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Conventional and novel control designs for direct driven PMSG wind turbines

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ABSTRACT

With the advance of power electronic technology, direct driven permanent magnet synchronous generators (PMSG) have increasingly drawn interests to wind turbine manufactures. This paper studies and compares conventional and a novel control designs for a direct driven PMSG wind turbine. The paper presents transient and steady-state models of a PMSG system in a d–q reference frame. Then, general PMSG characteristics are investigated in the rotor-flux-oriented frame. A shortage of conventional control mechanisms is studied analytically and through computer simulation. A novel direct-current based d–q vector control technique is proposed by integrating fuzzy, adaptive and traditional PID control technologies in an optimal control configuration. Comparison study demonstrates that the proposed control approach, having superior performance in various aspects, is effective not only in achieving desired PMSG control objectives but also in improving the optimal performance of the overall system.

1. Introduction

The variable-speed wind turbine with multipole permanent magnet synchronous generator and full-scale/fully controllable PWM power converter is considered to be a promising but not yet very popular wind turbine concept [1]. The advantages of such a PMSG configuration include: a gearless construction, an elimination of DC excitation system, full controllability of the system for maximum wind power extraction and grid interface, and ease in accomplishing fault ride through and grid support [2,3]. Hence, the efficiency and reliability of a full-PWM-converter PMSG wind turbine is assessed to be higher than that of a DFIG wind turbine [4–6]. Due to the intensified grid codes, a full-PWM-converter PMSG wind turbine is becoming favored by the wind power industry [5].

However, the performance of a PMSG system depends not only on the synchronous generator but also on how it is controlled. The two typical PMSG wind turbine configurations are (1) a PMSG system with a passive diode rectifier followed by an IGBT inverter [7,8], and (2) a more efficient PMSG system with two full-scale/fully controllable IGBT PWM converters [9–11]. Although other PMSG concepts are also proposed recently without using power converters between the generator and the grid [12], the variable-speed capability of those PMSG systems are not competitive to the above two PMSG configurations. Traditionally, a PMSG with full-scale PWM converters is controlled through the conventional decoupled d–q vector control approach using a current-regulated voltage-source PWM scheme [9,10]. The behavior of the controller is evaluated through either transient simulation or transient measurement approaches [9–11]. But, the steady-state characteristic study of this paper indicates that there is an inherent weakness associated with the traditional decoupled d–q vector control mechanism in the full-scale PWM converter PMSG system.

This paper proposes a novel control design for the purpose to improve the control effectiveness and overall performance of a PMSG system. The proposed approach employs a decoupled d–q vector control technique while the details of the control implementation are completely different from the conventional control technique. In the sections that follow, the paper first introduces the fundamental principle of the PMSG system in Section 2. Then, Section 3 presents both transient and steady-state models of the PMSG in a d–q reference frame, based on which general characteristics of the PMSG under d–q vector control are reviewed in Section 4. A weakness of the traditional d–q control strategy is analyzed through theoretical study and computer simulation. A novel control design is developed in Section 6. The proposed and traditional control approaches are compared and evaluated by using MAtLab SimPowerSystems. Finally, the paper concludes with the summary of the main points.

2. Direct driven PMSG wind turbine and controls

A PMSG for wind power generation is essentially a standard permanent magnet synchronous machine with the stator winding connected to the grid through a frequency converter (Fig. 1) [9].

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