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Stabilization of Solar-Wind Hybrid Power System by Using SMES

S.M. Mohiuddin*, M.R.I. Sheikh#
Departement of Electrical and Electronic Engineering
Rajshahi University of Engineering & Technology, Rajshahi 6204, Bangladesh

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ABSTRACT

The depleting fossil fuel reserves and increasing concern towards global warming created the need to surge for the renewable energy sources. Wind and solar power generation are two of the most promising renewable power generation technologies. This paper deals with the simulation of a Solar-Photovoltaic and Wind hybrid power generation system equipped with Superconducting Magnetic Energy Storage (SMES) in MATLAB/SIMULINK environment. The Solar-Photovoltaic Module and Permanent Magnet Synchronous Generator (PMSG) based wind turbine is simulated separately. Then they are connected to a dc bus. Since the intermittent nature of Solar and Wind makes the system unreliable, so an energy storage system SMES is introduced to reduce output fluctuations. Varying wind speed and solar irradiance value are taken as the input parameters. The simulation results show that a system with SMES is more reliable than a system without SMES.

Corresponding Author:

M.R.I. Sheikh
Departement of Electrical and Electronic Engineering,
Rajshahi University of Engineering & Technology
Rajshahi 6204, Bangladesh.
Email: ris_ruet@yahoo.com

1. INTRODUCTION

In numerous rural areas and islands where grid connection is not economically or technically feasible small-scale stand-alone power systems are becoming popular. Diesel generators are popular in remote area power system applications for their reliability, low installation costs, ease of starting, compact power density and portability. But owing to the disadvantages of diesel generators [1] renewable energy sources needed to be taken into consideration. Renewable energy sources such as solar energy and wind energy have been deemed clean, inexhaustible, unlimited, and environmental friendly [2].

The principal problem with the solar energy is that sun does not shine on every part of the planet with equal intensity. The intensity of the sunlight also varies at different hours of the day. Daily and annual fluctuations in solar irradiation necessitate appropriate control schemes to stabilize the power output from the PV system. The wind power generation system (WTGS) has its own characteristics that are different from the existing generation systems such as the wind dependence caused inconsistency in the generation of electric power. A wind at one moment may be different from the wind than the second earlier. Thus wind power generation introduces uncertainty also in operating a power system and it is continuously variable and difficult to predict. Since wind power varies randomly there must be a stand source to meet load demand.

There is no single renewable energy source which points itself out to be the only solution [3]. So, different energy sources have to be combined. Hybrid system is the integration of two or more power generation system on the same grid or bus. Hybrid power systems can provide higher efficiency, reliability, security and ensure robustness of the energy management system to avoid system black-outs when power from one renewable energy sources is not adequate to support all loads. Thus, in the present study solar and wind energies are combined to form a hybrid power system.

Different systems can be used to control ouput fluctuations. However, when the system capacity is more then energy storage is considered to be an effective means to improve the competitiveness of electric power production systems based on renewable energy resources. The intrinsic volatility of such energy resources has a negative impact on the quality of the electrical energy supply, and complicates efficient operation. This issue can be smoothed through energy storage systems [4]. Energy storage system makes the hybrid system more reliable and affordable. Several energy storage technologies are currently being developed, e.g., Compressed Air Energy Storage (CAES), Battery Energy Storage System (BESS), Superconducting Magnetic Energy Storage (SMES), Phase-Change Materials (PCM), and Flywheel Energy System (FES). Overviews of different types of energy storage system are given in [1, 5]. All systems have some merits as well as some demerits. In this study, a superconducting magnetic energy storage system (SMES) is used to control the output power fluctuation of the hybrid system.

Time response is a key feature when it comes to select an energy storage system for a particular application. The time response of energy storage systems depends on the physical principle on which they are based. The speed to store or deliver energy of SMES system based on the electromagnetic phenomena. SMES has the capability to provide both active and reactive power simultaneously & quickly, so it can be a good tool for the stabilization of power system [1, 6, 7]. In [8] a simulation of Solar-Wind hybrid system equipped with SMES has been explained, however output fluctuation cannot be maintained effectively. However, in the present study SMES have been controlled using PI with DC-DC chopper, thus effective results can be obtained.

