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Voltage Regulation of Transmission Line through Adaptive Neuro Fuzzy Inference System (ANFIS) Control of STATCOM

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***Abstract*: -- STATCOM will contribute quick and valuable reactive power support to continue voltage stability. Voltage instability results to uncontrollable decline in voltage. This can be adjusted to desired limits by injection of reactive power. So, STATCOM with an adaptive PI controller is proposed. Several conventional controls of STATCOM are not promising the effective performance with change in system. The existing system regulates the performance by selfadjustment of control gains in PI controller and gets matches to a desired response. In extension to that the proposed system got an advantage of adaptive Neuro Fuzzy Inference System (ANFIS) which improves the dynamic response accuracy under various disturbances and promises a secure and reliable power system. This paper has the intention to a brand new controller model supported associate degree Adaptive Neuro Fuzzy Inference System(ANFIS) to tune the criterion of STATCOM controller for dominant the reactive power require to steady the voltage variation, like totally different change of transmission network, successive disturbances, a harsh disturbance and totally distinct load levels. A simulink form of associate degree ANFIS STATCOM controller has been taken for the analysis victimization simulation in MATLAB computer code.**

***Index Terms*—Adaptive PI controller, ANFIS controller, Reactive Power Compensation, STATCOM, Voltage Stability**

I. INTRODUCTION

Voltage stability is an essential issue to contemplate the safety and dependability of power grid. The static compensator (STATCOM), a documented device for reactive power management, engineered on gate turnoff (GTO) thyristors, has achieved a lot of attention with in the preceding decade years. In most of STATCOM models, the management logic is administered with the PI controllers. Co-jointly several administration strategies are suggested for STATCOM controller, focusing mainly on administration style rather than finding a technique to set PI controller gains. However the controller parameters or gains play a considerable role in STATCOM performance. Therefore a few surveys are done on the controller parameter settings. However in these, the controllers of PI gains are fashioned approach with compromise in presentation and strength. STATCOM adaptive PI controller designed for voltage regulation is studied. PI controller parameters square measure usually self-adjusted mechanically and dynamically under different disturbances throughout an influence power grid, among this controller of adaptive PI technique. Once a disturbance happens with in the system, the controller of PI parameters for STATCOM usually computed mechanically in each sampling fundamental measure and may be in tune in existent time to trace the reference voltage. Based on thiselementary motivation, associate degree Adaptive Neuro-Fuzzy Inference System (ANFIS) controller of STATCOM voltage regulation be given during this paper. With this ANFIS controller technique, this technique won't be suffering from the initial gain settings, changes of system conditions, and the restrictions of human expertise and judgment. Additionally, this analysis work demonstrates quick, dynamic presentation of STATCOM in numerous operation conditions. This article is ordered the same as follows. Section II illustrates the system arrangement and STATCOM dynamic representation. Section III presents controller of adaptive PI technique. Section IV presents the Adaptive Neuro-Fuzzy Inference System (ANFIS) control technique. Section V compares ANFIS controller strategies with adaptive PI controller, and presents the simulation results. Finally, Section VI concludes this paper.

II. SYSTEM CONFIGURATION AND STATCOM DYNAMIC MODEL

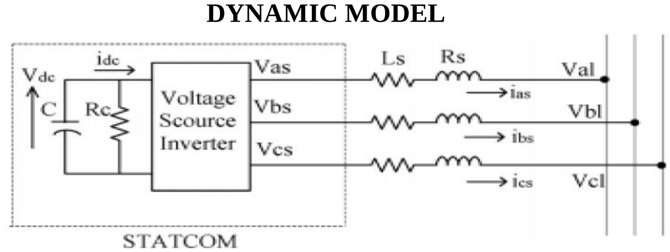

Fig.1. Circuit of STATCOM

As shown in Fig.1. During this configuration, the resistance Rs that is nonparallel with the voltage source inverter symbolizes the total of the electrical appliance winding resistances losses and electrical converter physical phenomenon losses. The leakage inductance of the electrical appliance is indicated by the inductance (Ls). The whole of the change losses of electrical converter and therefore the power losses in capacitance is diagrammatic by combination of Rc in shunt with the C. 1D.NAGAMANI, 2B.NARASIMHA REDDY, M.Tech, 1 PG Scholar, JNTUACE PULIVENDULA, 2 Academic assistant, JNTUACE PULIVENDULA 1nagmani222@gmail.com,2 buchupallinarasimha@gmail.com During this configuration, the 3-section STATCOM o/p voltages are Vas, Vbs and Vcs, the 3-section bus voltages are Val, Vbl and Vcl whenever because the as the 3-section output currents are $i{-}as$, $i{-}bs$ and $i{-}cs$ .Below is that the mathematical illustration of threephase STATCOM model.

$$L_s \frac{di_{as}}{dt} = -R_s i_{as} + V_{as} - V_{al} \quad (1)$$

$$L_s \frac{di_{bs}}{dt} = -R_s i_{bs} + V_{bs} - V_{bl} \quad (2)$$

$$L_s \frac{di_{cs}}{dt} = -R_s i_{cs} + V_{cs} - V_{cl} \quad (3)$$

$$\frac{d}{dt}\left(\frac{1}{2} C V_{dc}^2(t)\right) = -[V_{as} i_{as} + V_{bs} i_{as} + V_{cs} i_{cs}] - \frac{V_{dc}^2(t)}{R_c} \quad (4)$$

