Power for the World - A Common Concept

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ABSTRACT

Within the ALIZES program in Mauritania in the Traza district, 18 villages have installed a wind battery charger for village electrification during 1993 and spring of 1996. The wind turbines installed in 1993 are in the framework of a demonstration project to test the technical performance of the equipment, and to monitor the costs and benefits. The applications vary from village to village from collective lighting to individual battery charging and water pumping. The wind turbines are Dutch Fortis types F1003 with 1 kW rated output and F2500 with 2.5 kW rated output. GRET, a French NGO, initiated a large wind pumping project ALIZES by approaching the Mauritanian Ministry of Hydraulics and Energy (H&E) in 1987. The overall objective of the program is to develop the use of wind energy in rural areas in West Africa. The first five-year program was targeted at wind pumping and led to the installation of 100 wind pumps. The whole program was so successful that the Mauritanian Ministry of Hydraulics and Energy proposed a new program for electrification with small wind chargers, the program ALIZES-electric. The project aims at developing a methodology for diffusion of wind-power decentralized systems to small villages. As in the ALIZES-pumping program, the strategy to be economically viable is the introduction of a relatively large number (100) of reliable machines that will be installed in a limited area (Traza in the South West part of Mauritania) and to form a local company to handle operation and maintenance. This paper will concentrate on three villages with Fortis wind battery chargers and technology transfer for local production of components.

1. PROJECT BACKGROUND

Mauritania is a West African country with a land area slightly over one million sq. km, but with only two million inhabitants. Two-thirds of the land is desert; the southern region is Sahelian. Only in the flood plain of the Senegal river, the border between the two countries, there is abundant water and rich soil for intensive cultivation. Ten percent of the population lives in the desert; the majority lives in just 15% of the land, primarily in the Sahelian, coastal, and Senegal river regions. The subsector of concern in the present project includes the unelectrified population in both rural areas and the approximately one million people in the peripheral zone around Nouakchott.

Because the rural population density is very low, provision to the villages of basic services such as water pumping, health care, and lighting is difficult and expensive. Even in the more densely populated southern region, villages typically have only a few hundred inhabitants. A village like Keur-Macene with more than 1,000 inhabitants is considered large. Few villages have any access to electricity.

A major problem for the country is the very rapid growth of the urban population (about 20% a year), notably in Nouakchott, as a result of rural migration. In the absence of basic amenities in the rural environment, this trend is expected to continue even though Nouakchott's carrying capacity is being severely challenged. Many immigrants to the city are unable to find any employment, and living conditions in the shanty towns ringing Nouakchott are in many ways worse than the rural environments the new residents have left behind.

The modern economy of Mauritania depends on iron ore mining, fishing and agriculture (37% of GDP in 1987) and industry (primarily fish processing and iron ore treatment, but with sugar refining, production of dairy products and small import substitution industries).

While high quality fuels and electricity are required to improve the quality of life in the rural environment, Mauritania has only three sources of energy. These are fuelwood and charcoal, which are being increasingly used in a nonsustainable manner, solar and wind energy. Some use of solar electric (photovoltaic) water pumping technology is underway with support from the European Union (EU). The European Fund for Development of the EU, for example, is financing a program for the installation of PV pumps in several areas of the country within the framework of a US$ 40 million program for PV pumping in West Africa. A wind mechanical water pumping project has been extended to some 150 villages in Traza and other areas by Project ALIZES. A few small wind electric installations are also in progress. All petroleum is imported, and in rural areas the price of kerosene is about $100/bbl.

This project was designed to build on a very successful collaborative effort (Project ALIZES) between the Government (Ministry of Water and Energy, Division of Energy), and GRET, a French NGO to establish a sustainable program of village-based water supply using wind-mechanical water pumping units. GRET and the local private sector have established the in-country capability for equipment supply, installation, maintenance and service. By requiring (and getting) financial and social participation by the villagers, the program has been able to provide clean water on a reliable and continuous basis in over 150 villages now served. Over a period of six years, in collaboration with the local private sector, Project Alizes has implemented an effective program to bring wind mechanical water pumping technology to Mauritanian villages, and with it, reliable supplies of potable water. The project arranged an extensive collaboration and technology transfer between a Mauritanian and a French company. The significant benefits of this transfer of technology are:

- The local availability of high-quality units at a significantly lower price (approximately 30%) than if purchased abroad;
- Elimination of foreign exchange requirements:
- Elimination of difficulties (such as special permission from government) in importing machinery into the country; and
- In-country support of operation and maintenance warranty, something not practical with foreign-purchased mechanical equipment.

