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A novel optimizing power control strategy for centralized wind farm control system

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ABSTRACT

The wind energy industry has grown very fast among the developed countries as it is remarkably clean and has a better quality in power system design. Consequently, with the increase of wind power applications in power systems, wind farms are needed for participation in network operations using efficient control strategies. This paper offers a comparative study on the performance of wind farm system equipped with doubly fed induction generators (DFIG) wind turbine. The study concentrates on the wind farm controller, which distributes power reference among wind turbines based on the demands of operator control system, while reducing their structural loads. The proposed controller is based on optimization technique in order to minimize the destructive fluctuation of torque and generator speed, in addition to supplying a satisfactory quality of power. The suggested wind farm control system has a hierarchical structure with both a central control level and a local control level. The performance of the control strategies is evaluated through simulations of wind farm controller equipped with DFIG wind turbines and proper results in solving the problem of both power and load optimizations are illustrated.

1. Introduction

Over the past twenty years, renewable energy sources have attracted greater focus owing to the cost increase, limited reserves and unpleasant environmental impact of fossil fuels. Meanwhile, technological developments, cost reduction, and government incentives have made some renewable energy sources more competitive in the market. Among them, wind energy is one of the fastest growing renewable energy sources [1]. Nowadays, the main tendency of modern wind turbines/wind farm is clearly variable speed operation and a grid connection through a power electronic interface. The application of doubly fed induction generation (DFIG) has increased because of its obvious advantages such as the variable speed generation, the separate control of active and reactive powers, the decrease of mechanical stresses and acoustic noise and the improvement of the power quality [2–4].

The size of wind turbines has been enlarged from a few kilowatts to several megawatts. The larger the wind turbines, the lower the cost per kilowatt installed, since their production, installation and maintenance costs are lower than the sum of smaller wind turbines achieving the same power [5].

Wind turbines may be influenced by structural loads. Structural loads or actions are stresses, deformations, or accelerations applied to a structure or its components from external or internal forces. There are more possibilities to decrease the structural loads in variable speed wind turbine than fixed speed type. First of all, variable speed turbine can effectively decrease the torque fluctuations on the drive train, because the fast wind and aerodynamic torque variations can be absorbed as acceleration of the rotor inertia. Also, the power can be limited by the wind farm controller in variable speed wind turbine, either by reducing the rotor speed or by pitching the blades, so the structural loads will be lessened efficiently [6]. Reduced structural loads make it possible to reduce the costs of mechanical components.

There has also been some advancement toward real power control such as damping of electromechanical oscillations, frequency control, development of energy quality [7,8], and supervisory control of real power by a system operator [9,10]. Larger fluctuations of power have to be compensated by active control of a turbine or wind farm. This can be recognized by running a turbine or a wind farm, part-loaded or by utilizing any energy storage. When part-loaded, wind turbines (or whole farms) can run with constant power (balance control) or with a certain constant reserve

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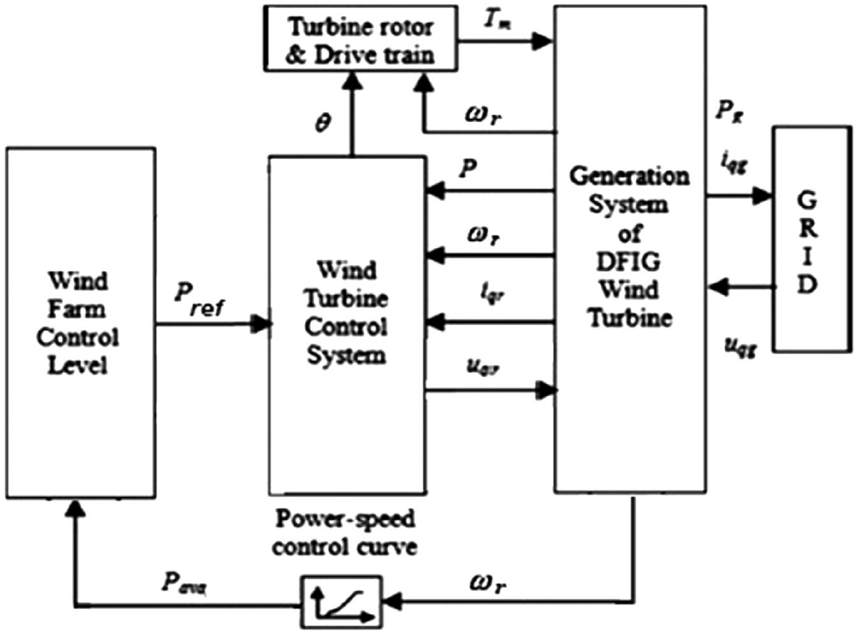

