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Prospects of solar photovoltaic–micro-wind based hybrid power systems in western Himalayan state of Himachal Pradesh in India

Sunanda Sinha, S.S. Chandel *

Centre for Energy and Environmental Engineering, National Institute of Technology, Hamirpur 177005, Himachal Pradesh, India

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ABSTRACT

The western Himalayan state of Himachal Pradesh is known as the hydro-power state of India with associated social and environmental problems of large hydro power plants. The reduced water inflow in the rivers during extreme winters affects power generation in the state. Therefore solar and wind resources need to be utilized to supplement power generation requirements. With this objective the prospects of photovoltaic–micro wind based hybrid systems are studied for 12 locations of the state. The NASA data, Artificial Neural Network predicted and ground measured data are used in the analysis of Hamirpur location whereas for remaining 11 locations estimated, NASA and Artificial Neural Network predicted data are used, as measured solar and wind data are not available for most of the locations in the state. Root Mean Square Error between three input data types are found to range from 0.08 to 1.89. The results show that ANN predicted data are close to measured/estimated data. A 6 kWp roof mounted photovoltaic–micro wind hybrid system at Hamirpur with daily average energy demand of 5.2 kWh/day is studied. This system specifications are used to obtain optimum PV–micro wind based hybrid power system configurations for all locations. The optimum configuration for Hamirpur is found to be a 5 kWp micro wind turbine, 2 kW converter, 10 batteries and 8 kWp PV system whereas for other 11 locations a 5 kWp micro wind turbine, 2 kW converter, 10 batteries and 2–9 kWp PV systems are obtained. The normalized solar and wind energy generation are found to range between 1034–1796 kWh/kWp/yr and 222–616.8 kWh/kWp/yr respectively for all locations. The study shows that state has good prospect of power generation from hybrid systems with major solar and minor wind components. However, a detailed follow up wind resource assessment programme is needed for the Himalayan region to identify true wind penetration for wind based solar hybrid power systems. The methodology presented can be used for the prediction of the photovoltaic and wind power generation potential for any region worldwide.

1. Introduction

The decentralized power generation using renewable energy sources is one of the best options for urban, rural and remote locations. Solar and wind energy systems have shown remarkable growth for power generation in recent years as these are freely available environmental friendly sources for electrical power generation.

Wind turbines and solar photovoltaic systems are clean energy systems does not greenhouse gas emissions like fossil fuel based power plants. However, energy produced by large wind farms have impact on environment like bird mortality, noise pollution, communication, etc. The large wind turbine farms can affect a larger area with noise than roof mounted micro wind turbines [1,2]. However, if wind turbine farms are designed and planned carefully, many of these negative impacts can be minimized.

The hybrid systems using both solar and wind resources are more advantageous than either a solar or wind based system as it improves system efficiency, power reliability and energy storage requirements. In order to utilize solar and wind resources efficiently and economically, optimum sizing of the hybrid system with lowest cost of energy has to be carried out. Climatic parameters like solar radiation, wind speed and air temperature for the location of interest are important for efficient utilization of renewable sources [3].

Building sector is a potential area where hybrid systems can be used effectively to minimize conventional and fossil fuel based energy consumption and CO_2 emissions. The roof mounted wind turbines with high elevation are exposed to higher wind speeds in comparison to ground based ones as such wind based hybrid

* Corresponding author. Tel.: +91 1972 254748; fax: +91 1972 223834.
E-mail addresses: sschandel2013@gmail.com, chandel_shyam@yahoo.com (S.S. Chandel).

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systems have the potential to make a significant impact on rooftop electricity generation which needs to be explored [4–12]. The large wind power generation is mainly focused in coastal or high windy regions, but presently roof mounted micro wind turbines are being used in low/medium windy locations as single or hybrid system with other sources like solar photovoltaic. The technical and economic feasibility of a renewable energy based hybrid system has to be established based on wind and solar resource potential for the location of interest [13,14]. Currently there is a widespread adoption of hybrid energy systems in remote locations as well as in built environment in developing countries like India [15]. The western Himalayan region in India is not in focus for PV–wind based generation till now.

The main objective of the study is to assess the potential of PV based micro wind hybrid systems for power generation so as to utilize the available solar and wind resources in difficult remote mountainous terrain of the state of Himachal Pradesh. In this context, the prospects of photovoltaic based micro-wind hybrid systems in twelve locations in western Himalayan state Himachal Pradesh namely Bilaspur, Chamba, Hamirpur, Kangra, Kinnaur, Kullu, Lahaul & Spiti, Mandi, Shimla, Sirmour, Solan and Una are assessed using Hybrid Optimization Model for Electric Renewable (HOMER) [16]. The solar and wind resource potential is assessed along with study of monthly and seasonal variation in 12 locations. Three types of input data namely National Aeronautics and Space Administration (NASA) meteorological data, Artificial Neural Network (ANN) predicted data, measured data (only for Hamirpur location) and estimated data are used in the analysis. The roof mounted 6 kWp micro wind–PV based real hybrid system installed at Centre for Energy and Environmental Engineering (CEEE), National Institute of Technology, Hamirpur, (NIT-H) is simulated to determine the annual energy generation at 11 other locations.

