ENHANCEMENT OF POWER SYSTEM STABILITY USING STATCOM IN MULTI AREA POWER SYSTEMS

T HEMANTH KUMAR[1], G SUNIL KUMAR[2]

[1]Lecturer, SKU College of Engineering & Technology, Anantapuramu, Andhra Pradesh-515003 India.

[2]PG Scholar, SKU College of Engineering & Technology, Anantapuramu, Andhra Pradesh-515003 India.

ABSTRACT-This paper presents using of Fuzzy Logic Controller (FLC)) controller for a static synchronous compensator (STATCOM) equipped with energy storage. It can be done with a signal estimation technique based on a modified recursive least square (RLS) algorithm, which allows a fast, selective, and adaptive estimation of the low-frequency electromechanical oscillations from locally measured signals during power system disturbances. The proposed method is effective in increasing the damping of the system at the frequencies of interest, also in the case of system parameter uncertainties and at various connection points of the compensator. The Proposed control strategy that optimizes active and reactive power injection at various connection points of the STATCOM will be derived using the simplified model. Small-signal analysis of the dynamic performance of the proposed control strategy will be carried out. The performance of STATCOM in presence of fuzzy logic controller is simulated for various system parameter uncertainties.

Index Terms —oscillation, Fuzzy Logic Controller recursive least square (RLS), static synchronous compensator (STATCOM), Energy storage, Fuzzy Logic Control (FLC).

I. INTRODUCTION

Disturbances in electric power systems may result in dynamic oscillations of generators rotor as well as fluctuations in voltages and active power flows throughout the transmission systems. These electromechanical oscillations often exhibit poor damping and elevated peak values when the power transfer is high in relation to the transmission strength [1]. The availability and a proper design of control schemes can significantly enhance the electromechanical oscillations stability and also sustain the voltage and frequency of the system within secured bounds. As a consequence, the safe operating limits of interconnected power systems are extended, while the power quality supplied by the system loads is improved. A common control scheme used for these purposes is an integrated generator excitation system including power system stabilizer (PSS) [1,2]. Since the PSS is located nearby the generators units, it may not provide a satisfactory control action in improving the power quality features in some remote buses of the transmission network. Additionally, the PSSs are not always effective to damp oscillations in tie-lines (precisely, the inter-area oscillations modes). This mainly occurs due to the difficulties related to tuning and The STATCOM/BESS is coupled to the ac system through a step-down transformer (which is represented by an inductance LS), as it can be seen in Fig. 1. The main components of this device are a conventional STATCOM and a BESS [10]. The conventional STATCOM is constituted by a voltage source inverter (VSI), a dc link capacitor and a control system [11].

The VSI is the interface between the dc-side and the ac system. Several kinds of VSI have been proposed, such as multi-pulse arrangement with zigzag transformer, the multi lever converter and the PWM modulation converter [10,12]. While the conventional STATCOM uses the capacitor for unbalanced system operation and harmonic absorption [10], the capacitor of the integrated STATCOM/BESS is still necessary, but it acts only as a lower pass filter (harmonic absorption) for reducing the ripple of the dc current from/into the BESS.

The control of STATCOM with energy storage (named hereafters E-STATCOM) for power system stability enhancement has been discussed in the literature [10]–[12]. However, the impact of the location of the E-STATCOM on its dynamic performance is typically not treated. When active power injection is used for FLC, the location of the E-STATCOM has a significant impact on its dynamic performance. Moreover, the typical control strategy of the device for FLC available in the literature is similar to the one utilized for power system stabilizer (PSS) [9],where a series of wash-out and lead-lag filter links are used to generate the control input signals. This kind of control strategy is effective only at the operating point where the design of the filter links is optimized, and its speed of response is limited by the frequency of the electromechanical oscillations. In this paper, a control strategy for the E-STATCOM when used for FLC will be investigated. Thanks to the selected local signal quantities measured in the system, the control strategy optimizes the injection of active and reactive power to provide uniform damping at

