POWER SYSTEM STABILITY FOR SINGLE MACHINE INFINITE BUS USING POWER SYSTEM STABILIZER BASED ON FUZZY LOGIC CONTROLLER.

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Abstract

The power system stability is facing number of challenges in terms of low frequency oscillations. To raise the system stability the excitation control in addition and power system stabilizer is needed which most commonly simple and effective technique. The power system stabilizer plays a major role in mitigating the oscillations of low frequency whereas the power system without PSS is highly unstable. But power system stabilizer is also having constraints like it works only for fixed operating conditions. However, it increases the system stability but to some extent. So, for varying operating conditions and for better damping to low frequency oscillations, Power system stabilizer based on the Fuzzy Logic Controller is used to improve the performance of PSS which in turn enhances the system stability. This all is performed on single machine infinite bus.

Keywords: *SMIB; PSS; Fuzzy Logic Controller; Fuzzy Logic Based PSS.*

1. Introduction

The power system operates in almost varying operating conditions that is why it is called as non-linear system. Number of factors which are responsible for the constantly changing operating conditions such as topology, load, generator output, etc. Initial operating conditions, nature of the disturbances are responsible for affecting the stability of the power system. The magnitude of the disturbance can be high and low, there may be fluctuations in the load constantly but the system has to remain in the state of equilibrium under varying conditions in order to meet the load demand satisfactorily.so, for severe nature of disturbances like loss of generator, short circuit occurrence on the transmission lines, many more the power system has to dealt with it.

The oscillations of low frequency have become a significant cause for small signal stability. They keep control over the steady state power transfer limits which in turn influences the system security and economics. To mitigate the oscillations of low frequency the excitation control, Power System Stabilizer (PSS) is required which is cheap, easier and a better way out of system's instability. The role of Power System Stabilizer is to give damping, increases the margin of steady state and repress the low frequency oscillations. The latest technologies in the field of power electronics results in developments of flexible alternating current transmission systems (FACTS) and hence complements to main control duties same as voltage regulation and reactive power injection should be able to damp power oscillations. A conventional PSS is framed by adopting certain theories such as linear control theory in this case, but it has few limitations such as it takes more time in tuning and the damping in entire operating process is not optimal. As far as stability is concerned, fuzzy logic controller (FLC), neural network (NN) controller or composition of both called as intelligent controllers i.e. neurofuzzy system provide better damping characteristics and able to transiently exchange active and reactive power with system, thereby an improvement in stability oscillation can be attained. Therefore in this paper, in corporation to conventional PSS a Fuzzy Logic Controller is used. The PSS improves the overall stability of power system and the Fuzzy controller further mitigates the oscillations. Methods of phase compensation and damping torque analysis are the conventional methods for design of power system stabilizer. In this study, to enhance small signal stability, coordination among PSS and Fuzzy is performed. The studies are performed on single machine infinite bus power system. An SMIB system is what, in power system, the dynamics of machine do not bring any virtual changes in voltage and frequency.

2. Power System Stability

Power System Stability is described as that characteristic of the electric power system which permits or allows the power system to stay in the equilibrium state when working in normal working condition and to maintain the state of equilibrium when subjected to disturbances. This tendency of the electric power system to hold on to the state of equilibrium when subjected to small perturbances is called as Stability. In contarary to that stability is a condition which defines falling out of step or loss of synchronism. So, to maintain the synchronism and the power system to work for long time, the stability of the electric power system have to be considered. As the power system is consistently growing day by day as the demand of electric power increases, so in context to that the power system is growing over a wide range of geographical ranges also results numerous difficulties in maintaining synchronism between the various power systems. For sake of convenience of analysis, stability is categorize in following three types:

a. Rotor Angle
b. Frequency
c. Voltage

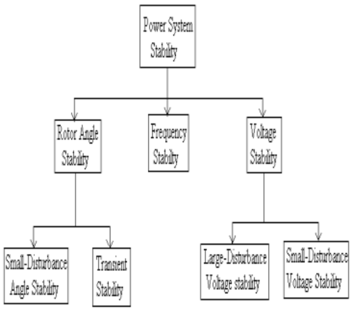


Fig.2.1: Classification of power system stability

Stability is also defined as to make the system intact under small perturbances between two opposing forces; which are as follows:

a. Electromagnetic torque (Te)
b. Mechanical torque (Tm)

