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A Review on Under Distorted Grid Voltage Direct Power Control of Doubly Fed Induction Generator

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Abstract*: Number of renewable energy resource is available but wind energy is most efficient and promising renewable energy among all, so integration of wind to grid will be a better choice. Double Fed Induction Generator is one of the best options among all generators as it can able to extract maximum energy from wind while operating at narrow speed ranges by using back to back power electronic converter. This paper presents a multiple target implementation technique for a doubly fed induction generator (DFIG) under unbalanced and distorted grid voltage based on direct power control (DPC). In direct power control the behavior of Double Fed Induction Generator is analyzed and the active and reactive power references are generated by means of direct power control. Grid Side Converter power references are provided by means of voltage and current sequence extraction. The availability of the proposed DPC strategy with a VPI regulator is verified by experiment results of DFIG system under harmonically distorted grid condition.

Keywords: Renewable energy, DFIG, Back to back converter, Direct power control.

I. INTRODUCTION

Wind power generation systems based on a doubly fed induction generator (DFIG) have acquired increasing popularity all over the world due to the advantages of smaller converter rating, independent regulation of active and reactive powers, and lower converter cost and power losses compared with the fixed-speed induction generators or synchronous generators with full-sized converters. The control strategy of a DFIG system under an ideal power grid has been well investigated to satisfy the requirements of wind energy conversion and grid code. However, the practical power grid would always contain negative and harmonic voltage components, especially the 5th and 7th harmonic components. Thus, a severely unbalanced and distorted DFIG stator current would be produced. Currently, a grid operator always requires that the current injected by the renewable energy generation system should be balanced and sinusoidal, so that the power grid would not be further polluted. However, as the ratio of renewable energy including solar energy and wind energy becomes increasingly higher in power supply, the pulsation components of total active and reactive powers generated by the renewable power generation system will also be increasingly higher. This will be a potential threat for the operational stability of power grid frequency and voltage. Even the safe and reliable operation of the power grid and renewable power generation system will be jeopardized. Therefore, to ensure reliable operation of the power grid and renewable energy generation system over the full range of operational conditions, the elimination of instantaneous active and reactive power fluctuation components at twice and six times the grid frequency is also chosen as a control target in this paper. Moreover, the DFIG electromagnetic torque pulsation caused by a non ideal grid voltage would also be harmful to mechanical units, such as the gearbox and rotor bearing. It is essential to improve the DFIG control strategy to eliminate these detrimental influences. Up to now, the control technique of DFIG under unbalanced grid voltage has been investigated to eliminate the harmful influence of the grid voltage negative sequence, that is, the unbalanced stator current, instantaneous stator active and reactive power pulsations, and electromagnetic torque pulsation.

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The authors in [7]–[9] introduced the unbalanced control strategy with the VOC technique, in which the detrimental influence on the DFIG system caused by negative component of the grid voltage was also analyzed. Several alternative control targets focusing on the elimination of negative component of stator/rotor current, as well as stator active/reactive power and electromagnetic torque pulsation were proposed. Zhouet al. [10], [11] explicitly illustrated the unbalanced control strategy using the DPC technique with different stator power compensation item, in which the five different control targets were proposed to improve the DFIG operation ability under transient unbalanced grid voltage. However, there are always voltage harmonic distorted components in the transmission system of the power grid. It has been pointed out that the highly distorted stator/rotor current, significant electromagnetic torque and power oscillations would occur if grid voltage harmonics are not taken into account by DFIG's control strategy [12]. The authors in [13]–[16] have presented a theoretical analysis and an improved VOC strategy for DFIG, in which alternative control targets were proposed to keep the three-phase sinusoidal stator/rotor current, or remove pulsations in both stator active and reactive powers, or remove pulsations in the electromagnetic torque and stator reactive power. Furthermore, in addition to the conventional rotor current control loop, a distinctive and independent stator current resonant control loop was also given out in [17] to successfully eliminate the stator current harmonic components. Nevertheless, all the aforementioned investigation on the DFIG system under the harmonic voltage is based on the VOC technique, which requires the decomposition of grid voltage fundamental and harmonic components; thus, the closed-loop operation stability and dynamic response of the entire control system will be deteriorated [10], [11]

II. METHODOLOGY

A. Mechanism of Wind Power Generation

The wind blows on the slanting blades of the rotor, causing it to spin, converting some of the wind's kinetic energy into mechanical energy. Sensors in the turbine detect how strongly the wind is blowing and from which course. The rotor automatically turns to face the wind, and automatically brakes in dangerously high winds to protect the turbine from damage. A shaft and gearbox connect the rotor to a generator so when the rotor spins, and hence generator rotates. The generator uses an electromagnetic field to convert this mechanical energy into electrical energy. With the consideration to its operation speed and the size of the associated converters, WTGs can be classified into three categories namely:

