by the initial gain settings, changes of system conditions,and the limits of human experience and judgment. So this is a "plug-and-play" device. In addition, in various operating conditions. It performs fast and dynamic.

II. STATCOM Model And Control

A. System Configuration

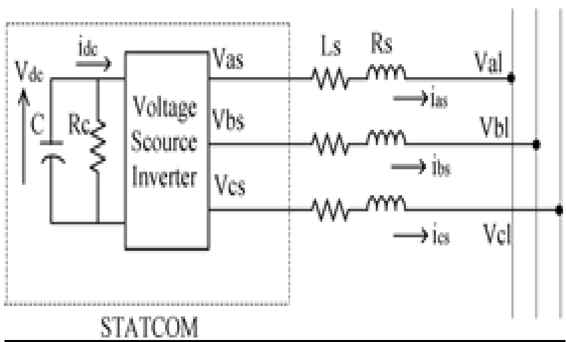

Fig. 1. Equivalent circuit of STATCOM.

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The three-phase mathematical expressions of the STATCOM is as follows.

$L_S \frac{di_{as}}{dt} = -R\, i_{as} + V_{as} - V_{al}$ - (1)

$L_S \frac{di_{bs}}{dt} = -R\, i_{bs} + V_{bs} - V_{bl}$ - (2)

$L_S \frac{di_{cs}}{dt} = -R\, i_{cs} + V_{cs} - V_{cl}$ - (3)

$$\frac{d}{dx}(\{1/2|CV^2\}) = -[i_{as}V_{as} + i_{bs}V_{bs} + i_{cs}V_{cs}] - \frac{V_{dc}^2(t)}{R_c}$$

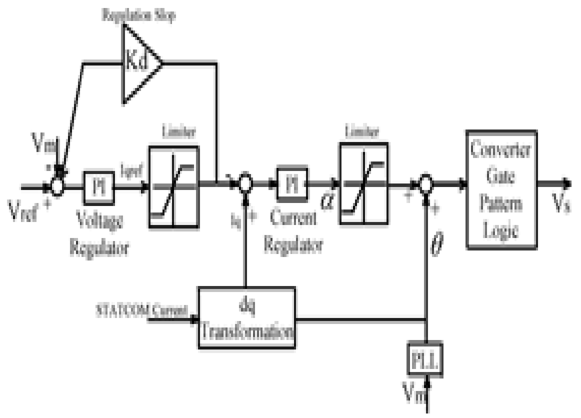
B. *STATCOM Dynamic Model*

STATCOM outputvoltage leads the bus voltage peak phase-to-neutral voltage on the ac side

voltage leads the bus voltage is the synchronously rotating angle speed of the voltage vector

In the figure shown, rs is the series resistance and it is sum of the transformer winding resistance losses and the inverter conduction losses. and the inductance Ls is the leakage V_{dl} and V_{ql} represents d and q axis voltage corresponding to V_{al} V_{bl} and V_{cl}.since V_{ql} inductance of the transformer ,Rc is the the switching losses of the inverter and capacitor.

Vas, Vbs and Vcs are the three-phase STATCOM output voltages and ias,ibs and ics the three-phase STATCOM output currents.



V_{dl} and V_{ql} represents d and q axis voltage corresponding to V_{al} V_{bl} and V_{cl} .since V_{ql} is zero.the active power and reactive power is given by, $p_1 = \frac{3}{2} v_{dl} i_{ds}$ (6)

$q_1 = \frac{3}{2} v_{dl} i_{qs}$ (7)

the traditional control strategy can be obtained based on the above equations. the reference angle to the measurement system is the basic synchronizing signal which is provided by the phase-locked loop(PLL) as shown in figure 2.

The required reactive reference current iqref is the difference between . Measured bus line voltage vm and the reference voltage vref. . 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.

III. Adaptive PI Control For STATCOM

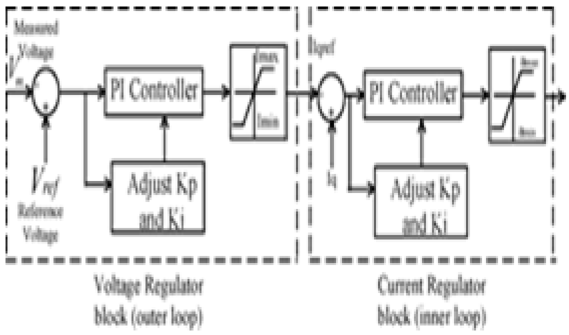


Fig. 3. Adaptive PI control block for STATCOM

The process of the adaptive voltage-control method for STATCOM is described as follows:

1).measure the bus voltage $V_{m(t)}$

2).compare the $V_{m(t)}$ and V_{ss} .where V_{ss} is the steady state voltage.if the difference between these two is not zero then K_{p_V} and K_{i_V} automatically and dynamically self adjusted to equate to zero.

