Renewable and Sustainable Energy Reviews 53 (2016) 408–421

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Evaluating wind energy potential in Pakistan's three provinces, with proposal for integration into national power grid

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ARTICLE INFO

Article history:
Received 2 May 2015
Received in revised form
31 July 2015
Accepted 23 August 2015

Keywords:
Wind energy
Wind turbine
Feasibility analysis
Weibull distribution
Grid integration
Pakistan

ABSTRACT

Pakistan is facing increasing power shortage from the last two decades. The Government of Pakistan (GoP) has taken various remedial measures and is offering incentives for private investment to generate electricity at cheap rates. New hydropower dams were proposed in the past, such as Kalabagh Dam, but could not be commissioned to date. Fossil fuels are depleting and oil has to be imported for oil-fired power plants, which is highly expensive and a burden for the country's economy. This scenario has raised serious concerns among citizens. In this frustrating situation, there is dire need for exploration and installation of alternate renewable energy resources, in particular, wind energy and solar energy to augment the existing power generation and distribution apparatus. These then need to be integrated with the national power grid. Pakistan has enormous wind energy potential, especially in three of its four provinces namely, Khyber Pakhtun Khwa (KPK), Sindh and Balochistan. The country's multifarious terrain includes coastal and hilly areas suitable for installation of large wind turbines. The GoP has taken active steps towards measuring wind speed statistics in various parts of the country. In this paper, the authors analyze wind speed data for the mentioned three provinces. The fourth province, Punjab, has very limited wind energy potential and hence is not considered. Wind speed data for Jiwani (a reference site in Balochistan) was obtained from Pakistan Meteorological Department (PMD) as a case study. The paper attempts to assess how much wind energy can be harnessed from the three provinces. It then focuses on Jiwani whose specific power density is estimated for wind turbine sizing. Lastly, a practical scheme is proposed for integration of wind power output (from windy sites) with the national power grid.

Contents

Abbreviations: AEDB, Alternative Energy Development Board; DG, Distributed Generation; EPA, Energy Purchase Agreement; FATA, Federally Administered Tribal Areas; GST, Geo-Spatial Toolkit; HVDC, High Voltage Direct Current; HVAC, High Voltage Alternating Current; IEE, Initial Environmental Examination; IGBT, Insulated-gate Bipolar Transistor; IPP, Independent Power Producer; KE, Karachi Electric (Supply Company); KfW, Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute); KPK, Khyber Pakhtun Khwa; LOI, Letter of Intent; MLM, Maximum Likelihood Method; NEPRA, National Electric Power Regulatory Authority; NOC, No Objection Certificate; NREL, National Renewable Energy Laboratory; NTDC, National Transmission and Despatch Company; PDF, Probability density function; PMD, Pakistan Meteorological Department; PPAF, Pakistan Poverty Alleviation Fund; PSD, Particle Size Distribution; PST, Pakistan Standard Time; PV, Photovoltaic; SEPA, Sindh Environmental Protection Agency; SVM, Space Vector Modulation; USAID, United States Agency for International Development; VSC, Voltage Source Converter; WT, Wind turbine

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http://dx.doi.org/10.1016/j.rser.2015.08.052
1364-0321/

