



Original Research Article

Low voltage ride-through enhancement of fixed-speed wind farms using series FACTS controllers



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ABSTRACT

This paper studies the application and control of three series flexible AC transmission system (FACTS) devices namely, the gate-controlled series capacitor (GCSC), the thyristor controlled series capacitor (TCSC), and series braking resistor (SBR), in order to enhance the low voltage ride-through (LVRT) in fixed-speed wind turbine generator systems (FSWTGS). Modeling and simulations are carried out in order to investigate and compare the performance of these devices, considering (1) successful reclosing of circuit breakers (CBs), (2) unsuccessful reclosing of CBs, and (3) connection of a dynamic load to the point of common coupling (PCC). Simulation results exhibit significantly enhanced transient stability of FSWTGS due to the employment of the GCSC. Furthermore, the GCSC is competitive with the TCSC and the SBR, and it requires less power rating to stabilize the wind generator system. Therefore, the proposed GCSC can be considered an effective tool to improve the LVRT of FSWTGS.

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1. Introduction

Environmental pollution and possible shortage of conventional fossil fuels are two of the most important energy-related issues facing the world today. These issues have led to increasing interests in electric power generation by renewable energy sources. Among the variety of renewable energy sources, wind energy is one of the most attractive and is rapidly being adopted around the world [1]. However, increasing interest and use of wind energy will inevitably lead to the connection of large wind turbine generator systems to the existing utility power grids. Although fixed-speed wind turbine generator systems (FSWTGS) are diminishing, they are still a substantial part of the fast-growing wind energy market [2].

The FSWTGS employ squirrel cage induction generators (IGs) and are directly connected to the utility power grid. However, the grid-connected IGs can cause stability problems since the IGs are not equipped with direct electrical control of torque or speed [3]. With increasing wind power penetration, the grid codes demand the wind farms to remain connected to the grid in the case of voltage drop, for a certain period of time. Low-voltage ride-through (LVRT) capability is one of the most important issues among grid codes [4,5].

A common technology employed to stabilize the FSWTGS and enhance the LVRT of FSWTGS is the pitch control system [6]. In addition, flexible ac transmission system (FACTS) devices, such as static synchronous compensator (STATCOM) [3,7], static var compensator (SVC) [4], thyristor controlled series capacitor (TCSC) [8], series braking resistor (SBR), and super-conductive magnetic energy storage (SMES) [9–12] systems are investigated as effective tools for stabilization of the FSWTGS. The gate-controlled series capacitor (GCSC) is a series FACTS device, which was initially proposed for series compensation of a transmission line to control power flow [13,14]. The benefits presented by the GCSC in the control of power flow in power systems have already been studied in the literature [15,16]. Moreover, the application of the GCSC has been studied for sub-synchronous resonance (SSR) damping in power systems by de Jesus, et al., in [17] and the corresponding author of the current work in [18–21].

This paper proposes application and control of the GCSC for transient stability enhancement of FSWTGS. In order to justify the effectiveness of the proposed GCSC, its performance is compared with the TCSC and SBR, in terms of point of common coupling (PCC) voltage, the IG real power, and the synchronous generator (SG) load angle. The studied power system in this paper consists of one SG and one fixed-speed wind turbine IG, delivering electrical power to an infinite bus via double-circuit transmission lines. The simulations are carried out using the electromagnetic simulation program EMTDC/PSCAD [22], considering both

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