The project ALIZES-electric, aims at developing a methodology for diffusion of wind-power decentralized systems to small villages. Started in 1995, it was financed by the Global Environment Facility (GEF) with a US$ 2 million budget for two years. Fortis, a Dutch company with 18 years experience in small wind turbine development, was selected in an international bid to provide wind turbines for the first stage. The strategy to be economically viable is to introduce relatively large number of reliable machines in a limited area. The objective is to allow a local company to handle the operation and maintenance.

The Alizes-electric principal project tasks are to:

- Conduct a market study to establish needs and opportunities for wind-electric systems,
- Choose the most appropriate end-use technologies,
- Select international suppliers and local enterprises through an international competitive bid,
- Install demonstration units in the Pilot Zone,
- Implement a training program for participating local enterprises,
- Evaluate and communicate the characteristics of the wind systems,
- Design a mechanism for diffusion of wind-electric electrification,
- Implement a training program,
- Conduct experimental tests and assessments,
- Install about 100 wind electric systems,
- Document and communicate the results of the project experience,
- Explore approaches for integration of renewable energy technologies into national policy,
- Prepare a preliminary Wind Energy Atlas of Mauritania,
- Catalyze the diffusion of small wind electric systems, and
- Secure project financing for Phase 2.

2. MAIN CHARACTERISTICS OF THE APPLICATIONS (SYSTEM DESCRIPTION)

2.1 Specifications of Components

All components of the system except the tower of the Fortis 1003 wind turbines were made in the Netherlands and shipped to Mauritania. The wind-turbines are traditional three-bladed upwind horizontal axis machines directly driving a permanent magnet alternator. The variable frequency, variable voltage output of the alternator is rectified to DC by a voltage control system which also regulates the charging current depending on the battery state of charge. An inverter that follows the battery bank to generate an AC output, also controls over-discharging of the batteries. Turbine overspeeding is controlled automatically by turning the rotor out of the wind at high speeds. In addition, the rotor can also be braked electrically by short-circuiting of the alternator terminals.

2.2 System Description

In this section the details of the three sites that are equipped with a wind turbine in the framework of the Project ALIZES-electric are discussed, namely: Tigent, Keur Macene, and M'Balal.

For Tigent

The schematic layout is given in Fig. 1. In this village the first and only Fortis 2500 was installed on a guyed tower of 18 m high. This wind turbine replaces the Fortis 1003, which was installed in 1993 for test and demonstration. A battery bank of 950 Ah distributes electricity through a 3 kVA sinusoidal wave inverter, to a small grid of 220 V/AC. Each user can apply for either one lamp of 18 W or two lamps (one of 18 W plus one of 10 W) and black and white TV. It serves two restaurants, 14 shops and 150 families. The electricity is available from about 18:00 hour to about 23:00 hour each day. Because there is a guarantee in power supply there is a 7 kVA diesel generator installed as back-up. The battery capacity is suitable for two days. During autumn when the average wind speed is very low the diesel generator set covers the shortage in power. The generator set is started and stopped by the operator. Solar modules are no alternative for the diesel generator because this extra power is only needed during autumn and to supply about 10 kWh per day a very large system is needed. Each family has a controller, which blocks the connection when the bill for the electricity is not paid in time.

