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Power Balancing Control of Hybrid Energy Sources Using Storage System

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Abstract: *Renewable energy is the promising solution for our growing energy demand with carbon free emission for greener environment. The intermittent nature of renewable energy is based on the different parameters such as environment and climatic change. So hybrid energy system will be ideal for sustainable energy generation. This paper proposed the controlled use of conventional power plant such as thermal, hydro power along with flow battery to support wind and solar to reach the near perfect balance. In this work flow battery is feasible to balance the variation in power and voltage in a short span of time with high storage capacity. PID controllers maintain the depth of discharge (DOD) of flow battery with conventional power plant. The proposed work is simulated using MATLAB/ SIMULINK with real time solar, wind and load forecasting data for the duration of 24 hours. The result shows the approximate power balancing of load forecasting with hybrid power plant in a short time interval of 15-20sec.*

Keyword: *Renewable energy source; Hybrid system; Power plants; Storage system.*

1. INTRODUCTION

The main goal of power system is to deliver uninterrupted power supply. India is one of the developing countries where the power demand increases exponentially, but the energy generation sources are diminished simultaneously. Hence conventional energy source is not ideal for fulfilling our growing energy demand due to its high fuel cost and carbon emission. With respect to economic and environmental aspect, renewable energy is highly appreciable for balancing the power demand with conventional power plant. Due to intermittent nature of renewable energy sources, energy storage system is essential to obtain the sustainable power generation. Flow battery (FB) is mainly needed to stabilize power and voltage balance in the hybrid system. This storage system is preferable for its high capacity and low transaction time [1]. In order to regularize the wind power variation, optimization based method is proposed for comprehensive design of energy storage system [2]. Energy storage system are widely available for different application, among them fly wheel is a new storage system which can store energy in a form of Kinetic energy rather than the chemical form. Flywheel is also used to smoothen the wind power generation as it injected to the grid [3]. Normally the power fluctuation occurs in wind power plant due to change in velocity of wind and climate condition. This can be managed by the supervisory control system [4].The varying renewable energy generation can be scheduled by 2-level energy storage system. This approach proposes a design procedure for the controller as well as sizing of the short term storage device [5].The various power plant models has been proposed using coordinated control system for power system analysis [6]. Hybrid system is most desirable for our increasing energy demand. Hence energy management strategy plays a vital role for deriving the potential benefit of grid connected rooftop solar system [7]. Distributed storage units proposed to provide power balancing in a power grid through charging & discharging [8]. DSM mainly focused to reduce the consumer energy cost by proper planning and monitoring the power consumption. This would probably balance the demand side load with the supply side and make the hybrid system more efficient [9].

This paper concentrates the power balancing control of hybrid energy sources using storage system. First the system is to be modelled for hybrid energy

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sources with the objective of balancing power with the control strategies using TPP, HPP and FB.

2. PROPOSED SYSTEM

The block diagram of proposed system is shown in Figure 1 which includes renewable energy sources as solar and winds power plants. Both power plants are used for generating the power and it transmitted to the grid. The renewable power plant does not need any controller because of its adequate availability and no fuel cost.

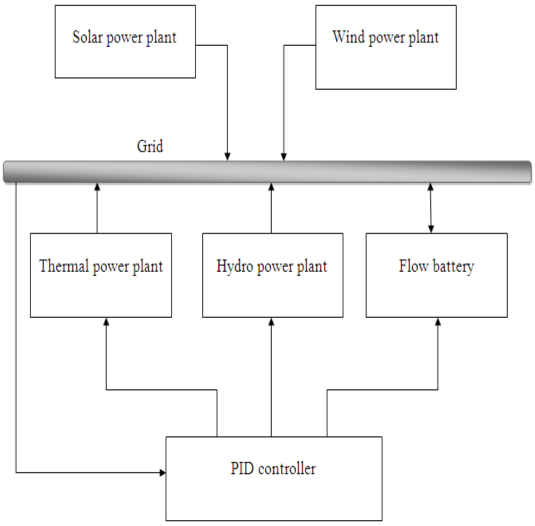

Figure.1 Block diagram of hybrid energy sources using storage systems

But the thermal (TPP), hydro (HPP) power plant and flow battery that uses Proportional Integral Derivative (PID) controller to minimize the power balancing error in hybrid power plant. Here flow battery is also used for storing the excess power in the grid.

