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Grid-Connected Wind Photovoltaic Cogeneration Using Back to Back Voltage Source Converters

[1]Aditya Jagtap, [2]Prof. A. P. Kinge

[1]Student, M.E., Power System, TSSM's Bhivarabai Sawant College of Engineering and Research, Pune, Maharashtra, India

[1]Professor, M.E., Power System, TSSM's Bhivarabai Sawant College of Engineering and Research, Pune, Maharashtra, India

***Abstract* - This paper introduces a new topology, yet simple and efficient, for a grid-connected wind-photovoltaic (PV) cogeneration system. A permanent magnet synchronous generator-based full-scale wind turbine is interfaced to the utility-grid via back-to-back (BtB) voltage-source converters (VSCs). A PV solar generator is directly connected to the dc-link capacitor of the BtB VSCs. No dc/dc conversion stages are required, and hence the system efficiency is maximized. The proposed topology features an independent maximum power point tracking for both the wind and the PV generators to maximize the extraction of the renewable energy. The regulation of the VSCs is achieved via the vector control scheme in the rotating reference frame. The detailed small signal models for the system components are developed to investigate the overall stability. The influence of the utility-grid faults on the performance of the proposed system is also evaluated. Nonlinear time-domain simulation results under different operating conditions are presented to validate the effectiveness of the proposed topology.**

Keywords: Power grid, Fossil-flue, PV distribution.

I. INTRODUCTION

The cost of the wind and solar energy generation has been rapidly falling since the last decade. Driven by their economic and technical incentives, the global installed capacity of photovoltaic (PV) and wind generators has approached 303 Giga watts (GW) and487 GW in 2016, as compared to 6 GW and 74 GW in 2006, respectively. Due to the intermittent and unregulated nature of the wind and solar energy, power-electronic converters are utilized as an interfacing stage to the load-side or the utility-grid, and hence distributed generation units are created. In literature, most of the distributed generation systems are solely dedicated for one form of renewable resources, e.g., a solar energy as in or wind energy as in. In order to maximize the benefits of the available renewable resources, the combination of the wind and solar energy in the same vicinity has been considered. The grid-connected wind-PV cogeneration systems are not widely addressee. On the contrary, several wind-PV cogeneration systems are proposed for the stand alone off-grid applications. A stand alone wind-PV cogeneration system is proposed in. On the small-scale level, a single-phase cogeneration system has been proposed where as a laboratory-scale system is introduced in generally, the system structure in comprises a common dc-bus that interfaces several parallel connected converters-interfaced renewable energy resources, which might reduce the overall system efficiency and increase the cost [12]. More importantly, the cascaded connection of power converters requires rigorous controller's coordination to avoid the induced interactions dynamics, which might yield instabilities.

A back-to back (BtB) voltage-source converter (VSC) connected to a doubly-fed induction generator is used to interface a dc-DC converter-interfaced PV generator and an energy storage unit in. In, a PV generator charging a battery bank and interfaced to a wind driven induction generator via a VSC is proposed. The wind-PV cogeneration systems in highlights the efficient integration of the renewable energy resources with the minimal utilization of power-electronic conversion stages. However, these systems are proposed for specific off-grid applications. In, the utility-grid integration of the renewable energy resources has been improved by using multiple-input converters. A buck/buck-boost fused dc-dc converter is proposed in. A dc-dc converter with a current-source interface and a coupled transformer is proposed in and, respectively. However, the proposed systems in are based on the dc power distribution which might not be the ideal distribution medium in the ac-dominated power systems. Upto the authors 'best knowledge, the combination of the grid-connected wind-PV systems has been solely addressed in. The system in comprises a BtB VSCs to interface the PV and wind generators to the utility-grid. On the machine-side-VSC, the dc-link voltage is regulated to the maximum Power point tracking (MPPT) value of the PV panels by an outer loop proportional-and-integral (PI) dc voltage controller. The reference values of the machine-side currents are calculated using the synchronous detection method, and a hysteresis current controller is utilized for the regulation. On the grid-side-VSC, a hysteresis grid-current controller is used to inject the total currents into the utility-grid. In spite of the potential benefits of the proposed system.

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II. METHODOLOGY

The proposed system consists of a VSR to interface the wind generator, and a VSI to connect the cogeneration system into the utility-grid as shown in fig 1.

The PV generator is directly connected to the dc-link capacitor of the BtB VSCs via a dc cable [27]. The VSR and VSI are two-level converters consisting of six cells; each comprises an insulated-gate-bipolar transistor (IGBT) in parallel with a diode. In the following subsections, the complete modeling and control of the proposed system is provided.

