

Study of Challenges, Scopes and Converter Topologies in Wind Energy System

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Abstract: Due to economic and environmental benefits, the Wind Energy Conversion System (WECS) has experienced tremendous growth over the past decade. The paper focusses on the new control strategy for a grid-connected doubly fed induction generator (DFIG)-based wind energy conversion system (WECS). The topology consisting of a battery energy storage system (BESS) to reduce the power fluctuations on the grid due to the varying nature and unpredictability of wind is presented. Existing control strategies like the maximum power point extraction of the wind turbine, unity power factor operation of the DFIG are also addressed along with the proposed strategy of “grid power leveling.”

Keywords: wind power system, current source converter, grid connector, DFIG.

I. INTRODUCTION

Due to the Economic and environmental benefits, Wind Energy Conversion System (WECS) have received tremendous growth in the past decade. The increased interest in wind energy has made it necessary to model and experimentally evaluate entire WECS, so as to attain a better understanding and to assess the performance of various systems. This paper describes a control strategy for a doubly fed induction generator (DFIG) with varying wind speed. Variable speed operation is essential for large wind turbines in order to optimize the energy capture under variable wind speed conditions. Variable speed wind turbines require a power electronic interface to permit connection with the grid.

The power converter can be either partially rated or fully rated. A popular interface method for large wind turbines that is based on a partially rated converter is the doubly-fed induction generator (DFIG) system. In the DFIG system, the power converter controls the rotor currents in

order to control the electromagnetic torque and thus the rotational speed.

Because the power converter only process the slip rotor power, which is typically 25% of the rated output power, the DFIG offers the advantages of speed control for a reduction in cost and power losses. The aerodynamics of the wind turbine and the mechanical dynamics of the induction machine need to be included to extend the use of the designing model for variable wind speed conditions.

LITERATURE REVIEW

Vijay Chand Ganti et al. [1] this paper presents a new control strategy for a grid-connected doubly fed induction generator (DFIG)-based wind energy conversion system (WECS). Control strategies for the grid side and rotor side converters placed in the rotor circuit of the DFIG are presented along with the mathematical modeling of the employed configuration of WECS. The proposed topology includes a battery energy storage system (BESS) to reduce the power fluctuations on the grid due to the varying nature and unpredictability of wind. The detailed design, sizing, and modeling of the BESS are given for the grid power leveling. Existing control strategies like the maximum power point extraction of the wind turbine, unity power factor operation of the DFIG are also addressed along with the proposed strategy of grid power leveling.

Jianwen Zhang et al. [2] This paper proposed in a low-voltage (LV) pulse-width modulated current-source converter (CSC) using reverse-blocking insulated gate bipolar transistor (RB-IGBT) devices is proposed in this paper for megawatt wind energy conversion systems

(WECSs) with a permanent magnet synchronous generator.

Benefiting from using the latest generation of reverse-blocking power semiconductors, the presented configuration is able to push the switching frequency to a higher range and overcome the traditional drawback of low efficiency in LV CSCs. Design of the configuration, switching scheme, and system control are briefly introduced. Semiconductor and converter loss models are developed for detailed efficiency study of the proposed system. The overall high-efficiency performance of the LV CSC based WECS is verified by simulation results and comparison with the state-of-the-art solution using voltage-source converters.

Eduardo Giraldo et al. [3] this paper proposes a new adaptive control strategy for a wind energy conversion system based on a permanent magnet synchronous generator and a pulse-width modulated current source converter. Most of the studies on wind farms are based on double fed induction technology. Nevertheless, the proposed conversion system is a good alternative due to its high efficiency and reliability. Electrolytic capacitors are not required in this type of converter and the voltage in the DC-link as well as the generated reactive power can be dynamically modified according to the wind velocity, being even negative if required. However, it is challenging from the control and stability standpoint. Capacitive filters placed on the AC side, which are required for safe commutation, can create resonances with the power grid. Reactive power is generated according to the capacity of the converter, the wind velocity and the load profile.

