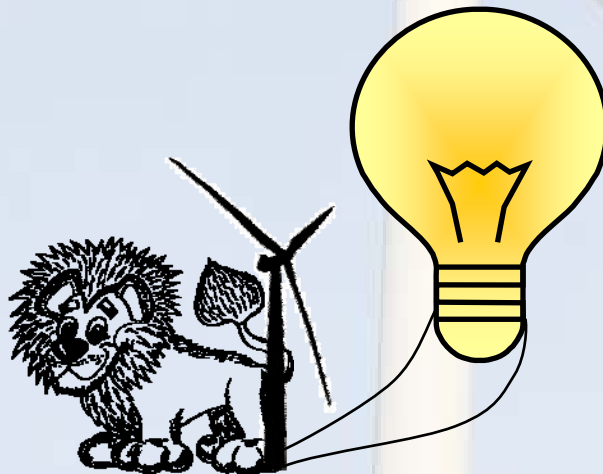


International Workshop on
**SMALL SCALE WIND ENERGY FOR
DEVELOPING COUNTRIES**

September 14-16, 2009, Nairobi, Kenya

Sponsored by:

Royal Ministry of Foreign Affairs of Denmark,
in the framework of Danida program and
in collaboration with the Institute of Energy and
Environmental Technology (IEET) of
Jomo Kenyatta University of Agriculture and
Technology (JKUAT), Nairobi, Kenya



PROGRAMME AND ABSTRACTS



**Participants from
International Workshop on
NATURAL AND LOW-COST MATERIALS IN WIND ENERGY TECHNOLOGIES
10-12 November 2008, Dhulikhel, Nepal**

Overview and Objectives

The renewable energy technologies can provide sources of unlimited, cheap and clean energy to the people in developing countries. Especially, communities in remote and dry regions, which do not have easy access to the hydro power, and can not afford the installation of long transmission lines or using solar photovoltaic power, could benefit from the wider use of wind energy. Small wind turbines can present a good, economically viable and environmental friendly solution to provide remote villages in hilly areas with light and electricity.

The Workshop will bring together African, Western and Asian specialists in the area of low cost renewable energies for developing countries, to discuss wind energy technologies, their reliability and perspectives in developing countries.

This Workshop is the follow-up to the International Workshop on Natural and Low-Cost Materials in Wind Energy Technologies, which took place in Dhulikhel, Nepal, November 10-12, 2008.

Workshop Topics

The workshop covers the following main themes:

- Wind energy technologies, their perspectives and applications in developing countries,
- Reliability of wind turbines, lifetime and strength of wind turbine components,
- Low cost and natural materials for wind turbines,
- Case studies, social and economic aspects of wind energy in developing countries.

Organizing Committee

Povl Brøndsted (Risø DTU, Denmark)

Peter Freere (Monash University, Australia),

Dorte Juul Jensen (Risø.DTU, Denmark)

Joseph M. Keriko (Chairman) (JKUAT, Kenya)

Leon Mishnaevsky Jr. (Chairman) (Risø DTU, Denmark)

Rakesh Sinha (KAPEG, Nepal)

Bent F. Sørensen (Risø DTU, Denmark)

Programme

September 14, 2008

9:00- 9:45 **Registration**

9:45-12:00 **Opening Session**

Chairman: Professor Zhou Hongwei (China)

9:45- 9:55 Opening Remarks, Leon Mishnaevsky Jr. (Denmark)

9:55-10:05 Opening Remarks, Rakesh Sinha (Nepal)

10:05-10:15 Opening Remarks, Joseph Mailutha (Kenya)

10:15-10:25 Opening Remarks, Joseph M. Keriko (Kenya)

10:25-10:35 Welcome and official opening of workshop, Professor Mabel Imbuga, Vice Chancellor, JKUAT (Kenya)

10:35-11:00 **Coffee**

11:00-11:30 Small wind turbines for remote power and distributed generation, David Wood (Australia)

11:30-12:00 Selection of materials for wind turbine blades, Povl Brøndsted (Denmark)

12:00-14:00 **Lunch**

14:00-16:40 **Session on Development and Design of Small Wind Turbines**

Chairman: Professor David Wood (Australia)

14:00-14:30 Low Cost Wind Turbines, Peter Freere (Australia)

14:30-14:50 Vertical axis turbines: a more appropriate technology? Leopoldo Salmaso (Tanzania)

14:50-15:10 **Coffee**

15:10-15:40 Potential benefits of small wind systems for use in developing countries, Christopher Oludhe (Kenya)

15:40-16:00 El Alumbre: Design, implementation and management of a community small-scale wind generation project, Laia Ferrer-Martí (Spain)

16:00-16:20 Reducing the Cost of Manufacturing Composite Small Wind Turbine Blades, Paul Peterson (Australia)

16:20-16:40 The benefits of small wind turbines: Understanding how small wind turbines can be of long-term benefit in the African context and how they are used today, Emma Sanan (South Africa)

18:30-20:30 **Dinner**

September 15, 2008

9:30-12:00 **Session on Wind Energy in Africa**

Chairman: Rakesh Sinha (Nepal)

9:30-10:00 Renewable energy in Africa: Status and perspectives, Joseph M. Keriko (Kenya)

10:00-10:20 Wind energy in Nigeria, Oluseyi Ajayi (Nigeria)

10:20-10:40 Energy development cooperation through GTZ in East Africa, Michael Franz (Kenya)

10:40-11:00 **Coffee**

Programme

- 11:00-11:20 Wind energy blows a bright future for Tsagwa village, Njeri Kahiu (Kenya)
11:20-11:40 Status and constraints of wind energy resources utilization in Kenya, J.T. Makanga, E. Ngondi (Kenya)
11:40-12:00 Case study from the Gambia: Access to modern energy services, community driven electrification using wind energy and challenges for regulators, M.L. Sompo Ceesay (Gambia)

12:00-14:00 Lunch

14:00-16:20 Session on Strength and Reliability of Materials for Wind Energy Applications

- Chairman: Professor Josef M. Keriko (Kenya)
14:00-14:30 Potential of natural fiber composites in wind energy applications, Janis Varna (Sweden)
14:30-14:50 Computational analysis of mechanisms and strength of timber for wind mills blades, Hai Qing (Denmark)
14:50-15:10 Estimating the braking stresses in a small wind turbine blade, David Wood (Australia)

15:10-15:30 Coffee

- 15:30-16:00 Selection of Nepalese timber for small wind turbine blade construction, Rakesh Sinha (Nepal)
16:00-16:20 On blade matching after batch production, David Wood (Australia)
16:20-16:40 Experimental investigations of damage mechanisms in fiber glass composites used for wind turbine blades, Hongwei Zhou (China)
17:00-18:30 Round Table on the Organization of the Society for Small Scale Wind Energy

18:30-20:30 Dinner

September 16, 2008

9:30-12:00 Session on Applications of Small Scale Wind Turbines

- Chairman: Dr. Peter Freere (Australia)
9:30-10:00 Kathmandu Alternative Power and Energy Group: Our experience in promotion of low cost wind energy in Nepal, Rakesh Sinha (Nepal)
9:30-9:50 Wind resource estimation and siting of turbines in a village electrification project, Laia Ferrer-Martí (Spain)
9:50-10:20 Determination of wind class, power and Weibull parameters for some selected sites in Kenya, J N Kamau (Kenya)

10:20-10:40 Coffee

- 10:40-11:00 The impact of city-site on urbanised small-scale wind systems: Comparing two sites to uncover the challenges and solutions Emma Sanan (South Africa)
11:00-11:20 Planning wind energy parks in Mozambique, Boaventura Chongo Cuamba (Mozambique)
11:20-11:40 Rural Electrification in Kitui District, Frits van Dorst (The Netherlands)
11:40-11:50 Closing Remarks, Joseph M. Keriko (Kenya)
11:50-12:00 Closing Remarks, Leon Mishnaevsky Jr (Denmark)

12:00-14:00 Lunch

ABSTRACTS

(Alphabetically, according to the first authors family name)

