Fuzzy based Excitation system for Synchronous Generator

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ABSTRACT-

Power system stability is essential requirement to reliable and economical operation of power systems. The quick-response excitation control with PSS is used as a power system stability improvement measure at the generator. For the effective and satisfactory performance of the Excitation control system of Synchronous generator, the fuzzy expert system has implemented in this article. A fuzzy excitation control system (FECS) based on the fuzzy theorem and having the function of both AVR and PSS, ware established to improve power system stability. To study the behavior of the Excitation control system with fuzzy logic controller (FLC), ST-2A type ECS Model is consider in this paper. The simulation test results with this Excitation control system model using fuzzy logic controller has found more satisfactory than without using it. This expert system should contribute to effective control of Voltage, reactive power flow and enhancement of system stability. In addition, it should be capable of responding instantaneously to a disturbance and to the modulation in the generator field, to enhance transient stability and small signal stability respectively.

Keywords:-Fuzzy logic controller (FLC), Excitation control system (ECS), Static Excitation system,stability

1. INTRODUCTION-

The power system is a dynamic system and it is constantly being subjected to disturbances. It is important that these disturbances do not drive the system to unstable conditions. From the power system point of view, the excitation system of synchronous generator must contribute for the effective voltage control and enhancement of the system stability[1]. The requirement for electric power stability is increasing along with the popularity of electric products. At present, power system can be simulated and analyzed based on a mathematical model; however, uncertainty still exists due to noise, lightning and change of loads and an occurrence of fault. Recently, fuzzy theory has been applied for a number of studies on power system. Being highly flexible easily operated and revised, theory is a better choice, especially for a complicated system with many variables. From the power system point of view, the excitation system[7] must contribute for the effective voltage control and enhancement of the system stability [9]. It must be able to respond quickly to a disturbance enhancing the transient stability and the small signal stability. Arising out of the need of the present time it is now mandatory to use the digital technology to perform the control and protection functions in the modern excitation control systems.

Recently the most powerful software MATLAB-SIMULINK has emerged as an appropriate tool in analyzing the various results of excitation systems [8] and developing the better and efficient control systems [5] by manipulating the real time operation parameters. This paper elaborates the results of experiments conducted on the fuzzy excitation control system [6] based on AC/DC power system simulator using fuzzy logic toolbox [4] of MATLAB software. Here the modern design of fuzzy excitation control system based on logical rules ware compared with the conventional quick response excitation system. Using this modern design of fuzzy excitation [3] control system based on fuzzy set theorems [4] with the function of both AVR and PSS achieves the much-needed improvement in the power system stability. By introducing the required slight modification in the logical rule base of this advanced design of the fuzzy logic controller it can be implemented in different IEEE type ECS [2] models varying from AC, DC, to Static.

2. CONTROLLER CONFIGURATION:

Fuzzy logic controller [FLC] has many advantages. simple in structure, it is relatively easy to be realized mathematical model of the controlled system is not required. Variation of the parameters and operating conditions of a controlled system does not affect the performance of the controller. The basis configuration of Fuzzy logic controller as shown below:

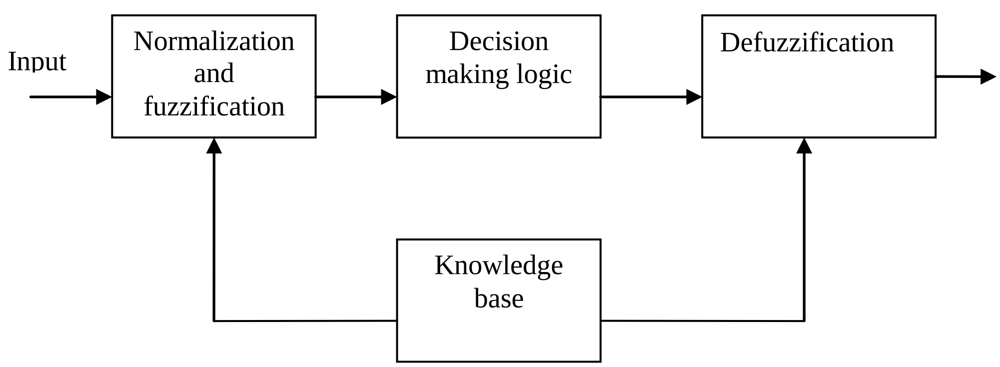

Fig.1-Fuzzy logic controller configuration

The principal components are
A Fuzzification interference, a knowledge base, decision-making logic and a Defuzzification interface.

1. The Fuzzification interface involves the following functions:
Measures the value of the input variables.

[b] Performs the function of Fuzzification that converts the input data into suitable linguistic values, which may be viewed as labels of fuzzy sets.
[c] Performs the scale mapping that transfers the range of values of input variables into corresponding universe of discourse.

