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Mitigation of wind power intermittency: Storage technology approach

T.R. Ayodele*, A.S.O. Ogunjuyigbe

Electrical & Electronic Engineering Department, Faculty of Technology, University of Ibadan, Ibadan, Nigeria

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ABSTRACT

In recent time, the concern for grid integration of wind power has been a subject of discussion in the academic community. At present, the penetration level is still moderate for most grids to accommodate. As the penetration level increases, wind power may cause additional problems to the grid due to its intermittent nature. One of the intending solutions to this problem is the adoption of energy storage. This paper examines the state of the art energy storage technology options that are capable of mitigating wind power intermittency on the grid and their challenges. It also highlighted the existing policies that aided the development of wind power and discusses the limitations of its integration into the grid. It was found that, the ability of storage technology to be effectively utilised in mitigating the wind power intermittency depends on the ramp rate of the technology, response delay time, duration of storage, maturity of technology, installation cost, efficiency of the technology, its environmental impact and the suitability of the site topology. Therefore, no single storage technology is capable of providing total solution at mitigating the effect of wind power intermittency on the grid. The effectiveness of the storage technology lies in the hybridization of the storage technologies depending on the level of cost and technical requirements.

Contents

* Corresponding author. Tel.: +234 8064339270.
E-mail addresses: tr.ayodele@ui.edu.ng, tayodele2001@yahoo.com (T.R. Ayodele), a.ogunjuyigbe@ui.edu.ng (A.S.O. Ogunjuyigbe).

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1. Introduction

With the deregulation of electricity markets, the structure of power systems has changed from the vertical to horizontally-operated power systems. This new structure allows distributed generators to be part of the modern power systems. Most of these embedded generators come from Renewable Energy Sources (RES) such as wind, solar, small hydro, wave, tide, geothermal, and biomass. The advantages of utilizing renewable energy generators in mitigating climate change have been severally discussed [1–3]. It is estimated that 1 GW of renewable capacity can power about 290,000 households and 959,000 electric vehicles in a year thereby saving 349 million Gallon of gasoline [4] which could avoid emission of millions of tons of CO_2 per year. Of the various RES, wind is the most utilized for electricity generation. This is because the technologies for harvesting the resources are better developed and well understood compared to the others. Moreover, most regions in the world are endowed with this resource. In addition, expansion and the developments of other RES such as hydro, tidal, geothermal and wave are limited, and most suitable sites have been developed which provides no room for further expansion. Wind generators have high modular characteristics and are fuel independent. They are environmentally advantageous and economically viable.

In recent years, the growth of wind power has been tremendous. In 2014, a joint venture between Mitsubishi and Vestas announced a single wind turbine generator of 8 MW [5] and it is envisaged that a single wind farm in the capacity of over 1000 MW will be possible in the future [6]. A total wind power capacity of 106 GW was installed in Europe alone at the end of 2012 as depicted in Fig. 1, this represent a growth of 12.6% per annum in the region [7]. It has also been reported that the total world installed capacity reached 318 GW at the end of 2013 as shown in Fig. 2 [7]. This could respond to 3.5% of the world total electricity demand. It is anticipated that at the end of 2030 and 2050, the wind energy will provide 4.9% and 18% respectively of the total electricity production in the world [8].

The tremendous growth experienced by the wind industry around the world is not without the policy support for wind energy development that continually improve the reliability, cost-effectiveness and overall understanding of wind energy [9–11]. Table 1 presents the overall review of some of the policy that enhances the exponential growth of wind energy industry.

However, with these laudable programs and the level of development in the wind power industry, there are concerns that wind power integration will increase technical complexity and ancillaries service cost of electricity production due to the intermittent nature of wind speed which is the prime mover of every wind turbines. Electricity from wind turbine is variable from time

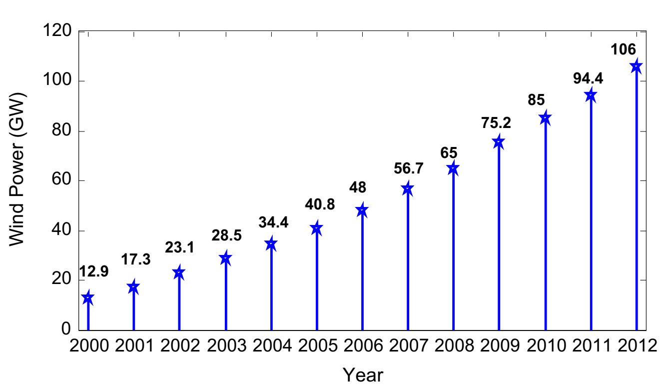

Fig. 1. Cumulative installed wind power in the European Union between 2000 and 2012.

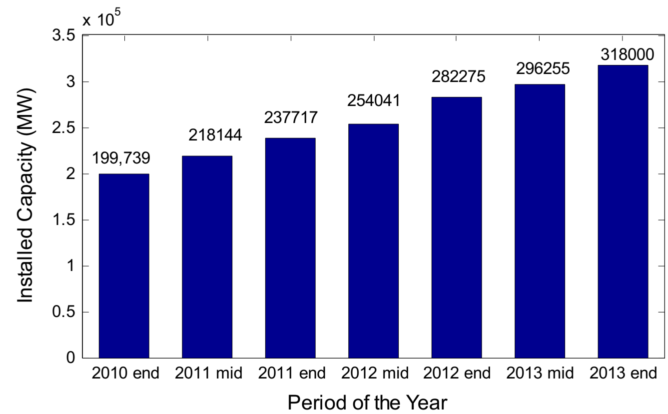

Fig. 2. Total installed wind capacity in the world between 2010 and 2013.

to time and therefore cannot be scheduled or controlled as that of thermal, nuclear, fossil or hydroelectric generators [9]. Due to the stochastic nature of wind speed, wind generators cannot ensure continuous supply of electricity [6].

Presently, efforts are being made at ensuring smooth integration of wind power into the grid with different technological methods. This paper therefore examines various available storage technologies options that are applicable to wind power application. These technologies are capable of improving the power system grid integrity i.e. the power system security, power system stability and power quality during the integration of intermittent wind power into the power system. This work is relevant under the theme of renewable energy and green technology.

2. Limitations of grid integration of intermittent wind power

Integration of wind power into the power system is often faced with reluctance by the utility operators due to intermittent nature of wind power. There is always a fear that a sudden change of wind speed as a result of its unpredictable nature could lead to shutting down of the wind generators. This could trigger security issues as a result of cascading tripping of other conventional generator for loss of generation. This paper identifies economic, technical and institutional factors as crucial factors facing wind power development.

2.1. Economic factor

In power system, there must be an instantaneous balance at all times between the aggregate demand for electric power and the total power generated by all contributing power plants [25]. Wind power generation is a variable and unpredictable source of power which may have consequences on the regulation reserve. Other conventional generators must offset the change in wind power output in order to balance load and generation in real time. This has, and continues to generate concerns among the utility operators that wind generators with variable output may increase the operating costs (ancillary-services costs) of the power system as a whole. It is believed that these stochastic nature will force the conventional power plants to provide the ancillary services in order to maintain system balance, thus causing the conventional power plants to deviate from operating points that have been chosen to minimize the total cost of operating the entire system [9]. Moreover, wind farms are located where the wind resources are found which most often are very far from the cities. This increases the transmission cost of delivering power to the load centres and may not be attractive to the Transmission System