WIND ENERGY IN NIGERIA

Oluseyi O. Ajayi

Mechanical Engineering Department, Covenant University, Ota, Ogun State, Nigeria

Nigeria is a nation whose population is increasing at a geometric rate. The present population is put at over 140 million. However, the ever increasing demand and meager supply of energy in Nigeria has been a great challenge to her development, with her increasing population trend not balanced by adequate energy development programme. The incessant power generation failure has grossly affected the economy of her populace causing a crawling effect on the developmental growth of rural and sub-rural settlements, with present energy policy mainly benefiting urban dwellers. People in rural areas depend on burning wood and traditional biomass for their energy needs, causing deforestation, greenhouse gases emission and environmental pollution. World energy projections stipulate that global energy needs will rise by over 34% between year 2002 and 2025, with that of developing nations doubling this percentage. Energy projection in Nigeria based on 13% Gross Domestic Product growth rate revealed that energy demand will increase from 5746 MW in 2005 to 297900 MW in 2030 while its supply should increase from 6440 MW to 276229 MW within the same period of years. Currently energy production within the country is less than 6000 MW due to fluctuations in the availability of production sources. Meaning that, a robust solution must be sort out for the nation to come out of her energy crises. One major way is through the use of renewable resources for energy production. These sources are cheap, easily accessible, naturally applicably, enormously available, environmentally friendly, non-depleting, non-toxic source of valuable and usable energy, under which is the wind energy. Depending on availability, wind as a source of energy is one of the cleanest and reliable source of energy. This paper is used to address the issues of wind energy utilization in Nigeria. It identifies the various challenges and prospects vis-à-vis its availability across the geo-political zones of the nation. More so, various initiatives by governments and researchers were surveyed and their outcomes reported. It was discovered that, though wind energy availability in the south-western and south-southern parts of the country is poor, offshore areas bounded by the Atlantic Ocean and running from the south-west coast through south-east to the south-south have enormous potential for wind energy cultivation for power generation. The far northern states and mountainous areas of the central and eastern zones of the country possess huge amount of wind energy, capable of producing about 86% of the possible total annual wind energy flux density for the country. Despite this potential, no wind installation for power generation is located anywhere in the country. The nation relies on the seasonal dependent and

fluctuating hydro-power source and on fossil fuel-gas driven turbines for power production. The majority of the power stations within the country are under producing due to unavailable or insufficient resources. This ought not to be, going by the identified prospect of wind energy within the country. These prospects can be converted to useful energy if the attendant challenges are overcome and the suggestions carried out. People in rural areas in some parts of the identified zones can also be made to benefit from wind through the use of stand alone, low cost wind energy turbine installations.

SELECTION OF MATERIALS FOR WIND TURBINE BLADES

Povl Brøndsted, Risø DTU, Roskilde, Denmark

The rotor blades of both small wind mills (micro wind turbines) and of very large wind turbines are structures that presents the most challenging materials, design, and engineering problems.

Wind turbine blades must be strong enough to withstand the applied loads without fracturing; thus, the ultimate strength must be sufficient to withstand the extreme loads, and the fatigue strength must be sufficient to withstand the time-varying loads throughout the intended life of the blade. The blades must also be stiff enough to prevent collision with the tower under extreme conditions. Stiffness, at a more local level, is also important for preventing buckling of those parts of the blade that experience compressive stresses. To minimize the cost of the power generated, the blade construction needs to be as light as possible; this has to be achieved through optimization of the structural arrangement and dimensions in parallel with the materials selection. The production processes used for manufacturing the blades must be sufficiently consistent and reliable to ensure that the end product is always compatible with the design assumptions and calculations.

The combined materials performance criteria identify the today candidates for rotor blades as woods and composites. Woods are potentially interesting because of their low density, but their rather low stiffness makes it difficult to limit the (elastic) deflections for larger rotorblades. Even wood materials with cellulosic fibers all aligned in the major load-bearing directions are close to the maximum performance possible for wood. Furthermore, wood is a natural material and thus environmentally attractive, but at the same time difficult to obtain in reproducible and high quality, which is a requirement for stable and economical manufacturing of rotorblades and thus economically attractive wind energy. Composites based on based on fiber-reinforced polymers have been most extensively used for larger blades. The reinforcements are typically fabrics consisting of continuous glass fibers and/or carbon fibers. These are combined in a laminated (i.e., layered) construction with thermosetting resins, generally polyester, vinylester, or epoxy; the resulting composite materials are commonly referred to as glass-reinforced plastic (GRP) and carbonfiber-reinforced plastic (CFRP).

New trends in the materials occur with respect to properties, design, and monitoring, as well as manufacturing technology. Sustainable materials from biological resources are introduced as candidates for the future generations of blades. Natural fiber composites consisting of wood, hemp, jute, bamboo etc. filaments embedded in biobased polymer matrices are foreseen to be introduced to the market fulfilling the demands of renewability and recyclability.

Important in the introduction of new, alternative materials is the design and qualification demands. Hence the manufacturing technology, the structural behaviour, and the mechanical properties must be well understood and documented. The main materials challenges will be to ensure a consistent quality in production as variations in the bio based materials and in the production techniques are introduced. Necessary is it also in a cost-effective way to take into account production defects and geometric imperfections that may be present. Improved knowledge of defects, their causes, and their influence on structural behavior under both static and time-varying loads will be essential to achieve this.

CASE STUDY FROM THE GAMBIA

Access to Modern Energy Services, Community driven electrification using Wind Energy and challenges for Regulators

M.L. Sompo Ceesay, Public Utilities Regulatory Authority, Kololi, The Gambia

The Gambia Public Utilities Regulatory Authority (PURA) was established by the PURA Act of 2001 to regulate the Telecommunications, Electricity and Water Sectors. In addition a sector specific legislation, the Electricity Act 2005, pursuant to the development and implementation of an Energy Policy, was enacted to supplement the PURA Act towards the regulation of the electricity market. The overriding objective of the regulatory framework is to facilitate private sector participation in the Gambian electricity market. The Act makes provision for licensing of generators and distributors etc. in order to encourage competition and efficiency.

The paper outlines how regulatory intervention can be used to facilitate electricity generation using renewable energy technologies in energy resource challenged countries such as The Gambia. It particularly showcases The Gambia's experience in the licensing of the first wind turbine for electrification.

A background is also given to outline the necessary institutional framework including the relevant legislative frameworks such as sector specific legislation, data, a regulatory agency and a brief note on the project details and the way forward.

The paper depicts PURA's experience as a regulator, in bringing renewable energy projects to reality and the lessons learnt. Suggestions are made for the way forward to

other regulators and policy makers in the development of community based energy services.

EL ALUMBRE: DESIGN, IMPLEMENTATION AND MANAGEMENT OF A COMMUNITY SMALL-SCALE WIND GENERATION PROJECT

José Chiroque¹ Rafael Escobar Portal¹ Laia Ferrer-Martí² Anna Garwood³

¹ Soluciones Prácticas – ITDG., Peru,

² Universidad Politécnica de Cataluña, Spain

³ Green Empowerment

Electrification systems based on renewable energy have proven suitable for providing decentralized electricity to isolated communities. Specifically, electricity generated through wind power is one of the technical options available, although infrequently used to date. The majority of small-scale wind projects in South America have been developed in flat areas with high wind potential, such as Patagonia [1] and the Atlantic Coast of Nicaragua [2].

This article aims to describe the aspects of technical design, implementation and management of the first small-scale community wind generation project for rural electrification in Peru. This project took place in the community of Alumbre [3], in the region of Cajamarca, which is a mountainous area characterized by low to medium wind resource. This project, implemented by Practical Action – ITDG, brought electric power to every family as well as the school and health center of the community.

Technical Description: Alumbre is a community located in the Northern mountains of Peru at 3850 meters above sea level. It has 33 families (151 inhabitants) who are mainly engaged in subsistence agriculture and livestock rearing. The electrification project is designed to cover basic household needs and community services (school and health center). In a first phase, 21 wind turbines of 100W (IT-PE-100) were installed in 21 homes and a wind turbine of 500W (SP-500) was installed in the school. In a second phase, 14 more family systems and a 500W wind turbine were installed to electrify homes and the health center. At each point of consumption, the equipment installed included a regulator, a battery bank and an inverter to facilitate the purchase and use of AC equipment.

The community was selected after an evaluation of the wind resource at different points in the region. The region is characterized by low to moderate winds. The wind turbines installed are models developed by ITDG, specifically designed to operate at low wind speeds [3]. The design prioritizes robustness and ease of maintenance, essential for project sustainability. The wind turbines are manufactured by local companies, thereby stimulating business creation and facilitating repair and parts replacement.

Management Model: A local micro-enterprise has been formed to operate, maintain and administer all of the systems. The formation of the small business promotes rural

entrepreneurial culture. The implementation of the management model developed in parallel to the installation of systems, and promoted active participation of beneficiaries, representatives and community leaders. First, the community itself selected candidates to run the micro-enterprise. Then, all of the candidates participated in a comprehensive training program which covered both administrative and technical skills. The project team and community leaders selected the top candidate based on evaluations during the training program as well as past community involvement. The micro-enterprise is legally registered as a sole proprietorship and has a tariff structure, register of users and a reserve fund. The Alumbre micro-enterprise for rural electrical services has been successfully operating for over a year.

