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Control Of Small Wind Turbine In The High Wind Speed Region

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ABSTRACT

This paper deals with the control of small power wind turbine using fixed-pitch blades. A three-phase permanent magnet (PM) brushless generator is connected to the grid through a double stage converter: active rectifier (VSR) + d.c.-link + inverter (VSI). A very simple and effective control strategy of the generation set (PM generator +VSR) is presented; it is mainly aimed to extend the wind-turbines operation range to high wind-speed region, maintaining the generated electric power constant and equal to its “rated” value.

By means of this technique, the cut-off speed can be considerably increased with respect to the usual values on the market, improving the energy production of the considered mini-generation plant during the years. The numerical analysis carried out in the paper shows that the VSR has to be “reasonably” oversized, while the PM generator ratings are not modified, because the overload operations do not produce any dangerous over-heating. The improvements linked to the proposed technique are more evident when the turbine blades are properly designed and when the wind speed frequently exceeds the ordinary values. Moreover, the proposed control algorithm is also able to improve the efficiency of the wind conversion system for wind speed values lower than the rated one.

INTRODUCTION

This paper presents an effective power control technique for small, fixed-pitch, wind turbine. A review of some technique to control the power is reported while Muljadi et al propose some possible alternative to pursue this goal. The purpose of the control is to limit the power produced by the turbine to the rated value in the region above the rated wind speed, and at the same time to have the widest possible operating range in this region. In fact, the available power in the wind depends on the cube of the wind speed. So, it is necessary that the control technique action is fast enough to contrast rapid power variations due to wind fluctuation. It does understand how it can be complex to maintain as uniform as possible a level of power. In the region below the rated wind speed, the control system tries to pursue the maximum power production for each wind speed, so the only kind of power filtering is given by the rotor inertia. Above the rated wind speed the control system works to reduce the power production to the rated value.

The risk of an overproduction of power should be avoided by suitable devices and/or control techniques, such as those of the adjustment step, and of course of emergency braking. In the case of fixed pitch the power extracted from the wind is regulated by limiting the rotation speed achievable by the rotor. In this way the performance of the rotor decays in that it imposes a operating regime different from the rated one. The case examined in this paper can be considered a "Variable speed-fixed pitch" small wind turbine. In the power range of 1÷3 *kW* or below, the small wind turbine grid connected systems are expected to play an important role in renewable energy conversion applications in order to extract and convert wind energy to electricity feeding utility grids; in fact they could be widely spread moving in this way to a kind of more distributed energy concept.

Brushless drives are nowadays widely used in several applications, mainly due to the simple and inexpensive PM motor, which presents rugged construction, low maintenance and high reliability. Thanks to high energy permanent magnets material, the motor presents high torque to volume and high torque to current ratios, together with high efficiency. Hence, brushless drives well-match the emergent “drive by wire”, in place of hydraulic and pneumatic actuators, and propulsion applications, resulting in a further market expansion.

With the aim of reducing the torque ripple and increasing the efficiency of Brushless DC motors, the authors proposed a novel solution consisting in supplying the motors under three-phase-on mode by means of a predictive optimal algorithm. The proposed technique requires the employment of speed and high resolution rotor position sensing. This drawback can be overcome by using either a digital encoder or a resolver. Nevertheless, this results in increased dimensions of the motor, higher costs and lower reliability, which could be unacceptable for certain applications. Therefore, a high resolution sensor-less control technique has been proposed together with the predictive optimal algorithm. The above mentioned work referred to motors having perfect trapezoidal emf shape.

Since the motors emf shape does not generally fit the ideal sinusoidal and trapezoidal one, reference is made, in this paper, to the case of PM machine showing a generic emf shape. This one is assumed to be made up of the superposition of a trapezoidal shape and an emf deviation. In the paper, the deviation is considered as a disturbance and, hence, the sensor-less predictive control technique is synthesized basing upon the Popov’s Hyper-stability Theory. The proposed sensor-less control is computer simulated by means of the Matlab Simulink tool in order to highlight the effectiveness of both the rotor position identification procedure and the optimal predictive control algorithm.

