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Design Of Dynamic Voltage Restorer And Active Power Filter For Wind Power Systems Subject To Unbalanced And Harmonic Distorted Grid

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ABSTRACT

This paper proposes a novel double-fed induction generator (DFIG)-based wind-energy conversion system (WECS), which incorporates a dynamic voltage restorer (DVR) and energy storage system (ESS). The DVR is in series with the output terminal of a wind turbine generator (WTG) and parallel to the dc link of the WTG with the ESS.

The control scheme of the WECS is designed to suppress wind power fluctuations and compensate grid voltage disturbances, which in turn improve the fault ride through (FRT) capability and the wind power penetration level. Finally, the performance of this WECS is investigated under various operation scenarios such as symmetrical and asymmetrical grid faults.

INTRODUCTION

The rapid growth of wind power has resulted in increased attention to wind-energy generation technologies. Currently, there are primarily four types of wind turbine generators (WTGs), each of which has some unique characteristics. The most popular WTG is the double-fed induction generator (DFIG) based WTG (DFIG-WTG), which combines the advantages of conventional WTG designs and can provide approximately 40% speed variation, maximizing the amount of wind energy captured. However, further development of this wind-energy generation technology is severely restricted by two important factors: 1) wind power fluctuations, which are caused by intermittent and stochastic wind speed and can result in deviations of grid frequency and voltage, affecting the stability and power quality of grid operation the fault ride through (FRT) capability, which is required by most grid codes to tolerate voltage dips at WTG's terminal and remain connected to the grid to support voltage and frequency during and post-fault, respectively.

Several methods have been proposed to suppress wind power fluctuations. The pitch angle control is proposed to achieve flicker mitigation and stable output power level. In [9], the use of turbine inertia for power smoothing is discussed. In [10], the capability of voltage source converters to control the active power output of WTGs is also adopted to smoothen power fluctuations. However, the capability and control range of these methods are limited owing to the reduced wind power acquisition. As an alternative, energy storage systems (ESSs) have been well considered. They not only can smoothen active power fluctuations but also can regulate reactive power. Furthermore, the capability of ESSs to maintain the maximum wind power acquisition of WTGs has shown desirable application prospects.

On the other hand, it has been proven that DFIG-WTGs exhibit problematic FRT behavior compared with other types of WTGs. It suffers high sensitivity to grid voltage disturbances. During grid faults, the DFIG's rotor may experience damaging over-current, the dc-link voltage may exceed the allowable limit, and the torque oscillation may reduce the lifetime of the drive.

Extensive studies have been conducted on realizing FRT capability improvements of DFIG-WTGs. Generally, these methods can be classified as software and hardware solutions. The software solution suggested can effectively improve the FRT capability. However, it will also increase the control system complexity and cannot solely satisfy the stringent requirements of grid codes. The hardware solution can enable WTGs to tolerate severe voltage dips. However, the main disadvantages, including the utilization of a crowbar, series dynamic resistors, dc link chopper, STATCOM and energy storage, indicate the increased system cost. When the dynamic voltage restorer (DVR) is introduced, a series voltage is quickly generated to correct the voltage at the WTG's terminal. Therefore, the protection control scheme inside the WTG can be greatly simplified.

Combining the advantages of ESS and DVR, a novel DFIG based wind-energy conversion system (WECS) is proposed, where a DVR is designed in series at the WTG's terminal and in parallel to the dc link of the WTG with the ESS. This structure is based on the modification of the system topology and it has the following benefits: 1) During normal operation, the ESS can absorb surplus wind power and release it when needed to smoothen the output power of the WECS. Thus, the wind power fluctuations can be greatly suppressed and the wind power penetration level in power grid can be enhanced. 2) Under fault conditions, the DVR can quickly compensate symmetrical and asymmetrical voltage dips; hence, the voltage at the WTG's terminal is maintained and the WTG remains in operation. Further, the ESS in this case will store the blocked wind power for further potential fluctuation mitigation.

EXISTING SYSTEM:

This paper presents a combination of the DVR and APF for refining the squirrel cage induction generator (SCIG) terminal power quality.

The positive sequence component at grid frequency is first extracted from the distorted SCIG terminal voltage for VSI synchronization. The unbalanced components can also be found by subtracting the positive sequence component from the distorted voltage.