Results and conclusions

- Wind turbines installed in each home cover the domestic use of electricity for 5 hours/day. An evaluation survey found that 100% of households use the system for lighting, 57% are now weaving or knitting in the evenings, 64% are using the lighting for studying, 43% have radios and 93% are charging cell phones. Energy in the school powers four computers (with electronic encyclopedias) and a DVD for educational videos, used by 80 students from Alumbre and neighboring communities. The health center, which attends to people in 4 communities, now has electricity for lights and a vaccine refrigerator.
- Following the wind potential evaluation, in the points with lower wind resource, the wind turbines were installed on higher towers.
- The operation and maintenance of the systems has been strengthened through the use of small visual manuals [4] and the participation of authorities and the local technician in the community training sessions.
 - As a result of the wind turbines, 70% families are expressing a reduction in expenditures in other energy sources such as kerosene or candles.
- The introduction of concepts of customer service in the structure of a single person micro-enterprise is an innovative way of promoting sustainability.
- Families have been using energy in a direct or indirect way in the implementation of small business such as a radio station, the production of sweaters, and the fabrication of cheese.

References

- [1] CREE, Patagonia wind aids remote communities, BBC News 10 February 2006, Max Seitz
- [2] blueEnergy (<http://www.blueenergygroup.org/index.php>)
- [3] Javier Coello; José Chiroque. Soluciones Prácticas–ITDG. (2008) “Aprovechamiento de la energía eólica para la electrificación rural en el Perú”. Energía y Negocios, Vol 59.
- [4] J. Chiroque, Soluciones Prácticas–ITDG. Microaerogeneradores de 100 y 500 W. Modelos IT-PE-100, SP -500. Lima: Soluciones Prácticas-ITDG; 2008.

ESTIMATING THE BRAKING STRESSES IN A SMALL WIND TURBINE BLADE

Philip Clausen¹, Paul Peterson², Sturt Wilson², David Wood²

¹School of Engineering, University of Newcastle, Australia

²Aerogenesis Australia

It is rare for small wind turbines to use a brake, and we are unaware of any published studies of braking and the stresses it induces in the blades. One consequence is that treatment of blade loads during braking in the IEC safety standard for small turbines, IEC 61400-2:2006, is very conservative.

The Aerogenesis 5 kW turbine, which is currently undergoing field testing at the University of Newcastle, does have a brake, and considerable experience in its operation has been acquired. The brake is powered off and so is virtually failsafe. When the power is cut, the braking torque of approximately 320 Nm stops the blades from their maximum design speed of 320 rpm in less than two seconds. Whether this time is too short provided the motivation for the present study of blade loads. It is noted, however, that the quoted brake torque is just sufficient to hold the blades stationary in a wind of 190 kmh or 52.5 m/s, the 50-year maximum wind speed for an IEC Class III turbine. Thus reducing the brake torque to increase the stopping time, would adversely affect turbine safety during parking.

Small blades must resist the (radial) centrifugal loads, which are significantly higher in small blades than large blades, and the (flapwise) bending due to aerodynamic loading. The circumferential braking loads (in the lead-lag direction) were not considered in the initial design of the 5 kW blades. The rough justification for this neglect is that blades are naturally stiffer in the lead-lag direction because this is almost parallel to the blade chord.

The braking experiments allowed estimates of the stress and strain levels from the finite element (FE) model used for the blade design. A detailed analysis of braking loads would require specifying the braking torque as a function of angular velocity and knowledge of the magnitude, location, and direction of the unsteady aerodynamic loads. However, these loads cannot be independently measured with the equipment available and cannot be accurately computed. Instead, we simply videoed the turbine stopping at 30 frames per second. The decrease in angular velocity shown in Figure 1 was estimated by measuring the blade location over typically five frames. The video can be watched at

<http://www.youtube.com/watch?v=vG5FP4uCeZo&feature=channel>

The blade angular velocity was input to the FE analysis which can be thought of as a determination of the loads on a blade rotating in a vacuum and decelerating at the same rate as the actual blade. Nevertheless, Figure 2 shows that the maximum stress in the blade is less than 18 MPa which is much less than the maximum stress during normal operation, so the blades are safe during braking.

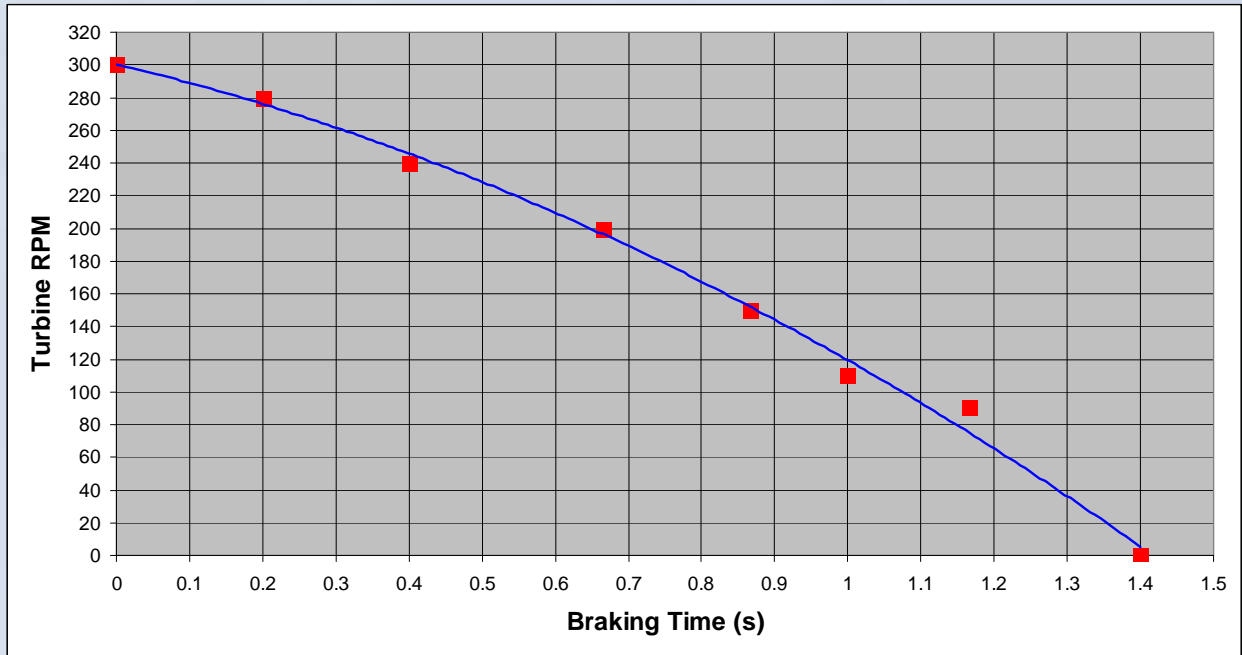


Figure 1: Turbine angular velocity during braking

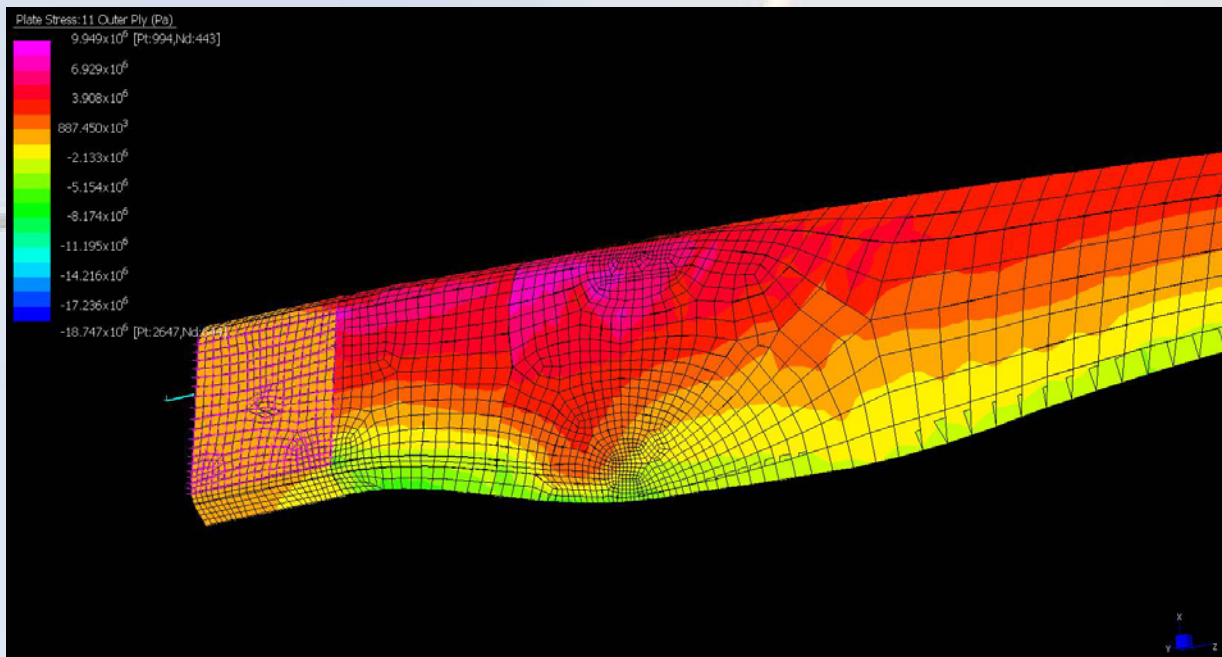


Figure 2: – Blade stress distribution at the max deceleration (0 rpm).

