Renewable and Sustainable Energy Reviews 39 (2014) 828–834

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Development of the wind power in Brazil: Political, social and technical issues

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ARTICLE INFO

Article history:
Received 20 June 2013
Received in revised form
15 April 2014
Accepted 8 July 2014
Available online 8 August 2014

Keywords:
Wind power
Brazilian electric matrix
Energy policies
Wind industry
Sustainable development

ABSTRACT

This paper aims to present a review of the increasing contribution of wind power to the Brazilian electric matrix and an analysis of the main impact on technical, political and social aspects. This work takes into account the state-of-art of the wind power technology, the wind resource potential and the evolution of installed capacity in the country. The institutional programs and the fiscal incentives provided by the Brazilian government are also discussed in this paper, including its impacts on the society. We have reviewed national and international reports and relevant scientific papers to realize this work. The analysis shows that electric crisis in 2001 led the Brazilian government to develop new energy policies that supported the rapid growth of the wind industry from imported technology. Later on in the year 2004, the government mandated that the technology be developed within the country. It is expected that from 2011 (of approximately 1500 MW) until 2021 the installed wind capacity would increase by a factor of 600%. However, the national technology acquisition and development is still incipient. It is important to produce locally wind turbine components and is highly desirable to increase collaboration between industries and universities in the country.

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http://dx.doi.org/10.1016/j.rser.2014.07.086
1364-0321/

1. Introduction

Since the oil crisis in the 1970s, and lately the impact of global warming on our environment, the search for renewable energy sources has accelerated substantially. However, the current global dependence on fossil fuels for the generation of electricity is still dominant and its total replacement seems unrealistic in the near future.

Brazil has an area of 8.5 million km^2 and a population of approximately 200 million. Because of the rapid industrialization and a better life-style for the people, the demand for electricity is increasing exponentially. However, at the present time almost 70% of the total generating capacity is from hydroelectric sources and additional sources of hydropower are diminishing [1–3]. Due to the impact of large hydraulic power projects on the environment, the search for other renewable energy sources, such as wind, biomass, solar and wave, are required to exploit.

Another challenge faced in Brazil is the recurrence of prolonged droughts for periods of two to three years, leading to shutdown of hydroelectric plants due to shortage of water in the reservoirs. This led to the blackouts in 2001 and 2002 which resulted into social and political backlash. Therefore the federal government instituted a wind energy program named PROEOLICA [4]. The aim of the program was to install 1050 MW wind capacity, and expected to alleviate electricity shortage. It should be emphasized here that, especially, in the Northeast of the country there is a good complementarity between water and wind resources. In other words, when there is drought, the wind are stronger and steadier during same period [3,4]. However, this program was not successful due to insufficient fiscal incentives to industry [5].

In 2004, another program for renewable energy sources, called PROINFA, was created from which wind power benefited the most [6]. At the end of 2013 more than 3300 MW of wind capacity has been installed and is distributed over 140 wind farms throughout the country [7].

The electric matrix can be approached from different perspectives. Among the most important are: social, technological development, political and environmental, and energy planning perspectives [8–12].

This work presents the state-of-art of wind power technology considering the technical, political, and social aspects. We also describe repercussions in the implementation of wind power and its important role in the development of the country.

This paper is structured into six sections. Section 1 consists of the introduction; the share of wind power in the Brazilian electric matrix is described in Sections 2 and 3 describes the Brazilian wind potential taking into account the wind resource and the installed generating capacity. Section 4 describes the main political decisions needed to meet the wind energy development in the country. In Section 5, several societal aspects that could help meet the goal of sustainable development outlined by the government are described. Finally, Section 6 presents the concluding remarks.

2. Present role of wind power in the electric matrix

Until about 2001, more than 90% of energy generation was generated from hydroelectric plants and the remaining came from coal-fired generators, and some quantity (from gas) was imported from a neighboring country [8]. As mentioned in the previous section, a remarkable shift in the electric matrix composition occurred in 2001 when government incorporated the program PROEOLICA [13]. Then in 2004 PROINFA was institutionalized where small-scale hydro, wind, biomass and solar were given incentives. Since then, the country's electric matrix has grown year by year in terms of installed capacity and, also, in the expansion of the distribution network.

Fig. 1 shows a pi-diagram of the electric matrix at the end of 2013. The highest contribution came from the hydroelectric source, 67.89%. The second highest came from thermal plants, comprising mainly of natural gas generators, 28.61%, wind power, 1.7%, and nuclear sources, 1.58% [2].

Another renewable energy source is solar energy with an installed capacity of about 4.9 MW [2]. Even though several institutions are engaged in the development, but as of now it presents an insignificant amount in the energy matrix [10].

Ricosti and Sauer [12] elaborated a study of annually and multi-annually complementarities which demonstrated the advantages of wind energy investments over thermal plants. The obtained results indicated a 200% increase on the per capita energy consumption, from today's 2.5 MWh to 7.5 MWh in 2040.

Furthermore, recent governmental energy planning studies indicate that flexible thermal plants and those not dispatched from the interconnected system due to electrical reasons should not represent restrictions to the flow of energy generated by wind farms [14]. Considering the intermittent nature of wind and solar sources, the *Operador Nacional do Sistema Elétrico* - ONS (National Operator of the Electric System) should maximize wind dispatch-ability. In this scenario, the ONS should provide an arrangement for flexible thermal sources (i.e. gas turbine plants running on natural gas and combined cycle gas turbine plants), with the purpose of stabilizing intermittency, reliability of the electric grid and supply security.

3. Wind energy development

3.1. Energy potential

There have been several studies aimed at estimating wind potential in Brazil. One of the most important published work was in 2001, named Wind Atlas of Brazil [15]. It has been estimated that Brazil has a potential of 143 GW and that it is possible to produce about 272.2 TWh/year (at an average hub height of 50 m). Fig. 2 shows the wind power potential in the five regions of the country. The potential for each of the region is estimated as: Northeast (75 MW), South (41.1 MW), Southeast (29.7 MW), North (12.8 MW) and Center-West (3.1 MW). The strongest and steadiest winds blow in the Northeastern and Southeastern regions of the country with an annual mean speed in order of 8 m/s [15].

Moreover, some Brazilian states have prepared their own wind atlases with detailed information than that indicated in Fig. 2. In 2013, a preliminary version of the wind atlas was presented for the state of Pernambuco, which is situated in the Northeastern region of the country with an estimated wind power potential in

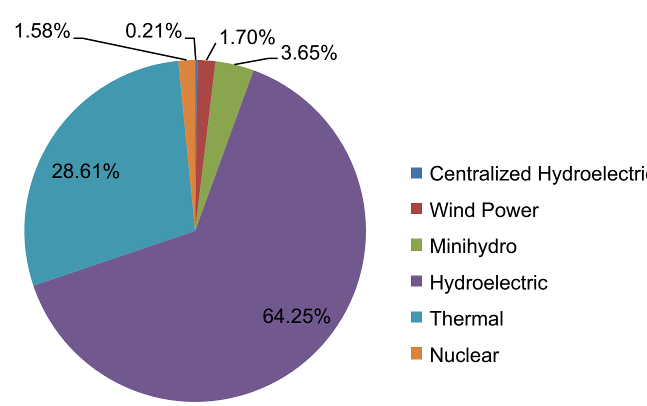

Fig. 1. Brazilian electric matrix in 2013.
Source: ANEEL [2], adapted by the authors.