2. The knowledge base: Comprises of knowledge of application domain and the attendant control goals. It consists of a "data base" and a "linguistic fuzzy control base."
3. The database provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulations in fuzzy logic controllers. The rule base characterizes the control goal policy of the domain experts by means of a set of linguistic control rules.
4. The decision making logic: Is the kernel of an Fuzzy logic controller, it has the capability of simulating human decision making based on fuzzy concepts and of interring fuzzy control actions employing fuzzy implications and the rules of inference in Fuzzy logic.
5. The Defuzzification inference performs the following functions:
[a] A scale mapping, which converts the values of output variables into corresponding universe of discourse.
[b].Defuzzification, which yields a non-fuzzy control action from an inferred fuzzy control action.
At present there is no systematic procedure for the design of a Fuzzy logic controllers. However the principal design parameters for a fuzzy logic controller are the following:
(1) Fuzzification strategies & interpretation a Fuzzification operator (fuzzier)
(2) Data base Discretization / normalization of universe of discourse.
Fuzzy partition of the input and output spaces. Completeness Choice of membership function of a primary fuzzy set.
(3) Rule base.
(a) Choice of Process State (input) variables and control (output) variables of fuzzy control rules.
(b) Source and derivation of fuzzy control rules.
(c) Types of Fuzzy control rules.
(d) Consistency, interactivity, completeness of fuzzy control rules.
(4) Decision making logic.
(a) Definition of a fuzzy implication.
(b) Interpretation of the sentence connective.
(c) Interpretation of the sentence connective.
(d) Definition of a compositional operator.

(5) Inference mechanism. Defuzzification strategies & the interpretation of a defuzzification operator.

3. FUZZY LOGIC CONTROLLER FOR TYPE ST-2A ECS

FECS based on fuzzy theorem and having the function of both AVR & PSS has established to improved power system stability. In Fuzzy excitation control system, the main part is fuzzy logic controller. For designing the fuzzy logic controller, takes different steps parts.

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For the Fuzzy logic controller voltage error signal (V_e) and change in error signal (dV_e) are chosen as inputs and the control action (e_f) is taken as the out put. All the variables are take on common universe of discourse. [-1 to +1].

From the data of inputs and output variables were portioned as shown in the membership function diagram given the Fig.2.

For constructing the rule base of the fuzzy logic controller the data pair generated by the exciter are used. A programming is as follows:

Let the data pair chosen be V_e1 and ef1 from the membership function & 'V_e' it is checked that V_e1 to which set of membership function with highest degree.

Let V_e1 belongs to Ps for highest degree then if part of the rule is

If V_e is PS.

The same procedure is used for V_e1 and says the highest degree corresponding to dv_e1 is Z.

Then the complete if part of the rule is.

If 'v_e is PS and 'v_e' is Z.

Now the procedure is again repeated for ef1 & says the highest degree corresponding to ef1 is PM.

Therefore the then part of the rule is

Then 'ef' is 'PM'

And the complete rule is

If 'v_e' is 'PS' and 'dv' is 'Z' then 'ef' is 'PM'

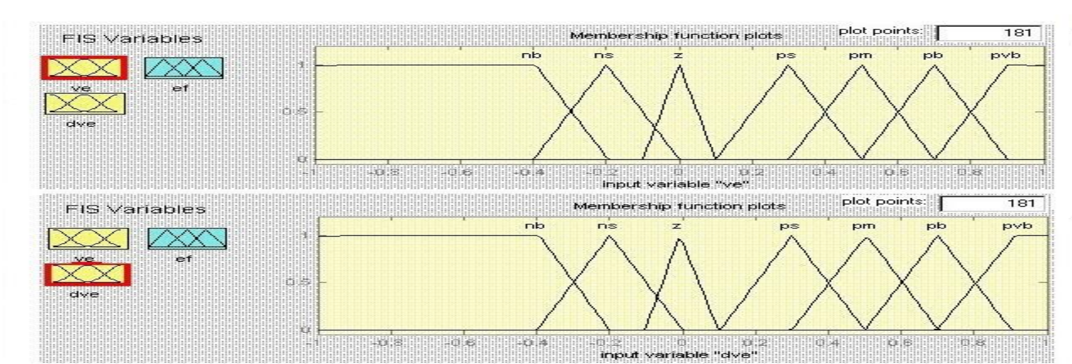
These rules shown in

Now the next data pair is taken and on the same lines the next rules are obtained. The procedures are continuing for all data pairs.

