

Automatic Load Frequency Control of Renewable Energy Integrated Hybrid Power System

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Abstract

Frequency aberration, power quality, and system instability may be caused by the general perception of Renewable Energy (RE). To control the frequency with the tolerable limit, load frequency control is being performed. Automatic Load Frequency Control (ALFC) must be provided with a proper controller. Ziegler-Nichols method is being used to tune the parameters of the Proportional-Integral-Derivative (PID) controller for Load Frequency Control of Hybrid Power System (HPS). Traditional PID controllers are capable of handling a larger varieties of rapid changes in load variations in renewable energy hybrid power systems. This work considers the HPS of 2000 MW power system including RE resources. The OP4510 is utilized for hardware-in-loop (HIL) simulation to test the accomplished controller's real-time applicability. The MATLAB simulation and the Real-Time simulator provide identical results.

Keywords: PID Controller, Renewable Energy, Load frequency control, Ziegler and Nichols, Aqua electrolyser

1. Introduction

The appropriate connection of a number of different utilities forms a hybrids power system network. Automatic load frequency control (ALFC) can help the power system achieve its goal. ALFC supports with the governance of variable frequency in a timely manner. Electricity generated from renewable energy sources helps the environment by reducing carbon dioxide emissions. Wind, solar, biomass, and geothermal renewable energy resources are seeing tremendous expansion in the future power system. Wind and solar power

production technologies and other renewable energy resources, a critical part is the generation of electrical power. On the other hand, wind generating plants suffer from wind flow discontinuity, which is a loss. Similarly, solar electricity is only available during daylight hours. As a result, renewable energy power plants must either overcome the decreased capacity factor or be backed up by power plants with more reserve capacity.

When renewable energies are adequate, spare renewable energy may be stored and used during power outages. Renewable energy will not be sufficient to meet load demand on its own; it would need to be supplemented with other advances. The use of a fuel cell helps reduce power fluctuations in the wind and solar systems. In industrial, commercial, and distant or inaccessible areas, FC is used as both main and backup power.

Because of its pure alternative fuel, environmental safety, exceptionally long operational lifetime, and more capacity than batteries, the RE system is one of the most promising long-term energy options.

In the literature, there have been several researches on load frequency management and hybrid power system modelling is being going on. Wind, Solar Thermal, Aqua electrolyser, fuel cells make up the hybrid system [2]. The modelling and control techniques of a hybrid energy system with a dispersed generating system are explored [3].

As a result, a gain scheduling controller can be utilized to do this. Because no parameter estimation is required in this method, control settings can be altered relatively quickly.

Furthermore, gain scheduling is simpler than both automatic tuning and controller parameter adaption approaches. However, due to sudden changes in system parameters, the transient response of this controller may be unstable. Moreover, at varying operating points, reliable linear time-variant models are impossible to develop.

The Ziegler-Nichols (Z-N) approach is used to adjust proportional Integral derivative (PID) in traditional integer controllers that can manage a greater variety of system characteristics and load fluctuations in the Power System.

2. System model

Figure 1 represents the proposed hybrid system, which includes STPG, WTPG, AE, and FC generation.

