Requirements and Design a Small Wind Rotor for a Small House in Guildford

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ABSTRACT

The adoption of renewable energy based systems for electricity generation, leaving aside fossil based energy systems is of paramount importance to humanity. The purpose of this paper is the design of a small wind rotor that meets the electric power requirement of a small house in Guildford, UK. The conceptual design developed, comes from the evaluation of the existing science and technology in terms of wind rotor design and their adjustment to the data, information and facts that apply in Guildford.

Keywords: Design, Guildford, Requirements, Rotor, Wind

1. INTRODUCTION

Wind energy exploitation, is not a new concept, as historically people were harnessing this force, with the propulsion of ships, irrigation systems and water pumping being its main usage (Vlasakoudi, 2012). Despite the vast development of small wind turbines in UK, this growth has not extended in Guildford so far, with no small wind turbines installed in this town according to Guildford’s City Borough Council. Guildford being a South UK town, is included to Policy CC2 Climate Change, according to which Local Planning Authorities (LPAs) should employ strategies and investment programs with the purpose of reducing the region’s carbon dioxide emissions to at least 25% below 1990 levels by 2015 (Planning Policy and Conservation team, 2009).

The rotor is a key part of a wind energy system, as the blades are in charge of extracting the power from the wind. The design of a wind turbine rotor depends on the desired energy output and the size configurations of the entire machine. UK Renewable small wind market, categorizes small scale wind systems to be within the 1.5-15kW power range (Renewable UK, 2011a). The design of a small wind rotor for the purpose of this paper is a theoretical design with the target of selecting the most efficient design.
suitable topology from the endless combinations of design choices and determining the blades’ shape.

2. TOPOLOGY CONFIGURATION

The Horizontal Axis Wind Turbine (HAWT) configuration, where the direction of the air-stream is parallel to the rotation of axis and the main driving force is lift, is found to be considerably more suitable mainly due to cost and efficiency advantages. The rotor will be facing the wind in the upwind position, with 3 blades mounted on a rigid hub, resulting in a simple and cost effective design. Regarding the rotor speed, variable speed wind rotors are a norm in modern small wind applications, rather than exception. They increase the cost of the project but they increase its efficiency as well and therefore this is the chosen option in this case (Vlasakoudi, 2012).

Additional concerns of the topology configuration of a small wind rotor include the material of the blades, the power control, the implementation of gearbox and the generator type of the turbine.

According to manufacturers and suppliers of small wind rotor blades, glass fibre composites (GFC) is a durable reinforced fiberglass material with a high power coefficient, $C_p=0.49$ (KM, 2009; Euros, 2012). In terms of power control, the pitch control concept is chosen to limit the power output by putting a ceiling on the rotor speed and thus output power as the wind velocity increases as well as the yaw control concept, to optimise power by rotating the entire wind turbine to face the oncoming wind. Another important factor to be determined is the optimal tip speed ratio of the rotor $\lambda_{opt}$ designed. The formulas to calculate its value incorporate experimental data, which are beyond the scope of this project. Therefore, the $\lambda_{opt}$ is chosen to be equal to 7, with respect to tables and plots available in literature (Vlasakoudi, 2012).

Once the optimum tip speed ratio is determined, the rotor can function near peak efficiency at all viable wind speeds (Vlasakoudi, 2012). Finally, the most favorable gearbox and generator options for a small wind rotor, is a gearless machine that drives a permanent magnet generator PMG. The choice of PMG is also beneficial for variable speed rotors and exhibits high efficiency levels, up to 93% (Bumby et al., 2006).

The tilt-up configuration is considerably more suitable for the purpose of this project. This is consistent with the general sentiment of the industry and texts. The rigid hub is chosen due to its simplicity. Both teetering and hinged hubs require complex bearing arrangements which have a negative impact on maintenance, reliability and project cost. Rigid hubs are the most common configuration regarding 3 blade rotors.

The blades are bolted to the hub and the latter does not incorporate flexible elements. As the name has it, the hub is rigidly attached in a fixed position to the turbine’s main shaft. The rotor is allowed a cyclic rigid motion, upright to the plane of rotation at angles smaller than $\pm10^\circ$ at the rotor’s speed frequency (Planning Policy and Conservation team, 2009).

3. POWER REQUIREMENTS

The annual electrical requirements of a small house in UK were found to be 4,117kWh which corresponds to 470W. Thus, the wind rotor will be designed for a house with annual power requirements at the level of 470W (Vlasakoudi, 2012). The actual output of a wind energy system compared to its theoretical maximum output from operating at maximum (or rated) capacity is determined by a parameter named Capacity Factor which for the UK wind resource is estimated to be 28.7% (Renewable UK, 2011b).

Hence, the actual annual power the wind rotor should be designed to produce $P$ theoretical output (Vlasakoudi, 2012):

$$0.287 = \frac{470}{P} \Rightarrow P = 1637.63W$$

(1)
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