Wind Turbine Blade Test Rig Development - Initial Thesis Report

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As governments worldwide look to renewable energy for their electricity needs, the wind turbine has gained renewed popularity as one of several viable methods of large scale electricity production. At the point in the system where the wind is converted into useable energy is the wind turbine blade. The blade, as part of a wind turbine rotor, is a key element within the wind turbine system and as such research aimed at improving blade performance is of great importance. The main objective of this project is to design, construct and validate the accuracy of a mobile apparatus that can measure the performance parameters of wind turbine blades as part of a rotor under realistic loading conditions. The apparatus will be able to test blades with up to 2.5m diameter swept areas. As this is the initial report; the project scope will be defined, the specific aims outlined and the current status of research and design discussed. At this stage the conceptual and preliminary design phases are complete. The detailed design and production phase is currently underway with the construction phase scheduled to commence as soon as possible. The apparatus testing and validation is scheduled for July 2009.

Nomenclature

\[ A = \text{rotor swept area (m}^2\text{)} \]
\[ a = \text{axial induction factor} \]
\[ C_P = \text{power coefficient} \]
\[ C_Q = \text{torque coefficient} \]
\[ C_T = \text{thrust coefficient} \]
\[ \lambda = \text{tip speed ratio} \]
\[ \omega = \text{angular velocity (rad.s}^{-1}\text{)} \]
\[ P = \text{power (W)} \]
\[ Q = \text{torque (N.m)} \]
\[ R = \text{rotor swept area radius (m)} \]
\[ T = \text{thrust force (N)} \]
\[ v = \text{upstream velocity (m.s}^{-1}\text{)} \]

I. Introduction

With the ever increasing demand for alternative, renewable electricity supply, the wind turbine has gathered renewed interest. This has been driven by environmental debate, in particular the threat of global warming and the recent oil supply and demand issues that evoked a greater global awareness of diminishing fossil fuel reserves. Wind derived energy has been identified by various government and commercial bodies as one, of several, viable methods used for the large scale commercial production of electricity. Wind turbine produced electricity is not the exclusive domain of the commercial sector however, with small scale turbines being routinely integrated into domestic power supplies to supplement household electricity use. Whilst the commercial and government sectors attempt to curb fossil fuel use from the top end of the consumption spectrum there a group of consumers attempting to curb its use from the bottom end of the spectrum up.

Within the wind turbine system it is the blades that are the initial interface with the wind’s energy making them a critical component within the system and the focus of this project, in particular blades with diameters not exceeding 2.5 meters as part of a rotor. In order to test the performance of completed prototype blades a test rig needs to be designed and developed. The design, construction and validation of the apparatus will likely be the entire scope of this particular project, however if time permits a rotor, made from cheap, readily available material, will be designed, constructed and tested using the test rig.

This initial report will endeavor to: detail the specific aims as per the client’s requirements; define the project by outlining its scope; discuss any theories and related research; detail what has been achieved to date.

\[ ^{1}\text{Wind Turbine Blade Test Rig Development, ZACM4050.} \]
and recommend the way forward by discussing what is yet to be achieved leading up to the project’s conclusion. It should also be noted that it is the project team’s intent that this endeavor will be a starting point for continuing research into blade and wind turbine development at UNSW@ADFA.

II. Aims

Detailed below are the primary aims of the project. These are based upon the original needs statement given to the project team by the client in relation to their expected outcomes. Each aim represents a milestone that when completed should lead to the successful completion of the project. These needs have been formalized into a Client Brief which can be found in Appendix 1. The aims are listed chronologically and are as follows:

1) Design a mobile apparatus that can accurately measure micro wind turbine blade performance.

2) Construct the apparatus.

3) Test the apparatus in the field ensuring that it can produce reasonable data resulting in the determination of blade performance.

4) Validate the test rig instrumentation’s ability to measure data.

5) Ensure that the at the completion of the project, the apparatus is in a serviceable condition so that research projects that continue on with wind turbine blade development have a suitable testing platform for their blade designs.

