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Development of Hybrid Renewable Energy System for a Rural Site in Uttarakhand

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Abstract

Renewable energy sources like solar and wind are never-ending, freely available and environment friendly. These renewable sources have capability to provide solutions to the power problems that are currently being faced by the developing countries like India. The solar and wind energy are not available all the time, therefore, the combined implementation of solar, wind and other renewable sources are in demand for generating electricity. In this paper, efforts have been made by the author to develop a hybrid renewable energy system (HRES) using solar-PV and wind energy for a district in Uttarakhand state. Further, the paper describes the challenges and future developments, which have capability to improve the attractiveness of such energy systems. These renewable energy resources not only deal with the power problems but also assure a green and sustainable planet.

Keywords: HRES, photovoltaics, wind energy

1. Introduction

India is the third largest consumer of electricity after China and United States. The energy requirement is expected to increase by 200% from FY 2015 to FY 2030 [2]. Therefore, to meet these growing demands, the exploitation of renewable energy sources like solar and wind is very crucial. So far, only 45,917 MW of renewable energy has been installed. The Government of India has a target of installing 175 GW of renewable energy by the end of2022 [2]. The employment of these renewable energy sources has become increasinglysubstantial, attractive and cost-effective. But the erratic nature and dependence on climatic changes hinder proper utilization of these resources. Due to the dependence on variable sunshine hours and changing wind speeds, these resources do not produce productive energy throughout the year [1]. But, the mix of two or more energy resources can mitigate these problems.

Fig.1 shows the block diagram of hybrid renewable energy system. In this system, solarand wind energy are taken as input and a battery is provided as a backup source of energy during non-availability of power. A diesel generator is also provided which can serve the load if both the solar and wind energy are not available. It can also serve the load during peak hours.

A large number of hybrid energy systems have been installed in the last decade, resulting in new technologies that can challenge the conventional energy systems [4]. In the past few years, research has been carried out in the development of efficient converters, maximum

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power point trackers (MPPT), improved batteries and optimal design and control of renewable energy systems [5][6].

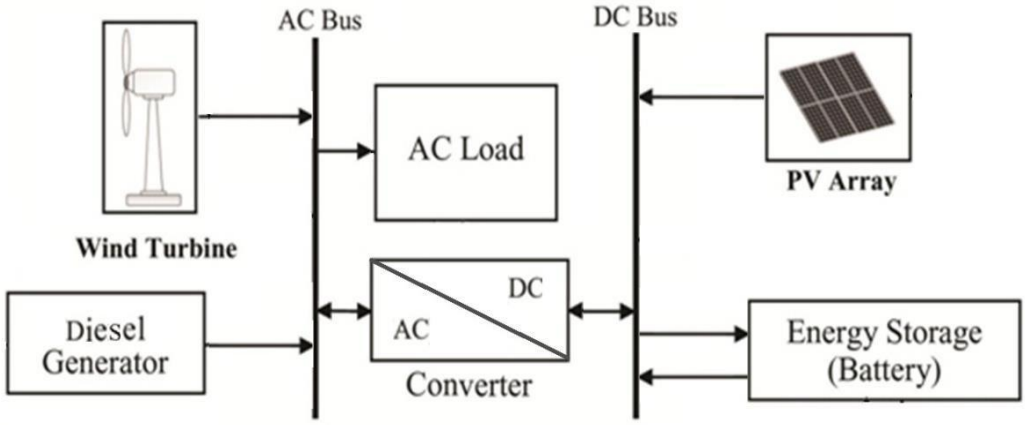

Figure 1. Concept of hybrid energy system

2. Pre-feasibility analysis of hybrid energy systems

The availability of solar and wind energy resources is determined by the climatic conditions at that specific location. Pre-feasibility studies depend upon the climatic data such as wind speed, solar irradiance and load demand for that particular location. To calculate the performance of a system, an appropriate weather data is needed. The weather conditions may vary from one location to other. The advantage of hybrid energy systems is that the energy can be exploited from several sources at the same time which will raise the overall efficiency of the system.