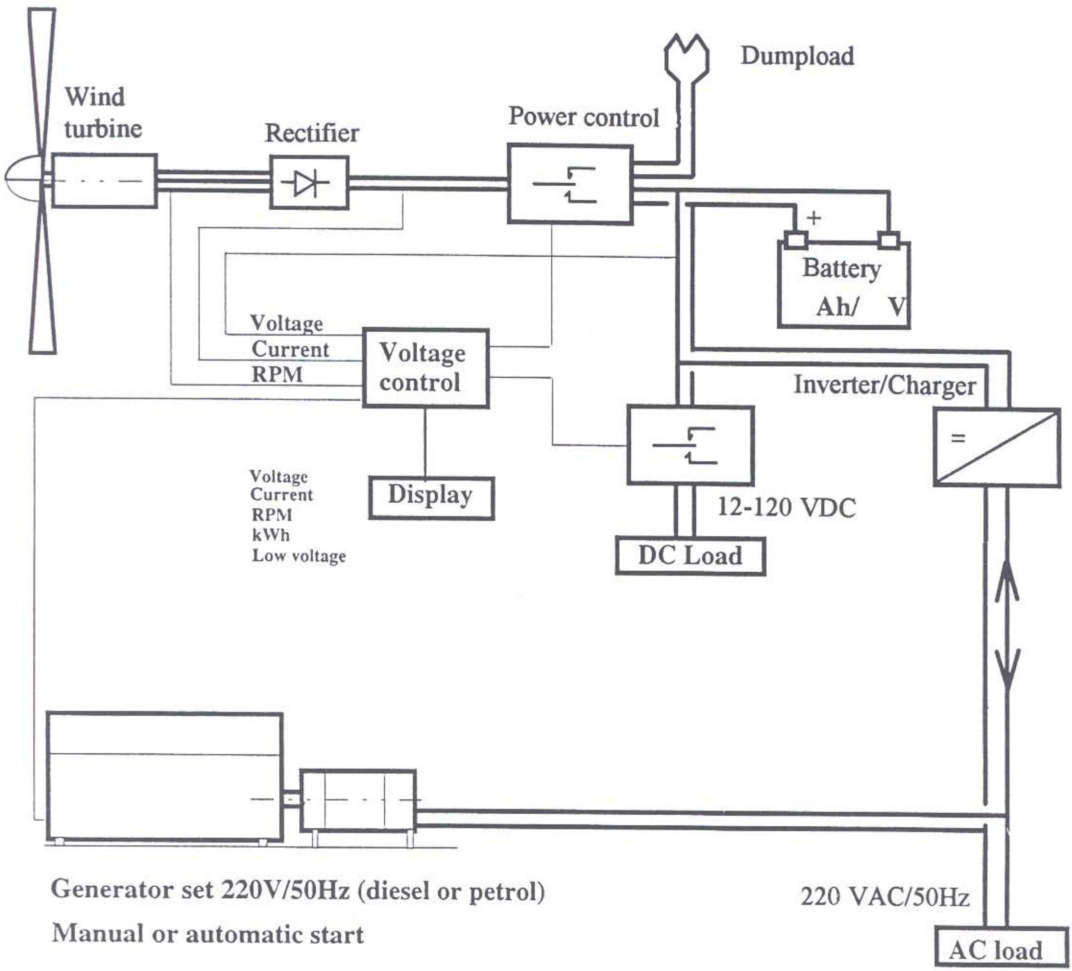

Fig. 1. Wind turbine - generator set stand-alone system with battery back-up.

For M'Balal

In M'Balal, a Fortis 1003 wind turbine was installed in 1993 for demonstration. The wind turbine was used to charge 50 Ah/12V batteries for individual use. Figure 2 gives the schematic layout. Some 50 to 60 users have bought an "energy box" that consists of a wooden box for transport and contains: one battery of 50 Ah/12V; one charge controller; and plug and socket for connection to the wind turbine or house installation.

The electricity production of the wind battery charger at the yearly average wind speed of 4.6 m/sec is 3.3 kWh/day on an average (measured value), which is sufficient to charge six to seven batteries per day. One family needs about three chargings a month. This means that average 60 families can be connected to the system. Because the wind speed in the autumn is low, the maximum number of families is set on 50. Of the 14 wind turbines installed in spring 1996, 12 were used as battery charging station for 50 families. Through increase in efficiency, it becomes possible to serve 60 families with one wind turbine.