2. MODELING OF THE HYBRID SYSTEM

The simulation model of the proposed hybrid system is shown in Figure 1. SMES is connected at DC bus.

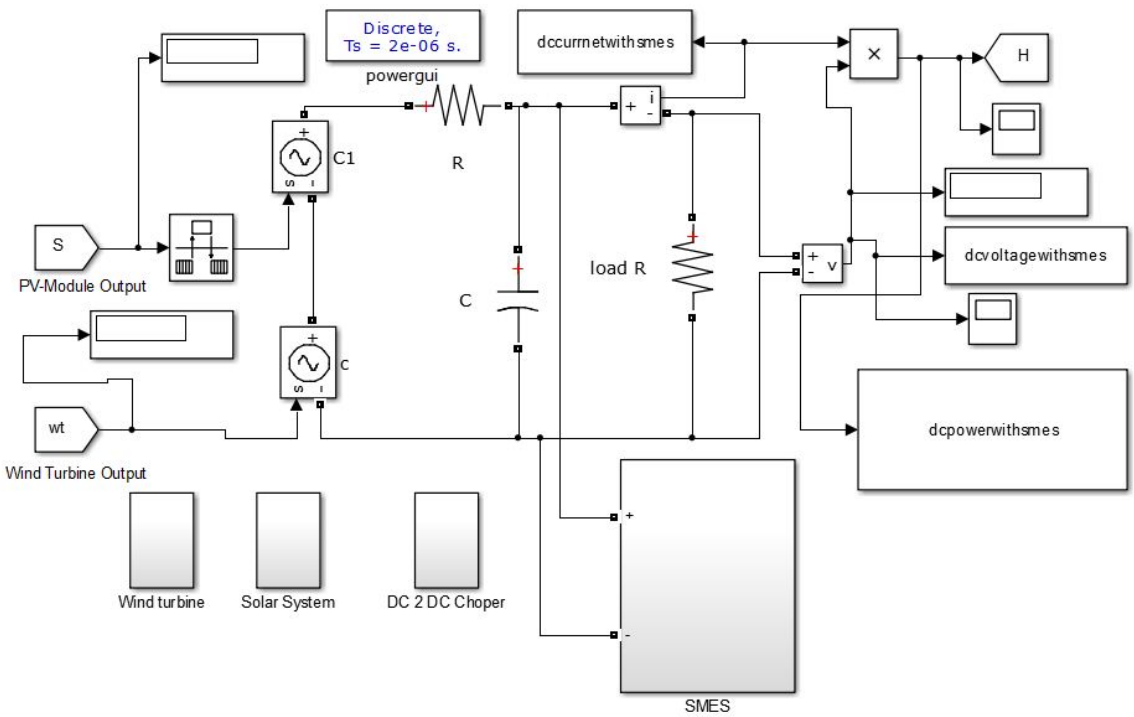

Figure 1. Hybrid System connected to the DC bus With SMES

The proposed hybrid system depicts in Figure 1. consists of the following basic components: (i) Wind Turbine Generation System (WTGS); (ii) Photo-Voltaic (PV) Module System; (iii) SMES Energy Storage System and (iv) DC-DC chopper control system for the for the SMES.

Figure 2 shows the model of Wind Turbine Generation System (WTGS). The wind generator is a permanent magnet synchronous generator (PMSG). Variable speed was taken as the input to the wind turbine which output was feed to the PMSG to model the WTGS. In this study, Wind Turbine [9] and PMSM [10] control toolbox has been used in the wind turbine model. The Ac outputs from WTGS has been converted to DC by using rectifier. The DC output from the WTGS was feed to the DC bus.

