CONTROL OF WIND POWER GENERATION SYSTEM – A SURVEY REPORT

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ABSTRACT

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INTRODUCTION

The global electrical energy consumption has been continuously rising leading to a steady increase of the demand on power generation. So, alternative energy source investment is becoming more and more important now days. Wind power generation systems are recently getting lots of attention, because they are most cost competitive, environmental clean and safe renewable power source. Recent evolution of power semiconductors and variable frequency drive technology has aided the acceptance of variable speed generation systems. In spite of additional cost of power electronics and control, the total energy captured in a variable speed wind turbine system is larger and therefore the lifecycle cost is lower than with fixed speed drives.

Denmark was the first country to erect windmill and the top five countries in the world to have the highest installed wind power capacity are Germany, Spain, Denmark, U.S.A and India respectively. The main objective of this paper is to focus on various recent techniques used in wind power generation system.

DOUBLY-FED WIND POWER GENERATION SYSTEM (WPGS)

Large scale wind turbine mostly adopts variable speed regulated pitch operating method and doubly fed generator connected to the grid by the rotor side converter excited. Doubly fed induction generator benefits the wind power generation system in various aspects including significant reduction of inverter ratings, constant stator flux linkage over the entire operation range to improve the utilization ratio of the generator, low dc bus voltage resulting low cost of the capacitor bank etc. [1] In this paper, a novel direct torque control of doubly fed wound rotor induction generator is proposed to pursue a simple control structure and high efficiency. The rotor power factor control is used to realize the control. The proposed rotor power factor control has two added advantages: a simple control system structure and the lowest inverter rating. [2] A doubly fed induction generator is coupled to the grid through power electronic converter connected between the rotor windings of DFIG and the grid. The voltage drop at the terminals will result in large, oscillatory currents in the stator winding of DFIG. Because of magnetic coupling between stator and rotor winding, these currents will also flow through the converter and high current can cause its thermal breakdown. During a fault, the rotor winding are short circuited by a set of resistors. The short circuit current will flow through this crow bar instead of the converter. This paper analyzes the behavior of a crow bar protected DFIG. Based upon this, approximate equations are derived that can be used to determine the short circuit current contribution of the turbine. [3] This paper analyzes the mathematical model for brushless doubly fed machine (BDFM) based on double synchronous reference frame by using rotor d-q model and based on the characteristic of BDFM, anew type of power control system is designed by applying flux oriented vector transformation control technology so that the decoupling control of the active and reactive power of the generator is achieved and maximal wind energy tracing and capturing are made possible. Because the BDFM structure is complex and BDFM parameters are variable according to the environment, fuzzy control is used for the power loop to further enhance the robustness of the system. [4] This paper focuses on the development of maximum power extraction strategies for variable speed constant frequency (VSCF) grid connected wind power generation systems with DFIG. A new optimal control method is proposed by controlling the generator stator active and reactive power. Based on the mathematical model of DFIG, the optimal stator reactive power value is derived for minimal machine copper losses. According to the wind turbine power characteristics and generator power flow equations, the optimal stator active power reference value is also obtained for capturing maximal output power from wind turbines. [5] In order to compensate initial error of position encoder used for ac excited DFIG, a controller method is proposed in this paper based on the steady state relationship between rotor currents and stator voltages with stator windings. A stage wise control strategy for grid connection is proposed by applying the compensate controller to DFIG WPGS. [6] A test-bed built for the experiments of VSCF WPGS, mathematical models and the control structures of both the grid side and rotor side converters are described. The test-bed is composed of a DFIG, a variable voltage frequency