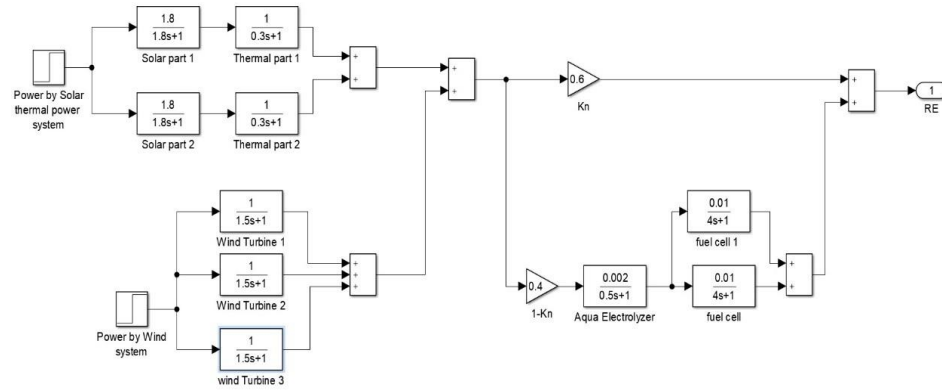


Figure 1. Renewable energy sources model

Figure 2 shows a dynamic HPS model with a reheat turbine, boiler dynamics, and even a system with nonlinearities like GRC and GDB, and also the integration of renewable energy sources.

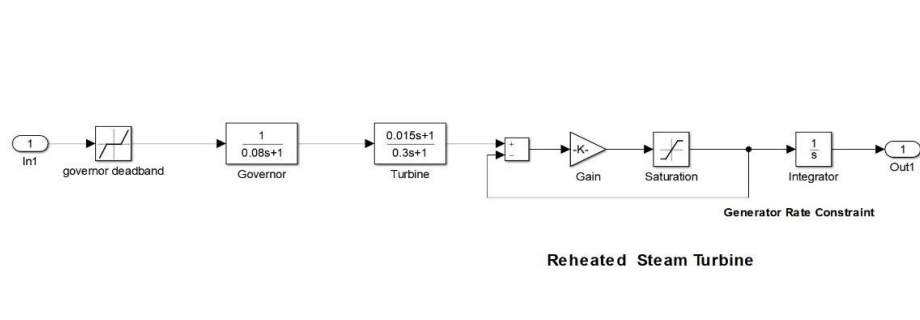


Figure 2. Power plant model with non-linearities

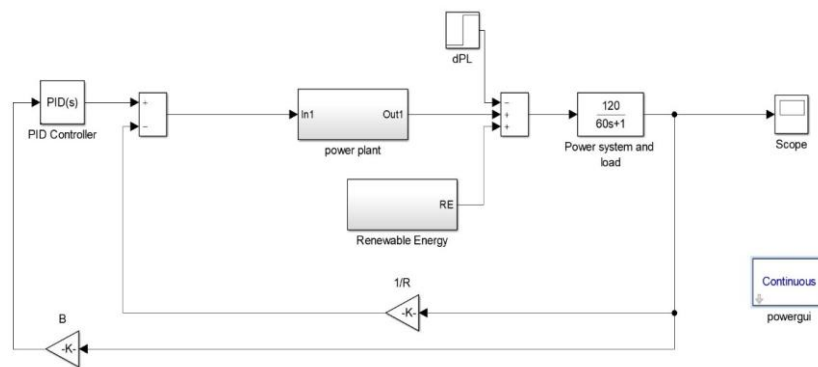


Figure 3. Model of a hybrid power system

The power change is calculated at 25 MW, while the whole thermal power plant capacity is 2000 MW. Standard Benchmark problem based on O I Elgerd's electric energy system [4]. All of the RE sources are integrated by the power system block. Figure 3 shows

the hybrid system's MATLAB/Simulink model. ALFC is accomplished through a feedback connection from the plant's output to a controller via a shift within the load.

2.1 Solar Thermal power generation

Solar thermal power generation (STPG) has been frequently employed to maintain a grid power balance in blends with fossil fuel and wind power sources, among several the other things [1]. The transfer function can be characterized as a combination of solar collector and steam turbine generator.

$$G_s(s) = \frac{K_s}{1+sT_s} \frac{K_T}{1+sT_T} = \frac{\Delta P_{STPG}}{\Delta P_{solar}} \quad (1)$$

where the gain constants are K_S and K_T , and the solar collector and steam turbine time constants are T_S and T_T , consequently.

Two STPG units are being investigated, each with its own 3 MW plant capacity.

