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Turbo-generator System Controlled by Fuzzy and ANFIS methods for the Operation at Normal and Abnormal Conditions

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ABSTRACT

This paper introduced modeling , simulation , and control of the turbo-generator(consisting of steam turbine with three stages including high pressure ,intermediate pressure and low pressure units with reheater and governor valve . this turbine is coupled with synchronous generator feeding an infinite bus bar through step up transformer and two parallel transmission lines).Two controllers are proposed; the first is the fuzzy logic controller , and the second one is adaptive neuro-fuzzy inference system controller (ANFIS) . The two controller control the governor position of the steam turbine at normal and abnormal conditions. ANFIS controller in this work introduced better performance and fast response than fuzzy controller at different operating conditions.

Key words: Fuzzy controller; ANFIS controller; Turbo-generator; stability study

1. INTRODUCTION

Fuzzy Logic has become a common buzzword in control. It is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem. Fuzzy logic itself is actually very straightforward; it is a way of interfacing inherently analog processes that move through a continuous range of values, to a digital computer, that likes to see things as well-defined discrete numeric values.

In this paper, another technique will be discussed to change the fixed fuzzy controller to an adaptive fuzzy controller. This technique can be applied using a function in the Matlab toolbox called "ANFIS", the acronym ANFIS derives its name from Adaptive Neuro-Fuzzy Inference System. ANFIS apply fuzzy inference techniques to data modeling that will customize the membership functions so that the fuzzy system best models the data [5-6].

Figure 2 shows the construction of ANFIS controller of six layers as in [7].

Traditional control systems are based on mathematical models in which the control system is described using one or more differential equations that define the system is described *using one or more differential equations that define the system response to its inputs. Such systems are often implemented as “proportional-integral-derivative (PID)” controllers. [1- 2] They are the products of decades of development and theoretical analysis, and are highly effective.

The reason is that fuzzy logic has proved to be more effective in various situations as well as having many advantages. In cases where the mathematical model of the control process may not exist, or may be too “expensive” in terms of computer processing power and memory, a system based on rules may be more effective.

Figure 1 shows a fuzzy logic controller construction as in [3-4].

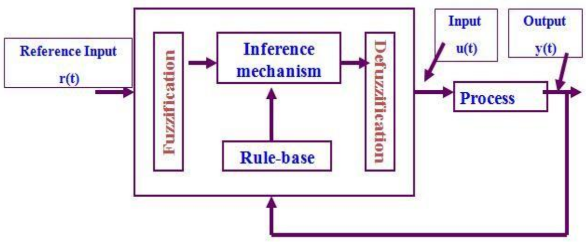

Fig. 1 Fuzzy logic controller structure

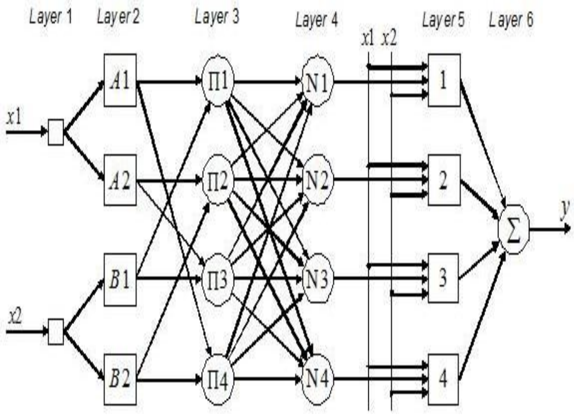

Fig. 2 ANFIS construction

ANFIS is the major training routine for Sugeno-type fuzzy inference systems; it uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference systems. It applies a combination of the least- squares method and the back propagation gradient descent method for training **FIS** membership function parameters to emulate a given training data set.

Using a given input/output data set, the toolbox function anfis constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a back propagation algorithm alone, or in combination with a least squares type of method. This allows your fuzzy systems to learn from the data they are modeling [8-9].

2. THE PROPOSED MODEL BLOCK DIAGRAM

The proposed system considered in this study consists of a turbo-generator unit connected to an infinite bus through a transformer and transmission system comprising two parallel transmission lines. As illustrated in Figure 3. The non-linear mathematical model of the synchronous generator is obtained from [1] and [2], as the assumptions contained in their derivation. The transmission system may be represented by lumped series resistance and reactance which can be combined with the equivalent impedance of the transformer. To achieve a good and fast control action, a thyristor bridge rectifier is used to supply the generator excitation. The generator is driven by three stages steam turbine with single reheater that can be represented by six-order model, with each state consisting of single time constant. The reheater, interceptor and main governor valve servomechanisms are also described with first order transfer functions. In this study the time constants of the turbine, valves and reheater are considered large with respect to the exciter time constant.

