

# **Fuzzy Logic Controller of STATCOM for Voltage Regulation**

Krutika Ashokrao Bhosale, Ass.Prof. Rayarao Santhosh Kumar

Dept. of EEE, Matsyodari Shikshan Sansthas College of Engineering and Technology, Jalna, Dr. Babasaheb Ambedkar  
Marathwada University, Aurangabad, India

Dept. of EEE, Matsyodari Shikshan Sansthas College of Engineering and Technology, Jalna, Dr. Babasaheb Ambedkar  
Marathwada University, Aurangabad, India

**ABSTRACT:** Structure of control system for AC-voltage controller STATCOM with fuzzy basis controller is similar to a nonlinear PI controller. In this, we have used a fuzzy method of reasoning controller as opposed to normal PI controller. Standard management for STATCOM moreover two or three utilizations of PI controller get PI snatches by strategy for an experimentation approach gives control parameters to the best execution at a given administrators reason won't not be productive at a particular masters reason. This try proposes another out of the carton new association model kept up versatile PI association, which may self-switch the association, gets all through an unsettling sway. The parameters are changed in a way that mix-up sign is minimized. To get the fancied result, we ought to apply a standard based system. The standard base for FLC is made by the experience out of mulling over the execution of STATCOM. The normal structure is kept up in MATLAB/SIMULINK PC code environment.

**KEYWORDS:** Adaptive management, Fuzzy Logic Controller, proportional-integral (PI) management, reactive power compensation, STATCOM, voltage stability.

## **I. INTRODUCTION**

Versatile AC Transmission Systems (FACTS) uses power equipment contraption to control the authentic and responsive power in current power structure for the better utilization of the present framework. They are used to wet out power swings thusly reducing the transmission setback by honest to goodness responsive impact control and redesign the transient steadfastness. Snappy acting Static synchronous compensator (STATCOM) is comprehensively used as dynamic shunt compensator for open power control in the transmission framework. VSC based STATCOM have been delivered to control power structure movement in the midst of issue condition. It has been represented by various examines that STATCOM with forefront controller can be used to make unfaltering quality of course of action of multi machine system and a single machine perpetual transport structure. Various impelled control headways have been proposed by the investigators for STATCOM in upgrading security of power system consistent quality.

Voltage quality might be a key thought in up the insurance and eccentricity of force structures. The static compensator (STATCOM), an all that all that much needed contraption for responsive force association kept up portal Side Street (GTO) thyristors, has gotten a great deal of vitality inside of the most recent decade for up establishment determination [1]. Inside of the past, wavered association ways are made diversion arrangements for STATCOM association. Normally talking, it's unreasonable for utility designers to perform experimentation studies to look out legitimate parameters once a crisp out of the plastic new STATCOM is connected with a structure. Further, despite the way that the organization increments are tuned to suit the expected circumstances, execution could similarly be dissatisfactory once a significant adjustment of the system conditions happens, as once a line is redesigned or leaves from organization [13]-[14]. The case is often even worse if such transmission topology modification is as a result of a contingency. Thus, the STATCOM system might not perform well once principally required. A few, however restricted previous works within the literature mentioned the STATCOM PI controller gains so as to higher enhance voltage stability and to avoid long standardization. as an example, in [15]-[17] linear best managements supported the linear quadratic regular (LQR) controls are planned. This management depends on the designer's expertise to get best parameters. In [18] an

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

exceedingly new STATCOM state feedback style is introduced supported a zero set idea. Almost like [15]-[17] the ultimate gains of the STATCOM state feedback controller still rely upon the designer's alternative. In [19]-[21] an exceedingly fuzzy PI management methodology is planned to tune PI controller gains. However, it is still up to the designer to settle on the particular, settled gains. In [22] the population-based search technique is applied to tune controller gains. However, this methodology typically desires a protracted period of time to calculate the controller gains. A trade off of performance and also the sort of operation conditions still needs to be created throughout the designer's decision-making method. Thus, extremely economical results might not be forever accomplishable underneath a selected in operation condition. Completely different from these previous works, the motivation of this paper is to propose an impact methodology that may guarantee a fast and consistent desired response once the system operation condition varies in alternative words, the modification of the external condition won't have a negative impact, like slower response, overshoot, or perhaps instability to the performance. There are three inputs of FLC and one output. This input and output gains of FLC are tuned by trial method in such a way to satisfy the minimum error, and best output response is tuned by changing the gain and other parameters. The parameters are changed in such a way that error signal is minimized. To get the desired result, we must apply a rule-based system. The rule base for FLC is designed by the experience of studying the performance of STATCOM.