3).similarly in the inner loop I_{qref} is compared with i_q.if there is any error between these two then k_{p_i} And k_{i_i} Automatically adjusted to find the suitable angle.so that the exact amount of reactive power can be injected in to the power system network.

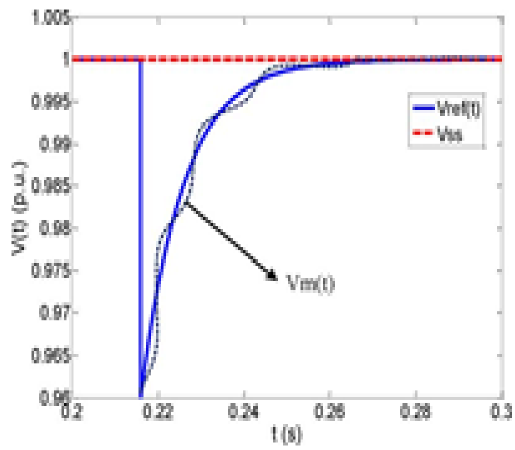


Fig. 4. Reference voltage curve

The key equations are given below:

$$\begin{bmatrix} V_{dl(t)} \\ V_{ql(t)} \\ 0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{al(t)} \\ V_{bl(t)} \\ V_{cl(t)} \end{bmatrix} \quad \text{———— (9)}$$

$$V_{m(t)} = \sqrt{{V_{dl(t)}}^2 + {V_{ql(t)}}^2} \quad \text{----- (10)}$$

$$V_{ref(t)} = V_{ss} - \left(V_{ss} - V_{m(t)}\right) e^{\frac{-t}{T}} \quad \text{(11)}$$

$$y(t - T_s) + K_{i\_V}(t - T_s) \times T_s \times \Delta V(t - T_s) \quad \text{- (12)}$$

where $(t) = K_{i\_V}(t) \int_t^{t+T_s} \Delta V(t)dt$

$$y(t - T_s) = K_{i\_V}(t - T_s) \int_t^{t+T_s} \Delta V(t - T_s)dt$$

$$y(t - T_s) = I_{qref}(t)$$

$$\Delta V(t) K_{p\_V}(t) + K_{i\_V}(t) \int_t^{t+T_s} \Delta V(t)dt - K_{i\_V}(t - T_s) \int_t^{t+T_s} \Delta V$$

(13)

Where $K_{i\_V}(t) = K_{i\_V}(t - T_s)$

$$\Delta V(t) K_{p\_V}(t) + K_{i\_V}(t) \int_t^{t+T_s} A dt = I_{qref}(t + T_s) - I_{qref}(t)$$

(14)

Where A= ΔV(t)- ΔV(t-T_s)

$$I_{qref}(t + T_s) - I_{qref}(t) = R \times \Delta V(t) \quad (15)$$

$$\Delta V(t_0) K_{p\_V}(t_0) + K_{i\_V}(t_0) \int_{t_0}^{t_0+5\tau} \Delta V(t)dt = R \times \Delta V(t_0)$$

(16)

$$K_{i\_V}(t_0^-) = 0$$

$$K_{p\_V}(t_0) = R \quad (17)$$

$$K_{i\_V}(t_0) = \frac{\Delta V(t_0) \times R}{\int_{t_0}^{t_0+5\tau} \Delta V(t)dt} \quad \text{— (18)}$$

$$m_V = \frac{K_{i\_V}(t_0)}{K_{p\_V}(t_0)}$$

$$I_{qref}(t + 5\tau) - I_{qref}(t) = k_V \times \Delta V(t_0) \quad \text{— (19)}$$

k_V can be considered as steady and ideal ratio

$$\frac{\frac{(I_{qref}(t+T_s) - I_{qref}(t))}{\Delta V(t)}}{\Delta V_{max}} \quad , \quad -1 \leq I_{qref}(t) \leq 1$$

$$\frac{\Delta V(t_0)}{\Delta V_{max}} = k_V \times \frac{\Delta V(t_0) K_{p\_V}(t_0) + K_{i\_V}(t_0) \int_{t_0}^{t_0+5\tau} \Delta V(t)dt}{R}$$

(20)

$$\Delta V_{(t)} K_{p}\_V_{(t)} + m_V K_{p}\_V_{(t)} \int_t^{t+T_s} A dt = K_v * \Delta V_{(t)} \quad (21)$$

