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A Prospect Low Frequency Oscillation Eliminate from Power System via ANFIS based Extreme Controller with PSS Excitation System

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Abstract

In the present era, the power system has become a vital part to provide stability enhancement. The stability of a power system depends on how low frequency disturbances which are typically in the frequency range of 0.2 to 3.0 Hz, accurately find out and cleared so that quick restoration and maintains a stability enhancement of power is accomplished. Loss of synchronism and stability enhancement are needs to be performed using ANFIS controlled based excitation of power system [3]. The significant factors which affect the operation of power system during the occurrence of low frequency disturbances are mainly; Loss of synchronism which might be excited by the disturbances in the system or, in some cases, might even build up spontaneously. These factors can be analyzed to find out the occurrence of the low frequency disturbance in the power line operation. Various techniques like Power System Stabilizer with algorithm based or logic controlled based, UPFC has been used in past to find out and cleared the different low frequency disturbances occurred in the transmission line. The proper selection of enhanced feedback is a very tedious and time consuming task and also requires brief knowledge of the system configuration. To avoid the drawbacks of conventional power system stabilizer with algorithm or logic controller based techniques, this dissertation proposed, an efficient and robust technique of stability enhancement using ANFIS based power system excitation. The advantage of the proposed technique is that; it improves the overshoot of power and reduced the time for low frequency oscillations [1]. The ANFIS based stability enhancement accuracy of proposed technique has been verified using MATLAB/Simulink 2013(a) software. The obtained results show that the proposed technique is efficient in stability enhancement of all type of loss of synchronism and hence reliable tool for low frequency disturbance occurred in power system.

Keywords— *Power System Stabilizer, Adaptive Neuro Fuzzy Interface, Unified Power Flow Controller, Automatic Voltage Regulator, Multi machine infinite bus, Excitation System.*

Introduction

With the development of interconnection of large electric power systems there have been spontaneous system oscillations at low frequencies in the order of several cycles per minute. These low frequency oscillations are predominantly due to the lack of damping of mechanical mode of the system. Since power oscillation is a sustained dynamic event, it is necessary to vary the applied compensation to counteract the accelerating and decelerating swings of the disturbed machine. Several years the power system stabilizer act as a common control approach to damp the system disturbances. However, in some operating conditions, the conventional stabilizer may fail to stabilize the power system, especially in low frequency disturbances (0.2 Hz to 3 Hz) [2]. These disturbance may be local, inter area and global oscillation in power system. As a result, other alternatives have been suggested to ANFIS based Power System Stabilizer technique used to stabilize the system accurately which is more enhanced possible with FACTS devices. Among all FACTS devices the UPFC most popular controller due to its wide area control over power both active and reactive, it also gives the system to be used for its maximum thermal limit. It's primarily duty to control both the powers independently. It has been shown that all three parameters that can affect the real power and reactive power in the power system can be simultaneously and independently controlled just by changing the control schemes from one type to other in UPFC [6]. Moreover, the UPFC is executed for voltage provision and transient stability improvement by suppressing the low frequency disturbances. For example, in it has been shown that the UPFC is capable of inter-area oscillation damping by means of straight controlling the UPFC's sending and receiving bus voltages. Therefore, the main aim of the UPFC is to control the active and reactive power flow through the transmission line with emulated reactance. It is widely accepted that the UPFC is not capable of damping the disturbances with its normal controller. As a result, ANFIS based controller UPFC is providing enhanced feedback from infinite bus for power system stabilizer that is the main purpose of enhanced excitation system. The auxiliary damping controller should be supplemented to the adaptive neuro fuzzy interface control of UPFC with Power System Stabilizer in order to retrieve the disturbances and improve the system stability.

System Model

Modeling of Power System stabilizer

The system consists of two subsystems, the adaptive plant identifier for the generator and the Adaptive Neuro Fuzzy Interface System based Power System stabilizer, as shown in Fig. 2.1.

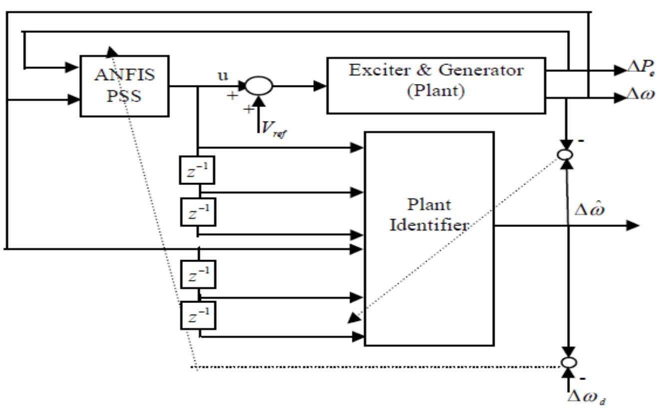


Fig. 2.1.: Structure of Controlled System

There is no desired controller in this system. The parameters of the plant identifier are updated by the error between estimated and actual plant outputs, while the parameters of the Adaptive neuro fuzzy interface based Power system stabilizer are tuned by back propagating the error signal between the estimated plant output and the desired output. This output represent reduced the overshoot and time settling whose are come during low oscillations frequency (LFOs) [11].

Structure of ANFIS PSS

A zero-order Sugeno-type fuzzy controller with 49 rules is used for the ANFIS PSS whose block diagram is illustrated in Fig. 2.2. The input to the PSS is the speed deviation and the accelerating power, which are passed through a washout filter to eliminate any existing dc offset. The first scaling block maps the real input to the normalized input space in which the membership functions are defined. The second scaling block is used to map the output of the fuzzy inference system to the real output needed [7]. The fuzzy inference system consists of Fuzzification block which changes the crisp input into linguistic terms throughout membership functions.