If the primary aims are met prior to the scheduled project completion date and it is assessed that there is enough time remaining a secondary set of aims will become extant. It should be noted that completion of the secondary aims is not necessary for the successful completion of the project, however in regards to providing a solid base of research for any future investigation by UNSW@ADFA into wind technology, it is a desirable outcome. The secondary aims are as follows:

1) Design a rotor from cheap, readily available material e.g. PVC pipe.

2) Construct the rotor.

3) Test the rotor’s performance using the test rig.

III. Project Scope

The main objective of this project is to design, build and test a mobile apparatus that can accurately measure the performance of a full sized small wind turbine rotor prototype. The device will be exposed to realistic environmental effects such as naturally occurring wind profiles over various terrain types. In doing this the test rig’s purpose, in the context of system’s design, is to validate the accuracy of the design process prior to rotor production. It is also to evaluate the rotor’s performance, when subjected to real world effects, as it relates to its capacity to maximize energy output. To initially determine if the test rig is producing reasonable performance data, it will be fitted with a turbine rotor (test rotor) with known performance parameters. The test rotor’s performance data was obtained through the research of Harrap 1988\textsuperscript{2}. The test rotor’s performance curve, as it relates to power, is at Fig. 1 and the initial objective will be to see if the test rig produces data

\textsuperscript{2} The test rotor is based upon the Clark Y airfoil design, for further information on this airfoil go to http://ntrs.nasa.gov/search.jsp.

![Figure 1. The test rotor performance curve. Taken from Ref. 1.](image)
that results in a similar fit to that of the above graph. Once it is established that the test rig is capable of producing reasonable results the next step will be to try and eliminate some of the expected scatter from the data. To do this the wind velocity vectors will be reduced down to their components normal to the rotor blades eliminating that part of the velocity vector not contributing to the power produced by the wind turbine. Therefore the use of anemometers and a wind vane to determine the velocity magnitude and direction will be key in producing reasonable performance data.

To fully appreciate the project’s scope several key knowledge areas/disciplines need to be utilised, these are: aerodynamics of wind turbine rotors; wind turbine site selection; wind profiles over varying terrain; engineering design incorporating structural mechanics and component design; data acquisition and measurement systems. These areas will be discussed further in the next section. It should be noted that Horizontal Axis Wind Turbines (HAWT) will be the focus of this research project, however, the design process may accommodate the possible conversion of the test rig to test Vertical Axis Wind Turbine (VAWT) blades in any subsequent research projects conducted at UNSW@ADFA.

IV. The Research Effort

Before the design effort could commence a theoretical baseline needed to be established. This included not only establishing the theories and processes needed for the design process but also to make sure that the research to be conducted had not been undertaken previously by other parties. Therefore the purpose of this section is firstly, to review all research and theory regarding the various disciplines that will be utilized throughout the project starting with the definition of blade performance. This will be followed by the review of any other related research into this and similar fields.

A. Aerodynamics of Wind Turbine Rotors

Aerodynamic forces will be used to determine the design parameters of the test rig, in particular, how these forces interact with the structure of the rig in both direct and indirect ways. They will also be used to interpret and derive the relationship between the energy in the wind and how it translates to the performance parameters when the rig is tested in the field.

To determine how well various blade designs perform when compared to each other, a set of performance parameters need to be defined. The performance of a HAWT, as proffered by Burton, Sharpe, Jenkins and Bossanyi3, is defined by the three parameters; thrust, power and torque and how they vary with differing wind velocities. The ideal values of these parameters, in particular thrust and torque, will be used to interpret and derive the relationship between the energy in the wind and how it translates to the performance parameters when the rig is tested in the field.

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The two common theories, as discussed by Bianchi, De Battista and Mantz4, used to determine the aerodynamic models for wind turbines are; actuator disk theory (ADT) and blade element theory (BET). ADT describes how energy is extracted from wind by a simplified rotor disk, where as BET discusses how the wind exerts forces on a blade element. For its simplicity ADT will be used to determine the design parameters for this particular project. ADT uses an ideal upper limit for power extraction, the Betz Limit and when the data for the power produced by the blade is gathered it can then be compared to the upper limit. ADT and the Betz Limit are discussed in detail by Wilson5 and it will be the relevant areas of this article, in conjunction with Ref.2 and Ref. 3, which will provide the theoretical baseline for the aerodynamics of the project.

