Performance analysis for the design engineering essay

Engineering

ANJU. M1 R. RAJASEKARAN21 PG Scholar, Department of EEE, SNS College of Technology, Coimbatore. 2 Asst. Professor, Department of EEE, SNS College of Technology, Coimbatore. 1 anju51011@gmail. com 2rare457@gmail. comAbstract - This paper proposes a detailed study about the performance analysis of doubly fed induction generator and permanent magnet synchronous generator. The Wind Energy Conversion System (WECS) mainly deals with three main electrical aspects: 1) wind turbine generators (WTGs), 2) power electronics converters (PECs) and 3) grid-connection issues. The topology of DFIG driven by a variable speed wind turbine through a multi-stage gearbox. The stator of the DFIG is connected directly to the grid, while the wound rotor is connected through a partial-scale frequency converter. DFIGs are typically more expensive and less robust than SCIG. Permanent Magnet Synchronous Generator (PMSG) runs at a constant speed and draws its excitation from a power source external or independent of the load or transmission network it is supplying. They are equipped with a DC electric or permanent magnet excitation system (rotating or static) associated with a voltage regulator to control the output voltage before the generator is connected to the grid. Design of both PMSG and DFIG is analysed by means of MATLAB/SIMULINK block set. Index terms – Fault Ride Through Capability, Voltage Dip, Wind Turbine Generators, Power Electronic Converters, Grid-Connection.

I. INTRODUCTION

In recent years more attention has been focused on induction machines for low and medium power application because they have attractive advantages over conventional generators such as low unit cost, less maintenance robust construction etc. Double-Fed Induction Generators (DFIG) are particularly suitable for isolated operation like in hydro and wind developments. Even in cases where load is an AC motor requiring reactive power coordination [1]. The global consumption of electrical energy will grow at an annual average of 2% between the years of 2003 and 2030. The forecast for the growth of demand for energy specifically in the electric form is even greater i. e. 2. 7% to the year, according to the U. S. Department of Energy, through of International Energy Outlook 2006 (IEO) report of Energy Information Administration (EIA) [2]. The wind generation includes fixed-speed system as well as variable-speed system. The variable-speed wind power generation is a tendency in nowadays wind generation development because it can operate on the maximum power point of the machine. This system include synchronous and asynchronous generator[3]. PMSG generate the output voltage without a constant frequency. The AC-DC-AC converter is responsible to controlling the frequency and to make the variable voltage constant. The PMSG does not need the gearbox and has a light mass and high efficiency. The whole power generated need to pass through the converter, so, the rated power of the converter must to be the same rated power of the generator [4]. In wind turbines based on DFIG, the stator is directly connected to the grid and the rotor is excited by three phase converter which can regulate both active and reactive power of stator machine through control of dq-axis rotor currents. The rated power of the back-to-back converter is smaller than the generator rated power, this converter must be specified by the slip power, which is approximately 25% of the rated power of the generator. The DFIG is heavier than the PMSG and needs the gearbox, which causes the whole system heaviest [6].

II. OPERATION OF DFIG

Now-a-days, the majority of wind turbines are equipped with Doubly Fed Induction Generators (DFIGs). In the DFIG concept, there will be separate winding employed for both stator and rotor. The wound rotor induction generator is grid-connected at the stator terminals as well as at the rotor mains via a partially rated variable frequency AC/DC/AC converter (VFC). This only needs to handle a fraction (25%-30%) of the total power to achieve full control of the generator. The Variable Frequency Controller consists of a Rotor side Converter (RSC) and a Grid-Side Converter (GSC) connected back-to-back by a dc-link capacitor, In order to meet power factor requirement (e. g. −0. 95 to 0. 95) at the point of connection. In order to get a complete control of entire transmission line, voltage across the dc link capacitor must be double the value of grid voltage. Most wind farms are equipped with switched shunt capacitors for conventional reactive power compensation. Moreover, because many wind farms are connected to weak power system networks which are characterized by low short circuit ratios and under-voltage conditions. Fig. 1. Wind turbine modelOne of the important issues related to the wind farms equipped with DFIGs is the grid fault or low voltage ride through capability and system stability. One technique of blocking the RSC is short circuiting the rotor circuit by a crow-bar circuit to protect the converter from over current. WTGs continue their operation to produce some active power and the GSCs can be set to control the reactive power and voltage. Fig. 2. Equivalent circuit of DFIGThe rotor leakage reactance, Lr and the rotor resistance Rr. In addition, the rotor circuit models the generated mechanical power by including an additional rotor resistance component, Rr(1–s)/s. Note that the rotor and stator circuits are linked via a transformer whose turns ratio depends on the actual turns ratio between the stator and rotor (1: k) and also the slip ‘ s’ of the machine. In an induction machine the slip is defined asS=(Ns-Nr)/Ns----------------------------(1)where Ns and Nr are the synchronous speed and the mechanical speed of the rotor respectively. The synchronous speed is given byNs=(120*fe)/p rpm -----------------------------(2)Where p = number of pole pairs and fe is the electrical frequency of the applied stator voltage.