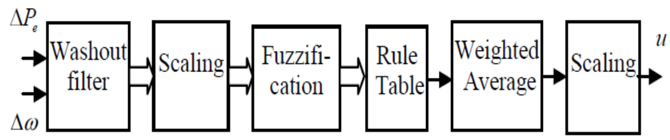


Fig. 2.2: Block Diagram of ANFIS Model

Fuzzification of ANFIS PSS

An only Sugeno type Fuzzification method is proposed for ANFIS; hence only this method is discussed here.

Sugeno fuzzy model

The Sugeno fuzzy model or TSK fuzzy model was proposed by Takagi, Sugeno, and Kang and was introduced in 1985. A typical fuzzy rule in a Sugeno fuzzy model has the form;

"IF x is A and y is B then z = f (x, y)",

Where A and B are fuzzy sets in the antecedent, while z = f (x, y) is a crisp function in the consequent. Usually z = f (x, y) is a polynomial in the input variables x and y, but it can be any function as long as it can appropriately describe the output of the model within the fuzzy region specified by the antecedent of the rule. When z = f (x, y) is a first-order polynomial, the resulting fuzzy inference system is called a first-order Sugeno fuzzy model. When f is a constant, we then have a zero-order

Sugeno fuzzy model. Training data of ANFIS has been already discussed in above section 2.1.

Rule Table of ANFIS PSS

The rule table block and the weighted average block together are equivalent to the combination of the aggregator and defuzzifier blocks in a regular fuzzy inference system. the Adaptive Neuro fuzzy Interface System. A specific signal may have non-zero membership value in more than one set and a specific control signal may represent the contribution of more than one rule. The linguistic terms used for the membership function ranges are PB (Positive Big), PM (Positive Medium), PS (Positive Small), ZE (Zero), NS (Negative Small), NM (Negative Medium), and NB (Negative Big). The control rules design is based on the understanding of the role and effect of the controller [4]. The rule matrix is obtained as shown in Table I. Each rule represents a desired controller response to a particular situation. The table gives the initial value of the output of each rule.

Acceleration / Speed	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	ZE	ZE	PS
NM	NB	NB	NM	NS	ZE	PS	PM
NS	NB	NB	NM	ZE	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NB	NM	NS	ZE	PM	PB	PB
PM	NM	NS	ZE	PS	PM	PB	PB
PB	NS	ZE	ZE	PS	PB	PB	PB

Table I: Initial premise and consequent parameters for Power System Stabilizer (ANFIS)

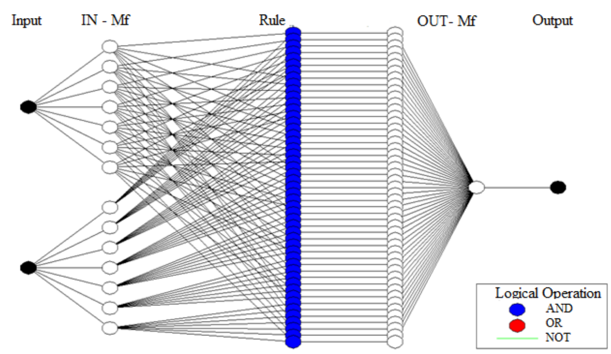


Fig. 2.3: ANFIS Architecture of PSS Controller

In this figure, IN, OUT and Rule are the input and output scaling factors, respectively. This network consists of four layers, with each layer representing a specific part in the ANFIS controller. The node function in the first layer represents the Gaussian membership function. The second layer is to calculate the firing strength of each rule which is the same as AND operation, hence the node function is a "min" function. The third layer calculates the normalized firing strength of each rule with the node function given by above equation, and the fourth layer combines the output of all rules to get the overall output of the controller with its node function given by above model [14].

Modeling Of Unified Power Flow Controller

A Unified Power Flow Controller (UPFC) is an electrical device for providing fast-sensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system compensation without an external electric energy source [9]. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance and angle or alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable Shunt reactive compensation. Viewing the operation of the UPFC from the standpoint of conventional power transmission based on reactive shunt compensation, series compensation and phase shifting, the UPFC can fulfill all these functions and thereby meet multiple control objectives by adding the injected voltage with appropriate amplitude and phase angle, to the terminal voltage [5]. The UPFC provides complete control over power flow in the line. A circuit equivalent diagram of the UPFC is show in the fig. 3.1.