The weather patterns, different at different locations, play an important role in designing and implementing the solar-wind hybrid energy system. The metrological station data has been preferred by many researchers for prefeasibility study, design and optimization of hybrid energy systems. Several feasibility and performance studies have also been carried out to evaluate options of hybrid PV- wind energy systems in [7]. In [8], an approach is suggested to inspect the feasibility of hybrid PV-wind energy system using artificially collected solar radiation and wind speed data.

3. Photovoltaic system

Solar energy is the abundant source of renewable energy on earth. It is a non-polluting, freely available renewable source of energy and, therefore, it helps in reducing the greenhouse gas emissions [12]. Solar energy can be utilized by either solar photovoltaic (SPV) or by solar-thermal technologies. In solar PV system, solar radiations from the sun are converted into electricity by using solar photovoltaic cells. The most commonly used materials for PV cells are mono and poly-crystalline silicon. The solar energy can be utilized in off-grid or grid-interactive mode to serve electricity. The solar PV technology can be utilized in different areas such as rooftop solar plants, telecommunication, transportation, refrigeration and most specifically in remote and rural electrification.

An off-grid solar PV system is shown in Fig 2. The SPV system consists of solar panelswhich are made up of a large number of solar cells, charge controller, battery bank and

inverter to serve AC load. MPPT trackers are also provided to extract maximum power fromthe solar panels. Charge controller is very important for battery management and prevents the battery from overcharging as well as over discharging. The inverter converts DC power into AC power to supply the AC load.

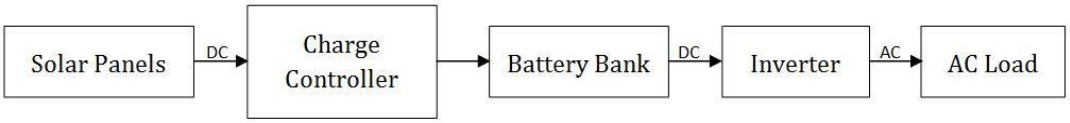

Figure 2. Block diagram of off-grid solar PV system

4. Wind energy system

Wind power as an alternative to traditional fuels like coal, is clean and plentiful and is one of the immensely growing renewable energy technology in India. It contributes to about 61% share in renewable energy in India [2]. For rural electrification, small scale wind turbines are proven technologies. Small-scale wind power is the name given to wind generation systems with the capacity to produce up to 50 kW of electrical power. These turbines can be used singly or in clusters which are generally called wind farms [11]. Fig 3 shows the wind energy conversion system.

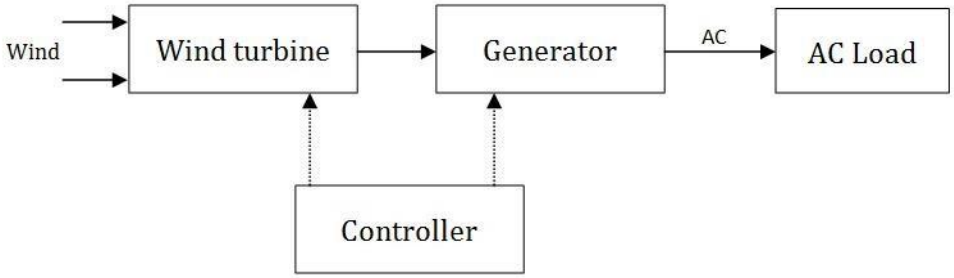

Figure 3. Block diagram of wind energy conversion system

So far, wind power plants have been installed in several parts of country such as in Gujarat, Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu and Rajasthan. The estimation of installed wind power potential in India is 102788 MW at 80 m hub-height, with 35071 MW estimated potential in Gujarat only [2].

