Strategic Plan Analysis for Integrating Renewable Generation to Smart Grid Technologies in Nigeria

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Abstract -- Smart grid is new emerging concept in power system. It observes the state of power system and intelligently takes decisions to maintain system equilibrium to avoid voltage collapse. The technology implicitly demands the capability to model the behavior, performance, and cost of distribution-level smart grid components. The modeling and simulation of such individual components, together with their overall interaction, will provide a foundation for the design and configuration of a smart grid. The smart grid is the integration of computing and communication technologies into a power network with a goal of enabling real time control, a reliable, secure, and efficient energy system. With the increased interest of the research community and stakeholders towards the smart grid, a number of solutions and algorithms have been developed and proposed to address issues related to smart grid operations and functions. Those technologies and solutions need to be tested and validated before implementation using software simulators. It is the primary intent of this paper, to provide a basic insight into the energy transfer of various distribution-level components by modeling and simulating their dynamic behavior. The principal operations of a smart grid will be considered, including variable renewable generation, energy storage, power electronic interfaces and variable load. The methodology involves deriving the mathematical equations of components, and, using the MATLAB/Simulink environment to create modules for each component. Ultimately, these individual modules may be connected together via a voltage interface to perform various analyses, such as the treatment of harmonics, or to acquire an understanding of design parameters such as capacity, runtime, and optimal asset utilization.

Index Terms: Smart grid, Renewable generation, system dynamic, renewable energy sources, energy storage, power supply, Simulink

1 INTRODUCTION

The electricity situation in Nigeria can be described as epileptic with no sign in view of improvement. This epileptic power situation affects the manufacturing, service and residential sectors of the economy which in turn affects the country's economic growth. Even with the recent reforms in the power sector, more than half of the country's population still lack access to electricity [1]. The epileptic condition of the power sector can be attributed to the inadequate and inefficient power plants, poor transmission, outdated distribution facilities and malfunctioning metering system used by electricity consumers. This paper proposed to present the way forward for the Nigerian poor electricity situation by reviewing the power sector as a whole and the renewable energy potentials. The work identified the problems in the national grid and then proposed a smart grid model which will include renewable energy sources. For this to be accomplished, renewable energy sources such as solar and wind power will be integrated into the distribution system, where home or business owners seek to actively manage consumption based on real-time information regarding energy usage. However, an important consideration is that solar and wind are variable power sources, which may or not be available when needed [2]. To overcome this variability in supply, energy storage technologies should be employed to make the system more predictable and enable more efficient use of resources. Furthermore, energy storage is also conducive to maintaining the balance between generation and consumption. The balance between generation and consumption must be sustained if the power system is to remain stable.

2 REVIEW OF RELATED WORKS

In Nigeria, electricity generation rose from few kilowatts that were used in Lagos by the colonial masters when the first generating plant was installed in 1898 [3]. By the Act of Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was established. Niger Dams Authority was set up in 1962 to develop hydroelectricity and was merged with ECN to form the Despite various effort by NEPA (which operated a monopolized market) to manage the power sector by providing electricity to the increasing population, it became clear that NEPA was losing the battle to meet up with the electricity demand in the 1990s. Hence, in 2001, the National Electric Power Policy (NEPP) was introduced to kick-off the power sector reform and this led to several other reforms in the past years [4]. The NEPP in 2001 created the roadmap for Nigeria's power sector privatization, but due to government bureaucracy; the policy was not signed into law until 2005. The signed document was the Electric Power Sector Reform (EPSR) Act of 2005 which was expected to level the playing ground for potential investors and improve the wellbeing of the citizens. The EPSR Act led to the incorporation of the Power Holding Company of Nigeria from NEPA, which was later defunct and divided into sub-sectors [3] [4].

2.1 Current Electricity Situation

Nigeria is faced with many electricity problems which range from generation, transmission to distribution and marketing.

Generation: The total installed capacity of the currently generating plants is 10,396 MW, but the available Capacity is less than 6056 MW as at December 2013. Seven of the twenty-three generation stations are over 20 years old and the average daily power generation is lower than the peak forecast for the current existing infrastructure. The current status of power generation in Nigeria presents challenges, such as inadequate generation, delayed maintenance of facilities, insufficient, obsolete equipment/tools and lack of exploration to tap all sources of energy from the available resources [5] [6].

