T-S FUZZY PID CONTROLLER FOR AN AVR SYSTEM USING

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ABSTRACT: In this paper, a T-S fuzzy Proportional integral derivative (PID) controller is proposed, for Automatic voltage regulator(AVR) of synchronous generator using fuzzy PID.Transfer function based mathematical model of AVR system with generator constitute transfer function of amplifier, exciter, generator, and sensor., these components must be linearized, which takes into account the major time constant and ignores the saturation or other nonlinearities. As a nonlinear controller can control a nonlinear process more efficiently, fuzzy controller can provide better performance in terms of smaller overshoot and small settling time. The proposed controller is developed and simulated. The simulation results show that both the transitory performance and the steady state performance are better than that of conventional PID controller.

- INTRODUCTION

An AVR is employed for automatically maintaining the output terminal voltage of the generator at set value under varying load. An AVR is a feedback control system in which an error signal (reference terminal voltage- actual terminal voltage) adjust the excitation of the generator.

The fluctuations in terminal voltage mainly occurred due to the variation in load. This variation may damage the system and equipment. AVR system prevent the variation in the voltage beyond allowable limit. An AVR system works on the principle of detection of errors. The generator voltage is sensed by direct connection to the output terminals of the generator. This sensed voltage is then fed to a measurement unit where it is converted to a low value direct voltage proportional to the generator voltage. Thus, output voltage of a generator obtained through a potential transformer is rectified filtered and compared with a reference. Error voltage is the term given to difference

between the reference voltage and the actual voltage. This is then amplified by an amplifier and is supplied to the main exciter. The amplifier is mainly used to modify the error to increase the accuracy and sensitivity of the AVR. The error signal is used to adjust an average value of the field current.

For efficient performance of AVR control system , PID controller gain parameters need to tuned efficiently. The key objective of the controller design is to accomplish better control performance for stability and robustness form the set point changes and load disturbances In ref[1] PID controller parameters of an AVR system are tuned optimally using the particle swarm optimization (PSO) algorithm. In ref[2] PID controller parameters of AVR system are tuned using hybrid Genetic Algorithm and Bacterial Foraging. In recent years , many optimization algorithms were proposed to tune the PID gains of the AVR system. Such as Genetic algorithm [3], Craziness based particle swarm optimization[4],Reinforcement Learning Automata (RLA) [5], Artificial Bee Colony (ABC) [6]. The main difference between two types of fuzzy such as Mamdani and Sugeno , is that the Sugeno output membership functions are either linear or constant.[7]The Takagi-Sugeno (T-S) fuzzy model has been prevalent because of its convenient and simple dynamic structure . This work proposes T-S fuzzy Proportional integral derivative (PID) controller for AVR system.

- AVR SYSTEM

An AVR system controls the system voltage and brings the operation of the machine nearer to the steady state. It reduces the over voltages which occurs due to the sudden loss of load on the system. It increases the excitation of the system under fault conditions to ensure that the maximum synchronizing power exists at the time of clearance of the fault. During the sudden change in load in the alternator, automatic voltage regulator helps in introducing a change in the excitation system to provide the same voltage under new load system. AVR al... ...nce and stability condition. An AVR system is used ...l appliances and electrical machines have varying ... of four main components, namely amplifier, exciter ...hese components must be linearized for mathematic... ...e major time constant and ignores the saturation or c...

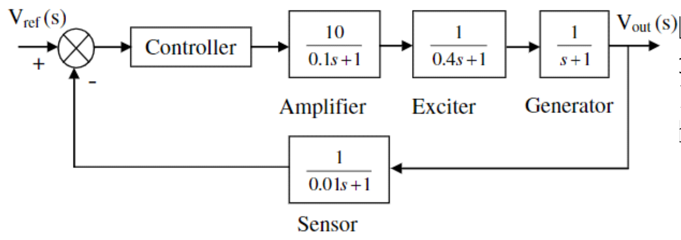


Fig1- Block diagram of AVR[1]

It consist of (a) PID Controller(b) Amplifier Model, (c) Exciter Model, (d) Generator Model, and (e) Sensor Model.

- DEVELOPMENT TAKAKGI-SUGENO FUZZY PID CONTROLLER

This section discusses the Takagi-Sugeno method of fuzzy inference. And development of T-S Fuzzy PID controller . Deciding Rules to obtain proper control action is very important[8,9]

A typical rule in a Sugeno fuzzy model has the form:

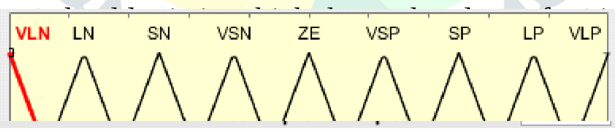
If Input-1 is x and Input-2 is y, then Output is z = ax + by + c

The fuzzy inference process under Takagi-Sugeno Fuzzy Model (TS Method) works in the following way:

Step 1: Fuzzifying the inputs − Here, the inputs of the system are made fuzzy.

Step 2: Applying the fuzzy operator − In this step, the fuzzy operators must be applied to get the output.

Fuzzy logic is a form of m... ...les may be any real number between 0 and 1 . I... ...ere the truth value may range between completely t... ...h values of variables may only be the integer values 0... ..., representing, manipulating, interpreting, ...d lack certainty



We have designed a Taka... ...unction. In Takagi-Sugeno fuzzy model the input para... ...e output parameters are of discrete form are as shown...

