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DYNAMIC STABILITY IMPROVEMENT ANALYSIS FOR AN INTEGRATED GRID-CONNECTED DFIG BASED WIND FARM

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ABSTRACT
The performance of the studied OWF is simulated by an equivalent doubly-fed induction generator (DFIG) driven by an equivalent wind turbine (WT) while an equivalent squirrel-cage rotor induction generator (SCIG) driven by an equivalent marine-current turbine (MCT) is employed to simulate the characteristics of the MCF. A damping controller of the STATCOM is designed by using modal control theory to contribute effective damping characteristics to the studied system under different operating conditions. A frequency-domain approach based on a linearized system model using eigenvalue techniques and a time-domain scheme based on a nonlinear system model subject to various disturbances are both employed to simulate the effectiveness of the proposed control scheme. It can be concluded from the simulated results that the proposed STATCOM joined with the designed damping controller is very effective to stabilize the studied system under disturbance conditions. The voltage fluctuations of the AC bus subject to the active-power variations of the studied system can also be effectively controlled by the proposed control scheme. A frequency domain control strategy based on a linearized system structure utilizing eigenvalue techniques and a time domain control scheme based on a nonlinear system model subject to various fluctuations are both employed to simulate the effectiveness of the recommended control approach. It can be finished from the gained responses that the recommended STATCOM combined with the designed with the damping controller is very effective to control the studied system under various voltage inequalities. The voltage changeability like the exterior three phase short circuit faults of the AC bus subject to the active power fluctuations of the studied system can also be effectively maintained by the suggested control strategy.

1. INTRODUCTION

During the last decades, Wind Energy Conversion System (WECS) has grown dramatically. Variable-speed wind Turbines (VSWTs) attract considerable interest around the world, which is one of the solutions with the highest potential to reduce wind energy cost. The VSWT systems are usually based on doubly fed induction generators (DFIGs) or permanent magnet synchronous generators (PMSGs). Basically wind farm consists of many wind turbines that are connected with each other to produce small amount of electrical power that becomes powerful after connecting with the transformer. Areas that consists of the number of wind turbines for the sake of power generation from wind and are connected with each other in the different way is called wind farm. Basically wind farm consists of many wind turbines that are connected with each other to produce small amount of electric power. Different strategies are used to build the wind farms in different locations or area. Generators driven by marine-current turbine (MCT) combined with offshore generators driven by wind turbine (WT) will become a novel scheme for energy production in the future.

Since oceans cover more than 70% surface of the earth, a hybrid power generation system containing both offshore wind farm (OWF) and marine-current farm (MCF) can be extensively developed at the specific locations of the world in the future. One of the simple methods of running an OWF is to connect the output terminals of several DFIGs together and then connect to a power grid through an offshore step-up transformer and undersea cables. To run an MCF may use several Permanent Magnets synchronous generators (PMSGs) connected directly to the power grid through an offshore step-up transformer and undersea cables.

This paper is organized as below. The configuration and the employed models for the studied integrated OWF and MCF with STATCOM are introduced first[1]. Then, the design procedure and design results for the PID damping controller of the proposed STATCOM using pole-placement technique are depicted. Both steady-state operation points under various wind speeds and marine-current speeds and the comparative dynamic responses of the studied system with the designed PID damping controller under different operating conditions can be elaborately done here. Finally, specific important conclusions of this paper are drawn.

Both wind energy and have been tied together. Water energy may contain energy yield by thermal, energy produced by wave, tidal energy of offshore wind, ocean current energy, etc. Generators driven by marine current turbine (MCT) coupled with offshore generators driven by wind turbine (WT) will become a new control strategy for energy production in the future. Since ocean cover more than 70% surface of the ground, a hybrid power generation system comprising both offshore wind farm (OWF) and marine current form (MCF) can be widely developed at the exact locations of the future. The detailed responses of stability improvement of power system utilizing STATCOMs and the damping controller design of STATCOMs were explained. The construction of generated output feedback linear quadratic controller for a STATCOM and a variable blade pitch of a wind energy conversion system to perform both controlling of voltage and mechanical power under grid connection or islanding conditions were illustrated.

Currently, both ocean energy and wind energy have been combined together in the United Kingdom [1]–[3]. The ocean is an