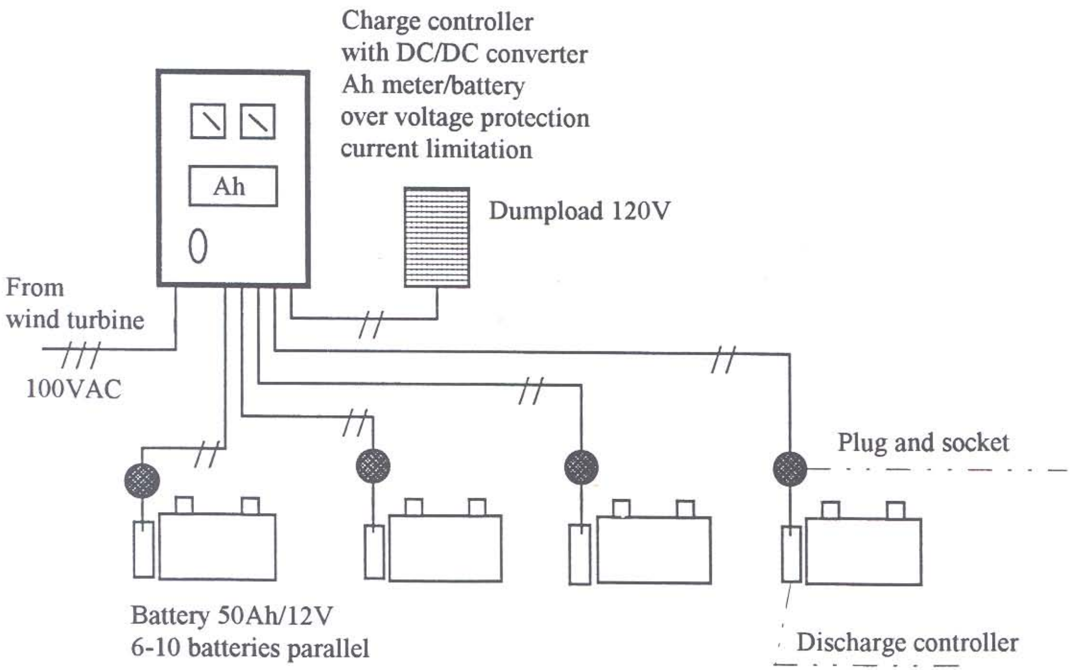

Fig. 2. Electric scheme of individual battery charging system.

For Keur Macene

The third application was a wind turbine Fortis 1003 installed along the river Senegal. Here the system was more complex, as depicted in Fig. 3. It provides electricity via an Atlas inverter to a water treatment plant that consists of the following components: a setting tank; a chlorinating/dechlorinating unit; a storage tank of 60 m^3; and two centrifugal pumps - one Allweiler providing 9 m^3/h for 4.5 m pumping head, and one Guinard submersible pump providing 4.5 m^3/h.

Besides, 24 V DC from the battery bank was made available for lighting. The electricity produced by the wind battery charger is 3.8 kWh/day over the year at the yearly average wind speed of 4.5 m/sec. The average energy demand of the water treatment plant was 70.5% of the energy production (measured in the month of February with an average wind speed of 4.6 m/sec.)

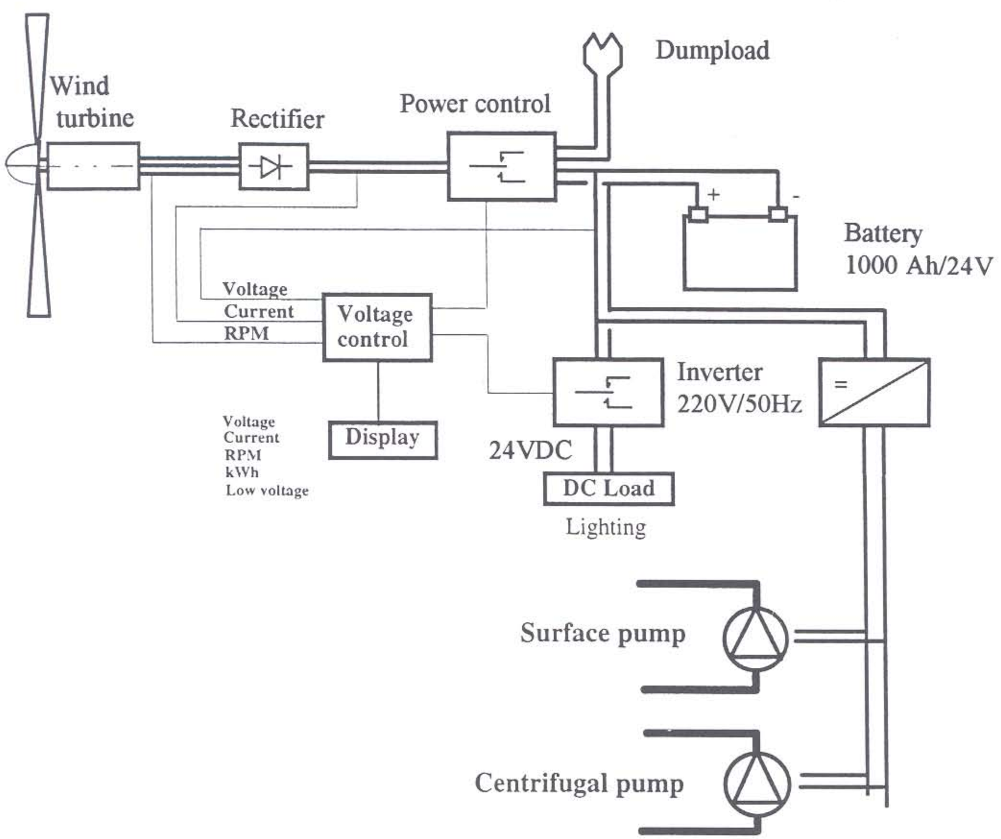

Fig. 3. Wind turbine - battery charging system with AC pumping system through inventer.

