Modeling and control of isolated hybrid system using wind driven DFIG

T.SINDHU[1] M.SANGEETHA[2] S.SINDHUJA[3]

[1]PG Scholar, [2,3]Assistant Professor,
[1,2]Department of EEE, The Kavery Engineering college, Mettur-dam ,salem, Tamilnadu.
[2]Department of EEE, SRM TRP engineering college ,Trichy, Tamilnadu.
sindhukvt.1993@gmail.com[1] m.sangeethasuresh@gmail. com[2] ssindhudeepthi@gmail. com[3]

Abstract— ***Wind and solar energies are the most important RE sources talked nowadays. The wind power is already supplying noticeable share of energy of many countries. In India, wind energy comprises 8% of the installed capacity. However, small wind energy system (WES) for off grid application has not gained popularity because of various reasons. Wind–solar hybrid system in right combination of their capacity combined and intelligent power electronic (PE) control can provide quality power for remote locations lying in wind rich zone. Wind energy and solar energy are complimentary of each other in daily as well as annual pattern. Doubly fed induction generator (DFIG) is the most common machine used for commercial wind power generation.***

Keywords—DFIG, Power electronic devices, solar, wind energy.

I. INTRODUCTION

The voltage-source converter is widely used as an interface for the renewable energy systems before they are linked to the grid like in the photovoltaic and wind power system cases, with its advantages in fully control of dc-link voltage, active and reactive power, as well as power factor[1]. A grid filter is normally introduced to avoid the pulse width modulation carrier and side-band voltage harmonics coupling to the grid that can disturb other sensitive loads or equipment.

For the megawatt-level wind power converter, due to the quite low switching frequency of the power switching devices (usually several kilohertz), a simple filter inductor consequently becomes bulky, expensive, and it may also bring poorer dynamics into the system. Induction machines are almost entirely used in producing electricity from wind turbine[2]. So, the importance of accurately controlled machine drives is increasing day by day[3]. Controllers can provide probably the best control properties for a wide variety of processes in wind energy conversion system.

The variable torque of wind turbine induced from the fluctuating wind speed can be controlled accurately, increase the efficiencies of the power electronic and electromechanical conversion processes and the most important is that a properly controlled wind turbine may save considerable amounts of energy[5]. Renewable energy, also known as alternative energy, is coming from natural resources such as sunlight, wind, rain, tides, and geothermal heart, which are renewable (naturally replenished), instead of from our primary energy supply such as fossil fuels, coal, oil and natural gas[6].

Renewable energy has received growing interests recently because of the two huge challenges nowadays: oil dependency and global warming. Since the prices of fossil-fuel are rising and their supplies are increasingly unstable, people have to discover new energy to make their life less dependent on oil. Also, the global warming problem has received increasing concerns due to pollutant emission. All these lead to the development of renewable energy. Presently, about 16% of global final energy consumption comes from renewable energies, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewable energies accounted for another 3% and are growing very rapidly[5].

A. SOLAR ENERGY

The sun is the largest energy source of life at the same time, it is the ultimate source of all energy (except power of geothermal[6]. The sun radiates 174 trillion kWh of energy to the earth per hour. In other words, the earth receives 1.74 x 10 17 watts of power from the sun. Characteristics of the sun is simplified as follows : mass 2× kg, beam length 700.000 km, age 5× years and estimated roughly 5 billion more years of life[7].

The surface temperature of sun is approximately 5800 K while the internal temperature is approximately 15.000.000 K. High temperature reactions is due to the transformation of hydrogen in helium[8]. The process of the nuclear fusion, which is characterized from the following reaction 4 → Energy, is the result of the sun high temperature and the large amounts of energy emitted continuously[9]. It is calculated that for each gram of hydrogen, that is converted to He, sun radiates energy equal with U= 1.67× kWh. The solar energy is emitted to the universe mainly by electromagnetic radiation[10].