The paper is organized as follows: description of study region is given in Section 2; Section 3 presents a brief overview on utilization of renewable energy sources in the region; description of data types is given in Section 4; PV–micro wind based hybrid system is described in Section 5; Section 6 describes the methodology for hybrid system analysis; Section 7 presents Results and discussion and Conclusions and future scope in Section 8.

2. Description of study region

The Indian state of Himachal Pradesh (H.P.) is located in North-Western Himalayas between latitudes 30.38°–33.21° North and longitudes: 75.77°–79.07° East, covering a geographical area of 55,673 km^2 (Fig. 1) with states of Jammu and Kashmir in north, Punjab in west, Haryana in the south-west, Uttarakhand on the south-east and Tibet in the east. The elevation of the state ranges from 250 m to 6795 m which extends from Shivalik hill range (600 m) to Dhauladhar mountain range (4550 m) and Great Himalayan range (5000–6000 m). Over 80% of population of the state lives in rural and difficult remote areas. Due to extreme variation in elevation, there is variation in the climatic conditions of Himachal Pradesh. The climate varies from hot and sub-humid tropical in the southern tracts to cold in higher alpine and glacial regions in the northern and eastern mountain ranges. The state mainly experiences summer, rainy, and winter seasons. Summer lasts from mid April till the end of June, rainy season (July–August) and winter lasts from November till mid March. Snowfall is common in alpine tracts (generally above 2200 m). The state with a population of 6.856 million, is divided into 12 administrative districts namely Kangra, Hamirpur, Mandi, Bilaspur, Una, Chamba, Lahaul and Spiti, Sirmaur, Kinnaur, Kullu, Solan and Shimla [17,18]. Fig. 1 and Table 1 give the details of the study locations.

3. Utilization of renewable energy sources in western Himalayan region – a brief overview

Himachal Pradesh is one of the most developed hill states of India. The state is also known as the hydro-power state of India with hydro power generation potential of 21,244 MW but only 3934.74 MW hydro electricity is generated up to now [19–22]. There are no nuclear or thermal power plants in the state. Glaciers are the main sources of water for all major rivers in higher Himalayas which do not release enough water in winters due to extreme low temperatures leading to shortage of water in rivers thus sufficient power cannot be generated and the state has to purchase power from other states to meet the energy demand. Apart from this there are financial, social, environmental and geographical

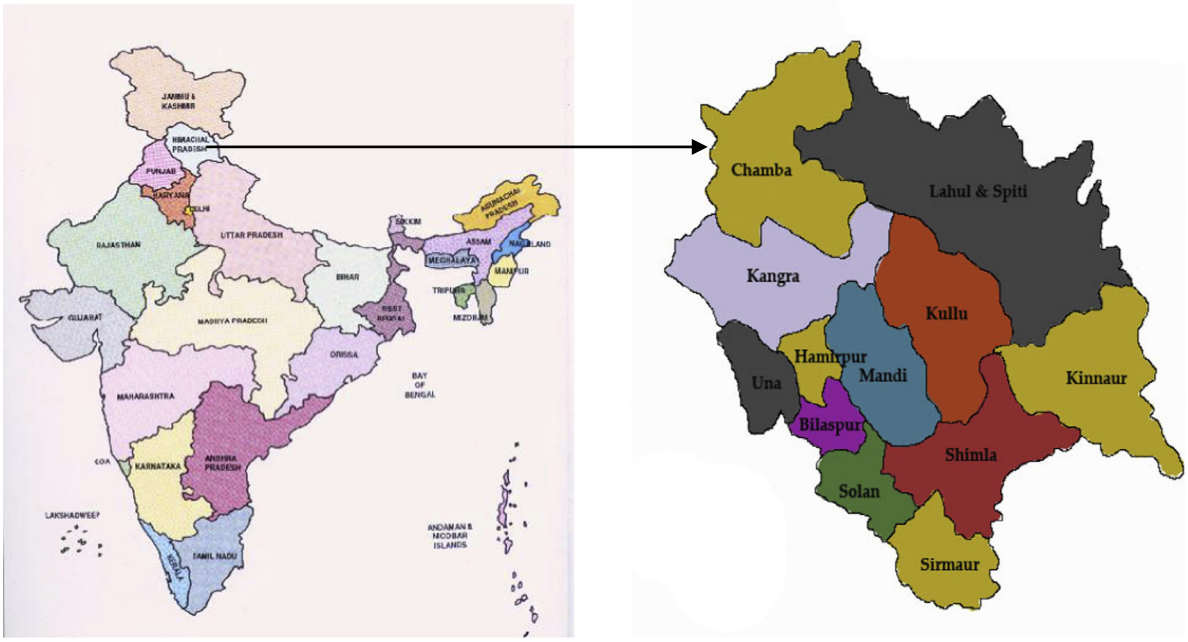

Fig. 1. Location of Himachal Pradesh in India and 12 study locations.