LOAD FREQUENCY CONTROL OF AN INTERCONNECTED RENEWABLE SYSTEM USING PID COMBINED ANFIS CONTROLLER

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ABSTRACT

The necessity for power generation is randomly increasing with the increasing load demand. As the non-renewable sources are getting extinct the use of renewable sources came into existence. To have the load demand to be equivalent with power generation Load Frequency Control (LFC) technique is employed. Using renewable sources will cause deviations in the system frequency. In this a PID combined with the Adaptive Neuro-Fuzzy Inference System (ANFIS) controller is used for controlling the frequency of load connected to two area renewable system for reducing the changes in frequency responses. When the outcomes of the presented controller were differentiated with commonly used PID it was observed that the controller used in this paper has resulted in better performance, reduced settling time and increased robustness than that of the conventional controller for the same system.

Key words: LFC, PID-ANFIS Controller, Renewable system.

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1. INTRODUCTION

An electrical power system is a circuit of electrical components used for electrical power supply, transfer and usage. The system that delivers electricity to an extended area is an

example of an electrical system. In these days the demand for electricity is very high therefore various methods have been adopted to increase the generation. The rapid exhaustion of the fossil fuels and their harmful impacts on the environment has lead to the use of the renewable energy sources. Renewable energy is the energy that is obtained from renewable resources that are produced naturally from sunlight, wind, rain, wind, waves, tides, and geo-thermal heat [1-3]. The rapid exhaustion of the fossil fuels and their harmful impacts on the environment has lead to the use of the renewable energy resources. The renewable energy sources effects the performance of the system causing variations in the frequency responses. Therefore it is required to enhance the frequency response parameters of the system for reliable supply.

Frequency control is required for reducing the oscillations in frequency which is mainly caused due to the mismatch of the load demanded and power generation. Load frequency control is used to provide an area to satisfy its load requirements first, then to support in returning the system's steady state frequency to zero. Previously there are various controllers used to settle down these fluctuations to some extent. In this paper a controller which is a combination of PID and ANFIS which is again the combination of both Neural Network and Fuzzy are been used to settle down the oscillations to enhance functioning of the network. It is also able to achieve better stability with two different renewable systems and load variations. This proposed controller is based on the training data that is it will adapt the changes in the environment and will adjust the inputs depending upon the output. In this paper the performance of the two area (one area connected to Photo Voltaic (PV) generation and the other area connected to wind source) renewable system with the specified controller is compared with the efficiency of the same system along with generally employed PID [4-6].

2. MODELING OF TWO AREA RENEWABLE SYSTEM

The power system is split into multiple areas, every area is generally connected to its adjacent area [7]. To connect these adjacent areas transmission lines which are called as Tie-lines are used. The schematic layout of the interconnected power system is depicted in Figure.1.

Figure 1 Representing Interconnected system

2.1. PV Generation Transfer Function

Solar power is regarded as most important renewable energy resource with a wide range of possibly numerous benefits. The Photo Voltaic (PV) is used to resemble the source of solar energy according to the reference [8-9]. This PV is a device that produces direct current (electricity) from solar radiations emitted from the sunlight, using semiconductor devices. The network function of the PV is as depicted in the Figure.2.

Figure 2 Photo Voltaic Generation Transfer function

2.2. Wind Turbine Generator Transfer Function

These days wind is the largely used renewable energy resource. The wind turbine blades rotate at a fixed or variable speed depending upon the wind that is the velocity of the rotor changes with respect to the velocity of the wind, in order to achieve better efficiency [10]. The electric power output obtained from the generator that is which connected to the shaft of the turbine. The network function for wind turbine and generator is as given in Figure.3.

Figure 3 Wind Turbine Generator Transfer function.

The overall system function model for the LFC of interconnected renewable system with PID combined ANFIS is depicted in the Figure.4. Here these two areas consist of PV generation and wind generation which were connected through a transmission line and a step input is given as a disturbance input [11].

Figure 4 System function model of Two-area Renewable system with presented controller.

3. MODEL AND DESIGN OF PROPOSED CONTROLLER

Here the cascade combination of PID and Adaptive Neuro Fuzzy Inference System (ANFIS) is being utilised for improving LFC for two area renewable systems.

3.1. PID Combined ANFIS Controller

This PID is nothing but a device formed by combining Proportional, Integral and Derivative controller. In this these three controllers were added up to compute the result of the PID. It takes the input from output $\Delta f(S)$ from feedback. The transfer function of PID in the Laplace form is given below.

$$L(S) = K_p + \frac{K_i}{S} + K_d \quad (1)$$

Where, K_p = value of gain for proportional controller.

