VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

A technical seminar report on
FLOATING MINDMILLS

Submitted in partial fulfillment as per VTU curriculum for VIII semester

Bachelor of Engineering

In

Mechanical Engineering

Of

Visvesvaraya Technological University, Belgaum

Submitted by

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2009-2010

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CERTIFICATE

This is to certify that the Technical Seminar report entitled
"FLOATING MINDMILLS"
has been presented by Mr. **SUNNY DUBEY**, **USN: 1DS05ME090** in partial fulfillment for the award of Bachelor of Engineering in **Mechanical Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2009-10. It is certified that all correction/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library.

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ACKNOWLEDGEMENTS

It is with great satisfaction and euphoria that I am submitting the Technical seminar report on "FLOATING MINDMILLS". I have completed it as a part of the curriculum of our university.

First of all I thank the almighty for providing me with the strength and courage to present the seminar.

I avail this opportunity to express my sincere gratitude towards Dr. K.J. Sudhakar , head of mechanical engineering department, for permitting me to conduct the seminar.

I am also indebted to all the teaching and non- teaching staff of the department of mechanical engineering for their cooperation and suggestions, which is the spirit behind this report. Last but not the least, I wish to express my sincere thanks to all my friends for their goodwill and constructive ideas.

SUN
NY DUBEY

ABSTRACT

A floating wind turbine system with a tower structure that includes at least one stability arm extending there from and that is anchored to the sea floor with a rotatable position retention device that facilitates deep water installations. Variable buoyancy for the wind turbine system is provided by buoyancy chambers that are integral to the tower itself as well as the stability arm. Pumps are included for adjusting the buoyancy as an aid in system transport, installation, repair and removal. The wind turbine rotor is located downwind of the tower structure to allow the wind turbine to follow the wind direction without an active yaw drive system. The support tower and stability arm structure is designed to balance tension in the tether with buoyancy, gravity and wind forces in such a way that the top of the support tower leans downwind, providing a large clearance between the support tower and the rotor blade tips. This large clearance facilitates the use of articulated rotor hubs to reduced damaging structural dynamic loads. Major components of the turbine can be assembled at the shore and transported to an offshore installation site.

CONTENTS

INTRODUCTION

A **floating wind turbine** is a wind turbine mounted on a floating structure that allows the turbine to generate electricity in water depths where bottom-mounted towers are not feasible. The wind can be stronger and steadier over water due to the absence of topographic features that may disrupt wind flow. The electricity generated is sent to shore through undersea cables. The initial capital cost of floating turbines is competitive with bottom-mounted, near-shore wind turbines while the rate of energy generation is higher out in the sea as the wind flow is often more steady and unobstructed by terrain features. The relocation of wind farms into the sea can reduce visual pollution if the windmills are sited more than 12 miles (19 km) offshore, provide better accommodation of fishing and shipping lanes, and allow siting near heavily developed coastal cities.

Floating wind parks are wind farms that site several floating wind turbines closely together to take advantage of common infrastructure such as power transmission facilities.

NEED FOR FLOATING WINDMILLS

A few hundred meters offshore, winds are twice as strong as on land in much of the world. Offshore wind energy has huge potential, and floating wind turbines is a promising technology. Such turbines are now being developed. They are meant to be used out at sea in deep waters, and they do not need to be permanently moored to the ocean bed. DEEP SEA. Criteria for location of an offshore wind farm is excellent wind conditions and suitable water depth. The wind farm must be situated near a strong onshore power grid and near harbours and shipyards.

- Energy is a major factor in today's society
- Alternative fuel and alternative energy resources are in great demand
- Most everyone in the world is looking for more energy-efficient ways to live
- Hybrid vehicles and other fuel-efficient technology is arising around the world
- The world has to change, this emergency that we are experiencing today should have been taken care of long before now.
- Now we have no choice but to develop new technology in very little time

HISTORICAL BACKGROUND

Humans have been using wind power for at least 5,500 years to propel sailboats and sailing ships, and architects have used wind-driven natural ventilation in buildings since similarly ancient times. Windmills have been used for irrigation pumping and for milling grain since the 7th century AD in what is now Afghanistan, Iran and Pakistan.

In the United States, the development of the "water-pumping windmill" was the major factor in allowing the farming and ranching of vast areas otherwise devoid of readily accessible water. Windpumps contributed to the expansion of rail transport systems throughout the world, by pumping water from water wells for the steam locomotives.[6] The multi-bladed wind turbine atop a lattice tower made of wood or steel was, for many years, a fixture of the landscape throughout rural America. When fitted with generators and battery banks, small wind machines provided electricity to isolated farms.

In July 1887, a Scottish academic, Professor James Blyth, undertook wind power experiments that culminated in a UK patent in 1891.[7] In the United States, Charles F. Brush produced electricity using a wind powered machine, starting in the winter of 1887-1888, which powered his home and laboratory until about 1900. In the 1890s, the Danish scientist and inventor Poul la Cour constructed wind turbines to generate electricity, which was then used to produce hydrogen.[7] These were the first of what was to become the modern form of wind turbine.