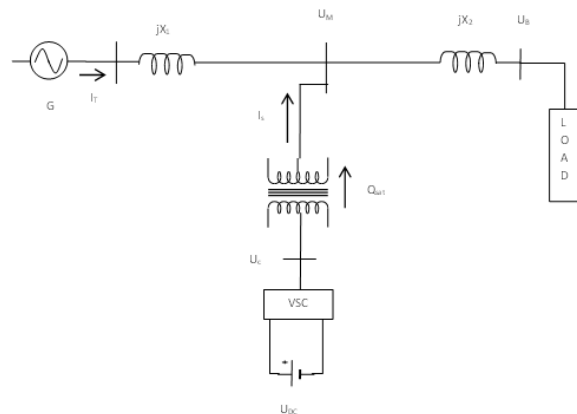


Fig1. Dynamic model system with STATCOM

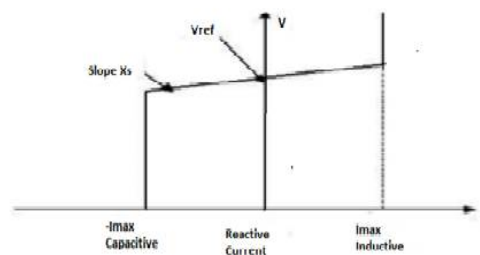


Fig2. V-I Characteristics of STATCOM

## II. STATCOM MODEL AND CONTROL

A. STATCOM model with fuzzy logic controller (flc). Structure of control system for AC-voltage regulator STATCOM with fuzzy logic controller. The fuzzy main controller is similar to a nonlinear PI controller. Nine fuzzy sets or linguistic variables are defined for E, ΔE1 & ΔE2, and nine for output signal. Fuzzy logic controller is a better option than conventional PI controller because it provides higher level of automation by incorporating expert knowledge and it also robust nonlinear control. In this, we have used a fuzzy logic controller instead of conventional PI controller. There are three inputs of FLC and one output. This input and output gains of FLC are tuned by trial method in such a way to

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

satisfy the minimum error, and best output response is tuned by changing the gain and other parameters. The parameters are changed in such a way that error signal is minimized. To get the desired result, we must apply a rule-based system. The rule base for FLC is designed by the experience of studying the performance of STATCOM.

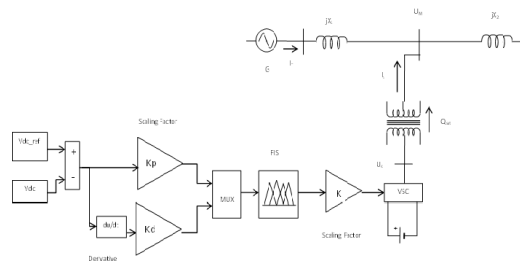


Fig. 3 Block diagram of STATCOM model with fuzzy logic controller (FLC)

### III. ADAPTIVE PI CONTROL OF STATCOM

A. Idea of the planned adjective PI management technique the STATCOM with mounted PI management parameters might not reach the specified and acceptable response within the facility once the ability system operative condition (e.g., hundreds or transmissions) changes. Associate adjective PI management technique is conferred.