Vol 10, Issue 4, April /2019
ISSN NO:0377-9254

various locations in the power system. It will be shown that the implemented control algorithm is robust against system parameter uncertainties. For this, a modified recursive least square (RLS)-based estimation algorithm as described in [13], [14] will be used to extract the required control

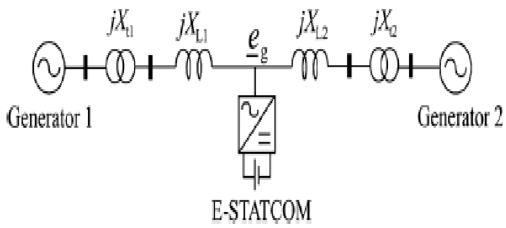

Fig. 1. Block diagram two-machine system with E-STATCOM.

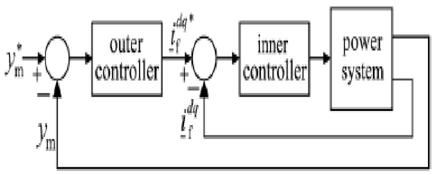

Fig. 2. Block diagram of the control of E-STATCOM.

signals from locally measured signals. Finally, the effectiveness of the proposed control strategy will be validated via simulation and experimental verification.

II. SYSTEM MODELING FOR CONTROLLER DESIGN

A simplified power system model, such as the one depicted in Fig. 1, is used to study the impact of the E-STATCOM on the power system dynamics. The investigated system approximates an aggregate model of a two-area power system, where each area is represented by a synchronous generator.

The synchronous generators are modeled as voltage sources of constant magnitude(V_{g1},V_{g2}) and dynamic rotor angles(δ_{g1}, δ_{g2}) behind a transient reactance($X^1{}_{d1}$,$X_{d2}{}^1$) . The transmission system consists of two transformers represented by their equivalent leakage reactance (X_{t1},X_{t2}) and a transmission line with equivalent reactance(X_L=X_{L1}+X_{L2}) . The losses in the transmission system are neglected for simpler analytical expressions. If the mechanical damping in the generators is neglected, the overall damping for the investigated system is equal to zero. Therefore, the model is appropriate to allow a conservative approach of the impact of the E-STATCOM when used for stability studies. For analysis purpose, the electrical connection point of the converter along the transmission line is expressed by the parameter as

$$a = \frac{X_1}{X_1 + X_2} \quad ….. \tag{1}$$

Where

$X_1 = X'_{d1} + X_{t1} + X_{L1}$

$X_2 = X'_{d2} + X_{t2} + X_{L2}$

The control of the E-STATCOM consists of an outer control loop and an inner current control loop, as shown in Fig. 2.The outer control loop, which can be an ac voltage, dc-link voltage or FLC controller, sets the reference current for the inner current controller. The generic measured signal y_m depends on the type of outer loop control. The control algorithm is implemented in dq -reference frame where a phase-locked loop (PLL) [15] is used to track the grid-voltage angle θ_g from the grid-voltage vector . By synchronizing the PLL with the grid-voltage vector, the - and -components of the injected current(and) control the injected active and reactive power

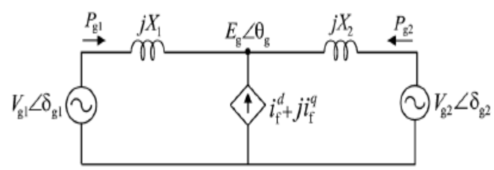

Fig. 3. Equivalent circuit for two-machine system with E-STATCOM.