By applying the abc/dq transformation, we will rewrite the equations from (1) to (4) be able to exist written as

$$\frac{d}{dt}\begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L_s} & w & \frac{K}{L_s}\cos\alpha \\ -w & -\frac{R_s}{L_s} & \frac{K}{L_s}\sin\alpha \\ -\frac{3K}{2C}cos\alpha & -\frac{3K}{2C}\sin\alpha & -\frac{1}{R_c C} \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{dc} \end{bmatrix} - \frac{1}{L_s}\begin{bmatrix} V_{dl} \\ V_{ql} \\ 0 \end{bmatrix}$$

Here, ids and iqs represent d and q currents with relation to ias , ibs and ics . The relation between the dc voltage and peak section to neutral voltage on the ac aspect is diagrammatic by an element 'K'. DC aspect voltage is diagrammatic withVdc . The point in time at that the STATCOM output voltage leads the bus voltage is publicized by 'α'. The synchronously rotating angle speed of the voltage vector is shown as 'w'. The d and q axis voltage with relation to Val, Vbl and Vcl are shown by Vdl and Vql. Supported fast reactive & active power meaning, as Vql=0, we will derive the subsequent equations.

$$p_l = \frac{3}{2} V_{dl} i_{ds} \quad (6)$$

$$q_l = \frac{3}{2} V_{dl} i_{qs} \quad (7)$$

III. ADAPTIVE PI CONTROL TECHNIQUE

Based on the above equations, the Adaptive PI controller strategy is often obtained, and STATCOM management diagram is shown in below Fig.2.

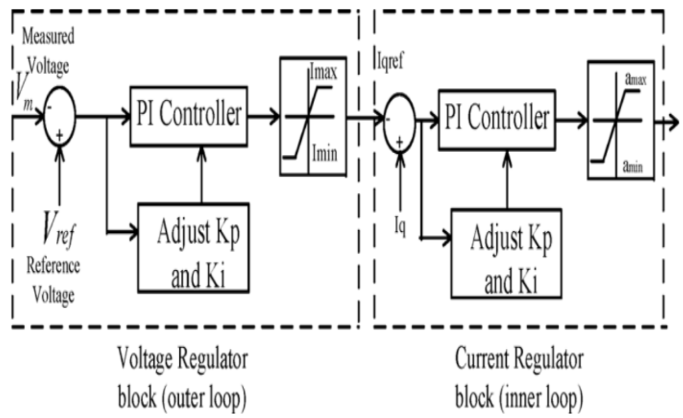

Fig.2. Adaptive PI controller block for STATCOM

The dynamic self-adjustment of PI controller parameters is often accomplished, with this adaptive PI controller technique. One exemplary desired curve is associate in nursing graph in terms of the voltage growth, shown in below Fig.3 that is about because the reference voltage within the outer loop. Alternative curves may additionally be used than the pictured graph as long because the measured voltage returns to the specified steady-state voltage in desired time period.

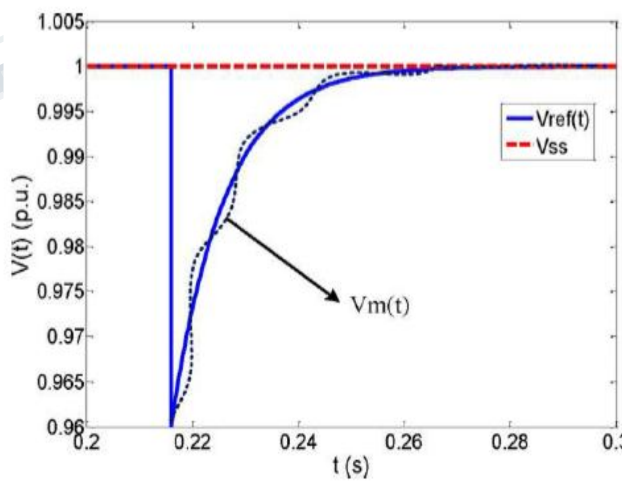

Fig.3. Reference voltage curve

The method of the adaptive voltage controller technique for STATCOM is represented with below flow sheet. Fig.4 is an exemplary flow sheet of the existing adaptive PI control for STATCOM for block diagram of Fig.2.

