GrIPP-Net News

A quarterly Newsletter of the EC-ASEAN Green Independent Power Producers Network
Vol. 3, No. 3 (July 2005)

Editorial

The third edition of the GrIPP-Net News highlights wind power developments in Europe and ASEAN. It reviews the EU wind power market, wind power development in the ASEAN, technology trends, and wind power project costs. Europe continues to be the leading market of wind power. Nine out of the world's ten largest wind technology manufacturers are based in Europe. Data for 2002 show that European companies supplied around 90% of the wind capacity sold worldwide.

Among the ASEAN countries endowed with commercially exploitable wind energy resources are Cambodia, Lao PDR, the Philippines, Thailand and Vietnam. At present, the Philippines takes the lead in terms of market deployment and promotion of private investments while Vietnam emerges as a main challenger with various activities being undertaken that could lead to huge investments in wind power development.

Among the initiatives of the Green IPP Network partner in the Philippines, the University of the Philippines Solar Laboratory (UPSL) is a national workshop on the Current Status of the Development of Green Independent Power Producers in the Philippines: Challenges, Strategies and Case Studies, to be held on August 10, 2005 at the PLDT Multimedia Hall, EEE Building UP Diliman Q.C. Details of the workshop can be obtained from the Philippine Green IPP Network Coordinator Ms. Gilba Joy Padilla (gilba@eee.upd.edu.ph).

INSIDE

The EU Wind Market

The world's wind energy resource is estimated to be around 53,000 TWh per year. More than one-fourth of these resources are found in North America while Africa and Eastern Europe (including the former Soviet Union), each account for one-fifth of these resources. Western Europe on the other hand accounts for only 9% (or 4,800 TWh) of these global resources; but its estimated technical potential for wind power is lower than the available resources. Onshore wind power technical potential is placed at 600 TWh per year while the offshore potential is estimated to be around 300 TWh per year.

Western Europe however leads globally in terms of wind power development, and is the leading market for wind power. In 2004, 71% (5886 MW) of the world's capacity additions were in Europe. The region's total installed wind power capacity at the beginning of 2005 reached 34.6 GW, representing 73% of the global capacity.

An interesting development in Spain is the passage of new improved legislation supporting wind power development. The country has become the new leader with respect to new capacity additions, dislodging Germany from the number one position in 2004 (Table 1). Spain recorded 2061 MW new installations in 2004 against Germany's 2020 MW. Germany however remains the global leader in terms of total installed capacity with more than one-third of the world's total installed capacity at the end of 2004.

Capacity additions in Denmark – the world's pioneer in wind power – have fallen to only 7 MW in 2004. This is mainly due to the government's decision to discontinue the feed-in tariff scheme, which was the driving force behind the wind power development in the country. Globally, Denmark occupies the fourth place in terms of total wind power capacity with 3117 MW in 2004.

Markets with more than 100 MW wind power capacities have also emerged in Europe. In 2004, medium-sized markets with growth more than 50% included Norway, Ireland, Portugal and France.

Other important markets of wind power in the world are the US, Asia and Australia. The US is the third largest market with a total installed capacity of 6740 MW in 2004. Capacity additions in 2004 slowed down to only 370 MW due to the delay in the extension of the production tax credit scheme.

India, Japan and China ranks 5th, 8th and 10th in the global market, respectively with total installed capacity of 2985 MW, 896 MW and 764 MW respectively in 2004. India's new installation of 875 MW in 2004 was also the world's third largest. Japan's capacity addition in 2004 is slightly higher than the US at 390 MW, while China commissioned 197 MW wind power capacity during the same period. Australia ranks 17th with the total installed capacity of 379 MW. Around one-half of the capacity was commissioned in 2004.