ADT provides an ideal model of a rotor, with infinite blades and no losses. It will be used to derive the initial loading values. Using the equation

\[ T = \frac{1}{2} \rho A v^2 C_T \]  \hspace{1cm} (1)

where

\[ C_T = 4a(1-a) \] \hspace{1cm} (2)

an ideal value of thrust, which is indicative of the worst case loading scenario, can be calculatediii. This maximum thrust value can then be applied to the test rig design to kick off the design process.

To determine the maximum torque for design purposes, Ref. 3 provides data that describes the typical variations for a fixed pitch wind turbine of the coefficients of torque and power with an increase in the rotor’s tip speed ratio. From this data the maximum coefficient of torque can be taken and used to design the test rig’s shaft.

iii The axial induction factor gives the highest value for thrust when it is equal to 0.5, resulting in \( C_T \) being equal to 1.
During the data acquisition/test rig testing phase, thrust will be given by a load cell and torque via a prony brake/load cell set up. The final parameter, power, will be derived from the relationship between the equations

\[ C_Q = \frac{C_p}{\lambda} = \frac{Q}{0.5\rho v^2 AR} \]  

(3)

where

\[ \lambda = \frac{\omega R}{v} \]  

(4)

and

\[ C_p = \frac{P}{0.5\rho v^2 A} \]  

(5)

noting that the angular velocity will also be known via an RPM measurement device attached to the test rig’s shaft. From this relationship Eq. (4) can be substituted into Eq. (3) to obtain the power coefficient, with this Eq. (5) may be solved. It is \( C_p \) as it relates to \( \lambda \) that will be compared to the test rotor data to ascertain whether the test rig is producing reasonable results.

B. Site Selection

Site selection becomes an important consideration when trying to expose the test rig to wind conditions that closely match that of the actual location the rotors will be employed. McGuigan6, succinctly details the considerations that should be taken into account when siting a wind turbine, the most relevant being where to site wind turbines on hills or knolls or in the vicinity of stands of trees. These considerations were used to assist in the selection of the primary and secondary test sites where it was decided to conduct the testing phase on gently sloping hills with little vegetation on or around them. The reasons for doing this are discussed in the next section.

C. Wind Profiles

The first major trade off that was encountered with the project was that the ability to test blades at differing heights was degraded by; the desire for mobility and finite resources. Therefore a fixed height was decided upon and was dictated by; the test rig’s mode of transport, a 3m x 1.5m trailer and the ability to determine, to a limited degree, the type of wind profile required using topography. The height of 6m from trailer tray to the centre of the swept area diameter was decided upon so that the test rig tower could fit inside the trailer in two 3 meters lengths. McGuigan (Ref. 5) briefly discusses the change in wind velocity with an increase in height and highlights the significant increase in energy gained for a small height addition. What becomes apparent is that the top half of the rotor swept area may experience a different wind velocity than that of the bottom half, resulting in energy losses and unnecessary loading due to bending moments. According to Wizelius7 this is due to the velocity gradient of the boundary layer at the earth’s surface, starting at zero and increasing with height. The rate at which velocity increases is dependant on how rough the surface is i.e. grass, trees, hills etc, see Fig. 2.

The implication for the test rig is that a theoretical profile should be developed for each test site to ensure that the velocity gradient moving through the swept area of the rotor is as even as it can be in the field.

A CSIRO Research Project Sheet8 highlights the use of hills or high ground to exploit the resulting speed up effect and flattening of the boundary layer velocity gradient through turbulence, see Fig. 3. This will help to ensure that an even as possible wind velocity profile moves through the rotor’s swept area, without the need to raise the test rig to an altitude where the velocity profile is relatively even. To assist with the selection of a suitable test site, a basic wind speed-up profile will be manually calculated. The ESDU mean wind speeds over hills and other topography simple model9 will be utilized for this purpose. Once the test site has been selected a more detailed model of the wind speed profile at the location can be created using the ESDU computer program for wind speed and turbulence properties10. It should be noted that the software is complex and that the corresponding software guide11 will be utilised to assist in the use of the program. The third step will be to
validate the previously calculated wind velocity profile at the test site using anemometers at varying heights from the ground up to the top of the rotor’s swept area. This measurement device, a profile anemometer, will also need to be designed and built and is discussed in detail in the measurement systems section.