Equilibrium is achieved between input mechanical torque and output mechanical torque and speed remains constant in steady state condition. If the system is disturbed leads to accelerate or decelerate the rotor of machine according to law of motion of rotating body. When the electric power system is subjected to a small perturbances and a small change in both the torques i.e. electromagnetic torque and mechanical torque is required can be resolved as

$$\Delta T_{e=} T_S\Delta\delta + T_D\Delta_\omega$$

Where $T_S\,\Delta\delta$ is torque component which defines change in phase with rotor angle perturbation $\Delta\delta$ and is taken as synchronizing torque component, where T_S is a synchronizing torque coefficient. $T_D\Delta_\omega$ is the torque component which is in phase with speed deviation Δ_ω and is taken as damping torque component, where T_D is designated as damping torque coefficient.

For convenience of analysis and for gaining useful in sight in to type of stability issue, it is customary to feature the rotor angle stability phenomenon in case of small signal and transient stability.

2.1. Small Signal Stability

The potential of electric power system to attain synchronism when small perturbances occur is called as small signal stability. In power system such small disturbances consistently persists because of small changes or alterations in the load and generation too. The disturbances are taken as sufficiently small for linearization of system equations to be acceptable. Instability can persists in two categories [1, 2].

a. Steady rise in rotor angle because of the lack of reasonable synchronizing torque.

b. Rotor oscillations of rising amplitude because of the lack of reasonable damping torque.

The types of system responses due to small disturbances rely on various factors such as initial conditions. Transmission system and type of generator excitation controls are used, for a generator connected radically to a large power system, in absence of automatic voltage regulators which provides constant field, the instability occurs because of lack of sufficient synchronizing torque. As the voltage regulators are acting in continuity, the small disturbance complication or obstacle arises which one of kind is obtaining sufficient damping of system oscillation.

Instability is genuine for oscillations of ascending magnitude. Figure 1.5 describes the type of generator response with Automatic Voltage Regulators.

2.2. Methodology

For a single machine connected to infinite bus system, a small signal proposed structure model is framed in foot lines of Heffron Phillips model to study the impact of variations in load and torque on power system. The study of system has been organized in four phases. Firstly, Single Machine Infinite bus system model, considered as original model, is simulated and corresponding results are observed. Then, a conventional Power System stabilizer is simulated and installed with SMIB model and the relative results when matched with results of previous SMIB model. Lastly, a Power System Stabilizer based on Fuzzy Logic Controller is performed in Matlab and the results are observed. The further comparison of results is made for PSS and Fuzzy Logic Controller.

Usually, the PSS consists of three blocks:

a. The Phase Compensation Block:

The Phase Compensation block facilitates the suitable phase-lead in order to overcome the phase lag occur between the exciter input and the generator electrical (air-gap) torque output. As per figure, two first-order block is cited, but practically, three or more first-order blocks can also apply to attain the required phase compensation. Generally, the frequency is nearly 0.1 to 0.2 Hz, also the phase lead network must facilitates compensation over the whole frequency range. The phase characteristics to be compensated alterations with system conditions. Normally, if under-compensation is needed so that the PSS, in addition to significantly increasing the damping torque, results in a little rise of the synchronizing torque.

b. The Washout Block:

It works as a high pass filter with time constant $(\boldsymbol{T_w})$ sufficiently high to permit signals related with respect to oscillation in $\boldsymbol{\omega_r}$. In case the washout block is not present, steady changes in the speed would modify the terminal voltage. The limits of Washout Time Constant $(\boldsymbol{T_w})$ should be in between 1 to 20 seconds. Major duty is washout time constant is efficiently large to allow stabilizing signals. In case of local mode oscillations vary in the range of .8 to 2.0 Hz, a washout of 1.5 seconds is sufficient. As far as low-frequency inter area oscillations is concerned, a washout time constant of 10 seconds or more than that is required, since lower-time constants at low frequencies gives a significant phase lead.at internal frequencies, the synchronizing torque will get reduce until it is compensated for elsewhere. This phenomenon of desynchronizing is deleterious to the transient stability of interarea as a result cause the areas to oscillate independently following a disturbance.

c. Stabilizer Gain Block:

Gain of this stabilizer measures the amount of damping introduced by Power System Stabilizer. In an ideal condition, it should be set at a value which corresponds to utmost damping. The stabilizer gain has a key role on rotor oscillations damping. The value of the gain is selected by determining the effect for a broad range of values. The damping increases with in stabilizer gain up to a certain point beyond which further increase in gain results in a decrease in damping. Whereas, the stabilizer gain is frequently bounded by other considerations. The higher voltage gain is permitable provided that the phase-lead compensation has been selected to give satisfactory phase characteristics over a frequency range that involve all dominant modes. In these type of cases, the higher value of the stabilizer gain is likely to control by practical considerations for the effectness on signal noise. Stabilizer gain is usually set to a value that influence as damping of the critical system mode as practical without compromising the stability of other system modes and resulting in over or extra amplification of signal noise.

