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Distributed Optimization Control Schemes Applied On Offshore Wind Farm Active Power Regulation

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Abstract

A key issue in the construction of grid-friendly offshore wind farm is how to reasonably achieve the optimal allocation of active power of each unit so as to improve the safety and grid power of the wind farm. This paper proposes a novel distributed control strategy for cooperative optimization active power output on the basis of the deficiencies of the traditional distribution strategies. A simple type division algorithm is proposed to solve offshore wind farm dispatch problem. The principle of division is in accordance with the actual conditions and power characteristics of the wind turbine. Secondly, we propose a distributed coordinated control scheme based on ratio consensus algorithm for two types of wind turbines. This algorithm is stem from distributed average consensus for undirected graph. Ratio consensus is guaranteed by updating the auxiliary variables state values with the step size of the distributed consensus algorithm is chosen appropriately. Simulation examples show the effectiveness of these design methods.

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Keywords: offshore wind farm; active power optimization; type division; ratio consensus; distributed coordinated control

1. Introduction

In recent years, wind power industry in China is developing rapidly, installed capacity continues growing, but according to the data released by National Energy Bureau, it shows that the situation 'brownouts abandoned wind' is still serious. In 2015 influenced by "grab mounted surge "and a variety of economic factors, the abandoned wind rate climbed to 15%, the abandoned wind power reached 33.9 billion kilowatts, which has directly caused economic losses more than 180 billion Yuan, which made the survival and development of the wind power industry face unprecedented difficulties [1]. Compared to the power generation on land, the working environment of the offshore wind turbine is more complicated

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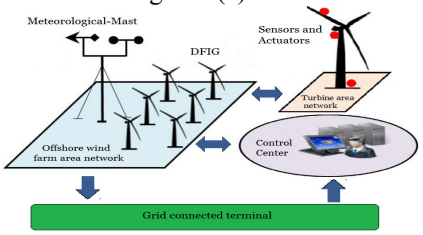
and technical bottleneck constraints, the large-scale “brownouts abandoned wind” problem will behave more obvious. In addition, in the "Made in China 2020" and ‘The 13th Five-year Plan’ it is clearly put forward to planning offshore wind power, focusing on solving the problem of “brownouts abandoned wind”, and coordinating power system dispatching operation. Constructing the power-grid-friendly offshore wind farm will, therefore, be a trend of development of wind power in the future.

Controlling the active output of offshore wind farm to follow the demand of power grid instead of maximum power output can more gracefully introduce wind power into the grid. However, it still remains a complex problem on how to distribute the active power difference among all the offshore wind turbine units. In this aspect, once it is in the average distribution mainly [2], but when there is a large difference among the units' conditions, it may lead to a large gap between the actual power output and network instruction. A centralized control strategy is proposed on the basis of it by Hu Kaikai etc. [3], taking full account of the control characteristics and operation state of the unit, the large gap is effectively reduced, but when the wind units are composed of many, the central controller has a large computational burden, which not only affects the work efficiency, but also causes communication failures. From wind turbine’s actual health and wind power prediction situation in references [4-5], wind farm units are classified in detail, which effectively reduces the unit’s failure rate, but exists deficiencies in the system’s flexibility and robust, lacks the advanced intelligent control algorithm application. Distributed control algorithm based on multi-agent system is applied to active coordination distribution [6-7], which greatly improves the system reliability and response speed, and reduces the calculation burden, but its distribution ways for the consistency regulation, are related to the differences between the various units in no detail.

In order to optimize the active power output of offshore wind farm, we present a new distributed coordinated optimization control strategy. The method, firstly based on the analysis of DFIG (doubly fed induction generator) as the foundation, according to the actual operating conditions and power control characteristics, divides all the units into three categories to follow the changes in power demand successive to involve in regulating the distribution; Secondly, in view of the low and high wind speed unit, based on distributed coordination control algorithm of ratio consensus, it is used to achieve the difference control of each unit. Finally, an example illustrates the effectiveness of these proposed control methods.

2. Power Control Characteristics Of Offshore Wind Farm And DFIG

In order to reasonably plan the output power of each unit and promote friendly grid connected to wind power. Based on literature [8], it is proposed a hierarchical distributed control structure for Offshore Wind Farm as the figure 1(a) shows.



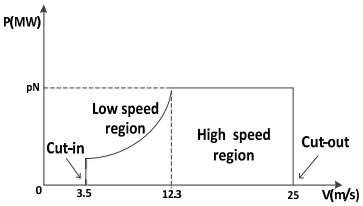


Fig.1. (a) Hierarchical distributed control frame (b) Wind speed-active power output curve of DFIG

In the hierarchical structure, there is the upper control for the optimal dispatch of wind farm active power output and the topology is from a benchmark for wind farm topologies proposed by S. Meie [9] .The lower is for the output active power control of DFIG, which controls the size of the output power by