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Fuzzy Logic Control of STATCOM for Voltage Regulation

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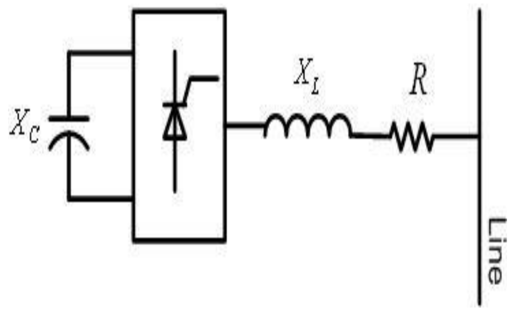
Abstract: This paper proposes a fuzzy logic control model based on STATCOM for voltage control, during a disturbance such that the performance always matches a desired response, regardless of the change of operating condition. Since the adjustment is autonomous, this gives the plug-and-play capability for STATCOM operation. STATCOM can provide fast and efficient reactive power support to maintain power system voltage stability. In the simulation test, the Fuzzy Logic control shows consistent excellence under various operating conditions, such as different initial control gains, different load levels, and change of transmission network, consecutive disturbances, and a severe disturbance. In contrast, 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 when there is a change of system conditions.

I Introduction

The static compensator (STATCOM), a popular device for reactive power control based on gate turn-off (GTO) thyristors, has gained much interest in this last decade to improve the network stability. In the past, various methods have been proposed to combat STATCOM control. References mainly focus on the control design, rather than to explore how (PI) is set proportional-integral control gains. In many STATCOM models the control logic is implement the PI controller. The control parameters or gains play a key factor STATCOM performance. At present, only few studies have been carried out in the control parameter settings. In the PI controller gains are designed in a case-by-case study or trial-and-error approach with compromises in performance and efficiency.

In this paper a new control model i.e., fuzzy logic control STATCOM for voltage regulation is introduced. With this proposed control method, the PI control parameters can even be adjusted automatically and dynamically under various disturbances in a power system. If a fault occurs in the system, the PI controller parameters can be calculated for STATCOM automatically in each sampling time periods and can be adjusted in real time to track the reference voltage.



(a)

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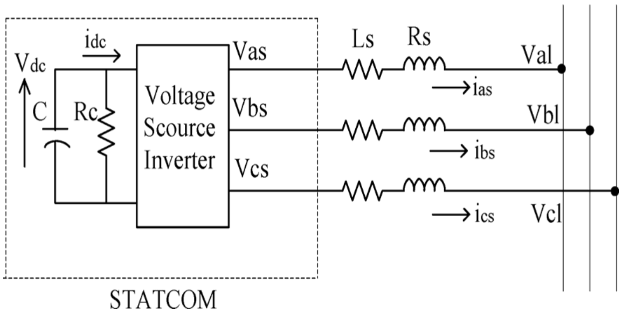


(b)

Fig.1.(a) Basic structure of STATCOM (b)Equivalent circuit of STATCOM

The STATCOM (also known as the static VAR generator (SVG)) is a voltage converter device which uses in order to generate the active and reactive power needed by the system. The STATCOM has several advantages including fast response, continuous and quick control of reactive power, and smaller storage capacitance. In addition, the ability of this active power compensation in STATCOM is better than SVC. Therefore, STATCOM may consider as an effective solution to the problem of voltage stability. Fig.1(a) shows the basic structure of STATCOM and (b) shows its equivalent circuit. 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 affected by the initial gain settings, and 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 fast, dynamic performance of the STATCOM in various operating conditions.

II STATCOM Model and Control

The STATCOM control block diagram is shown in fig.2. As shown in fig2. The phase locked loop provides the basic synchronizing signal which is the reference angle to the measurement system. Measured bus line voltage V_m is compared with the reference signal V_{ref}, and the voltage regulator provides the required reactive reference current I_{qref}. The droop factor K_d is defined as the allowable voltage error at the rated reactive current I_q is compared with I_{qref}, 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.