PLANNING WIND ENERGY PARKS IN MOZAMBIQUE

B. C. Cuamba¹, M. L. Chenene¹, M. L. Chissico¹, M. Benessene², J. Lovseth³, O. J. Nydal⁴ and J. B. Guerreiro⁵

¹Energy, Environment and Climate Research Group; Faculty of Sciences, Eduardo Mondlane University (UEM); Maputo, Mozambique

²Instituto Nacional de Meteorologia, Maputo, Mozambique

³Solar Energy and Environmental Group, Department of Physics (LADE), Norwegian University of Science and Technology (NTNU), Trondheim, Norway

⁴Department of Energy and Processing Engineering, Trondheim Norway

⁵Bruno & Lopes Moçambique Limitada (BLM); Maputo, Mozambique

Just as with the other Southern African Development Community (SADC) countries, Mozambique faces severe and interrelated problems of energy and environment linked with the massive consumption of fuel wood biomass. The conventional power grid provides less than 10% of the energy needs for the country's 20 million inhabitants. About 83% of the energy consumed in the country comes from biomass. Renewable energy resources can play an important role in the process of development of the country. From the vast renewable energy resources available, wind energy represents one of those with a good potential. A general characterisation of the wind energy resources in the country has been undertaken and the results are promising. The long coastline of about 2800 km represents area with the highest potential for wind energy deployment. Highlands of the interior in central and northern parts of Mozambique may also have a good potential. Detailed measurements are now being undertaken in selected sites. This paper presents major results of such evaluations and discusses steps being undertaken in the process of studies for the establishment of the first wind energy parks in Mozambique.

WIND RESOURCE ESTIMATION AND SITTING OF TURBINES IN A VILLAGE ELECTRIFICATION PROJECT

Laia Ferrer-Martí^{1,2}, Rafael Pastor², Matteo Ranaboldo¹, G. Miquel Capó¹, Enrique Velo¹

¹Research Group on Development Cooperation and Human Development,

²Institute of Industrial and Control Engineering, Technical University of Catalonia (UPC), Barcelona, Spain

Isolated electrification systems that use renewable energy are a suitable option to provide electricity to rural villages in development countries. Micro wind systems are a technical option that has recently been used in electrification projects in Cajamarca, a mountainous area in the North of Peru [1]. So far, due to the characteristic dispersion between households in the villages, the projects have installed individual wind turbines at each demand point. In addition, we propose to study the use of micro grids. This design option considers the use of more powerful turbines, economically advantageous, and does not constraint the energy of a demand point to its location.

The objective of this study is to develop a decision model to design wind electrification projects, taking into account the location of the demand points, the detailed wind resource map and the possible use of micro grids. The wind resource at each point of the village is calculated using specialised software (WAsP).

Model: We develop a mixed and integer linear programming (MILP) model to solve the design of the wind electrification project. This type of mathematical formulation is used to model combinatorial problems, and can be solved optimally using specialized software (ILOG CPLEX). These models are developed through the definition of: parameters to introduce the input data; decision variables to define the solution; an objective function to set the optimization criteria; and constraints to specify the project conditions.

As input data, we introduce the location and the energy and the power demand of each point. The detailed map of the wind potential of the village is also needed; the energy generated by each possible type of wind turbine is calculated using WAsP, from RISO. The results of the wind resource estimation are validated with the data of two anemometers [2]. The model considers the energy is stored in banks of batteries located at the generation points. The electric distribution from the batteries to the demand points is done in alternating single-phase current, at the nominal voltage. The model gives the location and size or type of the wind turbines, the batteries, the charge controllers, the inverters, and the wires to be used in the micro grids. The solving criterion is the minimization of the initial investment cost to fulfil the demand.

Results: The model is validated through its application to a real case implemented Cajamarca, Peru. The project consists on the electrification of the village El Alumbre It has been the first demonstration of community electrification with a micro wind system in Peru. The project was implemented by the non governmental organization Soluciones Prácticas – ITDG (Peru). The system was designed to fulfil basic electricity requirements of the school, the health care centre and the households. The project currently implemented has installed individual wind turbines at each demand point, one micro wind turbine of 500 W (SP-500) at the school and health centre and one micro wind turbine of 100 W (IT-PE-100) at each family.

The possible locations of the micro wind turbines introduced in the model are the demand points and also extra points generated all over the village The energy that may be generated by each type of turbine located in each possible point is calculated using WAsP. The model has been solved with different sets of possible locations of wind turbines. Although the village dispersion is significant, the solutions obtained tend to use the most powerful turbines to give energy to some demand points using small microgrids. These solutions reduce the initial investment costs, compared with the cost of the individual turbines. Moreover the total amount of generated energy is significantly superior.

Conclusions: This study presents a mathematical model to design a micro wind electrification project. The model considers the location of the demand points, the possible use of micro grids and it takes into account the detailed map of the wind potential of the

village. Comparing with a real case implemented in Peru, the solutions obtained with this model tend to use micro grids, despite the village dispersion, reduce the initial investment costs and produce significantly more energy.

References

1. Javier Coello; José Chiroque. Soluciones Prácticas–ITDG. (2008) “Aprovechamiento de la energía eólica para la electrificación rural en el Perú”. Energía y Negocios, Vol 59.
2. Niels G. Mortensen, Anthony J. Bowen and Ioannis Antoniou; “Improving WAsP Predictions in (too) Complex Terrain”.

ENERGY DEVELOPMENT COOPERATION THROUGH GTZ IN EAST AFRICA

Michael Franz

German Technical Cooperation (GTZ), GTZ Office, Nairobi, Kenya

The energy sector in East Africa: The energy scenario among the East African countries is very similar. All the countries are characterized by a dominant role of bioenergy in the primary energy supply and of hydropower in electricity generation. Firewood or charcoal for cooking energy continue to account for more than 75% of the primary energy supply. This practice is not sustainable due to a share of non-renewable biomass of more than 50%, i.e. more than half of the woodfuel demand is made up from stocks, leading to severe deforestation.

Less than 15 % of the population of about 180 million people in the East African region have access to electricity, with rural electrification rates as low as 2 %. Rural electrification has been traditionally characterized by a mostly ineffective grid extension and densification approach. A paradigm change is slowly crystallizing, with decentralized thermal and renewable power generation gaining ground.

The over-reliance on hydropower in the national grids has led to sustained power shortages in times of drought, which in turn has led to an uptake of relatively expensive fossil fuels. The increased use of thermal generation has, at the same time, created a vulnerability to price fluctuations at the international markets for petroleum products. The transport sector in the region has been hit particularly hard by the high oil price in 2008, leading to angry protests by consumers and frantic but mostly ineffective short-term action of politics. The electricity demand is expected to grow in tandem with the economy, by 6-8% annually.

All the countries in the region are making strong efforts to create additional capacity, pursuing a mix of conventional renewable and thermal sources. Decentralized renewable energy generation, however, so far remains sidelined and the vast potentials unexplored. Nevertheless, another paradigm shift is taking place, manifested in political declarations to

diversify and encourage investment. This is backed up by targeted policy reforms in several countries in the region, e.g. modification to the rural electrification strategies and introduction of feed-in policies to trigger independent power production on the grid.