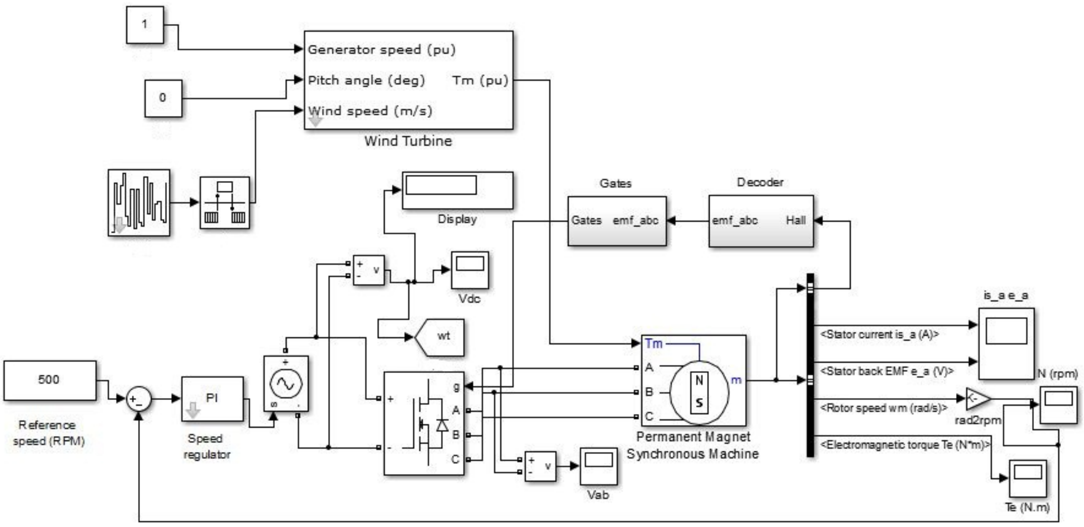

Figure 2. Wind Turbine Generation System (WTGS).

Figure 3 represents the PV module system. This model was developed using the Solar cell blocks of SimElectronics and Simulink [11]. To explore the intermittent nature of the solar energy variable solar irradiance value was taken as the input to the PV Module System. The output from the PV system was DC so that, no rectifier was required and the DC output was directly connected to the DC bus of the Hybrid System.

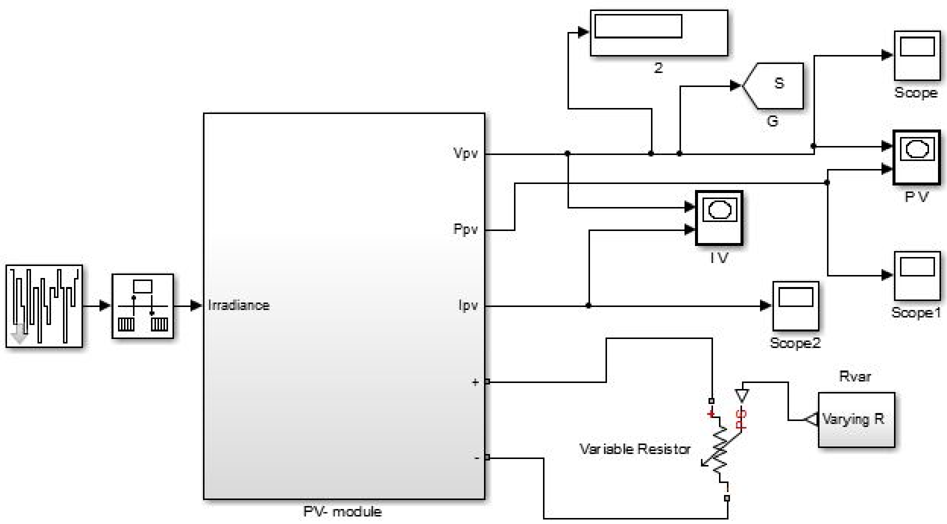

Figure 3. Photo-Voltaic (PV) Module Simulation.

Irregularity of the renewable energy sources produces fluctuating output in the Hybrid System. To reduce that fluctuation and to provide a reliable power supply SMES is connected in parallel to the DC bus of the Hybrid System. Figure 4 depicts the control system of SMES.