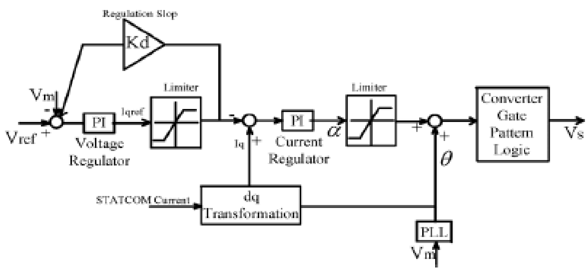


Fig. 2 Traditional STATCOM PI control block diagram

III CONTROL TECHNIQUES

FUZZY LOGIC CONTROLLER

Fuzzy logic is a new control approach with great potential for real time applications. Load voltage and load current taken as input to fuzzy system. For a closed loop control, error input can be selected as current, voltage or impedance, according to control type. To get the linearity triangular membership function is taken with 50% overlap. The output of fuzzy controller taken as the control signal and the pulse generator provides synchronous firing pulses to thyristors. The Fuzzy Logic is a rule based controller, where a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system. In fuzzy logic, the five linguistic variables expressed by fuzzy sets defined on their respective universes of discourse. Table-I shows the suggested membership function rules of FC-TCR controller. The rule of this table can be chosen based on practical experience and simulation results observed from the behavior of the system around its stable equilibrium points.

Table I

Change In Error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

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 can be realized.

An adaptive PI control block for STATCOM is shown in Fig.3. In Fig.3, the measured voltage

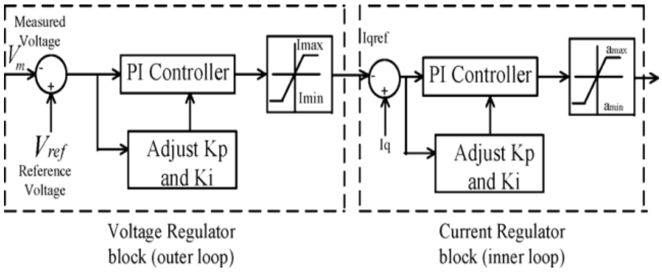


Fig.3 Adaptive PI control block for STATCOM

Vm(t) and the reference voltage Vref(t), and the q axis reference current and the axis current are in per unit values. The proportional and integral parts of the voltage regulator gains are denoted by KP-v and Ki-V, respectively. Similarly, the gains Kp-I, and Ki-I represent the proportional and integral parts, respectively, of the current regulator. In this control system, the allowable voltage error Kd is set to 0. The Kp-v, Ki-V, Ki-I , and can be set to an arbitrary initial value such as simply 1.0.

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

1) The bus voltage $V_m(t)$ is measured in real time.

2) 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_{iv} are dynamically adjusted in order to make the measured voltage match the desired reference voltage, and the q-axis reference current I_{qref} can be obtained.

3) In the inner loop, is compared with the q axis current Iq. Using the similar control method like the one for the outer loop, the parameters Kp-I

and Ki-I can be adjusted based on the error. Then, a suitable angle can be found eventually the dc voltage in STATCOM can be modified such that STATCOM provides the exact amount of reactive power injected in to the system to keep the bus voltage at the desired value.

