Solar—Wind Hybrid System for Optimized Planning and Coordination of Hybrid Renewable Energy

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Abstract It is well known fact that the rate of industrial growth of any country is a function of the amount of energy available in that country and the extent to which this energy is utilized. Energy plays an indispensable role in modern society. Besides energy independence the devasting impact of climate change has become an issue of critical consideration. The burning of fossil fuels to generate energy is a dirty process. Greenhouse gas (GHG) emissions result when fossil fuels are produced and consumed and these emissions contribute to climate change. Hence, transition towards a low carbon energy economy is the real solution for the mitigating the impact of climate change. Recommendations for the integration of renewable energy sources beyond other measures have been offered, especially with reference to the salient environmental benefits that accrue to it. A wind turbine upon which solar (PV) panels are placed supplementary which is ideal hybrid concept. Solar panels are attached to the structure of the turbine thus maximizing the power output of the device for its given size. Thus integration of the two renewable energy sources will help in maximizing the power output of a domestic-size, and improve the system's economics. Installing a hybrid system, instead of a pure solar or wind device, could assist in maximizing energy output from a given area and hence improve the economics of renewable energy.

Keywords Hybrid Renewable Energy · Solar and Wind energy · Greenhouse Gas · Environment · Climate Change

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1 Introduction

Renewable Energy Resources are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies which are most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, which are in direct relation with the use of micro and smaller in capacity power generating units that are installed in distribution part of each power combined system or all the possible locations that loads and energy consumers are concentrated. Hybrid systems are of different states [1]. One of the practices possible to provide these hybrids is combination of grid connected wind turbines and solar photovoltaic generators that together each could sit instead of the other one in a grid connection state when one of them cannot generate the required electricity for consumption by load properly. Moreover, Solar cells can generate the electricity required in the day while wind turbines can compensate the needs in the night by wind energy. This is exclusively where solar cells have gained more important effects in electricity generation of the world. They are consisting of a sort of assembly of different cells together to form a flat photovoltaic system to absorb the photons and generate electricity by electrons energized in the circuit. On the other hand, Systems for conversion of energy of wind use Permanent Magnet Synchronous Generators that are usually installed to generate electricity. Recently, wind turbines are even improved to VSD drives from constant speed generators which provides the machine the ability of generation based on cases that rotational speed varies with changes in speed of wind and that means better contributions for flexibility. These simplified hybrid systems are provided and Simulations are done to confirm expectation outcomes of this—connection.

With increasing concern of global warming and the depletion of fossil fuel reserves, solutions to preserve the earth for the future generations are undertaken. Renewable energy sources such as solar energy and wind energy have been, inexhaustible, unlimited, and environmental friendly [2, 3].

However, all renewable energy sources have drawbacks. The one that is common to wind and solar sources is their dependence on unpredictable factors such as weather and climatic conditions. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another [4].

A system that brings together solar and wind sources of energy is called a hybrid system. By combining these two intermittent sources the system's power transfer efficiency and reliability can be improved significantly. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference.

2 Morden Hybrid Systems

In the current economic climate domestic-sized solar energy systems are expensive. To develop enough energy to power a domestic residence, many panels are required, which accounts to a large amount of space. The wind power is intermittent in nature. And a stand-alone wind power system that supplies all demand is exceeded the storage capacity. This will increase the initial cost of the plant [].

The potential to address these issues lies in the use of a hybrid wind/solar system. A hybrid PV-wind system is expected to perform more reliably than a stand-alone wind system or solar system, when appropriately designed; however its overall performance strongly depends on the local resources.

For Hybrid Power Systems, areas without electricity supply from integrated networks but demand for electrification can be identified as potential markets. Large potential for rural electrification especially with renewable energy sources can be found in developing countries.

Hybrid solar-wind power generating system is suitable for industries and also domestic areas. The topic of hybrid solar wind energy system has been looked upon by many researchers all around the globe. The brief literature review helped for completion of this thesis is presented [5].