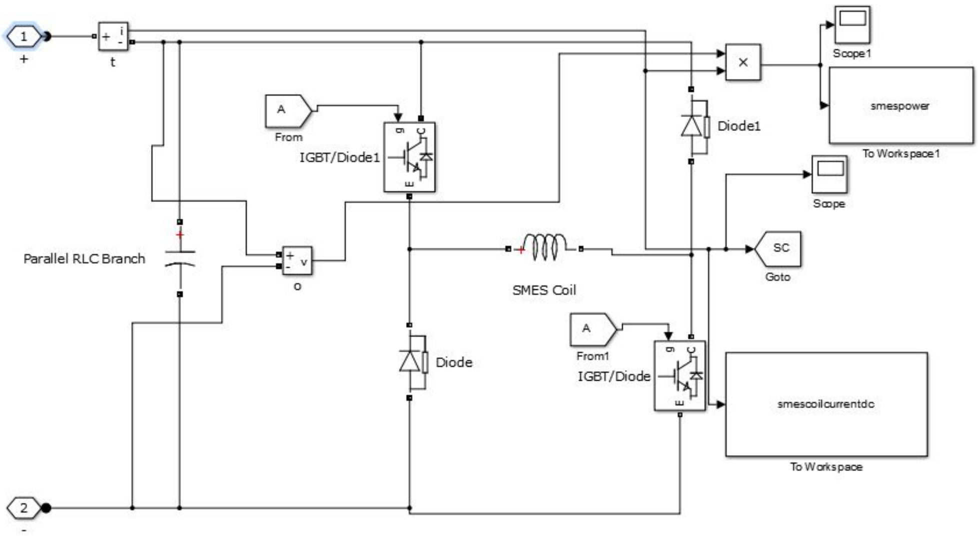

Figure 4. SMES System block model.

An appropriate control system was required to control the charging and discharging sequence of the SMES. This was accomplished by using PI controller based DC-DC chopper as shown in Figure 5. If the output of the Hybrid System is less than the reference value then DC-DC chopper sends signal zero (0) to the IGBT switch; otherwise signal one (1) will be sent. Signal zero (0) indicates IGBT switch open, SMES discharging; Signal one (1) indicates IGBT switch close, SMES charging.

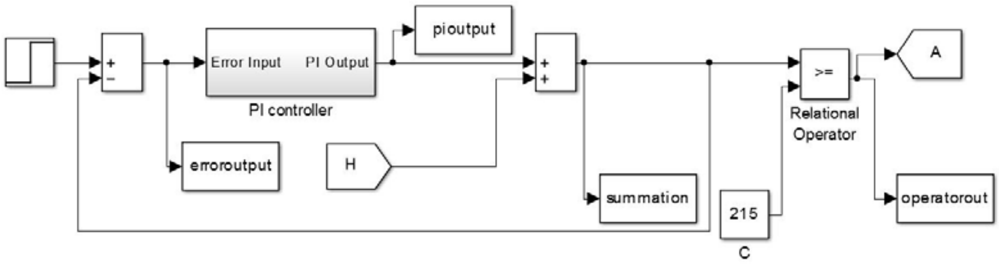

Figure 5. DC-DC chopper control block model.

3. SIMULATION RESULTS

In this section 3 case studies have been considered. In each case the input solar irradiance and the wind speed were considered different. The input solar irradiance and input wind speed, hybrid system power characteristics with and without SMES and SMES power characteristics are plotted for each case.

3.1. Case Study-I

In this case solar irradiance was increased from 400 W/m^2 to 1200 W/m^2 and wind speed was decreased from 25 m/s to 5 m/s. The input solar irradiance and the wind speed are shown in Figure 6 and Figure 7 respectively. For this input parameters the power characteristics of the Hybrid System (with and without SMES) and SMES power characteristics are shown in Fig. 8. Without SMES output from the Hybrid System fluctuates between 207W to 229W but with SMES the power fluctuates between 213W to 215W which was almost negligible. The SMES alternately charges or discharges to maintain a constant output power. The input parameters are shown for the entire time sequence but to indicate a clear discrimination output characteristics are drawn for a fraction of the time sequence.

