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A novel adaptative maximum power point tracking algorithm for small wind turbines

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ABSTRACT

A novel maximum power point tracking algorithm for small wind turbines is proposed. The solution presented here is an adaptive intelligent algorithm that uses a new advanced perturb and observe method to search for the optimum relationship of the system for tracking the maximum power point even under variable wind conditions. The validity of the proposed algorithm is analysed and the design procedure is presented. Its main virtue resides in its capability to adapt to changes in the turbine and in the surrounding environment, even under variable wind conditions, improving the efficiency of the system. The experimental results confirm the validity of the proposed algorithm.

1. Introduction

Small wind turbines (SWT) allow energy to be extracted in locations where the installation of large wind turbines is not possible, due to questions of safety, aesthetics, accessibility, etc. Very often, the wind conditions on these sites are not good [1]. In order to be able to optimise the capture of energy at these sites, the wind turbine must operate at variable speed. To do this, it is often necessary to know the aerodynamic characteristic of the wind turbine. This characteristic must be obtained by testing the wind energy conversion system (WECS) in accordance with the procedures established for this purpose. However, many manufacturers resort to imprecise methods to characterise the behaviour of their prototypes. In this sense, the domestic small-scale wind field test report drawn up by the Energy Saving Trust [2] points out that a number of manufacturers' power curves were deemed inaccurate or incorrect.

In these cases, those MPPT algorithms that need to determine beforehand the optimum characteristic of the SWT will fail in their attempt to bring the operating point close to the maximum power point (MPP). Likewise, it should be taken into consideration that the optimum characteristic of a SWT does not remain constant throughout its lifetime due to factors such as changes in air density, the ageing factor, debris build-up, etc. For all these reasons, it is clear that if it is wished to optimise energy capture throughout the lifetime of the wind turbine, it will be necessary for MPPT to have adaptive tracking capability.

2. Adaptive MPPT algorithms

Adaptive MPPT algorithms are characterised for the fact that they do not need to know the aerodynamic characteristic of the wind turbine in order to operate the WECS at the maximum power point (MPP).

Although a number of different approaches are described in the literature to develop adaptive MPPT algorithms [3–12], most techniques are based on the use of perturb and observe methods (P&O) [3–10]. However, the P&O control is subject to a number of common problems such as: mechanical stress due to the constant perturbations [13], fluctuations around the MPP [14], etc. Although some of these problems have been partially resolved (by using other control strategies in addition to the basic P&O [4,15]), none of these variations have been able to substantially improve the response to changes in wind speed. Consequently, the efficiency of these algorithms is especially low in those wind turbines subjected to sharp changes in wind speed, which is the case of most SWTs. This fact has led to the development of new algorithms incorporating a variant of the P&O control [5–10]. These algorithms generally emerge from the combination of a type of P&O control with one of the controls described below:

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- Linear Optimum Torque Control (LOTC) [16,17]. This control carries out MPPT by acting on the electromagnetic torque of the generator (T_e). To do this, it needs to know the ideal relationship between the rotor speed (ω_m) and T_e. This relationship is represented as

$$T_e = K_{opt}\omega_m^2, \tag{1}$$

where K_{opt} is the optimum gain.

- Optimal Speed Control (OSC) [18]. This control uses the optimum relationship between ω_m and the output power (P_o) defined as follows:

$$\omega_m = \sqrt[3]{\frac{P_o}{K_{opt}}}. \tag{2}$$

- Power Speed Feedback (PSF) control [19]. This control differs from the OSC in that the optimum relationship between ω_m and P_o is kept in a lookup table.
- Tip Speed Ratio (TSR) control [20]. TSR control adjusts ω_m making use of the optimum relationship that exists between this variable and the wind speed (V_w). This relationship is defined as:

$$\omega_m = \frac{\lambda_{opt}V_w}{r}, \tag{3}$$

where r is the blade radius.

The biggest problem of adaptative algorithms is the lack of a good compromise between the adaptation speed and the robustness of the control.

This paper presents an algorithm called Advanced Perturb and Observe Torque Control (APOTC). The APOTC uses a new, advanced perturb and observe method (P&O) to seek the optimum relationship between the electromagnetic torque developed by the generator and the rotor speed. The result is a robust control that in addition to the high tracking capability of the optimum torque control (OTC) offers a good adaptation capability. The APOTC has been validated for a vertical axis small wind turbine (VASWT) although it is also valid for a horizontal axis small wind turbine (HASWT).