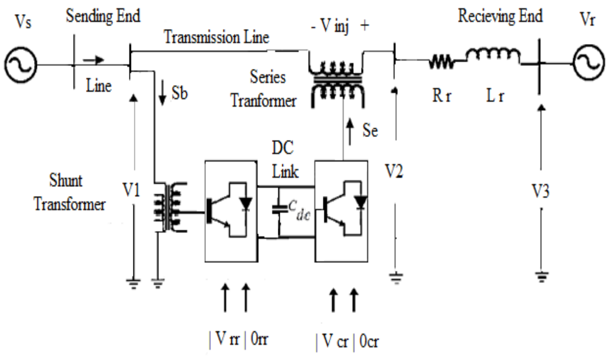


Fig.3.1: Connection diagram of UPFC with transmission line

The UPFC consists of two voltage sourced converters, as illustrated in Fig 3.1 these back to back converters, labeled "STATCOM" and "SSSC" in the figure, are operated from a common dc link provided by a DC storage capacitor. As indicated before, this arrangement functions as an ideal AC to AC power converter in which the real power can freely flow in either direction between the AC terminals of the two converters, and each converter can independently generate or absorb reactive power at its own AC output terminal. SSSC provides the main function of the UPFC by injecting a voltage Vinj with controllable magnitude Vcr and phase angle θcr in series with the line via an insertion transformer. This injected voltage acts essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive and real power exchange between it and the AC system. The reactive power exchanged at the AC terminal is generated internally by the converter. The real power exchanged at the AC terminal is converted into DC power which appears at the DC link as a positive or negative real power demand. The basic function of STATCOM is to supply or absorb the real power demanded by SSSC at the common DC link to support the real power exchange resulting from the series voltage injection. This DC link power demand of SSSC is converted back to AC by STATCOM and coupled to the transmission line bus via a shunt connected transformer. In addition to the real power need of SSSC, STATCOM can also generate or absorb controllable reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line [6]. It is important to note that whereas there is a closed direct path for the real power negotiated by the action of series voltage injection through STATCOM and SSSC back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by SSSC and therefore does not have to be transmitted by the line. Thus, STATCOM can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by SSSC. Obviously, there can be no reactive power flow through the UPFC DC link.

ANFIS based Unified Power Flow Controller

To maintain good dynamic response at various operating conditions with the four possible choices of UPFC control signal, the controller gains need to be adapted based on system conditions. An adaptive neuro fuzzy inference system has been used in this work to adapt the controller gains of UPFC damping controller. The various steps involved are elaborated with reference to UPFC installed in two machine infinite bus system.

Determination of initial fuzzy structure

In this thesis, UPFC is control active and reactive power in system by Adaptive Neuro Fuzzy Interface System (ANFIS) control technology. These controlled powers synchronize infinite bus system and provide feedback to excitation system of synchronous generator by ANFIS control technology. For UPFC the input to the proposed fuzzy inference system is taken as the deviation between active and reactive power (Δpq), and the output as the damping control signal,(Δu) same as in the case of constant gain controller. The linguistic rules, considering the dependence of the controller output on the controlling signal, are used to build the initial fuzzy inference structure [9].

An increasing trend in active and reactive power deviation results in excess accelerating power and the control action should be in such a way to promote the power flow to maintain the power balance and vice-versa.

Δq / Δp	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	ZE	ZE	PS
NM	NB	NB	NM	NS	ZE	PS	PM
NS	NB	NB	NM	ZE	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NB	NM	NS	ZE	PM	PB	PB
PM	NM	NS	ZE	PS	PM	PB	PB
PB	NS	ZE	ZE	PS	PB	PB	PB

Table II: Initial premise and consequent parameters for ANFIS (UPFC)

Training Data

The proposed fuzzy structure has 21 premise parameters and 14 consequent parameters to be estimated .The data base for the optimum input-output pattern required for the training of the ANFIS is generated as follows.

a. Design constant gain damping controller using phase compensation technique as given in section 2.2. Design is carried out at various combinations of loading and network conditions with active power $P_{e,}$ reactive power $Q_e$and system equivalent reactance $X_e$varying in the range given by {$P_{e,}$ Q_e , X_e} = {-2 to 2} (all in per unit).

b. Repeat step i. for the various choices of UPFC control signals namely Δp, Δq ,δp,δq

c. Generate (Δpq, Δu) training pairs from the constant gain controller so designed.

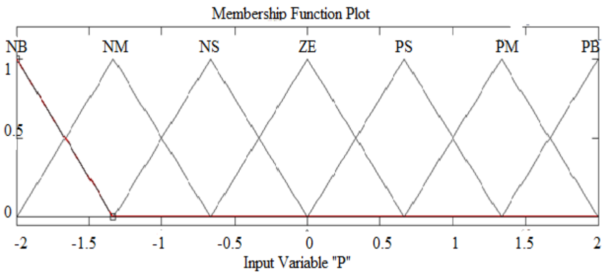


Fig. 3.2: Initial membership functions for input variable Δp

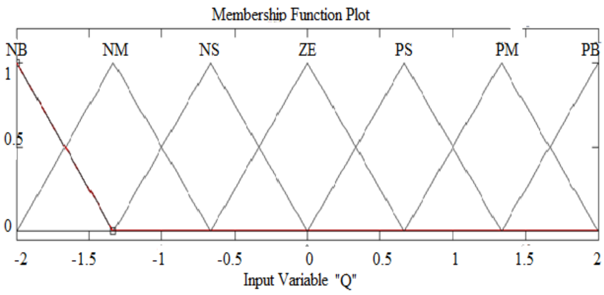


Fig. 3.3: Initial membership functions for input variable Δq

The adaptive network is trained using the training data generated and the hybrid-learningalgorithm. The distribution of initial fuzzy subset of the seven MF's (NBto PB) in theuniverse of discourse of input function $\Delta pq_{ref}$is equally spaced in the range [-2 2].