Solar-Wind Hybrid system can be used by any domestic user at a place where wind speeds are not predictable some of the loads may run through solar. It will charge the inverter battery even when there is no grid power. The switching action is provided from the microcontroller to the battery charging system based on the power received from solar photovoltaic panel and wind generators. It ensures the optimum utilization of resources and hence improves the efficiency as compared with their individual mode of generation. Also it increases the reliability and reduces the dependence on one single source.

A. *Hybrid Solar Wind System*

A stand-alone wind system with solar photovoltaic system is the best hybrid combination of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. They also complement each other during lean periods, for example, during winter when the solar is dull, wind takes over. The hybrid solar wind power system is as shown in Fig. 1. With the use of renewable energy based system the emission of carbon and other harmful gases are reduced to approximately 80–90% in environments. Initial cost for solar-wind hybrid power system is high, but it produces electricity at least cost.

The Wind Energy Conversion System consists of a wind turbine coupled to a PMSG. The three-phase diode bridge is used to rectify the generated ac voltage which is then connected to boost converter. Similarly photovoltaic panel which generates dc voltage is connected with boost converter to step up the dc voltage [6, 7].

Fig. 1 Solar-wind hybrid power system

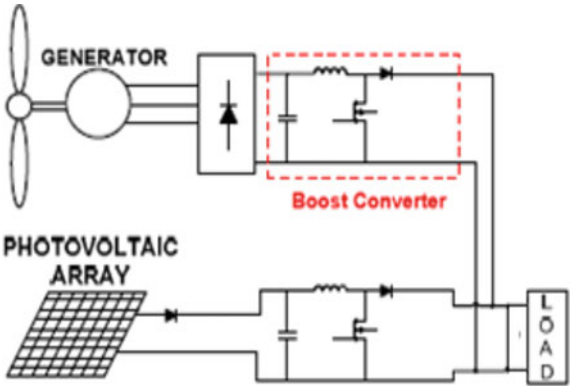

Fig. 2 Hybrid wind/PV system with multi-connected boost converter [2]

Fluctuating power is generated from solar and wind which varies voltage and frequency with variation in wind and solar radiation. The boost converter consisting of the inductor, the diode, and the switch will be current controlled to track the MPP and boost the voltage across the load resistor. Simulation is carried out using boost converter and MPPT techniques (Fig. 2) for power generation as shown in Fig. 3.