inverter driven squirrel cage motor for simulation, dual-DSP based controller and PC based data acquisition and control system. [7] This paper proposes an advance monitoring and diagnosis system for detection of incipient electrical faults in DFIG WPGS based on the analysis of the rotor modulating signals. In this application the rotor power is supplied by a converter for the control of active and reactive power flow from the generator to the mains. [8] discusses some important aspects including the steady state model, reactive power/voltage controller, Derivation of PI and BDFRM generator. These models show their similarities and how the BDFRM can be used instead of DFIG, with the added benefits of brushless operation. [10] This paper proposes a new active power control method for DFIG. This method does not require the transformation between a-b-c frame to d-q frame. The proposed method independently adjusts the magnitude and phase of stator output. [11] In this paper a practical bi-directional AC-DC-AC converter with IGBT modules is presented based on the DFIG model and field oriented control theory. It can operate at sub-synchronous and super-synchronous mode. The active and reactive power can be controlled flexibly and no harmonics are injected to the grid and the power flowing through the converter is the slip recovery power of DFIG. The converter offers unity power factor, high power quality, good performance and low cost. [12] This paper analyzes the mathematical model for BDFM based on synchronous reference frame by using d-q model as a start point and based on the characteristics of BDFM, a new type of power control system is designed, so that the decoupling control of the active and reactive power of the generator is achieved and maximal wind energy capturing is made possible. [13] Introduces a multi-pole low speed doubly fed brushless generator (DFBG) for direct driven VSCF WPGS which not only keeps the low cost feature but also increases the operation reliability due to the gearless and brushless structure. [14] In WPGS, operating conditions are continually changing due to wind speed fluctuations and load variations. This paper presents a voltage control methodology to regulate voltage at a specific location, i.e., point of common coupling (PCC). A proportional plus integral (PI) is designed by the Nyquist constraint design technique for robustness. [15] This paper presents a new sensorless method for the vector control of DFIG without using speed sensors or rotor position measurements which is based on model reference adaptive system (MRAS) estimating rotor position and speed from the machine rotor currents. This method is suitable for both stand-alone and grid connected operation of variable speed DFIGs. To design MRAS observer with appropriate dynamic response, a small signal model is derived. The sensitivity of the method for variations in machine parameters is also analyzed in this paper. [16] This paper develops a theoretical analysis of dynamic behavior of DFIG during three phase voltage dips. The proposed analysis contributes to understanding the causes of the problem and represents a very useful tool to improve the existing solutions and proposes new alternatives. [17] In this paper, the performance of the wind turbines with DFIGs during a voltage dip caused by external short circuit fault is analyzed. Two methods are introduced to improve the low voltage ride through (LVRT) performance of DFIG, which are the crowbar solution to protect the converter and the reactive power supplied by the stator side converter. [18] In this paper, a technique is described which the objective to keep DFIG has connected to the grid in case of a grid failure so that it can resume power generation after clearance of the fault in the grid. The key of the technique is to limit the high currents and to provide a bypass for it in the rotor circuit via a set of resistors that are connected to the rotor windings without disconnecting the converter from the rotor or from the grid. The wind turbine can resume normal operation within a few hundred milliseconds after the fault has been cleared. [19] This paper explores two DFIG configurations in which a series grid side converter (SGSC) is employed for voltage sag ride through. A control strategy applicable to both configurations is developed whereby the SGSC engages to stabilize the stator flux at the beginning and resolution of the sag event. [20] In this paper, a novel PI gain scheduler for a vector control scheme is proposed to improve the dynamic performance of a wind driven DFIG system. The advantages of this system are: better dynamic response, more accurate speed adjustment is achieved with less overshoot, less settling time and less steady state error as compared to the conventional PI controller with fixed gain. [21] The power factor control of DFIG using PI and fuzzy logic control algorithm using IGBT PWM power converter connected in rotor side has been proposed. Under fuzzy logic control, which enables superior dynamic performance, the power factor is independently controllable by decoupled rotor current in synchronously rotating reference frame. [22] The control strategies for a wind generation system has been proposed. A DFIG is used with two back to back converters on the rotor circuit in a slip power recovery scheme. The slip control results in an operating speed range that suits the wind energy generation requirements. The vector controlled DFIG enables the decoupling between active and reactive power as well as torque and power factor. Hence besides the optimal speed tracking for maximal wind energy conversion, an optimal control strategy for the two converters is developed. This strategy helps to minimize the electrical losses, hence optimizing the system overall efficiency. [23] This paper develops a dynamic model and control scheme for DFIG systems to improve the performance and stability under unbalanced grid conditions.
A dynamic DFIG model containing the positive and negative sequence components is presented using stator voltage orientation. The proposed model accurately illustrates the active power, reactive power, torque oscillations and provides a basis for DFIG control system design during unbalanced network supply.

