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Exploitation of moderate wind resources by autonomous wind electric pumping systems

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Abstract

A laboratory test rig has been developed, in order to analyse the mutual interaction of the different components of a low power WEPS, in the presence of arbitrarily chosen wind intensity. The performances with moderate wind speed of a system composed by a horizontal axis, fixed-pitch wind turbine, a synchronous generator and a centrifugal electric pump have been investigated, both at the start and under steady-state conditions. A control strategy of the alternator field voltage, which facilitates the starting of the pump in the presence of modest wind intensity and maximises average water discharge under any wind condition, has been defined, implemented on an electronic board and tested.

1. Introduction

The use of low power Wind Electric Pumping Systems (WEPS) is extremely attractive for autonomous applications (without any electric buffer such as batteries or grid) in rural areas or isolated sites even if their wind resource is moderate, as they combine the main advantages of wind energy utilisation with the minimisation of its handicaps [1–3].

The analysis of the performances of such WEPS architecture was carried out by the Department of Mechanical Engineering at the University of Calabria in collaboration with the CNR-CNPM (Milan) by means of field tests both in

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Calabria and in Sardinia [4], and the results were very satisfactory. The main weak point of the system was the starting up of the electric pump with modest wind intensity. The field tests, however, were unsuitable for investigating such behaviour in detail.

A laboratory test rig has therefore been developed, in order to investigate the mutual interaction of the different components of a WEPS, in the presence of arbitrarily chosen wind intensity, both at the start and under steady-state conditions [5]. In particular, the influence of the alternator field voltage on the performance of the overall system has been analysed in detail. On the basis of this study, a control strategy of the field voltage, which facilitates the starting of the pump in the presence of modest wind intensity and maximises average water discharge in any wind condition, has been defined, implemented on an electronic board and tested.

2. Experimental apparatus

2.1. Simulated wind turbine

The wind turbine and the gear box are simulated by a DC motor connected to a three-phase converter, which can control either the motor torque by the armature current, or the motor speed by the armature voltage, while the field voltage is usually kept constant. The rated torque is 12.5 Nm and the maximum speed at the rated field voltage is 3750 rpm.

In the reported tests a 5 m diameter, fixed-pitch, horizontal axis wind turbine and gear box with a speed ratio of 9 have been simulated.

A torque transducer with an angle marker, for measurement of torque and of rotational speed, is placed between the DC motor and the alternator.

A computer equipped with A/D input and D/A output converters manages the test rig and allows the DC motor to be operated either at constant velocity or at constant torque or along the torque-speed characteristic of a given wind rotor.

Figure 1 gives the scheme of the rig: the computer reads the rotational speed of the DC motor and sets the required torque according to the selected torque-speed characteristic. The calculated torque, as well as the measured actual torque, are sent to the DC/DC converter, which feeds the motor.

The effect of the difference between the moments of inertia of the real rotor and of the DC motor has been taken into account.

The calculated torque T_{DCm} required to the DC motor is, in fact,

$$T_{\mathrm{DCm}} = T_{\mathrm{WT}} - \Delta T \tag{1}$$

where T_{WT} is the torque resulting from the mechanical characteristic of the real wind turbine plus the gear box, for a given wind speed and for a given rotational speed (=shaft torque under steady-state), and ΔT is a correction term for the inertia effect (=zero under steady-state).