Table 1. EU Wind Power Installed Capacity and New Installation in 2004

Country	New Installation in 2004 (MW)	Total Installed Capacity, end of 2004 (MW)
Germany	2 020	16 628
Spain	2 061	8 263
Denmark	7	3 117
Italy	221	1 125
The Netherlands	170	1 078
United Kingdom	240	888
Austria	191	606
Portugal	223	522
Greece	124	489
Sweden	43	442
France	138	386
Ireland	153	339
Norway	176	276
Belgium	27	95
Finland	30	81
Poland	6	63
Luxembourg	13	35
Latvia	2	27
Czech	7	17
Lithuania	5	7
Estonia	3	6
Slovakia	3	5
Hungary	1	3
Cyprus	0	2
TOTAL	5 864	34 500
WORLD	8 321	47 616

Source: www.wwindea.org

The medium term prospect for wind power in Europe is robust, driven by the current Renewable Energy Directive of the European Union with strong policy support from individual member countries. The Directive aims to increase the renewable energy share in the total electricity consumption to 22% in 2010. The European Commission projects that wind power in Europe could reach 69,900 MW by 2010.

Sources: www.ewea.org; www.wwindea.org; Wind Force 12 (June 2005)

Offshore Sites: The New Frontier

Wind industry's new frontier are the offshore sites. These sites offer high and more predictable wind speeds averaging more than 8 meters per second at a height of 60 meters. Offshore sites in Northern Europe are estimated to deliver 20-40% more energy than good shoreline sites. Also, offshore sites have reduced landscape impacts. European countries with large offshore wind potential are Denmark, the UK, Sweden, the Netherlands and Ireland.

The cost of generating power in offshore sites is however high since offshore wind farms require strong foundations, longer power transmission cables, special equipment and marine vessels to undertake construction and maintenance works during favorable weather conditions. As the demand increases, economies of scale could nonetheless be achieved causing the costs to fall down.

Denmark is currently the leading European country in terms of offshore wind power development. Two offshore wind farms were constructed in 2002 (Horns Rev – 60 MW) and 2003 (Nysted – 165.6 MW). Two new projects of 200 MW each are being developed.

The United Kingdom on the other hand is challenging the Danish leadership. The country's first allocation round for exploration rights had generated proposals with more than 1,000 MW of capacity. At present, two wind farms have been already built (60 MW in North Hoyle and 60 MW in Scroby Sands). Two new sites are being developed – Kentish Flats and Barrow (both 90 MW) – with construction to begin this year. The second allocation round in 2003 had resulted in 15 proposals with a total capacity of 7,200 MW.

Another country with ambitious offshore plans is Germany. Construction permits were granted to 6 projects in the North and Baltic Seas with total capacity of up to 1,200 MW. The German government aims to generate offshore wind farms with total capacity of 25,000 MW during the period 2025 – 2030.

Other European countries with offshore plans include the Netherlands (the construction of 2 projects 120 MW and 99 MW to begin soon, Belgium (the construction of 1 300 MW to commence soon), Ireland (the Arklow Bank wind farm pilot project with total capacity of 520 MW was completed in 2003), and Sweden (approval was granted to 48 wind turbines to be installed in the Øresund Strait.

Source: Wind Force 12 (June 2005)

Wind Energy Development in ASEAN

ASEAN countries with commercially exploitable wind resources include Cambodia, Indonesia, Lao PDR, the Philippines, Thailand and Vietnam. The wind resource potential and current utilization in the region are summarized in Table 2.

Table 2. Wind Resource Potential and Utilization in ASEAN

Country	Potential	Utilization
Cambodia	Theoretical potential 1.3 GW (7-8 m/s) 120 MW (8-9 m/s)	
Indonesia	Theoretical potential Significant (3-6 m/s)	0.5 MW
Lao PDR	Theoretical potential 24 GW (7-8 m/s) 2,7 GW (8-9 m/s)	
Philippines	Theoretical potential 76,600 MW Technical potential 7,404 MW	1.18 MW (commercial operation)
Thailand	Theoretical potential 3 GW (7-8 m/s) 52 MW (8-9 m/s) Technical potential l,600 MW	0.7 MW
Vietnam	Theoretical potential 103 GW (7-8 m/s) 8.7 GW (8-9 m/s) 452 MW (>9 m/s)	

Sources: Cambodia - TrueWind Solutions, LLC (2001); Indonesia – Ministry of Energy and Mineral Resources (2004); Lao PDR - TrueWind Solutions, LLC (2001); Philippines – Department of Energy, Wind Power Kit (2004) and Philippine Energy Plan (2005); Thailand – DEDE (2004) and TrueWind Solutions, LLC (2001); Vietnam – TrueWind Solutions, LLC (2001).