B. WIND ENERGY

Wind is the continuous movement of atmospheric air masses and is determined by its speed and orientation[11]. This movement derives from the changes and the different values of the atmospheric pressure while these values are the result of the solar heating of different parts of the earth's surface[10][11]. Despite the fact that the atmospheric air moves horizontally and vertically as well, only its horizontal movement is actually considered as wind[11][12]. The wind energy derives from the air as a result of its movement which is depicted[13]. Wind energy is the conversion of a small percentage, about 0.2%, of the solar radiation that reaches the surface of the earth.

The wind power around the globe is estimated in 3.6×109 MW while, according to valid estimations of the world meteorology organization, the percentage which is available for energy exploitation in various parts of the world is only 1% and it is estimated around 0.6Q (175×1012 KWh)[14].

Characteristics of DFIG

DFIG are introduced by the special characteristics of the converter controlling the generator operation, widely known as 'frequency converter'. As mentioned it consists of two different converters linked together by a capacitance known as 'dc link'.

The main principle is to interpose a frequency converter between the variable voltage and frequency induction machine and the fixed frequency grid. The converters are defined as the grid-side converter and the rotor-side converter[3].

The main purpose of the grid-side one is to control the dc-link voltage so that it remains nearly constant during normal and abnormal operations. Moreover it is entrusted with the coupling between the rotor windings and the non- ideal grid. On the other hand the rotor side converter is directly related to the rotor windings and therefore it controls the frequency and the magnitude of rotor voltages fed to the machine[15].

It is obvious that the frequency of the rotor windings may differ from the fundamental frequency of the grid. Furthermore by the proper tuning of the frequency converter the whole system can operate on all 4-quadrants. This is definitely an advantage of paramount importance as the generator can either import or export reactive power from-to the grid[2].

In other words not only the DFIG can provide active power to the grid it can also support it during system failures, short circuits with an amount of reactive power[18].

Specifically below the synchronous speed, while in motoring mode and at super-synchronous operation, while in generating mode, the rotor-side converter operates as a rectifier, and thus slip power is fed into the grid. In contrast, at sub-synchronous speed, while in generating mode and above the synchronous speed, while in motoring mode, the grid side converter acts like a rectifier and hence the slip power is supplied to the rotor[16].

II. PROPOSED METHODOLOGY

The wind energy block consisting of a double fed induction generator (DFIG) is equipped with maximum power point tracking (MPPT) algorithm. The control of DFIG consists of two converters namely rotor side converter (RSC) and load side converter (LSC) connected back to back at DC link.

The MPPT operation requires speed control, which is realized using field oriented control through RSC. The rotor position required for vector control, is estimated with model reference and adaptive system (MRAS) algorithm. The voltage and frequency control is realized through LSC. The solar photovoltaic (PV) power is extracted using a DC-DC boost converter to the common DC link.

The DC-DC converter is also equipped with MPPT algorithm to extract maximum power from the incident irradiance**.** The proposed control approach requires low numbers of voltage and current sensors.

Moreover, numbers of PI controllers are subsequently low, which makes the system comparatively simple and cost effective. So, PI controller is used in the proposed topology to overcome the disadvantages in PIC controller. The rotor position and speed are estimated using model reference and adaptive system[3][17].