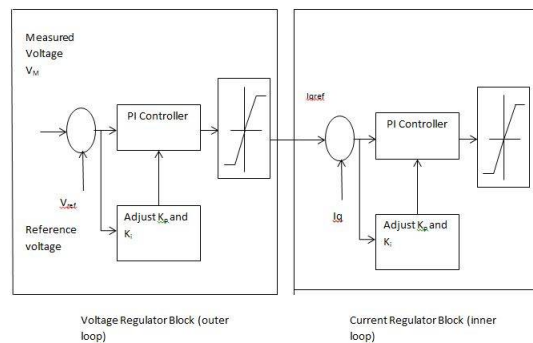


Fig. 4 Adaptive PI control block for STATCOM

Here specified response and to avoid activity trial-and-error studies to search out appropriate parameters for PI controllers once a replacement STATCOM is put in in an exceedingly facility. With this adjective PI management technique, the propellant self-adjustment of PI management parameters is complete. Associate adjective PI management block for STATCOM is shown in Fig. 3. In Fig. 3, the measured voltage and therefore the reference voltage, and the q-axis reference current and therefore the q-axis current square measure in per-unit values. The proportional and integral components of the transformer gains square measure denoted by  $k_{p-v}$  and  $k_{i-v}$ , severally. Similarly, the gains and represent the proportional and integral components, severally, of the present regulator. During this system, the allowable voltage error  $k_d$  is set to zero. The  $k_{p-v}$ ,  $k_{i-v}$ ,  $k_{p-i}$  and  $k_{i-i}$  can be set to associate capricious initial price like merely one.0. One exemplary desired curve is associate graphical record in terms of the voltage growth, shown in Fig. 4 that is ready because the reference voltage within the outer loop. Alternative curves may additionally be used than the delineate graphical record as long because the measured voltage returns to the specified steady-state voltage in desired time period. {The process|the technique} of the adjective voltage-control method for STATCOM is represented as follows.

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

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

- 2) Once the measured bus voltage over time, the target steady-state voltage, that is ready to 1.0 per unit (p.u.) within the discussion and examples,  $v_m(t)$  is compared with  $v_{nn}$ . supported the specified reference voltage curve,  $k_{p-1}$  and  $k_{i-1}$  are dynamically adjusted so as to create the measured voltage match the specified reference voltage, and therefore the q-axis reference current is obtained.
- 3) Within the inner loop,  $I_{qref}$  is compared with the q-axis current  $I_q$ . Exploitation the similar management technique just like the one for the outer loop, the parameters  $k_{p-1}$  and  $k_{i-1}$  is adjusted supported the error. Then, an appropriate angle is found and eventually the dc voltage in STATCOM is changed specified STATCOM provides the precise quantity of reactive power injected into the system to stay the bus voltage at the specified price.

It ought to be noted that the present and  $I_{max}$  and  $I_{min}$  the angle  $\alpha_{max}$  and  $\alpha_{min}$  square measure the bounds obligatory with the thought of the most reactive power generation capability of the STATCOM controlled during this manner. If one in every of the most or minimum limits is reached, the most capability of the STATCOM to inject reactive power has been reached. Certainly, as long because the STATCOM size has been befittingly studied throughout designing stages for inserting the STATCOM into the ability system, the STATCOM mustn't reach its limit unexpectedly

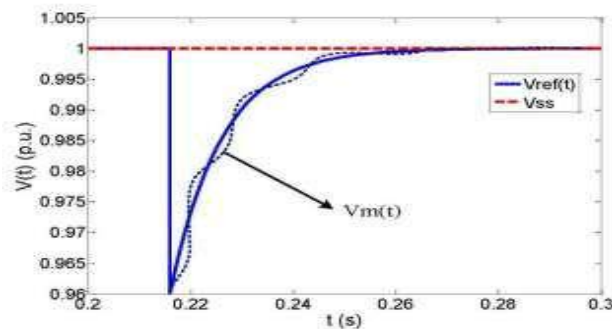


Fig. 5 Reference voltage curve.

Since the inner loop management is analogous to the outer loop management, the mathematical technique to mechanically regulate PI controller gains within the outer loop is mentioned during this section for illustrative functions. the same analysis is applied to the inner loop.