Development cooperation on energy issues through GTZ in East Africa: The GTZ (German Technical Cooperation) is an international cooperation enterprise for sustainable development with worldwide operations. GTZ supports the German Government in achieving its development-policy objectives providing viable, forward-looking solutions for political, economic, ecological and social sustainable development in a globalised world. Based on and implementing bilateral agreements between the Germany and its partner governments, GTZ has taken up the challenges in the energy sector in East Africa through a number of programme and project activities:

- Regional: EAC: East African Community, support to the EAC and its member states to formulate and implement the EAC Strategy for Upscaling of Access to Modern Energy
- Ethiopia: SUN Energy: Sustainable Use of Natural resources, focusing on biomass energy efficiency through improved cook stoves for households and institutions as well as policy advisory; AMES-E: Access to Modern Energy Services with activities focusing on solar PV and small hydro power; TERNA (Focus: Wind energy): feasibility analyses and wind assessments have been concluded, leading to a tender for a 120 MW wind energy project
- Kenya: PSDA: Promotion of Private Sector Development in Agriculture, comprising biomass energy efficiency through improved cook stoves for households and institutions as well as a biogas dissemination and capacity development project; ECOSAN: Ecological Sanitation through promoting recovery and usage of resources contained in wastewater, thereby treating the effluents and – for example – produce energy in biodigesters
- Uganda: PREEEP: Promotion of Renewable Energy and Energy Efficiency Programme with four programme areas, namely rural electrification, biomass energy technologies, energy efficiency, and energy policy.
- Tanzania: PROBEC: Programme for Basic Energy and Conservation in the SADC region, promoting biomass energy technologies in a commercial and policy-oriented approach
- Rwanda: NDBP: National Domestic Biogas Programme in partnership with MinInfra and the Dutch SNV, focusing on market development of biogas plants; PSP Hydro: Private Sector Participation in Micro-Hydro Power Supply for Rural Development, project to promote private sector in area of mini- and micro hydro power; Upcoming support to the formulation of a Bioenergy / Biofuels Investment Strategy and Policy

New regional initiative: the GTZ “Project Development Programme – East Africa”: Informed observers recognize the substantial and largely untapped potential in East Africa for “modern” renewable energy applications. At the same time, East African key players lack technical capacity and experience with these technologies. Potential investors are reluctant, since they cannot refer to experiences in the region. International players are hesitant facing uncertainties of entering a new market and finding appropriate partners.

In recognition of these obstacles, and in acknowledgement of Germany’s positive and considerable experience with the new renewable energies like Solar PV, wind and biomass power generation, the German Federal Ministry of Economics and Technology commissioned GTZ to facilitate the establishment of business-to-business partnerships between German and East African renewable energy companies.

GTZ’s facilitative role comprises: to provide targeted information for the business partners, to identify and mobilize potential participants in Germany and in the region, to assist in identifying business opportunities, to facilitate networking through events and travels, to provide capacity development for regional partners, and to provide support and advisory services related to the investment frameworks.

The project is building on GTZ’s experiences and network related to its pool of regional projects . The target group are small and medium sized enterprises along the entire value chain, i.e. from investors to project developers and technology providers. The sectoral scope is equally open, including solar PV, wind energy, bioenergy, geothermal energy, and hydropower.

LOW COST WIND TURBINES

Peter Freere, Matthew Sacher, James Derricott, Bryan Hanson
Dept. Electrical and Computer Systems Engineering, Monash University, Australia

A detailed case study is performed on a commercially available low cost wind turbine. A detailed model of the generator is produced from electrical laboratory measurements and then the turbine is tested in a wind tunnel with up to 13m/s wind speed, with starting and yawing behaviour observed. Mechanical losses were also measured, together with a thermal characteristics. The effect of electrical resistance changes with current were noted, as well as production variations between nominally identical turbines. The blade characteristics are measured, both as a function of wind speed and of the yaw angle, and with and without a nose cone. The turbine was then installed in the field and its performance measured and compared to that predicted from the models. Practical issues are noted as required for reliable operation, in particular the design of blades and their attachment to the turbine. Differing designs of controllers were investigated for both their steady state and dynamic performance and an understanding developed as to their requirements to operate well. Operation under fault conditions was investigated, together

with the effect on the controller. The influence of climate change on aspects of the electronics in the controller design will be illustrated.

The result of the investigation is that criteria for the design and construction of effective low cost turbines will be proposed

RURAL ELECTRIFICATION ON KITUI DISTRICT

Frits van Dorst (Eindhoven Technical University, The Netherlands) and SASOL. (Kenya)

The Kenyan NGO SASOL has been working closely with the Dutch NGO Edukans since 2003. The focus of their projects is capacity building in rural communities. Several projects have been done in the past years. A potential new project will be electrification in the rural areas by small scale wind power. My research focuses on the wind potential, the available technology, the available knowledge and the available materials. I am doing wind measurements on two locations in the Kitui district, which belong to the windiest places of the district according to the people working at SASOL. Both locations are also potential locations for a pilot project. One is situated at a secondary school compound, the other a primary school compound. The electricity generated will be stored in batteries and used at night time for lighting, to give students the opportunity to study when it is dark. The only light source at night time currently available are kerosene lamps.

KATHMANDU ALTERNATIVE POWER AND ENERGY GROUP: OUR EXPERIENCE IN PROMOTION OF LOW COST WIND ENERGY TECHNOLOGY IN NEPAL

Pramod Ghimire¹, Ranjan Sharma², Chudamani Lamichhane³, Peter Freere⁴, Rakesh Sinha⁵, Parash Acharya⁵

¹Dept. of Electrical and Computer Engineering, University of Canterbury, New Zealand

²Department of Electrical Engineering, Technical University of Denmark (DTU)

³Think Global AS, Norway

⁴Dept. of Electrical and Computer Systems Engineering, Monash University, Australia

⁵KAPEG Pvt Ltd, Dhulikhel, Nepal Rakesh Sinha, KAPEG, Nepal

This paper describes the research and development activities carried out by Kathmandu Alternative power and Energy Group (KAPEG) in promotion of wind energy technology in Nepal. Based on the published report, a brief review of wind energy practices in Nepal is presented. The future opportunities in wind energy in Nepal are discussed. KAPEG's completed and ongoing activities in promotion of small scale wind energy are presented. KAPEG has been receiving significant technical and financial assistance from international partners to develop the expertise which is also discussed. Finally, based on the KAPEG experience some of the future works are recommended for the development of wind energy technology in Nepal.

ON BLADE MATCHING AFTER BATCH PRODUCTION

Konrad Hitz¹, David Wood^{1,2}

¹School of Engineering, University of Newcastle, NSW 2308 Australia

²Aerogenesis Australia

Nearly all small wind turbine blades are made individually in batches and then combined in pairs or triples (or in larger numbers) to form the rotor. This presentation considers only pairing and tripling. Combining must satisfy limits on rotor properties such as the eccentricity of the centre of mass or on variations in blade properties such as mass. For example, the IEC standard for the safety of small wind turbines, IEC 61400-2:2006, assumes a default eccentricity of the rotor centre of mass of $0.005R$ where R is the blade tip radius.

The traditional way of balancing large and small blades is to add mass to the tip region of the lighter or lightest. This incurs extra manufacturing costs which may be unnecessary if the blade pairs or triples can be matched in an optimal manner. However, to our knowledge, blade matching has not been explored in the wind turbine literature. It is a special case of “Euclidean matching” in the field of combinatorial optimisation.

We distinguish between “simple” and “complex” matching, both based on minimising the sum of the mean square difference in a specified matching parameter over the entire batch. If the matching is simply based on, say, the mass, m , centre of mass, r , or their product mr , then it is easy to show that optimal matching is achieved by ordering the blades in terms of the matching parameter. In other words, if the blades are numbered in ascending order of the matching parameter, then (1,2) is an optimal blade pair, (1,2,3) is an optimal blade triple, and so on. Alternatively, matching is “complex” if the parameter for blade i depends on the blade(s) being matched to it. Then ordering is not possible and an algorithm is needed. An example of a complex matching parameter is the eccentricity of the centre of mass. The contribution, δ_{ij}^2 , from the blade pair (i,j) to the sum of the mean square difference can be approximated as

$$\delta_{ij}^2 = \left(\frac{m_i r_i - m_j r_j}{m_i + m_j} \right)^2 \quad (1)$$

by assuming that r_i and r_j are colinear with the axis of rotation. The matching parameter for blade i is $m_i r_i / (m_i + m_j)$, which is complex by the above definition. Ordering or simple matching on the basis of r or mr , is likely to be close to, but not necessarily, optimal for matching based on Equation (1). Any matching algorithm must be extremely efficient as, for example, the number of possible pairings from a batch of 20 blades exceeds 650 million. We have developed “branch and bound” algorithms for the complex matching of blade pairs and triples. These algorithms start from an approximate simple ordering, as it is very important to start with a matching that is close to optimal, and typically take 3 minutes on a modern PC to optimally match a batch of 20 blades.

WIND ENERGY BLOWS A BRIGHT FUTURE FOR TSAGWA VILLAGE

Njeri Waruingi Kahiu, Institute of Energy and Environmental Technology, Jomo Kenyatta University, Kenya

The availability of electricity in rural areas of Kenya is about ten percent (10%) resulting in deforestation, use of scarce resources to buy expensive fossil based fuels and in-door air pollution. To mitigate against these challenges a novel concept was developed in 2003. In the Wind Home System (WHS) concept each household was to be wired, a solar battery and energy saving lights provided. The battery would be recharged every three to four days. The nearest charging station was forty kilometres away. With wind speeds ranging from 5m/s to 12m/s, wind generators were a viable option. To demonstrate this concept of providing clean energy in Tsagwa village in Kilifi District, north of Mombasa Town on the East Africa coast, a grant of US\$48,321 was received from the United Nations Development Programme, Global Environmental Facility, Small Grants Programme to provide a wind charging station within the vicinity.