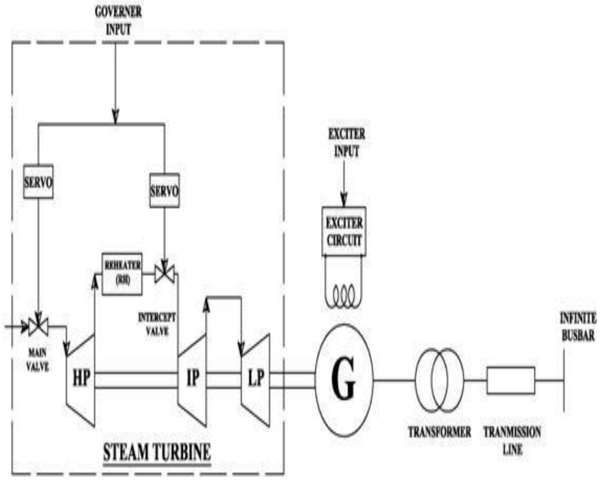

Fig. 3 Turbo-generator system

3. DESIGNING OF FUZZY LOGIC CONTROLLER FOR TURBO- GENERATOR SYSTEM

Designing Concept of Fuzzy Controller

Figure 4 displays the closed loop fuzzy control system for turbo-generator system, the controller inputs are the error and rate of error in the terminal voltage of the synchronous generator and by using fuzzy controller that controls the exciter voltage which controls the performance of the generator. For the turbo-generator system the method used for the fuzzy control comes from summation of three individual controllers one for the error voltage magnitude, the error in the active power output from synchronous generator and the third is the error in the change of delta (delta dot) and the here the output of these controllers give the control action to the governor vale position and the exciter voltage. Figure 4 shows the simulink model using MATLAB software of the turbo-genertor system.

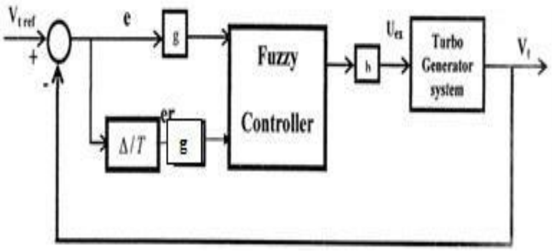

Fig. 4 Turbo-generator fuzzy control system

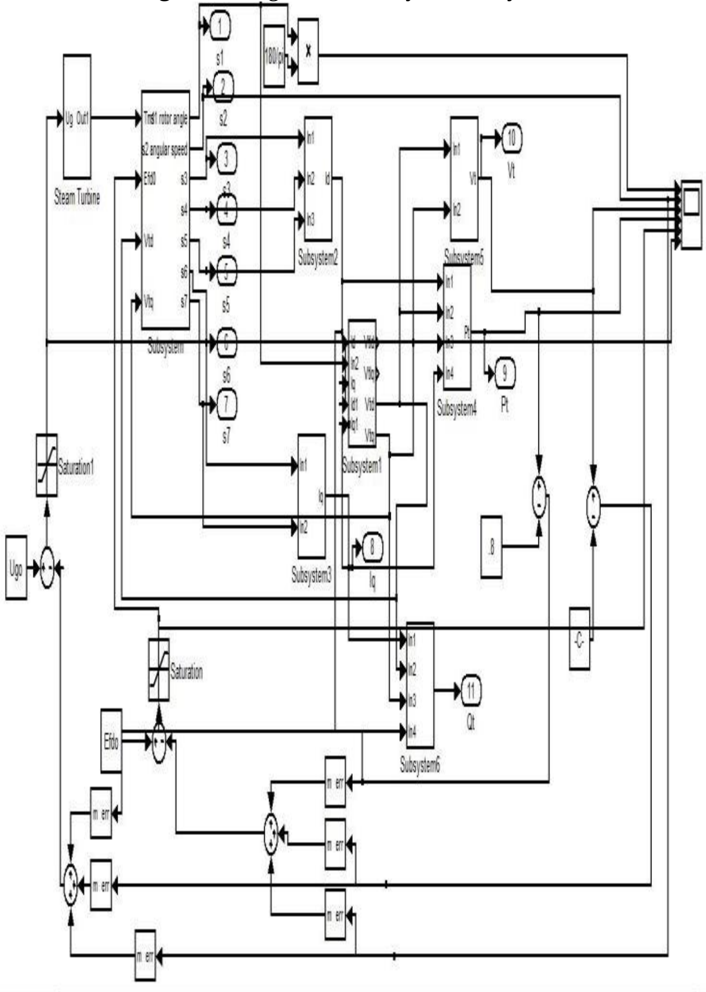

Fig. 5 The Matlab/simulink model of turbo-generator system with fuzzy controller

Considering the fuzzy controller shown in Figure 5, gains are introduced to the proportional and derivative terms (g and g_l respectively), and at the same time a gain h between the fuzzy controller and the generator exciter. The dynamic behavior of the fuzzy controller is highly dependent on these scaling factors. These factors have to be selected carefully in order to achieve good performance for both steady state and transient conditions [10, 11].