Transmission: The current transmission system comprises 5523.8 km of 330 kV, 6801.49 km of 132 kV, 32 number of 330/132 kV substations with total installed transformer capacity of 7688 MVA. 105 number of 132/33/11 kV substations with total installed transformer capacity of 9130 MVA. The average available capacity on 330/132 kV is 7364 MVA and 8448 MVA on 132/33 kV. The 330 kV transmission grid is characterized by high power losses due to the very long lines. Some of these lines include Benin-Ikeja West (280 km), Oshogbo-Benin (251 km), Oshogbo-Jebba (249 km), Jebba-Shiroro (244 km), BirninKebbi-Kainji (310 km), Jos-Gombe (265 km) and Kaduna-Kano (230 km) [6]. Increased power demand pushes the power transmission and distribution networks to its upper limits, resulting in system collapse [6][7]. The Nigerian transmission system does not cover every part of the country. It currently has the capacity to transmit a maximum of about 6056 MW and it is technically weak, thus very sensitive to major disturbances. Major problems associated with transmission systems include poor funding by the federal government, regular vandalization of the lines associated with low level of surveillance and security on all electrical infrastructures, transformers deployed are overloaded in most service areas, inadequate spare parts for urgent maintenance and poor technical staff recruitment [7] [8].

Distribution and Marketing: In most regions, the distribution network is poor, the voltage profile is poor and the billing is inaccurate. As utility service provider which inter-faces with the public, the need to ensure adequate network coverage and provision of quality power supply in addition to efficient marketing cannot be over emphasized. Some challenges identified are: weak and inadequate network coverage, overloaded transformers, bad feeder pillars, substandard distribution lines, poor billing system, unwholesome practices by staff and very poor customer relations, inadequate logistic facilities such as working vehicles, poor and obsolete communication equipment and insufficient funding [2]

Power Deficit: The total installed capacity of generating plants is 10,390 MW with available capacity less than 6056 MW. However, power generation has been below 4500 MW. Using the rule of Thumb in which 1000 MW is for 1,000,000 people, Nigerian population of 174,567,539 people [10] should have about 174,568 MW generated power. Unfortunately, power generation that had not exceeded 4500 MW. The exploitable renewable energy potential in Nigeria is presented in Table 2.1.

Table 2.1: Renewable Energy Capacity [5]

Renewable Energy Source	Capacity
Crop Residue	83 million tons/year
Animal Waste	61 million tons/year
Fuel Wood	13,071,464 hectares of forest and woodland
Solar Radiation	3.5 - 7.0 kWh/m^2/day
Wind	2 - 4 m^2 annually at 10 m height
Large Hydropower	11,250 MW
Small Hydropower	3500 MW

3.0 METHODOLOGY

The methodology adopted in this research work is presented in stages as follows: modeling of the solar smart grid using MATLAB Simulink, modeling of the wind smart grid using MATLAB Simulink, development of algorithm to compare voltage and analysis of the results.

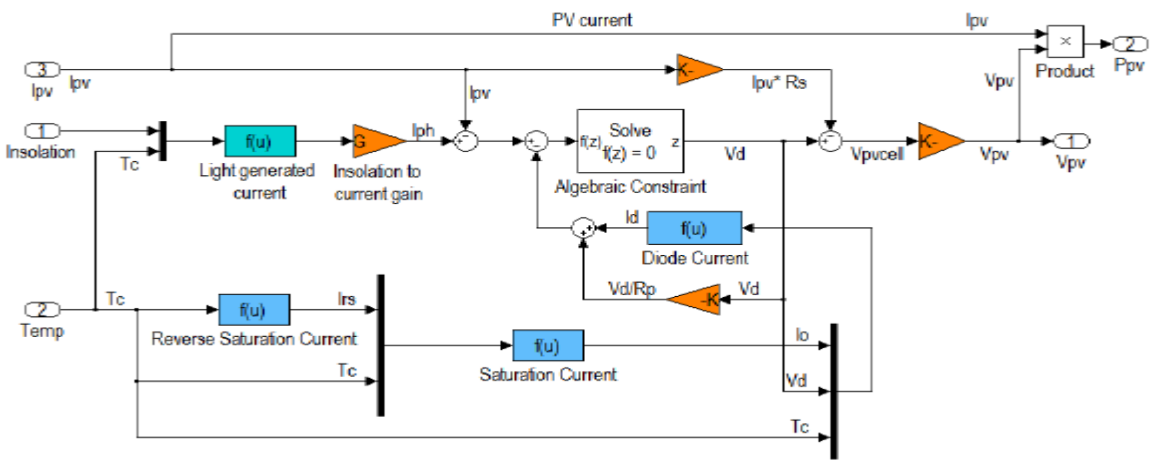

Figure 3.1: Implementation of the PV model.