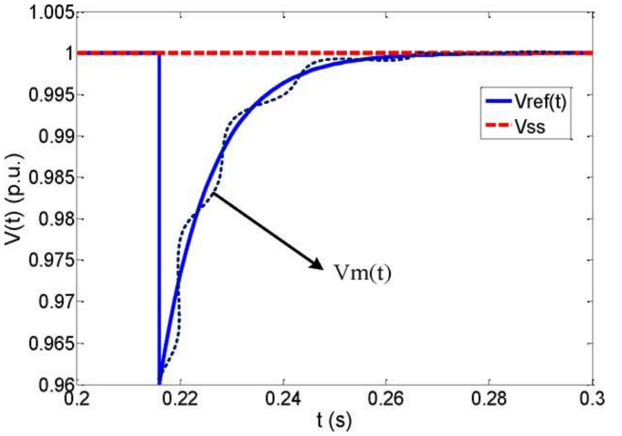
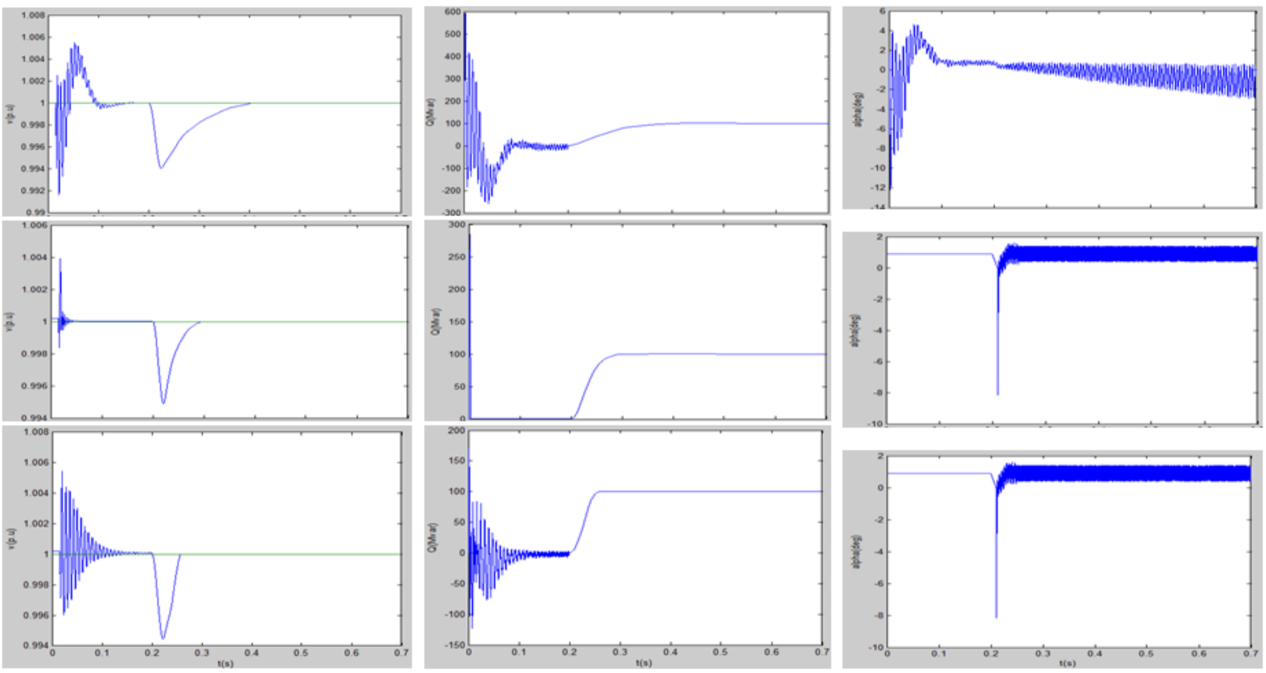


Fig. 4 Reference voltage curve

It should be noted that the current I_{max} and I_{min} and the angle α_{max} and α_{min} are the limit imposed with the consideration of the maximum reactive power generation capability of the STATCOM controlled in this manner. If one of the maximum or minimum limits is reached, the maximum capability of the STATCOM to inject reactive power has been reached. Certainly, as long as the STATCOM sizing has been appropriately studied during planning stages for inserting the STATCOM in to the power system, the STATCOM should not reach its limit unexpectedly.

