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Journal of Applied Research and Technology

Journal of Applied Research and Technology 13 (2015) 238-244

www.jart.ccadet.unam.mx

Original

Applying novel fractional order incremental conductance algorithm to design and study the maximum power tracking of small wind power systems

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Received 19 April 2014; accepted 18 August 2014

Abstract

The maximum power point tracking is a very important scheme of many renewable energy. It can increase the power efficiency. However, many traditional methods has defects for the applications. This study proposed a novel fractional order incremental conductance algorithm (FOINC) for the maximum power point tracking design of small wind power systems. The proposed method is prompt in the transient of maximum power point tracking and has good steady-state response. Moreover, it can increase the maximum power tracking efficiency of system without changing the wind power system equipments. The comparison between the traditional incremental conductance method (INC) and Perturbation and Observation (P&O) proved the reliability and effectiveness of the proposed method.

Keywords: Wind power; MPPT; Factional order

1. Introduction

The renewable energy source is being developed actively in various countries in recent years, among all the available renewable energy sources, the solar energy and wind power have attracted most attention. The wind power is very attractive, because it converts wind energy into kinetic energy, the vanes guide the generator to rotate, it is one of the cleanest energy sources. At present, the PMSG is one of the most frequently used wind turbines for compactness, high power density, low maintenance cost and easy control (Barakati et al., 2005; Jazaeri et al., 2012; Dumnic et al., 2012). The real environment has different wind speed conditions, the wind turbine will have different power characteristic curves, so the Maximum Power Point Tracking (MPPT) is required, so that the output of wind power system is kept at maximum power in different wind speed conditions.

Many MPPT technologies have been implemented in wind power systems in previous literatures, such as Incremental Conductance method (INC) (Kish et al., 2012; Faraji et al., 2014; Sera et al., 2013), P&O (Sera et al., 2013; Mahdi et al., 2012; Femia et al., 2004), and Hill-Climbing Search Algorithm (HCS) (Raza Kazmi et al., 2011; Yamakura & Kesamaru, 2012). However, most of wind power system control depends on wind speed sensing element, and this type of system needs additional wind speed sensor, so that it is confined to the cost and complexity of sensor (Koutroulis & Kalaitzakis, 2006). The FOINC proposed in this paper only captures the voltage and current of PGMG after the full-bridge rectifier converts the AC generated by the generator into DC. The DC/DC converter as booster adjusts the duty ratio, and the switching pulse width duty cycle of booster is adjusted by algorithm, so as to maximize the output power.

As compared with INC and P&O, the FOINC maximum power tracking controller proposed in this paper is prompt in the transient of MPPT and has good steady-state response. In the real environment, the module life loss resulted from power waveform oscillation can be reduced, the output efficiency of wind turbine is increased and the lost cost is reduced. In other words, the proposed method is practicable for small wind power systems.

2. Brief introduction to wind power systems

In terms of the acquisition of wind energy, the air flow generates air pressure to rotate the vanes to capture the kinetic

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energy of wind. Then it is converted into useful kinetic energy or mechanical energy. The energy is contained in the wind, and the rotor blades rotate in wind. Under the effect of aerodynamic force, the vanes generate torque. The power $P_{\omega m}$ generated by wind turbine is expressed as equation (1) (Hau, 2005):

$$P_{\omega m} = \frac{1}{2}\pi\rho C_p R^2 V_\omega^3 \tag{1}$$

where ρ is the air density, R is the blade radius, V_ω is the wind speed, C_p is the coefficient of performance of wind turbine. C_p includes the blade tip speed ratio λ. λ is defined as the relationship between blade tip speed and wind speed, expressed as equation (2):

$$\lambda = \frac{T\omega_m}{v_\omega} \tag{2}$$

where ω_m is the blade rotation speed. Figure 1 shows the power characteristic curves in different wind speed conditions (Nakamura et al., 2002).