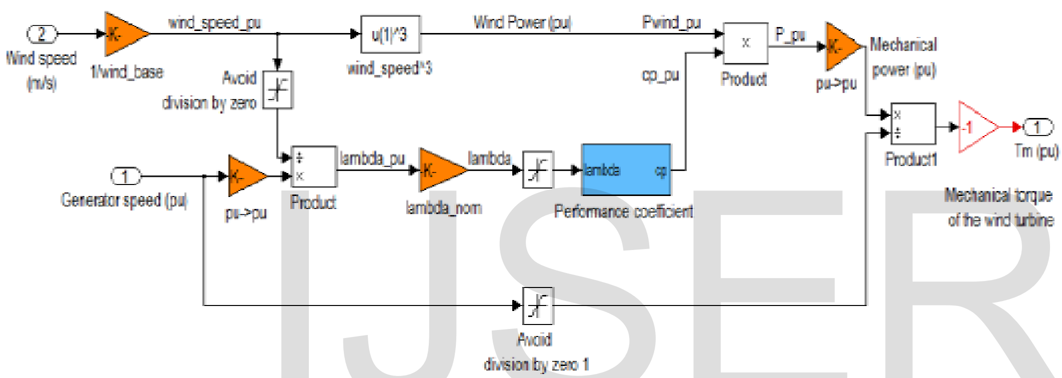

Figure 3.2: Simulink model for wind turbine.

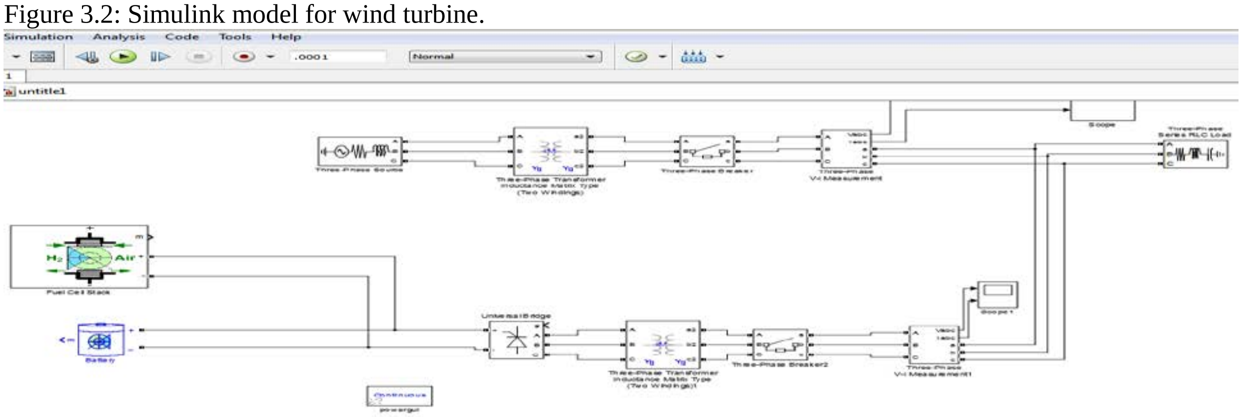

Figure 3.3: Simulink model for renewable on Smart grid.

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Figure 3.3 is smart grid system in two way directional power flow so that load on the grid is reduced at the pick time and during off pick time, the battery is charged to back up the network. In Figure 3.2, the wind turbine induction generator (WTIG) model is designed using the in-built Sims Power System library. The rotor shaft is driven by the WT which produces the mechanical torque according to the generator and wind speed values. The electrical power output of the generator (stator winding) is connected to the smart grid. That might be possible in the future, because PV is projected to continue its current cost reductions for the next decades and be able to compete with fossil fuel. The standalone wind system cannot meet the constant load demands due to significant fluctuations in the magnitude of wind speeds. Therefore, energy storage systems will be required for each of these systems in order to satisfy the power demands.

4.0 RESULT AND DISCUSSION

The block diagram of the integrated photovoltaic/wind turbine system is presented in Figure 3.1 and Figure 3.2. The major inputs for the proposed PV model were solar irradiation, PV panel temperature and PV manufacturing data sheet information. The I-V and P-V output characteristics for the PV model are shown in Figure 4.1. The output power and current of PV module depend on the solar irradiance and temperature as well as cell's terminal operating voltage. It was found from Figure 4.1 and 4.2 that with increased solar irradiance there is an increase in both the maximum power output and the short circuit current.