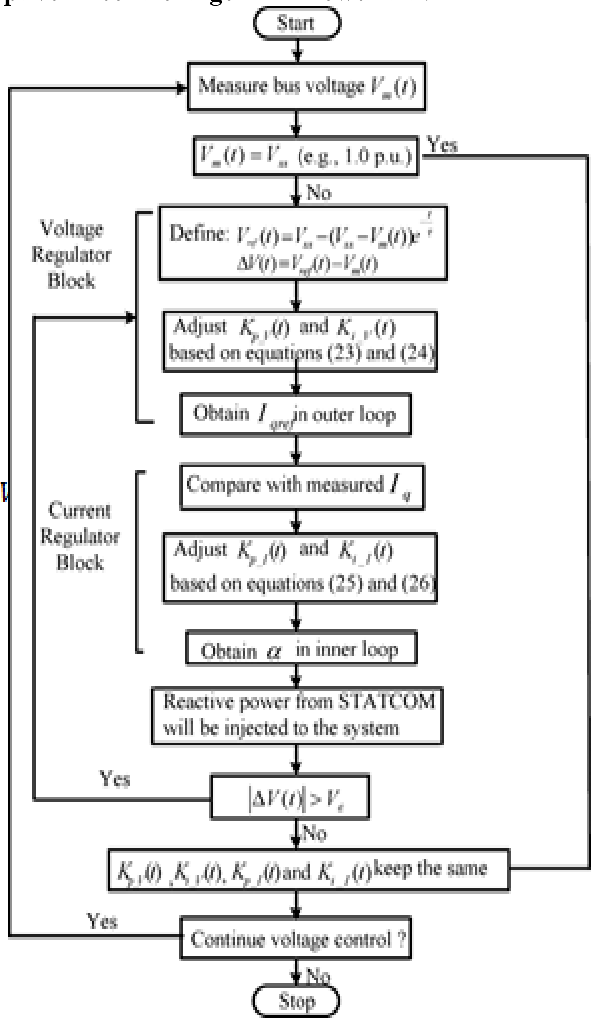
$$K_{p}\_V_{(t)} = \frac{K_V \Delta V(t)}{\Delta V_{(t)} + m_{v*} \int_t^{t+T_s} A dt} \quad (22)$$

$$k_{i}\_V_{(t)} = m_V K_{p}\_V_{(t)} \quad (23)$$

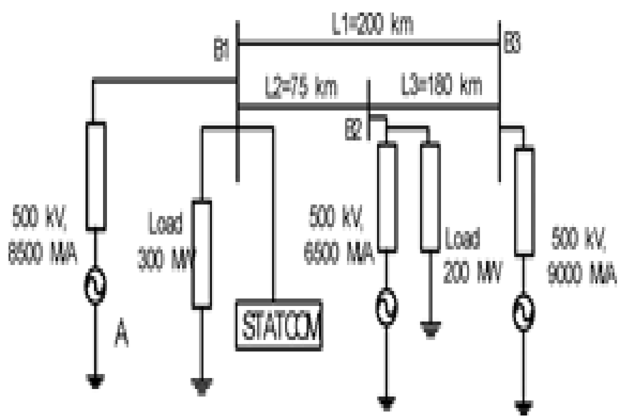
$$K_{p}\_I_{(t)} = \frac{K_{i*} \Delta I_q(t)}{\Delta I_{q(t)} + m_{i*} \int_t^{t+T_s} B dt} \quad (24)$$

$$k_{i}\_I_{(t)} = m_i K_{p}\_I(t) \quad (25)$$

Adaptive PI control algorithm flowchart :



Studied system:



IV. SIMULATION RESULTS

C. Response of the Original Model

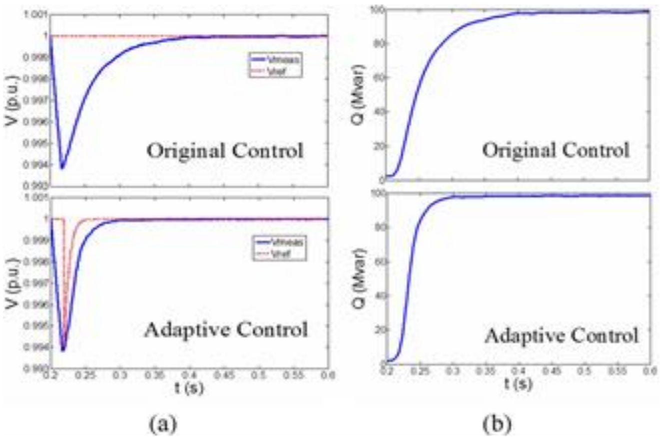


Fig. 7. Results of (a) voltages and (b) output reactive power using the same network and loads as in the original system