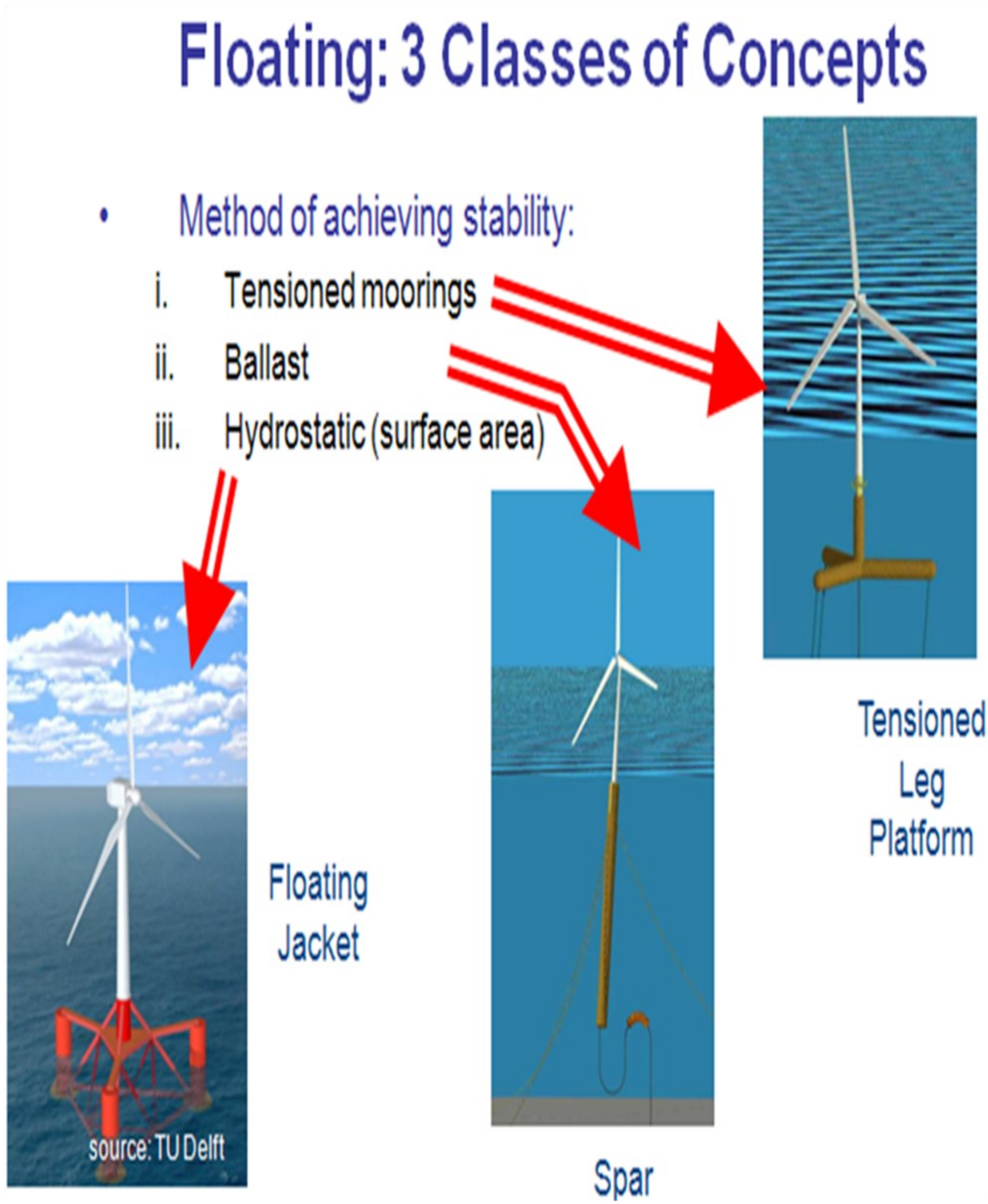
Small wind turbines for lighting of isolated rural buildings were widespread in the first part of the 20th century. Larger units intended for connection to a distribution network were tried at several locations including Balaklava USSR in 1931 and in a 1.25 megawatt (MW) experimental unit in Vermont in 1941.

The modern wind power industry began in 1979 with the serial production of wind turbines by Danish manufacturers Kuriant, Vestas, Nordtank, and Bonus. These early turbines were small by today's standards, with capacities of 20–30 kW each. Since then, they have increased greatly in size, with the Enercon E-126 capable of delivering up to 7 MW, while wind turbine production has expanded to many countries.