3. COST OF SYSTEMS (ECONOMICS)

The wind turbines are mainly used for charging batteries. These batteries will be used in private houses with one or two 8 W to 18 W tube lights and black/white TV set per household. The families in the villages pay 200 MU (US$ 1.5) monthly and 200 MU per charging. One family needs about 3 to 4 chargings a month. With 60 families connected to the wind turbine, the annual turnover is 576,000 UM (US$ 4,450) for each turbine. From this money, annual maintenance/ service cost and the operator cost can be paid. The maintenance cost includes the cost for replacement or repair of components within 72 hours. Once a year a general check-up of the total system will be carried out. The operator will connect the batteries to the wind turbine, collect the payment and will inform the "Deyloul" if any failure occurs in the system.

The investment needed for one Fortis 1003/1500 windturbine system completely installed is shown in Table 1 and the investment for one "energy box" is shown in Table 2. It can be concluded that the cost of the 60 "energy boxes" is two times the price of a completely installed wind turbine system. If it is taken into account that one family consists of 15 persons then a total of 750 persons is served.

Table 1. Budget prices for one FORTIS 1003/1500 windturbine system.

Windturbine System FORTIS/Deyloul PASSAT (1500)		
Fortis Passaat PM generator, output for 24 V DC	Hfl 961	= US$ 506
Fortis Pasaat rotor, diameter, 3,12 m, made of G.R. Polyester assembled and balanced	Hfl 1,577	= US$ 830
Tail and tailvane for Fortis Passaat	Hfl 465	= US$ 274
Frame and tower top section for Fortis Passaat	Hfl 488	= US$ 288
Tower of 12 m	UM 133,200	= US$ 987
Foundation for tower within 200 km from Nouakchott including the tower		
Installation cost within 200 km from Nouakchott	UM 95,000	= US$ 703
Housing for controller and batteries	UM 49,500	= US$ 367
Cable 20 m (3 x $10m^2$)	Hfl 336	= US$ 177
Voltage control with current limitation of 6 A and over voltage protection at 13.8 V to 14.2 V, suitable to charge 6 to 10 batteries of 50 Ah/12V with charged power meters	Hfl 2000	= US$1,052
Cost per Km when site is more than 200 km from Nouakchott	UM 57/km	
Total price for one installation	**Hfl 9,850**	**= US$ 5,184**
Transport cost CIF Nouakchott including 50 batteries Fulmen 50 A	Hfl 400	= US$ 235

Table 2. Price of battery kit.

Battery Fulmen type 50 ST, 50 Ah, including 2 cables of 0.4 m and strap	Hfl 182	=	US$ 96
Battery Support	UM 1000	=	US$ 7.5
Controller for under voltage protection 10 A	Hfl 100	=	US$ 58
Plugs/socket and switch	UM 2500	=	US$18.50
Assembling	UM 500	=	US$ 4
PLlight 12V- 11 Watt, 900 Lumen	Hfl 62	=	US$ 33
Total price of battery kit excluding tube light			**US$ 217**
Total price of FORTIS Passaat (1500) wind turbine with 60 battery kits	**UM 2,189,000**	**=**	**US$ 16,459**

Exchange rate: US$ 1 = UM 133 = Hfl 1.90
Annual income per system is:
Per charger 200 UM (3 to 4 charges per month)
Basic payment 200 UM/month
Total income per year is 576,000 UM = US$ 4,330

The installed capacity is 2 W per capita and the investment costs is about US$7 per capita for the wind turbine system. For the "energy box" the investment is $14,70 per capita, which makes a total investment of US$ 21.70 per capita.

According to Wolfgang Palz [1], the required installed PV capacity per capita in Africa is 6.6 W peak (10 Wp including technical losses) of which 1.1 W peak is required for lighting and TV. Installation price is about US$ 7 per watt peak, of which the module price is US$ 3. This module price is lower than the current market price. If the current market price of a watt peak is taken into account then for the rest of the PV system US$ 6 must be used. This makes the current market price for a PV system about US$ 12 per watt peak which is US$ 17.5 per capita. (This price does not include batteries and inverters).