Cambodia

The Cambodian Ministry of Industry, Mines and Energy (MIME) has identified the country's coastal areas to have the highest potential for wind energy development. The current activities involving wind power in Cambodia are the following:

1. Telecommunications. One telephone company has installed 400 W turbines in 5 sites at Koh Kong Province with total capacity of 8 kW.

2. Public infrastructure. Several non-governmental organizations have installed a total capacity of 5 kW in schools and health centers. These are mainly intended for water pumping using hybrid systems (solar and wind).

3. Individual households. A number of individual households and farms have installed mechanical wind pumps for water pumping.

4. Battery charging stations. Six battery charging stations were installed in Takeo Province powered by solar and wind hybrid system. Each system has an installed capacity of 508 W consisting of 400 W wind turbine and 108 W solar PV module.

Major barriers that impede the development of wind power generation in Cambodia are the following: lack of awareness and political support; lack of policy and legal framework; lack of resource potential information; lack of access to financing; and lack of institutional capacity for planning, implementation and maintenance.

Philippines

The Philippines is the most aggressive country in ASEAN in terms of wind power development. The government issued an executive order in 1997, the EO 462, which provides incentives and permits private sector participation in wind energy development in the country (this was later amended by EO 232 issued 2000). After the launching of the Renewable Energy Policy Framework in 1983, which targets the development of identified sites, the Philippine Department of Energy organized a trade mission to Europe in 1983; launched the Wind Power Investment Kit in June 2004; organized the Wind Power Summit in December 2004; and undertook the Wind Contracting Round in March 2005.

The incentives embodied in EO 232 are the following:

- Payment of production bonus shall be applied only after the project has fully recovered its pre-operating expenses.
- Developers shall be allowed to charge cost of assessment, field verification, and feasibility studies of other sites to its current commercial projects.
- The government facilitates developers in obtaining fiscal and non-fiscal incentives from the Board of Investment (BOI), and in securing access to lands and offshore areas.

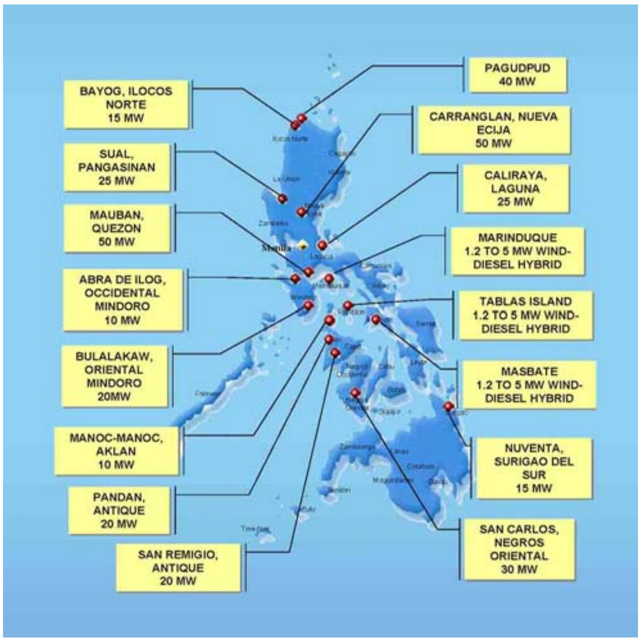
The BOI incentives include the following:

- Income tax holiday. 6 years for projects with pioneer status and 4 years for non-pioneer status.
- Additional deduction for labor expense. To be availed within 5 years of registration, additional deduction from taxable income 50% of the wages for direct labor of skilled and unskilled workers.
- Unrestricted use of consigned equipment.
- Employment of foreign nationals.
- Additional deduction in taxable income for necessary and major infrastructure works if

the project is located in less developed areas or areas with deficient infrastructure.

During the launching of the Wind Energy Kit, 16 potential wind sites were offered to the private sector with a total capacity of 345 MW. At the First Philippine Wind Power Contracting Round, the government granted pre-commercial contracts to develop 5 sites in the country with a total capacity of 85 MW (Philippine Hybrid Energy systems Inc. – 30 MW; Trans-Asia Renewable Energy Corporation – 30 MW; and San Carlos Wind Power Corporation – 25 MW).