D. Structural Mechanics

Essentially this is a design, build and test project and as such the test rig structure needs to be rigorously designed to ensure it can serve its intended purpose without failure due to the loads it will encounter in the field. For simplicity the design will be based primarily on the effects of static loading, however, the dynamic loading will also be examined to a lesser degree and applied to the individual materials that will make up the test rig structure. The structural design will utilise certain, relevant aspects of the system engineering model for wind turbine design as discussed by Eggleston and Stoddard, which covers the static case for the entire system and the dynamic case for the rotor. Eggleston and Stoddard describe the wind turbine system as consisting of three main subsystems: the rotor, the torsional mechanical drive including the load and the tower. When modeling these subsystems for design purposes, various theories and other author’s work will be utilised. The rotor will be modeled using ADT, this will produce an ideal thrust value. The stresses on the tower from the thrust loading will be modeled as a square hollow section beam secured at its base by pin joint and secured along its length by a wire in tension. The theory for the tower stress model has been taken from Hibbeler’s Statics and Mechanics of Materials texts.

The other major structure is the test rig shaft. The shaft will be designed using Mott’s step by step design procedure. The main design parameter will be the maximum torque that the shaft is subjected to with other relevant design parameters coming from the specific manufacturer’s product specification sheets, these will be discussed further in the component design section. The initial design calculations were complete at the time of this report’s submission.

E. Component Design

Once the major structural members have been designed the test rig can be broken down into its components and each part designed individually. The components that make up the test rig are: the tower leg mounts, tower legs, mast base plate, mast with test rig mounting plate, shaft, shaft bearings and housings, cowl, prony brake, guy chain, erection frame, splitter plate assembly and possibly, lightning protection. The only components that do not require manufacture are the bearings and housings and the splitter plate assembly. All other components have to be designed from the ground up. The loads and stresses discussed above will be used to determine the appropriate materials for each manufactured component based on the material manufacturer’s product specifications. The bearings and housings will be chosen based upon Mott’s (Ref. 14) design parameters for the shaft in combination with the manufacturer’s specifications, in this case from the SKF bearings catalogue

The software package that will be used throughout the project for graphical component design will be CATIA. This software can also be used to help verify the static loading calculations, for each component, that were calculated during the structural analysis. Appendix 2 contains the design drawing of the test rig in its assembled state and the individual part drawings that were completed at the time of this report’s submission.

F. Data Acquisition and Measurement Systems

For the project to be successful the test rig needs to produce accurate performance data. This section will discuss the methodology behind the proposed data acquisition capability of the test rig and the instrumentation that will be utilized for this purpose. The rig will not be self aligning with the wind direction as its instrumentation and capture software will be able to utilize wind from nearly every direction up to a limit no greater than 90° either side on the rotor’s spin axis, see Fig. 4. The limit will be determined by the wind velocity and direction required to overcome friction and spin the rotor from stationary or the dynamic force (due to wind velocity and direction) required to keep the rotor spinning as it continues to opposes friction. Basically if the rotor is spinning it is contributing to the data acquisition process. If the wind direction changes beyond this limit the trailer containing the test rig will be physically moved to reacquire the wind. The test rig has been
designed to be contained totally within the trailer making the job of reacquiring the wind relatively easy. Simultaneously a wind vane will record wind direction, the profile anemometer the average wind speed across the swept area of the rotor, the Prony brake the torque generated, the splitter plate and sensor the angular velocity of the shaft and the guy chain load cell the thrust produced by the rotor. This data will be fed into the field computer via Simulink where it will be reorganized into useable parameters. The data collection will continue until a certain spread of wind velocities have been recorded and a reasonable fit for the test rotor $C_p$ versus $\lambda$ curve achieved.

G. Related Research

It should be noted that up to this point, that all referenced literature has provided a theoretical basis for the design, siting and use of the test rig. The purpose of this section is to examine other related research into wind turbine performance and assess its relevance to this project as well as ensuring that this project’s scope is unique and not a repeat of another researcher’s efforts.