Simulation Results of Fuzzy Controller

Figure 6 shows that the terminal output active and reactive powers from generator to the grid are 0.8 p.u and 0.6 p.u respectively, for three phase faultt occurred at the sending end of transmission line with the duration of fault is 120 m.s, the fuzzy cotroller is used on the error of the terminal voltage of generator only. And these results have oscilations on the power angle delta and the change in the power angle delta dot.

Figure 7 terminal output active and reactive powers from generator to the grid are 0.8 p.u and 0.6 p.u respectively , for three phase faultt occurred at the sending end of transmission line with the duration of fault is 250 m.s , the magnitude of terminal voltage before fault is 1.0646 p.u and the power angle delta before fault is 46.65 deg ,the maximum power angle delta during the fault is 150 deg.

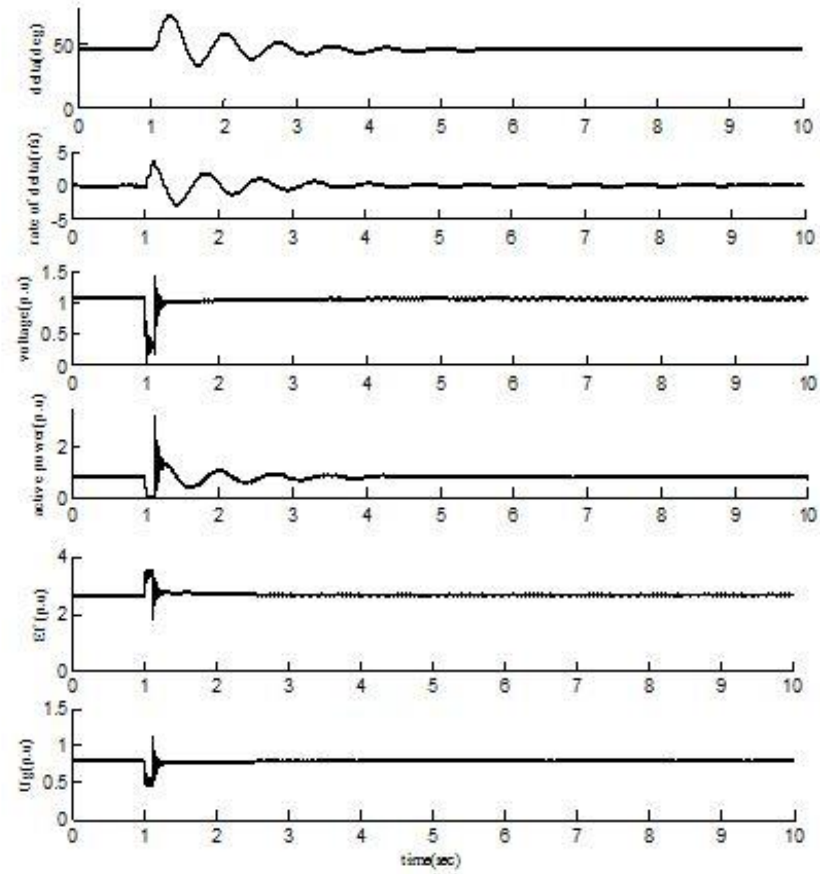

Fig. 6 Turbo-generator with Fuzzy controller 120 m.s fault time

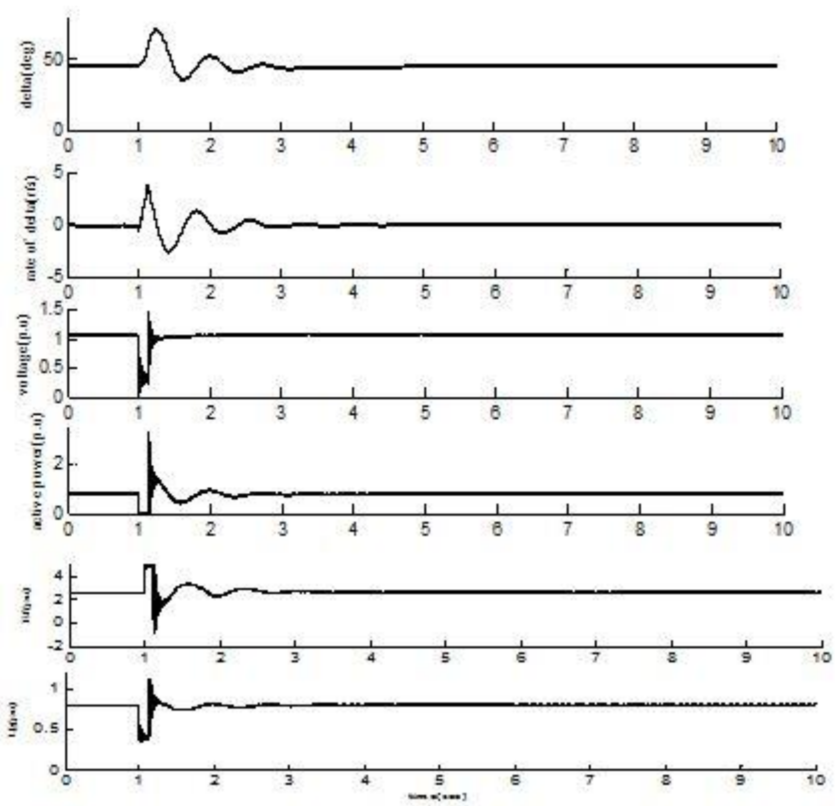

Fig. 7 Turbo-generator with Fuzzy controller of 250 m.s fault time

4. CONTROLLING OF TURBO-GENERATOR USING ANFIS CONTROLLER