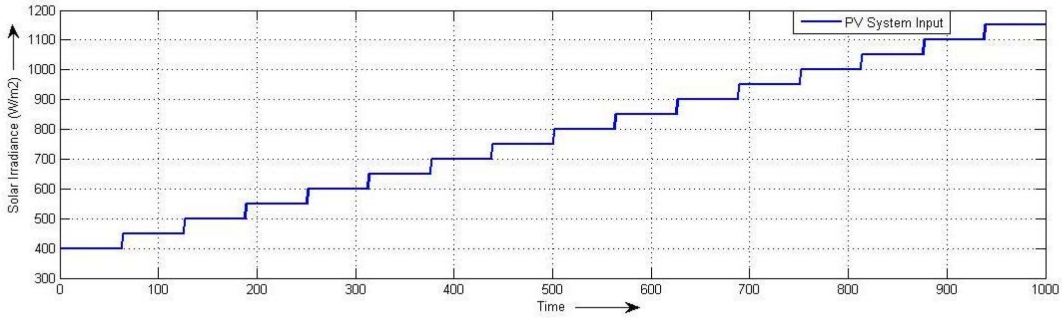

Figure 6. Input Irradiance to the PV module.

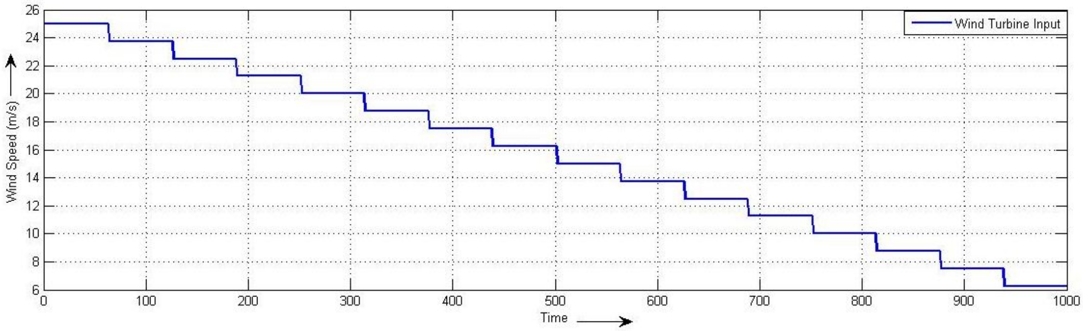

Figure 7. Wind Turbine Input Speed.

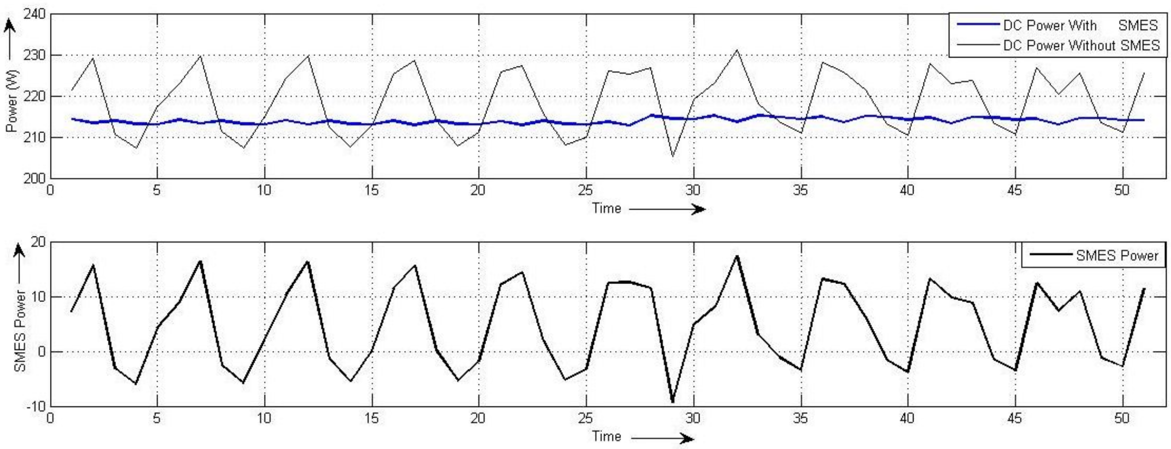

Figure 8. Output Power characteristics from the Hybrid Power System and the SMES System.

