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"The Design of a Fuzzy Logic Based Power System Stabilizer Applied to Two Electric Power Generation Units"

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Abstract: This paper presents PSS (Power system stabilizer) design based on fuzzy controller (FLPSS). The main motivation of this design was to stabilize and improve the damping of two synchronous machines. A speed deviation and an acceleration power were selected as fuzzy controller inputs. The controller output is injected into AVR. A "MATLAB" simulation program is used to design a model for a power plant in order to study the effect of a reactive power change in a terminal voltage and try to reduce it. A controller based on fuzzy logic is developed to simulate a power system stabilizer (PSS) in a transient stability power system analysis. Simulation is used to validate a fuzzy logic-based power system stabilizer (FLPSS) and to compare its performance with both proportional-integral-derivative based power system stabilizer (PIDPSS) and a conventional power system stabilizer (CPSS). The comparison was carried out on a CPSS, with a PIDPSS and a FLPSS. The results indicate that the inclusion of a fuzzy logic controller improves the damping of electromechanical oscillations introduced by a three-phased fault in the system, and hence improves the overall stability of the system.

Keywords: Automatic voltage regulator (AVR), Proportional-Integral-Derivative (PID), Conventional power system stabilizer (CPSS), Excitation system, Fuzzy logic (FLC), Fuzzy logic-based power system stabilizer (FLPSS) and MATLAB.

1. Introduction

The rapid growth of electrical power transmission since the Second World War has contributed in solving the problems of stability power systems so much, that the subject has today become an important sub-branch of electrical engineering. Very huge efforts have been exerted to understand reactive power and voltage control issues in power systems. In the last few years, efforts concerning traditional controls affected the interaction between the flow of real and reactive power with an objective to maximize real power transfer capabilities. There has been a strong temptation to try and separate the voltage/MVar problems with the angle/MW problems (A.K Raja,2006). The stability of an electrical power system can be classified into two broad categories, namely: transient (angular) and voltage stability. Traditionally the angular stability has been the main focus of power system engineers.

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With the increased demand in electrical energy fewer expansion plans of the power system, voltage instability has occurred more frequently and therefore, gained the attention of planners and operators (c.w. tailor,1994). In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. The following reasons have motivated the application of such a control technique:

1) improved robustness over the conventional linear control algorithms.
2) simplified control design for difficult system models;
3) Simplified implementation (P. Hoang and K. Tomsovic, 1996), (El-Hawary Mohamed, 1988), (Momah A. J., X. W. Ma, and K. Tomsovic, 1995).

The frequency of a power system is affected by changes in real power while the terminal voltage magnitude is affected by changes in reactive power. The load frequency control loop (LFC) controls real power and frequency while the automatic voltage regulator (AVR) controls the reactive power and voltage magnitude of an alternator. The role of the AVR is to hold the terminal voltage magnitude of a synchronous generator at a specified level. As the reactive load of consumers increase beyond the rated value of the generator, the result will be a decrease in its terminal voltage. The conventional control approach to the terminal voltage and reactive power regulation involves the development of the linear equations of the AVR models and hence the appropriate control theory is used to develop the controller. This conventional modeling and control approach have been observed to perform poorly when the system operating conditions change. This is due to the fixed parameters and linearized models of the system. Other reasons have also lead to the use of fuzzy logic control and programming in the control of the terminal voltage and reactive power of the AVR alternator. The presented excitation system aims to increase the level control of the voltage and then improve the stability of the power system. Fuzzy logic systems allow us to design a controller using linguistic rules without knowing the exact mathematical model of the plant.

This paper illustrates a power system stabilizer with an adaptive PID fuzzy controller for different operating conditions of the power system. Various techniques using (PIDPSS, CPSS and FLPSS) have been performed for a two-machines power system. Thus, the results indicate that the inclusion of a Fuzzy Logic Controller improves the damping of electromechanical oscillations caused by a three phased fault in the system. Such a case is a complicated one due to its non-linear situation, hence improving the excitation system of the synchronous generator is essential. The theory of a fuzzy logic controller is characterized by simplicity because it is applicable in all modern and complex automated control systems such as non-linear control systems.

2. Statement of the Problem

Some of the earliest power system stability problems included spontaneous power system oscillations at low frequencies. These low frequency oscillations (LFOs) are related to the small signal stability of a power system and are detrimental to the goals of both maximum power transfer and power system security. Once the solution of using damper windings on the generator rotors and turbines to control these oscillations were found to be satisfactory, the stability problem thereby would be disregarded for some time. However, as power systems begin to be operated closer to their stability limits, the weakness of a synchronizing torque among the generators would be recognized as a major cause of system instability. Automatic voltage regulators (AVRs) help to improve the steady-state stability of the power systems. But with the creation of large, interconnected power systems, another concern would be the transfer of large amounts of power across extremely long transmission lines. The addition of a supplementary controller into the control loop, such as the introduction of conventional power system stabilizers (CPSSs) to the AVRs on the generators, provides the means to reduce the inhibiting effects of low frequency oscillations. The conventional power system stabilizers work well at the particular network configuration and steady state conditions for which they were designed. Once conditions change the performance degrades. The conventional power system stabilizer such as lead-lag, proportional integral (PI) power system stabilizer and proportional integral derivative based power system stabilizer (PIDPSS) operate at a certain point. So, the disadvantage of such type of stabilizer cannot operate under different disturbances. This can be overcome by a CPSS design based on a fuzzy logic technique.

3. Literature review

The study of the literature revealed that researchers differ with respect to the form of the equation, implicit and explicit set of assumptions, data set and estimation- techniques. Therefore, it is not possible to generalize the result without accepting some margin of error. It would be appropriate if relevant studies are reviewed separately as presented below:

I. The conventional power system stabilizer

(Keay and South, 1971) proposed a power system stabilizer with frequency deviation as the only input signal. (Larsen and Swann,1981) – (Larsen and Swann,1981) gave the overview of a power system stabilizer from a practical point of view. (Chow and Sanchez-Gasca, 1989). propose a power system stabilizer by using pole placement techniques and this work is emphasized by (Yu and Li, 1990). For a nine-bus system (Hsu and Yuan-Yih,1986) proposed a proportional integral controller. (H Cai, Z Qu, D Gan and J F Dorsey,1962) proposed lapanov's approach for the design of a power system stabilizer. (Robak et al,2001). gave a comparison of different control structures. (Radman and Smaili,1998) proposed the proportional-integral-derivative based power system stabilizer (PIDPSS) and (Wu Chi-Jui and Hsu Yuan-Yih,1998) proposed the self-tuning proportional-integral-derivative based power system stabilizer (PIDPSS) for a two-machine power system.

II. The Proportional-Integral-Derivative (PIDPSS)

(G. Radman and Y. Smaili, 1988) proposed the proportional-integral-derivative based power system stabilizer (PIDPSS) and (W. Chi-Jui and H. Yuan-Yih,1988) propagated the self-tuning PID based power system stabilizer for a multi machine power system. (M. Dobrescu and I. Kamwa,2004) in their research paper described a PID (proportional-integral-derivative) type FLPSS with adjustable outside gains added outside in order to keep a simple structure. In order to validate the FLPSS, it was compared with two reference stabilizers; the IEEE PSS4B and IEEE PSS2B form the IEEE STD 421.5.

(A.alilvand, R. A. Jalilvand, R. Aghmasheh, and E. Khalkhali,2010) in their paper described the tuning of proportional integral derivative power system stabilizers (PID-PSS) by using an artificial intelligence (AI) technique.

III. The fuzzy based power system stabilizer (FLPSS).

(Metwally and Malik,1995) described in their research paper on fuzzy logic power system stabilizer the use of speed and power output variations as controller input variables. (Hiyama,2002) obtained the required information acceleration, speed deviation and phase deviation of a generator from a measured real power signal. (Pasand and Malik,1996) discussed fuzzy logic-based PSS implemented on an intel single board computer iSBC386/21. (Md S Majid, H A Rahman and O B Jais,2002) presented a fuzzy logic controller in which speed deviation and acceleration of rotor synchronous generator were taken as inputs. (R Gupta, D K Sambariya and Reena Gunjan,2006) proposed a robust PSS based on a fuzzy logic. In this speed deviation and acceleration of the rotor of a synchronous generator of a two-machine power system taken as an input to a fuzzy logic controller, results were obtained by using different defuzzification methods.

4. Solution Methodology

The "MATLAB" simulation program will be used to design a mathematical model for a power plant by using two synchronous generators to study the effect of a reactive power change in a terminal voltage (Vt) and try to reduce it. A controller based on a fuzzy logic was developed to simulate a conventional power system stabilizer (CPSS) in a transient stability power system analysis. By using a MATLAB SIMULINK, a controller based on a fuzzy logic was developed to simulate fuzzy logic-based power system stabilizer (FLPSS) in transient stability power system analysis. Then the controller developed has to be applied to a power system model in order to show its behavior, where results were compared to the results obtained with both the conventional power system stabilizer (CPSS) and the proportional-integral-derivative based power system stabilizer (PIDPSS). A detailed design methodology and implementation of PSS in a generating station at Ontario is explained by (Kundur et al,1994).

