ENGINEERING COMPANY OF CENTRAL AMERICA

Consulting – Engineering – Supervision
Industrial Plants – Buildings – Infrastructure

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NEWSLETTER

WIND POWER STATIONS

Wind power capacity has increased world-wide more than any other renewable power technology in 2008 (even more than hydro), with an estimated 27 GW added. This represented a 28% increase over 2007 (see Fig. 1). Wind power has also become one of the broadest-based renewable energy technologies, with installations in more than 70 countries (see Fig. 2).

Fig. 1 Wind Power capacity has experienced exponential growth over the past 10 years and experiences the largest growth of renewable power technologies. Source: World Wind Energy Association (2009).

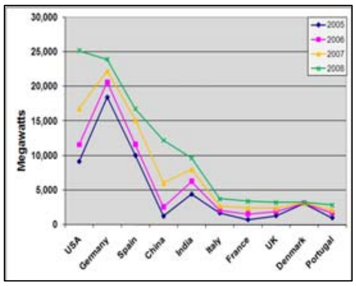

***Fig. 2 Top ten wind energy producers.** Development of the individual capacity from 2005-2008. In 2008, USA took the world-wide lead in installed wind power generating capacity. Both China and India exhibit large growth rates.*

Wind Power Origin

Solar power on earth corresponds to approx. $1.5*10^{18}$ kWh per year. It takes thus the sun roughly six hours in order to transfer the amount of solar power to earth that is equivalent to the global electricity consumption of one entire year (approx. 10^{15} KWh).

The heat generated by the sun is however distributed none-uniformly, as depicted in Figure 3. Regional differences in air temperature result in different air pressures. These thermo-dynamically unstable systems relax by moving air masses from high pressure to low-pressure regions: wind is generated. Approximately 2.5% of the solar power radiated to earth is transformed into wind energy. This amounts to approx. $3.75*10^{16}$ KWh per year, or 1.2 billion kWh per second.

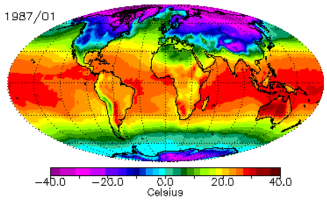

***Fig. 3:** Air temperatures on earth are induced due different sun-radiation intensities at the equator and poles, differences between daytime and nightime, different heat capacities between soil and water, topographical effects, cloudiness and air humidity.*

Other major forces that greatly influence the global winds are the Coriolis forces, which result from earth rotation (see Fig. 4) and friction forces. The latter are caused by interactions between wind and the surface topology of our planet and play as well a vey important role on a local scale.

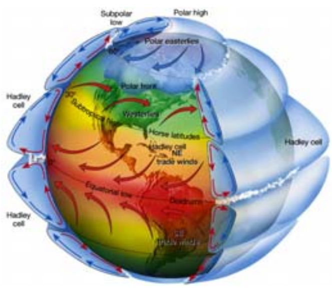

***Fig. 4 Global air circulation paths on earth**. In the tropical region, up to 30 degrees latidude, Hadley circulation is predominant: Hot tropical air elevates from the equator and moves toward the poles. Earth rotation and resulting Coriolis forces force these air currents to the east. At approx. 30 degrees the air descends and travels, in the form of Tradewinds back to the equator. This time, Coriolis forces direct the air streams to the west.*

Winds at the surface

At surface levels, the winds are generally slowed down considerably due to obstacles and surface roughness. At approximately 5km over sea level, in the geostrophic regions, winds are no longer influenced by earth roughness.

Between these two levels, wind speeds vary according to the height above ground. This phenomenon is called vertical wind shear (see also Fig. 5, left) and different climatological approaches exist in order to calculate wind speeds at different heights.

Winds are never constant as the wind speed varies considerably over time, due to the occurrence of wind turbulences and gusts. For the case of Wind Power Stations, the knowledge of the intensity of turbulences and wind gusts and thus the resulting loads is a critical design factor, as sudden wind speed increases, are the main cause of material fatigue.

Evidently, the wind properties (Magnitude, direction, transients) are the main parameters for calculating the expected energy output of a wind power station, as well as the choice of its type and the layout of a Wind Park.

