An Efficient Hybrid Neuro-fuzzy Control Scheme of Synchronous Generator: A Case Study

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Abstract - This paper presents an efficient hybrid neuro-fuzzy control scheme for synchronous generator. The scheme proves to be beneficial as the control scheme targets for the better control of Synchronous generator when used along with other sub systems. The system is stabilize after t=0.13. The control parameter the performances indices of IAE are 4.755 for fuzzy and 7.242 for hybrid neuro fuzzy and for ITAE it is 0.3665 for fuzzy and 0.6035 for neuro fuzzy control scheme.

Key Words: Control, Hybrid neuro-fuzzy, Synchronous generator

1. Introduction

Synchronous generator runs at a constant speed and draws its excitation from a power source external or independent of the load or transmission network. It has an exciter which enables the synchronous generator to produce its own reactive power and also regulate its voltage. It requires a speed reduction gear. It is an ac rotating machine whose speed under steady state condition is proportional to the frequency of the current in its armature and the magnetic field created by the armature currents rotates at the same speed as that created by the field current on the rotor and results in a steady torque. The rotor speed is proportional to the frequency of excitation hence the synchronous motors can be used in situations where constant speed drive is required. Since the reactive power generated by a synchronous machine can be adjusted by controlling the magnitude of the rotor field current, unloaded synchronous machines are installed in power systems specifically for power factor correction. Hence this machine becomes more economical in the large sizes than static capacitors. Hybrid neuro-fuzzy modeling allows a fuzzy system to be refined by neural training, thus avoid lengthy trial-and-error phases. An approach to obtain simple hybrid neuro-fuzzy model is proposed, which reduces the number of rules by means of a systematic procedure that consists in successively removing a rule and updating the remaining rules in such a way that the overall input-output behavior is kept approximately unchanged over the entire training set. A formulation of the proper update is described and a criterion for choosing the rules to be removed is also provided. Initial experimental results show the effectiveness of the proposed method in reducing the complexity of a hybrid neuro-fuzzy system by using its input-output data. Hence this paper presents an efficient hybrid neuro-fuzzy control of synchronous generator.

2. Case Study

The mathematical model of synchronous generator has been considered. This mathematical model helps in taking various control decisions keeping the stability in to consideration. Reference frame theory is quite important to the analysis of different electric machines analysis which has been given here. Variables which replaced the voltages, currents and flux linkages are associated with the stator windings of a synchronous machine with variables associated with windings rotating with the rotor. In other words, he transformed, or referred, the stator variables to a frame of reference in the rotor. Park’s transformation, which revolutionized electric machine analysis, has the unique property of eliminating all time-varying inductance from the voltage equations of the synchronous machine, which happen because of electric circuits in relative motion, electric circuits with varying magnetic reluctance. The model of two pole salient pole synchronous superconducting machine with damper windings is shown in Figure 1. d-axis is aligned with the N-pole of the rotor and q- axis is 90 degree apart from d-axis

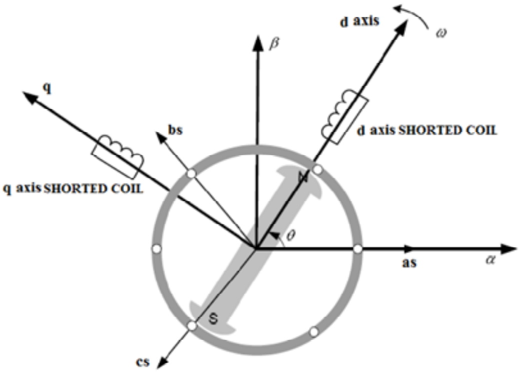

Figure1: d-q model of synchronous generator

Another method of vector control of synchronous machine is described and the proposed fuzzy control scheme of synchronous machine is also given in Figure 2.

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$$v_{ds} = R_s i_{ds} + \frac{d\phi_{ds}}{dt} - \omega\phi_{ds} \tag{1}$$