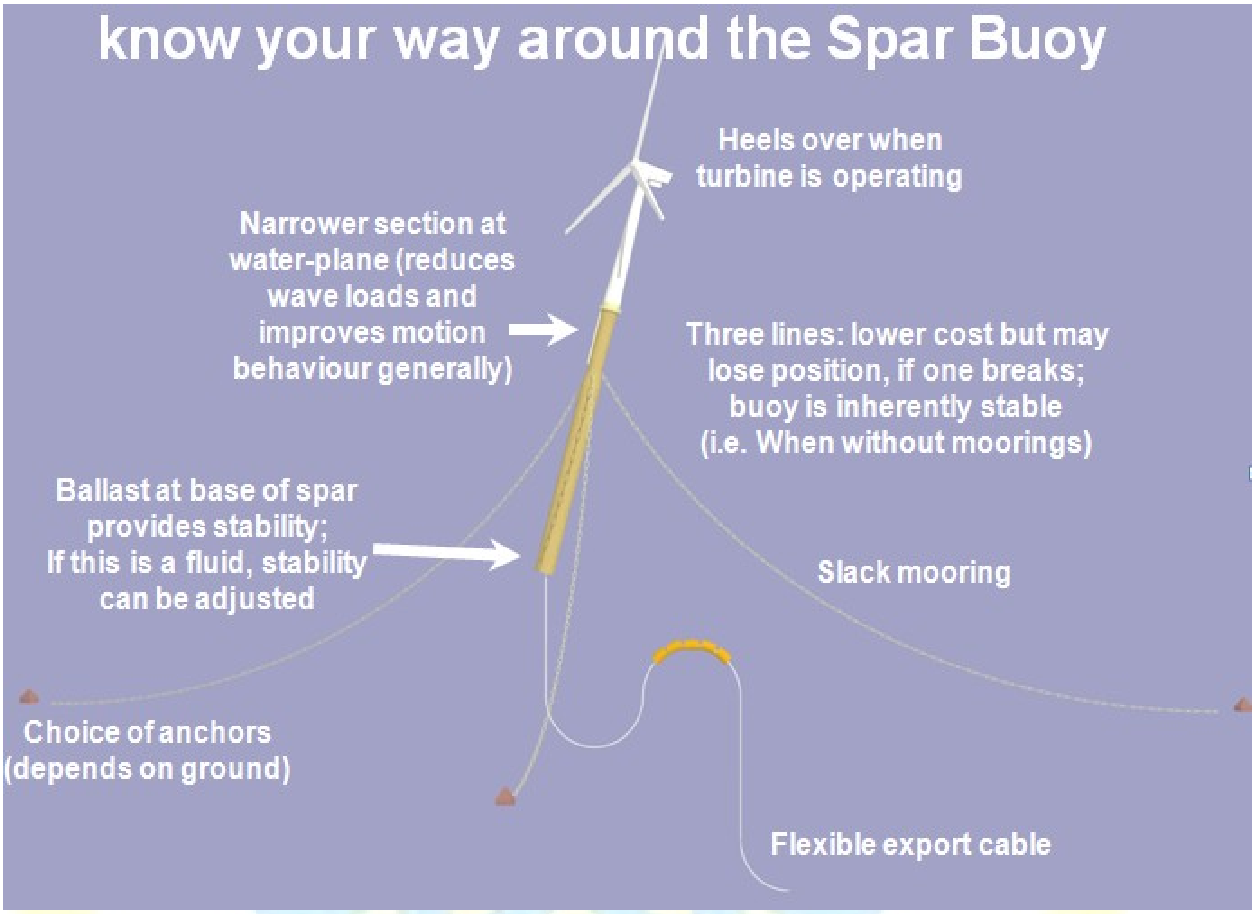
- The concept for "large-scale offshore floating wind turbines was introduced by Professor William E. Heronemus at the University of Massachusetts in 1972. It was not until the mid 1990’s, after the commercial wind industry was well established, that the topic was taken up again by the mainstream research community.
- As of 2003, existing offshore fixed-bottom wind turbine technology deployments had been limited to water depths of 30-meters. Worldwide deep-water wind resources are extremely abundant in subsea areas with depths up to 600 meters, which are thought to best facilitate transmission of the generated electric power to shore communities.

- Developed by Hydro, a Norwegian offshore producer of oil and gas and the third largest aluminum supplier in the world.
- Hydro is a fortune 500 country that was founded in 1905, with 33,000 employees in 40 countries
- Hydro has researched this plan for more many years, and the results look promising.