A full-scale wind turbine (FSWT) utilizing a permanent magnet synchronous generator (PMSG) is elected for its low maintenance and low operational cost [2].

The wind turbine model is represented as following, where $P"$ is the mechanical power captured by the wind turbine blades;C' is the rotor coefficient which is a non-linear function of the blade pitch angle (ϐ) and the tip-speed ratio(λ); ρ is the air density; R is the radius of the wind turbine blade; v is the wind speed; and ω is the mechanical speed of the rotor. In this paper, ϐ is set to zero in the normal operating conditions to maximize the wind power generation [13]. The PMSG is modeled as following,

$$P_m = \frac{1}{2} C_p(ϐ, \lambda) \rho \pi R^2 v_{wind}^3, \quad \lambda = \frac{R\omega_r}{v_{wind}} \tag{1}$$

$$\bar{v}_s = R_s \bar{i}_s + L_s \frac{d\bar{i}_s}{dt} + j\text{Ƥ}\omega_r(\psi + L_s \bar{i}_s) \tag{2}$$

$$J\frac{d}{dt}\omega_r + \beta\omega_r = \frac{3}{2}\text{Ƥ}\psi I_{sq} - T_m \tag{3}$$

In (2), $\bar{v}$A and $\bar{\imath}$A are the stator voltage and current in the complex vectors representation.

$$\bar{x} = X_d + \bar{j}X_q$$

Where a complex vector such that X4 and XN are the direct ($d-$) and quadrature ($q-$) components of $\bar{x}$ in the rotating reference frame; RA and LA are the stator-winding resistance and inductance, respectively; $j$is the imaginary unit number; ψ is the flux linkage of the rotor magnets; Ƥ is the number of poles pairs; $T"$ is the mechanical torque; whereas $J$and β are the motor inertia, and viscous friction, respectively.

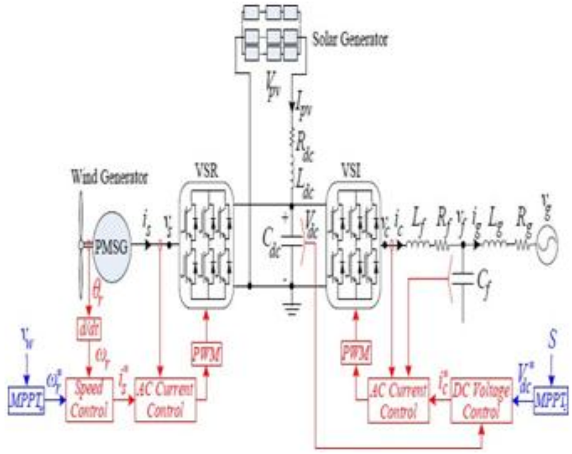

Figure 1: The proposed wind-PV cogeneration system

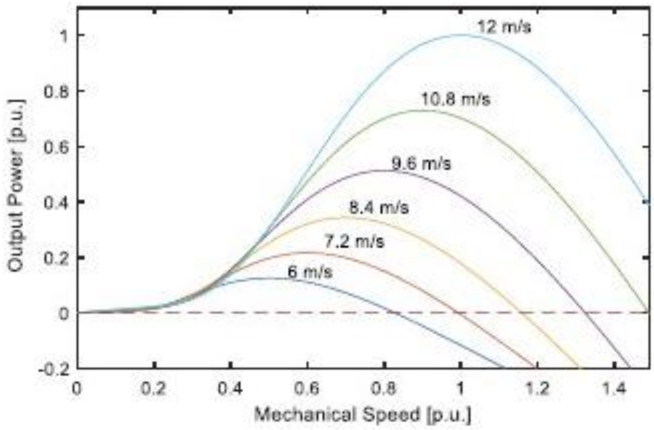

Figure 2: Mechanical characteristics of the wind turbine at different wind speeds

III. RESULTS AND CONCLUSION

This paper has presented the wind-PV cogeneration systems using vector-controlled grid-connected BtB VSCs. The VSR at the wind generator-side is responsible for extracting the maximum wind power following the wind speed variations. On the utility-grid side, the roles of the VSI are to extract the maximum PV power from the PV generator, achieve the balance between the input-output powers across the dc-link capacitor, and to maintain a unity PCC voltage under different modes of operation. A small-signal stability analysis has been conducted for the entire system.

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AUTHOR’S BIOGRAPHY

Aditya Jagtap, Student, M.E., Power System, TSSM's Bhivarabai Sawant College of Engineering and Research, Pune, Maharashtra, India.

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