In Table 3 the system price of the Fortis 2500 is given. The total installation price of the Fortis 2500 is US$ 14,889, or US$ 21,556 including batteries and inverter.

To create a local grid for 200 people, there is an investment requirement of about US$30,000. This means that the total investment is about US$ 55,000 for a small grid to serve 200 families. With a village of 3000 people with 200 families of 15 people each, the investment per capita in wind turbine system is US$ 4.30 with an installed capacity of 0.83 W per capita. If the total cost of the mini-grid is taken into account the investment per capita is about US$18.30.

The contribution of the villagers connected to the grid is about 800 UM (US$ 6/month or US$14,400/year).

Table 3. Price of windturbine system FORTIS Boreas (2500)-24 V.

One Fortis Boreas - 24 V windturbine, rotor diameter 5 m, output 2500 W (100 A) at 12 m/s. windspeed, max. output 2700 W, min. effective windspeed 2.0 m/s	Hfl 8,595 =	US$ 4,523
One voltage control type MP II 120 A - 24V with volt and ampere meters rectifier, power controller, dumpload	Hfl 2,323 =	US$ 1,223
One steel guyed mast of 18 m high, size 5" (139.7 x 5.0 mm) hot zinc dipped, fully equipped with turnbuckles, guy wires clamps and tiltable base plate	Hfl 4,395 =	US$ 2,313
One battery bank 1000 Ah/24V/100hour consisting of 12 HAGEN low maintenance marine type, lead acid, deep cycle batteries	Hfl 5,715 =	US$ 3,008
One inverter ATLAS 24/3000, input 24 V DC, output voltage 220V, 50Hz. Max. continuous load 3000 W	Hfl 4,615 =	US$ 2,429
Set electric cable 30 m, 3 mm x 10 mm (from windturbine to controller)	Hfl 504 =	US$ 265
Total price F.C.A. Groningen	**Hfl 26,147 =**	**US$ 13,762**
Transport cost including batteries together with Fortis Passaat windturbines	Hfl 600 =	US$ 353
Foundation and installation cost within 200 km from Nouakchott	UM 180,000 =	US$ 1,406
Housing for batteries	UM 49,500 =	US$ 198
Cost per km when site is more than 200 km from Nouakchott	UM 112/km	
Total price for one installation	**US$ 1,957 + 13,762 =**	**US$ 15,719**

4. CONCLUSIONS

If the price of a PV system is compared with the wind turbine system then wind energy is much cheaper than solar energy, even when the average wind speed is less than 4 m/sec and the solar radiation is 5000 W/m²/day (and even if the lifetime of a wind turbine system is about 15 years and the solar system have a lifetime of 20 years). Small wind turbine systems need only little maintenance a year.

The prices of installation per capita are:

- Solar energy system = $17.50; through mass production = $10
- Wind turbine Fortis 1003 = $7; through mass production = $4.25
- Wind turbine Fortis 2500 = $4.30; through mass production = $2.50

The wind turbines are supplied with a two-year warrantee. This means that there are no maintenance cost in the first two years. Both systems will become cheaper through mass production. The paper of Wolfgang Palz [1] assumes that the price reduction will be 50% in the module price.

The price of wind turbines can be further reduced to more than 50% as follows:

1. Mass produce wind turbines utilizing known technologies. This means that there is hardly any investment needed for R&D.
2. Utilize local industry to produce 50% to 80% of the wind turbine. China produces wind turbine 100% locally. The benefits of local production are:
   - Reduction in production costs because the labor costs in developing countries are less than that in European countries.
   - Economical benefits through reduction of import, more employment, and an impetus to local enterprises.
   - Import of new technologies which have influence on other local industries.

5. RECOMMENDATIONS

For large-scale introduction of small wind turbine the initial steps are:

1. To set-up design and test tools for the development of reliable small wind turbines. Of the small wind turbines available in the market only a few are tested but none of them are designed and tested according to IEC-88 regulation for small wind turbines. The cost of these tests is very high (sometimes 100 times the price of the product).
2. To draw up an inventory of projects with small wind turbines to be able learn from experience.
3. To list reliable products available. Financial institutes are willing to support projects for decentralized wind electric power.
4. To set-up a program to disseminate information and knowledge of small wind turbines and their applications.

6. REFERENCES

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