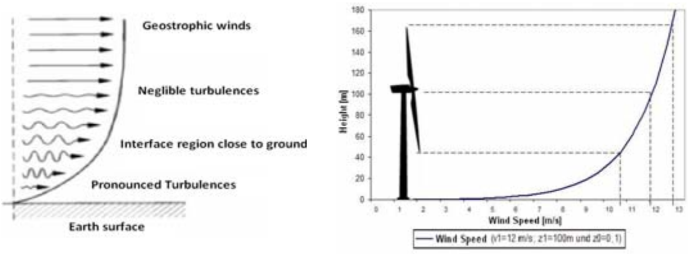

***Fig. 5. Left**: Typical wind shear curve showing the occurrence of turbulences in the lower regions. **Right:** Speed distribution for a wind with a speed of 12 m/s at 100 meter height, for a zone with roughness length of z_0=0.1 meter (Prandtl method). Different wind loads act on the blades at different times, with high impact on the machine parts. Wind power increases with an exponential factor of three with respect to the wind speed, and the local speed of the air at the rotor blade surface is generally up to 9 times higher than the wind speed (thus in the order of 250Km/h). Sudden changes of the wind speed thus cause additional strong variations of the loads applied on the station.*

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Main Elements Of Wind Power Station

Modern wind power stations consist of the following main parts: the rotor (including blades), the tower and the foundations (see Fig. 6). In the following, special attention will be given at the latter two.

The Tower

The tower is the largest and heaviest component of a wind power station. Its height is approximately 1-1.8 times the rotor diameter and may weight several hundred tons. The cost of the tower may assume 15-25% of the total cost of a wind power station and generally represents a significant part of transportation and erection costs.

Wind speed increases with height, whereas turbulences occur less often at higher altitudes. The function of the tower is thus to optimize energy generation, placing the rotors as high as possible and in a turbulence-free zone.

In some cases the tower may contain electrical parts such as transformer, converters, electric control cabinets and others. Alternatively these items may be installed in an adjacent small building.

Tower height and weight

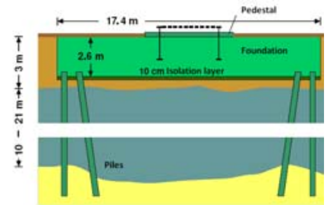
Fig. 7 show graphically the relations between wind station power generation, tower height and specific tower weight. In order to design the optimal tower height for a given location, several factors have to be considered:

- Locations with a high degree of turbulences call for the construction of higher towers, whereas locations with a small degree of turbulences and low surface roughness, generally need shorter towers
- Tower weight, and hence its cost increase approx. with the square of its height. As shown in Fig. 7 (right), a 100- high tower weights approximately 1.3 – 2.6 tons per meter height, whereas a 50m high tower “only” weights 0.6 – 1.3 tons per meter.

Tower Types:

The type of tower to be used for a particular wind power station depends on the size and type of the station itself, the height of the rotor axis and the wind strength at its location. Other factors to be considered include the seismicity of the zone. For the case of offshore stations, the interaction with sea waves is to be taken into account. Different tower types are depicted in Figs. 8-12.

Main components of generation unit:
1-Blades; 2-Rotor; 3-Pitch; 4-Brake; 5-Low speed shaft; 6-Gearbox; 7-Generator; 8-Contoller; 9-Anemometer; 10-Wind vane; 11-Nacelle; 12-High speed shaft; 13-Yaw drive; 14-Yaw motor; 15-Tower.



Typical foundation dimensions of a 1.5 MW wind power plant. Main dimensions: length 14-16 m, depth: 2-3 m. Approx. Weight: 750 tons.

Fig. 6: *Modern Wind Power Station and main elements.*

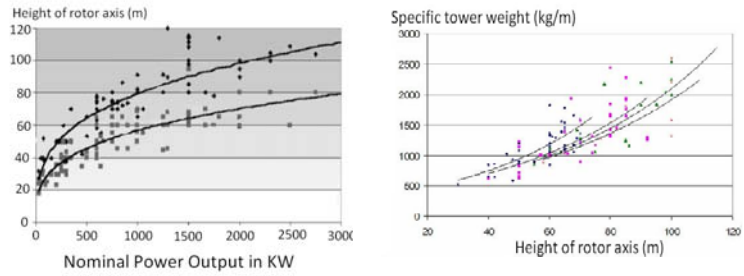


Fig.7: *Left: Relationship between wind station power output and tower height. Right: specific tower weight, expressed in Kg per meter height, plotted vs. total tower height.*

Steel pipe towers represent to day the most common tower type for Wind Power stations. Generally they are divided into segments of 20 to 30 meter length. Transport of the segments of large (>2MW) wind power stations may result problematic, as the diameter of the segments exceeds the height of bridges and tunnels.

Fig. 8 Lattice towers

Lattice towers were quite common for first generation Wind Power stations. They need less material (approx. half the materials used in steel tube towers) and are therefore lighter and easier to fabricate. In Europe however, lattice towers are more expensive, as they require significant amount of labor – however, they are used for high altitude applications – lattice towers can be constructed up to heights of 160 meters. Truss towers are very common in countries with relatively low labor costs (e.g. China, India)

***Fig. 9 Wired tubular Masts**.*

This type of towers are constructed from metal tubes, and held in place with help of steel cables. Typical for small stations, up to power outputs of 250kW. Very common for very small stations (10kW). These towers may be dismantled before an incoming extreme weather situation. Advantages: low weight/costs, easy to transport, can be placed at quite inaccessible regions (mountains). Permits to lower the tower for maintenance purposes.

