Grid Integration of Wind Power System for Voltage Stability Enhancement

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Olanrewaju Ade. Olanite,
Department of Electrical and Electronics Engineering
Federal University of Technology
Gidan Kwano, Minna, Nigeria
olaniteolanrewaju@gmail.com

Mark Ndubuka Nwohu
Department of Electrical and Electronics Engineering
Federal University of Technology
Gidan Kwano, Minna, Nigeria
mnnwohu@futminna.edu.ng

Babatunde Araoye Adegboye
Department of Electrical and Electronics Engineering
Federal University of Technology
Gidan Kwano, Minna, Nigeria
tunde.adegboye@futminna.edu.ng

Omokhafe James Tola
Department of Electrical and Electronics Engineering
Federal University of Technology
Gidan Kwano, Minna, Nigeria
omokhafe@futminna.edu.ng

***Abstract* - Integration of renewable energy for sustainable power supply is gradually securing prominence in energy deficit aversion and depletion of fossil fuels. This paper examines the impact of integration of Permanent Magnet Synchronous based Wind Turbine Generators (PMS-WTGs) on power system's voltage stability. Nigerian 52-bus, 330kV grid network is used as the study case. Successful modelling and simulation of the network were achieved in MATLAB. Ant Colony Optimization technique was used to determine optimal location and sizing of PMS-WTGs on the network. At simulation, Continuation Power Flow analysis indicates Aladja and Yola load buses as the best positions to place PMS-WTGs of respective optimal sizes of 100MW and 197MW with a 150% increase in load injection at 10% interval. The wind penetration levels maintain the ±5% bus voltage limit with the highest voltage level, 1.042p.u, at Damaturu. The overall results indicate integration of 297MW PMS-WTGs yields an improvement in voltage profile.**

Keywords: Ant Colony Optimization, Grid integration, Permanent Magnet Synchronous Generator, Voltage stability, Wind Turbine,

I. INTRODUCTION

The integration of renewable energy for sustainable power development is gaining importance as a means to meet the growing global energy need and reduce dependence on fossil fuels [1]-[2]. The on-going global adoption of RERs as an alternative to the presently dominating but depleting fossil fuels is prompted by increasing worry on global climate change, demand for carbon dioxide emission reduction and uncertainty in conventional fuels market. Most countries of the world now envision near-zero emission power sectors and reaching these targets would require grid-penetration of RERs [3-4]. Studies have been done on integration of RERs into power grids of developed nations [5]-[7]. Authors in [7] gives a decarbonization pathway model for Europe's electricity power system to satisfy the reduction targets of greenhouse gas (GHG) emission while the work in [6] discussed pathways to decarbonization in the United States. Researchers have also investigated the potential and integration of RERs into the Nigerian grid [11]-[12]. It is clear from indigenous researchers that northern states of Nigeria have highest wind energy potentials but little has been done to harness it effectively. Integration of RERs, especially wind energy, remains one of the viable options to douse Nigerian electricity crisis, reduce environmental pollution and climate change which are viewed as global security threats. Studies have been done on impact of integrating wind power on network voltage stability and various enhancement techniques [9], [13]. However, there are not enough research and technically feasible solutions for the integration of RERs into the national grid of developing nations. Also, none of the studies above analyzed the determination of allowable wind penetration level considering voltage stability into weak grids. Hence, the contributions of this study are investigations of penetration impact of PMS-WTGs on voltage stability of weak power grid using active power-voltage curve from CPF analysis and determination of allowable PMS-WTGs penetration level into the grid under static and changing loads.

Collaboration of wind power and national grid has benefits of helping to meet the consumers' demands. Other benefits for the stakeholders, utilities and consumers especially in rural communities are seen in areas such as [2].

A. Efficiency

Inefficiency characterize today's national grid but can be alleviated by integrating RESs like wind power.

B. Environment

RES technologies ensure environmental friendliness and more efficient power production compared to the current national grid with fossil fuel reliant energy sources.

C. Economics

Studies revealed that RESs could help nations build huge financial saving.

D. Reliability

Present national grid is unreliable due to its inability to execute the needed action of electricity delivery to the consumers. Bringing in wind power would solve that reliability problem by cutting down the number of times of power failure and blackouts. Benefits to stakeholders include decrease in frequency of power failures, provision of energy decentralization opportunity to rural communities, improved reliability of power system and more sales for the utilities.

The remaining of the paper comes in sections: Section II talks about the problem formulation while Section III discusses the Nigerian 330 kV grid network. Section IV elucidates the PMS-WTG's modelling. Section V describes the CPF and PV Curve for voltage stability determination.