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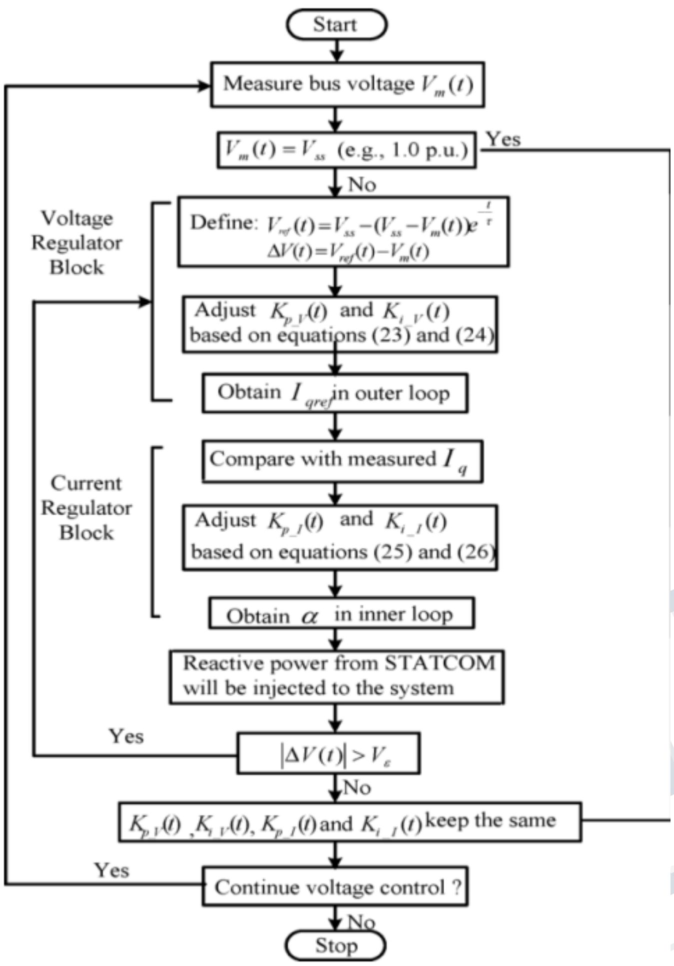

Fig.4 Adaptive PI controller algorithm flow sheet

IV. ADAPTIVE NEURO-FUZZY CONTROLLER

A. Introduction:

A fuzzy abstract thought system and a back circulation rule. For a traditional fuzzy abstract thought, the parameters contained by the membership functions are generally determined by expertise or the trial-and-error technique. However, the Adaptive Neuro-Fuzzy abstract thought system will overcome this disadvantage through the method of learning to modify the membership functions to the input/output information so as to description for these varieties of variations within the information values, instead of randomly selecting parameters related to a given membership functions. This learning technique works equally to it of neural networks. Adaptive Neural Fuzzy Inference System (ANFIS) is fuzzy Sugeno model place surrounded by the structure to make easy learning and adaptation procedure. Such network makes mathematical logic a lot systematic and fewer wishing on professional information. ANFIS are a category of adaptive networks that are functionally such as fuzzy abstract thought systems. ANFIS represent Sugeno e Tsukamoto fuzzy models. ANFIS uses a hybrid learning algorithmic rule.

B. Sugeno model:

Assume that the fuzzy abstract thought system has 2 input 'x' and 'y' and one output 'z'. A primary-order Sugeno fuzzy model has rules because the following:

Rule1:

If 'x' is A_1 and 'y' is B_1, then $f_1 = p_1x+q_1y+r_1$

Rule2:

If 'x' is A_2 and 'y' is B_2, then $f_2 = p_2x+q_2y+r$

$$f = \frac{w_1.f_1+w_2.f_2}{w_1+w_2} \quad (8)$$

C.ANFIS Architecture:

To current the ANFIS architecture shown in Fig.5, two fuzzy if-then rules supported a primary order Sugeno model are considered:

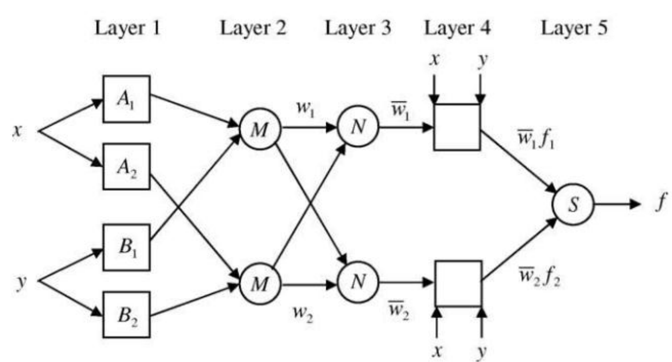

Fig.5. ANFIS Architecture

In the 1st layer, all the nodes are adaptive nodes. Each node i during this layer is an adaptive node with a node function. Ol,I is that the output of the i th node of the layer l.

$$O_{1,i} = \mu A_i(x) \text{ for } i=1,2, \text{ or} \quad (9)$$

$$O_{1,i} = \mu B_{i-2}(x) \text{ for } i=3,4 \quad (10)$$

Where 'x' is that the input node i and Ai (or Bi-2) could be a linguistic tag related to this node. Thus O1,i is that the membership grade of a fuzzy set(A1,A2,B1,B2). For example, if the bell formed membership functions is used, μAi(x) is given by:

]

$$\mu A_i(x) = \frac{1}{1+\left\{\left(\frac{x-c_i}{a_i}\right)^2\right\}^{b_i}} \quad (11)$$

Where ai, bi and ci are the parameters of the membership perform, governing the bell formed functions consequently.