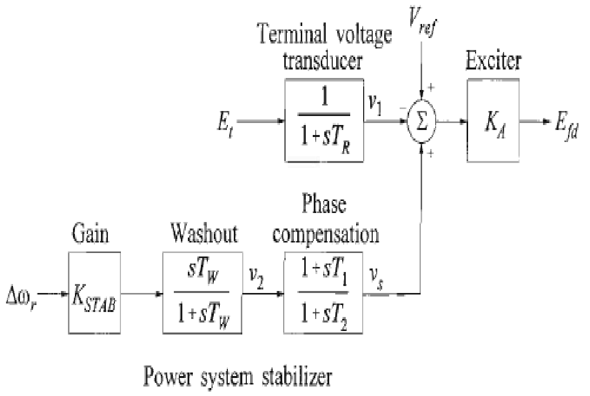


Fig2.2: Thyristor-excitation system with AVR and PSS [1]

2.3. Single Machine Infinite Bus System

A simplified model of a power system, which is called a single machine connected to an infinite bus, is used . For infinite bus a voltage source of constant frequency and constant voltage is considered.

The simplified model of single machine infinite bus is shown for a given condition validated to any system, the amplitude of infinite bus voltage (V_e) will be constant when machine is subjected to perturbances. Whenever the steady state condition of the system alters, the amplitude V_e become change, indicating a changed operating condition of external network. The single machine associated to an infinite bus is a multi- variable nonlinear time-variant system, defined by known set of equations. The analysis and design of control system for a synchronous generator is consider a simplified linearized model for application. The linearized model can be given by the following set of equations:

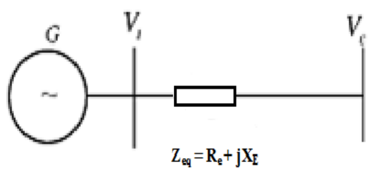


Fig.2.3: Line Diagram of Single Machine Infinite Bus

2.4 Single Machine infinite Bus System with PSS

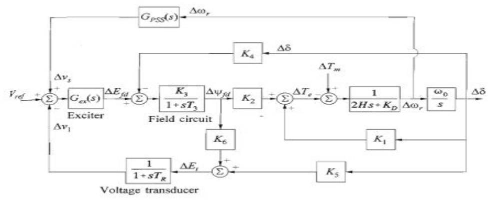


Fig 2.4: Block diagram of SMIB with PSS and AVR. [1]

Here the block diagram includes the blocks of field circuit dynamics and excitation system as well. The power system stabilizer is also shown in figure which provides damping to rotor oscillations by controlling its excitation using auxiliary stabilizing signal. Results of SMIB system with PSS are shown in chapter 4.

2.5 Fuzzy Logic Controller for Small Signal Stability Enhancement:

The low frequency oscillations have been studied all over the world. Presence of low frequency oscillations for a long duration causes instability of power system. Several methods, such as Power System Stabilizer have been adopted for suppression of low frequency oscillations. But electric power system is a not linear and time-variant system. So for this reason the Power System Stabilizer needs to be retuned because of the changing operating states of the dynamic power system. An alternative mean for the system is to use other devices to mitigate the oscillations. There are several conventional control strategies like, Flexible Alternating Current Transmission System and Schemes which can be brought in to system to damp out the oscillations.
Here in this paper work, dynamic behavior of Single Machine connected to Infinite Bus System in corporation with PSS and Fuzzy Logic Controller has been studied. The linearized model of System is also studied. Finally, the Controller is installed on system to suppress the low frequency oscillations. The simulation show that the performance of FL Controller discussed is quite Satisfactory.

2.6 Introduction to Fuzzy Logic:

Fuzzy Logic is a perspective in computing based on "degrees of truth" instead of the usual "yes or no" which is (1or 0) according to Boolean Logic where the modern computer is rely on. The concept of Fuzzy Logic was first discovered by Dr. Lotfi Zadeh, in 1965 from University of California of Berkeley.
Fuzzy Logic is a type of many valued logic where the truth values of variables can be real number exists in between 0 and 1. Fuzzy logic has been expanded to control the idea of partial truth in which the truth value ranges from completely true to completely false.