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5. Objectives of the work

1) To study the nature of power system stability, excitation system and an automatic voltage regulator for a synchronous generator and power system stabilizer.
2) To develop a fuzzy logic-based power system stabilizer which will make the system quickly stable when a three-phased fault occur in the transmission line.
3) To validate fuzzy logic-based power system stabilizers (FLPSS) and to compare its performance with both conventional power system stabilizer (CPSS) and Proportional-Integral-Derivative based power system stabilizer (PIDPSS).

❖ All the work is done by using MATLAB software, available with www. mathworks.com

6. The model of a process synchronous generator

i. Single machine system:

The basic concept of voltage stability can be explained with a simple 2-bus system shown in figure.1.

Figure. 1. Two-bus test system

The load is of constant power type. Real power transfer from bus 1 to 2 is given by this equation:-

$$P = \frac{EV}{X} sin\delta \qquad (1)$$

$$Q = -\frac{V^2}{X} + \frac{EV}{X} cos\delta \qquad (2)$$

Where:

$E = |E|\angle\delta$, the voltage at bus 1.

$V = |V|\angle 0$, the voltage at bus 2.

X is the Reactance of the line (neglecting resistance), δ is the Power angle.

Normalizing the terms in (2.18) and (2.19) With $v = V/E$,

$p = P.X/E^2$ and $q = Q.X/E^2$, one obtains, $p = vsin\delta$

$$q = -v^2 + vcos\delta \qquad (3)$$

Squaring the two equations above and rearranging we get:

$$v^2(sin^2\delta + cos^2\delta) = p^2 + \left((q + v^2)\right)^2$$

$$v^4 + v^2(2q - 1) + (p^2 + q^2) = 0 \tag{4}$$

Positive real solutions of v from (2.21) are given by: equation:

$$v = \sqrt{0.5 - q \pm \sqrt{0.25 - p^2 - q}} \tag{5}$$

The acceleration power in terms of the mechanical input power (P_m) and the electrical power output (P) is given by

$P_a = (P_m - P)$ in the form of swing equation motion, (6)

The acceleration power P_a is given by:

$$P_a = \left(P_m - \frac{EV}{X} sin\delta\right) = \frac{2H}{\omega_m}\frac{d^2\delta}{dt^2} \tag{7}$$

where P_m is the mechanical power input, ω_m is the rotor speed. t is the Time in sec. P_a is the acceleration power and H is the inertia constant, in MW. s/MVA.

ii. Two machine system:

In two machine system, a common system base must be selected. Let

$G_{machi} \quad = machine\ rating\ (base)$

$G_{system} = system\ base$

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = (P_m - P) \qquad pu \tag{8}$$

Equation (2.24) can then the rewritten as:

$$\frac{G_{machine}}{G_{system}}\left[\frac{H_{machi}}{\pi f}\right]\frac{d^2\delta}{dt^2} = (P_m - P).\frac{G_{machine}}{G_{system}} \tag{9}$$

$\left[\frac{H_{system}}{\pi f}\right].\frac{d^2\delta}{dt^2} = (P_m - P)\ pu$ on system base

Where

$$H_{system} = \left[\frac{G_{machi}}{G_{system}}\right] . H_{machine} \quad = \text{ machine inertia constant in system base.} \tag{10}$$

Let us consider the swing equation of two machines on a common system base.

$$\frac{H_1}{\pi f} \frac{d^2\delta_1}{dt^2} = P_{m1} - P_1 \tag{11}$$

$$\frac{H_2}{\pi f} \frac{d^2\delta_2}{dt^2} = P_{m2} - P_2 \tag{12}$$

Since the machine rotor swing in unison, $\delta_1 = \delta_2 = \delta$, we get

$$\frac{H_{eq}}{\pi f} . \frac{d^2\delta}{dt^2} = P_m - P \tag{13}$$

$$P_m = P_{m1} + P_{m2}$$

$$P = P_1 + P_2$$

$$H_{eq} = H_1 + H_2$$

$$H_{eq} = \left[\frac{G_{1,machi}}{G_{system}}\right] . H_{1,machin} + \left[\frac{G_{2,machi}}{G_{system}}\right] . H_{2,machine} \tag{14}$$

7. The Excitation system (P. Kundur,1994).

Figure.2. shows the functional block diagram of a typical excitation control system for a large synchronous generator. The following is a brief description of the various subsystems identified in the figure.

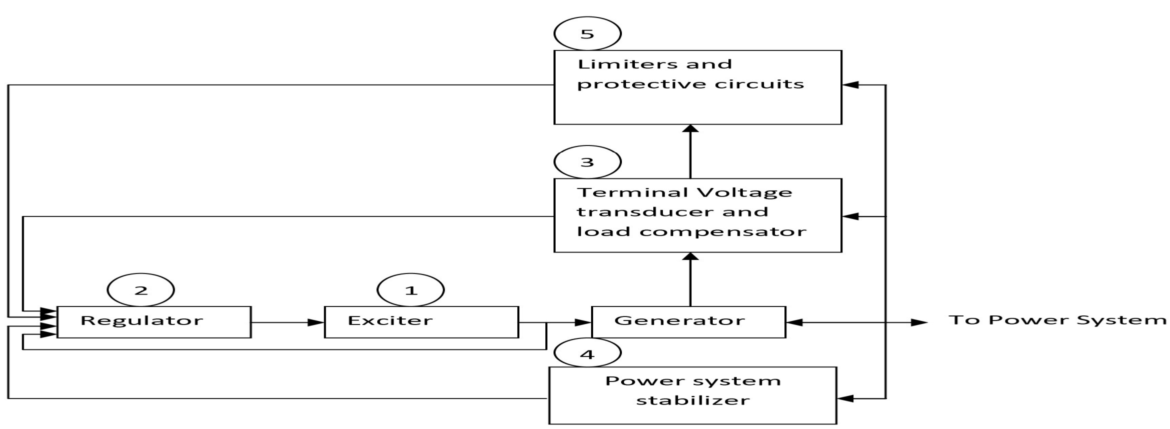

Figure.2. a general structure of excitation system.

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I. Exciter. Provides dc power to the synchronous machine field winding, constituting the power stage of the excitation system.

II. Regulator. Processes and amplifies input control signals to a level and form appropriate for control of the exciter. This includes both regulating and excitation system stabilizing functions (rate feedback or lead-lag compensation).

III. Terminal voltage transducer and load compensator. Senses generator terminal voltage, rectifies and filters it to dc quantity, and compares it with a reference which represents the desired terminal voltage. In addition, load (or line-drop, or reactive) compensation may be provided, if it is desired to hold constant voltage at some point electrically remote from the generator terminal (for example, partway through the step-up transformer).

IV. Power system stabilizer. Provides an additional input signal to the regulator to damp power system oscillations. Some commonly used input signals are rotor speed deviation, accelerating power, and frequency deviation.

V. Limiters and protective circuits. These include a wide array of control and protective functions which ensure that the capability limits of the exciter and synchronous generator are not exceeded. Some of the commonly used functions are the field-current limiter, maximum excitation limiter, terminal voltage limiter, volts-per-Hertz regulator and protection, and under excitation limiter. These are normally distinct circuits and their output signals may be applied to the excitation system at various locations as a summing input or a gated input. For convenience, they have been grouped and shown in Figure.2. as a single block.

8. Conventional power system stabilizer

The conventional power system stabilizer (CPSS) block can be used to add damping to the rotor oscillations of the synchronous machine by controlling its excitation. The disturbances occurring in a power system induce electromechanical oscillations of electrical generators. These oscillations are also called power swings and must be effectively damped to maintain the system stability. The output signal of the CPSS is used as an additional input ($Vstab$) to the excitation system block. The CPSS input signal can be either the machine speed deviation, $d\omega$, or its acceleration power, $P_a = P_m - P$

(difference between the mechanical power and the electrical power). The generic power system stabilizer is modeled by the following nonlinear system:

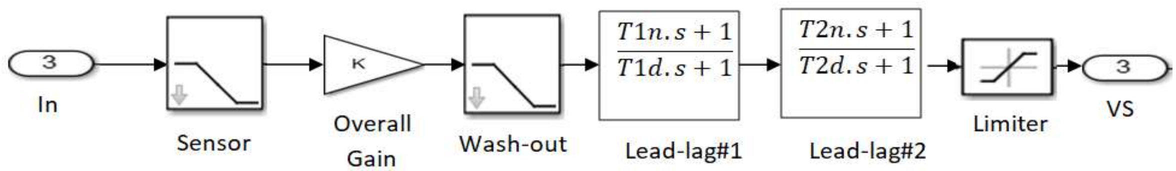

Figure.3. The Generic Power System Stabilizer

The output signal of any PSS is a voltage signal, noted here as VPSS(s), and added as an input signal to the AVR/exciter. The structure shown in Figure.3. is given by the following equation:

$$V_{stab} = \frac{KT_w.s(T1n.s+1)(T2n.s+1)}{(T1d.s+1)(T2d.s+1)(T_w.s+1)} \quad (15)$$

where; K is the power system stabilizer gain.T_w is the washout time constant, $T1n, T2n, T1d, T2d$ are the time constant selected to provide a phase lead for the input signal in the range of frequencies of interest.