2.2 Wind Turbine power generation

The first-order transfer function for small-signal analysis would be used to depict the kinetics of wind turbine power generation (WTPG).

$$G_{WTPG}(s) = \frac{K_{WTPG}}{1+sT_{WTPG}} = \frac{\Delta P_{WTPG}}{\Delta P_{wind}} \quad (2)$$

2.3 Fuel cell with electrolyser

The stored hydrogen is used to create energy by the FC when the REs generates low or intermittent power. As a result, AE produces hydrogen using a $1-K_n$ fraction of wind and photovoltaic energy, which may subsequently be utilized by two FCs to create additional grid power. The dynamics of the AE-FC are shown using the first-order transfer function.

$$G_{AE}(s) = \frac{K_{AE}}{1+sT_{AE}} \quad (3)$$

$$G_{AE}(s) = \frac{\Delta P_{WTPG}}{(\Delta P_{WTPG} + \Delta P_{STPG})(1 - K_n)} \quad (4)$$

The gain and time constant of AE are K_{AE} and T_{AE} , $P_T / P_{WTPG} + P_{STPG}$ is considered to be 0.600.

$$G_{FC}(s) = \frac{K_{FC}}{1 + sT_{FC}} \quad (5)$$

where FC's gain constant and time constant are K_{FC} and T_{FC} , respectively.

3. Controlling techniques

3.1 PID Controller

In the continuous-time domain, the transfer function of a PID controller is,

$$G(s) = K_p + sK_d + \frac{K_i}{s} \quad (6)$$

The proportional gain, integral coefficient, and derivative coefficient are represented by K_p , K_i , and K_d , respectively.

3.2 Tuning of PID Controller

The gain value of the PID controller is obtained using the Ziegler Nichols tuning procedure in MATLAB PID Controller.

Table 1. PID Controller Gain Parameters

Proportional(k_p)	-2.5727
Integral (k_i)	-2.7416
Differential (k_d)	-1.1232

4. Results and Discussion

The impacts of GDB, GRC, and renewable energy sources are taken into consideration by the PID controller for a single-area hybrid power system. The obtained findings show that the PID controller outperforms existing RT-LAB controllers.

4.1 Simulation Results

The output from MATLAB and the output from the RT-Lab HIL are indeed very comparable. For this work, a sample power system with a capacity of 2000 MW (Standard Benchmark problem mentioned from Electric Energy System O I Elgerd) is investigated, along with renewable energy resources. In HIL simulation, the OP4510 is frequently used to test the real-time applicability of the accomplished controller.

When the values of ΔP_L are set to 0.0125 p.u. and the single area power system is run for 30 seconds, the system will come into equilibrium, as shown in figure 4.