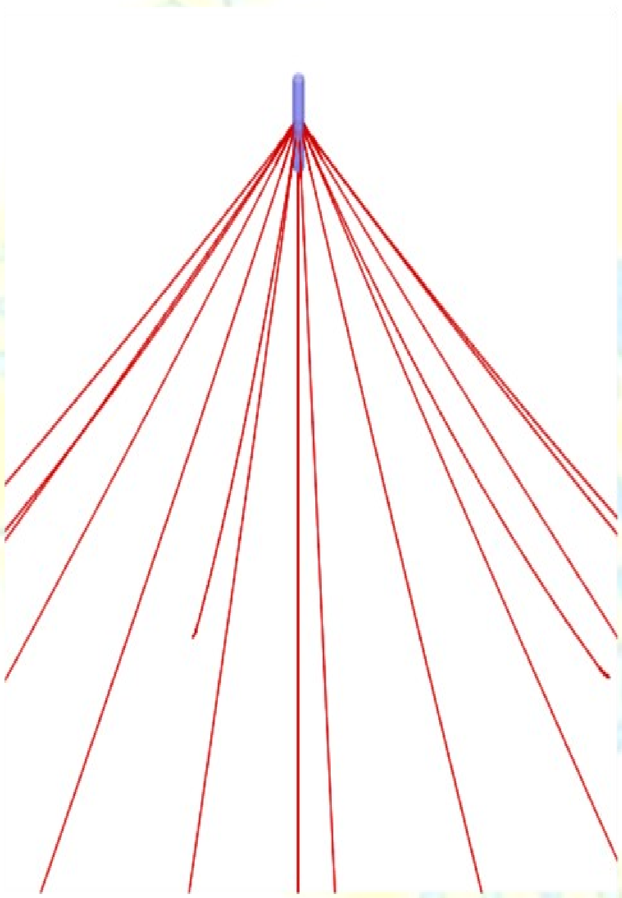
DESIGN CONSIDERATION

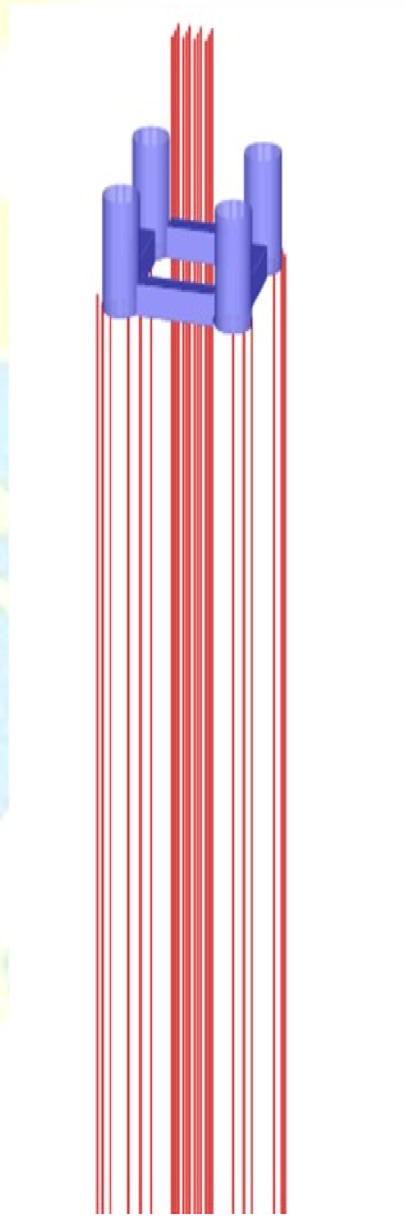


Floating: 3 Classes of Concepts
• Method of achieving stability:
i. Tensioned moorings
ii. Ballast
iii. Hydrostatic (surface area)
source: TU Delft
Floating Jacket
Spar
Tensioned Leg Platform


know your way around the Spar Buoy
Heels over when turbine is operating
Narrower section at water-plane (reduces wave loads and improves motion behaviour generally)
Three lines: lower cost but may lose position, if one breaks; buoy is inherently stable (i.e. When without moorings)
Ballast at base of spar provides stability; If this is a fluid, stability can be adjusted
Slack mooring
Choice of anchors (depends on ground)
Flexible export cable

Spar and TLP SML Simulation Models





4.1.2 TLP #2 Six Meter Sea State

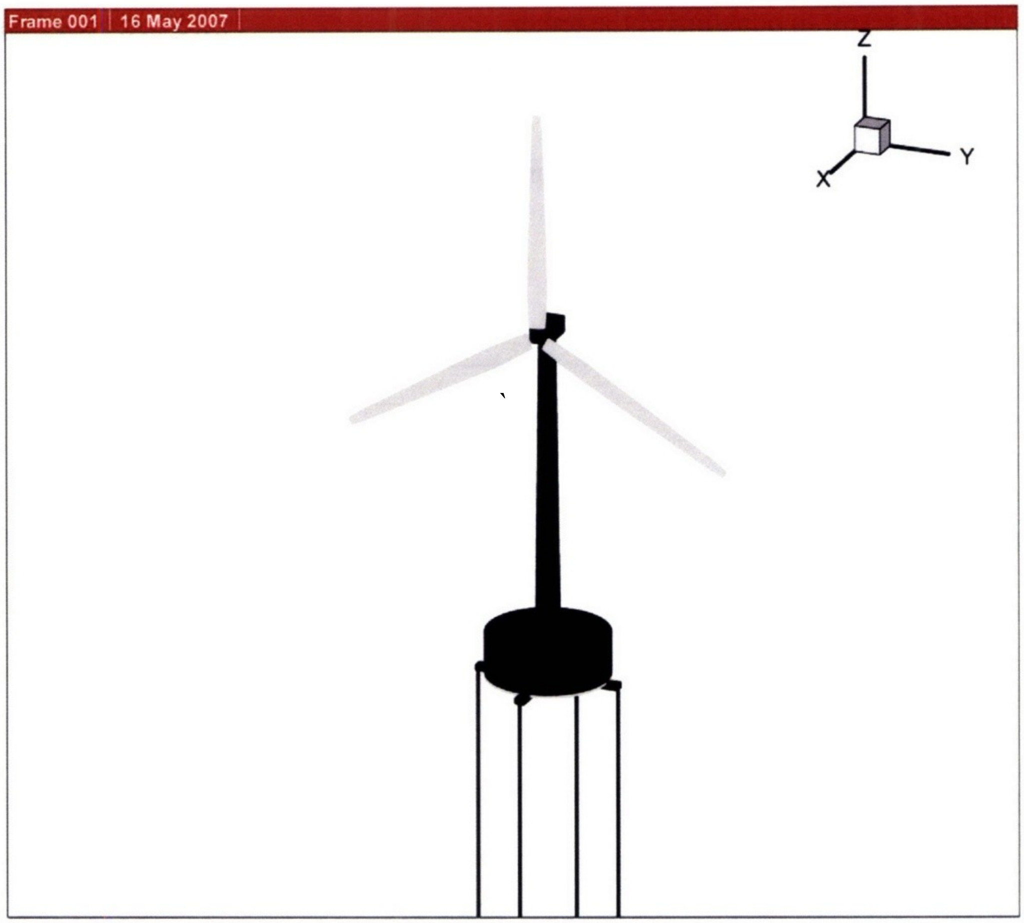


Figure 14: TLP #2, Six Meter Sea State

The second TLP structure has a much smaller displacement at just over 5000 metric tons. It is a much shallower, with a draft of just over six meters. Accelerations of the structure are significantly higher than the first TLP. The smaller mass and higher static tensions results in a larger surge natural frequency, and thus a larger RMS values of surge. It has the advantage of a shallower draft meaning that it would be more practical for coastal facilities with water depth limitations. Like the other TLP optimized for a six meter significant wave height, it does not