III. CONTROL DESIGN OF DFIG

Control design of DFIG consist of RSC (Rotor side Converter) and GSC (Grid Side Converter)The Rotor-Side Converter (RSC)The rotor-side converter (RSC) applies the voltage to the rotor windings of the doubly-fed induction generator. The purpose of the rotor-side converter is to control the rotor currents such that the rotor flux position is optimally oriented with respect to the stator flux in order that the desired torque is developed at the shaft of the machine. The rotor-side converter uses a torque controller to regulate the wind turbine output power and the voltage (or reactive power) measured at the machine stator terminals. The power is controlled in order to follow a pre-defined turbine power-speed characteristic to track the maximum power point. The actual electrical output power from the generator terminals added to the total power losses (mechanical and electrical) is compared with the reference power obtained from the wind turbine characteristic. Usually, a Proportional-Integral (PI) regulator is used at the outer control loop to reduce the power error (or rotor speed error) to zero. The output of this regulator is the reference rotor current irqref that must be injected in the rotor winding by rotor-side converter. This q-axis component controls the electromagnetic torque Te. The actual irq component of rotor current is compared with irqref and the error is reduced to zero by a current PI regulator at the inner control loop. The output of this current controller is the voltage vrq generated by the rotor-side converter. With another similarly regulated ird and vrd component the required 3-phase voltages applied to the rotor winding are obtained. To describe the control scheme, the general Park's model of an induction machine is introduced. Using the motor convention in a static stator-oriented reference frame, withoutsaturation, the voltage vector equations areῠs= is*Rs +dα/dt--------------------(3)ῠr= ir*Rr+ dα/dt--------------------(4)where ‘ ῠs’ is the stator voltage imposed by the grid. The rotor voltage ‘ ῠr’ is controlled by the rotor-side converter and used to perform generator control. The flux vector equations areαs = Ls*is + Lm*ir------------------(5)αr = Lm*is + Lr *ir---------------(6)where Ls and Lr are the stator and rotor self-inductances: Ls = Lm + Lls , Lr = Lm + Llr-----------(7)Defining leakage factor, σ= 1-Lm2/Lr*Ls----------------(8)L0= Lm2/Ls------------------(9)ῠrd= ird*Rr+ σLr*dird/dt-wslip* σLr*irq-----------------(10)ῠrq= irq*Rr+ σLr*dirq/dt-wslip (σLr*ird+L0*ims)-------------(11)wslip= ws-wr----------------------------(12)The stator flux angle is calculated fromαst= ∫(ῠst-is*Rs)dt----------------(13)αsb= ∫(ῠsb-is*Rs)dt----------------------------(14)θs= tan-1(αst / αsb)----------------------------------(15)The control scheme of the rotor-side converter is organised in a generic way with two series of two PI-controllers. Fig. 3 shows a schematic block diagram for the rotor-side converter control.

The reference q-axis rotor current irq can be obtained either from an outer speed control loop or from a reference torque imposed on the machine. These two options may be termed as speed-control mode or torque-control mode for the generator. Instead of regulating the active power directly. For speed-control mode, one outer PI controller is to control the speed error signal in terms of maximum power point tracking. Furthermore, another PI controller is added to produce the reference signal of the d-axis rotor current component to control the reactive power required from the generator. Assuming that all reactive power to the machine is supplied by the stator, the reference value ird may set to zero. The switching dynamics of the IGBT-switches of the rotor converter are neglected and it is assumed that the rotor converter is able to follow demand values at any time. Fig . 3 The Rotor-Side Converter (RSC)B. The Grid-Side Converter (GSC)The grid-side converter aims to regulate the voltage of the dc bus capacitor. Moreover, it is allowed to generate or absorb reactive power for voltage support requirements. The function is realized with two control loops as well: an outer regulation loop consisting of a dc voltage regulator. The output of the dc voltage regulator is the reference current icdref for the current regulator. The inner current regulation loop consists of a current regulator controlling the magnitude and phase of the voltage generated by converter from the icdref produced by the dc voltage regulator and specified q-axis icqref reference. Fig . 4 The Grid-Side Converter (GSC)C. Converter lossesThe losses of the converters can be divided into switching losses and conducting losses. The switching losses of the transistors are the turn-on and turn-off losses. For the diode switching losses mainly consist of turn-off losses, i. e., reverse-recovery energy. The turn-on and turn-off losses for the transistor and the reverse-recovery energy loss for a diode can be found from data sheets. The conducting losses arise from the current through the transistors and diodes. The transistor and the diode can be modeled as constant voltage drops, and a resistance in series. The switching losses of the transistor can be considered to be proportional to the current, for a given dc-link voltage. For a given dc-link voltage and switching frequency. The switching losses of the IGBT and diode can be modeled as a constant voltage drop that is independent of the current rating of the valves. D. DC-LINK ModelThe grid-side convertor is expected to keep the DC-link voltage constant. Therefore, all voltages and currents are transferred to a specific reference frame, which rotates at the speed of terminal voltage phasor. E. TORQUE CONTROLThe turbine model is based on the steady-state power characteristics of the turbine. The friction factor and the inertia of the turbine are combined with those of the generator coupled to the turbine. The output power of the turbine is given by: Pm = 0. 5*ρ*A*Cp*vw3------------------ (16)Where Pm is the mechanical output power of the turbine, ρ is the air density (Kg/m3) and A is the turbine swept area. A= π*R2---------------------------(17)‘ R’ is the blade radius (length), ‘ Cp’ is the performance coefficient of the turbine, and ‘ vw’ is the wind speed (m/s). The power coefficient is defined as the power output of the wind turbine to the available power in the wind regime. This coefficient determines the " maximum power" the wind turbine can absorb from the available wind power at a given wind speed. It is a function of the tip-speed ratio ‘ λ’ and the blade pitch angle ‘ β’. The blade pitch angle can be controlled by using a " pitch-controller" and the tip-speed ratio (TSR) is given asλ=

wR/V-------------------------(18)where ‘ w’ is the rotational speed of the generator and ‘ R’ is radius of the rotor blades. Hence, the TSR can be controlled by controlling the rotational speed of the generator. For a given wind speed, there is only one rotational speed of the generator which gives a maximumvalue of Cp, at a given . This is the major principle behind" maximum-power point tracking" (MPPT) and a wind turbine needs to be designed keeping this strategy in mind. Fig. 5. wind turbine Cp curves