respectively. In the notation in Fig. 2, the superscript " *" denotes the corresponding reference signals. In this paper, the outer control loop is assumed to be a FLC controller, and the detail of the block will be described in Section III. For this reason, we assume that the injected active and reactive powers in the steady state are zero. When designing a cascaded controller, the speed of outer control loop is typically selected to be much slower than the inner one to guarantee stability. This means that the current controller can be considered infinitely fast when designing the parameters of the outer controller loop. Therefore, the E-STATCOM can be modeled as a controlled ideal current source, as depicted in the equivalent circuit in Fig. 3, for analysis purpose. The level of Fuzzy Logic Controller provided by the converter depends on how much the active power output from the generators is modulated by the injected current, . For the system in Fig. 3, the change in active power output from the generators due to injected active and reactive power from the E-STATCOM is calculated as in

$$\Delta P_{g1,P} \approx -\Gamma_p P_{inj}, \Delta P_{g2,P} \approx -(1-\Gamma_p)P_{inj}$$

$$\Delta P_{g1,Q} \approx \left[\frac{V_{g1}V_{g2}\sin(\delta_{g10}-\delta_{g20})a(1-a)}{E_{go}^2}\right] \tag{2}$$

Where ($\Delta p_{g1,p}$, $\Delta p_{g2,p}$) and ($\Delta p_{g1,Q}$, $\Delta p_{g2,Q}$) represent the change the in active power from the corresponding generators due to injected active power (p_{ing}) and reactive power(Q_{ing}), respectively .ɾp, p_{ing} and Q_{ing} are given by

$$\Gamma_p = \frac{(\lfloor(1-a)V_{g1}\rfloor 2 + a(1-a)V_{g1}V_{g2}\cos(\delta_{g10}-\delta_{g20}))}{E_{g0}^2}$$

$$P_{inj} \approx E_{goi_f^d}$$

$$Q_{inj} \approx -E_{goi_f^q} \quad (3)$$

The initial steady-state PCC voltage magnitude and generator rotor angles((δ_{g10}, δ_{g20}) correspond to the operating point where he converter is in idle mode. A derivation to the expressions in (2) is given in the Appendix .It can be seen from (2) and (3) that the change in active power output from the generators depends on the location of the converter as well as on the amount of injected active and reactive power. Moreover, it can be understood from (2) that the effect of reactive power injection depends on the magnitude and direction of transmitted power from the generators.

III. FLC CONTROLLER DESIGN

The derivation of the FLC controller from locally measured signals will be made in this section.

A. Derivation of Control Input Signals

Considering the simplified two-machine system in Fig. 1,the active power output from each generator should change in proportion to the change in its speed to provide damping [9].From (2), it can be observed that the effect of the power injected by the compensator on the generator active power output highly depends on the parameter , i.e., on the location of the E-STATCOM. Using the equivalent system in Fig. 3, a control input signal that contains information on the speed variation of the generators can be derived. When the E-STATCOM is not injecting any current, the variation of the locally measured signals θ_g, and P_{tran} at different E-STATCOM connection points using the dynamic generator rotor angles δ_{g1}, δ_{g2} and is given by

$$\theta_g = \delta_{g2} + tan^{-1}\left[\frac{(1-a)V_{g1}\sin(\delta_{g1}-\delta_{g2})}{(1-a)V_{g1}\cos(\delta_{g1}-\delta_{g2})+aV_{g2}}\right] \quad (4)$$

$$P_{tran} = \frac{V_{g1}V_{g2}\sin(\delta_{g1}-\delta_{g2})}{X_1+X_2} A = \pi r^2 \quad (5)$$

From a small-signal point of view and under the assumption that the PCC-voltage magnitude along the line E_g does not change significantly, the required control input signals can be derived from the PCC-voltage phase and transmitted active power as [14]

$$\frac{d\theta_g}{dt} \approx \Gamma_p w_{g0}\Delta w_{g1} + (1-\Gamma_p)w_{go}\Delta w_{g2} \quad (6)$$

$$\frac{dP_{tran}}{dt} \approx \left\{\frac{V_{g1}V_{g2}\cos(\delta_{g10}-\delta_{g20})}{X_1+X_2}\right\} w_{g0}\left[\Delta w_{g1} - \Delta w_{g2}\right] \quad (7)$$