5.1.1 Slack Catenary #1, Six Meter Sea State

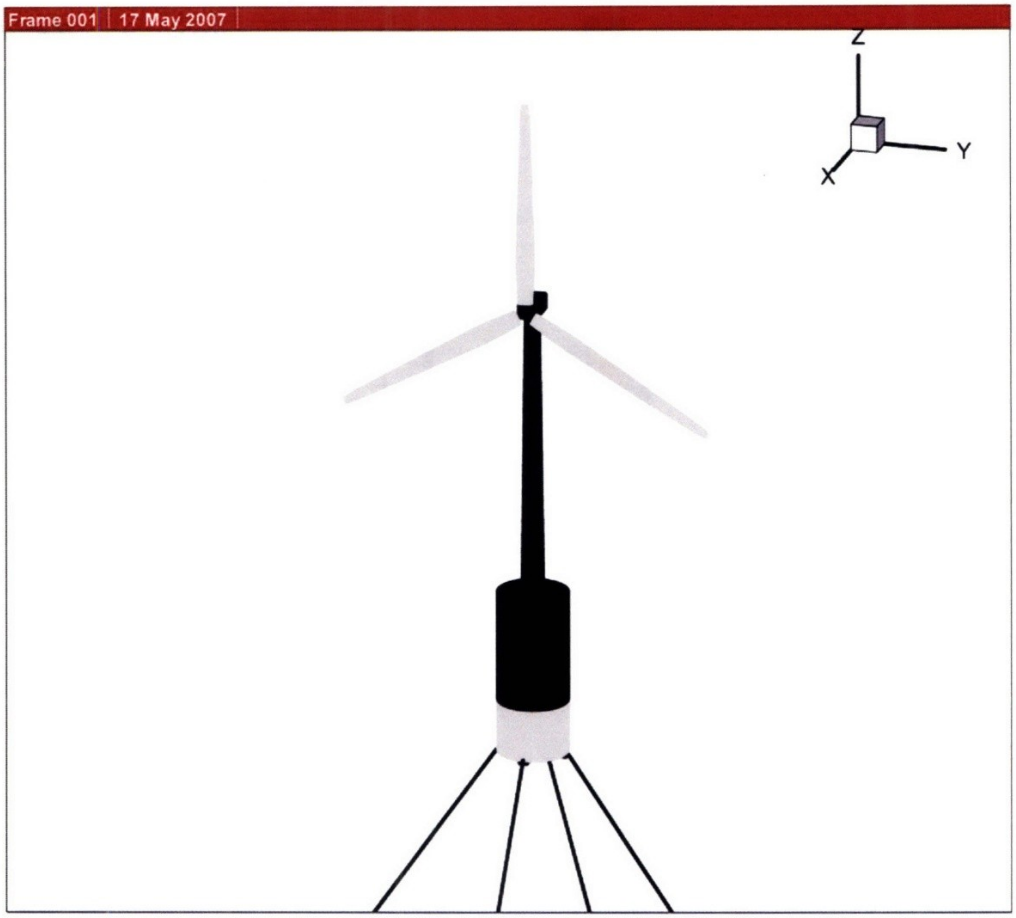
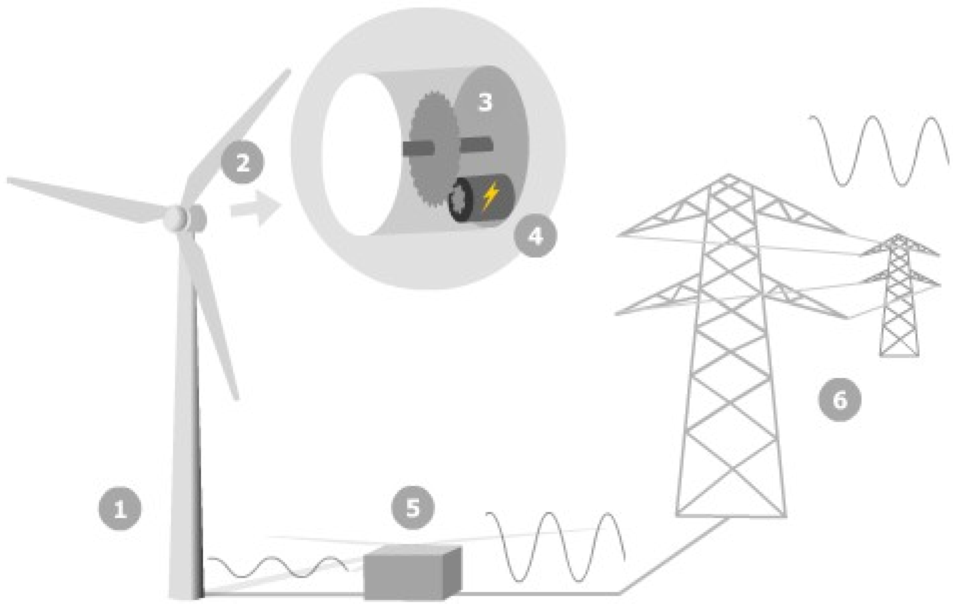


Figure 21: Slack Catenary #1, Six Meter Sea State

The first slack catenary design is a spar like structure with a relatively large displacement and is shown in figure 21. Because the mooring system provides little restoring, a larger draft and more concrete are necessary than the spar like TLP structure which is Pareto optimal for a six meter sea state. The mooring system provides no restoring in pitch, so the pitch displacements are larger than the equivalent TLP designs. For this type of structure, the pitch displacements roughly double the RMS acceleration of the wind turbine nacelle. The minimal restoring



1. The wind blows on the blades and makes them turn.
2. The blades turns a shaft inside the nacelle (the box at the top of the turbine)
3. The shaft goes into a gearbox which increases the rotation speed enough for...
4. The generator, which uses magnetic fields to convert the rotational energy into electrical energy. These are similar to those found in normal power stations.
5. The power output goes to a transformer, which converts the electricity coming out of the generator at around 700 Volts (V) to the right voltage for distribution system, typically 33,000 V.
6. The national grid transmits the power around the country.