Mao Meiqin et al.[4] This paper presents a stator flux-oriented direct torque control method based on space vector modulation (SFO-SVM-DTC). By the method, the most appropriate current space vector will be generated dynamically to fully compensate for the actual output torque and flux errors referred to the reference commands and to achieve a high performance DTC system with constant switching frequency. In addition, for the stator flux observation, a modified integrator with an adaptive compensation is adopted to solve DC drift in a pure integrator. Simulation and experiment results show that the proposed SFO-SVM-DTC method can effectively not only improve the system steady-state performances but

also benefits to achieve the unit power factor control of the PMSG.

II. THE WIND TURBINE SYSTEM

The system employs a back to back converter with reduced power rating. This bidirectional power converter consists of two conventional pulse-width modulated (PWM) inverters and is nowadays one of the most widely used converter topology in wind energy conversion system. The rotor side inverter is controlled so as to extract the maximum power from the wind turbine and to regulate the reactive power transferred to the utility grid. The main objective of the grid side inverter is the control of DC link voltage regardless of the wind speed. The DFIG is based on a wound rotor type induction machine. The torque speed profile of a typical induction machine with a short circuited rotor. Thanks to the back-to-back converter that allows a bidirectional power flow between the rotor and the grid, the induction machine has two operating regions, i.e. sub synchronous and supersynchronous, that correspond to rotational speed below or above the synchronous speed. The synchronous speed of the generator in rpm is defined by

$$n_s = \frac{f}{z_p} \times 60$$

Where

f is the grid frequency and

Z_p is the number of polepairs.

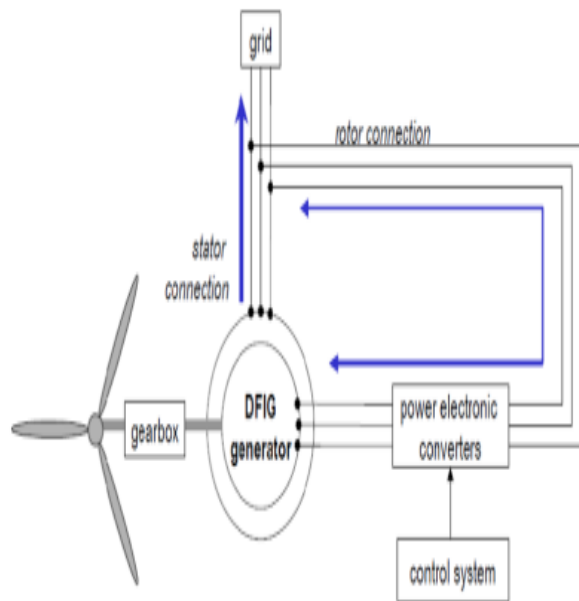


Fig. 1. Schematic diagram of WECS

III. DOUBLY –FED INDUCTION GENERATOR

Wind turbines can either operate at fixed speed or variable speed. For a fixed speed wind turbine the generator is directly connected to the electrical grid. For a variable speed wind turbine the generator is controlled by power electronic equipment.

There are several reasons for using variable-speed operation of wind turbines; among those are possibilities to reduce stresses of the mechanical structure, acoustic noise reduction and the possibility to control active and reactive power. Most of the major wind turbine manufactures are developing new larger wind turbines in the 3-to-5-MW range. These large wind turbines are all based on variable-speed operation with pitch control using a direct driven synchronous generator or a doubly-fed induction generator (DFIG).

DFIG is an abbreviation for Double Fed Induction Generator, a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly but there are problems with efficiency, cost and size. A better alternative is a brushless wound rotor doubly-fed electric machine. The Doubly-Fed Induction Generator (DFIG) with both stator and rotor windings.