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untapped resource that is capable of making a major contribution to our future energy needs. There are several different forms of ocean energy that are being investigated as potential resources for power generation. Ocean energy includes thermal energy, wave energy, offshore wind energy, tidal energy, ocean current energy, etc.Marine-current turbine generators (MCTGs) combined with offshore wind turbine generators (WTGs) will become a new trend for energy production in the future. There has been an extensive growth and quick development in the exploitation of wind energy in recent years, which requires the development of larger and more robust wind energy conversion systems. Today, more than 28 000 WTGs are successfully operating all over the world. Since oceans are covering more than 70% surface of the earth, a hybrid power generation system with both offshore wind farm (WF) and marine-current farm (MCF) can be extensively developed in the whole world in the future. One of the simple methods of running a WF or an MCF is to use many induction generators (IGs) connected directly to the power grid because IGs have the inherent advantages of cost effectiveness and robustness for variable-speed energy conversion systems. Moreover, both WTGs and MCTGs have very similar operating characteristics. However, an IG requires reactive power for magnetization. When the generated active power of an IG is varied due to wind or marine-current fluctuations, the absorbed reactive power and the terminal voltage of the IG can be significantly affected. The generated power and the terminal voltage of an IG are always fluctuating with time due to the inherent random characteristics of wind speed and marine-current speed. A power control scheme of a WF or an MCF is required under normal operation to allow proper control over active power production. In the event of increasing grid disturbances (e.g., grid faults), an energy storage system for a WF is generally required to compensate fluctuating components generated by the WF. A WF may combine with different flexible ac transmission system (FACTS) devices and energy storage systems such as static compensator (STATCOM) [4], [5], etc.

2. MODELS OF THE OFF SHORE WIND FARM AND MARINE CURRENT FARM

Figure 1, shows the structure of the studied integrated DFIG based OWF and PMSG based MCF with the proposed STATCOM. The 80MW OWF is represented by a large equivalent aggregated DFIG driven by an equivalent aggregated variable speed WT through an equivalent aggregated gearbox. The 40MW MCF is represented by a large equivalent aggregated PMSG driven by an equivalent aggregated variable speed MCT through an equivalent aggregated gearbox. The OWF, the MCF, the STATCOM and a local load are connected to an AC bus that is fed to the onshore power grid through an offshore step-up transformer and undersea cables [9]. The employed mathematical models of the studied system are described as below.

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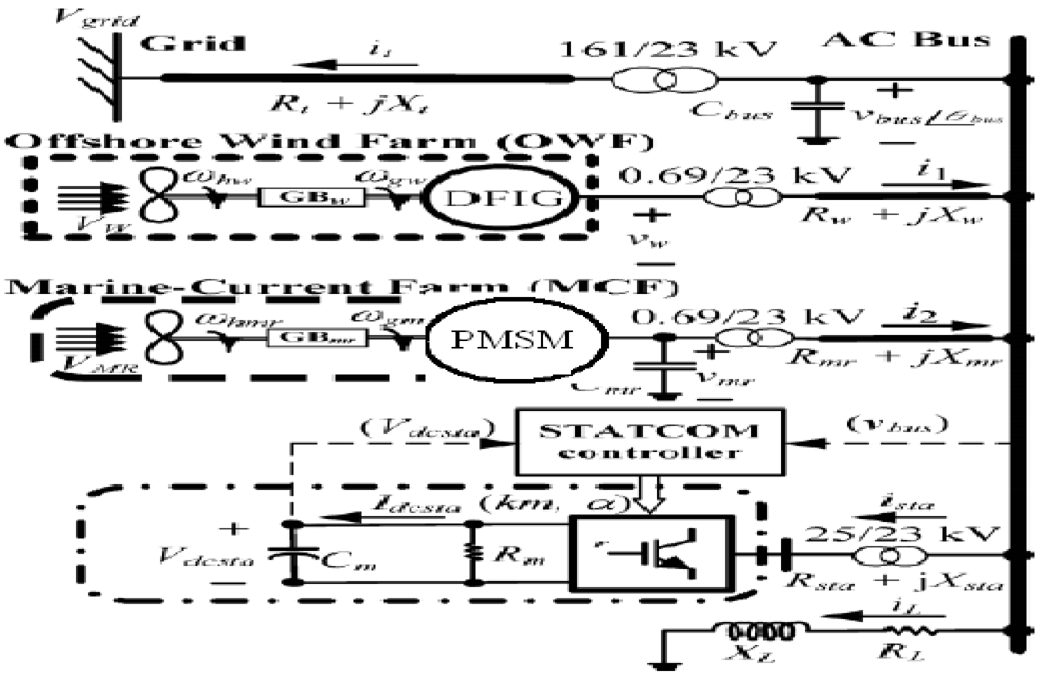

Fig.1. Composition of the integrated OWF and MCF with STATCOM

A. DOUBLE FED INDUCTION GENERATOR (DFIG):

DFIG is an abbreviation for Double Fed Induction Generator, a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly, but there are problems with efficiency, cost and size. A better alternative is a brushless wound-rotor doubly-fed electric machine. Figure 2 indicates the doubly fed induction generator model. DFIG is of great advantage, and is widely used in large capacity wind turbines in recent years.