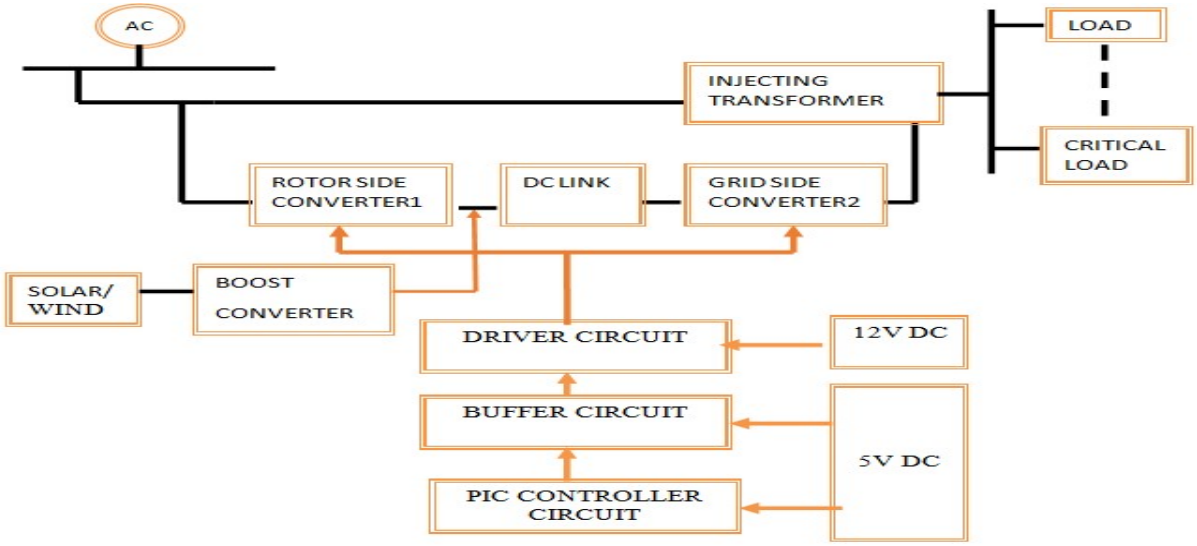

Fig 1. Proposed block diagram

This system has ability to deliver rated voltage and frequency under all operating scenario. Under all the scenarios, the DFIG stator currents as well as load voltages have THDs within an IEEE standard 519 for all types of loads.

a. Transformer

The system is designed for a AC system for which a zig-zag transformer is used to provide neutral terminal for un- balanced phase loads. As per the analysis, the voltage rating of LV side of transformer is chosen as 125 V and voltage ratio 125 V/415 V. The 415 V side of the transformer is connected to the load and stator of DFIG. The kVA rating of transformer should be more than kVA of the load and maximum power output of DFIG. In this scheme, a 6.3 kVA transformer is used to connect LSC with the load.

b. DC–DC Converter for Solar PV System

The dc–dc boost converter is connected to dc bus supported by a battery bank. Hence, the maximum voltage across the devices occurs when a battery bank is completely charged up to 2.25 V per cell, i.e., 270 V. Hence, PE devices must be designed taking consideration of the maximum continuous voltage of 270 V and 25% electrical tolerance.

III. SIMULATION & RESULT ANALYSIS

The Simulink is a block diagram environment for multi-domain simulation and Model-Based Design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis in figures 2,3,4 explains about simulation representation of proposed scheme and figure 5,6 explains about the simulation results of output waveform of Grid, Motor characteristics.