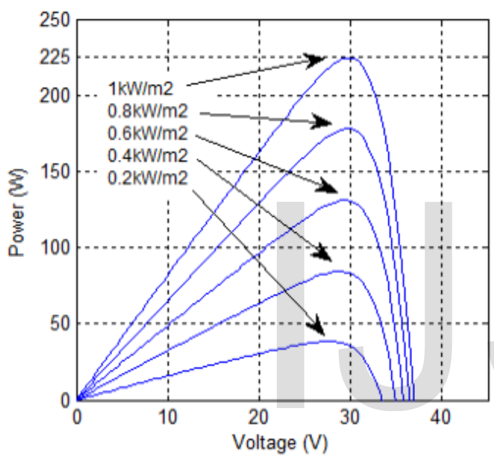

Figure 4.1: solar radiation power

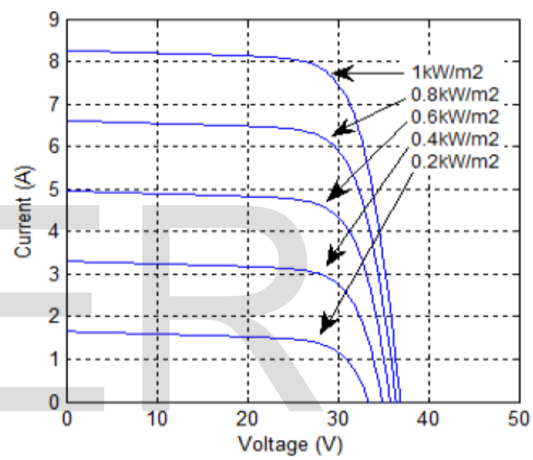

Figure 4.2: Solar radiation intensity

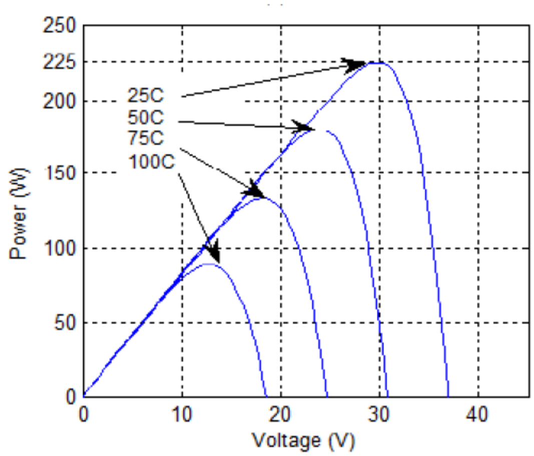

Figure 4.3: Simulink result for solar

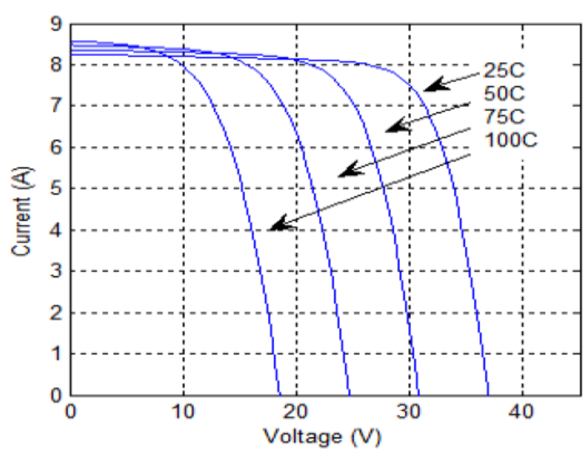

Figure 4.4: Simulink Result for Wind

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It was observed that, with an increase in the cell temperature, the maximum power output decreases whilst the short circuit current increases in Figure 4.3 and Figure 4.4

