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Control strategies of grid interfaced wind energy conversion system: An overview

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ABSTRACT

Wind energy conversion system (WECS) is interfaced with the utility system through power electronic converters which plays an important role in the integration of wind power into the electric grid. The main power quality disturbances due to integration of WECS to grid are variation in power and harmonics. To maintain grid synchronization and to keep total harmonic distortion (THD) within operational limits, appropriate control schemes are required for the grid side converter. The main objective of grid side controller is to control the power delivered to the grid, grid synchronization, to supply high quality power to grid and to meet grid code compliance. In this paper control schemes used in grid interfaced wind energy conversion system for generator side and grid side converter control, are reviewed thoroughly. The paper presents a comparative study of rotor flux oriented control and direct torque control (DTC) techniques applied in generator side converter of permanent magnet synchronous generator (PMSG) drives for wind turbine application. For grid side converter, various control schemes are developed mainly based on voltage oriented control (VOC) or on direct power control (DPC). The performance of VOC based control system basically depends on method applied for current control. A comparative study is done among them and findings are tabulated. Integration requirements of wind turbine to grid, grid synchronization and requirement of monitoring unit are also discussed.

Contents

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Nomenclature

T_e	generator torque
P	number of pole pairs
φ	magnetic flux
i_d, i_q	d axis and q axis stator currents
L_d, L_q	d axis and q axis stator inductances
V_d, V_q	d axis and q axis stator voltages
ω_r	turbine rotational speed
ω_g	electrical angular velocity
K_p	proportional gain constant of speed controller
K_i	integral gain constant of speed controller
K_{pi}	proportional gain constant of current controller
K_{ii}	integral gain constant of current controller
V_{dc}	DC link voltage

1. Introduction

In renewable power generation the wind energy has been noted as the most swiftly growing technology with the development in megawatts capacity wind turbines, large power generators and power electronics. It draws interest as one of the most money-spinning ways to generate electricity from renewable sources. Recently, voltage source converter (VSC) based permanent magnet generator (PMSG) wind turbine is assessed to be higher ranked than doubly fed induction generator (DFIG) wind turbine in terms of reliability and efficiency. The variable speed wind turbine with a direct drive multi pole PMSG with fully controllable voltage source converters is catching market progressively specially in offshore applications. Among the various power electronics topologies used in wind energy conversion system, the most promising one is permanent magnet synchronous generator (PMSG) with a full-scale back-to-back power converter [1,2].

The basic components in WECS include variable speed wind turbine, aerodynamic converter, an electric generator and power electronic interface. Wind energy conversion system is interfaced with the utility system through power electronic converters. Various power electronics interfaces are used in WECS to convert generator output power to suitable form. Controlled rectifiers and inverters with various inverter switching schemes have been used in modern wind turbines [3,4]. Each of them has its own relative merits and demerits. The main issue in the converter based grid connected wind energy conversion system is fluctuation of voltage and harmonic distortion [5]. It is very important to assure that the grid is capable of staying within the operational limits of voltage and frequency for all expected combination of WECS and consumer load and at the same time maintaining transient stability of grid.

Use of current controlled PWM inverter [6,7] has been in trend for interconnection of wind energy conversion system to grid, which provides high power quality injection by using appropriate designed control strategy. However, due to high switching frequency current distortion will occur, which needs to be attenuated to meet power quality standards according to Table 1, to connect an inverter to the grid.

The grid-connected converter control schemes can be divided into two parts: generator-side control and grid-side control [9]. The generator side control objective is to capture maximum power from source. Recently, few control algorithms used in grid connected inverter with power quality solution have been suggested. Control of grid side inverter is needed to achieve the following:-

i. Grid synchronization
ii. Power quality improvement by harmonics compensation at PCC
iii. Control of dc-link voltage
iv. Control of active power deliver to grid
v. Control of reactive power

To control the grid current through switching pulse of grid side inverter, authors in [10,11] used current control loop only in control scheme. Three phase currents are transformed into synchronous reference frame. Instantaneous active and reactive power is then controlled to obtain unity power factor. In [12] authors implemented the control of the grid connected inverter through two cascaded loops: an inner current loop to regulates the grid current, and an outer voltage loop, which is designed for balancing the power flow (active and reactive) in the system. In [13], Li et al. developed steady state model of grid side converter in d–q reference frame, which showed improved steady state performance in both active and reactive power control and improved power quality. The virtual-flux-based predictive control has been developed in [14] to improve the performance of the conventional control scheme. Instead of the grid voltage vector for power estimation the usage of estimated virtual flux vector in this algorithm results in a sensor less control technique with good dynamic response. Another control strategy proposed in [15] is called direct power control with no internal current loops and pulse width modulator block. Switching states of converters are selected from switching table obtained by calculation of the instantaneous errors between the estimated values and reference values of active and reactive power. Hence, the performance of the direct power control (DPC) scheme depends on accurate and prompt calculation of the active and reactive power.

This paper discusses the control strategies used in wind energy conversion system in both generator side and grid side converter of PMSG generator as per existing grid codes during healthy and fault conditions. The existing control strategies both for generator side converter and grid side converter are reviewed in Sections 3 and 4. In Section 5, comparative analysis in control strategies for grid side controllers has been done. Advantages and disadvantages of commonly used current control techniques for voltage source converters are listed. A summary of basic requirements of integrating a WECS to grid is given in Section 6. The requirements for grid synchronization and monitoring unit for such grid interfaced system are described in Section 7. Section 8 concludes the paper.

2. Control system in WECS

The control system is an important concern for the performance of wind turbine. It makes the most of the extracted power from the wind through all the modules and also makes sure that the delivered power to the grid meets the interconnection requirements. The control strategies are applied in different parts of the

Table 1
[8] Distortion limits recommended by IEEE STD 519-1992 for six pulse converters.

Odd harmonics	Limit in %	Even harmonics	Limit in %
3rd–9th	<4.0	2nd–8th	<1.0
11th–15th	<2.0	12th–16th	<0.5
17th–21st	<1.5	18th–22nd	<0.375
23rd–33rd	<0.6	24th–34th	<0.15
>33rd	<0.3	>34th	<0.075