3.2. Case Study-II

The PV module input is assumed to be decreased from 1200 W/m^2 to 400 W/m^2 and wind speed is a ramp varying from 5 m/s to 25m/s. These input parameters were shown in Figure 9 and Figure 10 respectively. Hybrid System power output and the SMES output is shown in Figure 11. Output power from the Hybrid System with SMES connected was almost constant 212W but without SMES output power varies between 204W to 222W.

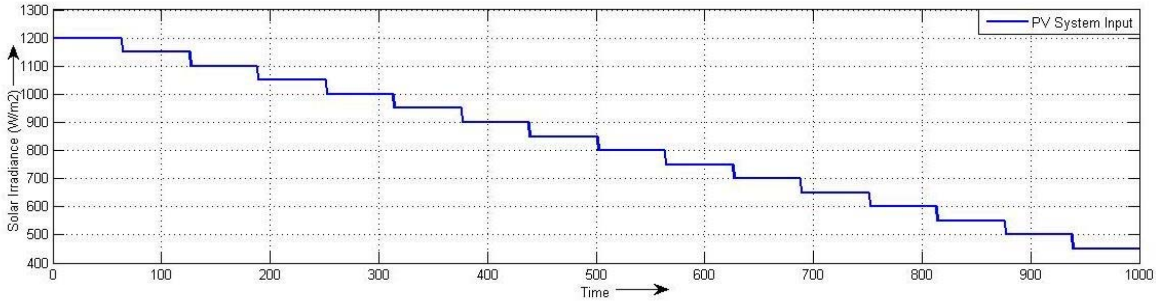

Figure 9. Input Irradiance to the PV module.

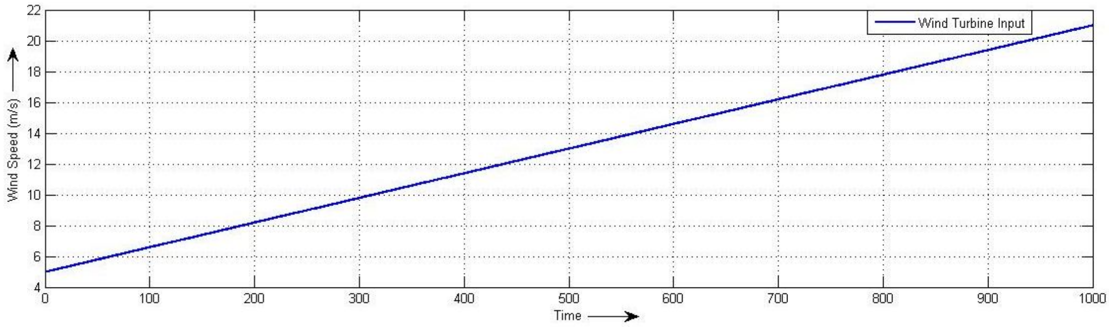

Figure 10. Wind Turbine Input Speed.