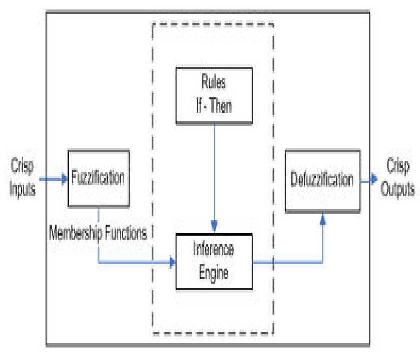


Fig 2.4: Block Diagram of Fuzzy Logic Controller

The input variables of the fuzzy control system are described in general mapped by membership functions comprised of sets, this is called as "fuzzy sets". The phenomenon of changing a crisp input value to a fuzzy output value is known as "fuzzification".

A control system also have number of types of switches like ON or OFF keys, inputs incorporate with its inputs(analog), and the inputs of course will be a truth value either equal to 1 or 0, but this phenomenon can deal with them as simplified fuzzy functions that happen to be either one value or other.
The set of rules is framed on decision basis:
All the rules that are employed are induced, applying the membership functions and truth values attained from the inputs, to examine the result of the rule which are framed.
This result is then mapped into a membership function which are comprised of sets and the truth value handling the output variable. These results are compiled to provide a exclusively crisp response, a process is called as "defuzzification".
The combination of fuzzy functions and rule-based inference explains a "fuzzy expert system".

2.6 The Single Machine Connected To Infinite Bus With Fuzzy Logic Controller:

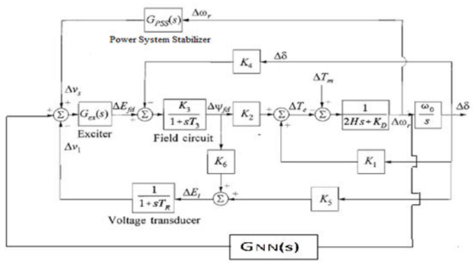


Fig 2.5: SMIB with Fuzzy Logic.

Block Diagram: Numerous differential equations and algebraic equations have been solved to examine the nature of machine. The quantities, which are not affected by perturbances, may be written by constants. The Heffron-Phillips model is utilize to define the SMIB system's dynamics and equations. The transfer function of single machine which is connected to infinite bus is shown in the diagram. All the quantities are defined in in per unit. Damping constant and inertia defines the mechanical system. Where the torque balances ΔTm - ΔTe is taken as an input and small incremental torque angle Δδ as an output.

2.7 Problem Description

Simulations on single machine infinite bus system are done to investigate the effects of Fuzzy Logic based Power System Stabilizer to mitigate the low frequency oscillations.
A generator with terminal voltage of 1.0 pu is supplying power to a load having terminal voltage magnitude of 1.0 pu. The transmission line through which the load is fed has reactance Xe = 0.4 pu.

Xd	Xq	X'd	T'do	H	D	F
1.6	1.55	0.32	6	6	0	60

Table 2.1 Generator data

V t	P g	E b	K E	T E
1 . 0	0 . 9	. 9 5	2 0 0	0 . 0 2

Table 2.2 Operating points

T w	K_{sta} b	T_1	T_2
1. 4	20	0.15 4	0.03 3

Table 2.3 Initial conditions
The analysis is carried out using the above mentioned condition on:
I. SMIB without PSS
II. SMIB with PSS
III. SMIB with PSS based on Fuzzy Logic Controller

Finally a comparison is drawn using the above mentioned cases.

2.8 SMIB system without PSS

The following figures shows the simulation diagram for the SMIB system for the defined operating conditions.

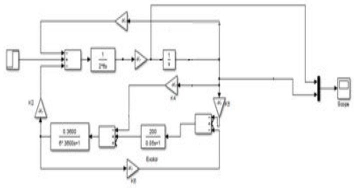
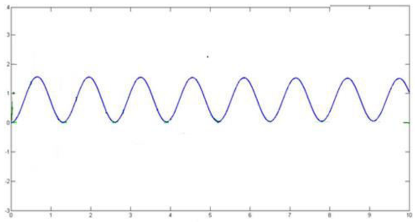
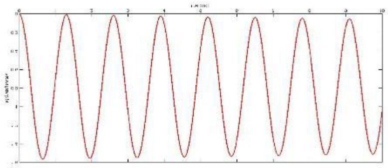


Fig. 2.6 Simulation diagram for SMIB system without PSS

Following figures represent the rotor angle deviation and speed deviation respectively



Graph.2.1: Machine Speed Angle Response of Original Model



Graph 2.2: Machine Rotor Angle Response of Original Model

From graph 2.1 and fig. 2.2, it is quite clear that the system is unstable as it doesn't settle to fixed operating point i.e. neither to fixed generator angle nor to fix speed.