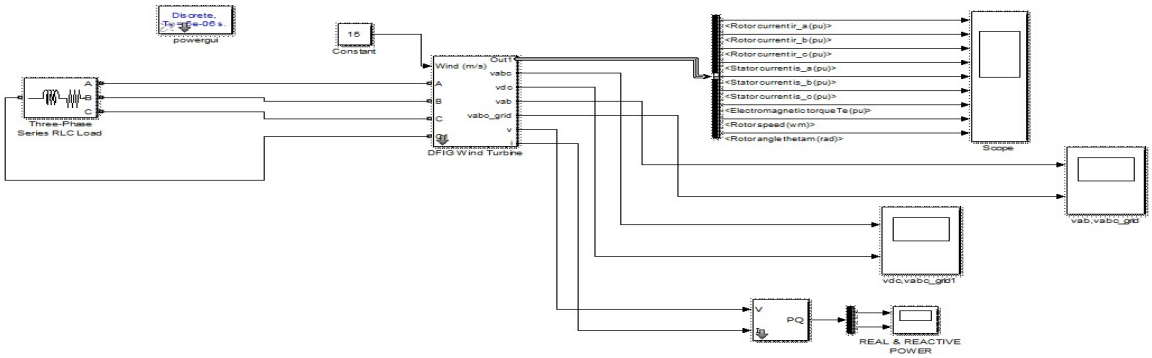

Fig 2. Simulation diagram of the proposed methodology

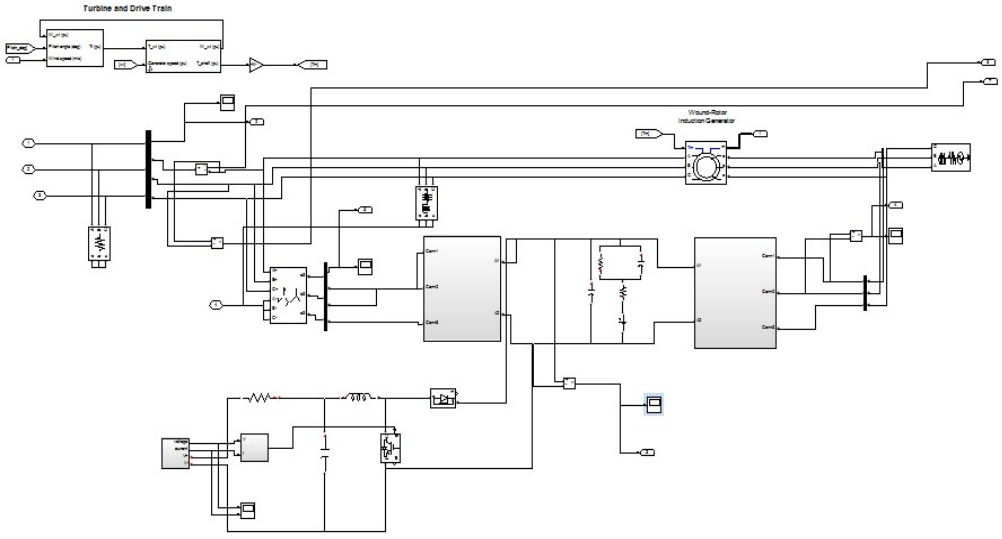

Fig 3. Simulation representation of Sub block model

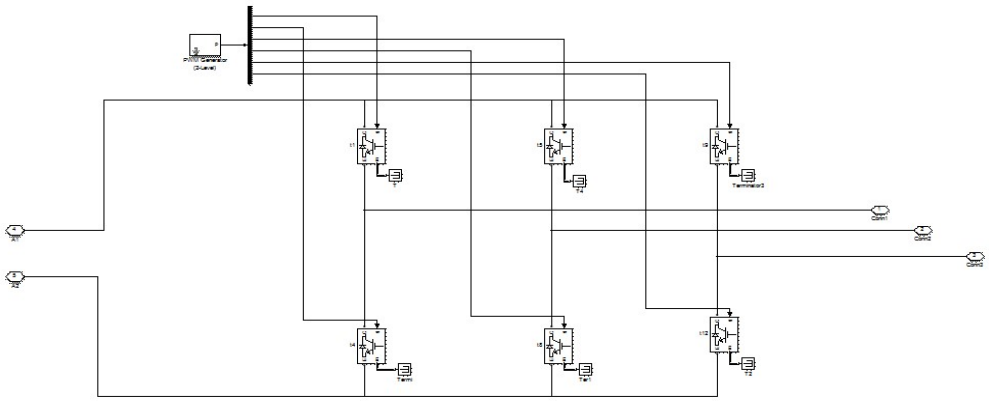

Fig 4. Simulation representation of Converter

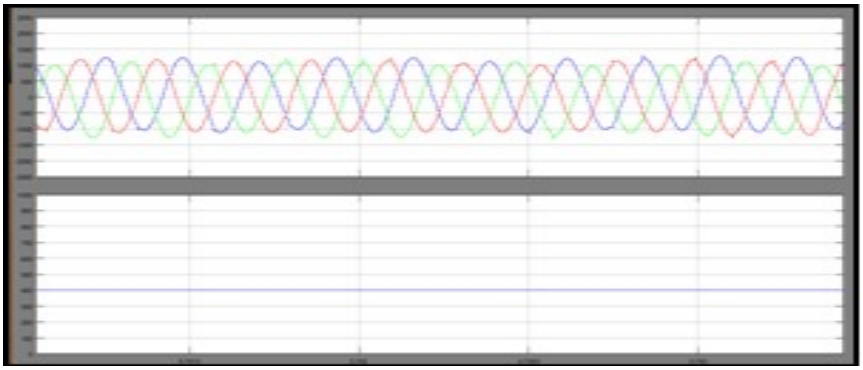

Fig 5. Output waveform of GRID

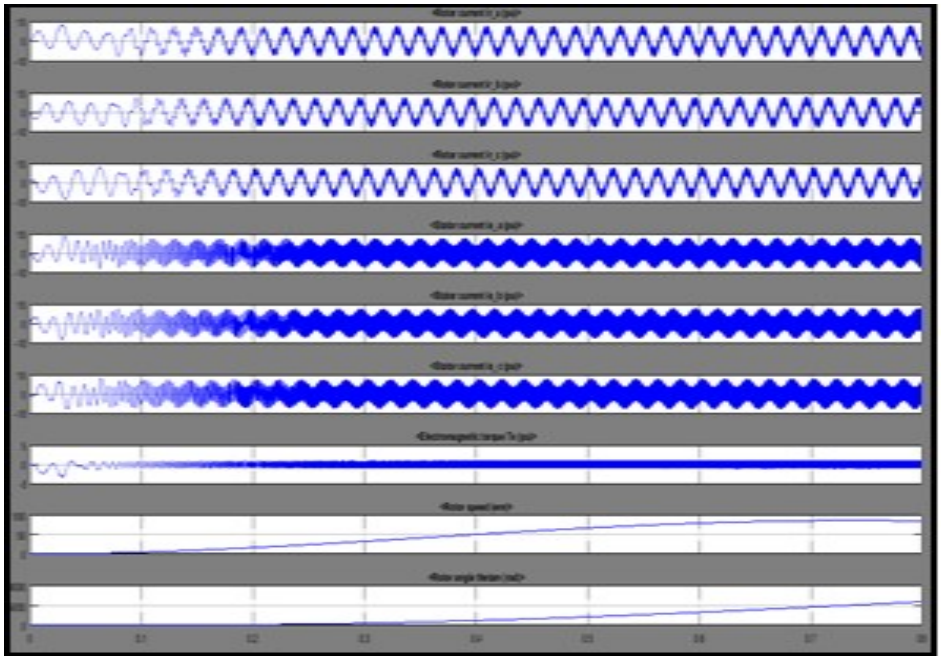

Fig 6. Output waveforms of Motor

In figure 6, the output waveform which comprises the rotor current of motor, stator current of motor, electromagnetic torque, rotor speed characteristics.

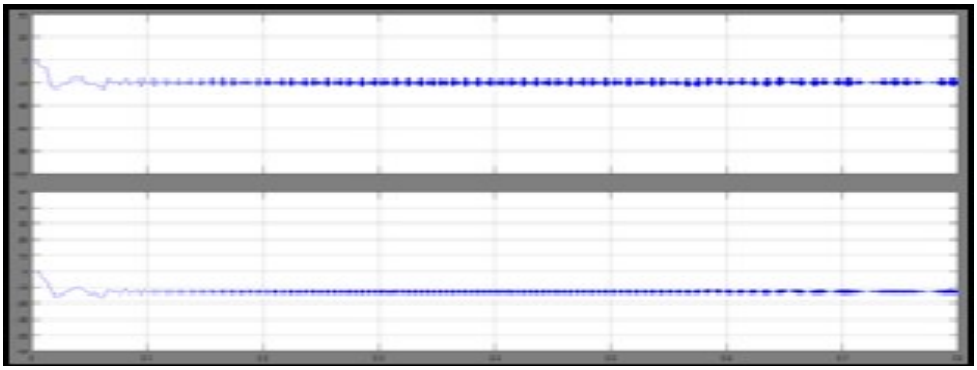

Fig 7. Output waveform of Solar and Wind

IV . Conclusion

Wind and solar energies are free of cost, however, unpredictable with high degree of variance. With the help of energy storage and intelligent PE control, these RE sources can be made customer friendly. This work presents theoretical and experimental validation of AWSHS consisting of wind generator with DFIG and solar PV array. Both solar and wind energy blocks are equipped with MPPT logic to extract the maximum energy. It is also found that the power quality is within acceptable limit. The high cost of the battery and its limited life may push up the cost of energy higher. However, in line with the solar module, battery prices have started falling driven by demand from electric vehicles, large storage stations combined with technological development. This increases the relevance of the system for DG system at remote locations so as the residents fulfill their energy requirement without dependency to external grid.