9. Proportional-integral-derivative based power system stabilizer (PIDPSS)

The controller is a generic control loop feedback mechanism that will correct the error between a measured process variable and the desired input by calculating and giving an output of correction that will adjust the process accordingly (Tan Qian Yi, Gowrishankar Kasilingan and Raman Ranguraman,2013). Figure.4. shows a control system with a PID controller. The control signal $u(t)$ is a linear combination of error e (t) for its integral and derivative.

$$u(t) = K_P e(t) + K_t \int e(t)\,dt + K_D \frac{de(t)}{dt} \quad (16)$$

$$u(t) = K_P \left(e(t) + \frac{1}{T_1}\int e(t)dt + T_D \frac{de(t)}{dt}\right) \quad (17)$$

where $K_P$is theproportional gain, K_t the integral gain,T_1 integral time and $T_D$derivate time. If the controller is digital, then the derivative term may be replaced with a black ward difference and the integral term may be replaced with a sun for small constant sampling time $u(t)$ which can be approximated as:

$$u(n) = K_P\left(e(n) + \frac{1}{T_1}\sum_{i=1}^{n} e(j)T_s + T_D\frac{e(n)-e(n-1)}{T_s}\right) \quad (18)$$

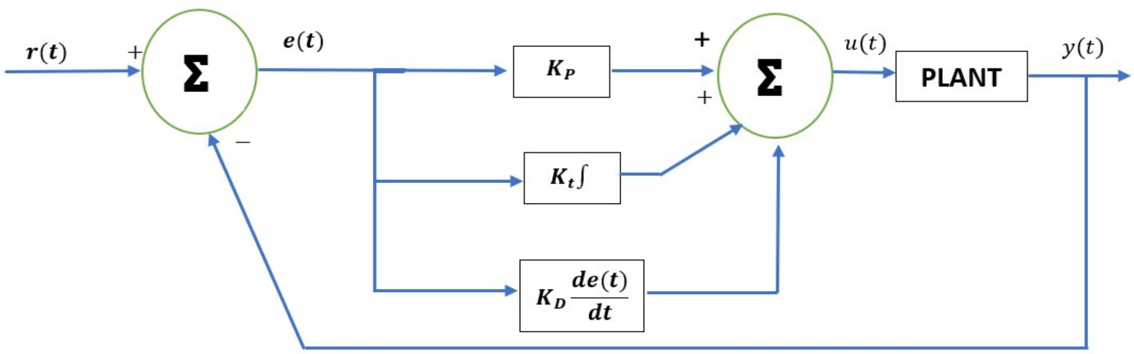

Figure.4. Schematic model of a PID controller

10. Fuzzy based power system stabilizer (FLPSS)

Since the concept of a fuzzy logic given by (Zadeh, 1973) applications have been found in various areas including a controller for power system stabilizer (T J Rose,1997) A fuzzy controller, as shown in figure.5., comprises four stages: fuzzification, a knowledge base, decision making and defuzzification. The fuzzification interface converts input data into suitable linguistic values that can be viewed as label fuzzy sets. The knowledge base consists of knowledge of the application domain and attendant control goals by means of a set of linguistic control rules. The decision making is the aggregation of output of various control rules that simulate the capability of human decision making. The defuzzification inference performs scale mapping, which converts the range of values of output variables into corresponding universe of discourse.

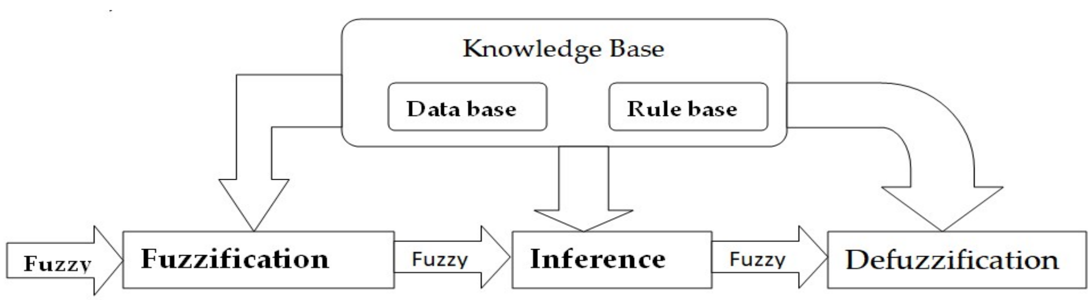

Figure.5. Schematic diagram of the FLPSS building blocks

1) Fuzzification module, the functions of which are, first, to read, measure, and scale the control variable speed, acceleration and, second, to transform the measured numerical values to the corresponding linguistic (fuzzy) variables with appropriate membership values.

2) Knowledge base, which includes the definitions of the fuzzy membership functions defined for each control variable and the necessary rules that specify the control goals using linguistic variables.

3) Inference mechanism, which is the kernel of the FLC. It should be capable of simulating human decision making and influencing the control actions based on fuzzy logic.

4) Defuzzification module, which converts the inferred decision from the linguistic variables back to numerical values. The fuzzy controller design consists of the following steps:

1) I dentification of input and Output variables.

2) Construction of control rules.

3) Establishing the approach for describing system state in terms of fuzzy sets, establishing a fuzzification method, fuzzy membership functions and selecting a compositional rule of inference. Defuzzification method means, transformation of the fuzzy control statement into specific control actions. Since the goal of this application is to stabilize and improve the damping of the synchronous machine, speed deviation dω and acceleration power, have been selected as the controller inputs. The controller output is then injected into the AVR summing point. This configuration implies that the FLC has two input parametersK_ω, and K_P, and one output parameterPa, K_V as seen in figure.6. The selection of these parameters is usually subjective and requires previous knowledge of the fuzzy control variables (input and output signals). Previous experience of the controlled system dynamics is also commonly used in the creation of the fuzzy control rules (Mohamed E. EL-HAWARY,1998).

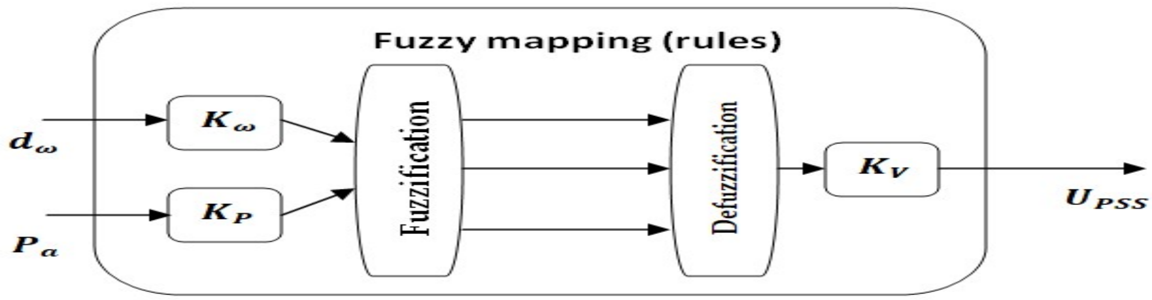

Figure.6. Schematic diagram of the FLPSS.

11. Design considerations.

The improvement of the control system based on fuzzy logic involves the following steps (Srinivas Singirikonda1, G. Sathishgoud and M. Harikareddy,2014):

a. Selection of the control variables

This is the first step in which the input variables, speed deviation and the power acceleration are generally taken in case of analysis of stability in terms of excitation system control. The output variable in form of voltage is a control signal to excitation input of synchronous generator, shown in Figure .7. Fuzzy Mamdani model is used to implement Fuzzy Logic Control. In this task, seven types of membership functions are considered for input and output variables. Input1 and input 2 are speed change ($d\omega$) and acceleration power (Pa). The membership function for all of parameters mentioned before is set to a triangular-shaped membership function ($Trimf$). No reference suggests different types of fuzzy model in terms of different membership function.

b. Rule formation

The rule actually shows the habit of the controller when it senses the changes of the input. It works like human brains, when a problem occurred. Brain might find the way out from the problems or constraints. The solutions for the problem were based on human experiences. If human brains were involved before in a similar problem, then the brain will solve the problem quickly. This concept is similar to the fuzzy controller rules. It will make a decision based on its rules. All the formulated 49-rules were shown in Figure.10.