Upon conducting the literature review, it becomes apparent that there are several accepted methods for the evaluation of blade performance. Amongst the accepted methods, the most common appear to be; wind tunnel testing, fixed site testing, 2D and 3D modeling using software or CFD packages, manual mathematical modeling or combinations of all of these. It is also apparent that the two most common theories used in the above methods are ADT and BET with some newer theories beginning to emerge.

Nathan’s paper on simplified design methods and wind tunnel testing is a combination of manual math modeling and wind tunnel testing. Nathan uses BET to model the blades which is beyond the scope of this project and uses a wind tunnel to verify the modeled performance, thrust is also not considered in Nathan’s research. Using a wind tunnel will produce results for a rotor subjected to near ideal conditions and limit the diameter of rotor tested. Whilst Nathan’s test rig could potentially be used in the field it would require significant redesign. Therefore the major difference between Nathan’s research and this project is that this project aims to test rotor performance under real world conditions and includes the thrust that the rotor produces and how it affects the wind turbine structure. Zhiquan’s research follows a similar method to that of Nathan’s, however also uses optimization software for the blade design. Once again the thrust produced by the rotors is not considered, with the focus of the research appearing to be the validation of the optimization software’s accuracy using a wind tunnel. When reviewing Zhiquan’s research, it could be said that the optimization software is the test rig in some respects. However, like the wind tunnel testing, it will likely not be able to simulate real world effects in the field. The common theme regarding the above research is that the focus was on blade performance, as it relates to power and torque only. In each case the test rigs were of simple design intended for a narrow spectrum of indoor use. In comparison, this project’s focus is the test rig, not the blade, therefore ensuring that the test rig will be of robust design and capable of testing all manner of blades in varying, real world, wind conditions.

Neff and Meroney’s research into wind and turbulence characteristics due to induction effects near turbine rotors was relevant and useful to this project. Whilst their primary objective is beyond this project’s scope, there were several aspects that were informative and of some assistance in relation to the development of the test rig. The method used for the conduct of the experiment and data acquisition will be of assistance when the test rig is deployed in the field. The Prony brake design used by Neff and Meroney, was simple yet effective and has contributed to the design of the project’s brake. Figure 5 is the Prony brake used for their research. Note the spring, wire and ruler device used for force measurement, this will be replaced by an electric load cell on the test rig’s brake, apart from this modernization of the experiment much will remain the same. As a suggestion for future projects, Neff and Meroney’s research could be expanded upon.

Hartwanger and Horvat discuss the use of 2D and 3D modeling in their investigation of various wind turbine model efficiencies. Whilst this paper focuses on large blades within a system of wind turbines it was
interesting to note their adopted process and could be of relevance if time permits the project to move into the blade design phase. Using ADT they build an ideal performance model and then compared it to the real world performance of various in service turbine models. Using the real world data they are able to modify the in service model blade designs in an effort to move towards the ideal performance parameters, as discussed previously with Betz limit. If the project has time to investigate blade design this paper could be of use in selecting a design method. Gould and Fiddes\textsuperscript{23} compare two computation methods for performance prediction. The methods discussed are the Non Linear Lifting Line (NLL) and the three dimensional method (3DM). They assess that the NLL is sufficiently accurate if reliable airfoil data is used and that the 3DM gives good power predictions but requires more work. Fuglsang and Madsen\textsuperscript{24} discuss an optimization method for blade design known as inverse design methods, “where the optimum geometric shape is determined from a prescribed target distribution of some aerodynamic quantity,” and whilst it is an informative paper it is once again only relevant if time permits for blade development. In regards to the primary aim of the project the above research is beyond its scope.

A research paper by Clausen and Wood\textsuperscript{25} highlights some of the issues involved with small wind turbine development that researchers were facing at the turn of this century. From research conducted thus far it appears that these issues are still extant 9 years on. Whilst most of the topics discussed in the paper are beyond the project’s scope, the issue of blade starting will no doubt become relevant when using the test rig in the field. The amount of torque required to overcome rotationally opposing forces, such as the friction associated with the Prony brake, will have to be accounted for. The starting torque will no doubt be measured prior to deployment in the field. The other main topic of blade material and manufacturing methods will be relevant to any future projects that utilise the test rig. One other useful piece of information from Clausen and Wood’s paper is their classification of wind turbines according to blade size and energy output, it classifies the blades mounted on the test rig as being in the micro range (based on diameter) and provides various useful data for this blade group, see Table 1. This classification system will be used from this point forward when describing the test rig in the hope that a standard system of wind turbine categorization will develop.