where the constant p has been defined in the previous section. The nominal system frequency is represented by ω_{g0} where as ω_{g0}, ω_{g1} and represents the speed variation of the generators in p.u. The electromechanical dynamics for each generator is given by

$$2H_{gi}\frac{d\Delta w_{gi}}{dt} = \Delta T_{mi} - \Delta T_{gi} - K_{Dmi}\Delta w_{gi} \quad (8)$$

where H_{gi} ω_{gi},ΔT_{mi}, ,ΔT_{gi},k_{Dmi} and represent inertia constant, speed variation, change in input torque, change in output torque and mechanical damping constant for the generator, respectively .The derivative of the PCC-voltage phase and transmitted active power are both dependent on the speed variation of the generators. Moreover, the derivative of the PCC-voltage phase depends on the location of E-STATCOM, through the parameter, as well as the mechanical dynamics of the generators as shown in (8).

This information will be exploited in the FLC controller design. For $\Delta\omega_{g12}=\Delta\omega_{g1}$-$\Delta\omega_{g2}$ the two machine system in Fig. 1, damping is related to the variation of the speed difference between the two generators,. From (2) and (3), it can be understood that the change in the output power from the generators due to injected active power is maximum when the compensators installed at the generator terminals (i.e. a=0 and a=1). Assuming equal inertia constant for the two generators, no damping is provided by injection of active power at the electrical midpoint of the line (i.e., a=0 and H_{g1}=H_{g2}) for) as the power output of the two generators is the same and the net impact is zero. At this location, the derivative of PCC-voltage phase is zero [see (6)]. This means that scales the speed variation of the two generators depending on the location of E-STATCOM and its magnitude changes in proportion to the level of damping by active power injection.

Therefore, is an appropriate input signal for controlling the active power injection? On the other hand, it can be understood from (2) that the change in the output power from the generators due to injected reactive power is maximum at the electrical midpoint of the line (i.e.,a-0.5) and minimum at the generator terminals(i.e. a=0 and a=1). As the changes in the power output of the two generators are the same in magnitude and opposite in sign, a signal that varies linearly with the speed variation between the two generators, is $\Delta\omega_{g2}$ an appropriate signal to control reactive power injection. This information can be obtained from the derivative of the transmitted active power $.dp_{tran}\backslash dt$

B. Estimation of Control Input Signals

As described in the Introduction, effective Fuzzy Logic Controller for various power system operating points and E-STATCOM locations require fast, accurate, and adaptive estimation of the critical power oscillation frequency component. The aim of the algorithm is therefore to estimate the signal components that consist of only the low-frequency electromechanical oscillation in the measured signals θg and P_{tran}. By using a PLL with bandwidth much higher than the frequency of electromechanical oscillations, the derivative of the PCC-voltage phase can be obtained from the change in frequency estimate of the PLL ($\Delta\omega_g$=dθ\d). Therefore, the low-frequency electromechanical oscillation component can be extracted directly from the frequency estimate of the PLL. On the other hand, the derivative of transmitted power is estimated by extracting the low-frequency electromechanical oscillation component from the measured signal, and then applying a phase shift of to the estimated oscillation frequency component. From the estimated control input signals and , which contain only a particular oscillation frequency component, the reference injected active and reactive current components (i^{d*}_{f}, i^{d*}_{f}) from the E-STATCOM can be calculated to setup the FLC controller as in Fig. 4. The terms K_P and K_D and represent proportional controller gains for the active and reactive current components, respectively. To describe the estimation algorithm, an input signal which could be either ω_g or P_{tran}, as shown in Fig. 4, is considered. Following a power system disturbance, will consist of an average value that varies slowly and a number of low-frequency