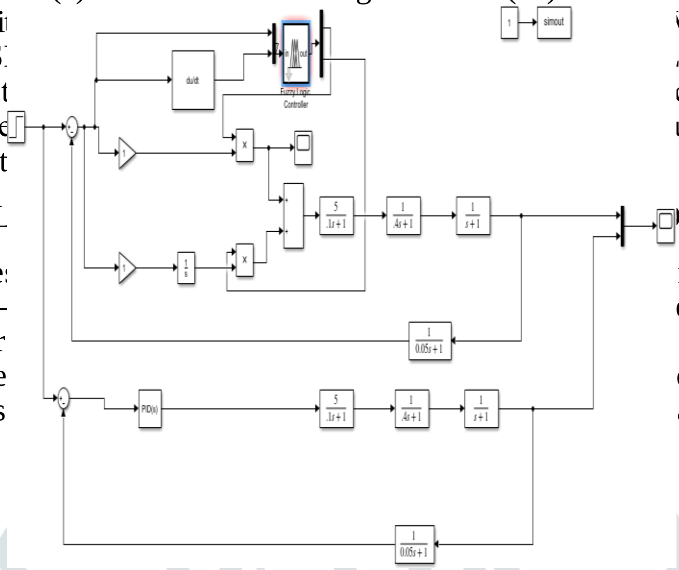
F...

Keeping in mind the behavi... ...error we designed separate set of rules of both Kp and ... ...r output variable Kp and Ki are presented in Fig4 and Fi...

U	de/dt								
e	VLN	LN	SN	VSN	ZE	VSP	SP	LP	VLP
VLN	VLN	VLN	VLN	VLN	VLN	LN	LN	VSN	ZE
LN	VLN	VLN	VLN	LN	LN	SN	VSN	ZE	SP
SN	VLN	VLN	LN	SN	SN	VSN	ZE	VSP	LP
VSN	VLN	LN	SN	SN	VSN	ZE	VSP	SP	LP
ZE	VLN	LN	SN	VSN	ZE	VSP	SP	LP	VLP
VSP	LN	SN	VSN	ZE	VSP	SP	SP	LP	VLP
SP	LN	VSN	ZE	VSP	SP	SP	LP	VLP	VLP
LP	VSN	ZE	VSP	SP	LP	LP	VLP	VLP	VLP
VLP	ZE	VSP	SP	LP	VLP	VLP	VLP	VLP	VLP

Fig5 Rule table for output variable Ki.

These two set of rules are developed for output of T-S fuzzy controller . The output of the fuzzy logic controller corresponds to the amount the generator field current should be increased or decreased in order to bring the output voltage to its desired value. The linguistic variables used (in the fuzzification process) for the voltage error (e) and the rate of change of error (de) are labelled as zero (Z), Very large positive (VLP), Large posi VSP), Very Small Negative (VSN), Small Negative (S .N).A typical rule obtained from the rule matrix is: if t change of voltage error" is negative big (NB), then the utput signal is converted to a crisp value using the cent



- SIMUL NTROLLER

The Simulink model is de nse of a conventional PID Controller with that of a T- em of the proposed control structure contains operator the gain factors according to the current trend of the ontrol rules are developed with the error and process al gains are consequent of each rules.

Fig6 - Simulink model of AVR with T-S fuzzy controller.

The Simulink model AVR with T-S fuzzy controller and conventional PID Controller is as shown in Fig6. The PID gain parameters are Kp=1.2; Ki=0.2 and Kd=0. (Trial and Error method). The PID gain parameters are fixed while T-S fuzzy controller parameter may vary depend on firing of control rule. To reduce the disturbance Kd parameter is taken as zero. Using this Simulink model, we compare the Takagi-Sugeno model with a Conventional PID Controller.

The proposed methodology R system. The AVR system consists of amplifier, exciter le set was used to create the nine membership function T od is used to decide a value universe of discourse gain oller. The controller control action depends on its gain pa rshoot and settling time then the Ki gain parameter is to b llations are reduced then Kp gain parameter is to be decr separate rules are developed to vary for the output variabl ned is as follows.

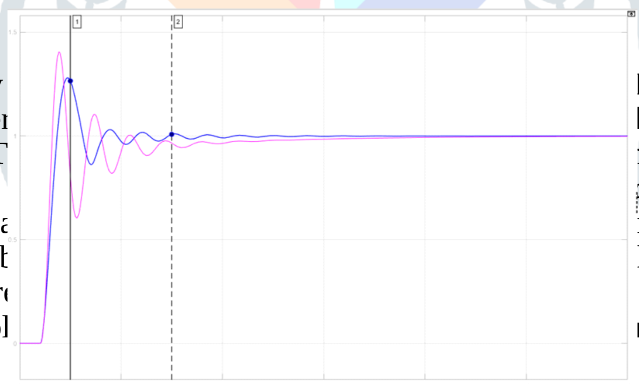


Fig7-response of AVR system

Fig7-Response of AVR system with T-S fuzzy controller and conventional PID controller (blue coloured response for T-S fuzzy and red coloured for conventional PID controller) for 1% change in reference voltage. From the Simulink result shown in Fig 7,it can be seen that with T-S fuzzy PID controller better time domain response in terms of overshoot and settling time is achieved than conventional PID Controller. The overshoot value and settling time for 1% step disturbance in reference voltage is as tabulated in Table 1

Table 1: Time domain response specification

Overshoot value	Settling time
1.281p.u.	17.2sec

- CONCLUSION

Here, the results of comparison between the fuzzy controller and the conventional PI controller, fuzzy controller of different membership functions, fuzzy controller with difference inference systems, and fuzzy controller with different disturbances are obtained. The comparison results of the fuzzy controller and the conventional PI controller show clearly that the fuzzy controller reaches the steady state faster than the conventional PI controller. It also has reduced peak overshoots than the latter.The peak overshoot and settling time is considerably reduced.

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