In order to harness maximum output from the wind energy systems, proper site selectionand prefeasibility studies such as technical viability and economic feasibility need to be performed [1]. Many researchers have also proposed several modeling techniques for wind energy conversion system (WECS). Arifujjaman et al. [9] presented the horizontal furling method for small wind turbines and compared the two control methods, tip speed ratio and hill-climbing, for maximum power output extraction.

5. Proposed hybrid system

The proposed hybrid renewable energy system (HRES) is shown in Fig.1. The proposed system has been designed and modeled in Hybrid Optimization Model for Electric Renewable (HOMER) platform. The modeling method includes site identification, load identification andresource assessment, technology selection, system constraints, optimization and economic

analysis.

At first the geographical details of the proposed site are collected. The energy demand of the selected site is estimated further. After estimation of energy demand, potential assessment and technology selection of renewable energy sources in the proposed location has been investigated. Then, the mathematical model of system components including renewable energy sources like solar and wind, load demand, energy storage system and converters is developed. Finally, the model is optimized to evolve optimal model for energy supply in the proposed site.

The study is done for a village in Pithoragarh in Bin block of Uttarakhand state with latitude and longitude of 29°35.0‟N and 80°13.1‟E, respectively. In this study, the approximate measured average annual consumption is taken as 282.76kWh/day with the peak load of 39.65kW. Fig. 4 shows the monthly average load profile. Fig. 5 shows the annual daily average solar radiation and clearness index for the proposed location, and is estimated to be 5.34 kWh/m2 and 0.619, respectively [10]. The average wind speed is about 4.73 m/s measured at 50m Anemometer height [10].

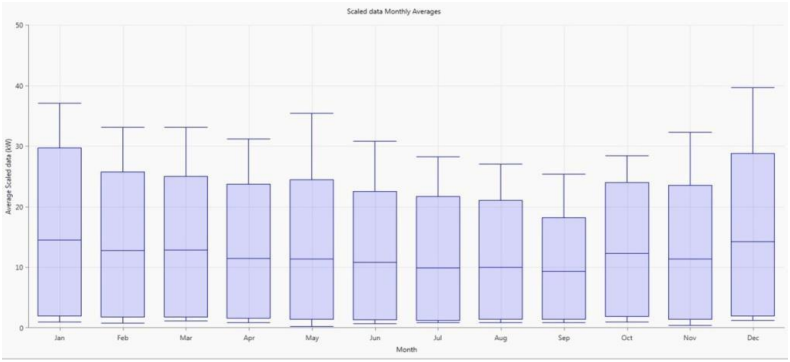

Figure 4. Average monthly load demand

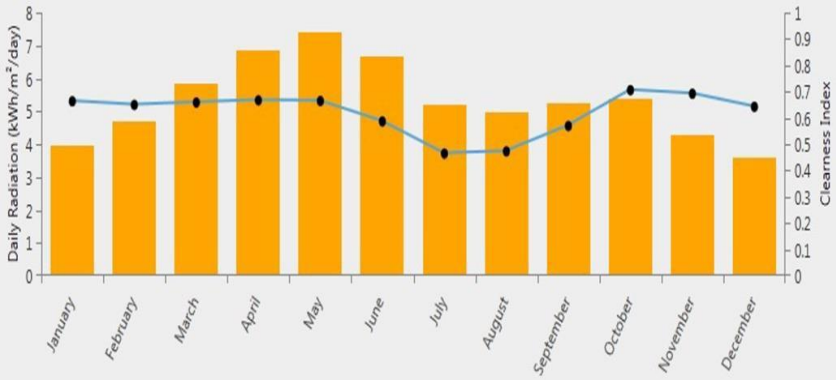

Figure 5. Average daily solar radiation and clearness index

The overall architecture of the system is shown in Table 1 below. A PV array of50kW, 2 wind turbine of 10kW each and two generators of 10kW each are used for the generation of power.

