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Damping of Oscillations in Power System Using Fuzzy Logic Controller

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Abstract

Low frequency oscillations are a common problem in large inter connected supply system. Damping oscillations is required for the electrical system to operate safely and steadily.

Low frequency oscillations can be caused by weak tie lines, high AVR gain, and minor disturbances such slight variations in load or generation. These oscillations reduce the transmission lines' capacity to transport power, can lead to synchronization loss, and occasionally even cause the power system to fail. One useful tool for reducing these oscillations is the Power System Stabilizer. To reduce oscillations, PSS gives the excitation system an extra control signal. Traditional lead lag every operating circumstance can not be satisfactorily operated by a power system stabilizer that is built for a certain operating point. Genetic algorithms, neural networks, and fuzzy logic are examples of artificial intelligence-based techniques that are utilized to get around the drawbacks of traditional power system stabilizers.

Keywords : PSS: Power System Stabilizer, AVR: Automatic Voltage Regulator, SMIB: Single Machine Connected to infinite bus, CPSS: Conventional power System stabilizer, FLPSS: Fuzzy Logic Based Power System Stabilizer

I Introduction

Many dynamic devices, including loads and synchronous machines, are part of the highly interconnected modern power system. For the electricity system to operate consistently and adaptably, it must be connected. Changes in load, modifications to the transmission and distribution structure or system faults can cause both minor and major disruptions to the power system.

Electrical torque changes as a result of these disruptions. The two components of the disturbance-induced change in electrical torque are the damping torque and the synchronizing torque [1,2]. Maintaining synchronism requires synchronizing torque, which lowers the rotor angle by increasing the pull between the stator and rotor flux. The excitation current's phase lag or lead causes the damping torque. Oscillations last longer and have the potential to harm the entire system if there is insufficient damping torque. In certain situations, oscillations can result in a loss of synchronization and impact the power transfer across the transmission lines.

The most economical method of reducing low frequency oscillations is to use a power system stabilizer [2]. To counteract the effect of the system's negative damping torque, the power system stabilizer generates positive damping torque in phase with the speed signal. By altering the excitation, the power system stabilizer counteracts oscillations. In order to rectify rotor angle oscillations, it employs phase compensation to modify the time of its corrective signal. The generator excitation system is closed-loop controlled by the power system stabilizer.

II. POWER SYSTEM STABILIZER[PSS]

For the power system to operate steadily and securely, oscillations must be dampened; otherwise, synchronism would be lost, line power transfer capacity will be reduced, and the power system will eventually fail. In order to address oscillatory instability issues, a power system stabilizer supplies an additional excitation control signal. To counteract the effect of the system's negative damping torque, Power System Stabilizers generate a positive damping torque in phase with the speed signal [3, 4, 5].

The primary purpose of excitation control is to preserve the stability of the power system. Closed loop control is used to the system in order to dampen low frequency electromechanical oscillations. The linear control theory is primarily applied by PSS in electric power systems.Approach that is based on a linear model of a fixed power system configuration and is adjusted at a certain operating condition. This kind of fixed parameter PSS, called conventional PSS (CPSS), is widely used in power systems [5].

III. Fuzzy Logic-based PSS

A knowledge-based system for control operations is fuzzy logic. When a clearly defined control aim is lacking, the fuzzy logic control strategy seems to be the most appropriate one to use. Either the system to be regulated is complicated, or there isn't a precise mathematical model for it. Numerous power system applications are beginning to use fuzzy logic control, which has become a potent tool [6,7].

The benefits of fuzzy controllers are numerous.-

1. A quick and easy approach.

2. No precise mathematical model of the system is required.

3. Nonlinearity of any complexity can be handled by it.

4. It is predicated on the generic IF-THEN structure of language rules.

5. Compared to traditional nonlinear controllers, it is more resilient.

6. The performance of the controller is not considerably impacted by changes to the parameters and operating conditions of the controlled system.

IV. Fuzzy Controller

A fuzzy inference mechanism and a series of rules regulate fuzzy logic controllers, which are a type of stare variable controller. Without an analytical description of the control algorithm or any codified knowledge about the controlled item in the form of mathematical models, the fuzzy logic control algorithm mimics the mechanism of control that humans implement.

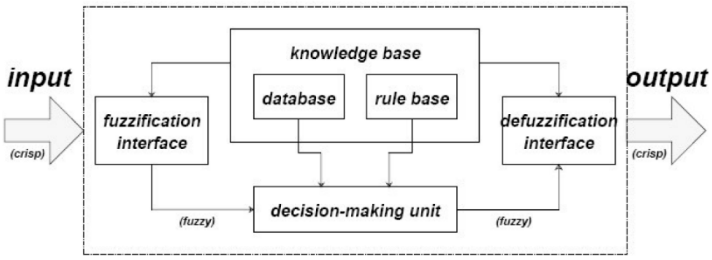

Fig :1: Block Diagram for a Fuzzy Controller System [8]

Membership Function

Voltage is the output variable and speed deviation and acceleration are the input variables selected for the fuzzy controller. Linguistic variables are utilized to represent input and output variables in fuzzy logic systems. The number of linguistic variables employed is typically odd. The design becomes increasingly complex as the number of rules rises in tandem with the number of language variables. There are various membership function types, such as trapezoidal and triangular, Gaussian and so forth. Each input and output variable in this case has seven linguistic variables chosen using a triangle membership function [3].