The charging station was a hybrid of two wind turbines and three solar photovoltaic panels. Each of the solar photovoltaic panels was rated at eighty five (85) watts. The wind turbines, each supported by a twelve (12) metre guyed steel lattice tower, comprised of three phase generators with a maximum output of 800W and a rated output 600 W at 12m/s. The rotor blades were made of glass-fibre reinforced polyester with a diameter of 2.2 metres. The twelve pole brushless permanent magnet generator had a maximum frequency of ninety (90) hertz. The alternating current was converted into direct current in the voltage control system, which contained a built in rectifier bridge. A dump load prevented overcharging of the batteries. Power from each generator was stored in six, 200 Ah lead/acid batteries. The system voltage was 24V (Figure 1). The battery charging station was housed in a community centre which comprised of two workshops and a multi-purpose room. The centre was equipped with one computer, printer, telephone, VCR and TV for recreational and educational purposes.

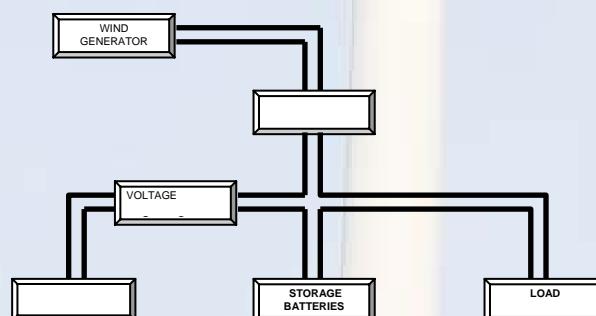


Figure 1: Block Diagram of Wind Power System

The community contribution was land, materials for the community centre and labour for all construction relating to the project. It had been envisaged that a total of 100 households would be provided with the WHS but only sixty four were provided with this service. The shortfall was due to failure of the community to honour their pledge and the project money was used to build the community centre.

To sustain the project a caretaker was appointed to manage the day to day affairs of the community centre with co-ordination with the management committee. All connected consumers were to pay fifty shillings per month towards the caretakers' salary. Income was to be obtained by hiring out of the workshops, battery charging fee, community telephone charges, wiring charges for new customers, educational and recreation activities in the community centre.

The wind charging station initially worked well but six months into commissioning problems started. One wind generator experienced fatal failure when the magnets came off from the generator rotor affecting the performance of the charging station. There was no repair shop in Mombasa which could handle the job. At extra cost the rotor was returned to the supplier and he supplied a new one. Soon after the other wind generator failed and on inspection it was found that water had entered into the bearing housing causing corrosion of the shaft and contamination of the lubricant.

Identical bearings and seals were not available on the market and the bearings were replaced with the nearest equivalent but the wind turbine did not perform.

The project demonstrated that wind energy does work but delivery of energy services is much more than technology functioning. The people dimension is a crucial. The main challenges were lack of spare parts, use of non-deep cycle batteries resulting in short life-span, poor community participation and lack of ownership by the community. Lessons learned from this project are first, it does not follow that all people living close together can unite for a common purpose. Other criteria like track record of other successful community ventures should have been considered. It was wrongly assumed that lighting is such a dire need that in a community of one hundred households a volunteer would be easily available.

Secondly, the grant should have included a one year stabilisation period for promotion and marketing. An entrepreneur could have been identified through competitive bidding to manage the community centre for a year to assess the actual revenue.

A lot of effort and time have been invested in this project and the wind speeds in Tsagwa are adequate. Installation of more sturdy wind generators and a management structure based on the energy business model would ensure the success of this demonstration project and enhance adoption of small wind energy systems in developing countries.

DETERMINATION OF WIND CLASS, POWER AND WEIBULL PARAMETERS FOR SOME SELECTED SITES IN KENYA

Kamau J N ¹., Kinyua R ¹., Gathua J K ²

¹ Department of Physics, Jomo Kenyatta University of Agriculture and Technology, Kenya

² Department of Physics, Kenyatta University, Kenya

In Kenya, most people live in the rural areas, and only about 10% have access to electricity. However the cost of oil based imports has increased by over 1000% in the past three decades and the cost of electricity alone has more than doubled in the past year. Currently the total installed capacity is about 1100MW; 79% of which is hydropower, 16% is geothermal, and 4% is thermal. Only 400KW of wind power is connected to the grid.

Due to unreliability in the rain patterns leading to persistent drought (1999-2002), (2005/6) and more recently 2008, Kenya cannot continue to rely on hydropower generation for most of its electricity needs. Therefore there is need for investing in alternative energy sources. Renewable energy sources such as solar, wind and geothermal are strong candidates since they are also “green”.

Recent interests in wind energy technology have resulted in bigger turbines, larger rotor diameters and reduced costs that are quite competitive with other resources, for example hydro and coal (AAS, 2000). Consequently wind energy is the world's fastest growing energy source, expanding at annual rates of between 25 and 35% (Shikha, et al, 2004). In 2007 alone world wide capacity increased by 26% to reach the 100GW mark (www.ieawind.org). However, to harness wind energy requires knowledge of certain wind characteristics for the chosen site

In this study, wind data consisting of hourly wind speed records over a period of 6 years, were obtained from the Kenya Meteorological Department and used to investigate the potential for wind to generate electricity and for domestic water pumping for Garissa (0° 28'S, 39° 38'E), and Marsabit (37° 57'N, 2° 19'E) towns in Kenya. Diurnal, seasonal and inter-annual variability parameters have been studied using empirical methods including the Power law and Weibull statistics. Garissa's average wind speed ranged between 2.5-3.5m/s giving power densities of between 37 and 97 W/m² at a height of 10m. The power densities at 50m ranged from 90-190 W/m². On the other hand Marsabit has Weibull parameter k which varies between 2.07 and 3.25 and a wind class of above 7 showing that it has a high potential for wind energy generation.

Key words: wind speed, power law, Weibull parameters, wind frequency, wind class, Wind Rose, energy potential.

RENEWABLE ENERGY IN AFRICA: STATUS AND PERSPECTIVES

Joseph M. Keriko

Department of Chemistry/Principal Nairobi Campus

Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya

The continent of Africa has from time immemorial been lagging behind in all sort of modern development including renewable energy technology as compared to other regions of the globe. Although there is great potential in Africa in terms of the availability of renewable energy resources such as the existence of enormous natural resources, the continent still lags behind in development. The continent of Africa is known to be rich in; solar energy resources (as results of its position within the tropics), Wind energy (existence of strong winds in low and highland regions), hydropower energy (existence of large rivers), biomass energy (enormous volumes of vegetation), biogas resources (great waste disposal), geothermal power potentials etc. Indeed lack of development in renewable energy in Africa is sometimes linked to either, extreme poverty, manipulation by the developed world, ignorance by the inhabitants, poor governance or lack of know-how in modern technologies. Thus, this paper will highlight the status and perspective of renewable energy in the African continent.

STATUS AND CONSTRAINTS OF WIND ENERGY RESOURCES UTILIZATION IN KENYA

J.T. Makanga and E. Ngondi

Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Energy has been identified as the prime mover that propels the wheel of economic development. Access to modern energy affects quality of life and supports the main aspects of sustainable development namely social equality, economic growth and environmental protection. Sub-Saharan Africa and many other countries with low per capita commercial energy consumption continue to exhibit correspondingly low per capita gross domestic products. In a continent where both per capita income and energy consumption are low, the use of renewable energy resources including biomass, solar, wind, geothermal and hydro power energy resources will be among the main solutions to clean and sustainable energy that will fuel economic growth and spearhead the fight against poverty. This paper reveals the status and constraints of wind energy resources utilization in Kenya.

Kenya is an East African country bordered by Ethiopia to the North, Sudan to the North East, Uganda to the West, Tanzania to the South, Somalia to the East and the Indian Ocean to the South East. It has a per capita gross domestic product (GDP) of US\$ 1400 and GDP composition per sector of 23.8% from Agriculture, 16.7% from Industry and

59.5% from services sector. The country's 11.85 million labor force is largely employed by Agriculture, Industry and Services.

The current energy supply in Kenya consists of an available power of about 1080 MW comprising of hydro power (677 MW), oil fired thermal power (271 MW), geothermal power (128 MW), cogeneration (2 MW) and wind power (0.4 MW). Other sources of energy include traditional energy resources such as wood fuel, charcoal, cow dung, agricultural wastes and solar voltaic systems. Exploration for oil, gas and coal have indicated that there are sufficient economically viable oil and gas reserves in the Indian ocean while sufficient coal deposits are found in Kwale, Kilifi and Mwingi districts.