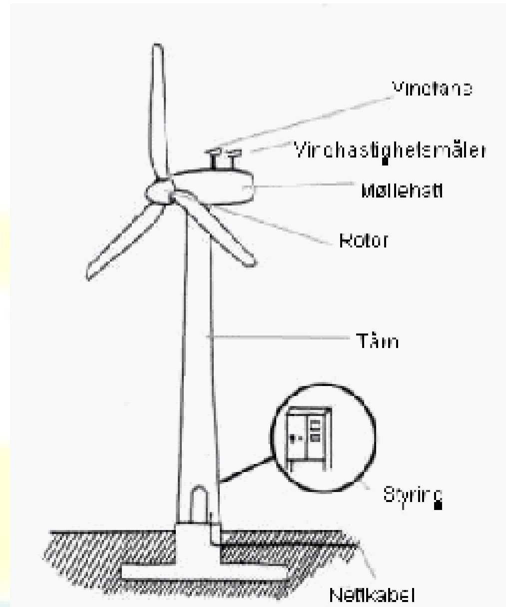
Instruments to measure the wind speed and direction are fitted on top of the nacelle. When the wind changes direction motors turn the nacelle, and the blades along with it, around to face the wind. The nacelle is also fitted with brakes, so that the turbine can be switched off in very high winds, like during storms. This prevents the turbine being damaged. All this information is recorded by computers and transmitted to a control centre, which means that people don't have to visit the turbine very often, just occasionally for a mechanical check. This is often done by local firms.

ADVANTAGES & DISADVANTAGES OF WINDMILLS

W

Advantages:

Compared to other energy sources, windmills are very kind to the enviroment. Compared to power stations driven by coal they will save the enviroment for:



This is a picture of a modern windmill.

- Carbon dioxide (CO_2) 850,0g
- Sulphur dioxide (SO_2) 2,9g
- Nitrogen dioxide (NO_2) 2,6g
- Dust 0,1g
- Cinders, and flying ashes 55,1g

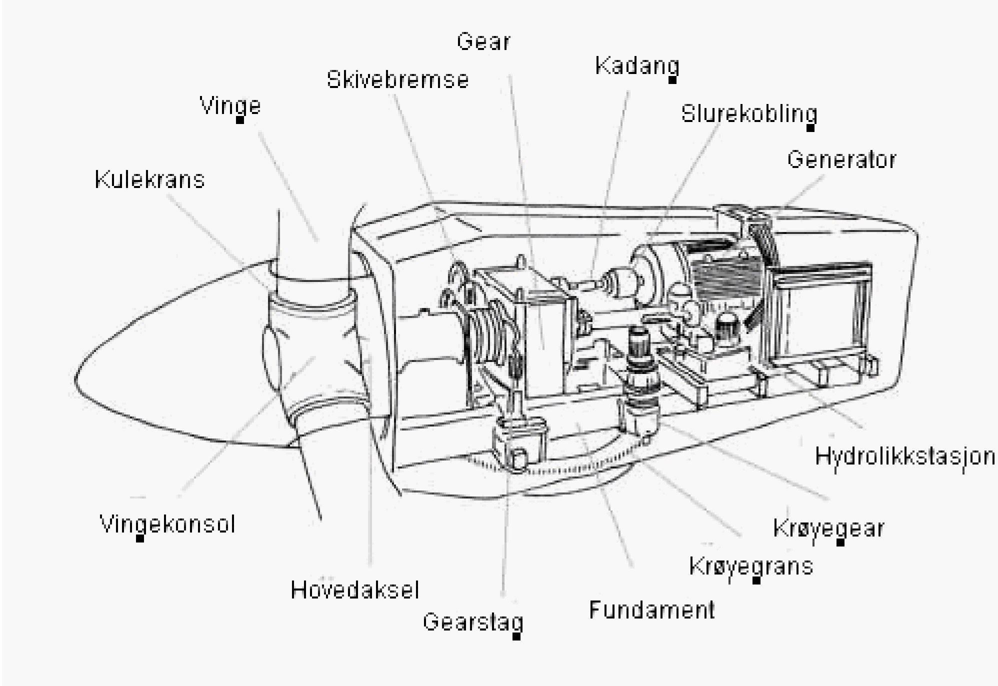
The brand new windmills are today so competitive on good places, that the use of windmillpower is one of the cheapest methods to reduce the emission of CO_2 from the production of electrisity. Windmills have no form of emissions of gases and other harmful substances.

The wind which tries to press the blade speed a little longer up causes the generator to start producing power on the net. When the speed of the wind has reached windpower at 13-15 m/s the mill grants on its maximum at 500 kw for a 500 kw mill.

Disadvantages:

Windmills are tall and they stand on places were the terrain is very open and free. Therefore there is also free outlook to the windmills.

If the windspeed has reached its maximum the mill is forced to reduce speed to not hurt the mills' machinery. It is a disadvantage that the windmils don't have an engine with a greater capacity.



This is a picture of a windmill from the inside.

The technology we use on windmills is very valuable and advanced, therefore the government hesitates to exploit windpower. As shown on the drawing below , you can see that this is advanced technology.

WIND POWER USAGE

There are now many thousands of wind turbines operating, with a total nameplate capacity of 157,899 MW of which wind power in Europe accounts for 48% (2009). World wind generation capacity more than quadrupled between 2000 and 2006, doubling about every three years. 81% of wind power installations are in the US and Europe. The share of the top five countries in terms of new installations fell from 71% in 2004 to 62% in 2006, but climbed to 73% by 2008 as those countries—the United States, Germany, Spain, China, and India—have seen substantial capacity growth in the past two years (see chart).