2.9 SMIB system with PSS

In order to improve the stability of the system, a power system stabilizer is inculcate to the system which has generator speed as the input and whose output voltage is acting along with the exciter as additional input. The PSS parameters are determined in terms of phase characteristics.

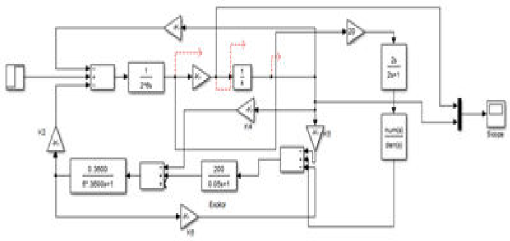
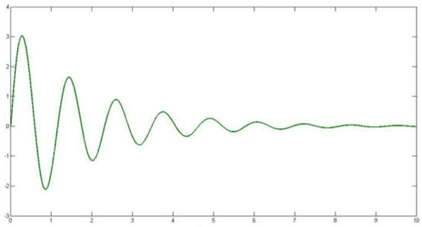


Fig. 2.5: SMIB system with PSS



Graph 2.4: Machine Speed Deviation Response with PSS

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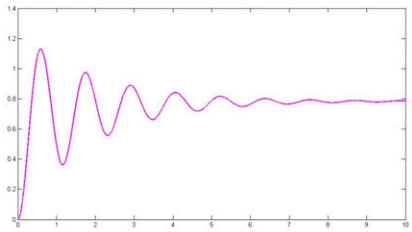

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Graph 2.3: Machine Rotor Angle Response with PSS

2.10 SMIB system with Fuzzy based PSS controller

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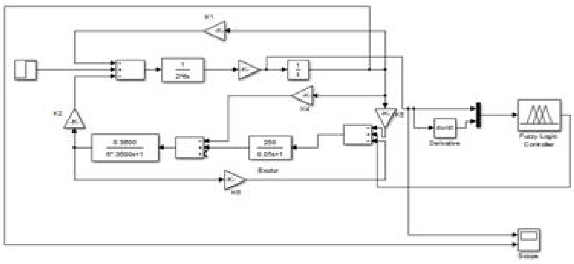
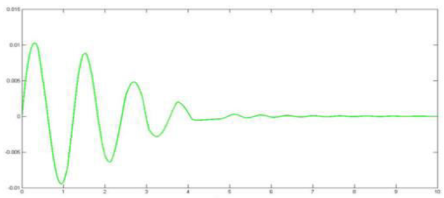


Fig. 2.6: SMIB system with Fuzzy based PSS controller.

[9]



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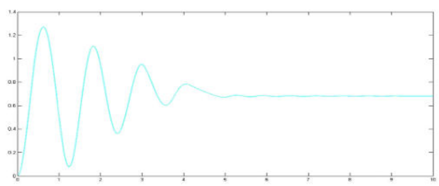
Graph.2.5: Machine Speed Deviation Response with Fuzzy based PSS controller



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Graph 2.6: Machine Rotor Angle Response with Fuzzy based PSS controller

[15]

Fuzzy Based PSS controller showing the response of machine rotor angle and speed deviation are quite better than the above two models as damping is done earlier than with the PSS and the peak value of machine rotor angle and speed deviation is minimized. [16]

[17]

3. Conclusion

In this thesis work, effort has been made to damp the low frequency oscillations with the help of Fuzzy Logic Based PSS Controller. [18]

With the purposed condition, bulk damping is achieved in comparison to the tuned PSS Controller

REFRENCES

[1] P. Kundur, Power System Stability and Control. New York: McGraw Hill, 1994.

[2] Guliyev H.B., Farkhadov Z.I., Mammadov J.F. "System of Automatic Regulation of Reactive Power by Means of Fuzzy Logic" Azerbaijan Scientific-Research and Design-Prospecting Power Institute Sumgait State University, vol.10 June 2015.