IV SIMULATION RESULTS

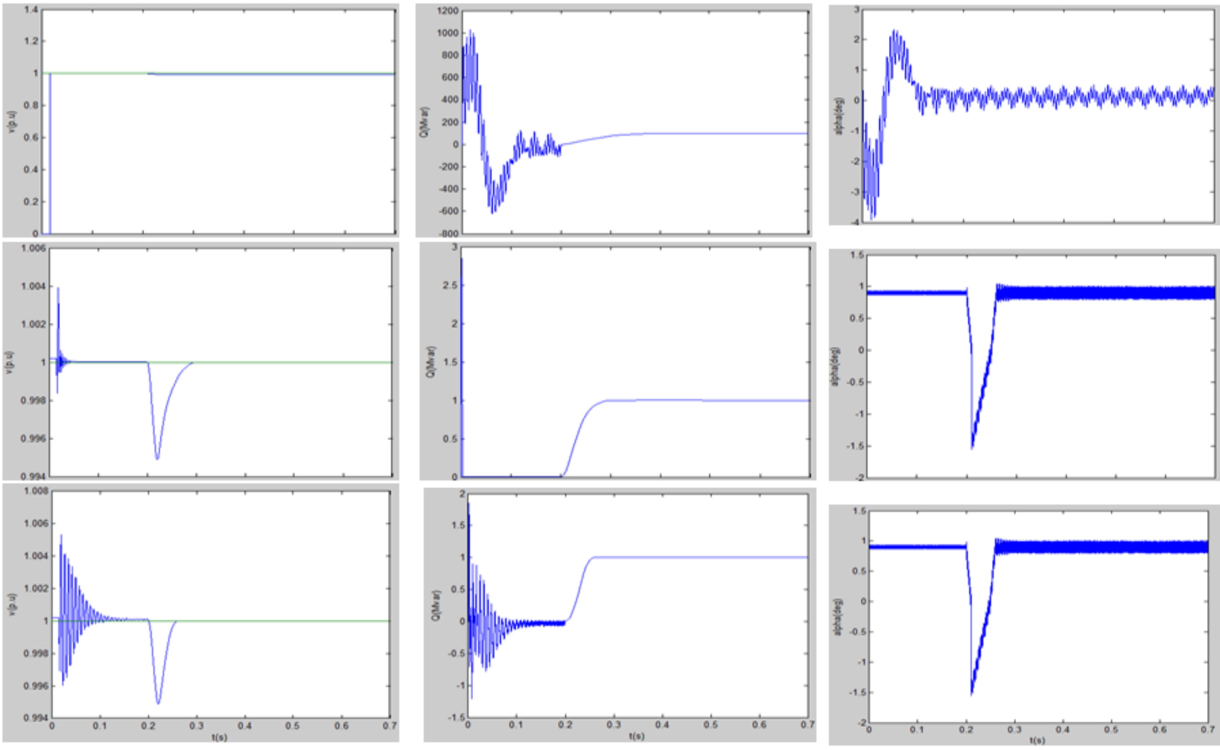
a. Response of the original model



(a) (b) (c)

Fig 5.Results of (a) voltages and (b) output reactive power (c) α using the same network and loads as in the original system.

