Different Factors Affecting Short Circuit Behavior of a Wind Power Plant

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***Abstract*—A wind power plant (WPP) consists of a large number of turbines interconnected by underground cable. A pad-mounted transformer at each turbine steps up the voltage from a generating voltage (690 V) to a medium voltage (34.5 kV). All turbines in the plant are connected to the substation transformer, where the voltage is stepped up to the transmission level. An important aspect of WPP impact studies is to evaluate the short-circuit (SC) current contribution of the plant into the transmission network under different fault conditions. This task can be challenging to protection engineers due to the topology differences between different types of wind turbine generators and the conventional generating units. This paper investigates the SC behavior of a WPP for different types of faults. The impact of wind turbine types, the transformer configuration, and the reactive compensation capacitor will be investigated. The voltage response at different buses will be observed. Finally, the SC line currents will be presented along with its symmetrical components.**

***Index Terms*—Fault contribution, induction generator, protection, short circuit (SC), wind power plant (WPP), wind turbine.**

I. Introduction

ENERGY and environmental issues have become one of the biggest challenges facing the world. In response to energy needs and environmental concerns, renewable energy technologies are considered as the future technologies of choice [1], [2]. Renewable energy is harvested from nature, and it is clean and free. However, it is widely accepted that renewable energy is not a panacea that comes without challenges. With the federal government's aggressive goal of achieving 20% wind energy penetration by 2030, it is necessary to understand the challenges that must be overcome when using renewable energy.

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In the years to come, there will be more and more wind power plants (WPPs) connected to the grid. With the goal of 20% wind penetration by 2030, the WPPs' operation should be well planned. The power system switchgear and the power system protection for WPPs should be carefully designed to be compatible with the operation of conventional synchronous generators connected to the same grid. This paper attempts to illustrate the behavior of short-circuit (SC) current contributions for different types of wind turbine generators (WTGs).

A. Conventional Power Plant Versus WPP

A conventional power plant consists of a single generator or several large (e.g., 100 MW) generators. The prime mover of the generator can be steam, gas, or a combustion engine. The generator is controllable and is adjustable up to a maximum limit and down to a minimum limit. The power output is dispatched according to the load forecast, which is influenced by human operation, and it is based on optimum operation (i.e., scheduled operation). It is usually located relatively close to the load center.

The typical conventional generator used is a synchronous generator. The rotational speed is fixed, which has no slip, and the flux is controlled via exciter winding. The magnetic flux and the rotor synchronously rotate.

A WPP consists of many (hundreds) WTGs. Currently, available WTG sizes are between 1 and 5 MW. The prime mover of the WTG is wind; and it is free, natural, and pollution free. The controllability of the WPP is typically curtailment (spilling the wind). The energy production of a WPP depends on the wind variability; its dispatch capability is based on wind forecasting, and it is influenced more by nature (wind) than human factors, with the goal set on maximizing energy production from renewable resources (i.e., unscheduled operation). Large-scale WPPs are located in a high wind resource region, and this may be far from the load center.

As described in Section II, there are four different types of generators commonly used (fixed speed: Type 1, variable slip: Type 3, variable speed: Type 3, and full converter: Type 4). For Types 3 and 4, the wind turbine is variable speed with a flux-oriented controller via a power converter. The rotor does not have to synchronously rotate with the rotating flux, as in a synchronous generator. Thus, the mechanical oscillation of the rotor does not have to be translated into electrical oscillation and vice versa.

Because a WPP covers a very large area, there are power output diversities found in a WPP. Each WTG in a WPP will