[3] K.R. Padiyar, "Power System Dynamic Stability and Control", second edition, BS publications, Hyderabad, 2002.

[4] S.Ramamoorthy,"Designandimplementation of Fuzzy Logic Based Power System Stabilizer" Middle-East Journal of Scientific Research 20 (11): 1663-1666, 2014.

[5] Seung-Mook Baek,"Sensitivity Analysis Based Optimization for Linear and Nonlinear Parameters in AVR to Improve Transient Stability in Power System "International Journal of Control and Automation Vol. 8, No. 7 (2015).

[6] Seung-Mook Baek ,"Sensitivity Analysis Based Optimization for Linear and Nonlinear Parameters in AVR to Improve Transient Stability in Power System "International Journal of Control and Automation Vol. 8, No. 7 (2015), pp. 167-174.

[7] Tejaswita Khobaragade, Amol Barve, "Enhancement of Power System Stability Using Fuzzy Logic Controller", in IJPEDS December 2012, vol.2.

[8] Ehsan Ahvar, Antonoi M.Ortiz, Noel,Crespi, "Improving Decision-Making For Fuzzy Logic Routing In Wireless Sensors Network", IEEE Transactions on Automatic and Trusted Computing,2013.

[9] Vivek Nath1, D.K Sambariya, "Analysis of AGC and AVR for Single Area and Double Area Power System Using Fuzzy Logic Control" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 4, Issue 7, July 2015.

[10] Doradla. Prathap Hari Krishna,B. Venkatesh, "Design Of Power System Stabilizer to Improve Small Signal Stability By Using Modified Heffron-Phillip's Model" International Journal of Engineering Science and Technology (IJEST) ISSN : 0975-5462 Vol. 3, June 2011.

[11] Shaoru Zhang and Fang Lin Luo, "An Improved Simple Adaptive Control Applied to Power System Stabilizer" IEEE Transactions on Power Electronics, Vol. 24, Feburary 2009.

[12] Hemisha P. Patel, Ami T. Patel, Jay S. Tandel. "Development of Intelligent controller for Power System stabilization for Single Machine Infinite Bus system" The International Daily journal ISSN 2278 – 5469 EISSN 2278 – 5450, 2015.

[13] Graham J. W. Dudgeon, William E. Leithead, Adam Dysko, John O'Reilly, and James R. McDonald, "The Effective Role of AVR and PSS in Power Systems: Frequency Response Analysis", IEEE Transactions on Power Systems, vol. 22, November 2007.

[14] M.N Udin, T.S. Radwan, M. Azizur Rehman, "Performances of Fuzzy Logic Based Indirect Vector Control for Induction Motor Drive", IEEE September 2002, vol.38.

[15] Adam Dysko, William E. Leithead, and John O'Reilly "Enhanced Power System Stability by Coordinated PSS Design", IEEE Transactions on Power Systems, vol. 25, February 2010.

[16] J.Ritonja, D. Dolinar, and B. Grcar, "Combined Conventional-Adaptive Power System Stabilizer," in Stockh Power Tech., Elect. Power Eng., Power Syst., 1995.

[17] Ehsan Ahvar , Antonio M.Orti , Noel Crespi, Improving Decision-Making for Fuzzy Logic-based Routing in Wireless Sensor Networks" 2013 IEEE 10th International Conference on Ubiquitous Intelligence & Computing .

[18] G.Venkateswarlu, Dr.P.S.Raju, "Implementation of Fuzzy Logic Based Maximum Power Point Tracking and PWM for the Solar Photovoltaic System". Progress In Science in Engineering Research Journal ISSN 2347-6680 (E).

[19] [19] D. R. Ostojic, "Stabilization of Multimodal Electromechanical Oscillations by Coordinated Application of Power System Stabilizers," IEEE Transaction. Power Syst., vol. 6.

[20] [20] I. Kamwa, R. Grondin, and G. Trudel, "The Limits of Performance of Modern Power System Stabilizers," IEEE Transaction. Power Syst. May 2005.

[20] [21] K.Lochan, J.P Singh, B.K.Roy. B.Subundhi, "Adaptive time-varying Super-twisting global SMC for projective synchronization of flexible manipulator" Spinger Netherlands ISSN 1573-269,2018.

[22] P.P Singh, J.P Singh, B.K Roy,"NAC based Sychronisation and Anti-Synchronisation Between Hyperchaotic and Chaotic Systems, its Analog Circuit Design and Application," IETE Journal of Research 63(6), 853-869(2017).