3 Modelling of Different Systems

B. *Modelling of Solar Energy System*

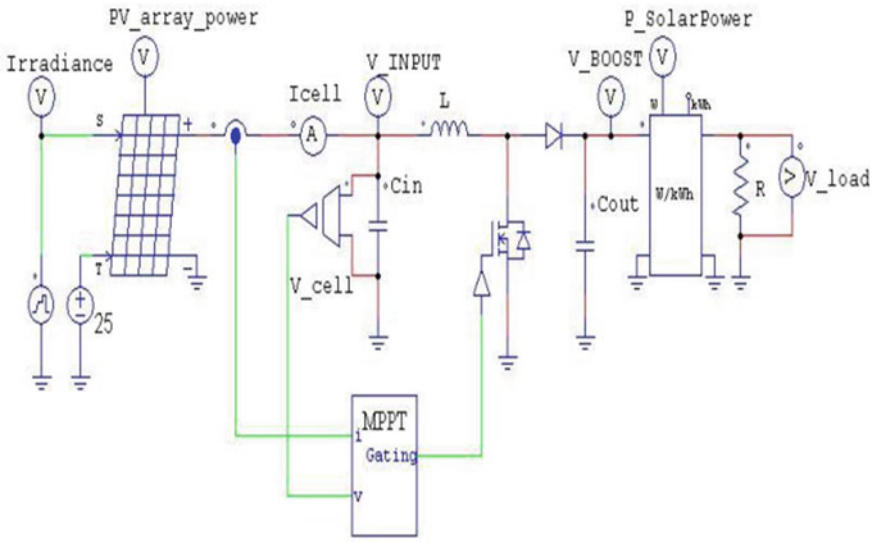

Fig. 3 Solar array with boost converter and P&O MPPT technique

Solar energy is a renewable energy resource which can be converted into the electrical power using PV cells. There are two factors-radiations and temperature which can affect the output of PV panels. If irradiance increases then current increases but variation in voltage is very less. If temperature increases, open circuit voltage decreases while if intensity of solar radiation increases, short circuit current increases. Thus I-V and P-V curve changes with change in temperature and irradiance, which also changes maximum power point. The power output from a solar photovoltaic system mainly depends on the nature of the connected load because of non-linear I-V characteristics. The schematic diagram of solar system to which MPPT technique will be applied is shown in Fig. 1. When PV panel is directly connected to the varying load its voltage keeps on fluctuating and thus voltage and current must be tracked continuously to achieve maximum power using MPPT technique. MPPT technique is used with boost converter to track maximum power and by extracting maximum power from the PV array using MPPT technique efficiency of the system can be increased.

III. Modeling of Wind Energy System

The maximum value of C p is 0.48 at $\beta = 0$ and $\lambda = 0.16$. So we cannot convert all the wind energy into electrical energy; we can only convert 48%, according to Betz limit. The schematic of the wind energy system to which the MPPT applied is shown in Fig. 4. Generator used is of permanent magnet synchronous generator type which is directly coupled to turbine due to its advantages like no need of gear box, small size, very less maintenance cost, no requirement of excitation current [8]. Instead of using three-phase controlled

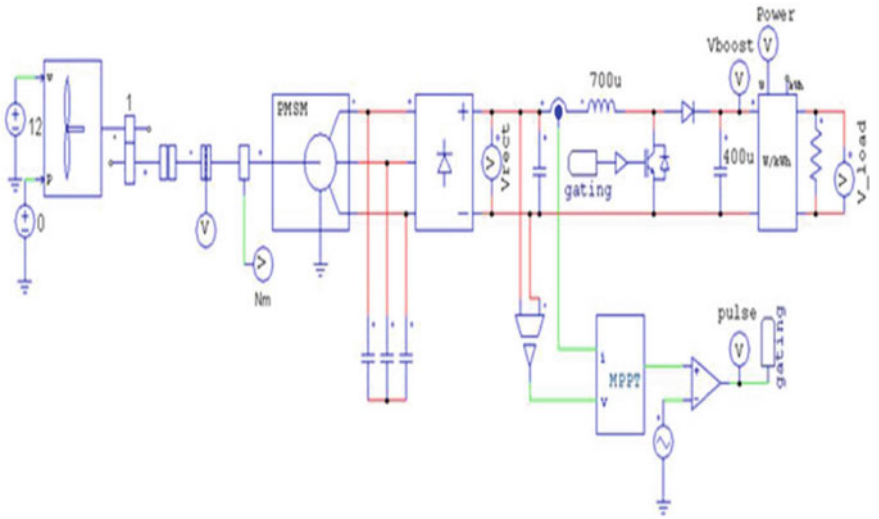

Fig. 4 Wind generator with MPPT technique

rectifier, diode bridge rectifier is used which converts the AC to a DC by rectifying voltage at constant level using boost converter.

IV. Hybrid Power System Installation

Solar Wind Hybrid Power System has been installed at many places. Out of which some are listed in Table 1. Some of them are installed and working while some power plants are under construction.

