Basic concepts Engineering, procurement and commissioning

2015-1-ES01-KA202-015935

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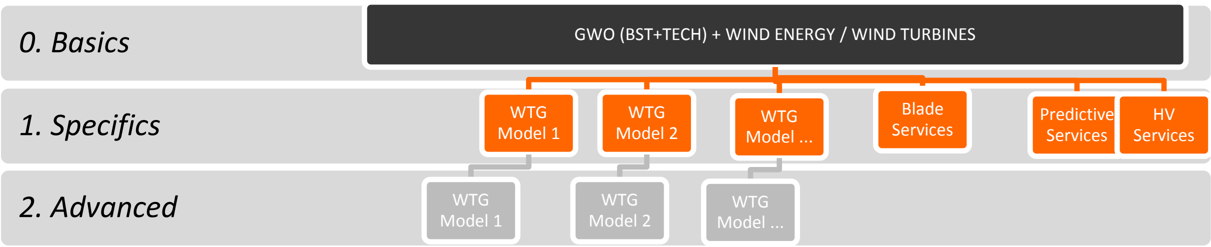
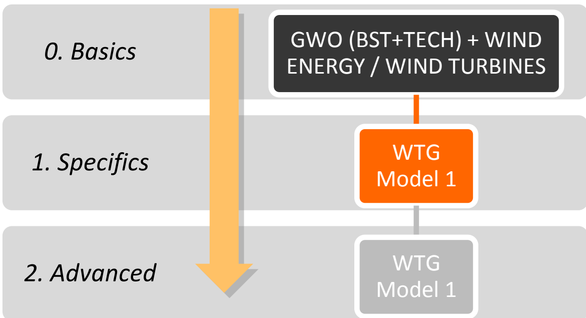
TRAINING PATHS

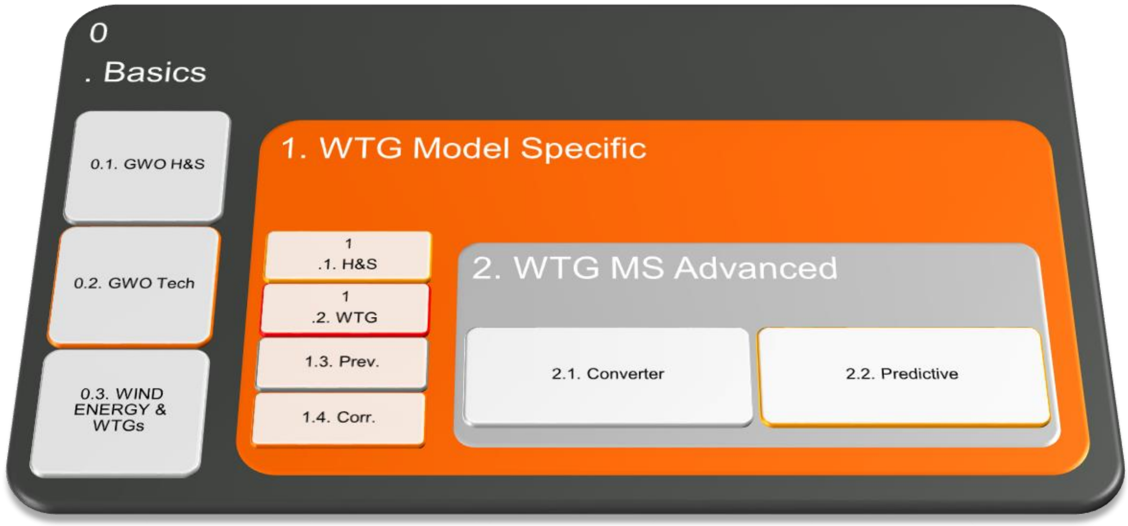


The WTG selected is the DFIG type, later presented for being the most commont in the market.

CONTENTS INCLUDED IN PATH #1

PATH #1. WIND FARM O&M TECHNICIAN





1.3. WIND ENERGY & WINDTURBINES

1.3.1. Lesson 1: Wind farm development

The aim of this lesson is to give the delegates the needed awareness of the different stages to develop a wind farm to know more in detail the technology characteristics as well as some specific aspects of the commissioning and construction which could later affect to the maintanenance taks:

To successfully complete this Lesson, students shall be aware of:

(1) Importance of an adequate metering of the wind resources.
(2) Influence of the land and soil characteristics
(3) Criteria to select the most appropriate WTG
(4) Civil works and foundations characteristics
(5) Principal activities for the transport and assembling of the WTG

The following diagrams represent different phases for the development of a typical Wind Farm and it is similar in all countries around the world. The different phases below represented and their span will be related to the specificities of each country and electrical systems.