- Fixed Speed Wind Turbine (FSWT)
- Variable Speed Wind Turbine (VSWT) with partial scale frequency converter (PSFC)
- Variable Speed Wind Turbine (VSWT) with full scale frequency converter (FSFC)

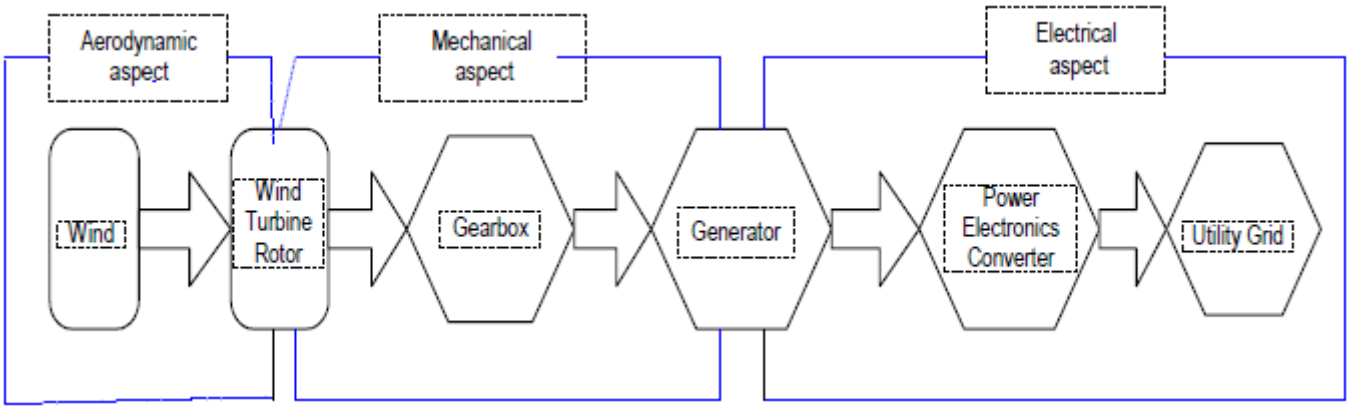

Fig.1. Wind Energy Conversion System (WECS)

III. 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 (see brushless doubly-fed electric machines), but there are problems with efficiency, cost and size. A better alternative is a brushless wound-rotor doubly-fed electric machine.

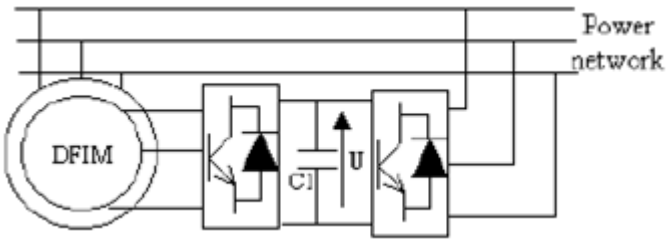

Fig.2: Doubly-fed induction generator

➢ MATHEMATICAL MODEL OF DFIG UNDER HARMONICALLY DISTORTED VOLTAGE

In order to investigate the DPC strategy, DFIG mathematical model under harmonically distorted grid condition should be established first. Under the harmonically distorted grid condition, grid voltage can be decomposed into fundamental frequency component and a series of harmonic frequency components. Considering that the fifth- and seventh-order sequences are the major harmonic components of the grid voltage this paper would focus on the DPC strategy under these two harmonic components.

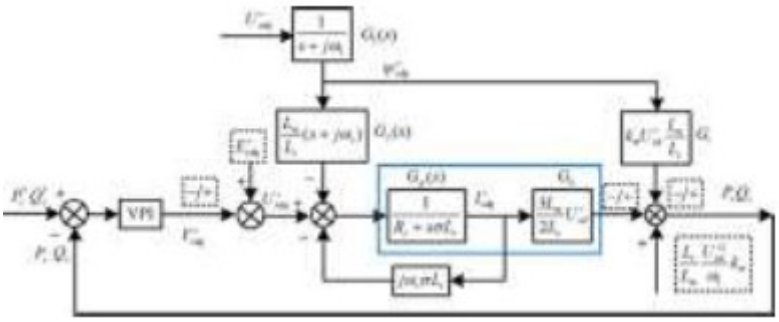

Fig. 3: DPC scheme of the DFIG under the Distorted Grid Voltage using the VPI regulator.

CONCLUSION

The paper has presented a VPI-based DPC strategy for a wind turbine driven DFIG system under the harmonically distorted grid voltage. By applying the VPI regulator to suppress the power pulsation component, the proposed DPC strategy .The operation of DFIG was reviewed and the mathematical model for real and reactive powers are derived from its equivalent circuit. The proposed DPC strategy also shows an excellent disturbance rejection ability and closed-loop operation stability.

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