K_i = value of gain for integral controller.

K_d = value of gain for derivative controller.

These gain constants are tuning parameters, which are adjusted to obtain the expected output.

The ANFIS is a combination of fuzzy logic controller and the artificial neural network. The fuzzy controller will work well when the membership functions are wisely chosen. Therefore to overcome this situation the adaptive approach of neuro-fuzzy is used. This is multi-layer network which uses both the knowledge gaining power of artificial intelligence and understanding capability representation of fuzzy logic for many modes of memberships [1]. This controller takes the two inputs from the PID controller and results in one output. It uses 'If then' rule base system of Sugeno's type. It uses the rules as following.

$$\text{If } \Delta f \text{ is } X_1 \text{ and } \Delta f' \text{ is } Y_1, \text{ then } u_1 = p_1 \Delta f + q_1 \Delta f' + r_1 \quad (2)$$

$$\text{If } \Delta f \text{ is } X_2 \text{ and } \Delta f' \text{ is } Y_2, \text{ then } u_2 = p_2 \Delta f + q_2 \Delta f' + r_2 \quad (3)$$

Figure 5 Multi-layer ANFIS controller architecture

Layer 1: The Fuzzification layer where it converts the crisp inputs into the fuzzy inputs that is, it will change the parameter values in reference to the error to produce the required response for each and every function for membership.

Layer 2: This is depicted as π and it is a fixed layer which consists of outputs of first layer which multiplies with one other. The output obtained gives the degree of firing capability.

Layer 3: Here the layer is denoted as N (Normalization layer). The firing strength which is normalized is computed.

Layer 4: Here the layer consists of consequent parameters.

Layer 5: The output for the entire device is obtained here.

Figure 6 Block diagram of PID combined ANFIS controller.

3.2. Designing of the Proposed Controller

At first the output is given to the PID controller through feedback. The gains of the controller are adjusted and are summed with the fuzzy logic based on Sugeno system. The input-output data obtained had been used for understanding data and Neuro-Fuzzy Designer is used for designing this controller. Detail designing of ANFIS is proposed in the literature [1].

4. RESULTS AND DISCUSSION

For depicting the efficiency of the presented controller, the simulation of presented two area renewable system with the common PID controller device is also carried out separately in the MATLAB Software. The results of the LFC of two area system with presented controller device considering the tie-line are compared with conventional controller simulation results for the same system. Parameters for PID and PID combined ANFIS controller are given in Table.1.

The frequency responses for individual systems respectively are shown in the figures below. The PV output, wind turbine output and tie-line output frequency responses for both the controllers shown in the Figure.7, Figure.8 are compared with each other and the comparison results have shown better performance and stability for proposed PID combined ANFIS controller than that of the conventional PID.

Figure 7 Frequency response for two area renewable system with PID combined ANFIS.

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Figure 8 Frequency response for two area renewable system with PID.

(a) PV response

(b) Wind response

(c) Tie-line response

Figure 9 Individual frequency responses with PID combined ANFIS.

(a) PV response

(b) Wind response

(c) Tie-line response

Figure 10 Individual frequency responses with PID.

Figure 11 Feedback signal waveform fed to the controller.

Figure 12 Output response of the signal from controller.

5. CONCLUSION

Here in this, PID which is combined with ANFIS is used for controlling the frequency of the load of specified renewable system. Obtained simulation results are differentiated with PID outputs. The proposed device improves stability and functioning of LFC of renewable system in terms of robustness, settling time, peak time. The efficiency of the explained controller does not depend on any mathematical calculations but mostly depends on the training data. This ability of the controller to adapt the changes and adjust the inputs depending on the training data makes it more effective and thereby, improving the quality of the power being given to meet the load demanded and system reliability.

Table 1 Parameters of the Frequency Response

Parameter	Settling time (sec)		Peak time (sec)		Maximum Peak Over Shoot (%)	
	PID combined ANFIS	PID	PID combined ANFIS	PID	PID combined ANFIS	PID
PV	37.50	112.50	8.300	28.846	1.320	1.661
Wind	37.50	112.50	10.368	36.733	0.402	0.246
Tie-Line	37.50	112.50	13.897	48.856	1.992	1.999

Table 2 Parameters of the two area renewable system

Components	Parameters	Description	Value
PV	K_{SPVG}	Solar photo voltaic generation gain constant	1.8
Wind	K_{WT}	Wind turbine gain constant	1.5
Tie-line	$K_{tie-line}$	Tie-line gain constant	0.04
PID controller	K_p	Proportional gain constant	0.01
	K_i	Integral gain constant	1.52
	K_d	Derivative gain constant	0.53

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