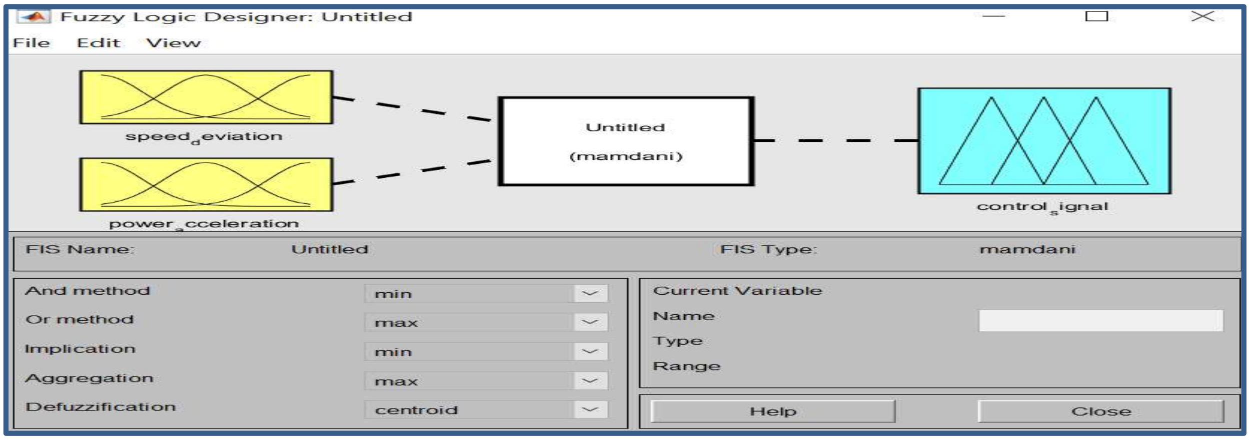

Figure.7. Fuzzy Mamdani model

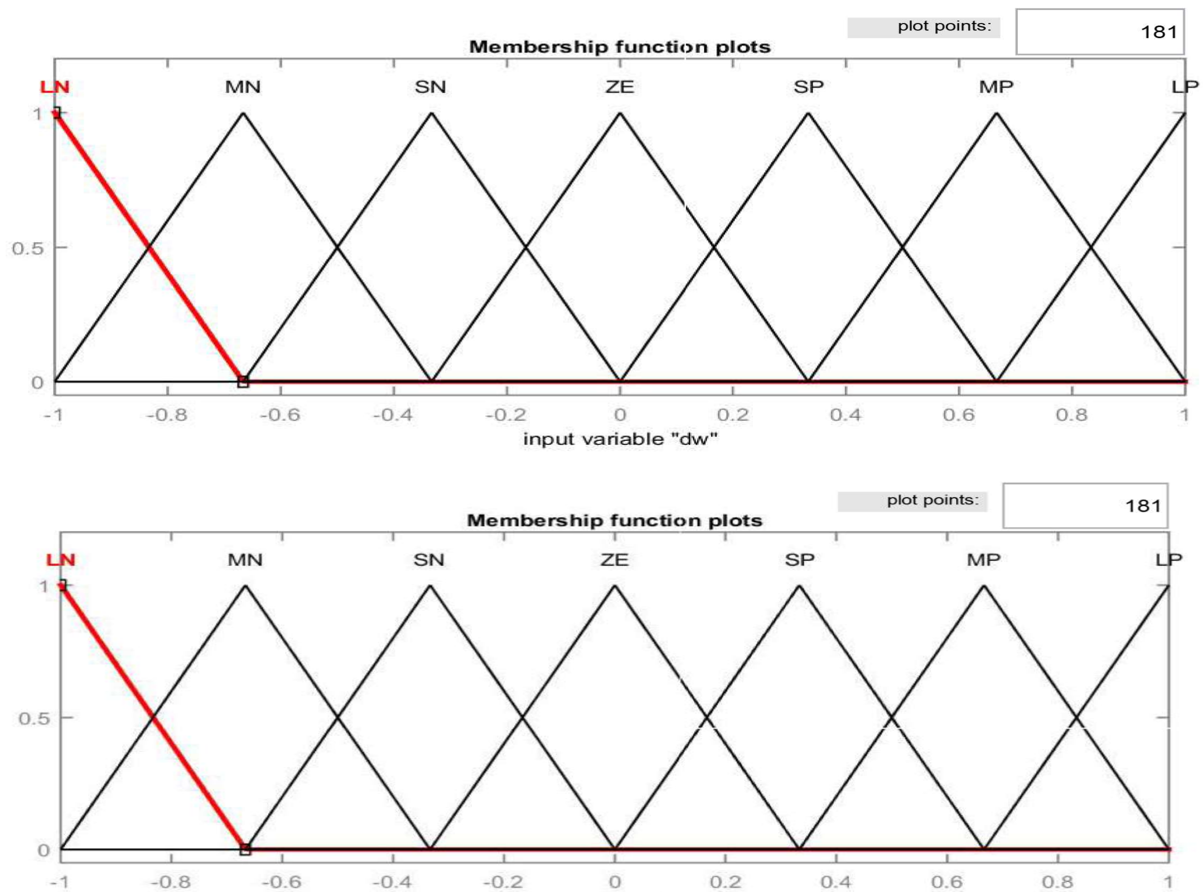

Figure .8. Input parameter added in FLPSS.

The range of membership function is set between -1 to 1. Figure 8 & 9 show two inputs and one output signal added in a model.

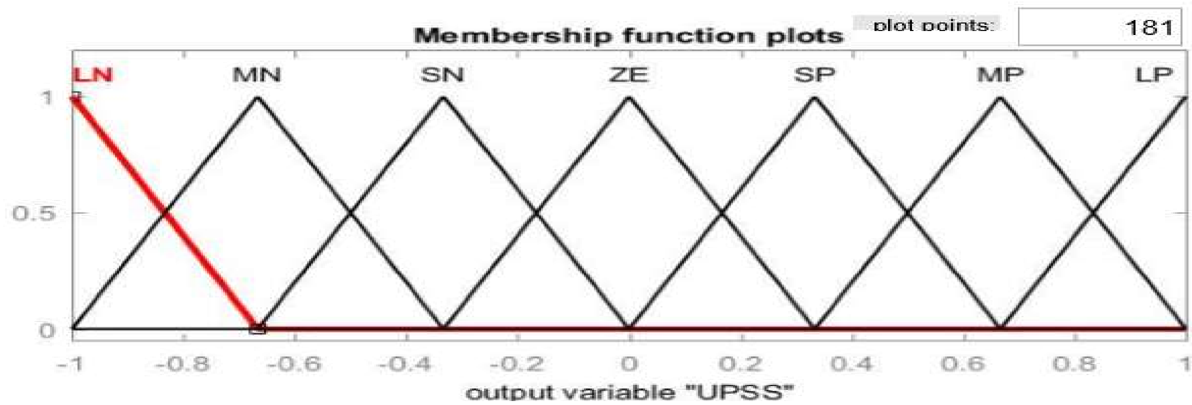

Figure.9. Membership function of output.

rotor speed deviation ($d\omega$)	acceleration of power (P_a)						
	LN	MN	SN	ZE	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	Z	SN
SN	LP	MP	SP	SP	Z	SN	MN
ZE	MP	MP	SP	Z	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	MN	LN	LN	LN

Figure: 10. Rule Formulation

12. Description of the Network Studied for two machines.

Figure .11. shows a schematic diagram of the test system with CPSS, PIDPSS and FLPSS. Since the goal of this application is to stabilize and improve the damping of a synchronous machine rotor speed deviation an acceleration of power ($Pa, d\omega$) have been selected as controller inputs. The controller output is then injected into AVR summing point.

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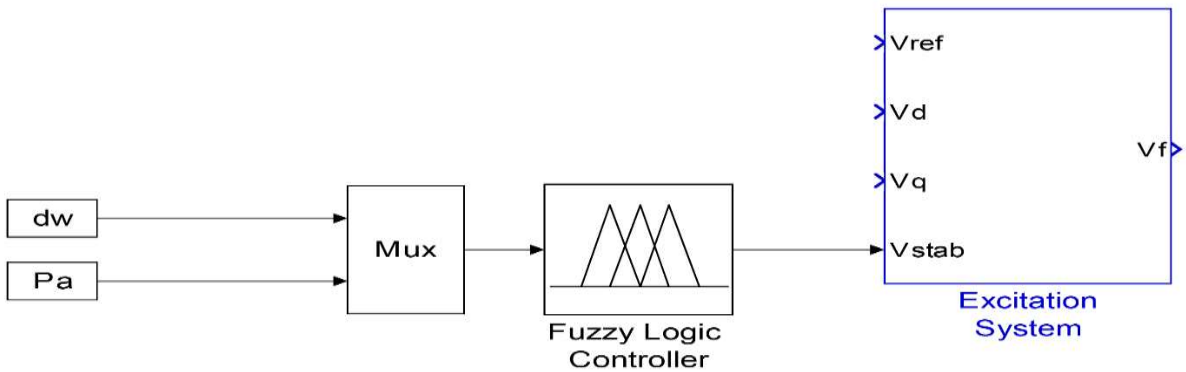

Figure.11. Fuzzy based power system stabilizer (FLPSS)

A simulink model of two machines (M1&M2) system installed with conventional power system stabilizer (CPSS), proportional-integral-derivative based power system stabilizer (PIDPSS) and fuzzy logic-based power system stabilizer (FLPSS) controllers are shown in figure.12. Machine M1 referred to a 200MW hydraulic generation plant while machine M2 referred to a 720MW generating plant. Each machine is equipped with a governor, excitation system and a power system stabilizer. These components are included in turbine &regulator1 and turbine &regulator2 shown in figure.13. and figure.14. A source load of 10,000 MVA is connected on a center between machine M1 and machine M2. The machine data is taken from (P. Kundur,1994) all parameter value system given in table 1, 2 and 3.