Table 1 List of Installation of solar wind hybrid energy system [9]

Location	*Project Capacity*	*Year of Installation*
Suzlon, Energy [Corporate Campus, Hadapsur, Pune]	155 kW Wind-solar hybrid system [4.75 kW Wind energy system and 55.89 kW Solar PV]	Installation complete and initial trials runs successful
Shree Jagadamba Devi Saravajanik Trust, Ahmednagar	10 kW Wind-solar system	2004 2007
Shree MartandDevSansthan, Pune	10 kW Wind solar system	2002 2005
Gujarat Energy Development Agency, Karai, Gandhinagar	10 kW Wind solar hybrid systems	2006
Reserve Bank of India, Pune	1.75 kW Wind solar hybrid system	2002
Dolat Capital Market pvt. Ltd, Mumbai	2 kW Hybrid system	2005

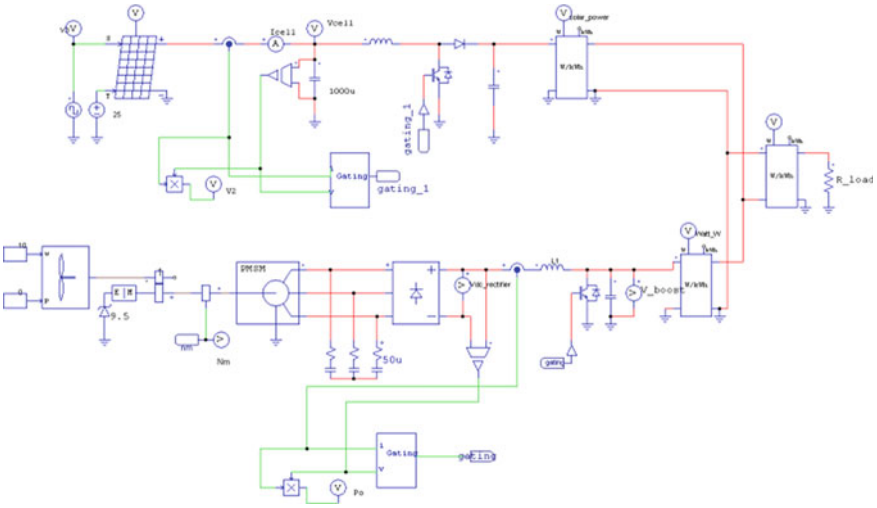

Fig. 5 Hybrid solar-wind system for battery charging application

E. Applications of Solar Wind Hybrid System

Applications of Solar-Wind Hybrid Power System are listed below [2]:

- Remote and rural village electrification.
- Ideal for cell phone recipient stations,
- Residential colonies and apartments for general lighting.
- Street lighting.
- Telecommunications.

F. *Hybrid Solar Wind Generation:*

The output from both these individual sources (which is DC after the rectification of wind generator output) is combined and it is used to drive DC loads. MPPT techniques are used to increase the efficiency of the system. Also by combining both the system, load of higher value can be used as energy generated by both the system when combined gets double (Fig. 5).

Here load value selected was 15 Ω. When solar energy system and Wind energy system were simulated individually, maximum load value obtained was 30 Ω. So by doubling load in hybrid energy system, i.e. decreasing resistance value by half obtained was 15 Ω.

4 Simulation Results

By combining solar energy system and wind energy system with MPPT techniques, results obtained are shown in Fig. 6 Both the systems are of different capacity. With load 15 Ω, power consumed is nearly 10.43 kW out of which wind energy system is