$$v_{qs} = R_s i_{qs} + \frac{d\phi_{qs}}{dt} + \omega\phi_{ds} \tag{2}$$

$$v_f = R_f i_f + \frac{d\phi_f}{dt} \tag{3}$$

$$J\frac{d\Omega}{dt} = C_e - C_r - B\Omega \tag{4}$$

$$\phi_{ds} = L_{ds} i_{ds} + M_{fd} i_f \tag{5}$$

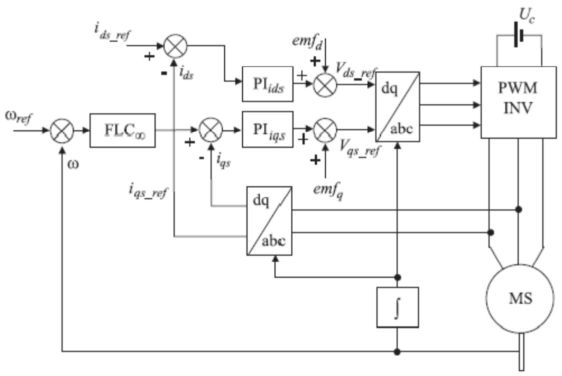

Figure 2: Fuzzy control scheme of synchronous generator

3. Problem Formulation

Fuzzy model reference learning controller in synchronous generator terminal voltage and reactive power control is designed so that its learning controller has the ability to improve the performance of the closed-loop. A fuzzy model reference learning controller for synchronous generator terminal voltage control system by generating command inputs to the synchronous generator plant and utilizes the feedback information from the synchronous generator. The fuzzy model reference learning controller is superior to conventional self tuning controllers which continue to tune the controller parameters because it will tune and to some extent remember the values that it had tuned in the past.

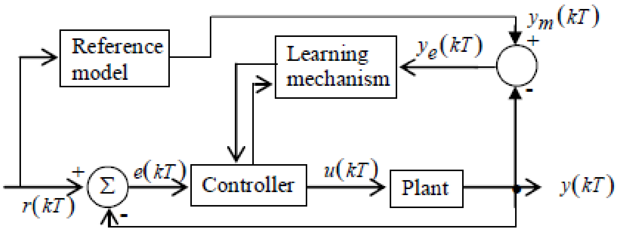

Figure 3: Basic control scheme fuzzy for synchronous generator

Figure 3 shows the basic control scheme fuzzy for synchronous generator It is made up of four main parts; the plant, the controller to be tuned according to type of controller used as here it isfuzzy controller, the reference model, and the learning mechanism. The scheme uses discrete time signals r(KT) and y(KT) with T as the sampling period. It also uses the learning mechanism to observe numerical data from a fuzzy control system. With this numerical data, it characterizes the fuzzy control system's current performance and automatically synthesizes or adjusts the fuzzy controller so that some given performance objectives are met. Here, the fuzzy control system loop operates to make y(KT) track r(KT) by manipulating u(kT), while the adaptation control loop seeks to make the output of the plant y(kT) track the output of the reference model ym(kT) by manipulating the fuzzy controller parameters. The synchronous generator which represents the plant has an input u(kT) from the fuzzy controller and terminal voltage output y(kT). The input to the fuzzy controller is the error, e(kT) = r(kT)− y(kT)

$$c(kT) = \frac{e(kT) - e(kT - T)}{T}$$

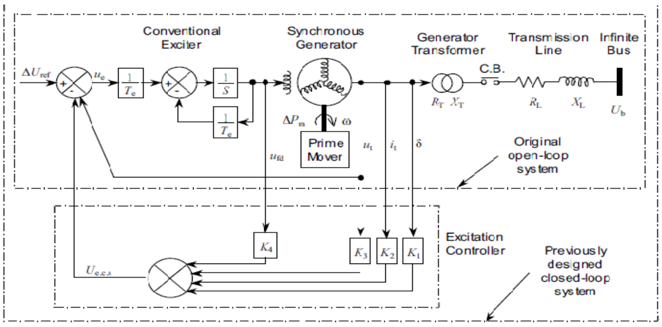

Figure 4: Adaptive control scheme for synchronous generator

In figure 4 the schematic of neuro-fuzzy has been shown. This represents the processing of knowledge in the neuro-fuzzy based model. This model is able to learn and optimize the control requirement.The use of ANFIS enables different layers to perform according to the weights assigned to them as in layer1,layer 2,layer 3,layer 4 and layer 5.The figure 5 shows the schematic of system considered as implemented using Simulink in MATLAB.