For many years human beings have used wind energy to grind grains, pumping water and transporting goods and people. Recently, wind energy machines which can generate electricity have been developed. The use of wind turbines or wind pumps in Kenya is marginal. The current energy capacity from wind turbines is approximately 750 kW. The Kenya Energy Generating Company (KenGen) installed two wind generators at Ngong Hills near Nairobi and one generator at Marsabit in Eastern province of the country. There are plans to connect an additional 10 – 15 MW capacity of wind generators to the electricity grid in the next 2 – 3 years. An average of 80 – 100 small wind turbines have been installed to date. Kenya has about 10 – 13 good sites with wind speeds of more than 7 m/sec. This could translate to a potential of about 100 MW of grid connected electricity from medium to large wind turbines.

Several constraints face the exploitation and utilization of wind energy resources in Kenya. These include:

- Site Selection: Wind potential assessments are site specific and time consuming. This means that wind energy development requires a large initial investment for careful wind prospecting. Expensive equipment and quality work is needed.
- Updated Wind Resource Map for Kenya: The Ministry of Energy has made some progress in this area. Suppliers of wind turbines often have to rely on meteorological data and customers' observations to determine whether a site is viable. Such information can be misleading and often leads to installation of poorly performing or non-performing systems.
- Low Awareness of Wind Energy Systems: Lack of Public Campaign and of a Professional Organization Marketing Wind Generators:

Distance From Transmission lines: Areas in Northern Kenya that have the highest potential for wind energy generation are too far from the nearest transmission line.

The government intervention regarding the promotion and utilization of renewable energy resources in general has been through the following:

- Fiscal Incentives e.g. the abolition of import duties on solar equipment.
- Policy to promote and support the development of renewable energy resources formulated in the year 2004.

- Capacity Building e.g. training of technicians and development of code of practice for technicians.
- Promotion and Awareness Creation e.g. organizing seminars and workshops, Energy bulletin publications and conducting demonstrations of renewable energy projects at the energy centers country wide.

POTENTIAL BENEFITS OF SMALL WIND SYSTEMS FOR USE IN DEVELOPING COUNTRIES

Christopher Oludhe,
Department of Meteorology, University of Nairobi, Nairobi, Kenya

Small wind turbines are devices that can produce electricity from the free flowing wind in which the moving air causes the wind turbine to rotate and generate clean, emissions-free energy that can be used to power an on-site home, farm, clinic, school, or small rural businesses.

Many home owners in developing countries have not yet realized the potential benefits of using small wind systems for their electric power generation and the reasons for this could be varied ranging from lack of familiarity with the technology to over dependence on grid connected power supply. Promoting the use of these small wind electric systems can make a significant contribution the overall energy needs of a nation.

This paper reviews the use of small wind powered systems in developing countries and provides the potential benefits of using such systems not only to community but also nationally and globally. Some of these benefits include among others, reduced pressure on the local electricity grid, reduced pollution from traditional sources of energy and increased local energy independence besides economic benefits.

REDUCING THE COST OF MANUFACTURING COMPOSITE SMALL WIND TURBINE BLADES

Paul Peterson, Sturt Wilson, David Wood, Aerogenesis Australia

This presentation will describe the development of the volume production of composite, 2.5 m-long blades for a 5 kW wind turbine. To minimise turbine cost and to encourage a substantial export market, the blades will be made in a number of countries which combine low labour costs and sufficient composite manufacturing skills. Thus a large effort has been expended in reducing the complexity, equipment requirements, and cost of blade manufacture.

The master moulds for each blade-half were machined to high accuracy at high cost from Aluminium blanks on a computer-controlled milling machine. These moulds will always

remain with Aerogenesis and plug moulds, cast from them, will be sent to prospective manufacturers. The first part of the paper will describe the production of the plug moulds.

There is a bewildering variety of possible methods of composite blade manufacture, with the main distinction being whether the moulds are closed or open. Closed moulds, whereby the blade is made in one piece, are more suitable for small blades, say 3 m long or less. However, Aerogenesis intends to develop a family of wind turbines up to 150 kW in capacity, and decided eventually that the same method should be used for all its blades. We have, therefore, finally settled on simple vacuum infusion. The blade halves, strictly the upper and lower blade surfaces from the leading to the trailing edge, are made separately and then glued together with a foam core taking the place of a spar or shear web on a large blade. Cores serve two purposes: first they keep the blade halves apart, prevent buckling, and provide some shear stiffness, and second, they act as a “glue-dam” for the leading edge. Since the laminates are typically 1.5 mm thick and meet at right angles at the leading edge, it is otherwise very difficult to ensure a good bond in this region. There is no such problem at the trailing edge.

Initially it was decided to use space-filling foam cores to simplify changing to closed-form moulding if that became necessary. The cores were machined from foam sheets – like many blade manufacturers, we use divynicell – which made it difficult to preserve the thin trailing edge region. Nevertheless, these cores proved very successful in blade making, but they cost nearly 80% of the total cost of blade materials. Abandoning the possibility of using closed moulds meant that the cores no longer had to be space filling. They could be terminated aft of the position of maximum thickness, giving cores with a very blunt “trailing edge”, and leaving a void ahead of the blade’s trailing edge. This would reduce material use and machining time. Even more radically, these blunt cores could be cast in an open mould. The presentation will describe the development of this method of making the cores.

Over the next 18 months, Aerogenesis will receive \$A750,000 from the New South Wales State Government to subsidise the installation of forty of the 5 kW turbines around the state by mid-2010. The 80 blades for these turbines will be made by a major composites company in China with whom Aerogenesis has a manufacturing agreement. The progress in transmitting the manufacturing technology and the making of these blades will be described in the presentation.

COMPUTATIONAL MICROMECHANICAL ANALYSIS OF THE STRENGTH OF TIMBER USED FOR WIND TURBINE BLADES

Hai Qing and Leon Mishnaevsky Jr.

Risø National Laboratory for Sustainable Energy, Technical University of Denmark, Denmark

The microscopic sources of high strength of timber used for wind turbine blades are analysed using the methods of computational mesomechanics [1, 2]. Using the developed 3D hierarchical computational model of softwood [3, 4], we seek to explore the effect of the wood microstructure on the service properties of wood (stiffness, strength, fatigue).

The computational model takes into account the structures of wood at several scale levels (cellularity, multilayered nature of cell walls, composite-like structures of the walls layers). At the mesoscale, the softwood cell is presented as a 3D hexagon-shape-tube with multilayered walls. The layers in the softwood cell are considered as composites reinforced by microfibrils (celluloses). With the use of the developed hierarchical model, the influence of the microstructure, including microfibril angles (MFAs, which characterizes the orientation of the cellulose fibrils with respect to the cell axis), the thickness of the cell wall and the shape of the cell cross-section, on the elastic properties of latewood was studied. The computational results are compared with experimental data.

References:

1. L. Mishnaevsky Jr, Computational Mesomechanics of Composites, John Wiley, 2007, 280 pp.
2. L. Mishnaevsky Jr, H. Qing, Micromechanical modelling of mechanical behaviour and strength of wood: State-of-the-art review, Computational Materials Science, Vol. 44, No. 2, 2008, pp. 363-370
3. H. Qing, L. Mishnaevsky Jr. 3D hierarchical computational model of wood as a cellular material with fibril reinforced, heterogeneous multiple layers, Mechanics of Materials (submitted)

VERTICAL AXIS TURBINES: A MORE APPROPRIATE TECHNOLOGY?

Leopoldo Salmaso

European Representative of TANDEM

www.tandem.or.tz sleopoldo@tiscali.it

In East Africa, as in most Developing Countries, the golden standard for windmilling is the "Old American" Horizontal Axis Turbine (HAT), which is used for pumping water through direct transmission to a mechanical pump of the force developed by the rotor. Alternative types of rotor are very rarely seen, and attempts to transform the torque of the "Old American" into electric power are sometimes made on empirical grounds.

After more than 30 years experience in Tanzania, we believe that the research for new solutions should not just look for more appropriate materials, but should reconsider the very design of the rotors. In particular, we believe that the Vertical Axis Turbines (VAT) are

more appropriate to our setting than HAT, for the reasons summarized in the following table:

	HAT	VAT
Mechanical joint points	2	1
Need of a helm	yes	no
Works with winds > 25 m/sec.	no	yes
Works with turbulent winds	poorly	fine
Resistance to hurricanes	poor	high
Relative complexity	high	low
Relative need of maintenance	high	low

We have put together a Consortium of Italian and East African subjects including:

MED srl (<http://www.ideamed.net/en/index.php>), Salesians of Don Bosco, East African Province (<http://www.dbafe.org/pages/index.php>), Eoleo (www.eoleo.org), TANDEM (<http://www.tandem.or.tz/>), TIRDO (<http://www.tirdo.org>), AGCI (http://www.assimpresa.info/AGCI_Veneto.htm), TATC (<http://www.tatcnyumbu.org/nyumbu.htm>).