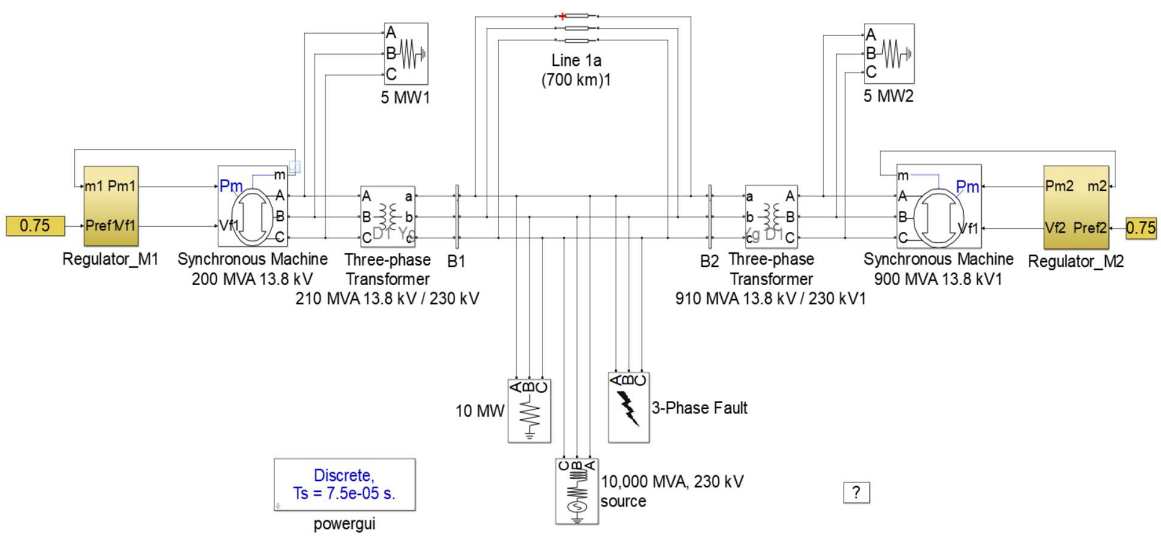

Figure.12. A two -machine two-bus test system modeled in Simulink /MATLAB.

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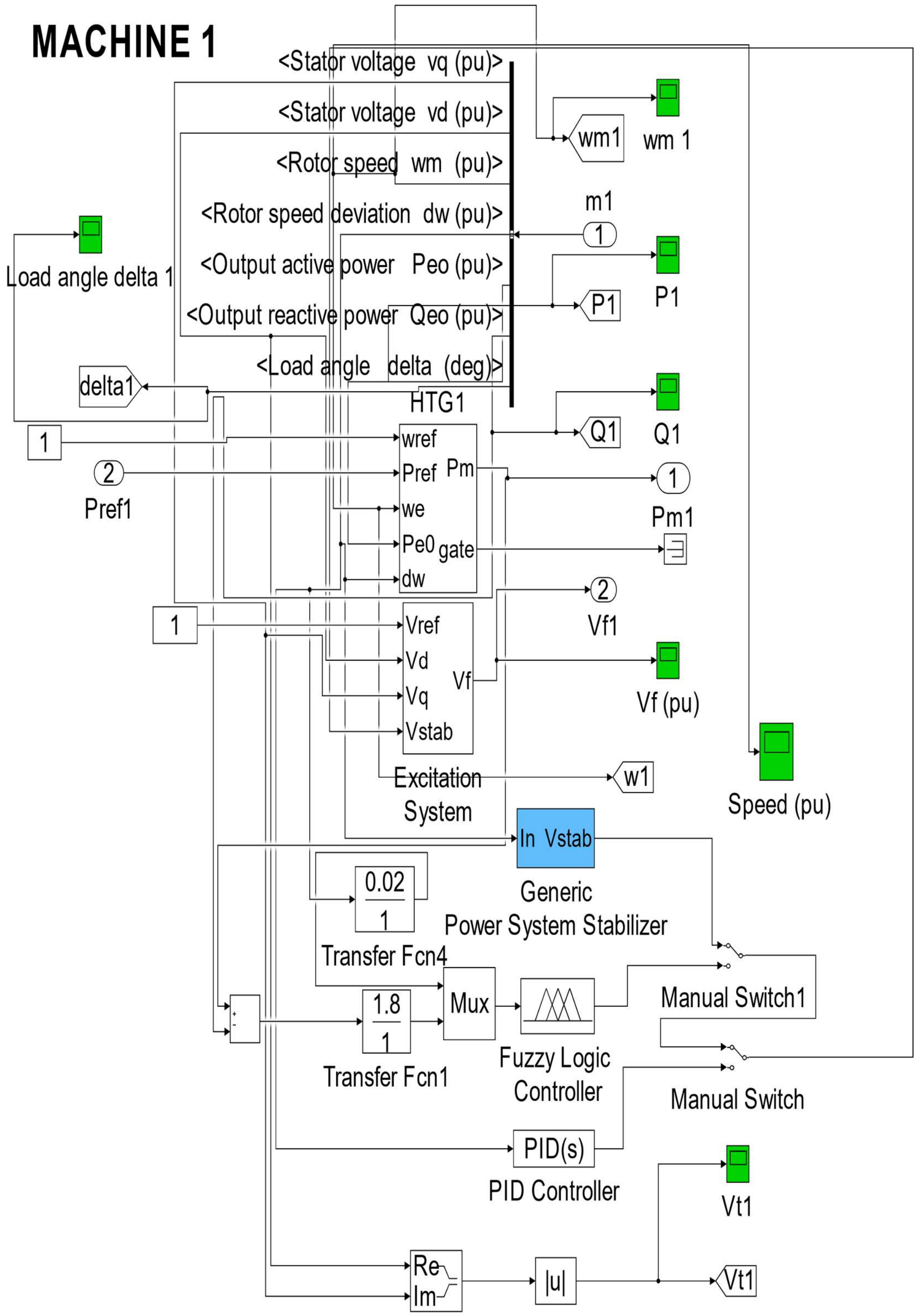

Figure.13. Subsystem of test model for machine M1.

