THE DESIGN AND TESTING OF A WIND TURBINE FOR ELECTRICAL POWER GENERATION IN MALAYSIAN WIND CONDITIONS

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This fruit of my efforts,

I humbly dedicate to ……

my beloved family members (especially my grandmother);

who have truly shaped my life

and my wife;

who has influenced my life in a wonderful way.

God bless all of you

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ABSTRACT

Malaysia is situated in the equatorial zone and experiences low and unsteady wind speed. As a result, most of the existing wind turbines are not suitable for Malaysian application. High capital cost, low regional wind speed, incorrect matching between existing wind turbines and available wind speed as well as the level of technology are barriers to the use of wind energy conversion system. This project is a study on low cost, medium rotational speed, small scale stand-alone wind turbine for electrical power generation in low wind speed region. It involves designing, fabricating, testing and determining (blade and rotor configuration) a suitable wind turbine. A study on wind resources in Malaysia and the feasibility of its application showed that there is a possibility to utilise wind energy especially in the coastal areas and islands. The conceptual design of the wind turbine prototype was developed by considering the aspects of application requirements, configuration, functions and performance. The rotor blades were the most critical parts and they were analysed using aerodynamic theory. Wind turbine rotor models were fabricated and tested in a wind tunnel. The components and mechanisms were designed, built and analysed through computer-aided-design (CAD) modeling, theoretical calculation and computer software simulation. Various loads on the wind turbine structures were also examined. An indoor test rig was built for the testing of the wind turbine prototype, in order to obtain the power and torque coefficient at various tip speed ratio (C_{Pmax} = 36.8%). The prototype was also field tested to verify its start-up speed and feasibility of power generation. It has demonstrated good strength, component integrity and yaw response in the field test. The findings suggested that the optimum performance of this innovative wind turbine (TSR = 2.7 - 4.0) falls in the operating range that matched with the available wind speed (V_∞ = 2.2 - 7.0 m/s) if the load matching is properly done. The work developed is sufficient for further investigation into the refinement of every sub-assembly of the system.

ABSTRAK

Malaysia terletak di zon khatulistiwa, dan mengalami kelajuan angin yang rendah dan tidak stabil. Oleh itu, kebanyakan kincir angin sedia adalah tidak sesuai untuk kegunaan di Malaysia. Kos kapital yang tinggi, halaju angin tempatan yang rendah, ketidak-sesuaian kincir angin sedia ada dan tahap teknologi merupakan halangan kepada penggunaan sistem penukaran tenaga angin. Kajian ke atas kincir angin kos rendah, berkelajuan putaran sederhana, berskala kecil dan beroperasi secara bersendirian telah dilaksanakan di dalam projek ini. Ia melibatkan rekabentuk, fabrikasi, pengujian dan penentuan (bilah dan konfigurasi rotor) kincir angin yang sesuai. Hasil kajian ke atas sumber angin di Malaysia dan kebolehlaksanaannya, tenaga angin didapati berpotensi untuk digunakan terutamanya di kawasan tepi pantai dan pulau. Rekabentuk konsep untuk prototaip kincir angin telah dibangunkan dengan mengambilkira aspek keperluan kegunaan, konfigurasi, cara berfungsi dan perilaku. Bilah rotor merupakan bahagian yang paling kritikal, dan telah dianalisa menggunakan teori aerodinamik. Model rotor kincir angin telah difabrikasi dan diuji dalam terowong angin. Komponen dan mekanisma telah direkabentuk, dibina dan dianalisa melalui permodelan CAD, pengiraan secara teori dan simulasi perisian komputer. Pelbagai beban ke atas struktur kincir telah dinilai. Sebuah kelengkapan pengujian dalam makmal telah dibina untuk menguji prototaip kincir angin bagi memperolehi pekali kuasa dan daya kilas pada pelbagai nisbah kelajuan hujung (C_{Pmax} = 36.8%). Prototaip ini juga diuji di lapangan bagi mengesahkan kelajuan permulaan dan kebolehlaksanaannya untuk penjanaan kuasa. Ia telah menunjukkan keupayaan yang baik, integriti komponen dan keupayaan untuk menukar arah rewangan dalam ujian lapangan. Hasil perolehan menunjukkan bahawa perilaku optimum kincir angin yang inovasi ini (TSR = 2.7 – 4.0) berada dalam lingkungan operasi yang berpadanan dengan kelajuan sumber angin yang ada (V_∞ = 2.2 – 7.0 m/s) jika imbangan beban dilakukan dengan betul. Hasil kerja ini juga memadai untuk penyelidikan lanjutan ke atas setiap bahagian sistem secara terperinci.