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Mitigation of voltage dip and power system oscillations damping using dual STATCOM for grid connected DFIG

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Abstract During grid fault, transmission lines reach its thermal limit and lose its capability to transfer. If this fault current enters generator terminals, it will lead to dip in stator voltage and consequently produces torque and real power oscillations. This further affects in the form of internal heat in rotor windings and finally damages the generator. A new control strategy is proposed to limit fault current using dual STATCOM, which will damp power oscillations and mitigate the voltage dip due to a severe symmetrical fault. It is achieved by diverting the fault current to the capacitor using the dual-STATCOM controller. It is best suitable to maintain power system stability with uninterrupted power supply, effective power transfer capability and rapid reactive power support and to damp inter-area oscillations. The effectiveness of SG and DFIG due to the transmission line short circuit symmetrical fault was studied.

1. Introduction

It is important to ensure proper steps in maintaining power system security while enhancing transfer capability and reliability. To achieve it, advanced FACTS technology is promising; however, it is very cost-effective alternative. Among FACTS family SVC, STATCOM and UPFC are found satisfactory for improving power system stability when a severe disturbance occurs in a system [1]. These authors [2–6] considered UPFC as a better device to damp oscillations due to disturbances such as external faults. As UPFC has both series and shunt control devices, it can control both voltage and the current and further can control independently real and reactive power of the system. Among shunt connected devices, Static compensator (STATCOM) is capable of regulating voltage, controlling reactive power and damping oscillations in the synchronous generator during symmetrical fault conditions [7–9]. In the series FACTS family, thyristor controlled series capacitor (TCSC) and static synchronous series compensator (SSSC) can damp inter-area oscillations [10], but removing from the

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system because of any reason makes the work complicated and also continuity of supply disturbs.

DFIG is said to be in synchronism even if the voltage drop near the grid decreases to zero and must regain its pre-fault state within the specified time described by their country grid codes as described in [11]. The DFIG is operated with different FACTS devices [12–19] to improve the grid restoring time and voltage mitigation, with HVDC–STATCOM for fault current limiting [12,13], comparison of TCSC, UPFC, SVC and STATCOM for controlling rotor speeds [14], a series compensating device to damp oscillations using Eigen analysis [15], interface neuro-controller using dynamic programming for STATCOM [16], STATCOM to compensate rotor current and voltage compensation in a real-time environment [17], using DVR for symmetrical and asymmetrical grid fault compensation [18], damping control for an offshore and marine current wind farm using STATCOM [19].

Among FACTS family STATCOM plays a major role in damping power system oscillations. If two STATCOMs are used and connected to a common coupling point in two lines or in a single line, it can be called as dual STATCOM. The major advantage of this is that separate series compensator equipment or pulse generating control circuit is not necessary. If the system is symmetric, same control strategy with different reference parameters can be adopted to the pulse generator of the two STATCOMs. For SSSC, three single phase transformers are required, which require more space than single three phase transformer, also does cost incurred for this can be reduced. The dual STATCOM can be connected to the circuit by stepping down voltage by using a step-down two winding transformer connected in shunt or using three winding transformer, Fig. 1. A common capacitor that can be shared by the two STATCOMs is another advantage. The common capacitance value can be made constant and transformer MVA rating can be made half for dual STATCOM for the effective damping of oscillation than single STATCOM. Therefore, it is found advantageous than single STATCOM or UPFC of the same rating.

DFIG is a variable speed constant frequency induction generator, whose rotor is driven using a wind turbine. It is more advantageous than a squirrel cage induction generator or a permanent magnet generator in terms of lower converter rating, efficient fault ride through capability, much power rating availability in the market, robust in design, four quadrant reactive power control. Hence, DFIG is preferred in this analysis.

In this paper, Kundur's two area system [20] is modified to have two synchronous generators (SG) in area-1 and two synchronous generators and a Doubly-Fed Induction Generator (DFIG) in area-2 and basic equations are taken from [21,22]. There are two parallel paths available in the midpoint of the system where two static compensators (STATCOMs) are connected in each line to a common capacitor bank and the set-up is called as dual-STATCOM. It has advantages as series pulse controller is not required and the same control circuit strategy with different voltage and current references from node buses is adopted to give pulses to the STATCOMs. The aim of this design of shunt controller is to act as a low impedance path for the short circuit current during fault condition, to divert the surge currents to VSC. If a symmetrical fault occurs in one of the lines in the dual path with fault resistance of 1 milliohm between phases and ground, the system behaviour is studied.

2. The configuration of the tested system

The one line diagram of an equivalent power system used in this study is given in Fig. 1. This system consists of four generators of equal rating. The system is divided into two areas: Each synchronous generator, rated at 200MVA, 13.8 kV and a stepup transformer with 210MVA, 13.8/230 kV and $\Delta - Yg$ are used for transmission. Buses 1–8 are treated as area 1 and buses 8–3 are treated as area 2. A three winding transformer of 60MVA, 230/230/20 kV with lower voltage winding is used for the STATCOM connection.

The first STATCOM is connected to the upper line and other STATCOM to the bottom line of the dual network. The ends of the two STATCOM terminals are connected to a common DC link capacitor and will share common voltage. The transmission line impedances Z_1, Z_2 and Z_3 and generator and load parameters and details of overall system parameters are given in the Appendix. For improving machine stability and for voltage regulation 5th order PSS and AVR are used. From the study of load flow analysis, the power flows from Area 1 to Area 2. If a fault occurs in a dual line network, circuit breakers at both ends must close simultaneously. Otherwise, the fault current may reach the other parallel line and will disturb the healthy system. Hence protection of the dual network with dual STATCOM is necessary. The Voltage Source Converter (VSC1) will inject current at a phase angle to compensate the voltage sag and swell between the buses 3 and 14, while VSC2 will inject between the buses 4 and 14 as shown in Fig. 1. These two VSCs will share a common DC link and will be having the same control circuit, but different voltage and current settings.

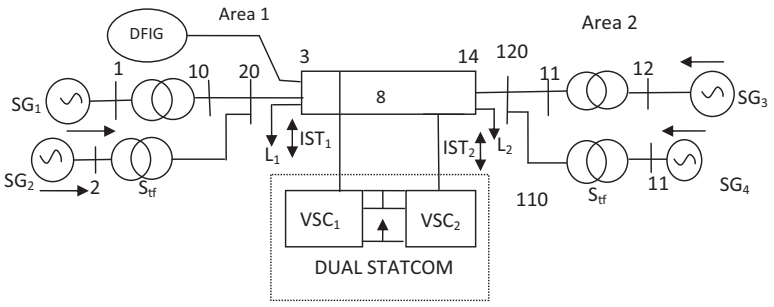

Figure 1 Modified Kundur four machine two area system with DUAL-STATCOM.