2.1 Model of Photovoltaic System

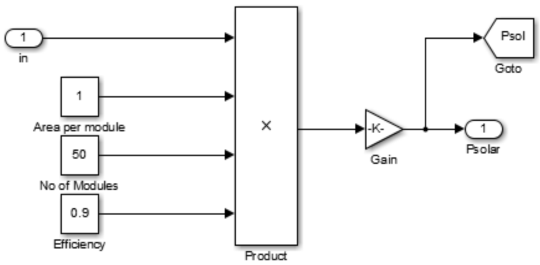

Figure.2 Simulink model for Photovoltaic system

Simulation diagram of Photovoltaic (PV) model figure 2 shows that the PV array module is designed in a generalized model. The product of solar insolation, area per module, number of modules and the efficiency is needed for obtaining the power generation in the photovoltaic system. Finally, the generated power can be calculated using above parameters in the photovoltaic system.

2.2 Model of Wind Power Plant

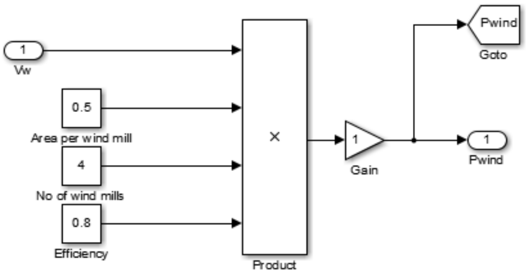

Figure.3 Simulink model for Thermal power plant

Simulation diagram of wind system model shows in figure 3 the input parameters of the wind model are based on wind velocity, area per wind mills, number of wind mills, and the total efficiency, to obtain the optimal power generation in the wind power plant.

2.3 Model of Thermal Power Plant

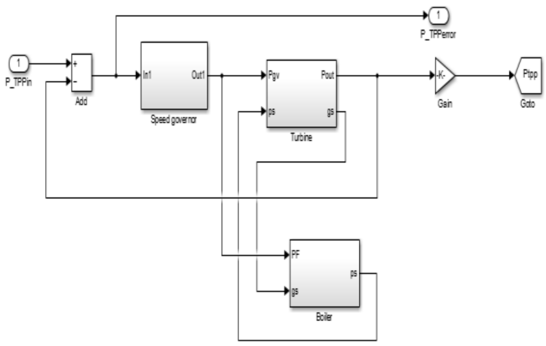

Figure.4 Simulink model for Thermal power plant

TABLE 1 PARAMETERS OF THE STEAM TURBINE

Parameter	Notation	value
Steam chest time constant	T_{SC}	0.25s
Re-heater time constant	T_R	5s
Crossover piping time constant	T_{CO}	0.5s
Factor of high pressure section	K_H	0.3
Factor of intermediate pressure section	K_I	0.3
Factor of low pressure section	K_L	0.4
Speed relay time constant	T_{SR}	0.1s
Speed motor time constant	T_{SM}	0.3s

Thermal power generating process and specific construction of steam power plant could cause power

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to vary significantly slower than that of HPP. Reliability of service has always been of prime importance to electric utility systems. In general, the basic activities associated with reliability assessment can be divided into two fundamental segments of measuring past performance and predicting the future hydro power plant. It only follows the trend and does not reduce the error noticeably. This block represents a general model of TPP has been created in Matlab/Simulink according to model found in [10, P.436].The block diagram of steam turbine can be found in [6, p. 2].the parameters of the turbine that was used for the investigation are presented in Table 1.

2.4 Model of Hydro Power Plant

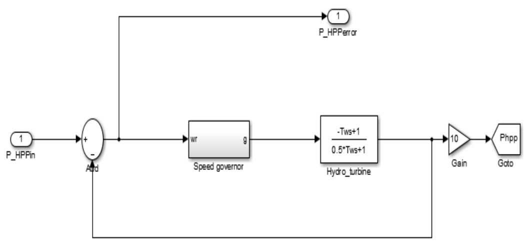

Figure. 5 Simulink model for hydro power plant

In the hydro power generation the medium frequency error and the hydro insulation is given as an input signal to the speed governor as shown in figure 5 Depending upon the speed governor output, the valve can be opened then the water flow into the hydro turbine to achieve the desirable output. The output of power generation can be calculated in the hydro power plant.