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

#### IV. FLOWCHART OF OPERATING PROCEDURE FOR FUZZY LOGIC CONTROLLER IN STATCOM

To enhance the performance of D-STATCOM a prototype is designed using MATLAB 2012a version; Fig below shows the flow chart of the control strategy of the system.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

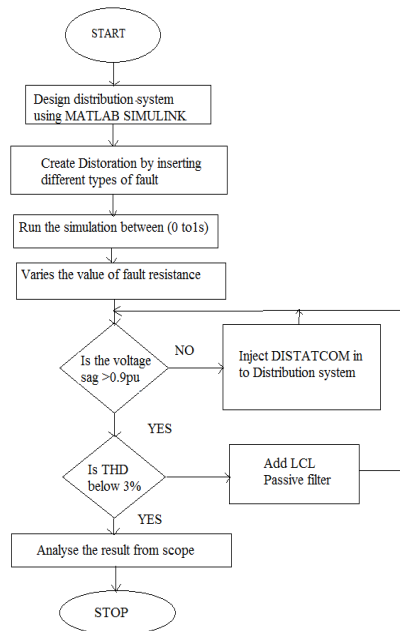


Fig 6Flowchart of Operating Procedure for Fuzzy Logic Controller (FLC) In STATCOM

## V. ALL VALUES OF ALL THE PARAMETERS

	Original Control
Lowest Voltage after disturbance	0.9938 p.u.
Time (sec) when V= 1.0	0.4095 Sec
$\Delta t$ to reach V = 1.0	0.2095 Sec
Var Amount at Steady State	97.76 MVar
Time to reach Steady State Var	0.4095 Sec

Performance comparison for the original system parameters

**For STATCOM:**

**Rated Power = 100 MVar**

**Rated voltage= 138 kV**

**Interface inductor (L) = 2.86 mH**

**Resistance (Rs) = 0.0898  $\Omega$**

**For Power Transformer (Y/Y):**

**Rated Voltage 220 kV/33 kV**

**Rated Power: 300 MVA**

**Three Phase Load**

**Load 1:**

**P= 100 MW**

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Q= 80 MVar

## VI. FLOWCHARTS OF THE ADAPTIVE PI CONTROL PROCEDURE

1. The accommodative PI management method begins at begin. The bus voltage over time ( ) is sampled in line with a desired rate. Then ( ) is compared with .If ( ) = , then there is no reason to alter any of the known parameters  $K_{p-v(t)}$ ,  $K_{i-v(t)}$ ,  $K_{p-l(t)}$  and  $K_{i-l(t)}$ . The power system is running swimmingly. On the opposite hand, if ( )  $\neq$  , then accommodative PI management begins.

2. The measured voltage is compared with , the reference voltage outlined in (10). Then,  $K_{p-v(t)}$  and area unit adjusted within the transformer block (outer loop) supported (23) and (24), that results in associate updated  $I_{qref}$  viaa current electrical circuit as shown in Fig.3

3. Then, the  $I_{qref}$  is compared with the measured q-current  $I_q$ . The management gains  $K_{p-l(t)}$  and  $K_{i-l(t)}$  area unit adjusted supported (25) and (26). Then, the phase  $\alpha$  is decided and felt a electrical circuit for output, that basically decides the reactive power output from the STATCOM.

4. Next, if  $|\Delta V(t)|$  is not at intervals a tolerance threshold  $V_c$ , which may be a terribly tiny price like 0.0001 p.u., the transformer block and current regulator blocks area unit re-entered till the amendment is a smaller amount than the given threshold  $V_c$ .

## VII. SIMULATION RESULT WAVEFORM OF FUZZY LOGIC CONTROLLER (FLC)

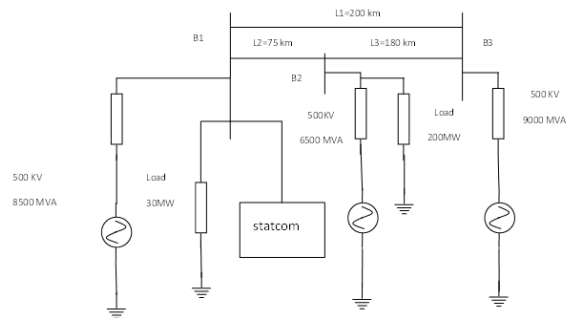


Fig. 7. Studied system

If there is the necessity to unceasingly perform the voltage-control method, that is typically the case, then the method returns to the measured bus voltage. Otherwise, the voltage-control method stops (i.e., the STATCOM management is deactivated). In the system simulation diagram shown in Fig. 6, a 100-MVAR STATCOM is enforced with a 48-pulse VSC and connected to a 500-kV bus. This can be the quality sample STATCOM system in Matlab/Simulink library, and every one machines utilized in the simulation square measure kinetic models. Here, the eye is concentrated on the STATCOM management performance in bus voltage regulation mode. Within the original model, the compensating reactive power injection and therefore the regulation speed square measure chiefly suffering from PI controller parameters within the transformer and therefore the current regulator. The first management are compared with the planned adjustive PI management model. Assume the steady-state voltage,  $v_{ss} = 1.0$  p.u.