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 9, September 2017

Within the second layer, the nodes are unchanging nodes. They are tagged with M, indicating that they perform as a straightforward multiplier factor. The yield of this layer is portrayed as:

$$O_i^2 = w_i = \mu A_i(x)\,\mu B_i(y) \quad i = 1, 2 \qquad (12)$$

This is the self-styled firing strengths of the foundations. Within the third layer, the nodes are also unchanging nodes. They're labeled with N, indicating that they play a standardization role to the firing strengths from the previous layer. The output of this layer is portrayed as:

$$O_i^3 = \bar{w}_i = \frac{w_i}{w_1+w_2} \quad i = 1, 2 \qquad (13)$$

This is the self-styled normalized firing potency Within the fourth layer, the nodes are adaptive nodes. The output of every node during this layer is just the result of the normalized firing potency and a primary order polynomial (for a primary order Sugeno model). Thus, the outputs of this layer are given by:

$$O_i^4 = \bar{w}_i f_i = \bar{w}_i(p_i x + q_i y + r_i) \quad i = 1,2 \qquad (14)$$

Within the fifth layer, nearby is only 1 single unchanging node labeled with S. This node performs the summation of all inward signals. Hence, the on the whole output of the model is given by:

$$O_i^5 = \sum_{i=1}^{2} \bar{w}_i f_i = \frac{\sum_{i=1}^{2} w_i f_i}{w_1+w_2} \qquad (15)$$

It is determined that there are 2 adaptive layers during this ANFIS architecture, particularly the primary layer and therefore the fourth layer. Within the primary layer, there are three adaptable parameters$\{ai, bi, ci\}$ that are associated with the input membership functions. These parameters are the self-styled principle parameters. Within the fourth layer, there are also three adaptable parameters$\{pi, qi, ri\}$, bearing on the primary order polynomial. These parameters are so-called resultant parameters. The fuzzy sets are determined as: N: negative, Z: zero, P: positive, correspondingly. The rule base with two projected input is shown as:

$e/\Delta e$	N	Z	P
N	P	P	Z
Z	P	Z	N
P	Z	N	N

In matlab the most distinction between fuzzy controller and adaptive Neuro fuzzy controller is merely we've got in matlab 2 sorts fuzzy controllers one is mamdani and other is Sugeno.

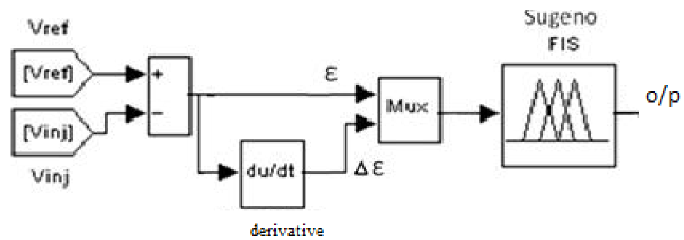

Fig.6. Simulink model of ANFIS

Mamdani is standard fuzzy controller during this we offer input and output by victimization some assumptions however in Sugeno sort we offer inputs solely they mechanically train outputs this can be the most distinction between 2 fuzzy controllers in matlab.

V.SIMULATION RESULTS

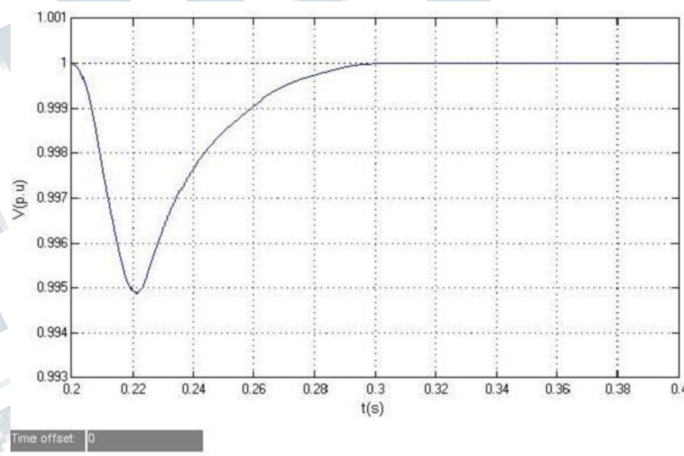

Fig.7a. voltage for adaptive PI

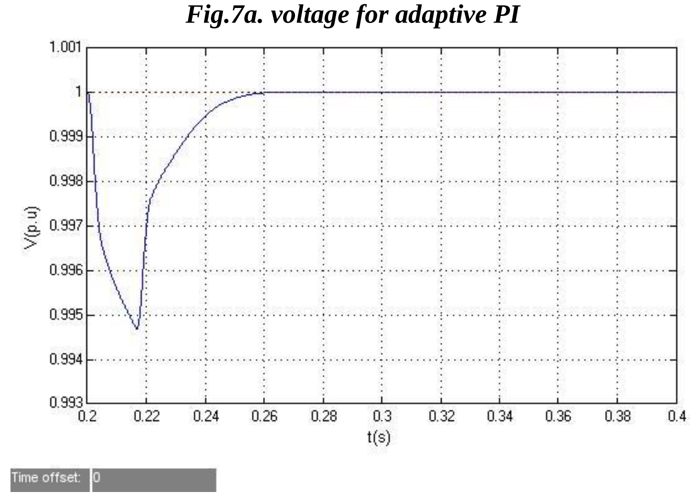

Fig.7b. voltage for ANFIS

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 9, September 2017

By using ANFIS controller voltage reaches stability point earlier than adaptive PI controller in original system from 0.3s to 0.26sas shown in Fig.7a and Fig.7b.