1. Introduction and background

Pakistan is located in South Asia with a population exceeding 180 million. The current total installed power generation capacity is around 22,800 MW which is a mix of mainly hydel, thermal and nuclear sources. Often the actual power generation is much lower due to many factors and can hit as low as 9000 MW, while the demand varies between 16,500 MW (summer) and 10,000 MW (winter). The country has four provinces namely, Punjab, Khyber Pakhtun Khwa (KPK), Sindh and Balochistan. Punjab is the largest province (population-wise) with approximately 56% of the country's total population. The capital of Punjab is Lahore. Punjab has a population of approximately 100 million and an area of 205,344 km^2. There is a growing demand of energy in this province. With respect to wind energy, it does not offer much potential except perhaps at its Kalarkahar region which is 10–20 km wide and 250 km long. KPK is home to 12% of the total population of Pakistan. This province is the smallest province by area, but is the most climatically diverse; with deserts, forests and tundras all located within. Some areas of this province have been identified for hybrid power systems such as solar-wind-hydro and there is a great potential for small scale wind turbine installations. Rural and off-grid communities will benefit from microhydro power, solar lighting system, and Photovoltaic (PV) powered water pumping systems. The Pakistan Poverty Alleviation Fund (PPAF) is working in this region for promoting renewable energy projects. Some projects are funded by Germany, through the German development bank, Kreditanstalt für Wiederaufbau (KfW). Sindh is the second largest province with land area of 140,914 km^2; its capital is Karachi, which is the most populous city of the country, as well as a huge commercial hub. Pakistan is developing wind power plants in Sindh areas namely Jhimpir, Bin Qasim, Gharo and Keti Bandar. A local concern (Fauji Fertilizer Energy Company) is building a wind energy farm of 49 MW at Jhimpir near Karachi. A Chinese company (Three Gorges) has planned to build two more wind power projects of 50 MW each at Jhimpir, Sindh in 2015. Area-wise, Balochistan is the largest province having land area of 347,190 km^2 forming approximately 44% of Pakistan. Here, population density is low on account of mountainous terrain and scarcity of water in most areas. Notably, Balochistan has seven wind corridors quite suitable for wind farms. Some of these are around 50% better and more efficient, when compared to that of Gharo in Sindh, but that potential needs to be explored and exploited. In 2013, the country's power shortfall surpassed 5000 MW in May–June (hot summer weather), then went down to 3000 MW in the month of July due to increased hydel generation which in turn, was due to plentiful rainfall. There was about 22% shortfall of electricity in Pakistan up to October in that year; and this can go much higher in case of less-than-average rainfall in any year. The government needs to overcome the ongoing precarious electricity crisis in Pakistan at the earliest. It is time to rid the country from this serious situation before further deterioration sets in.

The paper is organized as follows. Section 2 of this article discusses wind power as an alternative power generation source for the country and describes existing wind installations. In Section 3, the authors attempt to assess the wind energy potential in three provinces of the country. Section 4 lays out the wind power generation system deployment requirements and parameters. Section 5 works out the wind resource assessment for Jiwani. In Section 6, the authors focus on wind power system integration to national grid and propose an HVDC based scheme. Section 7 concludes the paper. Appendix-A goes through the Weibull parameter estimation.

2. Alternative/renewable resources: wind power

Among alternative and renewable resources, wind power has been identified as a significant potential source of renewable energy for Pakistan. The country has a total estimated gross wind power potential installable capacity of around 346,000 MW [1]. Wind resource assessment is necessary to identify the promising areas for wind project deployment. Identification of the potential areas helps to accelerate the investment in the utility scale wind projects by public and private sectors. Three of the major sources of wind data of Pakistan are Pakistan Meteorological Department (PMD), Alternative Energy Development Board (AEDB) [2], and National Renewable Energy Laboratory (NREL). PMD and AEDB are public sector organizations of Pakistan while NREL is a US based organization. Pakistan has high potential of wind energy in many parts of the country that can be a huge power generation source and can satisfy the national electricity demand. Not all of this can be exploited due to reasons such as lack of infrastructure for transmission and distribution, lack of active data for wind speed statistics and political situation of the country.

2.1. Wind resource studies

Among several wind resource studies undertaken, one significant effort was made in 2007 by NREL under the U.S. Agency for International Development (USAID) assistance program. This study has come up with a mesoscale map of Pakistan, Fig. 1, showing the wind speed potential available at 50 m height.

This wind map of Pakistan shows significant wind corridors in southern Sindh, north western locations in Balochistan and central areas of KPK, along with many relatively isolated wind corridors in central and western Punjab, central and southern Balochistan areas; and also in Gilgit-Baltistan, which is a remote northern area