Figure 1. Wind Sites Promoted for Development by the Philippine Department of Energy



The Philippine National Oil Company – Energy Development Corporation (PNOC-EDC) is planning to develop a 40 MW wind farm. The project is to be funded from ODA loan from the Japanese government through the Japan Bank for International Development.

The trade missions to Europe generated funding commitments from the governments of Germany (€40 million) and Spain (US$ 105 million) for the development of several potential sites in the country.

The major milestones in the Philippines are the following:

- Commissioning of the first wind-diesel hybrid power plant (3 x 60 kW wind turbine generators and 2 x 500 kW diesel generators) located in Batan Island in Batanes Province in August 2004. This project is a joint initiative of the Department of Energy, National Power Corporation, Department of Science and Technology, First Philippine Energy Corporation and the provincial government of Batanes.
- Commissioning of the first and the largest wind farm in Southeast Asia in April 2005 – the 25 MW Northwind Power Development Corporation Project. The Company is a joint venture between Danish and Filipino investors.

Sources: Philippine Energy Plan 2005 Update; Philippine Department of Energy.

Thailand

The Electricity Generating Authority of Thailand (EGAT) had taken the lead role in demonstrating electricity generation from wind. In the beginning, EGAT cooperated with various local institutions to demonstrate small-scale wind turbine generation ranging from 0.2 to 1.0 kW. At the later stage, EGAT installed several small-scale wind turbines at Leam Promtep, in Phuket Island. Two American manufactured 10 kW turbines were installed in 1993 and used for battery charging stations. In 1996, one unit of Nordtank's 150 kW was installed and connected to the local distribution network. EGAT aims to gain experience from this demonstration project on the selection of appropriate types of wind turbine generator. Also the information collected from the project, the technical skill developed, and the problems encountered during the installation would be useful for future investments on larger wind turbines.

Currently, the Department of Alternative Energy Development and Efficiency (DEDE) of the Ministry of Energy is undertaking wind measurements and policy studies to promote wind energy investments in the country. Wind energy has been identified as one of the sources to meet the renewable energy target of 8% and to qualify for the renewable energy portfolio standards (RPS) of 6% in 2011. Various incentives are being studied by DEDE.

Sources: EGAT, DEDE.

Vietnam

Vietnam's Institute of Energy (IE) has identified various sites along the coastal line and islands wind conditions suitable for construction of large farms wind farms, which could be connected to the national power grid. The country is poised for major wind power development in the near future.

Since the 1980s, IE was entrusted by the Ministry of Electricity (now Ministry of Industry) to review the implementation of wind turbines for power generation in islands and remote grid connected areas. IE and several research institutes (University of Hanoi, Institute of Mechanical Design, Research Center for

Thermal Equipment and Renewable Energy) had developed, manufactured and installed low capacity turbines in various villages and households.

Some of the recent wind power developments are the following:

- 15 kW solar PV-wind power hybrid system in one of the minorities' village with 40 households. The project was implemented by IE with grant from Tohuku Company of Japan.
- 800 kW wind power generator in Bach Long Island financed completely by the Government of Vietnam using Spanish wind technology (Made Technology S.A.)

The main incentive for wind power investors in Vietnam is the 100% tax exemption in the importation of wind power technology and equipment.

Future wind energy development in the country includes the following:

- 2 MW wind power installation in Ly Son Island. The feasibility study has been completed by the Institute of Energy. EVN is the main project investor.
- 15 MW wind farm in Binh Dinh Province. The tender for equipment supply is currently open. The feasibility study was prepared by Phuong Mai company.
- Wind Power Project in Ninh Tuan Province funded by the Indian Government and Electricity of Vietnam. IE completed the feasibility study.
- 84 MW Wind Power Project in Phuong Mai. The main investor is Grabowski Renewable Energy Company no. 1 Ltd.
- 2.5 MW wind project in Phu Quoc Island.
- 15 MW wind farm in Phu Yen Province. The project is owned by VINACONEX. IE prepared the feasibility study.
- 2.5 MW Wind Project in Co Dao Island. IE is currently undertaking the feasibility study.