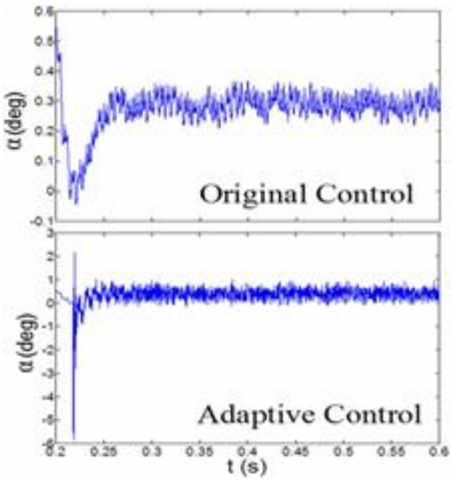


Fig. 8. Results of using the same network and loads as in the original system

Performance comparison:

	Original Ctrl.	Adaptive Ctrl.
Lowest Voltage after disturbance	0.9938 p.u.	0.9938 p.u.
Time (sec) when V=1.0	0.4095 sec	0.2983 sec
Δt to reach V=1.0	0.2095 sec	0.0983 sec
Var Amount at steady state	97.76 MVar	97.65 MVar
Time to reach steady state Var	0.4095 sec	0.2983 sec

D. If Pi Gain Change

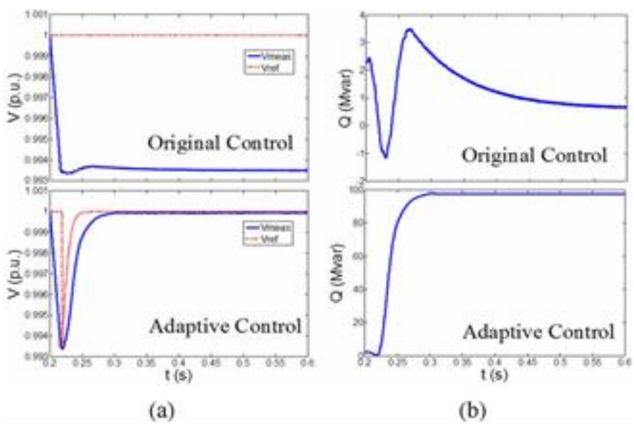


Fig. 9. Results of (a) voltages and (b) output reactive power with a change of load

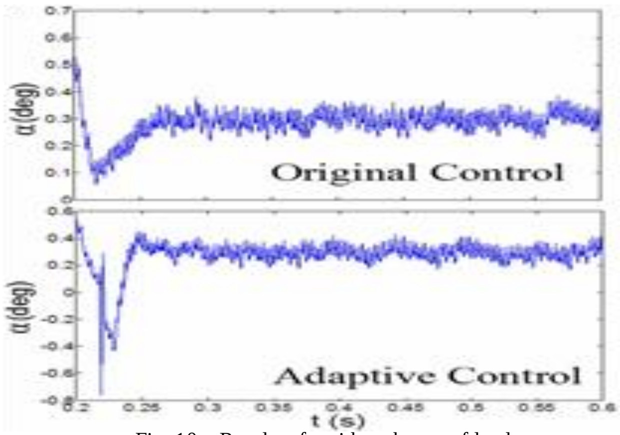


Fig. 10. Results of with a change of load.

1. *Change of Transmission Network:*

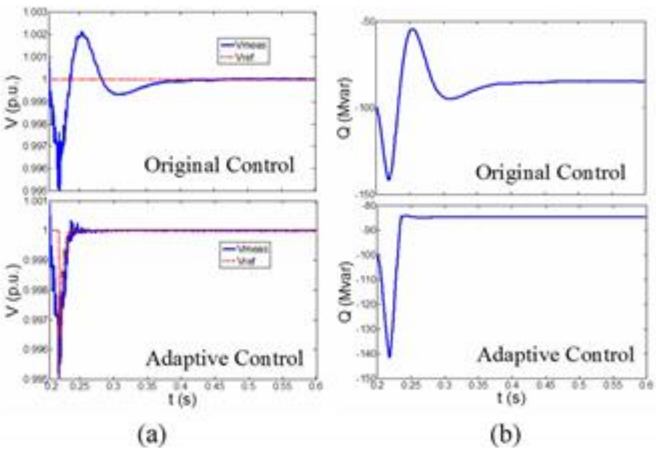


Fig. 11. Results of (a) voltages and (b) output reactive power with a change of transmission network

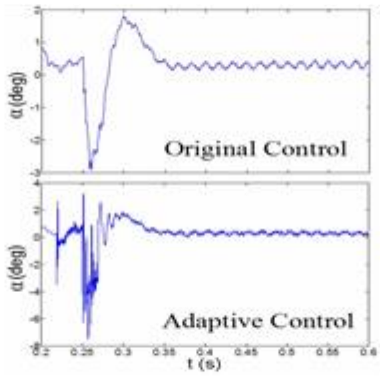


Fig. 14. Results of with a change of transmission network.

V. Conclusion

This Paper Proposes A New Control Model Based On Adaptive PI Control, Which Can Self-Adjust The Control Gains Dynamically During Disturbances So That The Performance Always Matches A Desired Response.

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