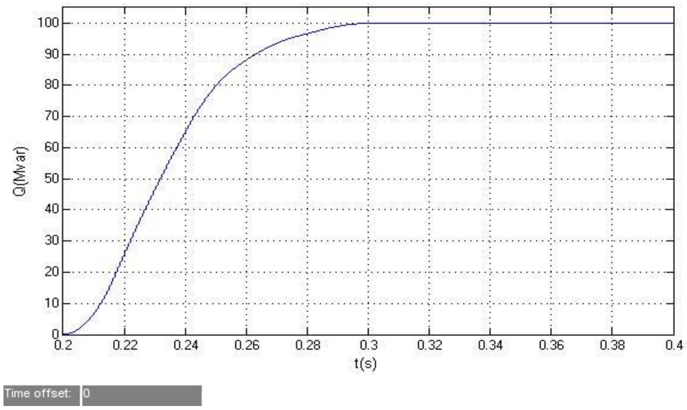

Fig.8a. reactive power for adaptive PI

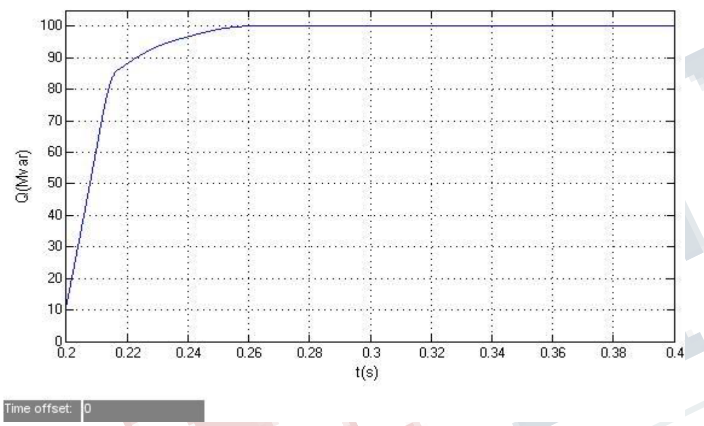

Fig.8b. reactive power for ANFIS

As shown figures Fig.8a and Fig.8b reactive power reaches steady state stability earlier in ANFIS than the adaptive PI controller in original system from 0.3s to 0.26s