4. Simulation and Testing

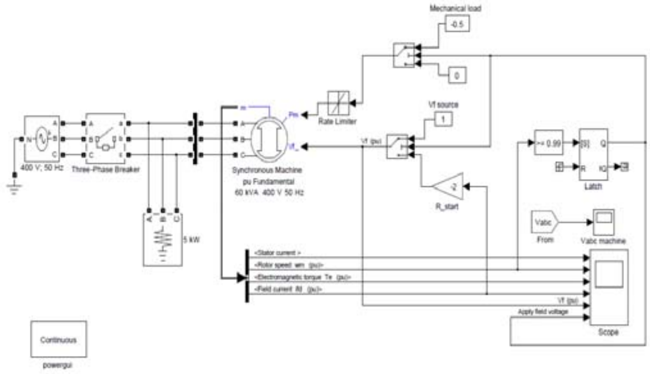

Figure 5: Simulink control scheme for synchronous generator

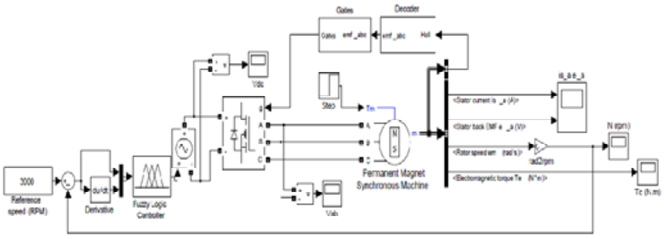

Figure 6: Adaptive control scheme for synchronous generator

The figure 6 shows adaptive control scheme for Synchronous generator when knowledge-base modifier performs the function of modifying the fuzzy controller's rule-base to affect the needed changes in the process inputs. The manual switching is done to incorporate the Hybrid neuro fuzzy control scheme as shown in figure 7.The control rules and the weights are selected and adjusted by the Simulink model automatically as designed by the design engineer. Hence the entire system is controlled by hybrid use of both control mechanisms of fuzzy and neuro controllers

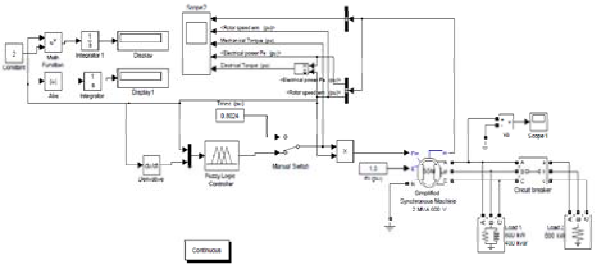

Figure 7: Switching control scheme for synchronous generator

5. Results and Discussions

The hybrid neuro fuzzy scheme has been implemented using simulink which resulted in better output waveforms. It provides following resulting waveforms for the better control of synchronous generator.

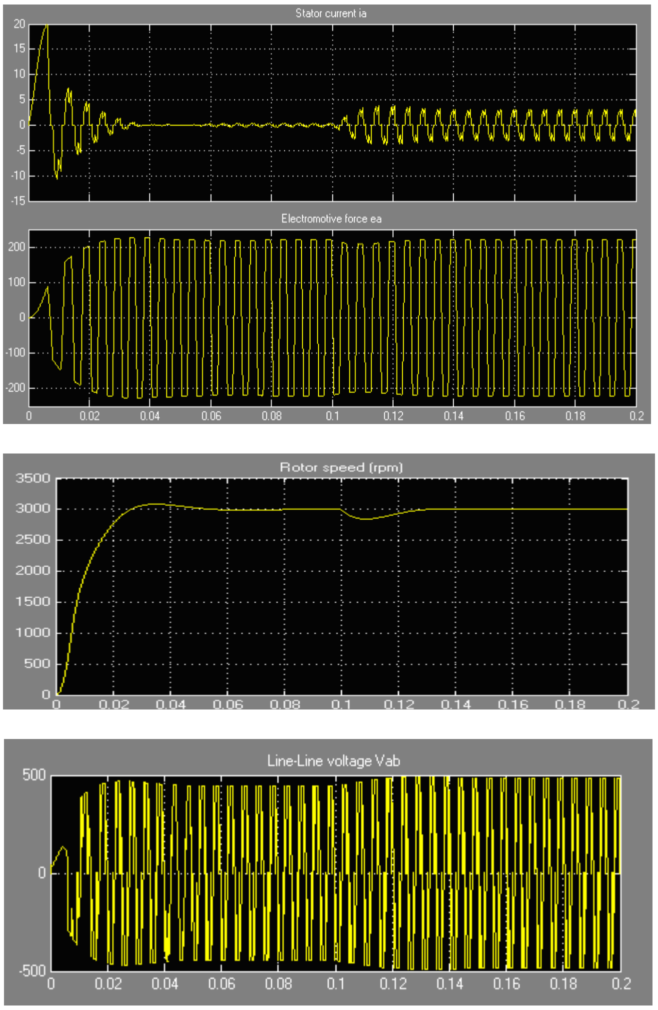

Figure 8: Response curves of stator current, emf, rotor speed, and line voltage in hybrid control scheme of synchronous generator

The graphs in figure 8 shows the response curves for stator current, rotor speed,emf and line voltage in fuzzy neuro based hybrid control scheme as implemented on Synchronous Generator. The system is stabilize after t=0.13.

6. Conclusions

Integral absolute error (IAE) and Integral time absolute error (ITAE) parameters for fuzzy based control system is 4.75 and 0.367. The IAE and ITAE performance index for hybrid neuro fuzzy control system is 7.24 and 0.61.They help in selection of control system for specific application of synchronous generator.

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