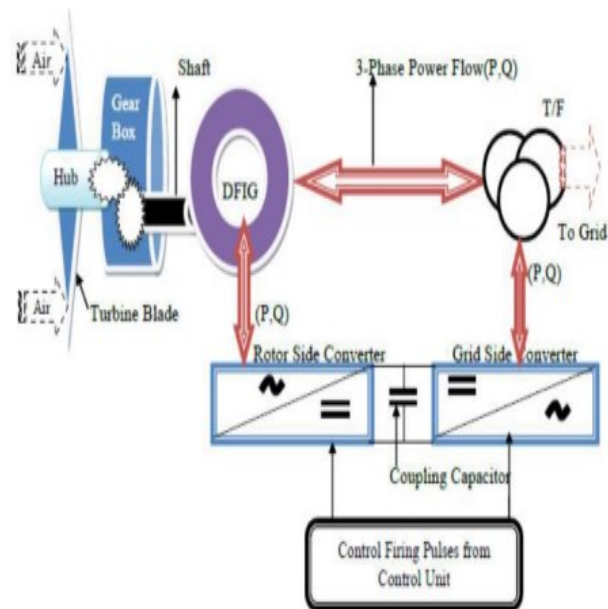


Fig. 2. Doubly-Fed Induction Generator (DFIG)

The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ from the grid frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed.

The doubly-fed generator rotors are typically wound with 2 to 3 times the number of turns of the stator. This means that the rotor voltages will be higher and currents respectively lower. Thus in the typical $\pm 30\%$ operational speed range around the synchronous speed, the rated current of the converter is accordingly lower which leads to a lower cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher than rated rotor voltage. Further, the voltage transients due to the grid disturbances (three- and two-phase voltage dips, especially) will also be magnified. In order to prevent high rotor voltages and high currents resulting from these voltages - from destroying the IGBTs and diodes of the converter, a protection circuit (called crowbar) need to be used.

IV. GRID CODE REQUIREMENT

Due to the significant increase of wind power penetration in the power system, many countries have revised their

grid code, by defining specific technical requirements for the wind farms. Grid code requirements typically refer to large wind farms, which is connected to the transmission system. Grid codes specify that wind farms must contribute to power system control, as much as conventional power generation stations and withstanding of wind system during abnormal condition. The Indian Electricity Grid Code (IEGC) provides the major technical rules to enable safe operation, maintenance, development and planning of electricity grid. The main objective of IEGC is to maintain safe and reliable operation of power system. The IEGC guideline and standards are suggested to be followed by various participants of the power grid. Indian Wind Grid Code (IWGC) has been developed only to enhance the secure operation of the wind farms and also their integration into the Indian electrical system. The Grid Codes address Fault tolerance, Reactive power/voltage control requirements, Ramp rate control and Frequency response capability. Indian Wind Grid Code (IWGC) structure includes (1) Role of various organization and their linkages (2) Planning code for transmission system evacuating wind power (3) Connection code for wind farm (4) Operating code (5) FRT is an important feature. For the wind turbines to remain connected to the grid during the faults, various technologies have been developed to withstand the voltage dips. This withstanding capability of DFIG against voltage sags is called Low Voltage Ride-Through (LVRT) or Fault Ride-Through (FRT) capability. If Fault Ride Through is not installed, generation would be susceptible to tripping when subject to a voltage dip even when connected to a healthy circuit for less than normal protection operating times.

V. ISSUES IN DFIG CONNECTED TO GRID

A. Voltage Control and Power Quality

Large variations of voltage in the power systems, is one of the most common problems. Large fluctuations create voltage dips in the wind energy power generation system. Voltage control and reactive power quality can arise when there are large numbers of generators in the network for starting or stopping the generation. In the absence of proper control, a single line to ground fault, may create serious voltage fluctuation problem to other users connected to the grid and there is a chance of flickering and harmonics.

B. Stability of the System and Frequency

Now a day most of the wind generation is integrated to grid and small disturbance can produce imbalance in the system. The instability occurs during the fault condition and light load condition. During the summer season the new generator would meet a significantly higher percentage than usual demand under windy conditions. This can be resolved by proper control. Current wind generation technology does not offer flexibility for balancing requirements. Generators can be adjusted automatically with the variations in power, and thereby we can adjust the frequency of the system.

C. Continuity and Protection

Continuity of the supply is a challenge even in case of renewable sources due to the high penetration of energy into the distribution network. Wind energy is not the only source to be depended on. It must be balanced with sufficient spinning and non-spinning reserve to ensure the supply continuously. Protection would interfere with operation of other sources and equipment's connected in point of common coupling (PCC).