b. Change of load

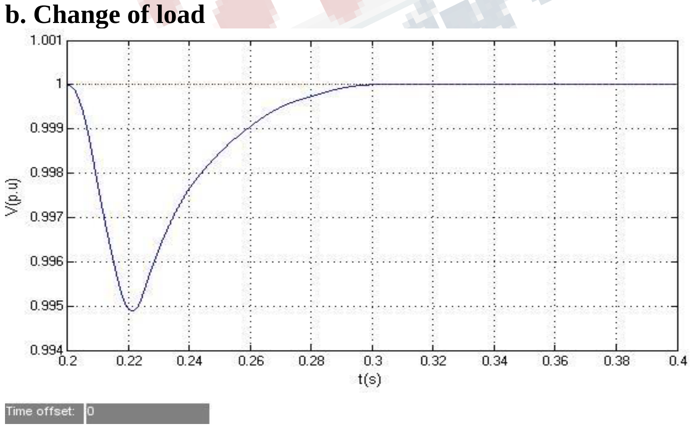

Fig.9a. voltage for adaptive PI

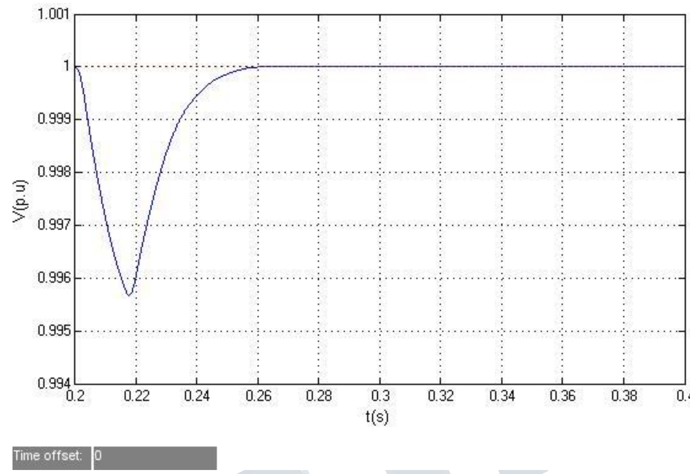

Fig.9b. voltage for ANFIS

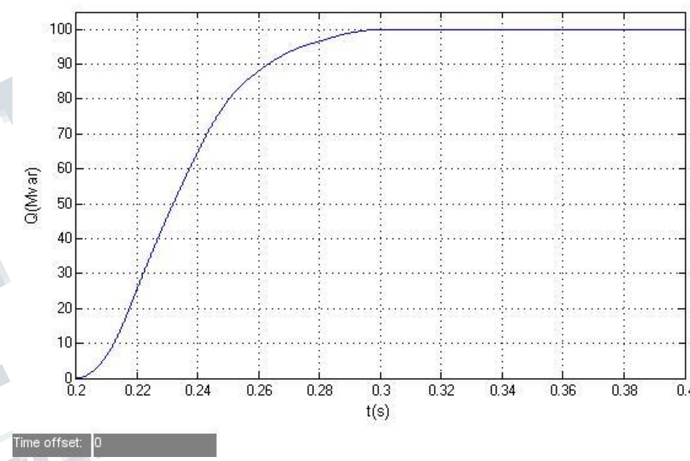

Fig.10a. reactive power for adaptive PI

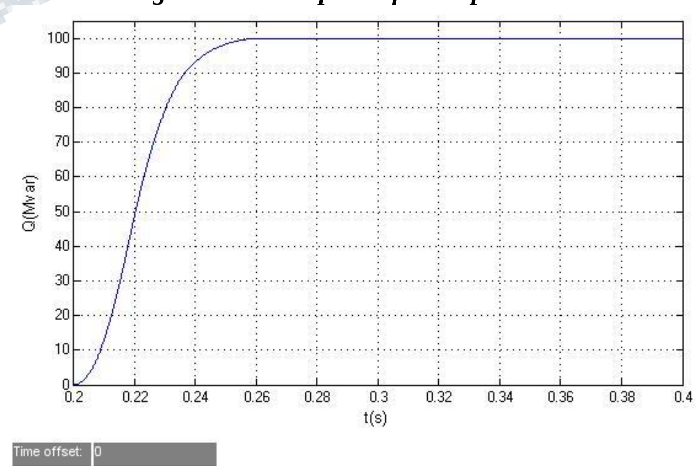

Fig.10b. reactive power for ANFIS

As shown figures Fig.10a and Fig.10b reactive power reaches steady state stability earlier in ANFIS than the adaptive PI controller in change of load from 0.3s to 0.26s

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Vol 3, Issue 9, September 2017

c. Change of transmission network

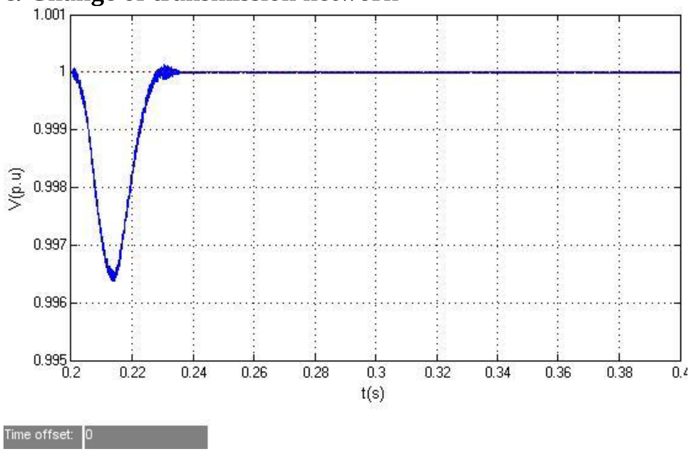

Fig.11a. voltage for adaptive PI

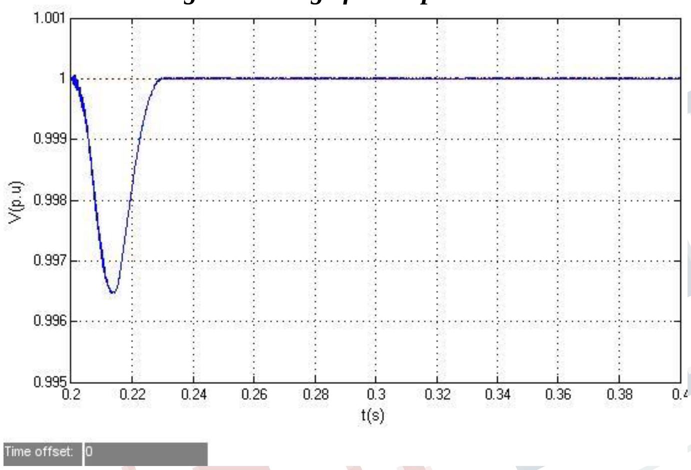

Fig.11b. voltage for ANFIS

As shown in figures Fig.11a and Fig.11b by changing transmission network ANFIS control has least ripples than the adaptive PI.

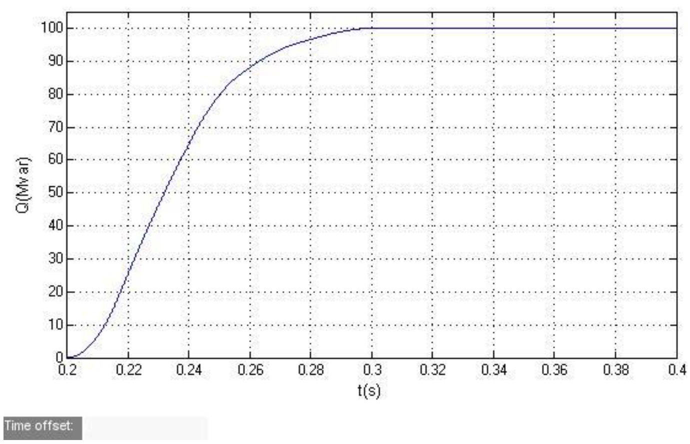

Fig.12a. reactive power for adaptive PI

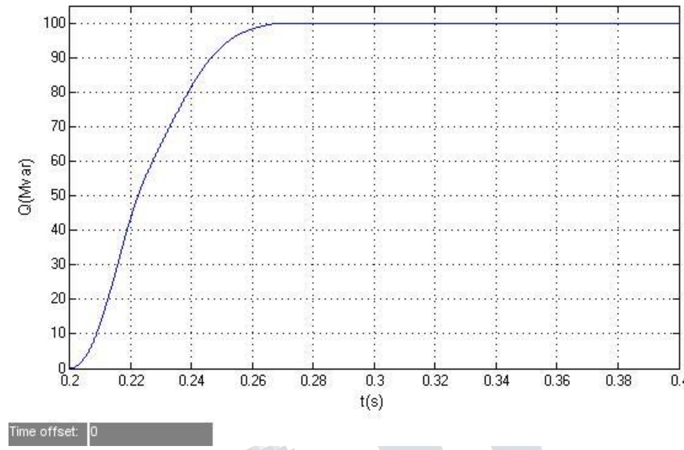

Fig.12b. reactive power for ANFIS

As shown figures Fig.12a and Fig.12b reactive power reaches steady state stability earlier in ANFIS than the adaptive PI controller in change of transmission network from 0.3s to 0.26s

