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Review on Grid-Connected Hybrid DFIG Based Wind and PV System

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ABSTRACT

This paper deals with review of hybrid wind solar system. The demand of electricity is increasing day-by-day and the conventional source of generating electricity is depleting. Renewable sources of energy are available in abundance and is never depleting source of energy. Wind energy combined with solar energy can provide better solution for compensating increasing demand of electricity in future. DFIGs are being used now a days over a great extent due to its advantage over other generators in wind turbine system. The main objective of this paper is to review hybrid DFIG and PV system for grid connected system.

Keywords : Doubly Fed Induction Generator (DFIG), Photo Voltaic (PV), Renewable.

I. INTRODUCTION

Renewable sources of energy are being used increasingly nowadays due to its availability. The significance of hybrid system is increasing due to crises in fossil fuel. Hybrid system by definition is combination of various energy sources. Hybrid system can increase quality and reliability of system. In this paper, the hybrid system taken for review is wind and solar energy. The prediction of both wind and solar is not possible. It varies from season to season as if maximum power from wind energy can be utilized at nighttime when power from solar cannot be utilized. Similarly, maximum power from solar can be utilized during day time because irradiance is maximum during day time [1][8].

There are different types of wind turbine generator i.e synchronous or asynchronous generators. Both the type of generators can be used for utilizing power from wind but the added advantage of asynchronous generator is variable speed operation. Out of different configuration of wind turbine generator, asynchronous generators are widely used nowadays. In asynchronous, DFIG is used preferably nowadays due to its various advantages like ability to capture wind during variable speed operation, increased efficiency and reliability. DFIG can operate at synchronous, sub-synchronous and super-synchronous speed [2].

Similarly, there are different types of technologies for conversion of solar energy into electricity like polycrystalline silicon, thin film, and concentrating photovoltaic collector. Most of the solar plants using polycrystalline silicon as the technology are well developed, it is easily available and requirement of maintenance after installation is on lower side as compared to others. In addition, different materials can be used for producing photovoltaic effect i.e. crystalline silicon, gallium arsenide, amorphous silicon, copper-indium-diselenide etc. Each PV cell, regardless of its area, produces approximately 0.6 volts DC when open-circuited and exposed to sunlight. The current output of a cell is directly proportional to its area and the solar irradiance. PV system is used to transform solar radiation directly into electricity. In proposed hybrid system both system are combined together to produce electricity.

II. METHODS AND MATERIAL

Modelling of Different System

A. Wind System Model

Wind system extract power from wind. A wind system consists of tower, hub, nacelle, blades as basic component of wind turbine generator. Nacelle consist of gearbox, generator, transformer which is connected to control unit at bottom of tower. At the time when wind passes over blade, it exerts forces on blades, which in turn rotate the shaft connected to blade. This low speed shaft is connected to gearbox, which increases its rotational speed. Gearbox is connected to generator which produces electricity and produced electricity is fed to transformer and then through transmission line to grid [2].

The power harnessed through wind is given by equation:-

$$P=0.5C_P \rho AV^3$$

Where
C_P=power coefficient
ρ=air density in kg/m^2
A=swept area of rotor blade m^2
V=velocity of wind in m/s

In 1920, Albert Betz studied the best utilization of wind energy and established a theoretical limit for wind power extraction i.e. Independent of the turbine design, only 59% of wind kinetic energy can be converted into mechanical energy. This is known as Betz's limit. Fig 1 shows the extracted power from wind. As shown in figure as the wind speed increase, maximum power can be utilized from wind energy.

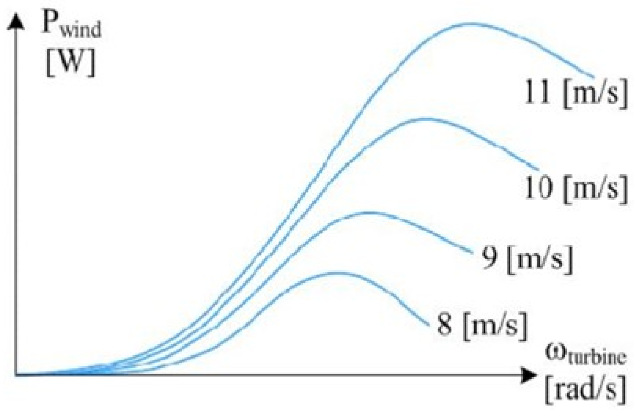


Figure 1. Extracted power from wind

Wind turbine configurations are classified both by their ability to control speed and by the type of power control they use. Applying speed control as the criterion, there are four different types of wind Type A, Type B, Type C, Type D. Type A denotes the fixed-speed wind turbine with an asynchronous squirrel cage induction generator (SCIG) directly connected to the grid via a transformer. Here, capacitor bank is used for reactive power compensation as it always draws reactive power from grid. Type B denotes the limited variable speed wind turbine with variable generator rotor resistance, known as Opti-Slip It uses a Wound Rotor Induction Generator (WRIG). Type C configuration, known as the Doubly Fed Induction Generator (DFIG) concept, corresponds to the limited variable speed wind turbine with a Wound Rotor Induction Generator (WRIG) and partial scale frequency converter on the rotor circuit. Type D configuration corresponds to the full variable speed wind turbine, with the generator connected to the grid through a full-scale frequency converter. The frequency converter performs the reactive power compensation and the smoother grid connection. The generator can be excited electrically through WRSG or WRIG or by PMSG [3].