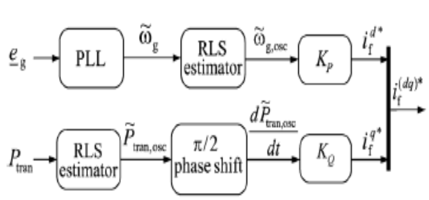

Fig. 4. Block diagram of the FLC controller.

are excited by the disturbance. For simplicity, let us assume that there exists a single oscillatory component in the input signal. Therefore, the input signal consists of an average component Yavg and Y_{osc} an oscillatory component which can be modeled as

$$y(t)=Y_{avg}(t)+Y_{ph}(t)\cos[w^{t}_{osc}+\emptyset(t)] \qquad (9)$$

Where is Y_{OSC} expressed in terms of its amplitude (Y_{ph}) , frequency ω_{osc} and(φ) phase . The model in (9) is rewritten using the oscillation angle as $\theta_{osc}(t)=\omega_{osc}(t)$

$$y(t)= Y_{avg}(t)+Y_{phd}(t)\cos(\theta_{osc}(t))- Y_{ph,q}(t)\sin(\theta_{osc}(t)) \qquad (10)$$

where the terms $p_{hd,d}$ and $P_{hd,q}$ are given by From an observation matrix φand measured input signal Y(t), the estimated state vector h is derived using the RLS algorithm in discrete time as [13], [14]

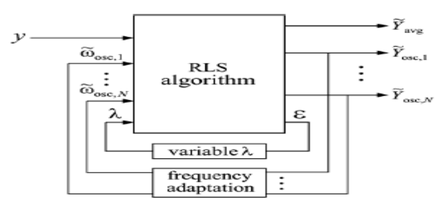

Fig. 5. Block diagram of the modified RLS estimator for multiple oscillation

modes. Frequency selectivity of the algorithm reduces. For this reason, the conventional RLS algorithm must be modified in order to achieve fast transient estimation without compromising its steady-state selectivity. In this paper, this is achieved with the use of variable forgetting factor as described in [13]. When the RLS algorithm is in steady-state, its bandwidth is determinedly the steady-state forgetting factor . If a rapid change is detected in the input (i.e., if the estimation error magnitude, exceeds a predefined threshold), will be modified to a smaller transient forgetting factor δ_{tr} . Thus, by using a high-pass filter with time constant , δ will be slowly increased back to its steady-state value δ_{SS} .Besides δ, the performance of the estimation method depends on accurate knowledge of the oscillating frequency ω_{OSC}, . This frequency is dependent on the system parameters and its operating conditions. If the frequency content of the input changes, the estimator will give rise to a phase and amplitude error in the estimated quantities. Therefore, a frequency adaptation mechanism as described in [14] is

Vol 10, Issue 4, April /2019
ISSN NO:0377-9254

implemented to track the true oscillation frequency of the input from the estimate of the oscillatory component, YOSC.

IV. STABILITY ANALYSIS OF SYSTEM MODEL

The mathematical model of the system in Fig. 3 is developed in this section to investigate the performance of the FLC controller using active and reactive power injection. Using the expressionism (6)–(7) for dθ\dt and d_{ptran}\dt , the injected currents are controlled as

$$i_f^d \approx K_p w_{g0}\left[\Gamma_p \Delta w_{g1} + (1-\Gamma_p)\Delta w_{g2}\right] \tag{11}$$

$$i_f^q \approx K_Q w_{go}\left\{\frac{V_{g1}V_{g2}\cos(\delta_{10}-\delta_{20})}{X_1+X_1}\right\}\left[\Delta w_{g1}\right] - \Delta w_{g2} \tag{12}$$

where the constant is as defined in (3). Linear zing around an initial steady-state operating point, the small-signal dynamic model of the two-machine system with the E-STATCOM in per unit is developed as in