### A. Change of PI Control Gains

The other system parameters remain unchanged while the PI controller gains for the original control are changed to  $k_{p-v}$ ,  $k_{i-v}$ ,  $k_{p-l}$  and  $k_{i-l} = 1$ . The dynamic control gains, which are independent of the initial values before the disturbance but depend on the post fault conditions.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Based on the Fuzzy control model can be designed, and the results are shown in Figs. respectively.

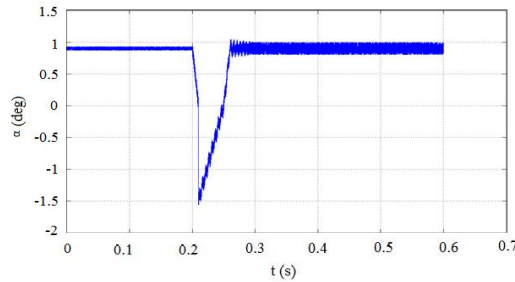
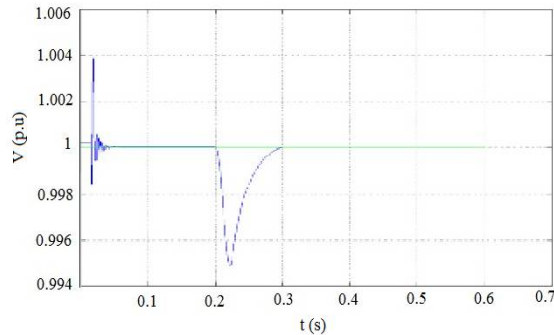
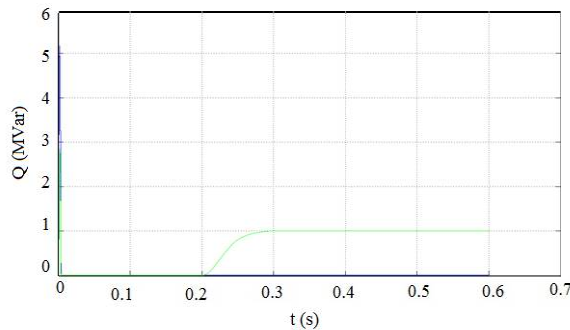


Fig.8 Results of  $\alpha$  with changed PI control gains



(a)



(b)

Fig.9 Results of (a) voltages and (b) output reactive power with changed PI control gains

## B. Change of Transmission Network

The PI controller gains remain unchanged, as in the original model. However, line 1 is switched off at 0.2 s to represent a different network which may correspond to scheduled transmission maintenance. The adaptive PI control model can be designed to automatically react to changes in the transmission network. The results are shown in Figs the initial transients immediately after 0.2 s lead to an over absorption by the STATCOM, while the adaptive PI control gives a much smoother and quicker response, as shown in Fig.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

