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A REVIEW OF MULTI ROTOR WIND TURBINE DESIGN & COST SCALLING

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ABSTRACT

Today, among the various renewable energy sources, wind power is the primarily acknowledged and confirmed its cost effectiveness. Globally, wind power utilization is increasing at noticeable rate. Continuously the technology is enhancing in order to obtain more power output from wind turbines. As the wind power output is proportional to the swept area of wind turbine, the rotor size is increasing continuously with grown-up capabilities of engineering and technology. On the other side, increasing rotor size generates some problems. To solve these problems some scientists and manufacturers are working on multi-rotor wind turbine, in which number of small rotors equivalent to a attempt with the objective to present various concepts of multi-rotor wind turbines together. This paper also aims to explore detailed systematic features of various multi-rotor wind turbine designs. This may provide guidelines for practical and economical ways to accelerate further research on the multi rotor wind turbines.

Keywords: wind turbine, multi rotor, co-planer, co-axial, counter rotating

I. INTRODUCTION

After, 1973 energy crisis people began to realize that the world's oil supply would not last forever and other energy sources in addition to oil and natural gas must be developed (Johnson, G. L., 2006). Furthermore, due to serious environmental issue like global warming the development of renewable and clean energy is accelerated. Wind energy has become the fastest increasing renewable energy source in the world and stands as a pillar of the energy supply in many countries

It is worth noting that a number of wind turbine concepts such as diffuser augmented wind turbines, multi rotor wind turbines, vari-blade wind turbines, Kite Power Systems, etc. have been proposed and in a few cases built (Manwell, et al., 2002; Sharma & Madawala, 2012). The approach wind velocity can be increased with the use of diffusers. A small amount of increase in wind velocity increases power output significantly. Two-three fold increase in power output is observed in diffuser augmented wind turbines. Researchers are working to make diffuser more compact (Wang, et al., 2007). In the variable length blade wind turbine, blades are extended when wind speeds drop below rated level. This increases the swept area and thus maintains a relatively high power output.

Field tests conducted by Energy Unlimited Inc. have shown that the energy yield of their variable length bladed turbine, with up to 44% increase in blade length, increased by 30% (Sharma & Madawala, 2012). Kite power is the technology of high-altitude wind power generation, which uses the automatic flight of tethered airfoils to extract energy from wind blowing between 200 and 800 m above the ground.

II. MULTI ROTOR WIND TURBINES

Basically, multi rotor wind turbine concept is developed with two motivational reasons. First is, to use more number of small rotors of equivalent swept area to replace a single large rotor and second is to reuse energy in the wake of first rotor to enhance power coefficients (Jamieson, & Branney, 2012; Patel, 2006). The multi rotor technology put forward the expectation of accomplishing much higher capacities per tower compared with conventional single-rotor types.

Instead of increasing rotor diameter, numbers of small rotors are used to produce same amount of power and provides better solution to the problems occurs because of increasing blade length. For example, a system with five 1 MW units makes a 5 MW multi-rotor system. Based on the concept of equivalent area two models are developed. Fist model consists of number of small rotors (n), arranged in one plane with connected generators (n numbers). The rotor shafts are parallel to each other and placed at suitable distance from each other. Power produced by all generators is collected. The first model is named as array wind turbines or co- planer multi-rotor wind turbine. The second model, unidirectional co-axial series rotor wind turbine consists of two or more number of rotors (of equivalent area) rotating in one direction simultaneously to drive a common shaft coupled to generator. These rotors rotate in different planes.

Co-planer Multi Rotor Wind Turbine

Multi-rotor wind turbine technology has a long history. In 1930, Hermann Honnef, built a 250 m high lattice type tower fitted with three double-rotors arranged with a 120 m diameter front rotor and two 160 m diameter rotor at the rear.

In the 1980s and 1990s Lagerwey Wind, developed a variety of multi-rotor systems as shown in Figure 5a to 5c. They faced key engineering issues such as yawing and rotor integrations. For a particular six-rotor system they claimed satisfactory performance but customers preferred conventional system.

In the year 2010 a multi-rotor wind turbine consists of seven rotors (Figure 5d) is tested in NASA laboratory, delivered encouraging results for future work (Jamieson & Branney, 2012).

The scaling relationship between conventional single rotor and multi rotor wind turbine shows that economical advantage increases with rotor numbers. They retain the economic advantage of smaller scale systems and yet may achieve power equivalent to a larger overall capacity. In wind farm, wind turbines are suitably placed apart to avoid wake effect. The spacing between turbines is decided in terms of rotor diameter.

Counter Rotating Horizontal Axis Wind Turbine

Counter rotating horizontal axis wind turbine (Figure 6a) can be developed by three methods as follows,

Jung, et al. (2004) developed a counter-rotating wind turbine system. It consists of a small auxiliary upwind rotor and a big main upwind rotor. These rotors rotate in opposite direction. The mechanical power output of both rotors is combined by gears and used to drive a generator. The system produced 21 % more power than a single rotor.

Kari (2003) and Kanemoto & Galal (2006) developed twin rotor in series turbine for use with synchronous generators. The power developed by the upstream rotor would drive the internal armature while the downstream rotor would provide power for the external armature. It produces more power than single rotor wind turbine.

Kari (2003) developed counter rotating wind turbine having two separate generators associated with two rotors.

Counter rotating wind generators offers advantage of increase in power compare to single rotor wind turbine up to maximum claimed 43% (Shen, et al., 2007). It also delivers enhancement in power coefficient (up to 64%) compare to single rotor. Researchers have claimed better structural stability for this wind turbine.

Counter rotating wind turbines as per first method needs complex gearing arrangement and subsequent synchronization. Twin rotor generator has complex construction.

III. ASSESSMENT OF MULTI ROTOR WIND TURBINES

The practicability, need of modifications required, limitations and commercialization viability of these multi-rotor wind turbines need to be discussed. Multi-rotor wind turbine concepts are capable to produce power as per claims of researchers. For large power output systems electronic yaw control can be used, but for small capacity it is not economical. The counter rotating wind turbine and unidirectional co-axial series rotor wind turbines may not feasible at MW scale because of overhang shaft in order to maintain appropriate distance between rotors. Modifications are required in yawing mechanisms, synchronization of power (mechanical and/or electrical) in case of counter rotating wind turbine. Though multi-rotor wind turbine concept is very old, successful acceptance of traditional single rotor design demoralized research and development and become barrier in commercialization of multi- rotor systems. Extra supports may make them feasible at MW scale.

IV. CONCLUSION

Though, concept of multi-rotor wind turbine is fallen out of mainstream because of perception of its complexity, many researchers are working optimistically for the development of multi-rotor wind turbines. Realization of limited rotor size will soon attract many researchers and manufacturers to focus on them.

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Standardization in manufacturing can be advantageously used for preferred size rotors used in multi-rotor systems and further it will cause reduction in cost. Co-planer multi-rotor wind turbine and unidirectional co-axial series rotor wind turbines are advantageous compare to counter rotating wind turbine as cost effectiveness increase with increase in number of rotors. These results are sensitive to many assumptions but suggest that the multi-rotor concept deserves more intensive results

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