Fig. 1. Model and control system of a DFIG wind turbine.

capacity (delta control). Operation in the balance control mode effectively removes power fluctuations to DFIG [11,12]. T. Surinkaew, I. Ngamroo [13], propose a robust control design of power oscillation damper for a DFIG-based wind turbine using a specified structure mixed $H2/H\infty$ control. Firefly algorithm is applied to solve optimization problem of system.

The successful coordination between wind turbines and system operators is accomplished by using a centralized wind farm control system. The wind farm control system acts as a central part of the system and distributes active power references among wind turbines. The wind farm control system achieves its goals by means of two hierarchical levels of controllers, central control level and local control level.

An optimization algorithm for wind power generation is presented in Ref. [14]. This algorithm is implemented at a supervisory wind farm control level with the purpose of ensuring that the wind park active and reactive power outputs conform to operator demand. Zhao, Chen, and Blaabjerg [15], propose an optimization technique to maximize the capacity of new wind arrays based on physical limitations of system. In order to optimize the model, probabilistic analysis without considering aerodynamic interaction among turbines is used in this paper.

Different strategies for computing active and reactive power references for each wind turbine based on network demand have been suggested up to now [16–19]. The simplest strategy is based on calculating the same power references for each wind turbine [19]. Then, all wind turbines generate the same active power. This strategy does not appear to be applicable due to changes in wind direction and other possible errors for each wind turbine. A new and more efficient strategy is proposed in Refs. [16,17], where the power reference for each wind turbine is considered from a proportional distribution of the available active power, and so no turbine becomes overloaded. The aim of this paper is to control a wind farm network consisting of doubly fed induction generators and concentrate on the ability of the wind farm control strategy to adjust the wind farm power production to the reference power ordered by the system operators. The presented wind farm control has a hierarchical structure with both a central control level and a local control level. The proposed controller is not still optimum because it does not reduce fatigue and structural loads. In Ref. [20], in order to reduce structural loads, a wind farm controller which aims at optimal distribution of power references among wind turbines is developed. The control algorithm establishes the reference signals for each individual wind turbine controller in two scenarios based on low and high wind speed. However, the specific wind turbine controller that follows the reference is not specified in this paper.

The objectives of Aeolus paper [21], is to reduce fatigue loads experienced by wind turbines by considering wind direction and its values on each turbine. In this paper a wind field is modeled and the effect of fatigue loads on downstream wind turbines has been studied. The fatigue load is estimated from turbine sensor signals and used in the wind farm controller, which effects the distribution of the power references on the wind turbines.

In Ref. [22], evaluation of turbine capacity in presence of faults is performed using SCADA data and fault logs. Also, performance of

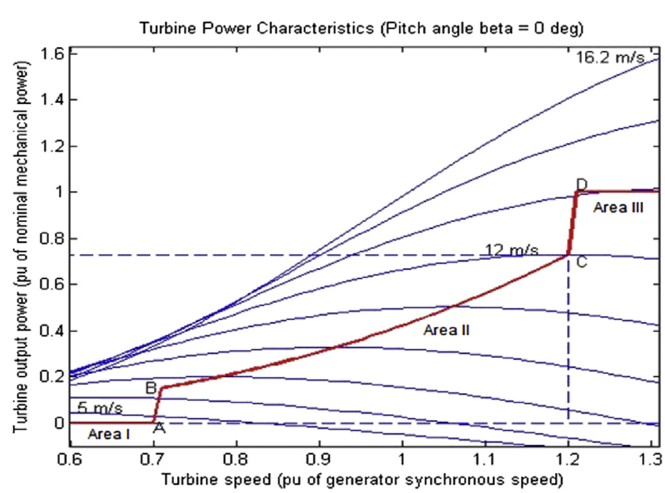

Fig. 2. Aerodynamic mechanical power of wind turbine.