d. two consective disturbances

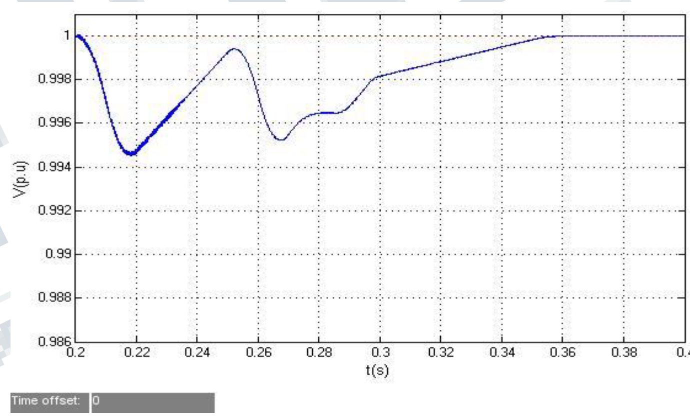

Fig.13a. voltage for adaptive PI

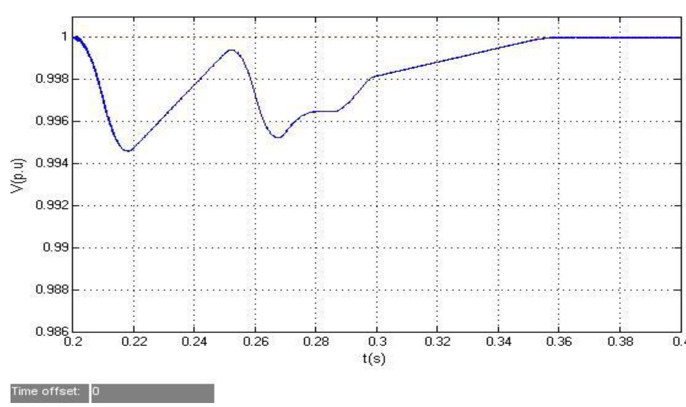

Fig.13b. voltage for ANFIS

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International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 9, September 2017

As shown in figures Fig.13a and Fig.13b when two consecutive disturbances occurs ANFIS control has least ripples than the adaptive PI.

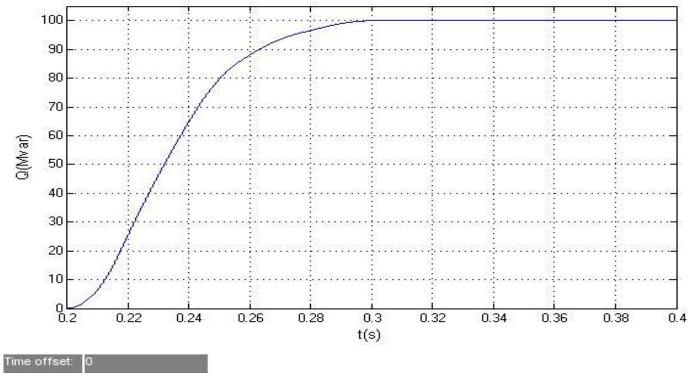

Fig.14a. reactive power for adaptive PI

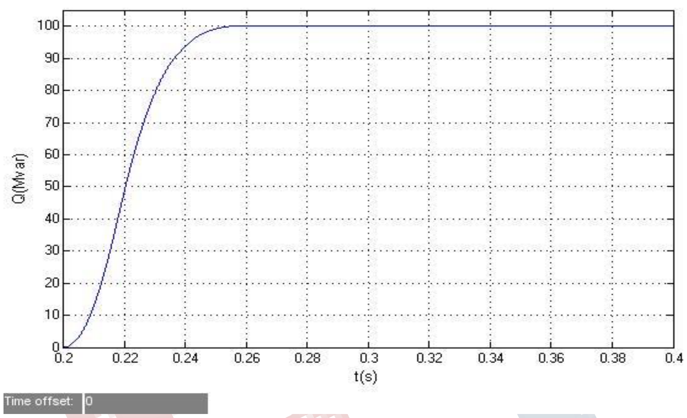

Fig.14b. reactive power for ANFIS

As shown figures Fig.14a and Fig.14b reactive power reaches steady state stability earlier from 0.3s to 0.25s in ANFIS than the adaptive PI controller when two consecutive disturbances occurs.