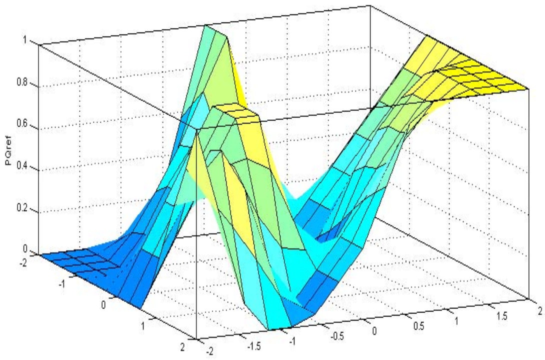


Fig. 3.4: Initial membership functions for output variable Δpq_{ref}(Surface View)

Result and Discussion

According to the previous chapter analysis, the Adaptive Neuro Fuzzy Interface UPFC with Power System Stabilizer Excitation System is simulated by control to the Low frequency oscillations for different type of loads in the environment of MATLAB/SIMULINK. In this study, two steps are observed with change in speed deviation and acceleration or active and reactive power. First step is speed deviation in rotor angle and the second one is reactive power in an infinite bus system. The basic parameters are shown in appendix. Simulation results for the system including comparison between ANFIS controller and conventional controller are discussed below. From the results, ANFIS controller UPFC with Power System stabilizer is good when compared to conventional controller for both normal and abnormal (switching, fault, heavy load) conditions, its response and also reduction of peak overshoot is observed with Adaptive Neuro Fuzzy Interface System. Consequently, simulation results show that ANFIS controller efficiently increases the damping rate and decreases the amplitude of transients.

The Case Study

a. **Case i:** For normal load without vulnerable condition, the variation of speed deviation, field voltage, rotor angle, load angle, active and reactive power were analyzed for conventional PSS and Adaptive Neuro Fuzzy Interface UPFC with PSS Excitation System.

b. **Case ii:** System was subjected to vulnerable (fault) condition, the variation of above mentioned cases were analyzed.

c. **Case iii:** The variation of above mentioned cases were analyzed for PSSs when subjected to different loading condition.

The above cases are illustrated clearly, how the controller reduces the peak overshoot and settling time to the nominal level when subjected to Adaptive Neuro Fuzzy Interface based Unified Power Flow Controller (UPFC) with Power System Stabilizer (PSS)Excitation System is the inference of the simulation results are as follows;

Normal Load without Fault.

Here, the synchronous machine subjected to normal load of 2000 MVA without fault condition in the transmission line and the following observations from the dynamic responses are made in Fig.4.1 to 4.5 with respect to the stability enhancement of the system.

From the Fig.4.1 to Fig. 4.5 it is observed that the Adaptive Neuro Fuzzy Interface UPFC with PSS can provide the better damping characteristic than the conventional Power System Stabilizer. The Adaptive Neuro Fuzzy Interface extreme controller with PSS excitation system reduced and maintains rotor angle, speed deviation and terminal voltage in initial transient period of system. It is also show that settling time of stabilization decreases up to 2 to 3 sec as compare to conventional Power System Stabilizer which are given in table 4.1. Active power and reactive power membership function are as input variables for Adaptive Neuro Fuzzy Interface with extreme controller.

Fig 4.1 shows that terminal voltage of synchronous alternator which is also representing reduction of peak overshoot and settling time during transient periods in terms of change in reactive power deviation in power system. It is necessary to maintain the bus terminal voltage in the synchronous generator; care should be taken to make the system to reach steady state as early as possible for that Adaptive Neuro Fuzzy interface extreme controller with power system stabilizer give better optimal solution compared to others by using reactive power control in system. It reduced overshoot and settling time in normal load condition by adaptive Neuro fuzzy interface based unified power flow controller with power system stabilizer approximately 0.8to 0.85 p. u. as given in table 4.1. It performs as an output for adaptive control extreme controller with PSS excitation system.

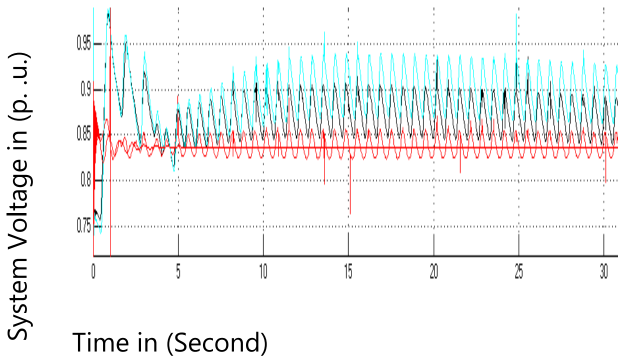
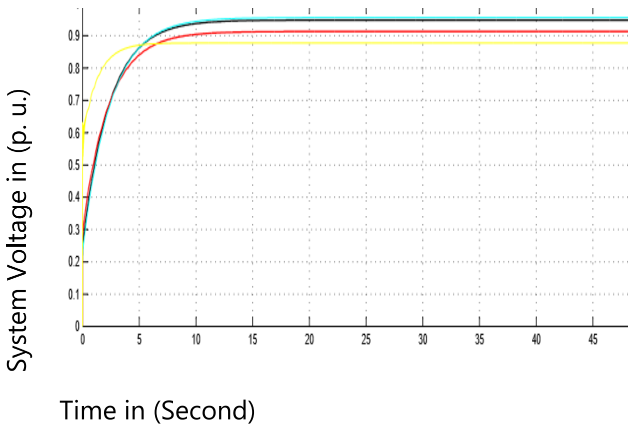


Fig 4.1 (a): System Voltage at Normal Load Condition with conventional PSS

Fig 4.1 (a, b and c) shows system output voltage, here represent fig 4.1 (a) with conventional load is continues deviate around 0.85 to 0.95 i.e. taken more overshoot and settling time with conventional power system stabilizer as compare Fuzzy and extreme controller which are shown in fig 4.1 (a) and (b). System voltage stable within 3 sec and deviation get reduces with help of fuzzy and extreme controlled power system stabilizer there



comparison has shown in table 4.1.