Wright and Wood\textsuperscript{26}, obviously acting on the recommendation from Ref. 23, carried out research into the starting and low wind speed behavior of small HAWTs. Their research was a combination of; field testing of a HAWT and then comparing the results to a “quasi-steady blade element analysis”. It is the method by which the HAWT was tested in the field that is of most interest, however the starting behavior is of great importance for both the test rig start up torque considerations as well as future research. Wright and Wood’s test rig comprised of a three bladed rotor attached to a permanent magnet generator feeding a rectified 24V battery. The turbine was mounted at 8m above the ground with buildings below and trees of the same height in the vicinity, the result being an erratic start and stop behavior. RPM, wind speed and direction, turbine yaw and battery charge were all measured with the assumption that once the battery started charging that the turbine starting sequence was complete. Of interest to this project is; the locations of measuring devices in relation to the HAWT, the field test method and the behavior of a turbine that isn’t directionally fixed. All these considerations, as discussed by Wright and Wood, will be taken into account during the data acquisition phase.

<table>
<thead>
<tr>
<th>Category</th>
<th>W (kW)</th>
<th>R (m)</th>
<th>max. rotor speed (rpm)</th>
<th>typical uses</th>
<th>generator type(s)</th>
<th>Examples</th>
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</thead>
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<tr>
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<td>1</td>
<td>1.5</td>
<td>700</td>
<td>electric fences, yachts, remote houses</td>
<td>Permanent magnet (PM)</td>
<td>Web-site (1)</td>
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<td>400</td>
<td>remote houses</td>
<td>PM or induction</td>
<td>Web-site (2)</td>
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<td>20+</td>
<td>5</td>
<td>200</td>
<td>mini grids, remote communities</td>
<td>PM or induction</td>
<td>Web-site (3)</td>
</tr>
</tbody>
</table>

V. Current Progress

The project commenced on 2 March 2009, the first major task being the review of publications and data relating to the scope of the research. It should be noted that the research topic/client’s needs, had already been established prior to the project commencing. Whilst review of relevant material will continue throughout the design, construction and testing phases, it was important to establish a theoretical baseline in order to commence the conceptual design. Also important was the establishment of previous research efforts to ensure that time is not wasted on ground already covered. Throughout this review phase the aims, based on the client’s research topic, were refined and established. Management documentation in the form of a Gantt chart and client brief were generated once the aims were established, these can be found at Appendix 4.

Once a theoretical baseline and the aims were established the conceptual design commenced. During this phase various configurations were discussed with the client. The baseline design became a balance between mobility, available material, budget and HAWT aerodynamics, with the test rig configuration changing numerous times. It is assessed that the numerous configuration changes were due to: a continually growing understanding of the baseline theory; the evolution and understanding of more complex theory as time
progressed; initial calculations showing a certain configuration to be deficient in some aspect and changing client needs. The end product of the conceptual design phase was the test rig configuration that would move through to the preliminary design phase.

With the conceptual design configuration in hand the preliminary design phase. Initial calculations were conducted to determine the material types and dimensions required for the test rig. During this time the various instrumentation required for the project were either acquired or researched for purchase. The end product of the preliminary design was a configuration with known material types and dimensions.

Once the test rig’s configuration, dimensions and material types were known the detailed design process could commence. During this phase each component within the test rig system was/will be rigorously designed. At the time of this report’s submission the project was moving into the final stages of this process, with most components having been designed. Once the component designs and overall configuration of the test rig has been approved by the client and work shop supervisors, they will be submitted for construction. It is anticipated that this will occur no later than the 5 May 2009. As part of ensuring that the trailer housing the test rig is serviceable, its electrics have been checked and repaired where needed by the electrical workshop’s staff. A suitable test site was researched and the Mildura Military Range found suitable as a possible primary test site, it has now been booked for use. Based on the wind profile research discussed in the project scope, there are several features within the range that have suitable gradients and terrain for the test rig deployment. The proposed test sites are located near the Canberra Airport which will also help in determining rough wind directions based on aircraft takeoff and approach.