By 2010, the World Wind Energy Association expects 160 GW of capacity to be installed worldwide,[54] up from 73.9 GW at the end of 2006, implying an anticipated net growth rate of more than 21% per year.

Denmark generates nearly one-fifth of its electricity with wind turbines —the highest percentage of any country—and is ninth in the world in total wind power generation. Denmark is prominent in the manufacturing and use of wind turbines, with a commitment made in the 1970s to eventually produce half of the country's power by wind.

In recent years, the US has added more wind energy to its grid than any other country, with a growth in power capacity of 45% to 16.8 GW in 2007[55] and surpassing Germany's nameplate capacity in 2008. California was one of the incubators of the modern wind power industry, and led the U.S. in installed capacity for many years; however, by the end of 2006, Texas became the leading wind power state and continues to extend its lead. At the end of 2008, the state had 7,116 MW installed, which would have ranked it sixth in the world if Texas was a separate country. Iowa and Minnesota each grew to more than 1 GW installed by the end of 2007; in 2008 they were joined by Oregon, Washington, and Colorado.[56] Wind power generation in the

U.S. was up 31.8% in February, 2007 from February, 2006.[57] The average output of one MW of wind power is equivalent to the average electricity consumption of about 250 American households. According to theAmerican Wind Energy Association, wind will generate enough electricity in 2008 to power just over 1% (equivalent to 4.5 million households) of total electricity in U.S., up from less than 0.1% in 1999. U.S. Department of Energy studies have concluded wind harvested in the Great Plains states of Texas, Kansas, and North Dakota could provide enough electricity to power the entire nation, and that offshore wind farms could do the same job.[58][59] In addition, the wind resource over and around theGreat Lakes, recoverable with currently available technology, could by itself provide 80% as much power as the U.S. and Canada currently generate from non-renewable resources,[60] with Michigan's share alone equating to one third of current U.S. electricity demand.[61]

China had originally set a generating target of 30,000 MW by 2020 from renewable energy sources, but reached 22,500 MW by end of 2009 and could easily surpass 30,000 MW by end of 2010. Indigenous wind power could generate up to 253,000 MW.[62] A Chinese renewable energy law was adopted in November 2004, following the World Wind Energy Conference organized by the Chinese and the World Wind Energy Association. By 2008, wind power was growing faster in China than the government had planned, and indeed faster in percentage terms than in any other large country, having more than doubled each year since 2005. Policymakers doubled their wind power prediction for 2010, after the wind industry reached the original goal of 5 GW three years ahead of schedule.[63] Current trends suggest an actual installed capacity near 20 GW by 2010, with China shortly thereafter pursuing the United States for the world wind power lead.[63]

India ranks 5th in the world with a total wind power capacity of 10,925 MW in 2009,[1]or 3% of all electricity produced in India. The World Wind Energy Conference in New Delhi in November 2006 has given additional impetus to the Indian wind industry.[54]Muppandal village in Tamil Nadu state, India, has several wind turbine farms in its vicinity, and is one of the major wind energy harnessing centres in India led by majors like Suzlon, Vestas, Micon among others.[64][65]

Mexico recently opened La Venta II wind power project as an important step in reducing Mexico's consumption of fossil fuels. The 88 MW project is the first of its kind in Mexico, and will provide 13 percent of the electricity needs of the state of Oaxaca. By 2012 the project will have a capacity of 3500 MW.

Another growing market is Brazil, with a wind potential of 143 GW.[66] The federal government has created an incentive program, called Proinfa,[67] to build production capacity of 3300 MW of renewable energy for 2008, of which 1422 MW through wind energy. The program seeks to produce 10% of Brazilian electricity through renewable sources.

South Africa has a proposed station situated on the West Coast north of the Olifants River mouth near the town of Koekenaap, east of Vredendal in the Western Cape province. The station is proposed to have a total output of 100 MW although there are negotiations to double this capacity. The plant could be operational by 2010.

France has announced a target of 12,500 MW installed by 2010, though their installation trends over the past few years suggest they'll fall well short of their goal.

Canada experienced rapid growth of wind capacity between 2000 and 2006, with total installed capacity increasing from 137 MW to 1,451 MW, and showing an annual growth rate of 38%.[68] Particularly rapid growth was seen in 2006, with total capacity doubling from the 684 MW at end-2005.[69] This growth was fed by measures including installation targets, economic incentives and political support. For example, the Ontario government announced that it will introduce a feed-in tariff for wind power, referred to as 'Standard Offer Contracts', which may boost the wind industry across the province.[70] In Quebec, the provincially owned electric utility plans to purchase an additional 2000 MW by 2013.[71]. By 2025, Canada will reach its capacity of 55,000 MW of wind energy, or 20% of the country's energy needs

GROWTH & COST TRENDS

Wind and hydroelectric power generation have negligible fuel costs and relatively low maintenance costs. Wind power has a low marginal costand a high proportion of capital cost. The estimated average cost per unit incorporates the cost of construction of the turbine and transmission facilities, borrowed funds, return to investors (including cost of risk), estimated annual production, and other components, averaged over the projected useful life of the equipment, which may be in excess of twenty years. Energy cost estimates are highly dependent on these assumptions so published cost figures can differ substantially. A British Wind Energy Association report gives an average generation cost of onshore wind power of around 3.2 pence (between US 5 and 6 cents) per kW·h (2005).[91] Cost per unit of energy produced was estimated in 2006 to be comparable to the cost of new generating capacity in the US for coal and natural gas: wind cost was estimated at \$55.80 per MW·h, coal at \$53.10/MW·h and natural gas at \$52.50.