D. Fault Ride Through and Grid Code

As the penetration of wind energy increases, the need to address the fault ride-through capability issues will also increase. The wind turbines were allowed to trip when a voltage dip occurs. During the fault ride through wind turbines are expected to remain connected to the grid both during and after a fault. Also upon voltage recovery, the wind turbines are not expected to absorb the excessive reactive power and it should match with the grid code requirements also.

VI. BATTERY ENERGY STORAGE SYSTEM

A battery Energy Storage System (BESS) is a technology developed for storing electric charge by using specially developed batteries. The underlying idea being that such stored energy can be utilized at a later time. Enormous amount of research has led to battery advances that has shaped the concept of Battery Energy Storage System into a commercial reality.

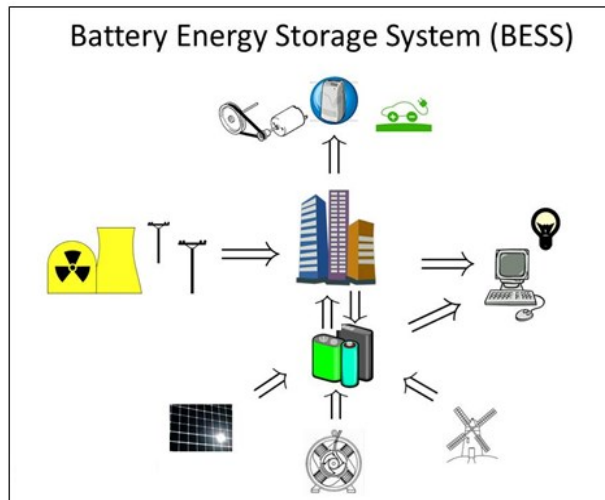


Fig. 3 battery energy storage system

Battery Energy Storage Systems (BESSs) are a sub-set of Energy Storage Systems (ESSs). Energy Storage System is a general term for the ability of a system to store energy using thermal, electro-mechanical or electro-chemical solutions. A BESS typically utilizes an electro-chemical solution.

VII. MPPT TECHNIQUES

In a wider sense all MPPT techniques can be categorized into two types: Sensor based MPPT methods and Senseless MPPT methods based on sensor required for measuring the wind velocity. Further classification is shown in Fig. 1.4. Sensor based MPPT techniques consists of MPPT methods which uses anemometer to find out the actual wind speed at any instant; like TSR control or Wind Speed Measurement (WSM) technique. Sensor less MPPT technique comprises of algorithms which do not use any device (like anemometer) to measure wind velocity for extracting maximum power. Either they use indirect methods for it or may use separate algorithms which do not even require knowledge of wind speed at all.

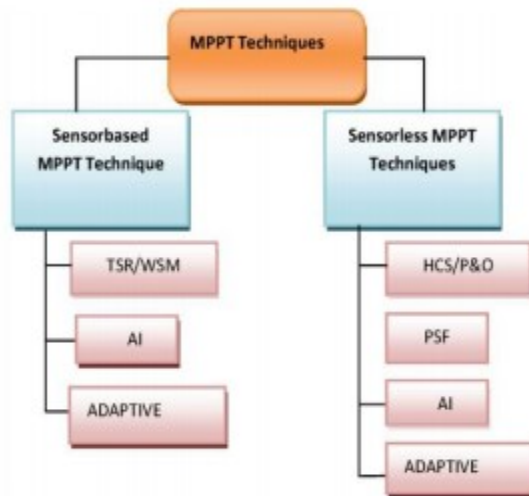


Fig. 4. Classification of MPPT Techniques

Artificial Intelligence technique; comprising application of fuzzy logic, Neural Network (NN) approach and adaptive methods can be placed in either of categories as they may or may not use sensors for wind speed measurement depending on particular algorithm being used.

VIII. CONCLUSION

This paper is mainly focused on various challenges in grid connected nonlinear wind turbine. It has also addressed about important control challenges of the DFIG machine connected with wind turbine. However, in order to enhance the efficiency of the DFIG power output, control strategy must be improved. Efficient choice of the converter control techniques can be useful in mitigating issues associated with the modeling of wind energy systems.

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