$$\frac{d}{dt}\begin{bmatrix}\Delta w_{g1}\\ \Delta\delta_{12}\\ \Delta w_{g2}\end{bmatrix} = \begin{bmatrix}\beta_{11} & \beta_{12} & \beta_{13}\\ w_{go} & 0 & -w_{go}\\ \beta_{31} & \beta_{32} & \beta_{33}\end{bmatrix}\begin{bmatrix}\Delta w_{g1}\\ \Delta\delta_{12}\\ \Delta w_{g2}\end{bmatrix} + \begin{bmatrix}\frac{1}{2H_{g1}} & 0\\ 0 & 0\\ 0 & \frac{1}{2H_{g2}}\end{bmatrix}\begin{bmatrix}\Delta T_{m1}\\ \Delta T_{m2}\end{bmatrix} \tag{13}$$

Where $\Delta_{g12}=\Delta g_1 \text{-} \Delta_{g2}$ represents the rotor angle difference between the two generators and other signals as defined previously.

$$\begin{bmatrix}\beta_{11}\\ \beta_{12}\\ \beta_{13}\\ \beta_{31}\\ \beta_{32}\\ \beta_{33}\end{bmatrix} = \begin{bmatrix}\frac{w_{go}(K_pE_{go}\Gamma_p+K_Q\Gamma_Q)}{2H_{g1}}\\ -\frac{V_{g1}V_{g2}\cos(\delta_{g10}-\delta_{g20})}{X_1+X_2}\\ \frac{w_{go}(K_pE_{go}\Gamma_P(1-\Gamma_P)-K_Q\Gamma_Q)}{2H_{g1}}\\ \frac{w_{go}(K_pE_{go}\Gamma_P(1-\Gamma_P)-K_Q\Gamma_Q)}{2H_{g2}}\\ \frac{V_{g1}V_{g2}\cos(\delta_{g10}-\delta_{g20})}{2H_{g2}(X_1+X_2)}\\ \frac{w_{go}(K_pE_{go}(1-\Gamma_P)+K_Q\Gamma_Q)}{2H_{g2}}\end{bmatrix} \tag{14}$$

Assuming no mechanical damping and the initial steady-state speed of the generators ω_{g0} set to , the constants are derived as in

where is ∟q given by

$$\Gamma_Q = \frac{[V_{g1}V_{g2}]\sin\left(2(\delta_{g10}-\delta_{g20})\right)a(1-a)}{2E_{go}(X_1+X_2)} \tag{15}$$

The terms β_{12} and β_{32} represent the synchronizing torque coefficients resulting from the selected operating point and the contribution of the E-STATCOM is zero. The terms β_{12} and β_{33} determine the damping torque coefficient provided by the E-STATCOM with respect to the change in speed of the respective generator. To provide positive damping, β_{12} and β_{33} should be k_p negative. For this, the sign of should be negative and the

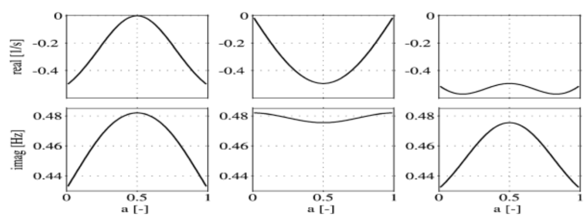

Fig:6 Real and reactive power part of the complex conjugate poles versus position Active power injection. (b) Reactive power injection. (c) Active and reactive power injection. 0.4444 p. u

sign K_q of should be chosen based on the Sign of ∟q . For a transmitted power from Generator 1 to Generator 2, will be positive and the sign of should be negative. For a transmitted power in the other direction, the sign of should be opposite. The terms and are the cross coupling terms between the two generator speed variations. With active power injection only, the cross coupling terms reduce the damping as the speed variation of the generators will be opposite at the oscillatory frequency. At the mass-scaled electrical midpoint of the line where, the damping that can be provided by is zero. Therefore, the active power injected by the E-STATCOM at this location is set to zero by the control algorithm. When moving away from this point towards the generator terminals, increases and at the same time the cross coupling terms decrease.