Fig 4.1 (b): System Voltage at Normal Load Condition with Fuzzy Logic PSS

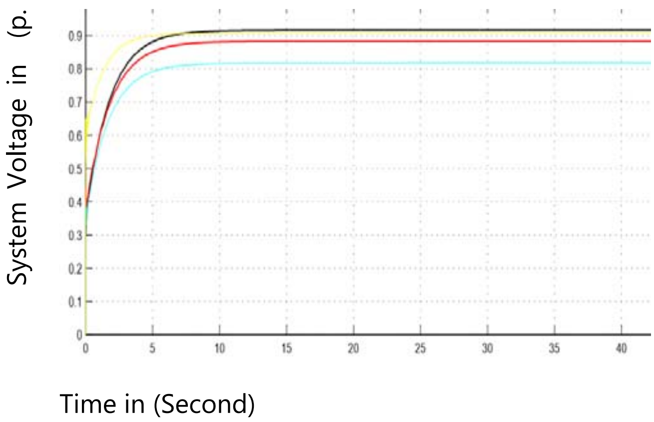


Fig 4.1 (c): System Voltage at Normal Load Condition with Extreme Controller

The rotor angle deviation and speed deviation of alternator is the most important things for power system stability enhancement, Fig 4.2 and Fig 4.3 are show simulation result graph of rotor angle deviation and speed deviation irrespectively which are input membership function for Adaptive Neuro Fuzzy Interface PSS. These represent with conventional stabilizer in fig 4.2 (a) the reduction of peak overshoot rotor angle deviation about 6 to 8 degrees which is the large deviation during transient periods. It's to overcome by fuzzy and Extreme controller based stabilizer rotor angle deviation reduced up to 2 to 3 degree which is least deviation and least settle down as shown in fig 4.2 (b) and fig 4.2 (c). It is also show that settling time of rotor angle which is stabilize just up to 0.3 sec of practical value of rotor angle (30^0 to 35^0) as possible. There comparison has been shown in table 4.1.

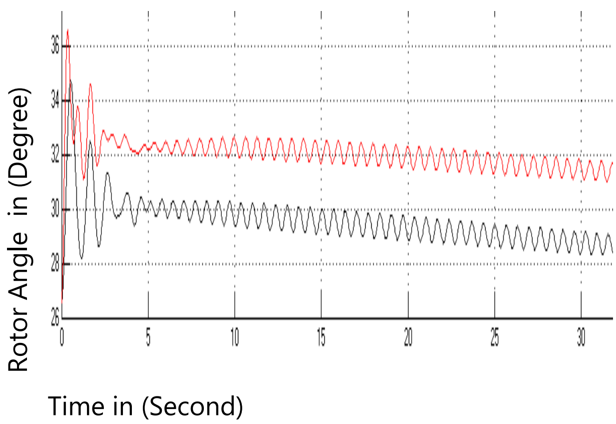


Fig 4.2 (a): Rotor Angle of Machine at Normal Load with Conventional PSS

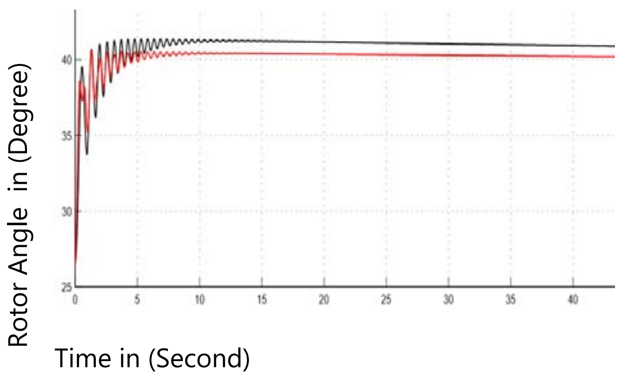


Fig 4.2 (b): Rotor Angle of Machine at Normal Load with Fuzzy Logic PSS

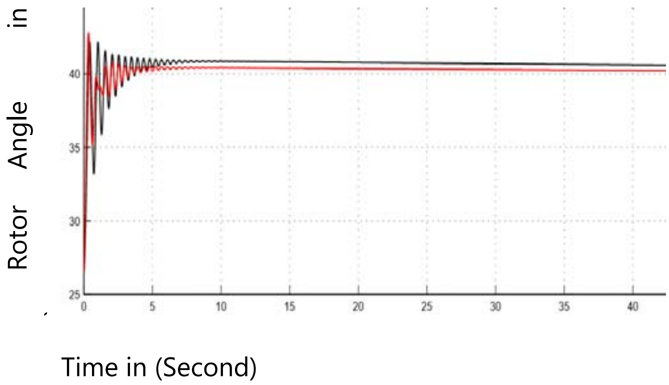


Fig 4.2 (c): Rotor Angle of Machine at Normal Load with Extreme Controller

Rotor angle deviation and speed deviation both are very important for stabilizing enhancement of power system. The Fig. 4.3 shows the speed deviation of synchronous alternator which is stabilized in just before 0.3 sec, and also reduced the peak overshoot of deviation in range just 1 to 0.05 p. u.