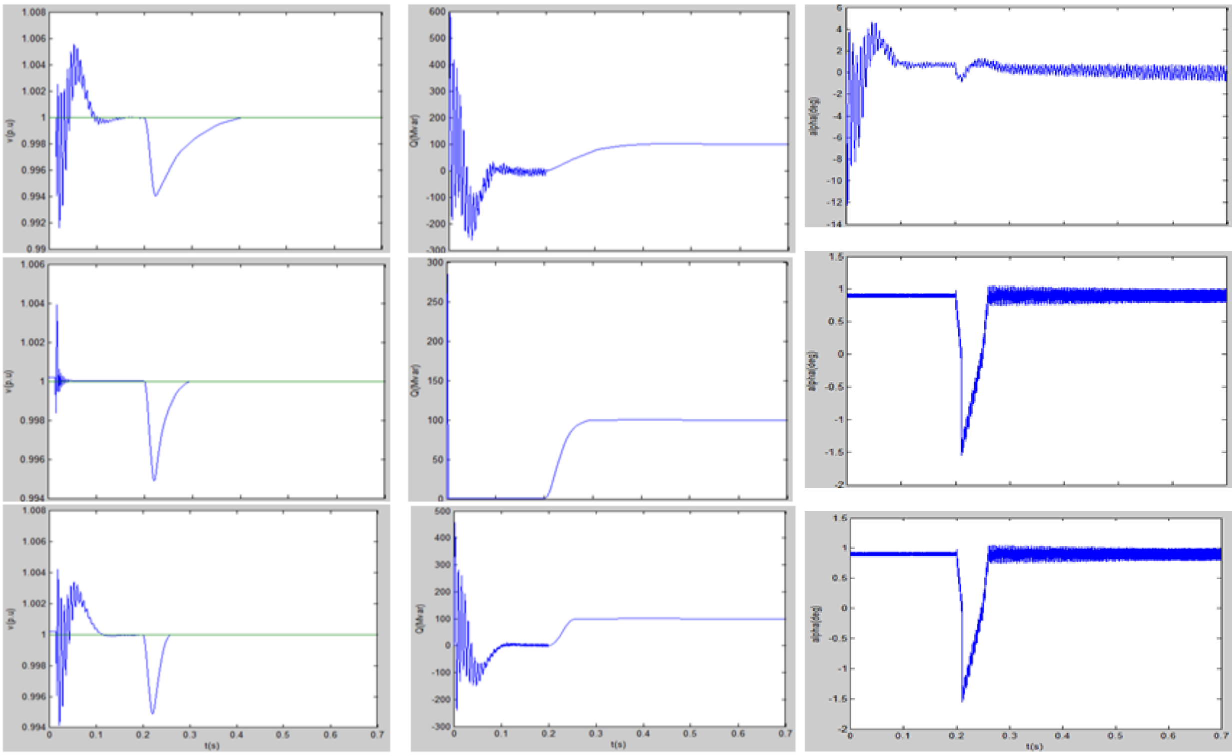
b. Change of PI control gains



(a) (b) (c)

Fig 6.Results of (a) voltages and (b) output reactive power (c) α with changed PI control gains

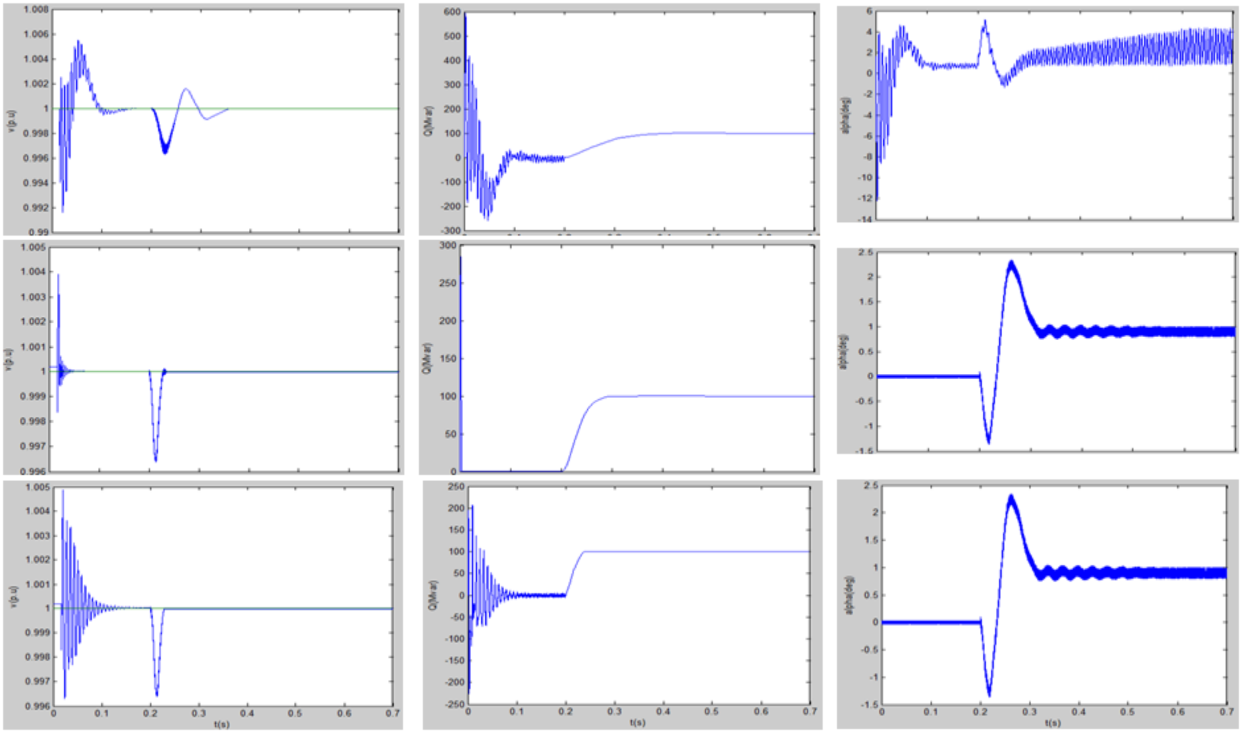
c. Change of load



(a) (b) (c)