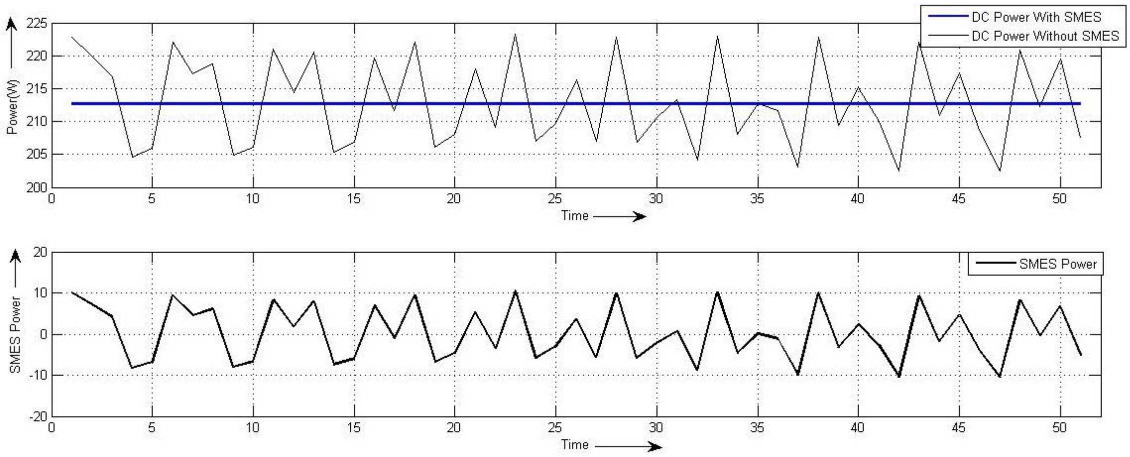

Figure 11. Output Power characteristics from the Hybrid Power System and the SMES System.

3.2. Case Study-III

In this case random input parameters have been considered for both the PV module system and WTGS system. The input characteristics are given in Figure 12 and Figure 13 respectively. SMES power characteristics and the power characteristics of the Hybrid System are shown in Figure 14. In this case it is also seen that SMES maintains a constant output power 218W in the Hybrid System.

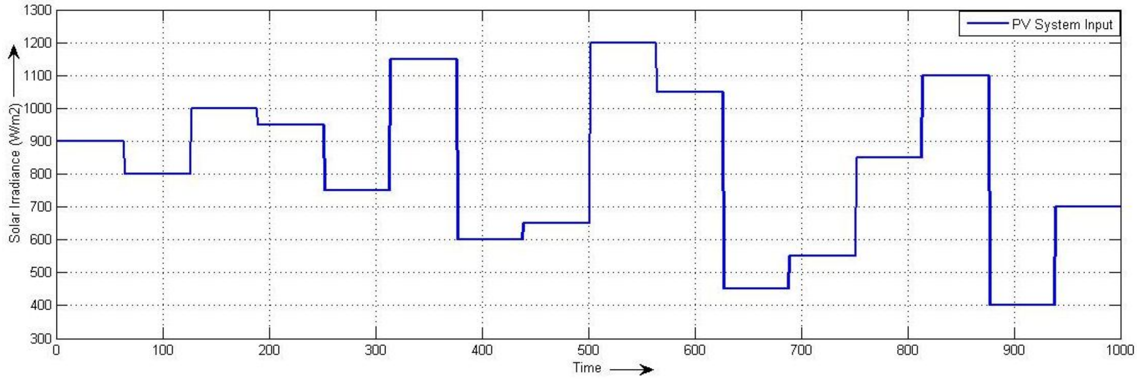

Figure 12. Input Irradiance to the PV module.

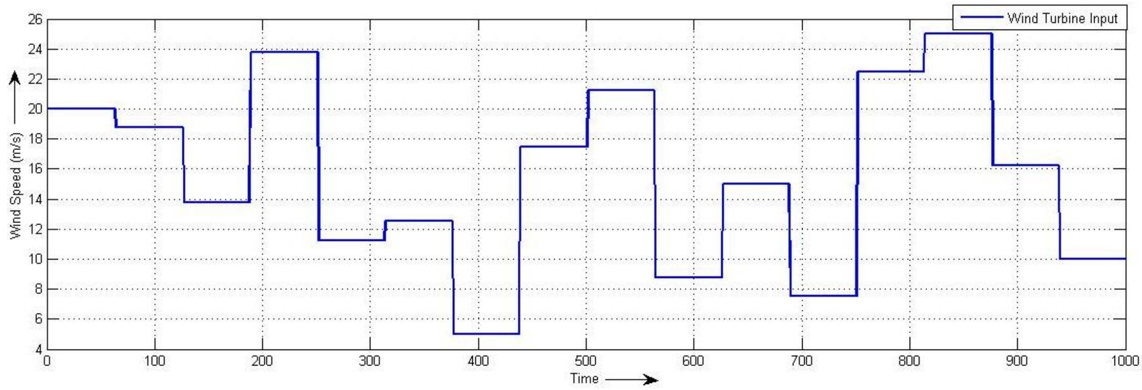

Figure 13. Wind Turbine Input Speed.