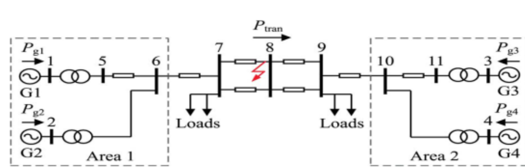

Fig. 7. Simplified two-area four machine power System.

V. SIMULATION RESULTS

Vol 10, Issue 4, April/2019
ISSN NO:0377-9254

The FLC controller described in Section III is here verified via MATLAB/SIMULINK known two-area four-machine system in Fig. 7. The implemented system is rated20/230 kV, 900 MVA and the parameters for the generators and transmission system together with the loading of the system are given in detail in [9]. The system is initially operating in steady state with a transmitted active power, 400 MW from area 1 to area 2. A three-phase fault is applied to the system on one of the transmission lines between bus 7 and bus 8. The fault is cleared after 120 ms by disconnecting the faulted line. Due to the applied disturbance, a poorly damped oscillation is obtained after the fault clearing. With the FLC controller structure described in Fig. 4, the performance of the E-STATCOM following the fault at three different locations is shown in Fig. 8. As described in the small-signal analysis for two-machine system in Section IV, when moving closer to the generator units, a better damping

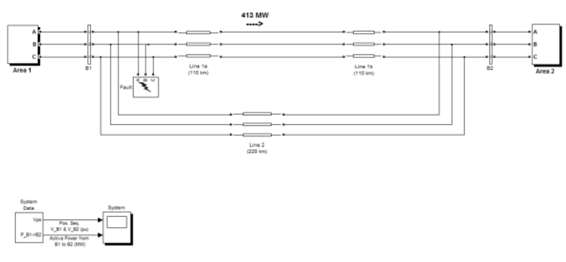

Fig 9: Proposed FLC based two areas Power System

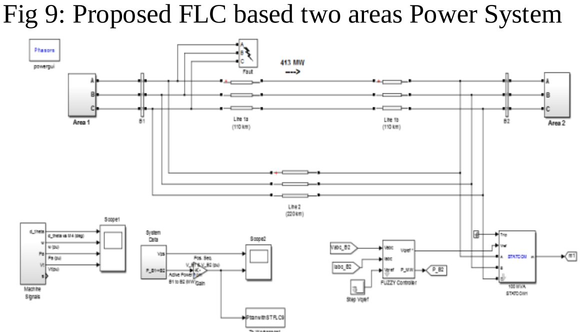

Fig 9: Two areas Power System without Controllers

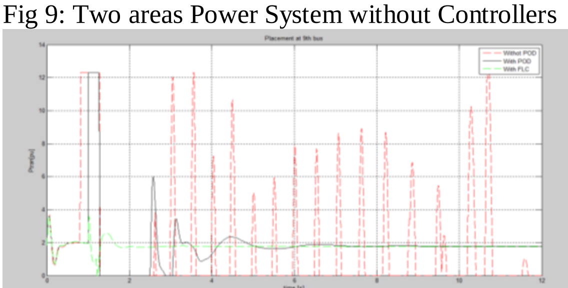

Fig10 Generator power of the two area Power System

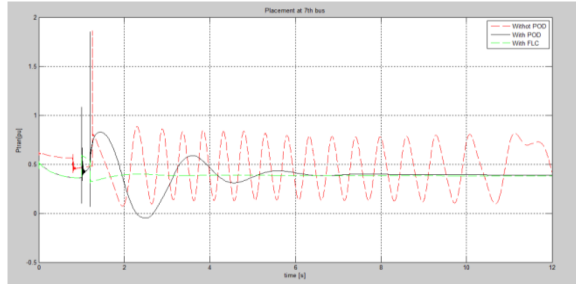

Fig11 Change in Tie line Power (ΔP) of the two areas Power System

VII. CONCLUSION

An adaptive FLC controller by E-STATCOM has been developed in this paper. For this, a modified Flc has been used for estimation of the low-frequency electromechanical oscillation components from locally measured signals during power system disturbances. The estimator enables a fast, selective and adaptive estimation of signal components at the power oscillation frequency. The dynamic performance of the FLC controller to provide effective damping at various connection points of the E-STATCOM has been validated through simulation as well as experimental verification. The robustness of the control algorithm against system parameter changes has also been proven through experimental tests. Furthermore, using the frequency variation at the E-STATCOM connection point as the input signal for the active power modulation, it has been shown that active power injection is minimized at points in the power system where its impact on FLC is negligible. This results in an optimal use of the available energy source.

REFERENCES