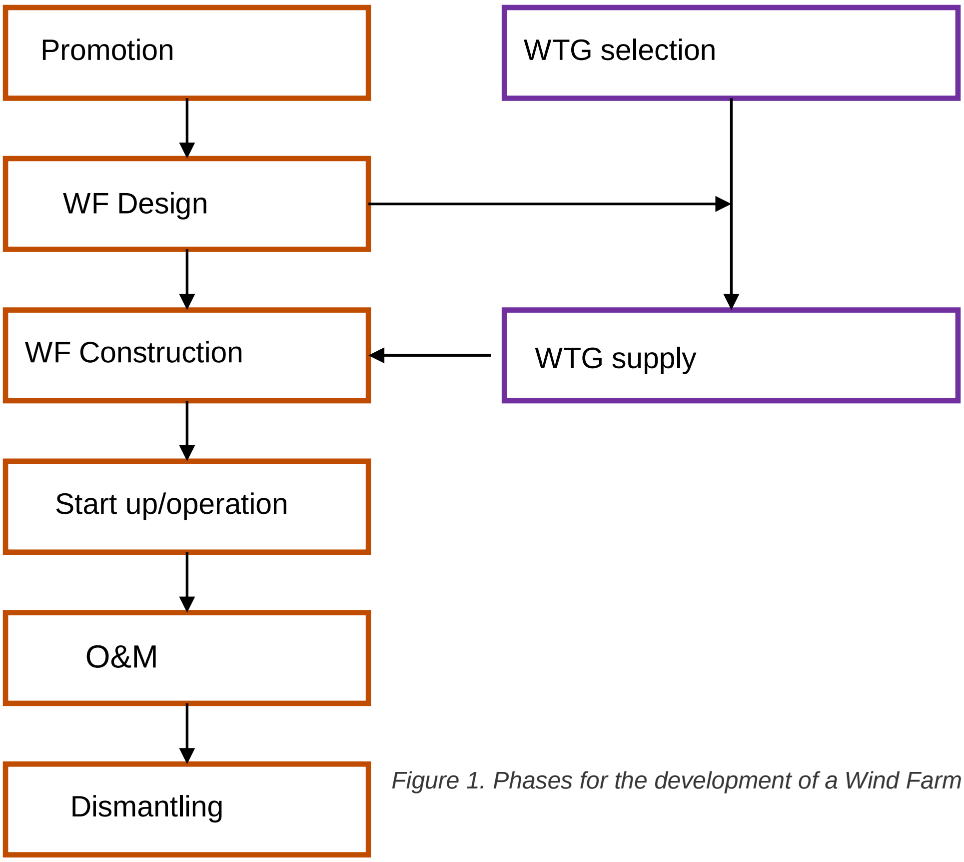


Figure 1. Phases for the development of a Wind Farm

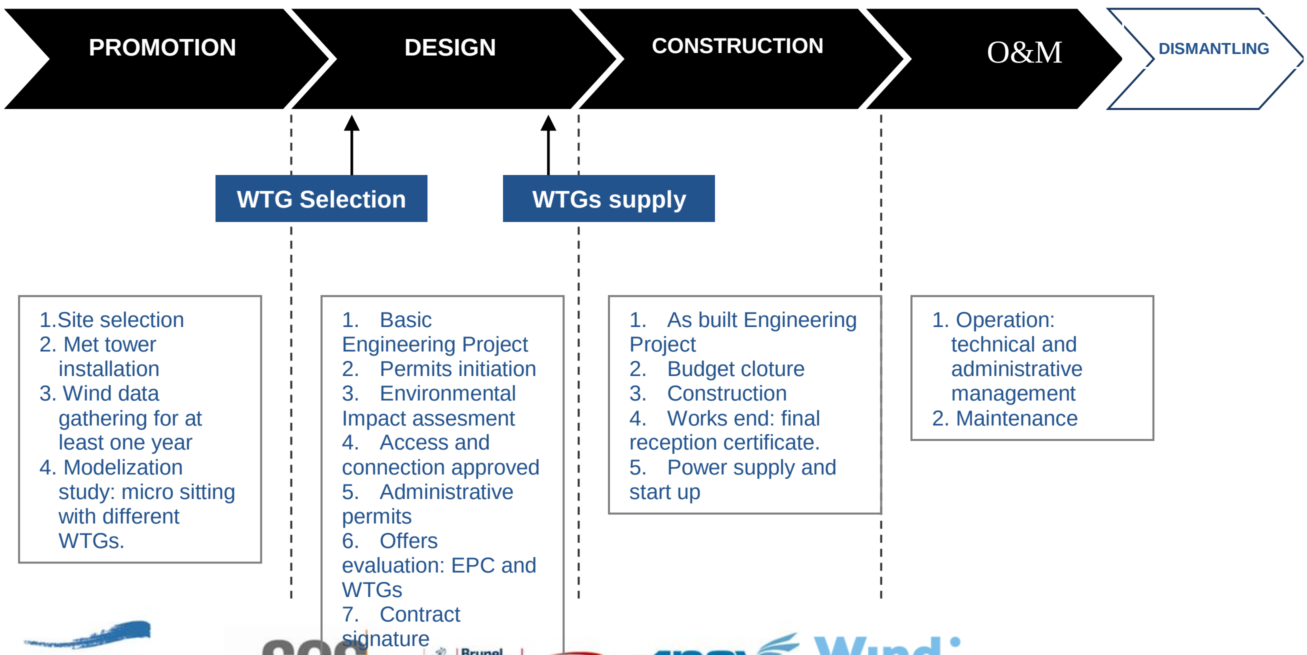


Figure 2. Wind farm design, construction, operation and maintenance

There is little experience in dismantling a Wind Farm around the world, but some manufacturers are already including in the technical documents, the different phases to take the different components, especially now that it has been shown a clear trend for used Wind Turbine Generators.

1.3.1.1. Wind farm design

In the following sections the different phases to design a wind farm are subsequently presented.

As we have already commented it is important to know the specifics of:

- To meter the wind data through the installation of the met towers.
- To identity the wind turbines, manufacturer, serial number of machines, technical specifications ...
- To carry out the micro siting of the wind turbines.
- To design the Internal networks of the Wind Farm, both MT network and internal paths, initially used for the assembling of the WTGs but later used for the maintenance goal.
- To design the wind farm Substation, to increase the voltage from MT to HT to connect the wind farm to the public mains.

For the identification of the wind turbines of wind farms, it is necessary:

- Constitution of a record for each position.
- The record of the position is the set of documentation on the position (The location where a wind turbine is installed). It consists of the following documents:
  - ✓ Wind in the position.
  - ✓ Documentation concerning civil works. That will include:
    - –Land soil characteristics,
    - –Build planes as electrical conduits and positioning grounding.

- ✓ Documentation of the wind turbine. What includes:
  - The traceability of all its components from the factory to the site.
  - The results of the startup.
  - Historical troubleshooting and replacement of parts and components.
- This record is used to measure the profitability of the wind turbine, which is given by:
  - ✓ The actual wind since its implementation, comparison between the estimated and actual wind.
  - ✓ The quality of the wind turbine as a product, measured in terms of technical availability.
- The maintenance is carried out of the wind turbine. This maintenance turn feeds the information contained in the record of the position:
  - ✓ In case of repetitive failures wind turbine traceability to find fault will look, checking the whole process from wind turbine manufacturing, assembly, installation and commissioning, to correct the initial cause that causes the problem.