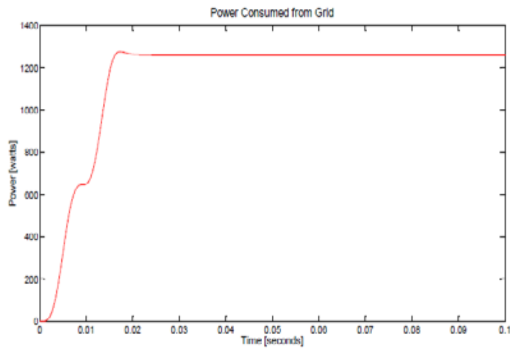

Figure 4.5: Simulated power consumed from grid

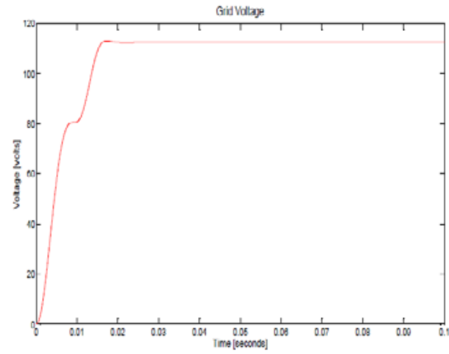

Figure 4.6: Simulated Grid Voltage

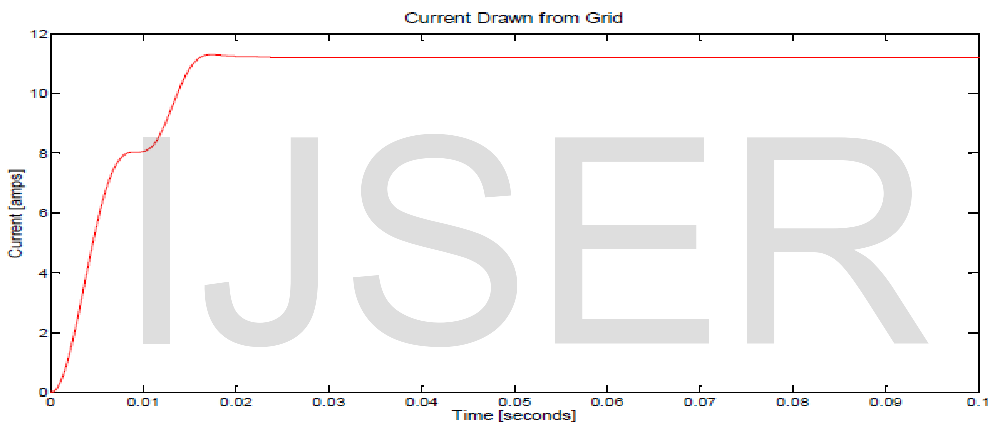

Figure 4.7: Simulated current drawn from grid

Usually storage system is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. Hybrid power systems can also be used to reduce energy storage requirements. By integrating and optimizing the solar photovoltaic and wind systems, the reliability of the systems can be improved and the unit cost of power can be minimized. In Nigeria, the Solar-Wind hybrid power plants are technically approved by the federal government. These Solar/Wind hybrid power plants generate electricity and can be an alternate source for the costly diesel generators which are run during the power outage and in locations where continuous electricity supply is not available.

5.0 CONCLUSION

This research presented an hybrid power system designed and modeled for smart grid applications. The developed algorithm comprises of system components and an appropriate power flow controller. The model has been implemented using the MATLAB/SIMULINK software package, and designed with a dialog box like those used in the SIMULINK block libraries. The available power from the PV system is highly dependent on solar radiation. To overcome intermittent deficiency of the PV system, the PV module was integrated with the wind turbine system. The dynamic behavior of the proposed model was examined under different operating conditions and the model offers a proper tool for smart grid performance optimization.

6.0 REFERENCE

[1] World bank Databank. http://www.tradingeconomics.com/nigeria/access-to-electricity-percent-of-population-wb-data.

[2] Koledoye, T.O., Abdul-Ganiyu, J.A. and Phillips, D.A. (2013) "The Current and Future Challenges of Electricity Marketing in the Face of Nigerian Deregulation Process" African Journal of Engineering Research, (**1)**, 33-39.

[3] KPMG Nigeria (2013): A Guide to the Nigerian Power Sector

[4] Sambo, A.S., Garba, B., Zarma, I.H. and Gaji, M.M. (2003) "Electricity Generation and the Present Challenges in the Nigerian Power Sector" Energy Resources Review (**4)**, 7-10.

[5] Patrick, O., Tolulolope, O. and Sunny, O. (2013) "Smart Grid Technology and Its Possible Applications to the Nigeria 330 kV Power System" Smart Grid & Renewable Energy, (**4)**, 391.

[6] Sunday, O.O. and Friday, O.O. (2010) "Empirical Modeling of Power Losses as a Function of Line Loadings and Lengths in the Nigerian 330 kV Transmission Lines" International Journal of Academic Research, (**2)**, 47-53.

[7] Nigeria Population, http://www.cia.gov/library/publications/the-world-factbook/geos/ni

[8] Energy Commission of Nigeria (2005): 1st Energy Lecture Series.

[9] Aniefiok, E., Igweonu, I.E., Eguzo, C.V. and Robert, B.J. (2013) "Integrating Smart Grid Model in Nigeria Power Network. International Journal of Advances in Engineering & Technology, (**6)**, 1760-1768.