Table :1 Linguistic variables for membership functions in input and output

LN	Large Negative
MN	Medium Negative
SN	Small Negative
Z	Zero
SP	Small Positive
MP	Medium Positive
LP	Large Positive

Adjacent fuzzy subsets share 50% of the input and output variables' membership functions.

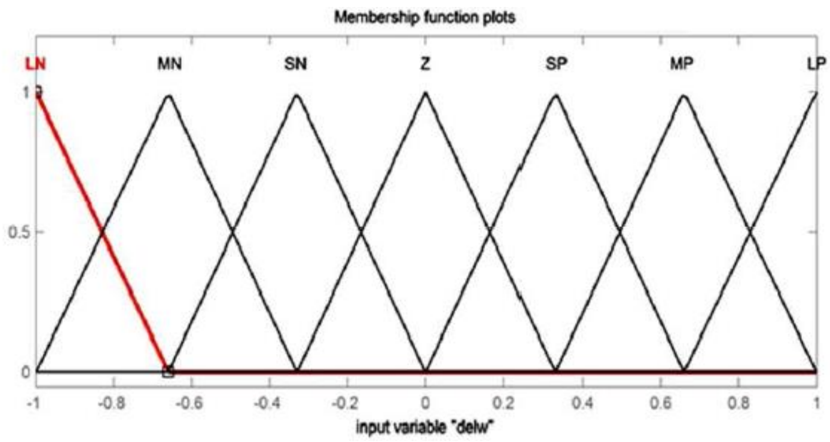

Figure 2: Function of Triangular Membership

V. MATLAB Simulink Model of SMIB with FLPSS

Figure 3 displays the SMIB MATLAB model using FLPSS. Fuzzy Logic-based PSS takes the role of traditional PSS. The system parameter determines which normalization and renormalization factors are used.

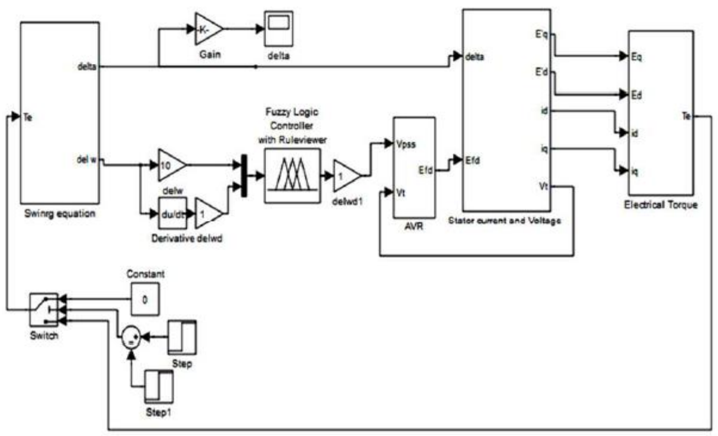

Figure: 3 SMIB Model in MATLAB with FLPSS

VI. Design of FLPSS in MATLAB

Based on fuzzy logic the fis file in MATLAB is used to prepare PSS, and Fig. 4 illustrates the file's basic format. The fuzzy inference system (FIS) properties listed below are put into practice.

And Method: Min

Or Method: Max

Implication: Min

Aggregation: Max

Defuzzification: Centroid

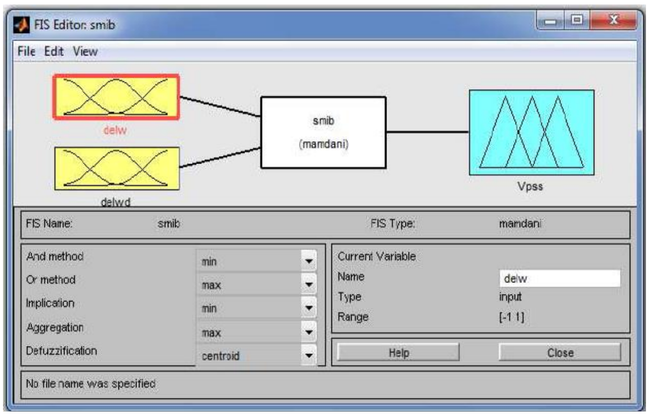

Figure 4: FIS Editor

Here, the MAMDANI fuzzy inference system—also referred to as the maximal minimal method—is employed. After choosing the lowest value for each rule, it adds up all the rules to determine the highest value possible.

Both of the inputs to the FIS System have seven input membership functions, which add up to 7*7=49 rules. These rules are displayed in the form of a fuzzy rule viewer in Figure 5-8.

The Viewer of Rules A road map of the entire fuzzy inference procedure is shown in Figure 5. The membership functions that the antecedent (the if-part of each rule) refers to are displayed in the first two plot columns. The membership functions are displayed in the third plot column.

