Voltage Stability Analysis of a Distributed Network Incorporating Wind Power Resource

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ABSTRACT

This paper investigates the impacts of a wind farm connected at Harterbeespoort substation in South Africa on voltage stability of the power network. The site wind speed was determined and analyzed for viability. A comparison is made between the use of Doubly-Fed Induction Generators and Self-excited Induction Generators driven by the wind turbines. The resulting P-V and Q-V curves from load flow studies are presented and analyzed. The models for this study were implemented in DigSILENT PowerFactory.

Keywords: Digsilent, Induction Generator, Voltage Stability, Wind Energy, Wind Farm Viability

1. INTRODUCTION

South Africa has an energy intensive economy, which is highly reliant on fossil fuels, and sees economic growth based on energy intensive industries as a key means to development. The Energy Sector is a large-scale industry that bears the full imprint of a strong reliance on cheap coal that exists in large quantities. As a result, the country is one of the biggest Carbon Dioxide (CO₂) per capita emitters in the world. The giant energy monopolist ESKOM is one of the lowest-cost energy suppliers globally. Today it generates more than half of all generated power on the African continent and has a total installed generating capacity of some 42,000 MW (Net 36,200 MW, Peak 34,200 MW) with already new peak capacity in demand in the recent past. Of this total power production capacity, 93% is of coal based (10 large plants), 5% nuclear and 2% hydroelectric. Small power stations and back-up gas-turbines represent less than 1% of the national output, another 3% is used for own consumption by independent power produc-

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ers. It is anticipated that this capacity will be outstripped by energy demand by 2011 (African Wind Energy Association, 2008).

With the continued reliance on fossil fuels, energy crisis and environmental concerns, it has become critical to call alternative sources of energy into the energy mix. South Africa has set some target to generate 10,000GWh from renewable energy sources by 2013 – an equivalent to 4% of the forecasted power demand by then (Department of Minerals and Energy, 2007). Of this, close to 70% of the country renewable energy needs are anticipated to come from wind. Renewable energy can in many ways provide the least cost alternative sustainable energy supply, particularly when the social and environmental costs are considered, with wind power having the greatest potential as compared to other renewable sources.

Unlike the conventional power plants, wind power introduction into the grid comes with a number of technical challenges, quite notably the voltage stability issue. This will always affect the operation and security of wind farms and the larger power grid. The intermittent nature of wind power is still a challenge. Many studies have been performed on grid-connected wind farms and their associated power quality issues. A model to investigate the power quality impact during normal operation on power system is given in Hansen, Sorensen, Janosi, and Bech (2001). The performance of a large wind farm connected to an external grid is discussed in Li, and Yang (2009). The effects of short circuit power capacity at the point of common coupling and the reactive power compensation on the system stability were determined in Muyeen et al. (2007).

In this paper, the study about the steady state model of grid-connected wind farm connected at Harterbeespoort substation is reported. Steady-state voltage stability analysis is conducted. The wind turbine model used in load flow calculations is implemented in the power system simulation tool DigSILENT PowerFactory. The P-V and V-Q curves obtained from power flow are used in the determination of the voltage stability of the power system with increased wind power penetration level. For comparison a wind farm based on both the traditional induction generator (IG) and the doubly-fed induction generator (DFIG) is analyzed. A wind farm based on DFIG is further proposed as the continuous reactive power source to support system voltage control due to its reactive power control capability.

The grid data used in this study are estimates measured from the utility while the average wind speeds are obtained from measurements that were made by NASA at a height of 50 meters from the ground.

The study of small hybrid power systems is very important, especially for African countries, since demand currently outstrips generation capacity in the majority, if not all, of the countries on the continent. The utility companies are not in a position to increase plant capacity at the same rate as load growth due to a number of factors. Generation of power using renewable resources at load centres, where possible, will go a long way in easing the capacity burden on supply authorities.

The main limitation with respect to maximum rating and integration of the wind power into the grid may be associated with voltage stability of the local network. As a consequence of this, the voltage control assessments and reactive power compensation are vital factors to consider when planning for development of large-scale wind power integration. The choice of the wind farm site and accurate estimation of wind speed variability over time is equally important (Juma, Mochusi, Munda, & Jimoh, 2010).

The paper is organized as follows: Section 2 details a brief summary of the software tool used. Sections 3 and 4 provide a brief introduction of wind energy, including definition, characteristic and the application model. Sections 5 and 6 presents a brief description of the network under study and the wind resources, respectively. Results alongside some
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