PERMANENT MAGNET SYNCHRONOUS GENERATOR (PMSG) IN WIND POWER GENERATION SYSTEM (WPGS)

Paper [24] discusses a unique axial flux permanent magnet synchronous generator (AFPMSG), suitable for both vertical as well as horizontal axis wind turbine generation systems. An outer rotor design facilitates direct coupling of the generator to the wind turbine, while a coreless armature eliminates the magnetic pull between the stationary and moving parts. The design and construction features have been reviewed, the performance equations of the AFPMSG are derived and the condition for maximum efficiency is deduced for both constant speed and variable speed operations. [25] This paper proposes an output power maximization control scheme for an interior PMSG (IPMSG) in a variable-speed WPGS. The optimal d-axis and q-axis stator current commands are obtained as a functions of the generator speed by solving a constrained non-linear optimization problem that minimizes the copper and core losses in the IPMSG while considering the voltage and current limits of IPMSG. To eliminate the effect of non-linearity caused by magnetic saturation, an input-output feedback linearization (IOL) technique is used to design the high performance non-linear current controllers. [26] A novel PM brushless machine for WPGS has been proposed. Because of the adaptation of outer rotor topology, the proposed machine can capture wind power directly. By artfully incorporating the coaxial magnetic gear, the proposed machine can offer high torque low-speed operation while holding small volume and light weight. [27] A novel control system for a switched reluctance generator as a part of WPGS. Here two control converters are used; one to control the machine phase currents and other to supply energy captured by the wind turbine into the grid. For low and medium speed, the output power is controlled in order to drive the WPGS to the point of maximum aerodynamic efficiency. For high speed, the output power is controlled to drive the wind turbine to stall operation. A three mode current controller is used, employing compensation for machine non-linearities, which provides good current control over the full speed and current range. A novel power control system is designed, using linearized model, which employs gain-scheduling to maintain excellent power control characteristics for the full operation envelope of the WPGS by compensating for machine non-linearities. [28], [29] The focus is on the development of a novel maximum power extraction algorithm (MPEA) including a maximum power error driven (MPED) mechanism and a maximum power differential speed (MPDS) control for WPGS for PMSG. In this proposed scheme, the MPED mechanism, operating like a traditional hill-climbing method, drives the output power gradually to its maximum value by regulating the direction of current command according to the power variation trend. The MPDS control produces an additional step of current command based on the instantaneous difference of generator speed, so that it can prevent the wind turbine from stalling at the suddenly dropping wind speed and achieve the object of maximum power extraction instantly as a stiff wind flowing through the wind turbine.

INTELLIGENCE CONTROL OF WIND POWER GENERATION SYSTEM (WPGS)

[30] A new methodology to control horizontal axis WPGS using neural network. The proposed control system consists of neural network inverse and forward identifiers, which are used to model inverse and forward dynamics of the system respectively and to adapt neural controller parameters and reference model that are used to enhance trajectory training, and neural controller which is used to generate control signal to pitch angle actuators. [31],[32] It deals with the development of artificial neural network (ANN) wind power forecaster and the integration of wind power forecast results into unit commitment (UC) scheduling considering forecasting uncertainty by the probabilistic concept of confidence interval. The main aim of the wind power forecaster is to balance the cost savings and the risk on system reliability. [33],[34] In this paper neural network principles are applied for wind speed estimation and robust control of maximum wind power extraction against potential drift of wind turbine power coefficient curve. This control system will deliver maximum electric power to customer with light weight, high efficiency and high reliability without mechanical sensors. This control method is applicable to both wind turbine directly driven PMSG and a cage induction machine wind generation system (CIWG). [35] It deals with the stabilization of power system with WPGS by active power control of a number of micro superconducting magnetic energy storage (SMES) units. Here a performance index is defined with the oscillations of synchronous generator taken into account. In order to obtain the optimum allocation of micro SMES units of predetermined number, genetic algorithm (GA) is adopted based on performance index. [36] This paper analyzes the control strategy and performance of an HVDC link based on voltage sourced converters (VSC), which is controlled by using fuzzy logic principles. The system can feed power to weak or even dead network under fluctuations and big variations of the input power. The fuzzy logic based control of the system helps to optimize efficiency of HVDC link under disturbances or fluctuations.
CONTROL OF HYBRID GENERATION SYSTEM

Renewable energy sources have unpredictable random behaviors. However, some of them, like solar radiations and wind speed have complimentary profiles. Some papers present modeling and control design of wind-hybrid power system that include battery storage and dump-load. The proposed control scheme is based upon Takagi – Sugeno (TS) model and linear quadratic regulator. The proposed controller is compared with the conventional PI controller and is more effective against disturbances caused by the wind speed and the load variations, which helps to achieve a better power quality. Thus a better quality is achieved on the given site. Some papers discuss the different interconnections of micro-grid and the interconnection stability. A microgrid is a network system that attempts the existence of utility grid and the distributed generation. The evaluation models in the microgrid stability are tie-line power flow and frequency deviation. Some papers deal with power control of a wind and solar hybrid generation system for interconnection operation with electric distribution system. The proposed system consists of a variable speed direct drive wind generator, wind-side converter, solar array, DC-DC converter and grid interface inverter. Power control strategy is to extract maximum energy available from varying condition of wind speed and solar irradiance while maintaining power quality at a satisfactory level. In order to capture the maximum power, variable speed control is employed for wind turbine and maximum power point tracking is applied for photovoltaic system. The grid interface inverter transfers the energy drawn from wind turbine and PV array into the grid by keeping common DC voltage constant.

CONCLUSION

Wind power technology has become one of the most promising renewable energy sources in the recent past. With increasing demand of wind energy, several research areas arose comprising of design of doubly fed induction generator and permanent magnet synchronous generator as wind generator, voltage stabilization and output voltage control due to variable nature of wind, stabilization of grid, etc. The main aim of this paper is to survey the recent different methodologies used in wind power generation system in order to enhance better performance and high efficiency of the wind power generation system.

REFERENCES