Fig. 10: Concrete towers

Concrete towers are much larger and heavier than steel towers (5 to 6 times). As steel towers, they are constructed conically. Fabrication occurs either at site, or alternatively they are assembled from prefabricated elements. The latter have some economical advantages when built in larger series.

Main advantages of the locally built concrete towers: less transport costs. Quality control however is more difficult.

Fig. 11 Hybrid towers

Hybrid towers consist of a lower part made of concrete, whereas the upper part is steel. In such way, transport problems for the lower tower segment with large radii can be avoided. Left: a steel tube is being uplifted for its placement on the already erected concrete base. Right: Finished hybrid wind power station.

FOUNDATIONS

The technical data of a specific foundation of a wind power station strongly depends on location (geology, soil properties), meteorology (wind zone), station size (height, weight) andf seismicity. For the case of soft grounds, the concrete foundations rest on piles.

The form of the foundation may vary (octahedron, circle, cross). The foundation of a 1.5 MW Wind Power station is approx. 14-16 m long, 2-3m deep and weighs around 750 tons. The foundation costs represent approx. 5% of the project overall costs. A typical example is depicted in Fig. 12.

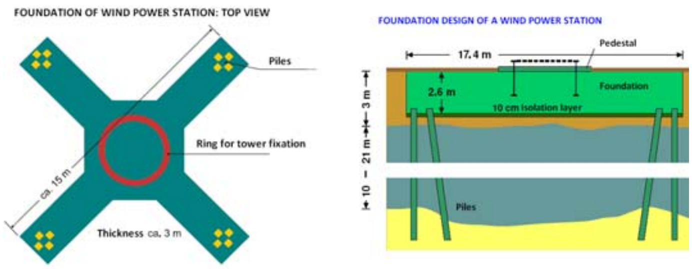


Fig. 12: *Typical cross-type foundation of a 2 MW Wind Power Station. Left: top view; right: lateral view. The concrete cross rests on driven piles*

Offshore foundations

Additional factors like water depth and the presence of sea currents and waves must be accounted for when designing and building offshore-foundations. These may be built from concrete, as well as steel piles or multiple framed structures. The experience gained with oil drilling platforms has shown that corrosion at open seas doesn't represent a major threat. Electrical corrosion protection enables to design foundations with expected lifetimes of approx. 50 years.

The particular foundation type of an offshore station depends largely on the water depth. Different options of foundations for offshore wind power plants are illustrated in Figs. 13-15

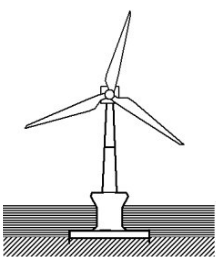


Fig. 13 Gravitational foundation. *Caissons are fabricated at the coast in a dry dock, towed to the planned location, then sunk to the ground and filled with sand and gravel*

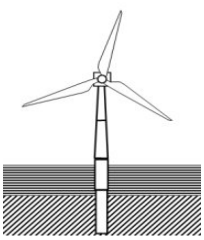


Fig. 14 Steel mono-piles. *The methods suits for 2-3 MW stations up to water depths of 20m and is specially economical for 3-5 MW stations at water depths of 15m.*

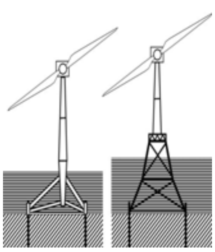
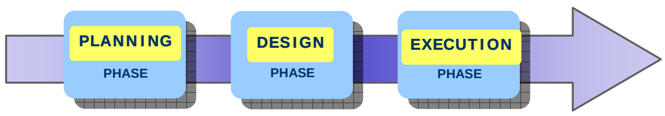


Fig. 15 Tripods and Quadripods. *Trussed structures are necessary for the case of sea depths of >20m. They are fixed to the sea ground with driven piles or gravi-tational foundations.*

SCOPE OF SERVICES IN WIND POWER PLANT PROJECTS

Support from EC for Wind Power Plant projects is given during different project stages, reaching from the planning phase until the construction/execution phase.



Scope of services during Planning Phase:
Site investigations, provision of local cost levels, obtaining site-specific seismic design parameters, topographical surveys, review of geotechnical studies, hydrological reports, geophysical investigations, coordination of geotechnical soundings, inspection of existing structures, and definition of suitable structure types, "Spot-type" engineering assistance.

Scope of services during Design/Engineering Phase:
Seismic and structural design of foundations and towers based on international standards. Seismic and structural evaluation of existing wind power stations. Issuance of construction drawings, specifications, calculation reports via web-based communication system.

Scope of services during Execution Phase:
Construction management assistance from EC includes both on-site civil works supervision services, as well as spot-type consultancy during the execution of the different construction processes.