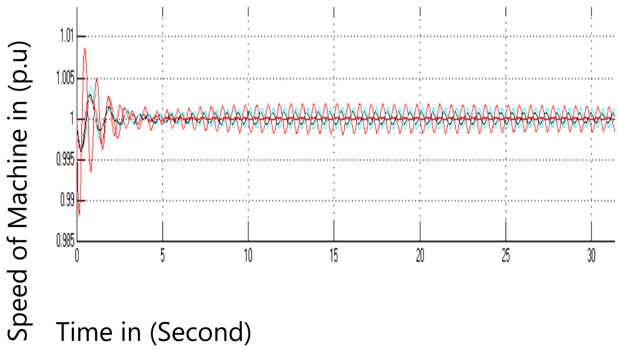


Fig 4.3 (a): Speed Deviation of Machine at Normal Load with Conventional PSS

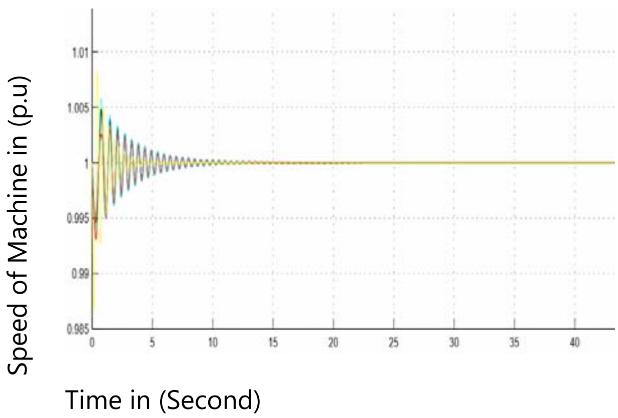


Fig 4.3 (b): Speed Deviation of Machine at Normal Load with Fuzzy Logic PSS

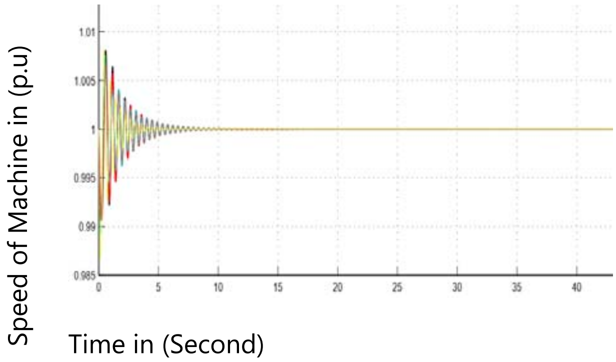


Fig 4.3 (c): Speed Deviation of Machine at Normal Load with Extreme Controller

Finally Fig. 4.1 to Fig 4.3 has shown that adaptive Neuro fuzzy interface system based UPFC with PSS is give good response under normal condition of system as compare other conventional stabilizers responding peak overshoot as well as settling time of control techniques. It result also represent in table 4.1 the ANFIS Extreme controller with PSS Excitation System technology is fast response as compare other conventional Power System Stabilizer controllers.

Parameters / Stabilizer	Rotor Angle Deviation (Degree)	Speed Deviation (P.U.)	Terminal Voltage (P.U.)
Conventional – PSS	15- 60	0.8 – 1.0	0.85-1.2
FUZZY- PSS	20 – 60	0.985 – 0.995	0.75 – 0.8
ANFIS Extreme Controller with PSS Excitation System	35- 42	0.99 – 0.995	0.6 – 0.85

Table 4.1: Comparison between Power System Stabilizer on normal load conditions

Fault Condition

This illustrates the stability of the system during vulnerable condition; a three phase fault is assumed to happen at the transmission line. The fault persists in the system, after 15 sec of system and it is cleared just after 2 to 3 sec. The parameters of the system during fault condition are illustrated in Fig. 5.4 to Fig.4.6 on the basis of active power, reactive power, bus voltage, rotor angle and speed deviation of system.

From the Fig. 4.4 to Fig. 4.6 shows the active power and reactive power control during fault condition of power system, after 0.3 to 0.5 sec it has cleared. It is observed that the adaptive Neuro fuzzy interface system based unified power flow controller with PSS excitation system can also decreases the settling time of stabilization after the fault about 0.3 to 0.5 sec. The ANFIS based extreme controller with PSS gives better control management between active and reactive power control in system.