Source: Institute of Energy

ASEAN's First Wind Farm

ASEAN's first wind farm was inaugurated last June 2005. The US$ 47.6 million wind farm is owned by the Northwind Power Development Corporation - a joint venture of Filipino and Danish investors. The project comprises 15 units of 1.65 MW Vestas turbines arranged in single row along the coast of Bangui Bay in Ilocos Norte Philippines. The project includes the construction of a 50 km 69 kV overhead transmission line to deliver the power to the switchyard of the Ilocos Norte Electric Cooperative (INEC), which has the exclusive franchise to distribute electricity in the province.

Northwind signed an Electric Sales Agreement (ESA) with INEC in July 2002. The project is estimated to generate 74.48 GWh annually, which is 40% of the electricity needs of Ilocos Norte Province in 2003.

The Danish government through Danida provided a capital of US$11.2 million to seed the project and another US$8 million in grants for its completion. An export credit facility of US$29.35 million has been arranged under a loan agreement between the Northwind Power Development Corp., the Trade and Investment Development Corp. of the Philippines, ABN-AMRO bank NV and the Danish Export Credit Agency, payable in 10 years with zero interest rate. The Philippine Export-Import Agency has agreed to guarantee up to US$28.8 million of the total project cost.

The incentives granted to the project by the Board of Investment are income tax holidays for 6 years and reduced import tax of 1% (instead of 3%) for capital equipment, spare parts and accessories. Northwind Power Development Corp had also signed with the World Bank an emission reduction purchase agreement (ERPA) for the purchase of carbon emission reductions credits generated by the project.

Another 15 wind turbines will be added in the second phase of the project.

Source: Wind Force 12 (June 2005).

Figure 2. 25 MW Northwind Project Under Construction (March 2005). Picture copyright – Per Nørgaard, Risoe National Laboratory

Wind Energy Technology Trends

The principal components of a commercial wind turbine are the following: rotor which consists of the blade and hub; nacelle which houses the gearbox and generator; tower; control; foundation; and transformer. Modern wind turbines have 3 blades and their speeds are controlled by either stall or pitch regulation. The rotor of commercial turbines are either connected to the generator through the gearbox and drive train or coupled directly to the generator.

Wind turbine design drivers include the following: low wind and high wind sites; grid compatibility; acoustic performance; aerodynamic performance; visual impact; and offshore expansion. The large unexploited potential of offshore areas drives the recent developments of wind technology. Considerations for the development of large turbines for offshore areas are: low mass nacelle arrangements; large rotor technology and advanced composite engineering; and design for offshore foundations, erection and maintenance.

Turbine Size, Rotor Diameter and Hub Height

The size of commercial wind turbines has steadily increased from 20-60 kW units in 1980s. Commercial prototypes of 1-2 MW turbines appeared in 1990s. The first 4.5 MW prototype was constructed in 2002 and two 5 MW prototypes in 2004. 7-12 MW wind turbines are being talked as the next generation of offshore turbines.

Wind turbine's power rating is determined by the square of the rotor diameter. Thus, the increase in turbine size is associated with increase in rotor diameter. The 50 kW turbines in the 1980s had diameter of 15 m, the 500 kW units in early 1990s had 40 m diameter, the 2 MW models have 80 m diameter, and the 5 MW prototypes have more than 120 m diameter. The 7-12 MW turbines could have rotor diameter of more than 200 m.

For turbines with the same power rating, there has also been a remarkable increase in rotor diameter. For 1.5 MW wind turbines, for example, turbines manufactured in 1997 have average diameter of 65 m while models in 2003 have average diameter of 74 m. This is partly due to the optimization of design to maximize energy capture on low wind speed sites.

Hub height selection is site dependent. There is a trade off to be made between the benefits of extra energy derived from elevating the rotor to higher heights and the cost of larger towers. Offshore sites have relatively low wind shears and will not benefit from increasing the height of the towers. Large offshore turbines could be expected to have less than or equal to the rotor diameter with provisions for blade tip clearance in extreme wind conditions.

Power Control and Speed Variation

During high operational wind speeds, power is regulated either by stall or pitch regulation. Stall regulation requires speed control, which is achieved by connecting the generator to the grid. The grid holds the rotor speed constant regardless of changes in wind speed. As the wind speed increases, flow angles over the blade section steepen and the blades become increasingly stalled thus limiting power to the desired levels. Pitch regulation on the other hand involves turning the blades about their long axis to regulate the power. Pitch regulation however requires changes to rotor geometry as well as active control systems to sense blade position, measure output power and instruct changes in blade pitch.