TABLE 2 PARAMETERS OF HYDRO TURBINE

Parameter	Notation	Value
Permanent droop	R	0.06
Temporary droop	R	0.5
Temporary droop time constant	T_r	5 s
Auxiliary servo motor time constant	T_f	0.2 s
Gate servo motor time constant	T_g	0.2 s
Water time constant	T_w	4s

A hydro turbine was used to compensate the imbalance in the system that is left after TPP. The turbine output power follows the load variation trend and aims to reduce the error. It also helps to compensate losses associated with FB. The HPP was modelled in matlab using traditional governor controller/regulator popularly, a transfer function of hydro power turbine and the block diagram can be found in [11, p.33]. The rest of the hydraulic turbine and speed regulator model parameters are given in Table 2.

2.5 Model of Flow Battery

The main characteristics of flow batteries were estimated during the process of modelling the flow battery. The model does not take into account any electrochemical processes inside the cell nor the kinetic energy of the electrolyte itself. The main parameters considered were the limits of the power and energy Pmin, Pmax, Emin, Emax, losses (efficiency) and reaction time. The main objective of the flow battery model was to simulate the response to power imbalance. When balancing wind and solar power, the power to be balanced by the FB is determined as the difference between the initial error and power generated by TPP and HPP.

$$P_{FBin} = P_{error} - P_{TPP} - P_{HPP} \quad (1)$$

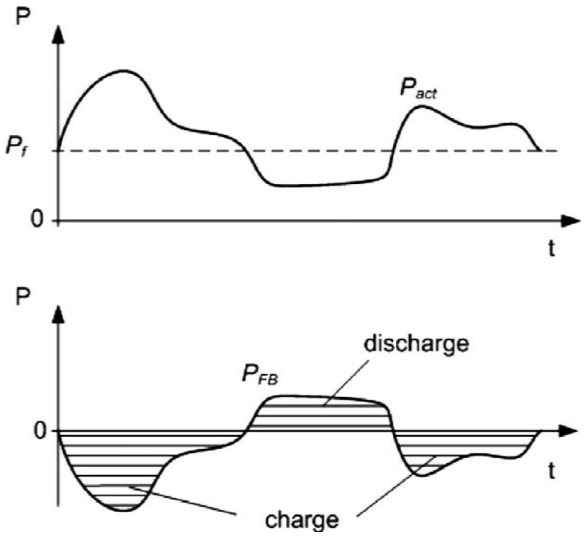

Figure. 6 Characteristics of flow battery

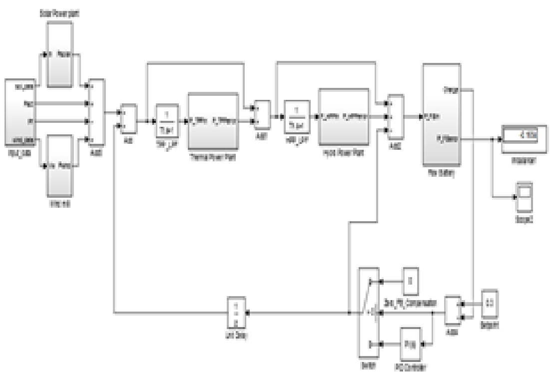

Figure. 7 Simulink diagram for proposed system

PTPP and PHPP is power generated by thermal and hydro power plants correspondingly. The main principle is to charge the battery when there is a surplus of energy and to discharge when the energy is scarce

Figure 6. The power of flow battery should be kept within the interval (Pmin, Pmax) and energy stored in the flow battery EFB should stay within the limits of (Emin; Emax). Controlling the flow battery's charge and discharge rate should compensate the high frequency part of the wind and solar power variation from forecasted profile.