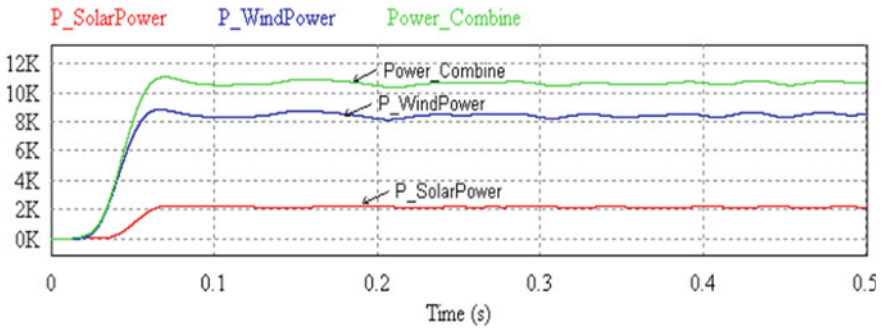

Fig. 6 Power in hybrid energy system with constant load 15 Ω

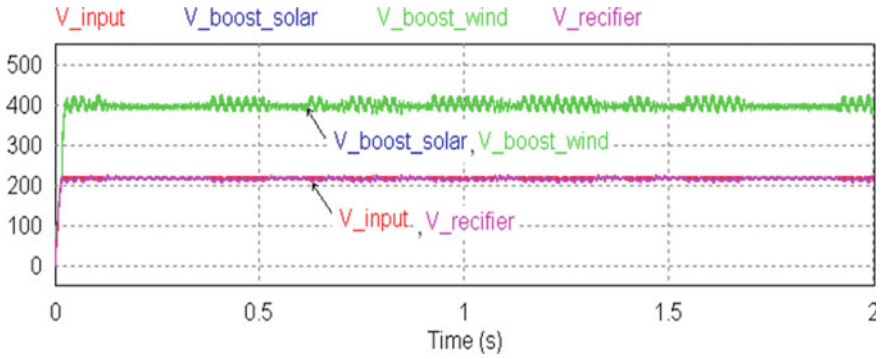

Fig. 7 Output of boost converter for hybrid system

generating 8.2 kW and Solar Energy System is generating 2.1 kW. Output of boost converter, when both sources are combined, is shown in Fig. 6. From input 210 V it is boosted to higher level of 400 V using boost converter (Fig. 7).

Conventional top-down and bottom-up models have inherent weaknesses which limited their usefulness to police-makers in energy and climate policy analysis. Accordingly, policy modelers have explored the development of a new generation of hybrid energy-environment economy models which contains both technological foundation of bottom-up models and the economic richness of top-down general equilibrium models. In this paper we have introduced a hybrid modeling approach for energy and climate policy analysis. It is a static, multi-sectoral, applied hybrid top-down/bottom-up CGE model formulated as a mixed complementarity problem designed to assess the effects of alternative energy and climate policies in a small open economy. The costs of these policies can be substantially reduced if an assessment is made of the most efficient policy instruments and technological options. Such impacts can be properly captured by using this type of modeling tool [10–14]. The practical suitability of the model is illustrated by an empirical application for the Portuguese economy to evaluate the economic and environmental effects of

the current feed-in tariffs (FITs) policy to promote electricity from renewable energy sources. This is a significant contribution of this study which is, to our knowledge, the first attempt in the Portuguese empirical literature. Results from our simulation show that the promotion of RES electricity through the feed-in tariffs instrument requires relatively modest adjustment economic costs. From an environmental perspective, the increase of the share of RES-E in overall electricity production with carbon-free power generation technologies replacing partly high-carbon fossil fuels technologies represents environmental benefits with emphasis on CO2 emissions reduction.

5 Conclusion

Energy challenges of today include increasing energy dependency, growing energy consumption, ensuring security of energy supply, reaching for sustainable development and tackling environmental concerns, most importantly climate change. Bangladesh is one of the low energy consuming countries of the world. Still the national grid can so far cover 49% of the total population. Renewable energy sources offer considerable opportunities to respond to growing energy crisis and have multiple advantages over conventional energy sources. In Bangladesh most of the electricity generation is by non-renewable energy sources like furnace oil, natural gas etc. But the reserves for these non-renewable sources are limited and will be exhausted soon. Therefore, searching alternative sources is the only option to solve the problem of electricity shortage. In order to meet sustained load demands during varying natural conditions, different renewable energy sources need to be integrated with each other like solar, wind, ocean, geothermal, biomass, wave energy, fuel cell technologies and hydro. Biogas technology combined with solar technology can have a huge positive impact on the present power sector of Bangladesh. This paper will discuss on design of a cost-effective biogas-solar hybrid power generation system and also feasibility analysis of that system considering different types of sensitivity and environmental aspects.

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