VI. The Way Forward

Once the detailed designs have been submitted for construction a range of concurrent activities can commence. Obviously supervision of the construction will need to occur, however this should not monopolize a large amount of time. The intent is to commence the testing of the instrumentation in the lab and the field. The load cells and RPM measurement device will need to be tested for serviceability and accuracy, however testing them in their final positions will have to occur once the test rig is complete. The testing of anemometers and wind vanes can also be carried out. Due to a shortage of instrumentation a makeshift anemometer will be built. The anemometer will consist of several hobby motors with propellers attached to a pole at regular intervals up to an approximate height of 8m. It will allow a measurement of the wind speed profile across the swept area of the rotor. Each of the motors will be calibrated using the main lab wind tunnel where their output voltage will be measured against the wind tunnel speed. Another task, during the construction phase, will be a visit to the proposed locations of the experiment, to physically check on their suitability as test rig sites. This will be achieved using the makeshift anemometer, which as discussed in the scope, will verify hand and computational calculations of the wind profiles at those locations. It is anticipated that interfacing the instruments with the test computer will be the most time intensive.

Once the test rig is built it will be tested locally to ensure that the instrumentation is serviceable and that it interfaces correctly with the test computer. This should be complete no later than the 12 July 2009, as the test location has been booked for the period 13–17 July 2009, presenting the project with a small window to collect the data required to validate the test rig’s accuracy. Once the data is acquired, it can be analysed and any further collection undertaken if required. Once the data has been represented in an appropriate form i.e. graphs, in particular a graph of $C_p$ versus $\lambda$, it can be assessed for its accuracy. Once the test rig is producing reasonable data sets the main objective will be complete. If enough project time remains the investigation of economic blade designs may commence. In particular, the examination of PVC pipe will be a priority, taking into account its cost and availability.

VII. Project Management

Included at Appendix 3 are the Gantt and Milestone charts for the project. The project’s primary aims represent the various milestones within these charts and as such provide the baseline for the design and works timelines. Due to a small window of opportunity in which to collect the data in the field all events leading up to and including the data collection do not have much room to slide and will be supervised carefully to ensure there are no delays in the schedule. After the data is collected the use of time is a little more flexible leading up to the project’s completion date and hopefully the secondary aims can be attempted. It should be noted that the secondary aims have not been included within the works timeline in the assumption that they may not be attempted, however should the opportunity present itself to attempt them then a timeline of events will be drafted and the relevant management tools produced. At this stage the project has progressed without any delays in the time allocated.

Regarding the project’s allocated budget every attempt is being made to use only in house equipment and material. At this stage it is still unclear if any purchases are required.
In regards to risk management and OH&S various facets of the project have been identified as having the potential to cause harm to either personnel, equipment or both. The facets identified are; the rotor when spinning, the test rig tower regarding its weight and movement across rugged terrain by vehicle with trailer attached. The risk to project delays is also being considered. The risk assessment is in the process of being compiled and will be complete prior to any use or transportation of the test rig. All OH&S measures will be in place prior to any travel or field work commencing.

VIII. Summary

The majority of the reviewed research into the performance of wind turbine blades focuses on the comparison of wind tunnel results with mathematical or computational models. The reasoning behind this is likely to be to make the modeling stage more accurately reflect the rotor’s performance in real world conditions without having to leave the lab. This project will endeavor to take this research to the next level by producing a mobile test rig that can be set up in the field to make use of real world weather effects to determine a rotor’s performance against less than ideal wind profiles. This will hopefully contribute to a modeling stage that more accurately reflects actual performance of various blade configurations in the field. To date the test rig is in the final stages of its detailed design and development with its construction scheduled to commence as soon as possible.

References

17 CATIA, Design Software Package, Ver. 5.16, Dassault Systems, 2005.

Initial Thesis Report 2009, ACME, UNSW@ADFA

Appendices

1. Client Brief
2. Design Drawings
3. Project Management Charts