Table 1. System architecture of the proposed system

PV	GenericflatplatePV	50kW
WindTurbine	Generic10 kW	2
Generator	10kW	20kW
Battery	TrojanIND23-4V	96 strings
Converter	SystemConverter	40kW
DispatchStrategy	CycleCharging	

The selection and sizing of different components of hybrid renewable energy system has been carried out using HOMER software [13]. Thousands of simulations are carried out by the software and results in the best possible design for the system in terms of feasibility and optimal economic cost. For the PV capacity of 50kW, 2 wind turbines of 10kW each, 20kW diesel generator, 40kW converter and 96 number of batteries, the Total Net Present Cost (TNPC), Cost of Energy (COE) and operating cost are $3,98,881, $0.299/kWh and $6,117 respectively. Fig. 6 shows the monthly average electricity production. Table 2 shows the Net Present Cost (NPC) cash flow summary by component type. The total NPC of the proposed system is $3,98,881 including all the capital cost, replacement cost and O&M costs.

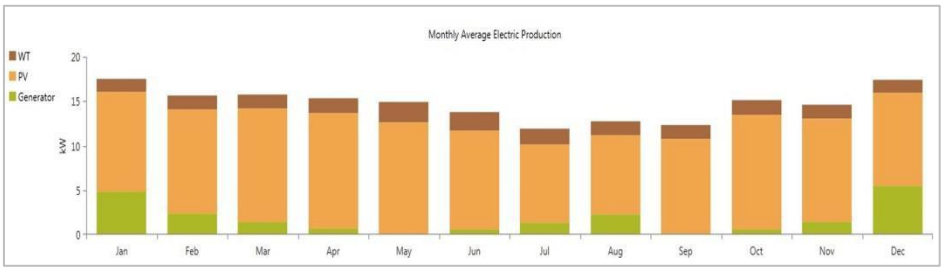

Figure 6. Monthly average electricity production of hybrid renewable energy system

Table 2. Net present cost by component type

Component	Capital ($)	Replacement ($	O&M ($)	Fuel (L)	Salvage ($)	Total ($)
GenericflatplatePV	2,50,000	0	6,464	0	0	2,56,464
Generic10 kW	2,000	6,695	388	0	-3,773	32,310
10 kWGenset	6,000	1,481	6,694	54,708	-538	68,345
TrojanIND23-4V	28,800	9,887	0	0	-4,577	34,110
Converter	6,000	2,037	0	0	-383	7,653
System	3,19,800	20,100	13	54	-9,272	3,98,881

6. Challenges and future scope

At present, coal is predominantly used to generate electricity in India despite the fact that it is limited, non-renewable and also emit enormous CO2 that contribute to global warming. So the use of renewable energy resources alone or by mixing with some other resource for

generating power can result in reduction of CO2 emissions. Still, there are several challenges for the employment of hybrid energy systems. Some probable solutions are:

- HRES have much accomplished in last couple of years. Even though there are still certain challenges in terms of their efficiency and optimal performance. The renewable energysources demand cutting-edge technology to harness maximum useful power.
- The major impediment towards the use of solar photovoltaics is its poor efficiency. It can be enhanced by using efficient materials for the fabrication of solar cells.
- The problems in grid interconnection, power quality of the renewable energy systems are of major concern and needs suitable R&D.
- The switching losses associated with power electronic converters should be reduced tominimum.
- The capital cost of renewable energy sources is a major problem that needs serious attention. This will eventually provide an opportunity to residential and industria lconsumers to use such systems.

Future, the leading edge technology development is required to boost the overall efficiency of hybrid energy systems. The widespread use of hybrid renewable energy systems will circumvent the energy issues and ensures a clean and bright future for next generations.

7. Conclusion

In this paper, a hybrid system with mix of solar and wind energy for a rural site is developed, and the economic analysis of proposed system is done. However, the issues in terms of efficiency, power quality, stability and economic feasibility have hampered the use of these resources. These issues in implementation of hybrid renewable energy systems can be conquered by future R&D efforts. Hybrid renewable energy sources have immense potential to meet the increasing energy demands of the country along with sustainable future.

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