2.6 Simulink Model for Power Balancing of Hybrid System

The proposed system shown in figure 7 illustrates that the solar, wind, thermal, hydro and flow battery model of the hybrid system is successfully simulated in MATLAB/SIMULINK. Each module is simulated separately which are integrated in to a single model and then repeat the simulation process. Each major component of the solar, wind, thermal, hydro and flow batteries design are included in the simulation. Depending upon the load, the flow battery can be adjusted. If the load power is high the flow battery can be discharged, and if the load is less the flow battery can be charged.

3. RESULTS AND DISCUSSION

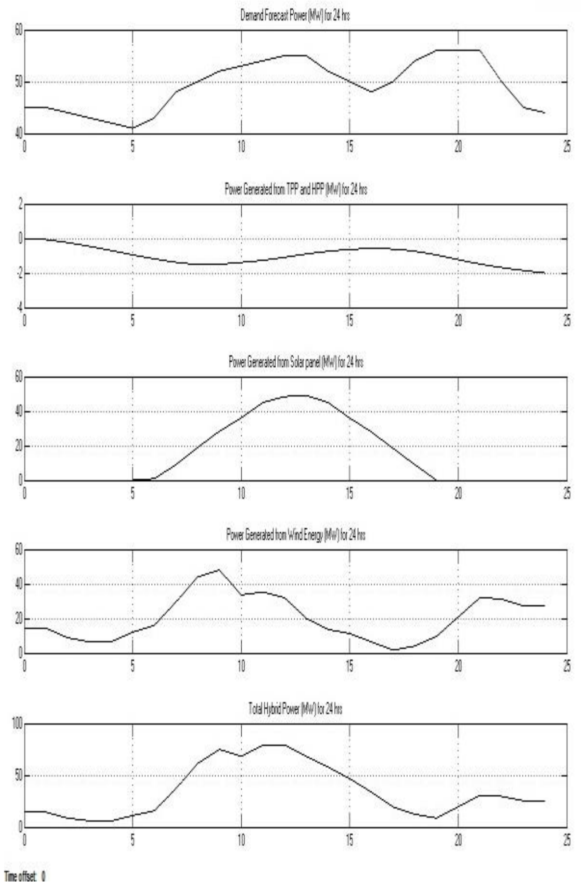

Figure. 8 Output power of proposed system

The output power of proposed system is shown in Figure 8 the inference of the graph is the forecasting power increases with increase in time for period of 24 hours. The hybrid power system increases and decreases with respect to time variation. Solar power generation reaches its zenith during peak solar irradiance particularly at the noon time. The wind power also varies exponentially with the change in time and climate. The final graph shows the sum of all powers which will be sustainable to satisfy the peak demand (forecasting power).

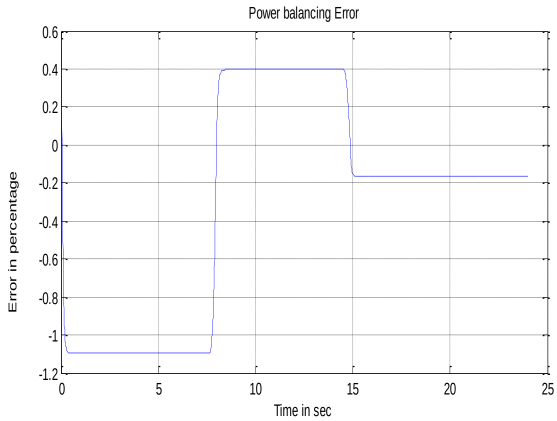

Figure. 9 Power balancing output of proposed system

The compensating output for demand and power is shown in figure 9.During initial state, the output becomes negative for a particular period of a time (i.e.,) if a forecasting power is lower than the total generated power. After the demand increases, the output reaches the positive value (i.e.) the total power generation is decreased in the time interval. Finally the output becomes stable within 15-20 sec, which matches the forecasting power with total power.

4. CONCLUSION

The proposed hybrid solar and wind power balancing technique, using TPP, HPP and FB control strategy shows positive result in balancing the renewable power. The high frequency response of the flow battery provides optimal balancing with the help of PID controller. This proposed work is modelled using MATLAB/SIMULINK to obtain the optimal result that can be compared with the real time data. This work recommends that flow battery is highly suitable to balance the load and hybrid power.

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