Fig 7.Results of (a) voltages and (b) output reactive power (c) α with changed load

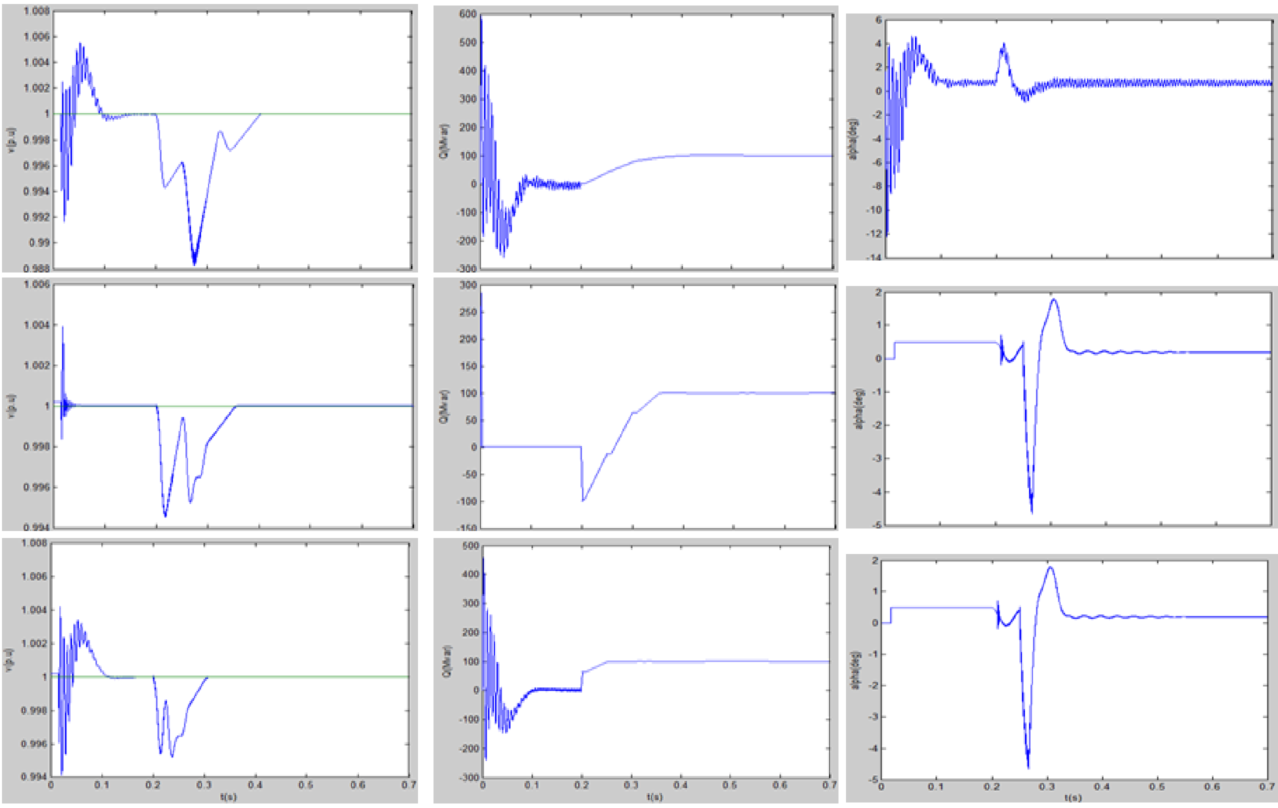
d. Change of transmission network



(a) (b) (c)

Fig 8.Results of (a) voltages and (b) output reactive power (c) α with changed of transmission network