After forming all the data rules for all the available data, there may be some rules, which has generated; such rules are to be taken only once.

There may be some rules, which may have same if part but different then part. However in a rule base for a given if part one that part is possible. In such cases only that than part is taken which appear maximum number of times and the remaining than parts are dropped.

Using the eight rules shown in Fig.3, the ECS is simulated and for step input the results were observed. It is seen that as long as the error is positive, the response is satisfactory.



Input Membership Functions

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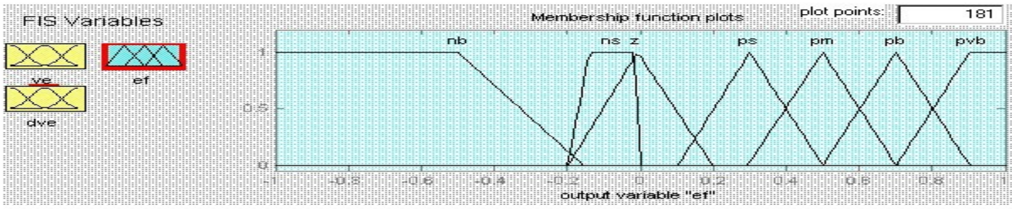
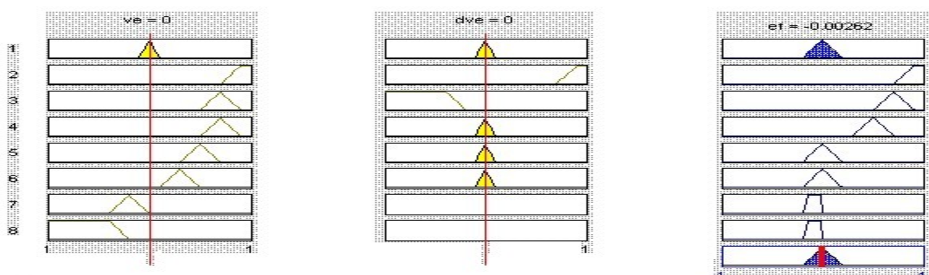
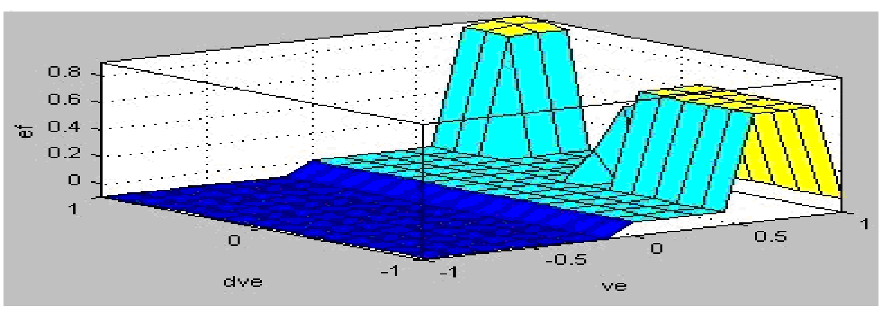


Output Membership Function

Fig.2 Mambership function of designed fuzzy logic controller



Rule View for FLC



Surface View For FLC

Fig.3 Rule Base for Designed fuzzy logic controller.

By small modification in the rule-base, this fuzzy logic controller is implementing in any type of excitation systems.

4. PERFORMANCE OF FUZZY EXCITATION CONTROL SYSTEM-

The simplified IEEE type ST-2A model with fuzzy logic controller is in the block diagram form shown in fig.4

This type excitation model represents a compound-source rectifier excitation system. The exciter power source is formed by phasor combination of main generator armature voltage and current. The regulator controls the exciter output through controlled