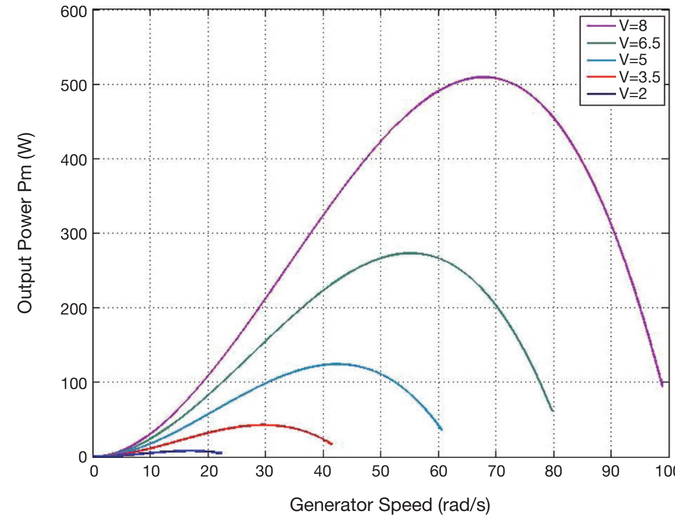

Fig. 1. Power characteristic curves.

2.1. Wind power system architecture

The wind power system architecture proposed in this paper is shown in Figure 2, the wind turbine is coupled to the PMSG directly, connected to a set of rectifier, converting the AC of generator into DC. The DC voltage and current signals are obtained, and the signals are connected to the DC-DC boost converter. The MPPT is used to control signals and adjust the duty cycle of switching pulse width modulation (PWM). Finally, the DC-DC boost converter is connected to the load, and the system output power is measured. The basic structure of the converter is shown in Figure 3. When the switch is "on", the wind power system charges the inductor via the switch. When the switch is "off", the wind power system releases the inductance energy to the load via diode. The output voltage and current can be changed by different input voltages and currents by adjusting the duty ratio. When the switch is off t_{off} and on t_{on}, the current through inductor can be expressed as:

$$\text{Switch on } t_{on} : \Delta I_L^+ = \frac{V_i}{L} t_{on} \tag{3}$$

$$\text{Switch off } t_{off} : \Delta I_L^- = \frac{V_i - V_o}{L} t_{off} \tag{4}$$

Duty ratio (D) of control switch is:

$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{T_d} \tag{5}$$

As the one-cycle voltage variation of inductor is 0, i.e. $\Delta I_L^+ = \Delta I_L^-$.

The equation of output voltage V_o can be obtained:

$$V_o = V_i \frac{t_{on} + t_{off}}{t_{on}} = \frac{V_i}{1 - D} \tag{6}$$

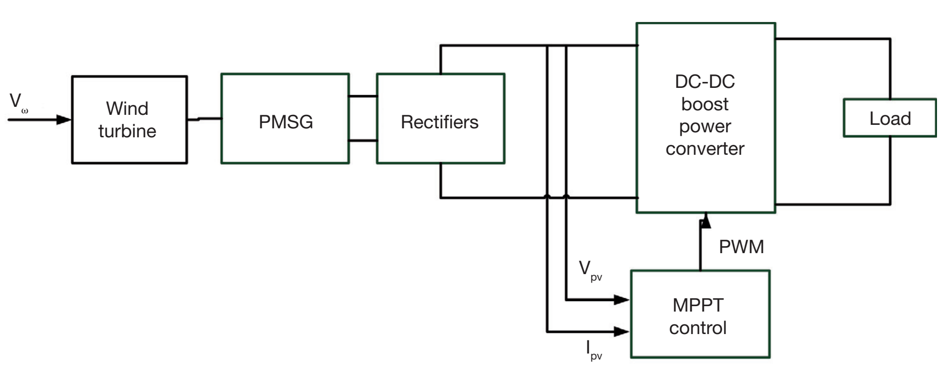

Fig. 2. Wind power system architecture.