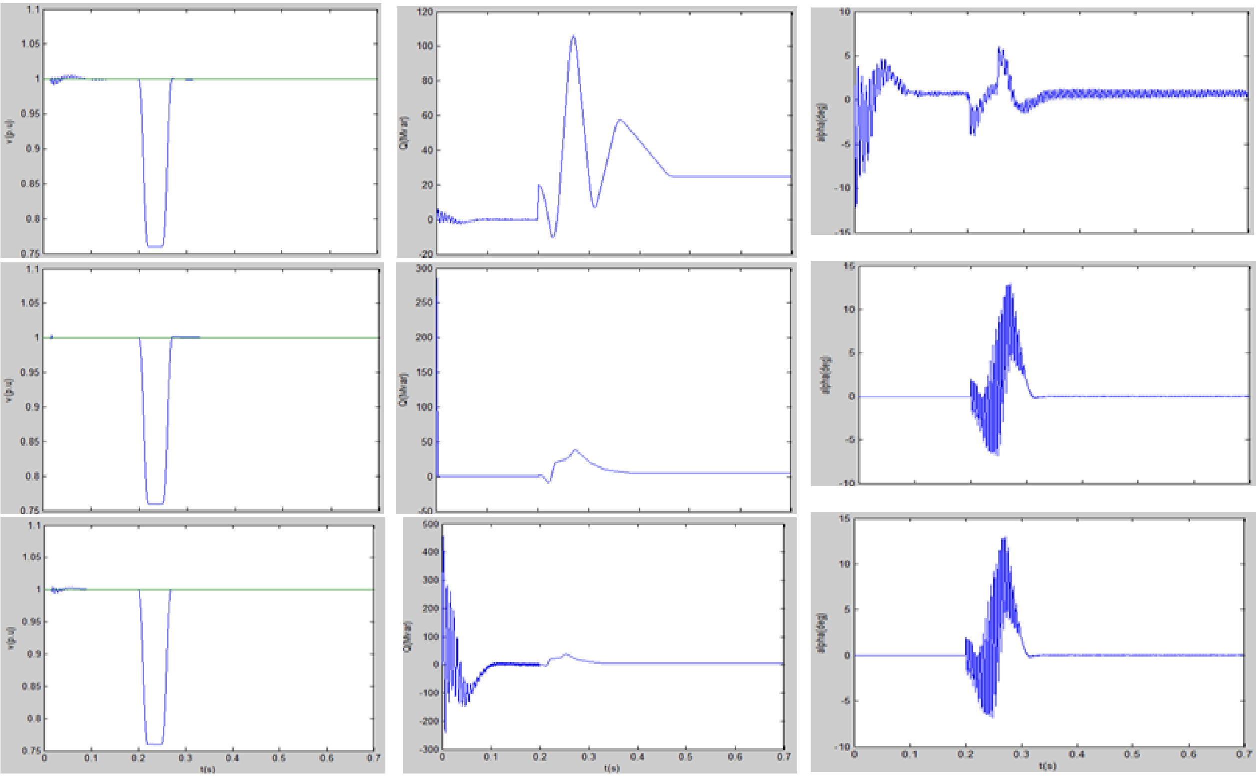
e. Two consecutive disturbances



(a) (b) (c)

Fig 9.Results of (a) voltages and (b) output reactive power (c) α with two consecutive disturbances

f. Severe disturbance



(a) (b) (c)

Fig 10.Results of (a) voltages and (b) output reactive power (c) α in a severe disturbance

V CONCLUSION

In the paper, different methods for controlling STATCOM are discussed. This paper proposes a new control model based on Fuzzy logic which regulates voltage dynamically during disturbances, so that the power will always fit a desired reaction, regardless of the change in operating condition. Since the setting is autonomous, that is the "plug-and-play" capability for STATCOM operation.

In the simulation study, the proposed fuzzy control for STATCOM is compared with adaptive PI control and with the conventional controller of STATCOM pre tuned fixed PI gains to verify the advantages of the proposed method. The result show that the fuzzy control provides consistently good performance under various operating conditions such as different initial control gains, different load levels, modification of the transmission network, successive disturbances, and serious incident. In contrast, the conventional control STATCOM with fixed gains PI has an acceptable performance in the original system, but cannot efficiently perform, such as the proposed control method when there is a change of system conditions.

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