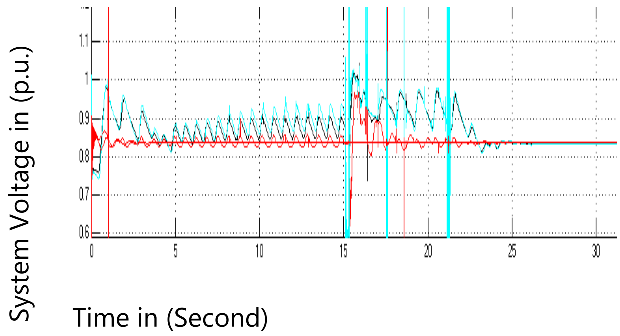


Fig 4.4 (a): System Voltage at Fault Condition with Conventional PSS

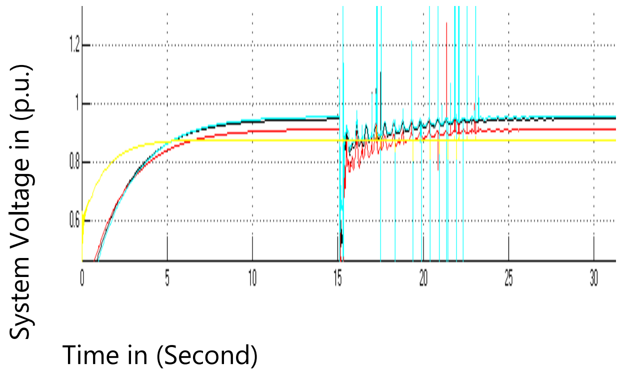


Fig 4.4 (b): System Voltage at Fault Condition with Fuzzy Logic PSS

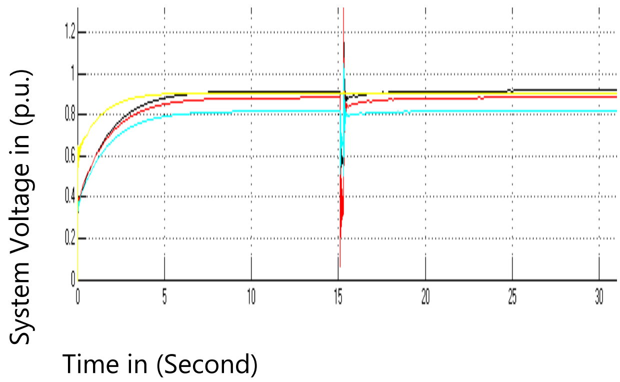
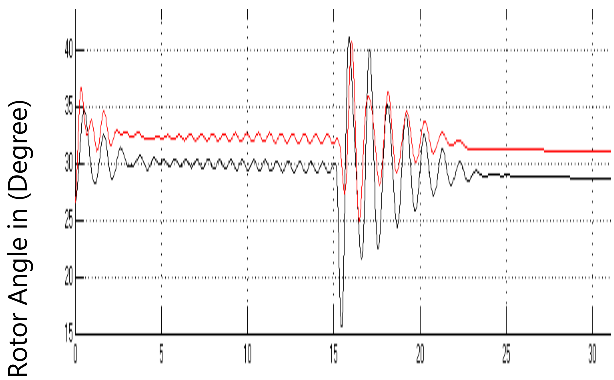


Fig 4.4 (c): System Voltage at Fault Condition with Extreme Controller PSS

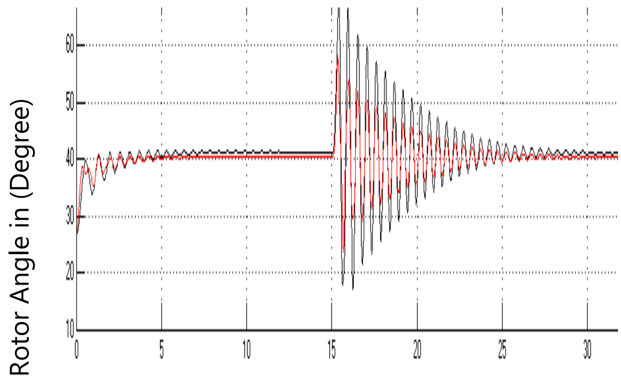
According to Fig. 4.4 (a) with conventional PSS has shown large deviation 0.6 to 0.8 p.u. of voltage magnitude and settling time which may be create some abnormal values and respect to their fuzzy and extreme controller based power system stabilizer has represent their overcome, the overshoot is least up to 0.3 to 0.4 p. u. of system voltage at fault condition for Adaptive Neuro Fuzzy Interface extreme controller with PSS Excitation System as shown in fig 5.4(b) and (c); therefore the stability of the system is maintained after that fault. The adaptive Neuro fuzzy interface system based unified power flow controller with power system stabilizer excitation system reduces the overshoot to ±0.3 p. u. as given in table 4.2 and makes the system to reach steady state before 0.2 sec to 0.3 sec. From this case, it is inferred that ANFIS based extreme controller with PSS supports the synchronous generator to maintain synchronous buses terminal voltage even at severe fault conditions.

During the fault condition, conventional PSS maintains the load angle around ± 8 - 10 degree. Normally for the smart system the rotor angle should be maintained around 40 to 42 degree. The ANFIS based extreme controller with PSS provides better solution by maintaining the load angle around 40 - 45 degree. The Fig 4.5 (a) shows that rotor angle deviation of system during fault; it represents that large deviation around 15 to 42 degrees with low frequency oscillation of rotor angle that is the causes of power loss and failure of synchronism. The Fuzzy and also Adaptive Neuro Fuzzy Interface extreme controller with PSS Excitation System, Rotor angle of system stability maintained at economic level of deviation which is generally negligible as compared to conventional PSS as shown fig 4.5 (b) and fig 4.5 (c).



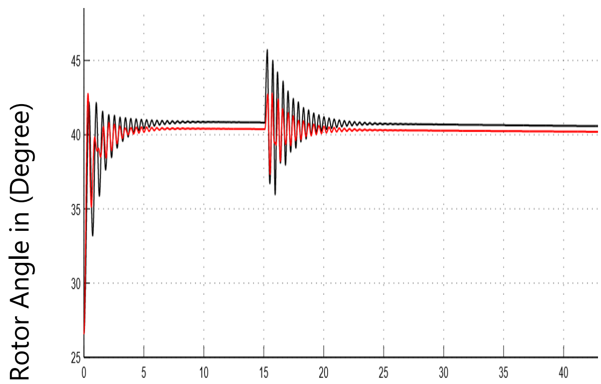
Time in (Second)

Fig 4.5 (a): Rotor Angle at Fault Condition with Conventional PSS



Time in (Second)

Fig 4.5 (b): Rotor Angle at Fault Condition with Fuzzy Logic PSS



Time in (Second)

Fig 4.5 (c): Rotor Angle at Fault Condition with Extreme Controller

Fig. 4.6 shows that speed deviation of synchronous generator which is also representing reduction of peak overshoot about ± 0.02 p. u. It is necessary to maintain the speed deviation in the synchronous generator; care should be taken to make the system to reach steady state as early as possible for that ANFIS based extreme controller with PSS give better optimal solution compared to others as given in table 4.2.