Fig 2 shows the DFIG system connected to grid. As it is doubly fed means power can be fed both by stator and rotor whose rotor part is directly connected to grid and stator is connected through converter to grid. The converter is back to back converter with DC link in between two converter. The converter which is connected to rotor is called rotor side converter and converter connected to grid is called grid side converter.

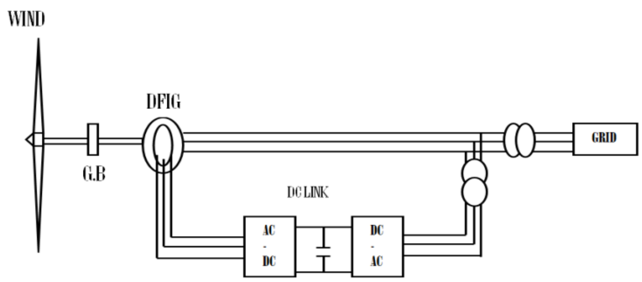


Figure 1. DFIG connected to grid

B. PV System Model

PV cells are semiconductor devices that convert sunlight into direct current (DC) electricity. Groups of PV cells are electrically connected in series and parallel to form a module and arrays, which can be used to charge batteries, operate motors and power any number of electrical loads. With suitable inverter, the DC power produced is converted to AC compatible with any conventional appliances or can be interconnected to the utility grid. Generally, PV systems can be grid tie, off grid or standalone system and PV direct. Grid tie system is most effective system with no battery bank for storage unlike in grid tie system where battery is installed for storing the charge produced by sunlight. In Grid tie system, utility grid act as battery requires no maintenance and replacement. Also through net metering, it saves extra money i.e. during excess generation power can fed to utility grid. Fig3 shows the model of PV solar cell where current source in parallel with diode represent PV cell.

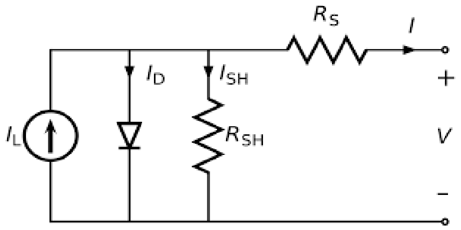


Figure 3. Model of PV solar cell

The diode current is given by equation,

I_D=I[(q V_T / kT) -1]
V_T= V+IR_S

The solar cell output current is given by equation,

I=I_L-I_D-I_{SH}
I=I_L - [(q V_T / kT) -1] - [(V+IR_S)/R_{SH}]

Where:
Rs: Series resistance of solar cell (Ω)
Rsh: Shunt resistance of solar cell (Ω)
I: Solar cell current (A)
Ish: Light generated current (A)
I_D: Diode current (A)
q: Electron charge (1.6×10-19 C)
k: Boltzman constant (1.38×10-23 J/K)
T: Temperature of cell in Kelvin (K)
V:Output voltage of solar cell (V)

C. Hybrid System Model

Figure 4 shows grid connected hybrid wind solar system.Many factors are considered in designing wind solar system such as phase amplitude of voltage frequency should meet the grid specification. AC and DC converters are used in system meet the parameters of grid. In WTG AC-DC-AC power conversion devices are used while in PV module DC-AC power conversion is performed as power produced by PV system is DC which must be converted to AC To feed power to utility grid. Stability and power quality are the problems arise in hybrid system [4]. Harmonics in the system arises due to use of power conversion devices such as converters and inverters in the system.