We have patented a family of Appropriate Technology Windmills under the brand Eo-Leo™, to be almost entirely produced in East Africa (except the electrical components) in the range of 0,5 to 15 KW. The Eo-Leo windmills will be made accessible, royalty free, to any manufacturer in the East African Countries, and possibly in other Developing Countries.

One major boost to our project will come through the East African network of Vocational Training Centres (VTCs) run by the Salesians of Don Bosco. In fact we are preparing the curriculum for an Intensive Postgraduate Course (residential, one month) whereby the best graduate pupils from seven East African Salesian VTCs will be selected, trained and followed up so that they can earn their life by autonomously producing, installing and maintaining the Eo-Leo windmills, while remaining linked to a dedicated "Association of Past-Pupils". Through such Association we will grant follow-up, supervision, on the job retraining, archiving and networking for continuous improvement and standardization of models. Another very important part of this project is a system of incentives meant to protect the environment through the safe disposal of the poisonous Lead-Acid batteries and/or the use of non-pollutant Lithium-Polymer (LiPo) batteries.

Further external contributions for the elaboration and implementation of the Curriculum are welcome, and the potential for replication is huge because the Salesians run Vocational Training Centres in 132 Countries worldwide.

THE IMPACT OF CITY-SITE ON URBANISED SMALL-SCALE WIND SYSTEMS:

Comparing two sites to uncover the challenges and solutions

Emma Sanan, Eveready-Kestrel Wind Turbines, South Africa

Small-scale decentralised grid connected energy systems will play a significant role in the future of energy autonomy, security and supply stabilisation. Every installation has its challenges. The Encraft Warwick Wind Trials Project has highlighted issues in a developing market that need to be explored at this stage in order to find a viable solution that will enable the efficient and affective delivery of small wind systems in urban masse areas. As with the roof mounted small-scale systems there seems to be an issue coming to the fore in the urbanised small wind industry. In populated areas with buildings as well as topographical factors small-scale installation may not be reaching there full potential, as indicated in manufacturers energy output predictions. This report identifies these factors and challenges and proposes solutions with regard to urban area decentralisation and home energy diversification, by comparing an ideal site installation to an identical turbine installed only a few kilometres away. The wind, power and energy data from both shows the impact and importance of siting installations correctly and accounting for all the factors that are faced in the populated sites. Looking to the future, this article also outlines the possibility of Geographic Information Systems (GIS) overcoming the challenges that small-scale systems face. Two small-scale wind turbine sites were selected for comparison. The sites were selected for their geographical proximity to one another, as well as the system similarities, outlined below. According to Google Earth the sites are 10.14km away from each other. Site 1, at the Eveready-Kestrel Wind Turbine factory, may be found at 33° 54' 41.36" S and 25° 35' 31.24" E (refer to Figure 1 for visual). Site 2, an installation in the suburb of Lovemore Heights at a private residence, may be found at 33° 59' 15.75" S and 25° 31' 49.87" E.

THE BENEFITS OF SMALL WIND TURBINES:

Understanding how small wind turbines can be of long-term benefit in the African context and how they are used today

Emma Sanan, Eveready-Kestrel Wind Turbines, South Africa

Small-scale energy systems, whether on-grid or supplying power to areas where there is not electricity access (which is largely the state of the continent) will play a significant role in the future energy mix, autonomy, security and supply stabilisation of Africa. This presentation, through the showcasing of current small wind turbines in Africa, identifies the future role of the technology in the development of the continent and its citizens. It begins with a current state of the nation look at African energy intensity in comparison to itself and

other developing countries, as well as the African wind potential. The small wind turbine installations that are showcased include:

1. Telecommunications: Off-grid small wind systems are, currently, powering telecommunications in South Africa, Namibia and Malawi
2. Emergency Services: Off-grid small wind systems are being installed in extreme weather sites in Lesotho (and Alaska) to power radio towers used for emergency services and railway switches
3. Residential Smart Grid: To alleviate grid dependence and the impact of supply issues and promote energy independence and autonomy, a small-scale on-grid system with battery back-up has been installed in South Africa
4. Industry Efficiency: Commercial businesses and industry are using wind in innovative ways to reduce their energy usage, including IT-back up systems and ventilation tunnel installations

Looking to the future, the world is struggling to change its energy dependence and is only further inhibited by a badly designed and eroded infrastructure. Africa has the unique opportunity to not repeat the mistakes of the developed world and is doing so in its pioneering small wind systems that are now being exported to Sri Lanka, India, America and the Pacific Islands. Renewable energy will be a significant player in the world, and it can, if used properly and this stage of its development, will also be a significant contributor to African development.

SELECTION OF NEPALESE TIMBER FOR SMALL WIND TURBINE BLADE CONSTRUCTION

¹Rakesh Sinha, ¹Parash Acharya, ² Peter Freere, ³Ranjan Sharma, ⁴Pramod Ghimire, ⁵Leon Mishnaevsky Jr.
¹Kathmandu Alternative Power and Energy Group Ltd. (KAPEG), Bhatti Danda, P.O. Box 25060 Kathmandu,
Nepal

²Department of Electrical and Computer Systems Engineering, Monash University, Clayton, Australia

³Department of Electrical Engineering, Technical University of Denmark(DTU)

⁴Dept. of Electrical and Computer Engineering, University of Canterbury, New Zealand

⁵Materials Research Division, Risø National Laboratory for Sustainable Energy, Technical University of
Denmark Frederiksborgvej 399, DK-4000 Roskilde, Denmark (leon.mishnaevsky@risoe.dk)

The paper includes selection of timber for development of small wind turbine blades on the basis of locally based low cost materials and technologies for remote area application along with the selection of coatings to protect timber from weathering. The selection criterion of timber includes timber properties, weathering effect on coatings, Price, growth and availability of timber. Mechanical properties such as Young's modulus, breaking strength, breaking strain and Brinell's hardness number of selected hard and soft woods are presented. The effects of weathering on timber without coating and with different coatings are analysed on the basis of change in weight of timber due to the effect of

temperature, humidity and rainfall over the period of nineteen months. Degradation of different coatings on timber are compared

EXPERIMENTAL INVESTIGATIONS OF DAMAGE MECHANISMS IN FIBER GLASS COMPOSITES USED FOR WIND TURBINE BLADES

H. W. Zhou¹, L. Mishnaevsky Jr.², P. Brøndsted², J. B. Tan¹, L. L. Gui¹

¹Institute of Rock Mechanics and Fractals, China University of Mining and Technology (Beijing), P. R. China

²Risø National Laboratory for Sustainable Energy, DTU, Roskilde, Denmark

An increasing effort has been directed toward wind power technology in last decades. European Commission through the 6th Framework Programme Grant UpWind focuses on future wind power technology and will develop substantially improved models of the principles wind turbine components, which the industry needs for the design and manufacture of very large scale wind turbines (>8-10MW and rotor diameter>120m), both on- and off-shore. One of the challenges inherent in the creation of such power stations necessitate the advanced materials with extreme strength to mass ratios. Glass fiber-reinforced polymer (GFRP) composite, as a kind of material with high ratio of strength to mass, has been used widely in wind turbine blade.

The purpose of this study is to analyze and to clarify the micromechanisms of damage in GFRP composites under uniaxial tension tests. The GFRP specimens in the paper named laminates GF / UD (4 layers, lay-up (90/0 - 0/90 - 90/0)S, fibres PPG 2002) were provided by the Knowledge Centre of Wind Turbine Materials and Constructions (WMC), the Netherlands. The specifications of these materials are as follows: identification number 595/c, system resin RIM 135, system hardener RIM/H 134/137, system mix ratio 100/30, vacuum curing 1000, post-cure 10hrs at 70°C, material density 1940,79, Saertex weaver, curing tabs glue 2hrs at 65°C.

All the dog-bone shape GFRP specimens were prepared by water jet technology. In order to investigate the influence of fiber orientation angles on the mechanical behavior of composite materials, the fibers were arranged at different orientation angles with respect to applied tension load direction such as 0°, 15°, 30°, 45°, 60°, 75°, and 90°, respectively. 3 specimens were prepared for each orientation angle, resulting in 21 specimens in total, divided into three groups. Scanning Electron Microscopy (SEM) in-situ experiments of damage growth in GFRP composite under uniaxial tension loads were carried out. By summarizing the experimental results of three groups of samples with different orientation angles of fibers, the dependence of mechanical parameters on the orientation angles of fibers were analysed. Some statistical relations between the strengths, the elastic modulus of the composites and the orientation angles of fibers were suggested by a regression analysis. In addition, SEM photos were taken at different loads in order to characterize the meso-scale structure change in the GFRP composite. Moreover, the damage growth and meso-scale structure changes in GFRP composites during uniaxial tension loads were analyzed in the paper