The Danish classic wind turbine designs are stalled regulated but pitch regulation is becoming favored for large wind turbines. Most multi-MW wind turbines available in the market at present are pitch regulated. This is due to the fact that pitch regulation offers better output power quality. Also, for certification purposes, the independent operation of each pitch actuator allows the rotor to be regarded as two independent braking systems.

During the earlier years of wind power generation, wind turbines operate at fixed speed when generating power. At the start up, the rotor is initially parked, then accelerated by the wind until the desired speed is reached during which the connection to the grid is only made. As wind speed continues to increase, the rotor speed is controlled by either stall or pitch regulation. Variable speed designs were later introduced to allow the rotor speed and the wind speed to match in order for the rotor to maintain the best flow geometry to achieve maximum efficiency. The rotor could be connected to the grid at low speeds and would speed up in proportion to the wind speed. Once the rate power is achieved, the rotor is controlled to operate at constant speed through pitch regulation. Two speed systems were also introduced to improve energy capture and noise emissions of stall regulated wind turbines.

At present, pitch regulation and variable speed are the design routes pursued by many manufacturers for large turbines. Of the 52 models with more than 1 MW power rating from 20 wind turbine manufacturers in 2003, 37 models had variable speed, 12 had 2 speed systems, and only 3 with fixed speed. It appears that multi-MW wind turbines require some degree of speed variation and continuous variable

Continued on page 8

Wind Power Project Costs

Investment Costs

Wind turbine constitutes the largest share of wind power project costs. The share ranges from 74 to 80 %, based on wind projects in the UK, Spain, Germany and Denmark. The other cost items with important shares include grid connection, electrical installation and foundation (Table 1). There are however considerable variations of these costs per country and per size of the turbine.

Table 1: Cost structure for a typical Medium Sized Wind Turbine (850 kW – 1500 kW)

	Share of total cost (%)	Typical share of other costs (%)
Turbine (ex works)	74-82	-
Foundation	1-6	20-25
Electric installation	1-9	10-15
Grid connection	2-9	35-45
Consultancy	1-3	5-10
Land	1-3	5-10
Financial costs	1-5	5-10
Road construction	1-5	5-10

Source: www.ewea.org

The total cost per installed capacity for onshore projects ranges between US$1,000 per kW to US$1,500 per kW for onshore wind power plants in 9 western European countries and the US. One project reported by the IEA in Czech Republic costs slightly higher at around US$1,600 per kW. Offshore wind power projects in Denmark, Germany and the Netherlands have investments costs which range from US$1,500 per kW to US$2,600 per kW.

In general, wind power investment costs declined since the past two decades. Data from Denmark show that the average investment cost in 1989 was around €1000 per kW for 150 kW turbine. This had progressively declined in the 1990s reaching around € 700 per kW for 600 kW machines in late 1990s. Investment costs per kW however had increased with the entry in the market of 1 MW turbines. The average investment cost per kW for these turbines in early 2000 was around €900 per kW. This is mainly attributed to larger rotor diameters and higher hub heights for turbines with more than 1 MW capacities. Also, 1 MW turbines were also new in early 2000. With economies of scale, investment costs will eventually decline over time.

Operation and Maintenance Costs

O&M costs are estimated to represent between 20-25% of the total levelized costs per kWh over the lifetime of the wind power project. O&M costs share may be low at around 10-15% when the plant is relatively new but may increase to 20-35% towards the end of the project life. Wind power projects in Germany, Spain, the UK and Denmark have O&M costs at around 1.2-1.5c€/kWh.

O&M costs include insurance, regular maintenance, repair, spare parts and administration. A three-year-old 600 kW wind turbine in Denmark has O&M cost structure as follows: insurance – 35%; regular service – 28%; administration – 11%; repair and spare parts – 12%; and other purposes – 14%. Insurance, maintenance, and administration are fairly uniform throughout the project life while repair and spare parts costs are influenced by the age of the turbine, starting low and increasing over time.