  - ✓ A monthly report of the actions of maintenance is elaborated the energy production and estimates of work to be done in the future are included. This report is submitted to the responsible operating the Wind Farm, whether it is the company that owns the park or a third company.

The importance of all these records lies in the subsequent maintenance can know which components are present in each wind turbine, which has been his previous behavior and predict future behavior through the trees called Fault components.

<u>Maintaining documentation File Position is important work to be carried out thoroughly.</u>

If the wind turbine, or one of its elements, or any component is replaced during the life of the position, the file must be updated with the relevant information concerning it replaced.

If this position undergoes a change during the life of the wind turbine, the part of the record of the position regarding the wind turbine will compose the record of the new position. Updating all documentation relating to the assembly in the new position, but keeping the information relating to the previous assembly, it allows to the compare the changes which may have suffered the turbine.

1.3.1.2. Tasks for the design of the wind farm

The Promotion of a Wind Farm begins selecting an area where it is detected that it may be enough wind to achieve profitability to build a wind farm.

In the process of a wind farm development, it will be established:

- Topography.
- The access to the site, existing or to be constructed, their curves, bridges, urban areas to be crossed and kilometers to build.
- The soil type site (clays, rocky, swampy) will determine the needs, size and configuration of the foundation, whether it should be normal, special to the ground or it needs piles also has their own characteristics depending on whether the area is wet, dry, etc.…

Depending on the location, altitude, humidity, rainfall, the air will have higher or lower density, so this affects the energy, which is produced by wind turbine, but also to the load and mechanical stresses of the WTGs

The working conditions and cooling affect therefore to the life of the wind turbine.

The location and access tracks have a very direct effect to perform maintenance in every weather conditions (rain, snow, sandstorms, etc.).

The distance to a village, where the maintenance workers can live, affects the profitability of the wind farm. With all this information, a construction project of a wind site is generated.

