ABSTRACT

Worldwide interest in renewable energy systems has increased dramatically due to environmental concerns like climate change. Wind power is a major source of sustainable energy and that can be harvested using both horizontal and vertical axis wind turbines. Contribution of wind energy for the power generation in Sri Lanka is still at a very low level. The aim of this research is to design and develop an efficient vertical axis wind turbine which is suitable for Sri Lanka. In this research, Simulations of airflow through the turbine rotor were performed to study the performance characteristics of the turbine. Model tests and a prototype tests were performed to verify the results of numerical analysis.

Initially numerical simulations were carried out on modelling wind turbines and the results were verified with the wind tunnel designed and built as a part of the research project. Considering efficiency improvement related factors, design requirements have been identified and H-Darrieus type wind turbine has been selected as the developing turbine type.

Numerical simulations were carried out with a computational fluid dynamics (CFD) software package. CFD has been a useful modelling tool for analysing the performance of wind turbines and an inexpensive and effective method of simulating and testing a large number of models that could not be readily examined in wind tunnels within the practical scenario. Small design changes can be studied with these models, and tested quickly. In this study, a 2-D numerical analysis has been completed using a multiple rotating reference frame formulation, to predict time averaged results. A sliding mesh model was used to examine the transient effects arising from flow interaction between the stationary components and the rotating blades. From the performance curves, an optimum tip speed ratio was acquired. This performance characteristic was determined based on a modified blade profile configuration. The results are useful in determining the optimal shape and size of blade profile relevant to diameter of the rotor. Numerical results obtained with the CFD simulations were compared with the existing experimental and numerical results in the literature, in order to confirm the accuracy of the simulation technique and results.

The new blade profile was designed considering the maximization of the torque effect of the turbine blade for one revolution of the turbine with the numerical verifications on the efficiency improvement. Deflectors with Rudder unit were also introduced to the turbine to further increase the efficiency of the turbine. The Deflector-Rudder Unit (DRU) was designed considering the maximization of coefficient of performance of the turbine which was verified with the results obtained from the CFD simulations. The performances were analysed considering the power coefficient values of the turbines with respect to the tip speed ratios. These relationships can be used to predict and represent the performance of any turbine rotor, irrespective of the size.

Experimental test series were carried out for verification of numerical results. Those include an open loop wind tunnel test, Model test at the actual site and a prototype test at an actual site. An open loop wind tunnel was designed and built to evaluate the newly designed turbine performance. A wind tunnel test series has been carried out to analyse the performance of the new turbine and new turbine with the introduction of deflectors. Model tests at the site were carried out for proposed turbine and the proposed turbine with the deflectors. Finally a prototype test was carried out for the proposed turbine. Experimental non-dimensional performance analysis has been carried out for each experimental test and such experiments would provide more useful data on the effectiveness of the proprietary design elements and allow recommendations to be made about further areas of improvement for the VAWT.

According to experimental results, the new blade profile with DRU gives around 0.20 power coefficient at tip speed ratio of 1. Simulations show a power coefficient of 0.30 at tip speed ratio of 1.30. . Therefore, the newly developed vertical axis wind turbine is found to be unique and more efficient in harvesting wind energy at low tip speed ratio values. It makes it a good choice for electricity generation in cities and rural area. The power coefficient can be improved through further geometrical optimization of the turbine and DRU by enhancing it's force contribution.