European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'10)
Granada (Spain), 23rd to 25th March, 2010

A Comparative Study on Variable-Speed Operations of a Wind Generation System Using Vector Control

A.J. Mahdi, W.H. Tang, L. Jiang and Q.H. Wu
Department of Electrical Engineering and Electronics
The University of Liverpool, Liverpool, L69 3GJ, U.K.
E-mail: whtang@liv.ac.uk

Abstract. The optimal operation of a wind generation system (WGS) is important due to the high initial cost and the low efficiency of the wind turbine generator systems. There are many factors that contribute to increasing wind turbine efficiencies, including the number of rotor blades, a blade pitch angle, and tip-speed ratio (TSR) which is the ratio of circumstantial speed to wind speed. In a small-scale WGS, the only possible control variable for yielding the maximum amount of energy from wind is TSR by adjusting the rotational speed at optimal speeds that ensures optimal TSRs and consequently maximum power coefficients over a wide range of wind speeds.

This paper presents a comparison study among three control methods based on vector control for maximising the output power and improving the performance of a small-scale WGS. The three control methods are a hysteresis-band current controller (HBCC), a PI current controller (PICC) and an improved PI current controller (IPICC) which is based on particle swarm optimisation (PSO). The basic idea of vector control is to adjust permanent magnet synchronous generator (PMSG) rotational speeds according to an optimal reference speed. The rotational speed is controlled by changing the electromagnetic torque of the PMSG via dq-axis currents. In this control, the d-axis reference current is set as zero in order to avoid the demagnetisation of rotor permanent magnets, to linearise the relationship between the electromagnetic torque and the stator current which is only equal to the q-axis current, and to decrease the copper losses in a stator winding. The PI controllers are tuned using the zero and pole placement method which decreases the closed loop overshoot. PI controllers are optimally tuned using a PSO without knowing PMSG parameters.

The WGS investigated in this paper (Fig. 1) consists of a PMSG directly driven by a vertical-axis wind turbine (VAWT), a current controlled PWM rectifier, and a stand-alone DC load. Simulations are based on actual parameters which are obtained experimentally from a real wind turbine generator system. The simulation results (Fig. 2) show the effectiveness of the IPICC method compared with the HBCC and PICC methods due to its satisfactory dynamic responses with fast MPPT under wind speed variations. It can be concluded that the implementation of PSO for optimising the parameters of the PI controllers is a practical solution compared with conventional PI tuning methods.

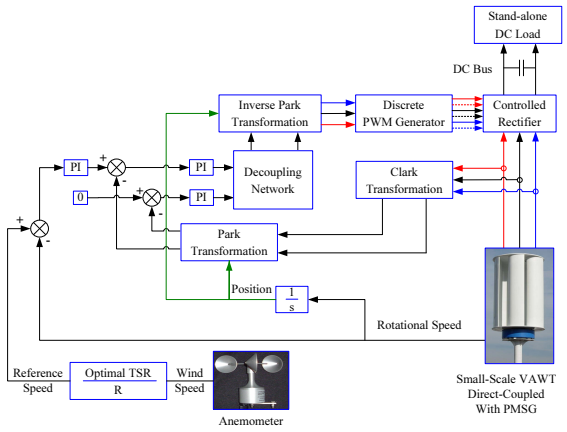

Fig. 1. A small-scale WGS controlled by the PICC technique

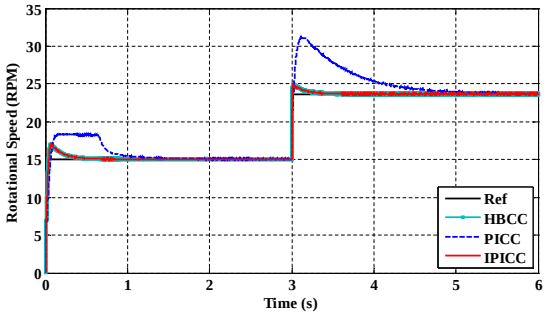

Fig. 2. Rotational speed responses under wind speed variations from low to rated with the proposed techniques