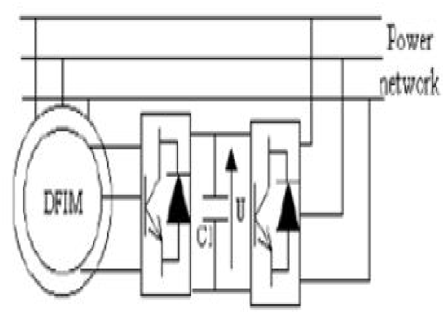

Fig.2. Doubly Fed induction generator model

B. PERMANENT MAGNET SYNCHRONOUS MACHINE:

A synchronous machine is an ac rotating machine whose speed under steady state condition is proportional to the frequency of the current in its armature. Figure 3 indicates the PMSM Cylindrical rotor and Salient rotor structures.The magnetic field created

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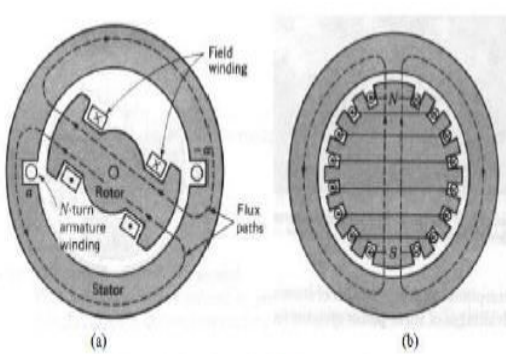
by the armature currents rotates at the same speed as that created by the field current on the rotor, which is rotating at the synchronous speed, and a steady torque results. Synchronous machines are commonly used as generators especially for large power systems, such as turbine generators and hydroelectric generators in the grid power supply. Because the rotor speed is proportional to the frequency of excitation, synchronous motors can be used in situations where constant speed drive is required. Since the reactive power generated by a synchronous machine can be adjusted by controlling the magnitude of the rotor field current, unloaded synchronous machines are also often installed in power systems solely for power factor correction. The armature winding of a conventional synchronous machine [3] is almost invariably on the stator and is usually a three phase winding. The field winding is usually on rotor and excited by dc current, or permanent magnets. The dc power supply required for excitation usually is supplied through a dc generator known as exciter, machine which is often mounted on the same shaft as the synchronous.



Schematic illustration of synchronous machines of
(a) round or cylindrical rotor and (b) salient rotor structures

Fig.3. Cylindrical rotor and Salient rotor structures

3. PROPOSED SYSTEM:

3.1 Steady-State Analysis under Various Operating Conditions

The study state operating condition results of the examined system when Vw is improved from 4 to 24 m/s while VMR is improved from 1 to 4 m/s. 3.2 Non Linear Model Simulations Here in this segment utilizes the nonlinear system model developed to compare the damping characteristics committed by the recommended STATCOM joined with the designed PID damping controller on dynamic stability betterment of the examined system under a noise speed fluctuations, a marine current speed fluctuations, and a three external phase short circuit fault at the grid. 3.3 Noise Wind-Speed Disturbance Here the examined system with and without the recommended STATCOM and the developed PID damping controller under the noise wind speed fluctuations

3.2 Marine-Current Speed Disturbance

The investigated system with and without the recommended STATCOM and the developed PID damping controller under the marine current speed fluctuations as illustrated in Fig.6, when t < 0s, the OWF works under a base wind speed of Vw =12 m/s and the MCF works under a base marine current speed of Vmr =25 m/s. It is observed from the dynamic simulation responses that all quantities are slightly deviated from the steady state working points at t = 0s due to the small fluctuations on marine current rapidity. Meanwhile marine current speed is approximately associated to the output active power of the Marine CurrentTurbine; it is detected that the dynamic reply of Pmr as depicted, is alike to the one of Vmr and the factor of high frequency consisting in Vmr. 3.5 Three-Phase Short-Circuit Fault at Power Grid The transient response of the examined system with and without the suggested STATCOM integrated with the developed design PID damping controller under a three phase short circuit fault at the grid side. The OWF works under a base wind speed of 12 m/s and at the same time the MCF works under a base marine current speed of 2.5vmeter/sec. A three phase short circuit fault is unexpectedly integrated to the grid at t =1s is eradicated at certain time. It is detected from the transient simulation results. The most quantities abruptly drop to smaller values when the fault happens. When the fault is recompensed, all responses become unchanging and homecoming the original steady state operating condition within 4s. The mentioned STATCOM with the established PID damping controller can offer better damping characteristics to the examined system under the severe three phase short circuit fault than without the controller of PID.

CONCLUSION

The main focus of this paper has been the study and control of a direct-driven PMSG used in variable speed windenergy system connected to the grid. This wind system was modelled using d-q rotor reference frame and is interfaced with the power system through an inverter and a filter modelled in the power system reference frame. This paper has presented the dynamic stability improvement of an integrated OWF and MCF using a STATCOM. A PID damping controller has been designed for the STATCOM by using a unified approach based on pole-assignment approach. Eigen value calculations and time domain simulations of the studied system subject to a noise wind-speed disturbance, a marine current speed disturbance, and a three-phase short circuit fault at the grid have been systematically performed to demonstrate the effectiveness of the proposed STATCOM joined with the Designed PID damping controller on suppressing voltage fluctuation of the studied system and improving system dynamic stability under different operating conditions. It can be concluded from the simulation results that the proposed STATCOM joined with the designed PID damping controller is capable of improving the performance of the studied integrated OWF and MCF under different operating conditions.

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