Figure 8 shows the simulink model for the turbo- generator system by training the fuzzy control system developed in the previous section, then obtain the model for ANFIS controller, here the three inputs are gathered which are the error in the terminal voltage, the error in the active power output from the synchronous generator and the error in the rate of change of power angle delta (delta dot), by these inputs the ANFIS controller will give the output control action faster than the fuzzy controller. The output of this controller are the exciter voltage and the governor valve position. The main advantage of the ANFIS control system is obtaining the output control action very fast than any other control system.

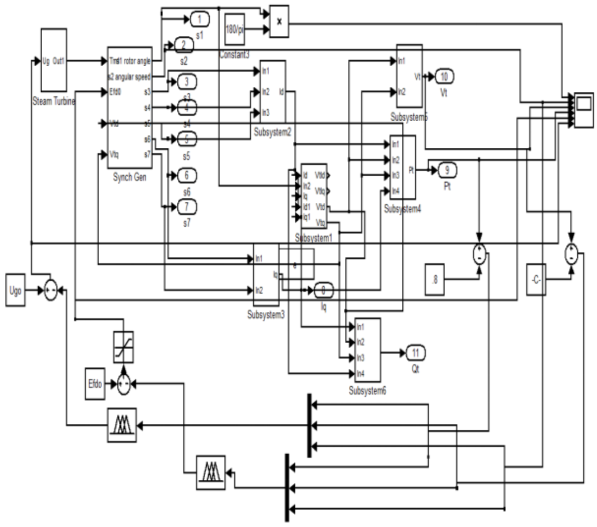

Fig. 8 The Matlab/simulink model of turbo-generator system with ANFIS controller

Simulation Results of Fuzzy Controller

Figure 9 shows that the terminal output active and reactive powers from generator to the grid are 0.8 p.u and 0.6 p.u respectively, for three phase faultt occurred at the sending end of transmission line with the duration of fault is 120 m.s, the ANFIS controller is used to obtain the performance for the turbo-generator system. It's clear that from results the oscillation occurred due to fault is reduced with large value.

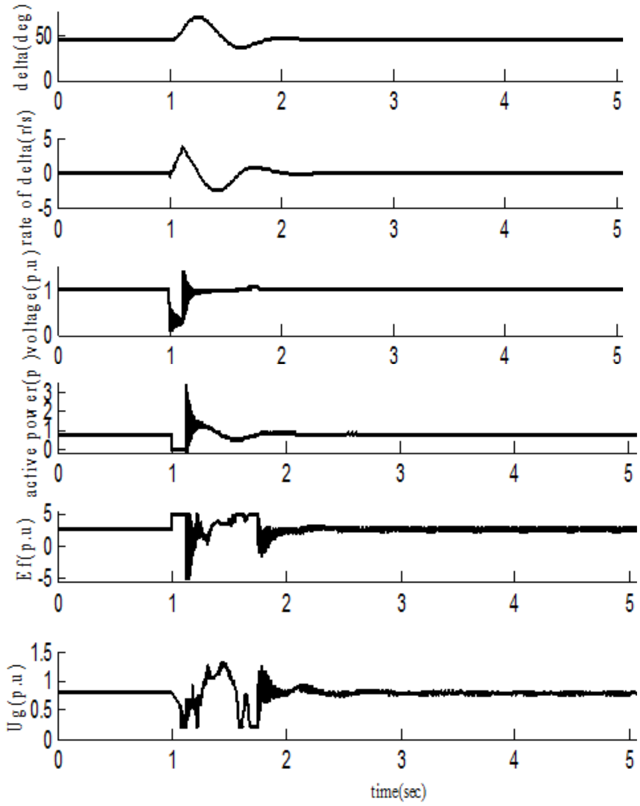

Fig. 9 ANFIS controller with P=0.8 p.u, Q=0.6 p.u and tf=120 m.sec

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