[92] Other sources in various studies have estimated wind to be more expensive than other sources (see Economics of new nuclear power plants, Clean coal, and Carbon capture and storage).

In 2004, wind energy cost a fifth of what it did in the 1980s, and some expected that downward trend to continue as larger multi-megawattturbines were mass-produced.[93] However, installed cost averaged €1,300 a kW in 2007,[94] compared to €1,100 a kW in 2005.[95] Not as many facilities can produce large modern turbines and their towers and foundations, so constraints develop in the supply of turbines resulting in higher costs.[96] Research from a wide variety of sources in various countries shows that support for wind power is consistently 70–80% among the general public.[97]

Global Wind Energy Council (GWEC) figures show that 2007 recorded an increase of installed capacity of 20 GW, taking the total installed wind energy capacity to 94 GW, up from 74 GW in 2006. Despite constraints facing supply chains for wind turbines, the annual market for wind continued to increase at an estimated rate of 37%, following 32% growth in 2006. In terms of economic value, the wind energy sector has become one of the important players in the energy markets, with the total value of new generating equipment installed in 2007 reaching €25 billion, or US$36 billion.[94]

Although the wind power industry will be impacted by the global financial crisis in 2009 and 2010, a BTM Consult five year forecast up to 2013 projects substantial growth. Over the past five years the average growth in new installations has been 27.6 percent each year. In the forecast to 2013 the expected average annual growth rate is 15.7 percent.[98][99] More than 200 GW of new wind power capacity could come on line before the end of 2013. Wind power market penetration is expected to reach 3.35 percent by 2013 and 8 percent by 2018.[98][99]

Existing generation capacity represents sunk costs, and the decision to continue production will depend on marginal costs going forward, not estimated average costs at project inception. For example, the estimated cost of new wind power capacity may be lower than that for "new coal" (estimated average costs for new generation capacity) but higher than for "old coal" (marginal cost of production for existing capacity). Therefore, the choice to increase wind capacity will depend on factors including the profile of existing generation capacity.

ENVIRONMENTAL EFFECTS

Compared to the environmental effects of traditional energy sources, the environmental effects of wind power are relatively minor. Wind power consumes no fuel, and emits no air pollution, unlike fossil fuel power sources. The energy consumed to manufacture and transport the materials used to build a wind power plant is equal to the new energy produced by the plant within a few months of operation[*citation needed*]. Garrett Gross, a scientist from UMKC in Kansas City, Missouri states, "The impact made on the environment is very little when compared to what is gained." The initial carbon dioxide emission from energy used in the installation is "paid back" within about 9 months of operation for offshore turbines[*citation needed*].

Danger to birds and bats has been a concern in some locations. However, studies show that the number of birds killed by wind turbines is very low, compared to the number of those that die as a result of certain other ways of generating electricity and especially of the environmental impacts of using non-clean power sources. Fossil fuel generation kills around twenty times as many birds per unit of energy produced than wind-farms.[108] Bat species appear to be at risk during key movement periods. Almost nothing is known about current populations of these species and the impact on bat numbers as a result of mortality at windpower locations. Offshore wind sites 10 km or more from shore do not interact with bat populations. While a wind farm may cover a large area of land, many land uses such as agriculture are compatible, with only small areas of turbine foundations and infrastructure made unavailable for use.

Aesthetics have also been an issue. In the USA, the Massachusetts Cape Wind project was delayed for years mainly because of aesthetic concerns. In the UK, repeated opinion surveys have shown that more than 70% of people either like, or do not mind, the visual impact. According to a town councillor in Ardrossan, Scotland, the overwhelming majority of locals believe that the Ardrossan Wind Farm has enhanced the area, saying that the turbines are impressive looking and bring a calming effect to the town.[109]

Finally, noise has also been an important disadvantage. With careful implanting of the wind turbines, along with use of noise reducing-modifications for the wind turbines however, these issues can be easily addressed.[*citation needed*]

GROWTH & COST TRENDS

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FLOATING WINDFARMS vs OIL AND GAS RESERVOIRS

- 1 Barrel of Oil ~ 130 kg ~ 1.5 MWh of Energy (~ 12 kWh / kg)
- 1 MW of Rated Wind Turbine Power @ 40% Capacity Factor ~ 9.6 MWh / Day ~ 6.4 Barrels of Oil / Day

- Conversion Efficiency of Oil & Gas Engines / Turbines, Wind Turbines ~ 40-50%
- 1 GW Wind Farm (30 year life) ~ 70 M Barrel Oil Field ~ 6,400 Barrels / Day
- Breakeven Cost of Wind Turbines $3M / Rated MW = $3 B / Rated GW
- Equivalent Cost per Barrel of Oil ~ $43 / Barrel
- Investment Risk in Oil & Gas: Exploration Costs & Volatility of Oil & Gas Prices
- Investment Risk in Wind: Volatility of Wind Speed & Electricity Prices.

CONCLUSION

- Optimized Spar Buoy and TLP Wind Turbine Floaters
- Low Responses – Use of Onshore Wind Turbines
- Hybrid Offshore Wind & Wave Farms

- Optimal Control to Enhance Wind and Wave Power Output
- Design of Offshore Electric Grids
- Attractive Economic Attributes
- Project Finance for Utility Scale Offshore Wind & Wave Farms

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