Once the positive and negative sequence components are determined, the defect of unbalance in voltage as well as the positive sequence component can both be compensated by the DVR. To avert the SCIG stator from specific harmonic currents distortion, an APF control design that focuses on the low-order harmonic currents was presented.

PROPOSED SYSTEM

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The proposed novel WECS is composed of three parts: the DFIG-WTG, the DVR and the ESS. The DVR is in series connection at the WTG's terminal. Besides, both the DVR and the ESS are connected in parallel to the dc link of the WTG. The modeling of each part is described below.

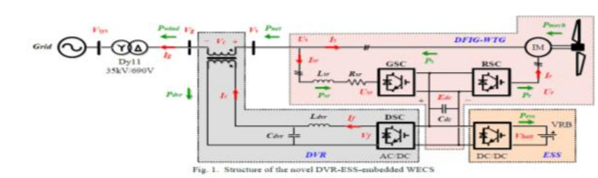

Fig 3.1: Structure of the novel DVR-ESS-embedded WECS

WIND TURBINE:

The mechanical power Pmech captured from wind energy with the wind turbine depends on the power coefficient Cp (λ, β) and the wind speed Vw where ρ is the air density, Ar is the area swept by the rotor blades, and λ is the tip-speed-ratio and β the blade pitch angle.

$$P_{mech} = \frac{\rho}{2} \cdot A_r \cdot C_p(\lambda, \beta) \cdot V_W^3$$

DFIG:

Basically, the stator of the DFIG is directly linked to the grid and the rotor slip-rings are connected to the grid through the partially rated back-to-back converter. The operating principle of a DFIG can be analyzed using the classic theory of rotating fields and the well-known d-q model, where the q-axis is assumed to be 90° ahead of the d-axis in the direction of rotation, and the positive current directions are defined as feeding the generator. The reduced order DFIG model in per unit is obtained below.

Stator:

$$\begin{cases} U_{sd} = R_s I_{sd} + d\psi_{sd}/dt - \omega_1 \psi_{sq} \\ U_{sq} = R_s I_{sq} + d\psi_{sq}/dt + \omega_1 \psi_{sd} \end{cases} \quad (2)$$

$$\begin{cases} \psi_{sd} = L_s I_{sd} + L_m I_{rd} \\ \psi_{sq} = L_s I_{sq} + L_m I_{rq} \end{cases} \quad (3)$$

Rotor:

$$\begin{cases} U_{rd} = R_r I_{rd} + d\psi_{rd}/dt - (\omega_1 - \omega_r)\psi_{rq} \\ U_{rq} = R_r I_{rq} + d\psi_{rq}/dt + (\omega_1 - \omega_r)\psi_{rd} \end{cases} \quad (4)$$

$$\begin{cases} \psi_{rd} = L_m I_{sd} + L_r I_{rd} \\ \psi_{rq} = L_m I_{sq} + L_r I_{rq} \end{cases} \quad (5)$$

Where Usd and Usq are the d-axis and q-axis stator voltage components, respectively, Rs is the stator resistance, and Isd and Isq are d-axis and q-axis stator current components, respectively.

Ψsd/ψsq is the stator flux linkage vector, ω1 the synchronous speed, ωr the rotor speed, Ls is the stator inductance, and Lm is the magnetizing inductance. "s" and "r" in the subscript distinguish quantities or parameters on the stator or rotor side.

CONCLUSION

In this paper, a novel DVR-ESS-embedded WECS is proposed. The system configuration and its control scheme are designed, and simulations are conducted under normal operation and fault operation conditions to test the system performance. The main conclusions are as follows. The embedded ESS can store surplus wind power for release when needed. By designing different power output\ commands, i.e., constant output power or filtered output power, the ESS can effectively suppress the wind power fluctuations and further improve the penetration level of wind power.

The use of a DVR can significantly improve the FRT capability of the WECS under symmetrical and asymmetrical voltage fault conditions, and is particularly suitable for already installed DFIG-WTGs that do not possess sufficient FRT capability. During a disturbance, the blocked wind power generation is stored for subsequent use to suppress wind power fluctuations without any loss of energy. A novel DVR-ESS-embedded WECS is proposed. The system configuration and its control scheme are designed, and simulations are conducted under normal operation and fault operation conditions to test the system performance. The embedded ESS can store surplus wind power for release when needed.

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