REFERENCES

[1] P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor, T. Van Cutsem and V. Vittal, "Definition and classification of power system," IEEE Trans. Power System, vol. 19, no. 3, pp. 1387-1401, May. 2004.
[2] C. P. Steinmetz, "Power control and stability of electrical generating stations," AIEE Trans., vol. XXXIX, Part II, pp. 1215-1287, Jul. 1920.
[3] AIEE Subcommittee on Interconnection and Stability Factors, "First report of power system stability," AIEE Trans., pp. 51-80, 1926.
[4] V. I. Vorotnikov, Partial Stability and Control. Cambridge, MA: Birkhauser, 1998.
[5] V. V. Rumyantsev and A. S. Osiraner, Stability and Stabilization of Motion with Respect to a Part of the Variables. Moscow, Nauka, Russia, 1987.
[6] N. Rouche, P. Habets, and M. Laloy, Stability Theory by Liapunov's Direct Method. New York: Springer, 1977.
[7] P. Kundur, Power System Stability and Control. New York: McGrawhill, 1994.
[8] T. Ackermann, Wind Power in Power Systems, England, 2005.
[9] E. H. Camm, M. R. Behnke, O. Bolado, M. Bollen, M. Bradt, C. Brooks, W. Dilling, M. Edds, W. J. Hejdak, D. Houseman, S. Klein, F. Li, J. Li, P. Maibach, T. Nicolai, J. Patino, S. V. Pasupulati, N. Samaan, S. Saylors, T. Siebert, T. Smith, M. Starke and R. Walling, "Characteristics of wind turbine generators for wind power plants," IEEE Power & Energy Society General Meeting, PP. 1-5, 2009.
[10] Y. Mishra, S. Mishra, F. Li, Z. Y. Dong, and R. C. Bansal, "Small-signal stability analysis of a DFIG-based wind power system under different modes of operation," IEEE Trans. Energy Conversion, vol. 24, no. 4, pp. 972-982, Dec. 2009.
[11] L. Holdsworth, X. Wu, J. B. Ekanayake, and N. Jenkins, "Comparison of fixed speed and doubly-fed induction wind turbines during power system disturbances," Proc. Inst. Elect. Eng., Gener., Transm., Distrib., vol. 150, no. 3, pp. 343-352, May. 2005.
[12] F. Mei, and B. C. Pal, "Modelling and small-signal analysis of a grid connected doubly-fed induction generator," IEEE Power Engineering Society General Meeting, 2005.
[13] F. Mei and B. C. Pal, "Modal analysis of grid connected doubly fed induction generator," IEEE Trans. Energy Conversion, vol. 22, no. 3, pp. 728-736, Sept. 2007.
[14] Y. Lei, A. Mullane, G. Lightbody, and R. Yacamini, "Modeling of the wind turbine with a doubly fed induction generator for grid integration studies," IEEE Trans. Energy Conversion, vol. 21, pp.257-264, Mar. 2006.
[15] F. Wu, X. P. Zhang, K. Godfrey, and P. Ju, "Small signal stability analysis and optimal control of a wind turbine with doubly fed Induction generator," IET Gener. Transm. Distrib., vol. 1, no. 5, pp. 751-769, 2007.

[16] R. Cardenas, R. Pena, G. Tobar, P.Wheeler and G. Asher, "Stability analysis of a wind energy conversion system based on a doubly fed induction generator fed by a matrix converter," IEEE Trans. Industrial Electronics, vol. 56, no. 10, pp. 4194-4206, Sept. 2009.
[17] W. Qiao, G. K. Venayagamoorthy, and R. G. Harley, "Design of optimal PI controllers for doubly fed induction generators driven by wind turbines using particle swarm optimization," Int. Joint Conf. In Neural Networks, Canada, pp. 1982-1987, Jul. 2009.
[18] F. Wu, X. P. Zhang, K. Godfrey, and P. Ju, "Small signal stability analysis and optimal control of a wind turbine with doubly fed induction generator," IET Gen. Trans. Dist., vol. 1, no. 5, pp. 751-760, 2007.