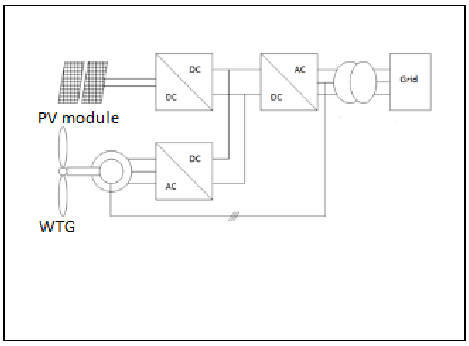


Figure 4. Grid connected hybrid wind solar system

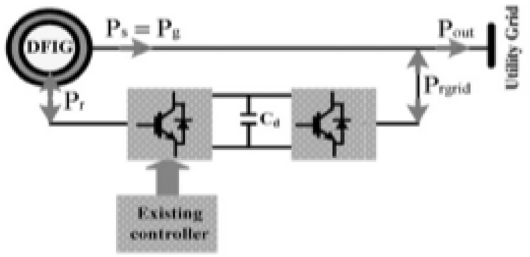
III. RESULTS AND DISCUSSION

Review on Hybrid Wind Solar

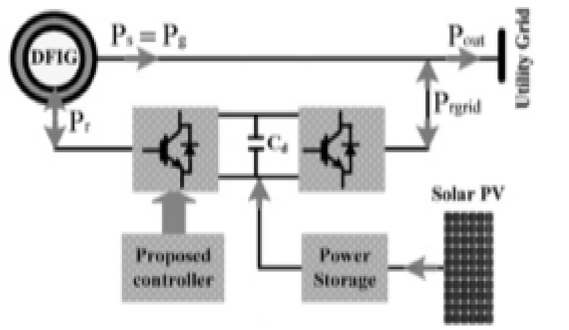
In [1], hybrid wind solar is considered for maintaining grid power constant. Here DFIG wind generator along with BESS is used to reduce the power fluctuation, which arises due to continuous changing wind speed and direction. MPPT is used for PV system and wind system to extract maximum power from both wind and solar. The system is simulated in such a control strategy to maintain grid power constant. The proposed system is simulated in MATLAB simulink. For the proposed system, design of BESS, control of GSC & control of RSC,PV array and MPPT are considered for design and control of system. The waveforms for stator voltage (Vabc), grid current (Iabc), rotor speed (wr), reactive power (Q), grid power (P) and battery power (Vdc) are observed for different wind speeds i.e. 10m/s,13m/s and 7m/s. By either charging or discharging the battery in the corresponding region of operation the value of the grid power is maintained constant at 5 MW i.e. grid power reference . BESS is used to maintain grid power constant i.e. when generation is more than required, the excess power is stored in battery (BESS) at the time when generation goes low, the power stored in BESS is supplied to grid to maintain grid power level. PV array system is more reliable i.e. at time when wind generation is not available for long period, the PV array charges the BESS. When enough power from solar energy is available, it can be directly fed to the grid.

In [5], hybrid wind PV system is described for an isolated area. The modeling and simulation are performed in MATLAB /simulink. For different wind speed and irradiance, the performance of the system is evaluated. The waveforms for three different cases are obtained i.e first for wind system alone, for solar PV alone and for hybrid system. It is observed that temperature and irradiation changes mainly affect the PV system output voltage and output current when solar was operating alone. In Hybrid system AC voltage varies due to variation in wind speed and solar irradiation. Here battery system is used to maintain balance between load and source. In hybrid system, 14m/s in wind system and 800W/m^2 in solar PV system performance has been analyzed and this system is expected to meet up electricity demand in remote area.

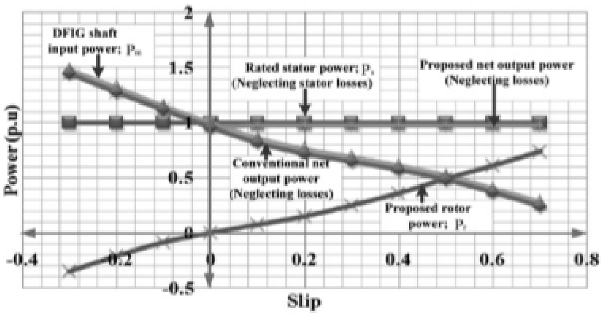
In [6], a wind solar hybrid system using DFIG is considered. Here a control scheme is proposed for minimum losses in the induction generator during operation. A PV unit with rechargeable battery is installed at rotor circuit to supplement power to rotor at the time of weak generation. An optimal flux control technique improves efficiency and longevity of system. The proposed system is implemented with 2.5kW DFIG and a 3.5 kW,1500 rpm separately excited DC motor with a necessary torque control is coupled to DFIG model. For implementation of experimental setup a dSPACE CP1104 module with PC interface is used. The power was measured at various points when solar isolation is constant, wind speed varies, and variations are observed. Fig-5(a) and 5(b) shows the power flow diagram of conventional scheme and proposed scheme.



(a)



(b)



(c)

Figure 5. Power flow and power distribution

a) Power flow for the existing schemes
b) Power flow in proposed scheme
c) Power distribution of the proposed and existing conventional generation schemes

In conventional scheme, during lower generation from wind i.e. sub-synchronous mode ,the rotor takes power from grid to provide excitation to rotor winding. So, power fed to grid by doubly fed induction generator is reduced DFIG is reduced as shown in fig 5(c). However in proposed scheme, due to low shaft power input, the injected rotor power increases with increasing slip which can be observed from fig 5(c). Here, from measured input power to DC motor, the mechanical shaft power input is calculated. The power absorbed by rotor is decreasing and power fed to grid is increasing by observation. This proposed work has potential to improve generation efficiency of wind energy dominated grid.

IV.CONCLUSION

Both solar and wind energy are meant to seasonal variation. For different wind and solar irradiance system performance is evaluated. In addition, various control schemes are proposed for minimum losses in DFIG. Therefore, combining both the sources can effectively meet the demand of electricity in future and by different control scheme, the system can be made more efficient. Also By various power analysis tools analysis of system can be performed to make hybrid system more reliable and efficient.

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