3. System configuration

The system used to implement the APOTC consists of the following parts (Fig. 1):

1. Wind turbine: this is a straight-bladed Darrieus vertical axis small wind turbine (SB-VASWT) without pitch control. Due to the low start up torque of this kind of wind turbines [21], the wind turbine starts in motor mode. This is possible only when the power converter is bidirectional, as is the case of the back-to-back converter. The measurement of the wind speed V_w provided by the anemometer is used to decide when the wind turbine must start.
2. PMSG: this is a surface-mounted PMSG with three Hall sensors installed in the stator of the generator. The PMSG is coupled directly to the SB-VASWT.
3. back-to-back converter & control: The field oriented control (FOC) implemented in the rectifier will be responsible for controlling torque for MPPT. Likewise, the inverter control will be responsible for injecting the power captured into the grid.

4. WECS characteristics

The power of the wind captured by the wind turbine P_w is defined as:

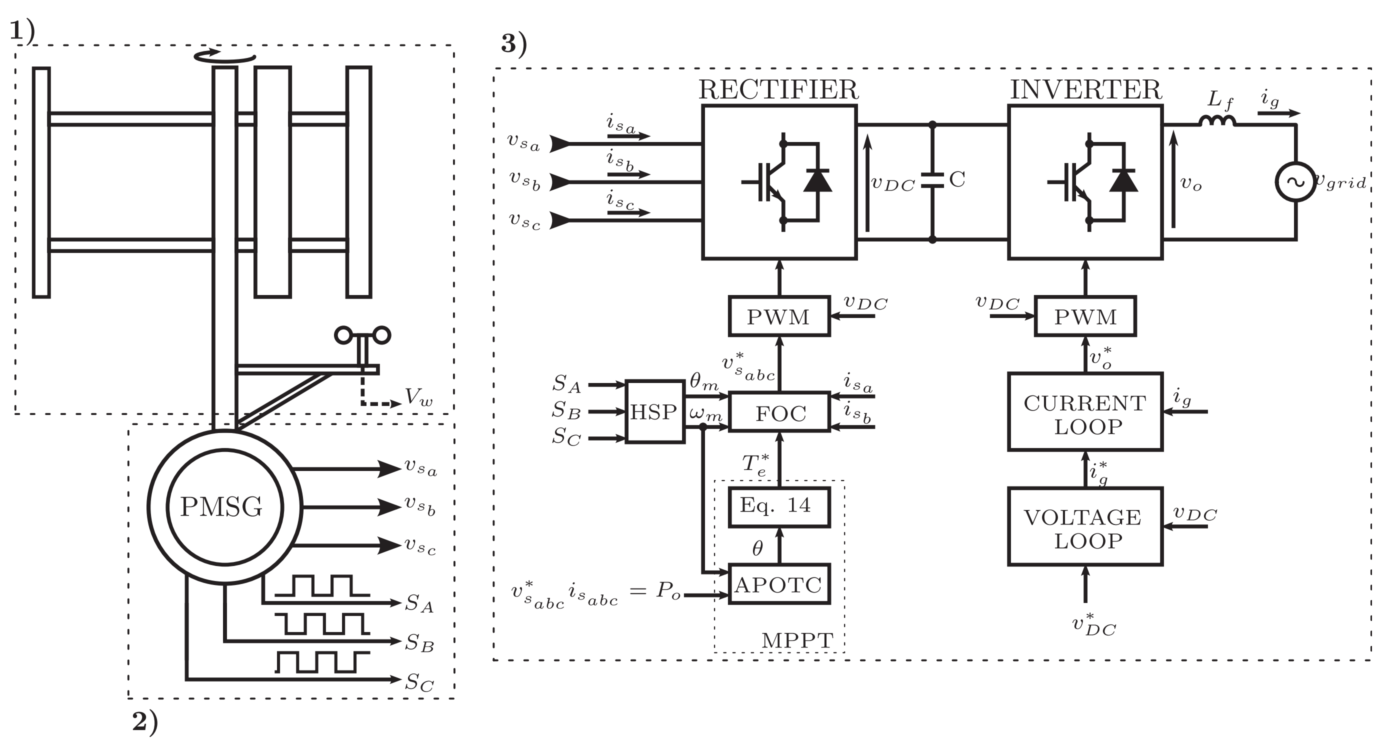

Fig. 1. Configuration of the proposed WECS.