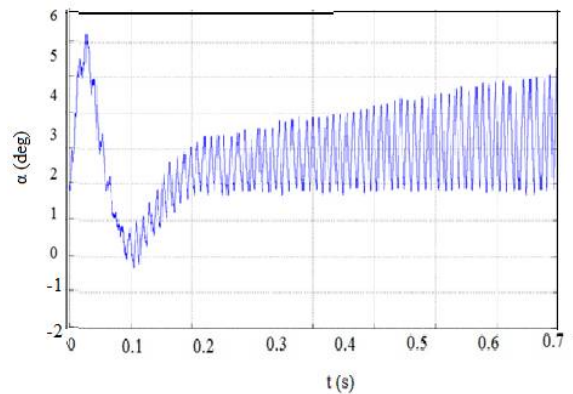
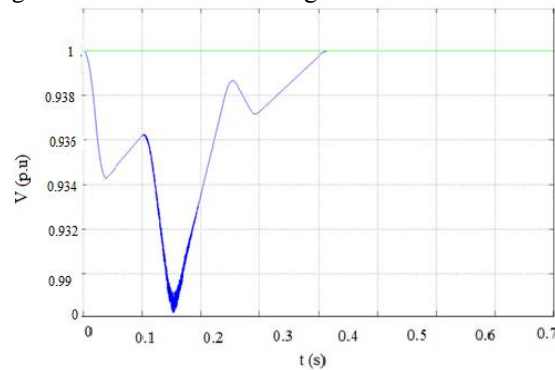
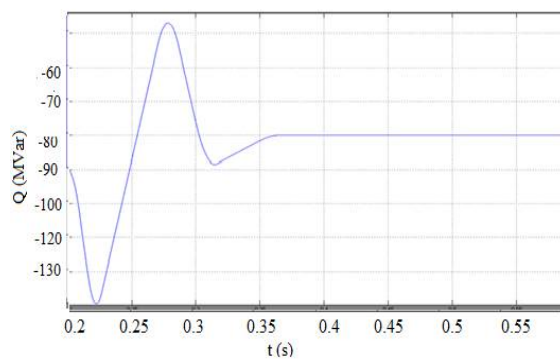


Fig.10 Results of  $\alpha$  with change of transmission network



(a)



(b)

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

### C.Two Consecutive Disturbances

In this case, a disturbance at 0.2 s causes a voltage decrease from 1.0 to 0.989 p.u. and it occurs at substation A. After that, line 1 is switched off at 0.25 s. The results are shown in it is apparent that the adaptive PI control can achieve much quicker response than the original one, which makes the system voltage drop much less than the original control during the second disturbance.

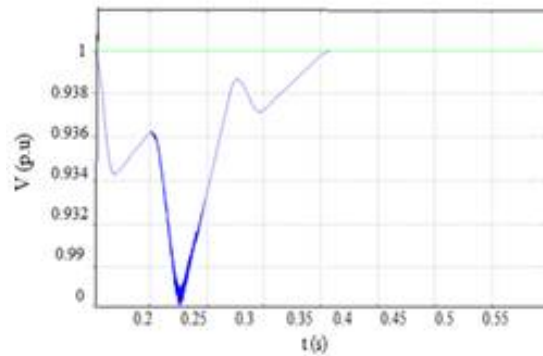
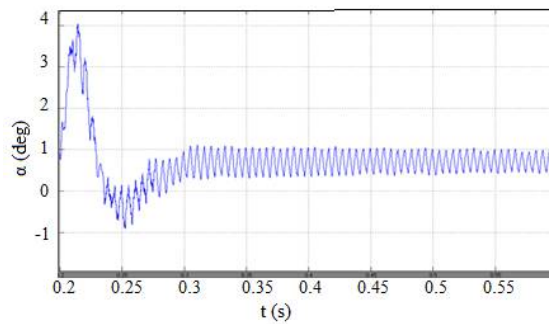
That the largest voltage drop during the second disturbance event (starting at 0.25 s) with the original control is 0.012 p.u., while it is 0.006 p.u. with the proposed adaptive control.



# International Journal of Innovative Research in Science, Engineering and Technology

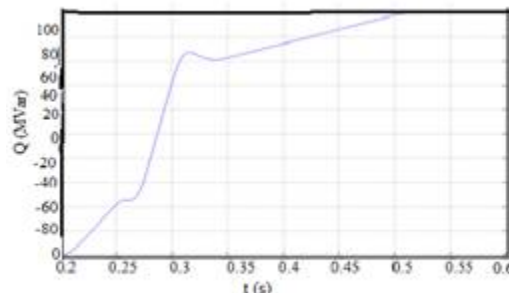
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016



(a)

Fig.12 Results of  $\alpha$  with two consecutive disturbances



(b)

Fig.13 Results of (a) voltages and (b) output reactive power with two consecutive disturbances