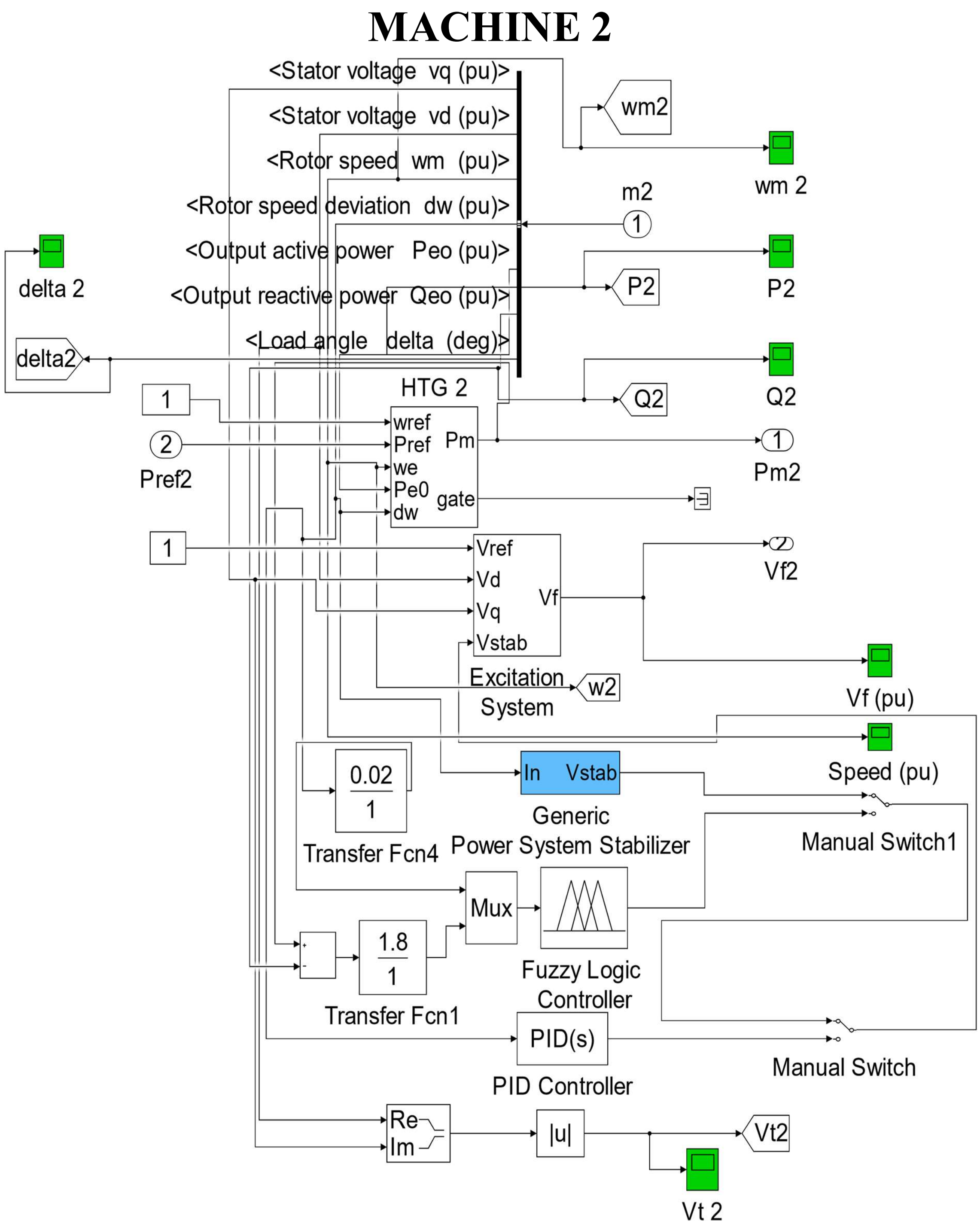

Figure.14. Subsystem of test model for machine M2.

Table 1: Generator parameter

Generator -1 (G1) nominal power $[Pn\ (VA), fn(Hz)]$	[200× 10^6,60]
Generator -2 (G2) nominal power $[Pn\ (VA), fn(Hz)]$	[900× 10^6,60]
Stator resistance $Rs\ (pu)$:	2.8544e-3
Inertia constant $H(s)$	3.2
Friction factor $F(pu)$	0
Pole pair	2
G1, G2-Power factor	[0.8,0.85]
Reactances $[\ Xd, Xd', Xd'', Xq, Xq'', Xl]\ (pu)$:	[1.305, 0.296, 0.252, 0.474, 0.243, 0.18]
Time constants $[\ Td', Td'', Tqo''](s)$:	[1.01, 0.053, 0.1]

Table 2: Transformer, line and load parameter

Transformer-1 nominal power and frequency $[\ Pn(VA)\ , fn(Hz)\ ]$	[210× 10^6 ,60]
Transformer-2 nominal power and frequency $[\ Pn(VA)\ , fn(Hz)\ ]$	[910× 10^6, 60]
Winding 1 parameters $[\ V1\ Ph - Ph\ (Vrms), R1(pu)\ , L1(pu)\ ]$	[13.8 × 10^3,0.0027 ,0.08]
Winding 2 parameters $[\ V2\ Ph - Ph(Vrms)\ , R2(pu)\ , L2(pu)\ ]$	[230× 10^3, 0.0027,0.08]
Magnetization resistance $Rm\ (pu)$	500
Magnetization inductance $Lm\ (pu)$	500
3-phase fault	Transition time [0.1 0.2] sec

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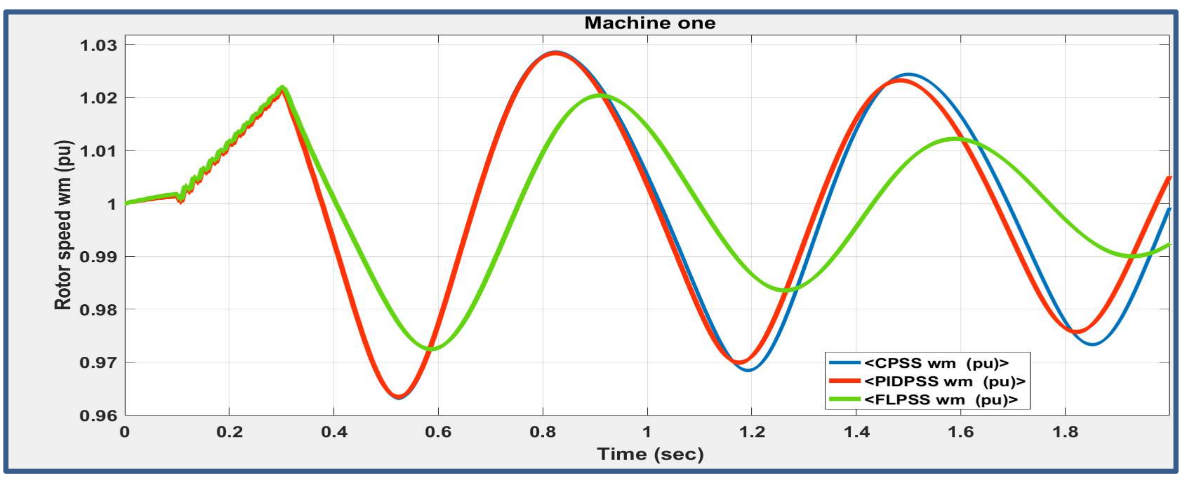
Table 3: power system stabilizer parameter

Sensor time (sec)	15×10^{-3}
Washout	0.7
Lead-Lead	60×10^{-3}

Table 4: Excitation parameter

Low-pass filter time constant Tr(s):	20×10^{-3}
Regulator gain and time constant [Ka (), Ta(s)]:	[300, 0.001]
Exciter [Ke (), Te(s)]:	[1, 0]
Transient gain reduction [Tb(s), Tc(s)]:	[0, 0]
Damping filter gain and time constant [Kf (), Tf(s)]:	[0.001, 0.1]
Regulator output limits and gain [Efmin, Efmax (pu), Kp ()]:	[-11.5, 11.5, 0]
Initial values of terminal voltage and field voltage [Vt0 (pu), Vf0(pu)]:	[1,1.29071]

13. Result and discussion



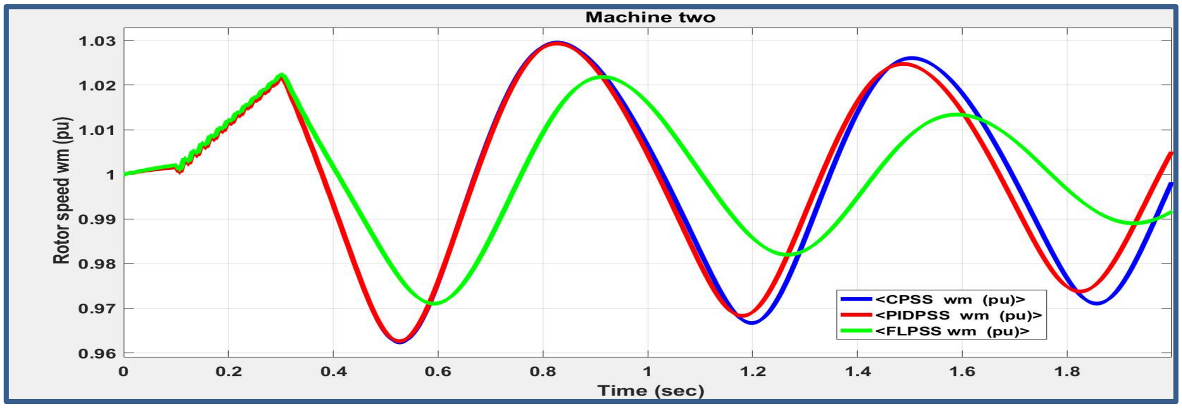


Figure.15. Rotor speed $(\omega_m)$of each Generator with CPSS, PIDPSS and FLPSS.