Study in Germany shows that the O&M costs for the first two years were relatively low at 2-3% of total investment costs corresponding to 0.3-0.4 c€ per kWh. After six years, the share increases to almost 5% of total investment costs, which is equivalent to 0.6-0.7 c€ per kWh. Data for 55 kW turbines in Denmark reveal that O&M costs rapidly increases right from the start and reaching a high but stable level of 3-4 c€ per kWh after 5 years. O&M costs therefore appear to be correlated with age. In the first few years, these costs are relatively low since manufacturers provide technology warranty. After 10 years, large repairs and reinvestments could be expected.

Another interesting experience in Denmark is that newer and larger wind turbines have O&M costs lower than the older and smaller turbines. Old 55 kW wind power plants have O&M costs of around 3.5 c€ per kWh while those of the new 500 and 600 kW turbines are less than 1 c€ per kWh. One could expect that O&M costs of new multi-megawatt wind turbines will be significantly lower than those experienced at present for 55 kW machines.

Levelized Generation Cost

Levelized generation costs is calculated by discounting and levelizing investment and O&M costs over the lifetime of the wind energy project, divided by the annual electricity production. The levelized generation cost is an average cost over the lifetime. In reality, the actual costs may be lower than the average cost at the beginning of the project due to low O&M cost but will increase over the project period.

In addition to investment and O&M costs, other variables that influence the estimation of the levelized cost include wind availability/capacity factor, turbine lifetime and discount rate.

The availability/capacity factors of 19 wind power plants in Europe and USA in the recent IEA study are the following: 17-38% for onshore wind power plants and 35-48% for offshore projects. The economic lifetime of the wind power plants used in the same study is 20 years, except for one case study in Denmark and the US where the lifetime is 25 and 40 years respectively. The investments costs for both onshore and offshore projects were already presented earlier. At 5% discount rate, the levelized generation costs for wind power plants were estimated to range between US$ 0.35 and 0.95 per kWh. At 10% discount rate, the levelized costs range between US$ 0.45 and 1.40 per kWh.

The above results are also consistent with the EWEA study on levelized generations costs for land-based medium sized wind turbines (800-1,500 kW). Other assumptions made in the study are the following: investment costs range from € 900 – 1,100 per kW; O&M costs are assumed to be 1.2 c€ per kWh; wind turbine lifetime is 20 years. At 5% discount rate, the levelized generation costs are the following: 6.5 c€ per kWh for low wind areas (load factor of around 17%); 5.5 c€ per kWh for medium wind areas (load factor of 24%); and 4 c€ per kWh for coastal areas (load factor of 33%). At 10 % discount rate, the costs are 9.0 c€ per kWh for low wind areas; 6.5 c€ per kWh for medium wind areas; and 5.5 c€ per kWh for coastal areas.

Sources: www.ewea.org; IEA (2005), Projected Costs of Generating Electricity, 2005 Update.

Technology *... Continued from page 6*

speed designs are the preferred choice of the majority of manufacturers.

Variable speed is realized in various ways. The details to achieve variable speed from direct drive systems are significantly different from the conventional gearbox and drive train systems.

Transmission Systems

The conventional design to transmit the energy captured by the rotor to the electric generator is through the drive train and the gearbox. The rotor is attached to a main shaft, which is connected to the gearbox. The gearbox increases the speed of the shaft to a speed required by the generator. A large wind turbine at MW scale could have a three stage gearbox and four or six-pole generator.

Due to various difficulties associated with the gearbox, direct drive systems were also pursued by a number of manufacturers. In direct drive systems, the rotor is directly coupled to the generator. The system has gearless drive train and multi-pole generator. The advantages of direct drive systems are reductions of capital costs, drive train losses, downtime and maintenance cost. On the other hand, direct drive trains are heavier than conventional drive trains since the mass and size of direct drive generators are large.

Some manufacturers developed a new drive system, which is a compromise between the conventional drive train and direct drive. This hybrid system consists of a single-stage of gearing and multi-pole generator. This type of power train avoids the complexity of a multi-stage gearbox and has a lower system mass since it uses a medium speed multi-pole generator.

At present, the conventional drive train dominates the market but direct drive systems and hybrid systems started to appear in the market.

Source: www.ewea.org; Eize de Vries, Thinking Bigger, Are there limits to turbine size. Renewable Energy World May-June 2005.