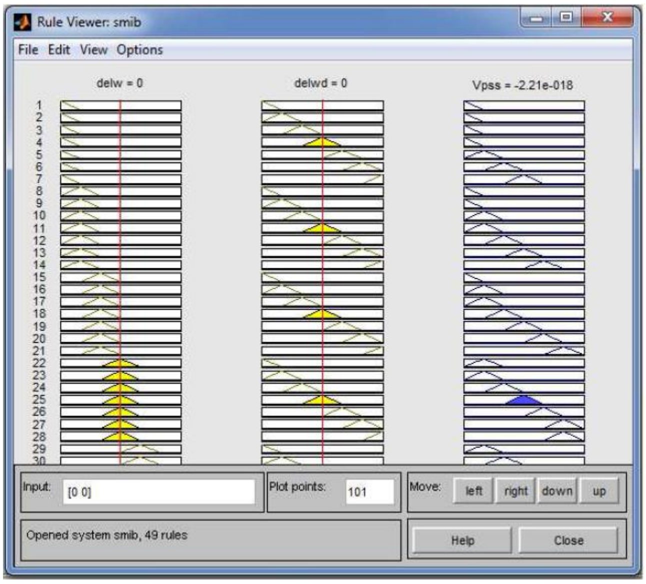

Figure 5- Viewer for Fuzzy Rules

Cited by the consequent, which is each rule's then-part. The antecedent rules that were fired for a specific value are represented by the yellow color (or shading) in the first two plots, and the antecedent's effect on the output is shown by the blue color (or shading) in the third column. The final, exact value determined by the centroid defuzzification approach is indicated by the blue color line in the third column's final block.

VII Simulation Results

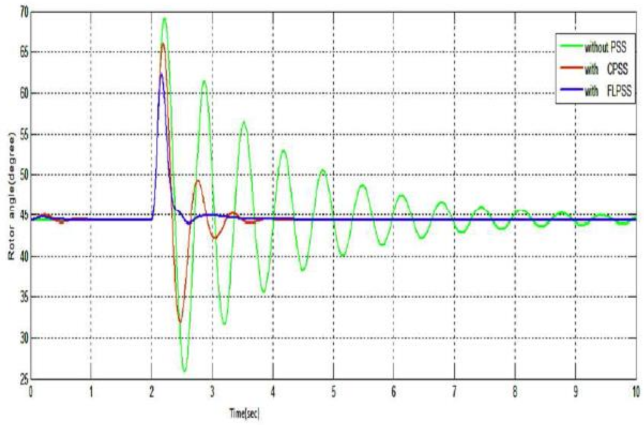

Figure 6: Rotor angle variation for Pt=0.9, Qt=0.6, with CPSS and FLPSS, and without PSS

For 0.1 seconds, simulation results are obtained for generator-side faults. Results of rotor angle variation with CPSS, FLPSS, and no PSS for Pt=0.9 and Qt=0.6 are displayed in Figure 6.This result shows that the PSS based on fuzzy logic has the least amount of overshot and settlement time.

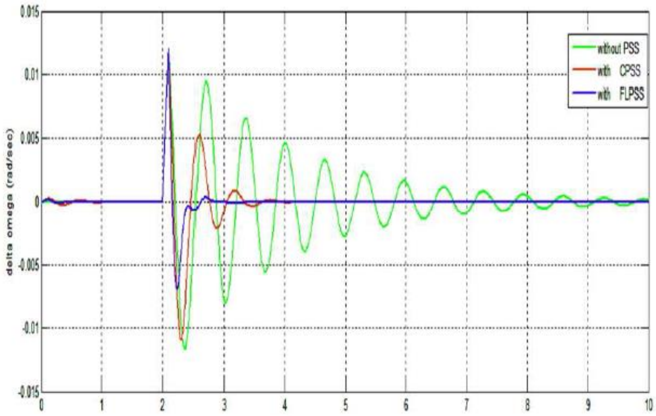

Figure 7 : Delta omega variation for Pt=0.9, Qt=0.6 with CPSS and FLPSS, and without PSS

Results of variation in delta omega without PSS, with CPSS and FLPSS for Pt=0.9, Qt=0.6 are displayed in Figure 7.This result shows that the PSS based on fuzzy logic has the shortest settlement time. Table 2 presents the analysis of the results.

Table -2: Analysis of SMIB system results for generator-side fault

Condition	Rotor Angle	
Pt=0.9, Qt=0.6	Overshoot	Settling Time
Without PSS	69	Greater than 10 Sec
With CPSS	66	4.3 Sec
With FLPSS	63	3.6 Sec

VIII Conclusion :

This research first examines the efficacy of a traditional power system stabilizer before introducing a fuzzy logic power system stabilizer. The fuzzy controller receives voltage as the output signal and speed deviation and acceleration of the synchronous generator as input inputs.

When it comes to dampening effect and settling time, FPSS performs better than power system stabilizers. Thus, the controller may be implemented effectively. Consequently, as the oscillations are damped out much more quickly, it can be said that the suggested FPSS performs significantly better.

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