Power electronic converters are now used in many grid-connected applications including STATCOMs, UPFCs, and active interfaces for distributed generation systems (e.g., PV, wind etc.). These converters are commonly based on a voltage source inverter (VSI) connected to the supply network, operated to achieve objectives such as power flow regulation or power factor optimization by regulating the current into the grid using schemes such as synchronous frame controllers, Predictive Current deadbeat control, or hysteresis-based strategies. Typically, simple series inductors are used as the filter interface between the VSI and the grid network. However, these filters require high switching frequencies to acceptably attenuate switching harmonics, particularly in weak-grid applications where the supply is sensitive to these harmonics. In contrast, the alternative LCL form of lowpass filter offers the potential for improved harmonic performance at lower switching frequencies, which is a significant advantage in higher-power applications.

EXISTING SYSTEM:

Soft-stall methods operate the turbine at a non-optimal tip speed ratio (TSR) to decrease the power extracted from the wind. The proposed soft-stall methods; consider that a high wind speed condition is produced when there is a mismatch between the maximum wind power that can be extracted with the turbine and the load demand. Therefore, the TSR is reduced to make the extracted power equal to the load power. Those methods assume that the generator drive (i.e. generator and power converter) can always produce a torque to counteract the torque produced by the wind turbine. Nevertheless, in grid connected applications, assuming a strong grid, the maximum power that can be extracted will only be imposed by the rated power of the generating system. In this case, the relevant variable that must be kept under control in terms of high wind speed protection is the turbine torque rather than the turbine power.

PROPOSED SYSTEM

The cut-off speed can be considerably increased with respect to the usual values on the market, improving the energy production of the considered mini-generation plant during the years. The numerical analysis carried out in the paper shows that the VSR has to be “reasonably” oversized, while the PM generator ratings are not modified, because the overload operations do not produce any dangerous over-heating.

The main features of a wind turbine are suitably synthesized by the well-known curve of the power coefficient (Cp) against the Tip Speed Ratio (TSR), which is equal to $TSR= \Omega\ rR/Vw$, where Ω r is the rotating speed of the turbine, R is the blade radius, Vw is the wind speed. A typical Cp (TSR) curve for mini-wind plants (< 10 kW) is drawn in fig.1. In order to simplify the explanation of the control strategy proposed [4] in what follows, from the curve of fig.1 we can easily derive the behavior of torque T and of power P produced by the turbine as function of the rotating speed Ω r and for different Vw wind speed values. Reference is made to Prated=3 kW application.

Usually, the steady-state operating points are fixed on the stable region of the curves T (Ωr) (i.e. on the right hand of the maximum in fig.2a) for every wind speed value, ensuring an acceptable stability margin (see the bold dot points in fig.2a). These operating points are really close to the maximum of T(Ω r) for values of wind speed less than the rated one, i.e. for * Vw ≤ Vw . In our current analysis, the value of * Vw is set to * 10 / Vw ≅ m s.

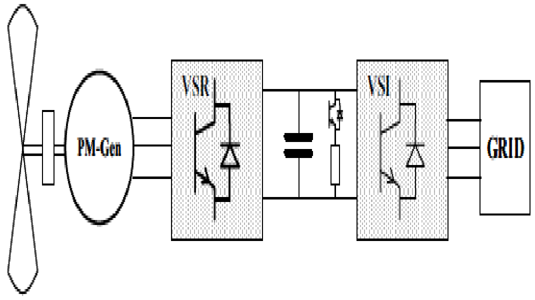

Fig: Schematic lay-out of the wind conversion system

CONCLUSION:

An efficacious power control strategy for small fixedpitch wind turbine has been presented in order to extend the operating range to the high speed region. The proposed control strategy has been validated by a numerical analysis. The results have been achieved by means of a very simple MPPT algorithm that tracks the optimal operating point without the need of additional sensors. The simulation results show that the control technique is able to maximize the generated power for wind speed values lower than the rated ones. The proposed technique is also able to extend the operating range of the wind turbine, keeping the generated power constant and equal to the rated value over the target wind speed. One relevant feature of the technique is the ability to minimize the overload of the brushless generator in each operating condition. In this way the oversizing of the VSR converter is really reduced with respect to the extension of the speed range. In order to further verify the effectiveness of the proposed control, some experimental tests are being executed on proper laboratory set-ups, and the correlated results will be presented in a next work

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