[1] N. G. Hingorani and L. Gyugyi, *Understanding FACTS. Concepts and Technology of Flexible AC Transmission Systems*. NewYork ,NY,USA: IEEE, 2000.

[2] G. Cao, Z. Y. Dong, Y. Wang, P. Zhang, and Y. T. Oh, "VSC based STATCOM controller for damping multi-mode oscillations," in *Proc.IEEE Power and Energy Soc. General Meeting—Conversion and Delivery of Electrical Energy in the 21st Century*, Jul. 2008, pp. 1–8.

[3] M. Zarghami and M. L. Crow, "Damping interarea oscillations in power systems by STATCOMs," in *Proc. 40th North Amer. PowerSymp.*, Sep. 2008, pp. 1–6.

[4] Z. Yang, C. Shen, L. Zhang,M. L. Crow, and S. At city, "Integration of a statcom and battery energy storage," *IEEE Trans. Power Syst.*, vol.16, no. 2, pp. 254–260, May 2001.

[5] A. Arulampalam, J. B. Ekanayake, and N. Jenkins, "Application study of a STATCOM with energy storage," *Proc. Inst. Electr. Eng.—Gener., Transm. and Distrib.*, vol. 150, pp. 373–384, July 2003.
[6] N. Wade, P. Taylor, P. Lang, and J. Svensson, "Energy storage for power flow management and voltage control on an 11 kV UK distribution network," Prague, Czech Republic, CIRED paper 0824, Jun. 2009.
[7] A. Adamczyk, R. Teodorescu, and P. Rodriguez, "Control of full-scale converter based wind power plants for damping of low frequency system oscillations," in *Proc. IEEE PowerTech*, Trondheim, Norway,Jun. 2011, pp. 1–7.
[8] H. Xie, "On power-system benefits, main-circuit design, control ofStatcoms with energy storage," Ph.D. dissertation, Dept. Electr. Energy Conversion, Royal Inst. Technol., Stockholm, Sweden, 2009.
[9] P. Kundur, *Power System Stability and Control*. New York, NY,USA: McGraw-Hill, 1994.
[10] K. Kobayashi, M. Goto, K. Wu, Y. Yokomizu, and T. Matsumura,"Power system stability improvement by energy storage type STATCOM," in *Proc. IEEE Power Tech Conf.*, Bologna, Italy, Jun.2003, vol. 2, DOI 10.1109/PTC.2003.1304302 *Conf.*

T H Kumar received the B.Tech. and M.Tech. degrees in Electrical Engineering from Narayana Engineering college and JNTU Anantapuramu, in 2010 and 2013, respectively, He is currently lecturer with the Department of Electrical and Electronics Engineering, SKU of Engineering and Technology,Anantapuramu, Andhra Pradesh. His research interests include control systems and energy conversion systems for renewable energy resources.

E-mail id:hemanthkumar219@gmail.com

G SUNIL KUMAR received the B.Tech. in electrical and electronics engineering from ALITS, Andhra Pradesh, India, in 2014 and pursuing M.Tech.(EPS) degree in SKU college of engineering and technology, Andhra Pradesh, India. research interests include control of electrical drives and renewable energy resources.

E-mail id:yadva.sunilkumar@gmail.com