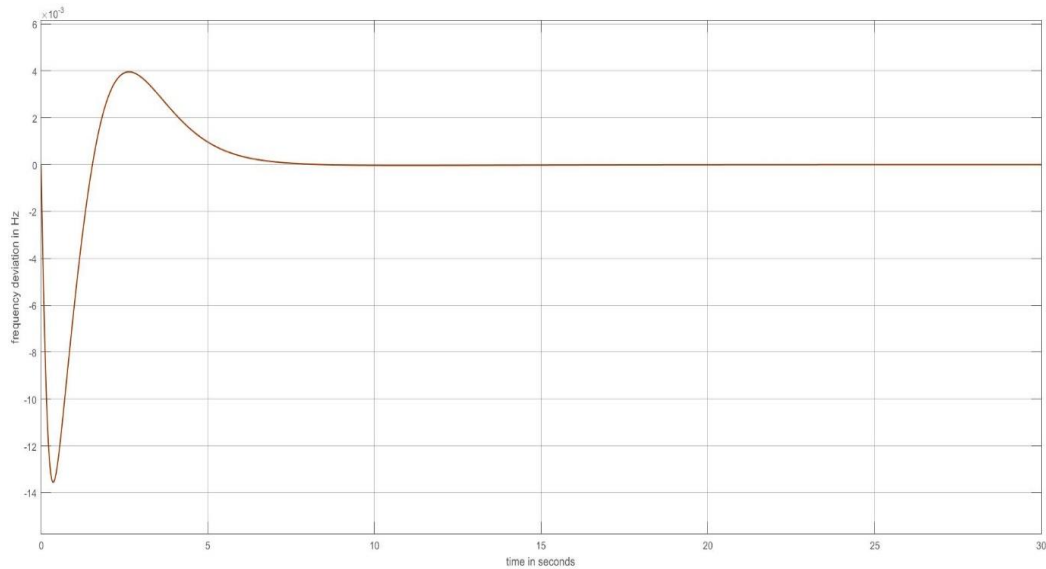


Figure 4. Frequency deviation in single area integrated hybrid power system with PID Controller

4.2 RT-LAB HIL Simulation Results

The MATLAB model is developed as a hardware model with the help of RT-Lab Software, and the output is captured using a Mixed Signal Oscilloscope.

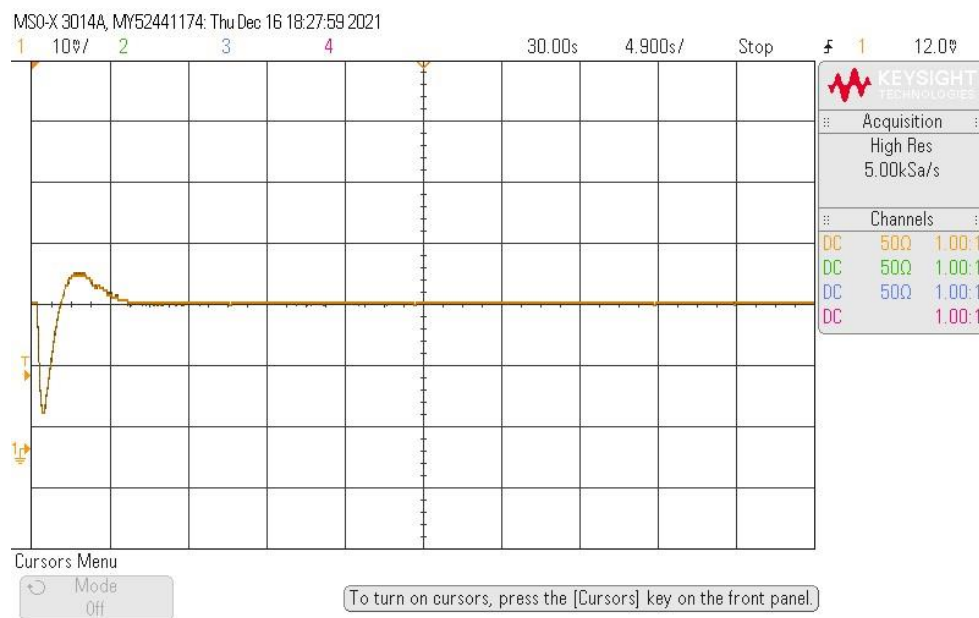


Figure 5. Frequency deviation of single area integrated hybrid power system in RT-Lab HIL Simulation

The results from the MATLAB simulation and the RT Lab are identical, as shown in table 2. In this scenario, the settling time and peak overshoot are compared.

Table 2. Comparison between MATLAB and RT- Lab HIL results parameters

	MATLAB Simulation	RT-Lab HIL-Simulation
Settling time	5.5 sec	5.6 sec
Peak overshoot	2.1%	2.3 %

5. Conclusion

The work in this paper is mainly focused on frequency control of an isolated thermal power generating system with renewable energy sources and an energy storage system. A model is simulated and the response of frequency deviation is studied. The simulation results obtained show that the PID controller reduces the transient performance such as peak overshoot, and settling time of frequency deviation of the system. The single area power system is authenticated through a hardware-in-loop digital simulator.

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