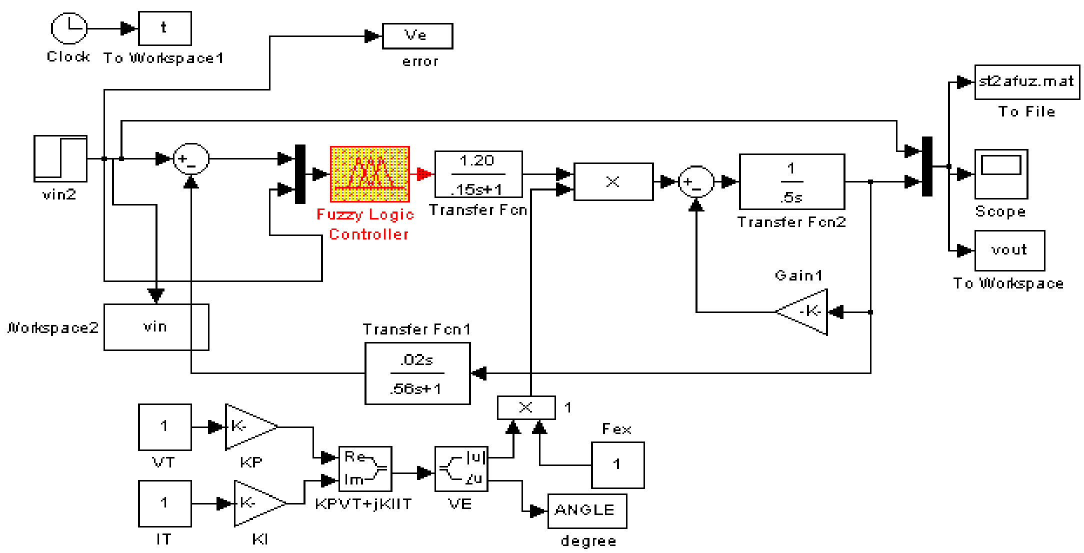


Fig.4 ST-2A ECS Model with FLC.

saturation of the power transformer. Using SIMULINK and FUZZY LOGIC Toolbox develops the model of this system is shown in Fig.4 . In this system previously designed fuzzy logic controller with two input and single output is connected in forward path. This is a closed loop control system. The Input of this system is step input signal.

The time response of this fuzzy excitation control system to a step inputs are shown in Fig. 5. Studying the small signal system stability; analyze the performance of the system.

The performance results of the system are shows as under.

Settling time =6.5sec
Maximum Overshoot =nil
Steady state error=2%
Delay Time=1sec

Steady state error and overshoot is satisfactorily reduced. Thus fuzzy excitation control system is much better then the conventional ST-2A Excitation control system. Thus the system stability is improved

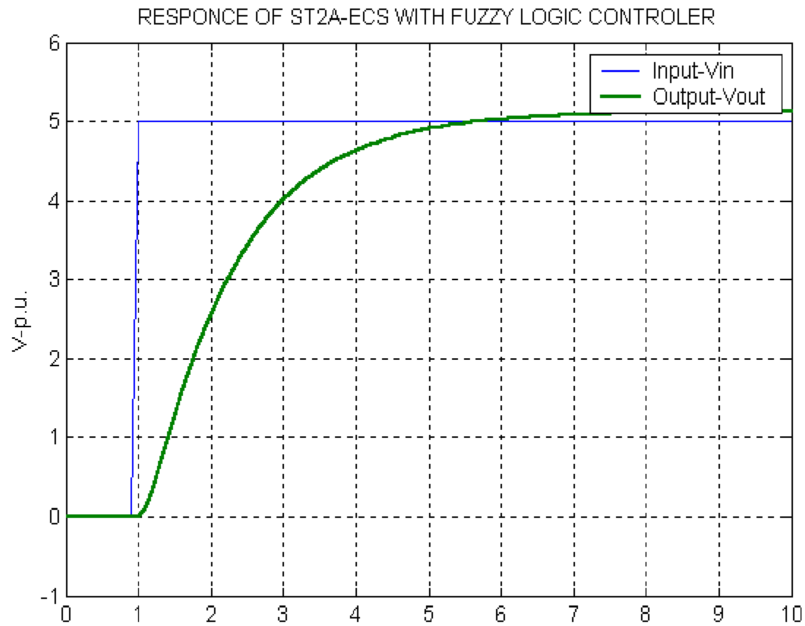


Fig.5. Performance of ST-2A ECS model with fuzzy logic controller

5. CONCLUSION

Synchronous Generator Excitation control is one of the most important necessities to enhance power system stability and system performance. The different type of excitation control system models (ECS) i.e. DC, AC, ST, Digital ECSs have been studied for analyzing the performance behavior and stability of the system. Recently the digital technology has implemented in the direction of modernization of ECSs.

Using fuzzy logic toolbox, the fuzzy logic controller (FLC) with two input and single output has designed and developed. Fuzzy Logic controllers are the processes user-defined rules governing the target control system, it should be modified easily to improve or drastically alter system performance.

In the present work, the fuzzy logic controller has developed for studying the IEEE type Static excitation control system model -ST-2A.The main aim of designing this controller is to enhance the performance behavior of the ECS models.

The simulation test results of FECS shows the improved the ECS performance characteristics. Steady states error, overshoot, settling time is reduced. This simulation result shows the effectiveness of the proposed FECS over the conventional quick response ECSs.

The FECS is applying to the "AC/DC" power system simulator with any type of synchronous generator units, which simulate the actual generator characteristics. It can also be implemented in hardware, software, or a combination of both. This FECS could also be applied into generator and single machine infinite bus system.

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