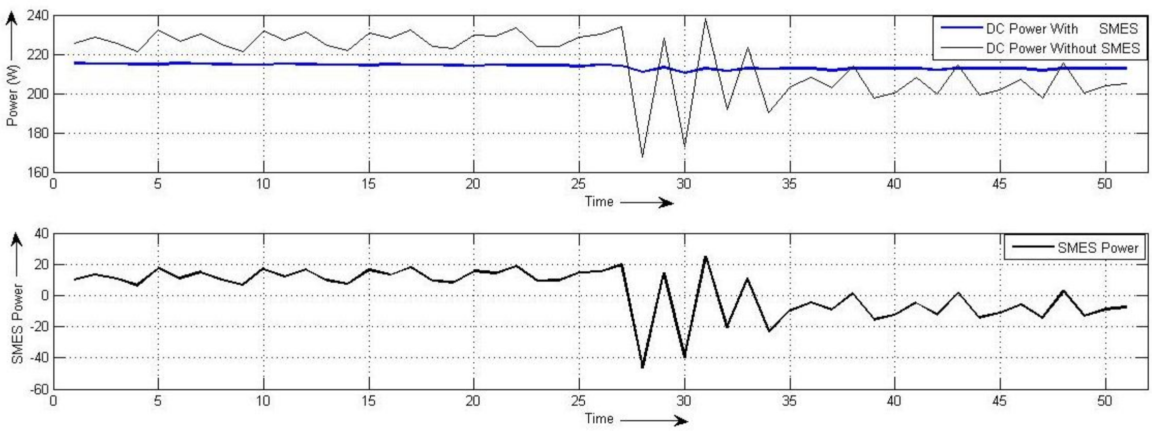

Figure 14. Output Power characteristics from the Hybrid Power System and the SMES System.

4. CONCLUSION

In this study a simulation model of a Solar-Wind hybrid power system has been developed and the application of SMES system is presented in the developed model. Since the Solar and Wind energy are intermittent in nature, so different irradiance value and wind speed are taken as the input to the hybrid system. The output DC voltage of the solar system is about 85V and Wind turbine is 72V. As the two systems are connected in series through controlled voltage source so a dc voltage of about 148V is obtained from the hybrid system. Three cases have been considered to show the effectiveness of the proposed controlled SMES system. It is seen from the simulation results that SMES can improve the quality of output fluctuations. Thus increase the reliability of hybrid power system.

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BIOGRAPHIES OF AUTHORS

Sheik Mohammad Mohiuddin was born in Chittagong, Bangladesh on November 01, 1991. He received the Bachelor of Science Degree in Electrical and Electrical Engineering from the Rajshahi University of Engineering & Technology in 2013. He is currently serving as a lecturer in East Delta University, Chittagong.

Dr. M.R.I. Sheikh- received B.Sc. Engineering and M.Sc. Engineering Degrees from Rajshahi University of Engineering & Technology (RUET), Bangladesh, in 1992 and 2003 respectively and Doctor of Engineering Degree from Kitami Institute of Technology, Japan, in September, 2010, all in Electrical and Electronic Engineering. Currently, he is working as Professor in the Electrical and Electronic Engineering Department, RUET. His research interests are, Power system stability enhancement including wind generator by using SMES, FACTs devices and Load Frequency Control of multi-area power system. His biography has been published in the 2011-2012 (11th) Edition of "World Who's Who in Science and Engineering". He published more than 100 papers (including journals and conferences) and published a book "Stabilization of a Grid Connected wind farm by using SMES". He also performs editorial work of a book "Energy storage" and published another two book chapters.