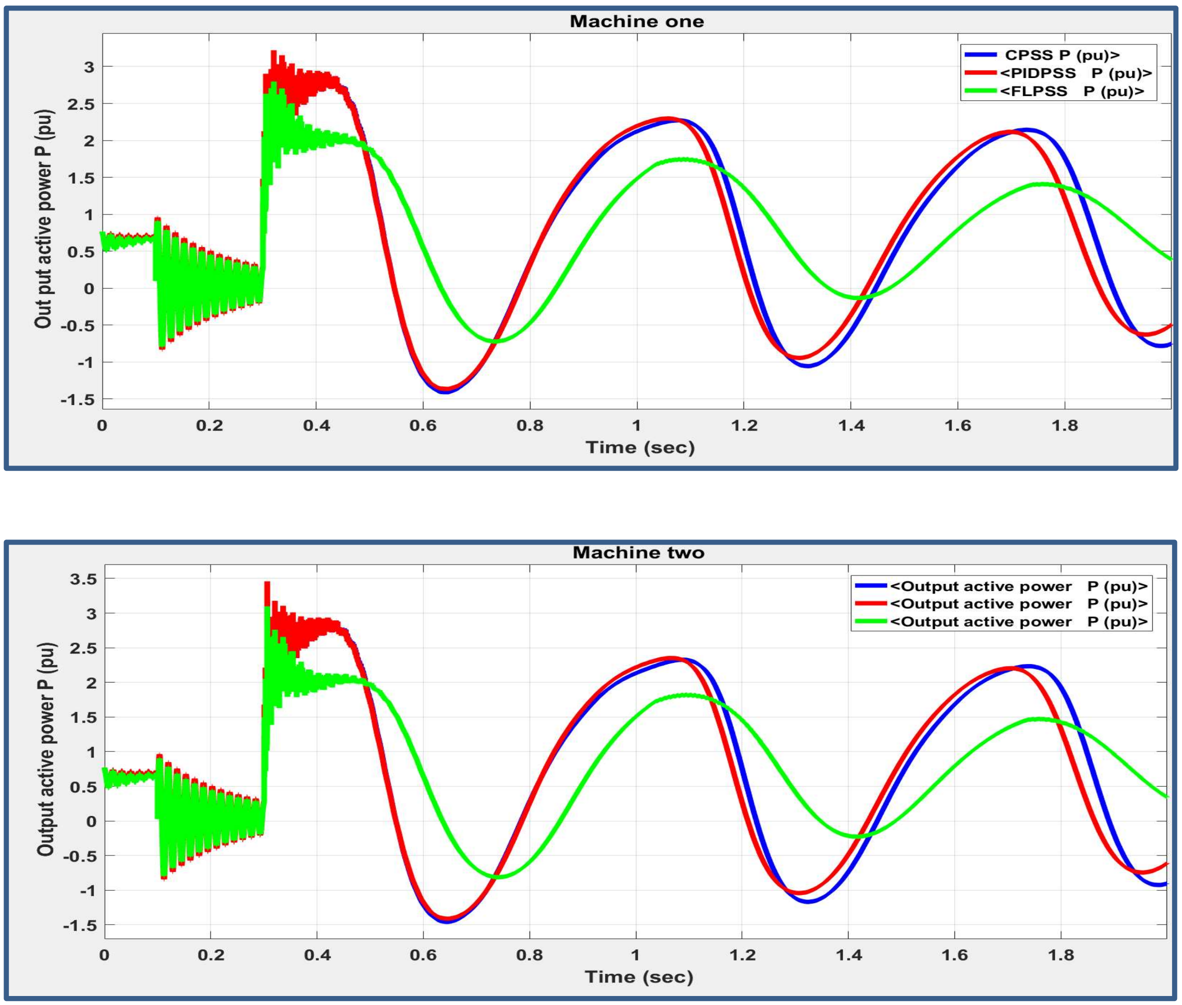


Figure.16. output active power (P) of each Generator with CPSS, PIDPSS and FLPSS.

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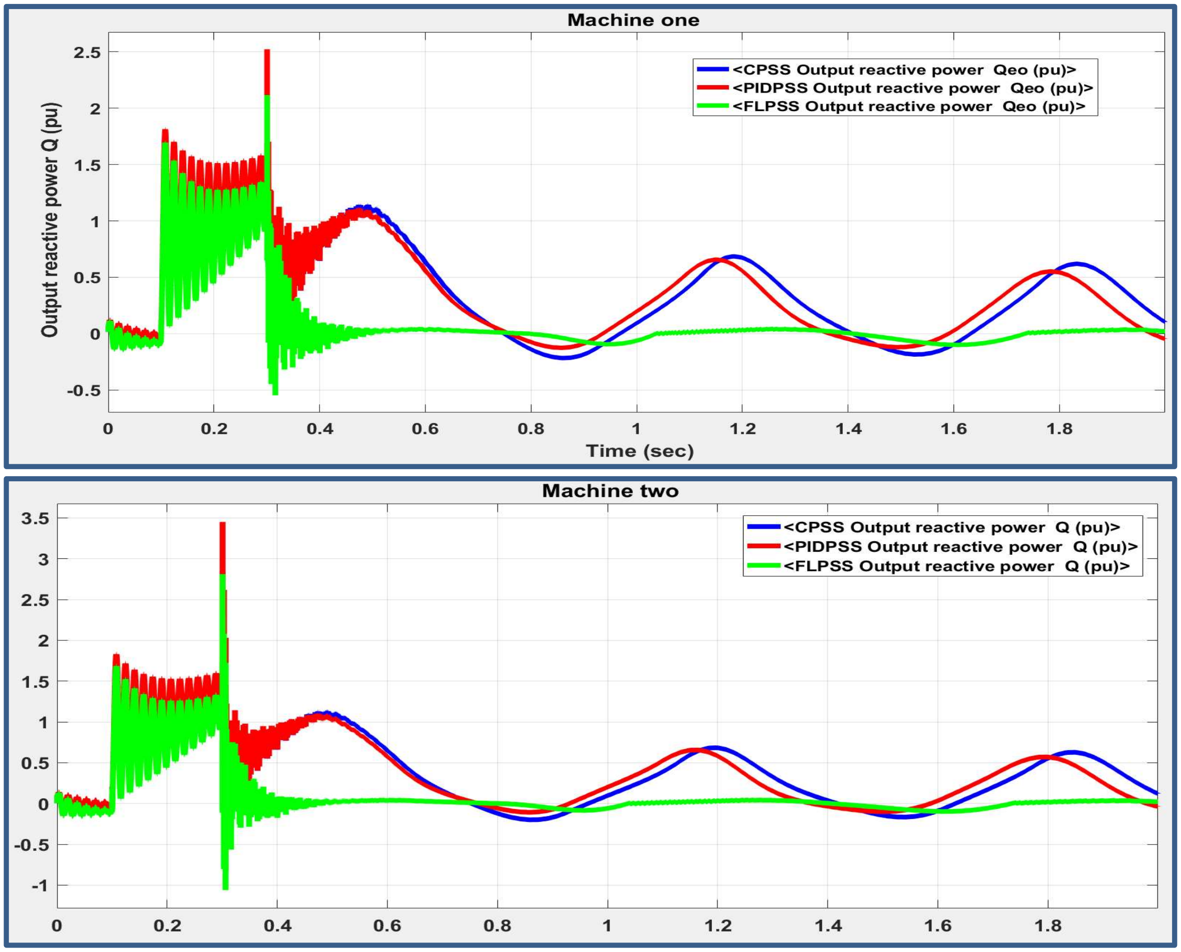
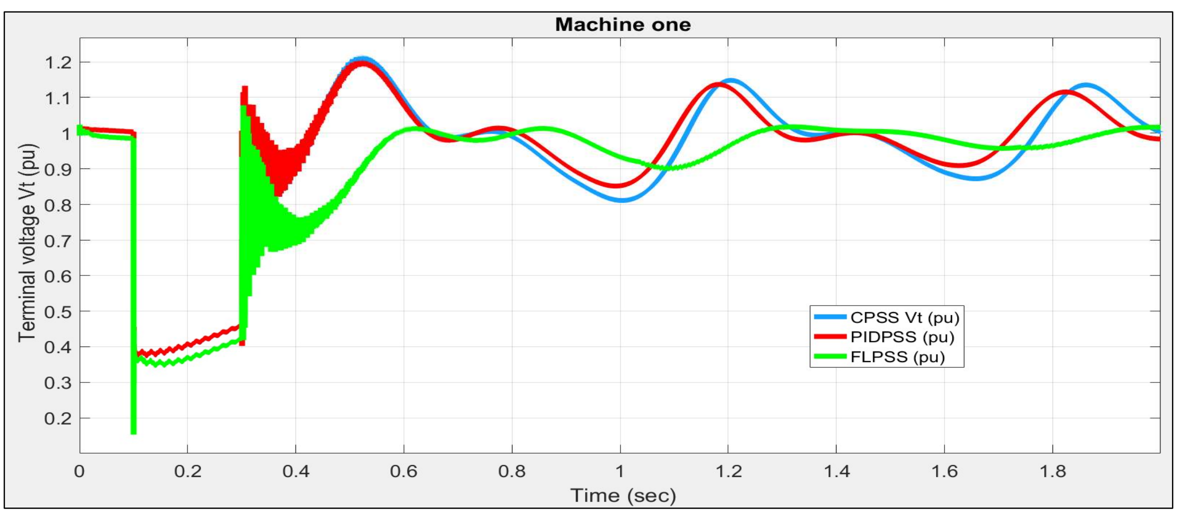


Figure.17. output reactive power of each Generator with CPSS, PIDPSS and FLPSS.