e. Severe disturbance

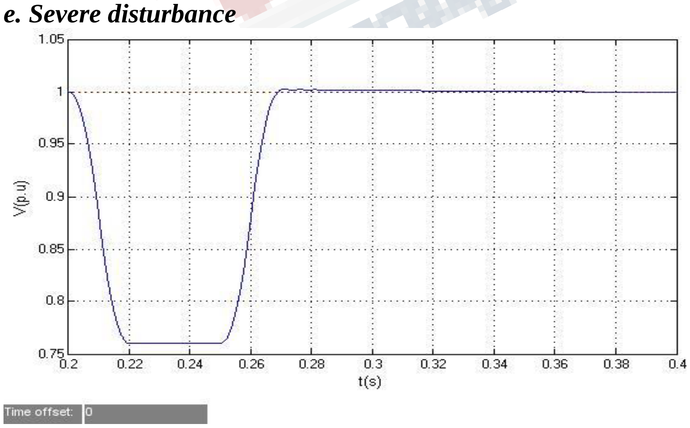

Fig.15a. voltage for adaptive PI

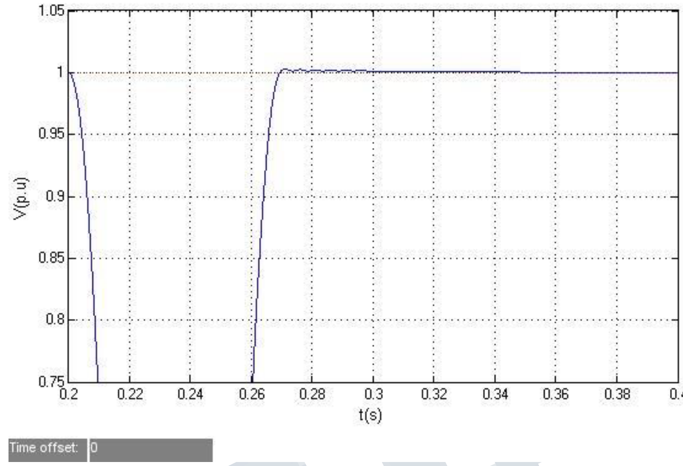

Fig.15b. voltage for ANFIS

Above figures Fig.15a and Fig.15b represents comparision of voltage between adaptive PI controller and ANFIS controller in severe disturbances.

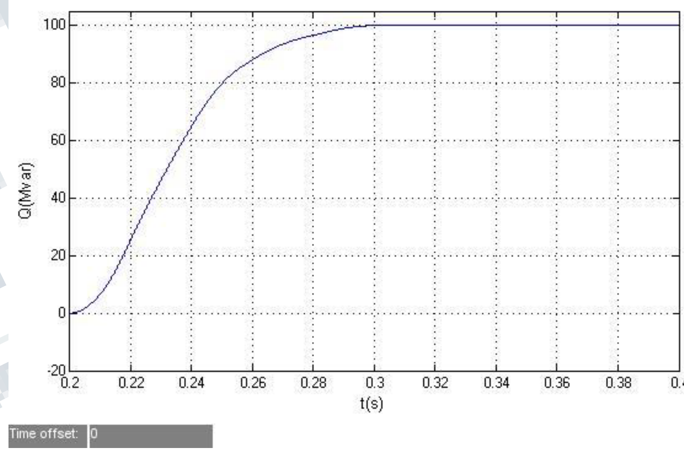

Fig.16a. reactive power for adaptive PI

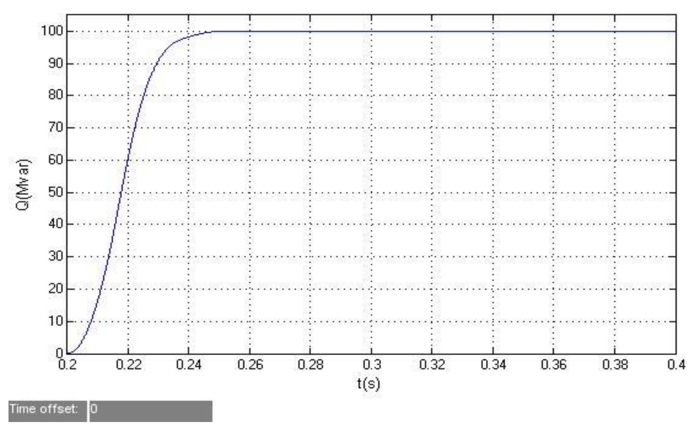

Fig.16b. reactive power for ANFIS

As shown figures Fig.16a and Fig.16b reactive power reaches steady state stability earlier from 0.3s to 0.24s in ANFIS than the adaptive PI controller in severe disturbances.

VI. CONCLUSION

In this article, ANFIS STATCOM controller technique has been discussed which standardize voltage productively during disturbances, so that the power will always become stable, disregarding of the change in operating condition.
In the simulink study, the intended ANFIS STATCOM control is compared with adaptive PI control. The results shows that the ANFIS control provides consistently good performance than the adaptive PI controller under various operating circumstances such as change of transmission network, a severe disturbance, distinct load levels and successive disturbances.

REFERENCES

[1] Yao Xu, Fangxing Li, IEEE Trans. On power del., “adptive PI control of statcom for voltage regulation” VOL. 29, NO. 3, JUNE 2014

[2] 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.

[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] Hazlina Hamdan, “An exploration of the Adaptive neuro fuzzy Inference system(ANFIS) in modeling survival”.

[5] J.S.R.Jang., ANFIS: Adaptive Network-based Fuzzy Inference Systems, IEEE transactions on systems,Man, and Cybernetics,Vol.23,No.03,pp.665-685,1993