## V. CONCLUSION AND FUTURE SCOPE

The guideline focus of the proposed system is to develop a circuit for enhancing transient resiliency at 33KV system. Cushioned basis controller was used as a piece of controlling STATCOM. It was found that numerical exhibiting in synchronous turning plot lessens the circuit multifaceted nature. In the written work, diverse STATCOM control systems have been discussed including various employments of PI controllers. Regardless, these past works get the PI grabs by method for a trial-and-error methodology or wide studies with a tradeoff of execution and genuine nature. Along these lines, control parameters for the perfect execution at a given working point may not be fruitful at an other working point. Resulting to the congruity is self-representing; this gives the "fitting and-play" capacity for STATCOM operation. In the propagation look at, the proposed adaptable cushy method of reasoning control for STATCOM is differentiated and the routine STATCOM control with pretuned modified PI increments to check the advantages of the proposed procedure. The results exhibit that the adaptable PI control gives dependably

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, Februray 2016

splendid execution under various working conditions, for instance, particular initial control increments, differing trouble levels, and change of the transmission framework, progressive unsettling impacts, and a compelling irritation.

## VI. FUTURE WORK

Conversely, the traditional STATCOM control with settled fluffy rationale controller increases has worthy execution in the first framework, yet may not execute as proficient as the proposed control technique when there is a change of framework conditions. Future work might lie in the examination of various STATCOMs since the association among various STATCOMs might influence one another. Likewise, the augmentation to other force framework control issues can be investigated.

## REFERENCES

1. F. Li, J. D. Kueck, D. T. Rizy, and T. King, "A preliminary analysis of the economics of using distributed energy as a source of reactive power supply," Oak Ridge, TN, USA, First Quart. Rep. Fiscal Year, Apr. 2006, Oak Ridge Nat. Lab.
2. A. 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.
3. D. Soto and R. Pena, "Nonlinear control strategies for cascaded multilevel STATCOMs," IEEE Trans. Power Del., vol. 19, no. 4, pp. 1919–1927, Oct. 2004.
4. F. Liu, S. Mei, Q. Lu, Y. Ni, F. F. Wu, and A. Yokoyama, "The nonlinear internal control of STATCOM: Theory and application," Int. J. Elect. Power Energy Syst., vol. 25, no. 6, pp. 421–430, 2003.
5. C. Hochgraf and R. H. Lasseter, "STATCOM controls for operation with unbalanced voltage," IEEE Trans. Power Del., vol. 13, no. 2, pp. 538–544, Apr. 1998.
6. G. E. Valdearannma, P. Mattavalli, and A. M. Stankonic, "Reactive power and unbalance compensation using STATCOM with dissipativity based control," IEEE Trans. Control Syst. Technol., vol. 19, no. 5, pp. 598–608, Sep. 2001.
7. H. F. Wang, "Phillips-Heffron model of power systems installed with STATCOM and applications," Proc. Inst. Elect. Eng., Gen. Transm. Distrib., vol. 146, no. 5, pp. 521–527, Sep. 1999.
8. H. F. Wang, "Applications of damping torque analysis to statcom control," Int. J. Elect. Power Energy Syst., vol. 22, pp. 197–204, 2000.
9. Y. Han, Y. O. Lee, and C. C. Chung, "Modified non-linear damping of internal dynamics via feedback linearisation for static synchronous compensator," IET Gen. Transm. Distrib., vol. 5, no. 9, pp. 930–940, 2011.
10. A. H. Norouzi and A. M. Sharaf, "Two control schemes to enhance the dynamic performance of the STATCOM and SSSC," IEEE Trans. Power Del., vol. 20, no. 1, pp. 435–442, Jan. 2005.
11. M. S. E. Moursi and A. M. Sharaf, "Novel controllers for the 48-pulse VSC STATCOM and SSSC for voltage regulation and reactive power compensation," IEEE Trans. Power Syst., vol. 20, no. 4, pp. 1985–1997, Nov. 2005.
12. Matlab & Simulink, GTO-based STATCOM Dec. 2013. [Online]. Available: <http://www.mathworks.com/help/physmod/sps/powersys/ug/gto-based-statcom.html>, Feb. 2012
13. H. Li, F. Li, J. D. Kueck, and D. T. Rizy, "Adaptive voltage control with distributed energy resources: Algorithm, theoretical analysis, simulation and field test verification," IEEE Trans. Power Syst., vol. 25, no. 3, pp. 1638–1647, Aug. 2010.