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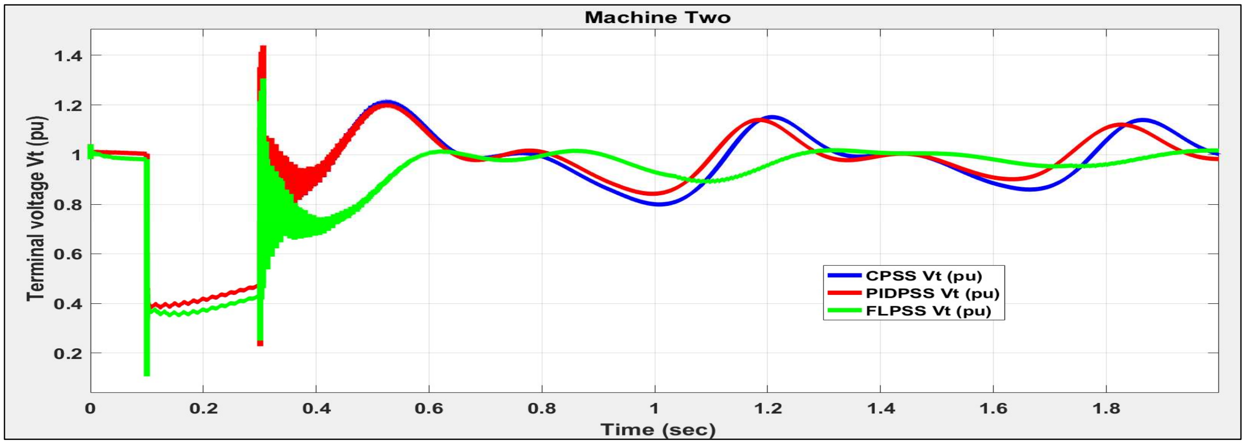

Figure.18. terminal voltage of each Generator with CPSS, PIDPSS and FLPSS.

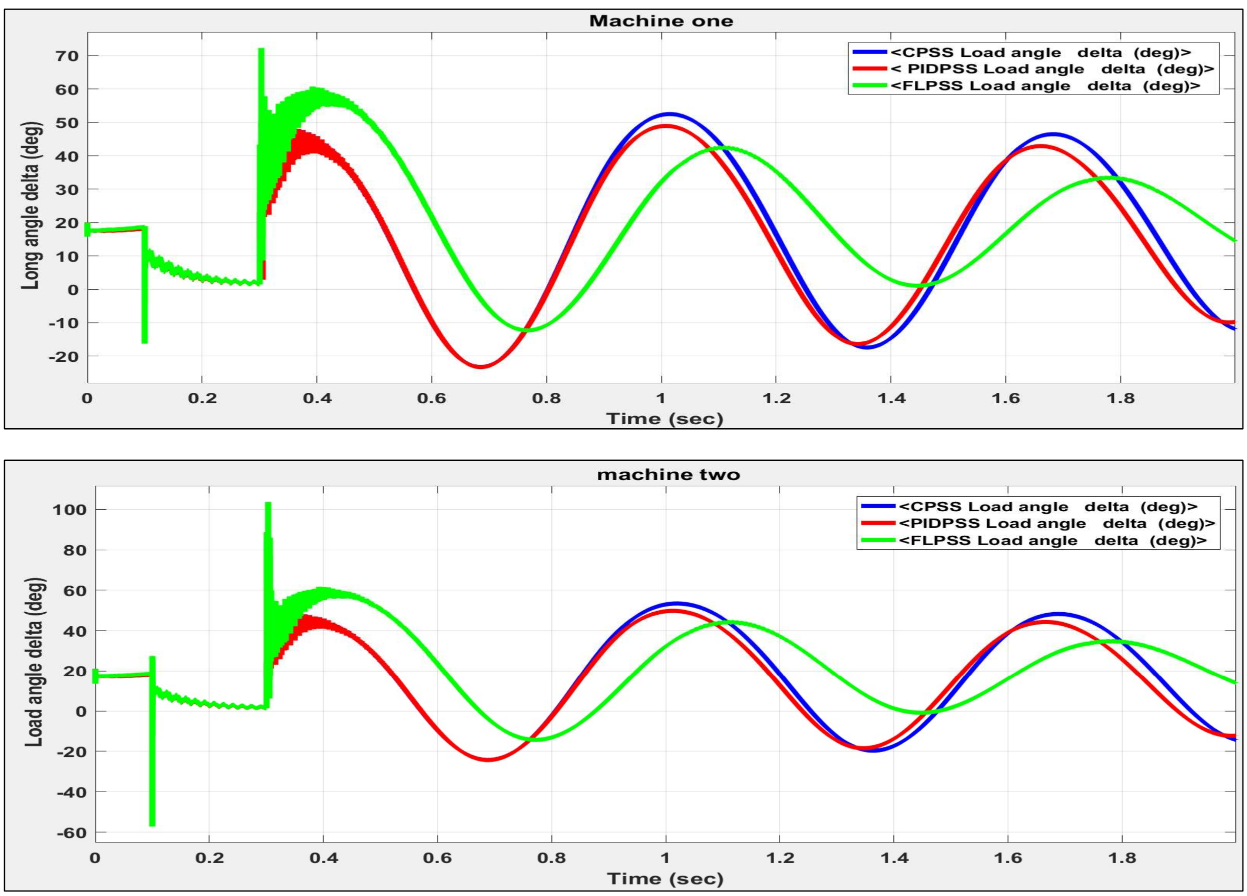

Figure.19. Load angle delta of each Generator with CPSS, PIDPSS and FLPSS.

14. Conclusion

In this paper, dynamic behavior of two machine systems and a single machine installed with a conventional power system stabilizer (CPSS) is investigated under 3-phased fault. Fuzzy based power system stabilizer and proportional-integral-derivative based power system stabilizer (PIDPSS) are designed to improve the transient stability of the given system. Speed deviation $d\omega$ and acceleration power Pa are taken as input parameters (K_{ω}, K_a). While $Vstab$ is taken as an output parameter K_v for fuzzy logic-based power system stabilizer. Proposed controllers were implemented by using MATLAB/SIMULINK. Fuzzy logic-based power system stabilizer (FLPSS) and proportional-integral-derivative based power system stabilizer (PIDPSS) were compared with the conventional power system stabilizer (CPSS). Simulation results indicate that the fuzzy based power system stabilizer installed with two machines and a single machine system, provides better damping characteristics as compared to both conventional power system stabilizer (CPSS) and proportional-integral-derivative based power system stabilizer (PIDPSS) More over it provides improved transient stability as compared to both conventional power system stabilizer (CPSS) and proportional-integral-derivative based power system stabilizer (PIDPSS).

15. future scope of work

1) To design a fuzzy logic power system stabilizer controller for improving transient stability in a multimachine system.

2) Testing the use of more complex network models can be carried out.

3) Using of more membership function and studying the rule-base can achieve more accuracy.

4) Fuzzy logic controller can also be used for other dynamic security assessment techniques such as

I. Dynamic breaking.

II. Static var compensators (SVC).

III. HVDC links.

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المستخلص

تم إستخدام هذه الطريقة لتحسين اداء تخميد مولدين لمحطة توليد قدرة كهربائية . ومن أجل تحقيق استقرارية الدوران للمولد التزامني من حيث التغير في السرعة وقدرة التعجيل تم اختيارها كمدخل لمتحكمة المنطق الغامض (FLPSS). خرج متحكمة المنطق الغامض تم توصيله مع منظم الجهد التلقائي (AVR).

والعامل الأساسي المسبب لعدم استقرارية الجهد هو عدم مقدرة نظام القدرة لمقابلة الطلب للقدرة الردية.بواسطة برنامج الماتلاب للمحاكاة. وسوف يتم تصميم نظام لمحطة قدرة كهربية لدراسة تاثير تغيير القدرة الردية في إستقرار الجهد عند خرج المولد ومحاولة تقليل هذا التأثير ، بواسطة متحكمة بالمنطق الغامض (FLPSS) لمحاكاة عمل مثبت نظام القدرة التقليدي (CPSS) في حالة الاستقرارية العابرة للنظام ومقارنتها مع مثبت نظام القدرة المعتمد على المتحكم التفاضلي التكاملي (PIDPSS).

وعليه تشير النتائج الى أن مثبت نظام القدرة المعتمد على المنطق الغامض (FLPSS) يقدم تخميدا للتذبذبات الكهروميكانيكية الناجمة عن عطل ثلاثي افضل بكثير من كلا مثبت نظام القدرة التقليدي (CPSS) ومثبت نظام القدرة الذي يعتمد على المتحكم التفاضلي التكاملي (PIDPSS). وفي هذه الحالة يعتبر النظام غير خطي اي انه معقد لذلك يحتاج الى تحسين نظام الاثارة للمولد التزامني عن طريق نظرية المنطق الغامض التي تتميز ببساطتها وتطبيقها في كافة أنظمة التحكم الالي الحديثة والمعقدة مثل الأنظمة الغير خطية.

الكلمات المفتاحية : منظم الجهد التلقائي ، مثبت نظام القدرة المعتمد على المتحكم التفاضلي التكاملي ، مثبت نظام القدرة التقليدي ، مثبت نظام القدرة المعتمد على المنطق الغامض ، المنطق الغامض ، برنامج الماتلاب للمحاكاة.