Here fig 4.6 (a) shows speed deviation with conventional power system stabilizer which has poor response in respect of low frequency oscillation of speed that also causes of failure of synchronism. Fig 4.6 (b) and fig 4.6 (c) has overcome to reduce this low frequency deviation of speed and settle down within minimum time response with extreme controller power system stabilizer, there comparisons has to be shown in table 4.2.

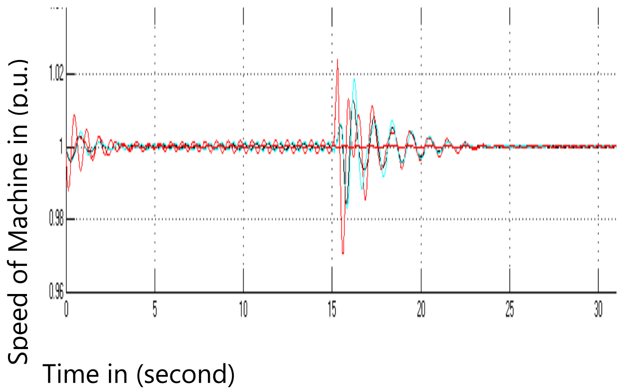


Fig 4.6 (a): Speed Deviation of Machine at Fault Condition with Conventional PSS

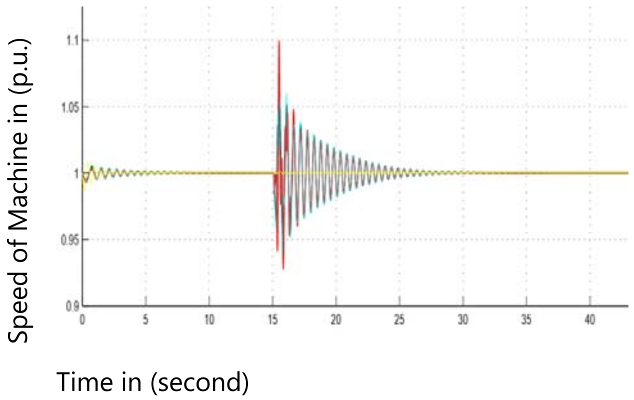


Fig 4.6 (b): Speed Deviation of Machine at Fault Condition with Fuzzy Logic PSS

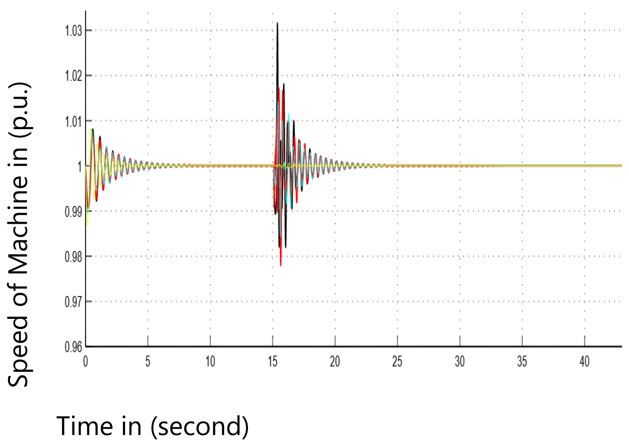


Fig 4.6 (c): Speed Deviation of Machine at Fault Condition with Extreme Controller PSS

Finally Fig. 4.4 to Fig 4.6 has shown that ANFIS based Extreme controller with PSS is give good response under fault condition of system as compare other conventional stabilizers responding peak overshoot as well as settling time of control techniques. It result also represent in table 5.2 the ANFIS based control technology is fast response as compare other conventional controllers under fault condition.

Table 4.2: Comparison between Power System Stabilizer under fault conditions

Parameters / Stabilizer	Rotor Angle Deviation (Degree)	Speed Deviation (P.U.)	Terminal Voltage (P.U.)
Conventional – PSS	15- 60	0.8 – 1.0	0.85-1.2
FUZZY- PSS	20 – 60	0.985 – 0.995	0.75 – 0.8
ANFIS Extreme Controller with PSS Excitation System	35- 42	0.99 – 0.995	0.6 – 0.85

Conclusion

In this paper work initially the effectiveness of power system stabilizer in damping power system stabilizer is reviewed. In this paper work initially the effectiveness of power system stabilizer in damping power system stabilizer is reviewed. Then the ANFIS based Extreme Controller with power system stabilizer is introduced by taking speed deviation and acceleration of synchronous generator as the input signals to the ANFIS based PSS controller, voltage as the output signal. For ANFIS based Extreme Controller by taking active and reactive power as the input signals, $(p\ q)_{ref}$ as the output signal. ANFIS based Extreme Controller with PSS shows the better control performance than power system stabilizer in terms of settling time and damping effect. Therefore, it can be concluded that the performance of ANFIS based Extreme Controller with PSS is better than conventional PSS. However, the choice of membership functions has an important bearing on the damping of oscillations. From the simulation studies it shows that the oscillations are more pronounced in case of triangular membership functions. The response with Gaussian membership functions is comparable to triangular membership functions. However, the performance of ANFIS PSS with triangular membership functions is superior compared to other membership functions.

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