1.3.1.3. Wind resource assessment:

The wind resource is characterized by:

- Speed: Average values, maximum, minimum and temporal variation.
- Direction: Wind rose.
- Roughness.
- Air density.
- Turbulence
- Vertical share.

All wind farm project begins with estimation of the wind resource at the site for which you must perform a measurement campaign using anemometers and wind vane at different heights.

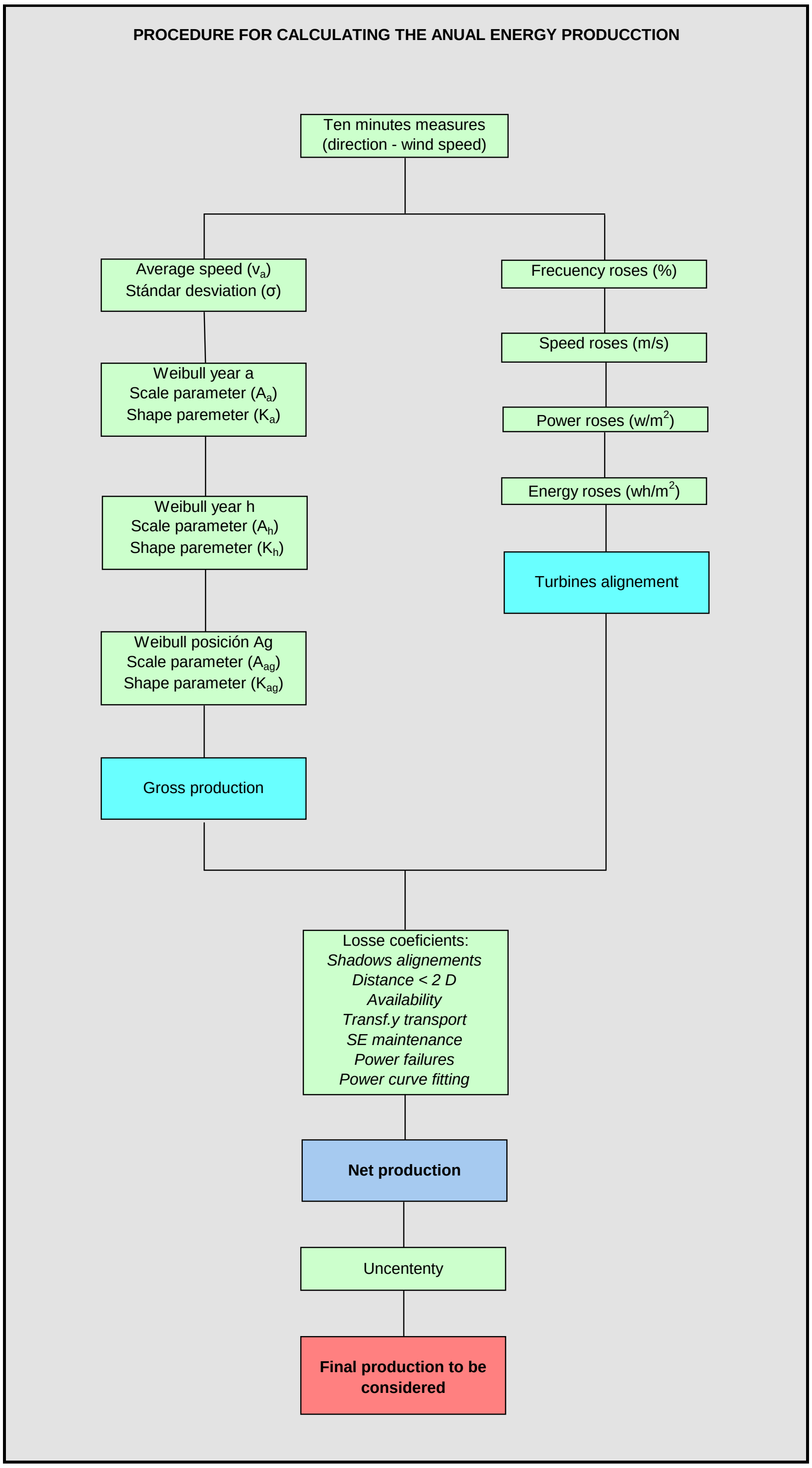


Figure 3. Procedure for calculating the anual energy production

The station is responsible for recording the time series data of wind speed and direction at different heights above the ground over a multiyear period in order to obtain seasonal and annual variation of the onsite wind.

Meteorological tower:

The meteorological station consists of the following equipment:

- Tower: It is a metal or concrete structure on which are installed at different heights anemometers and wind vanes. The height of the tower should be the turbine hub height and failing is recommended to be at least 2/3 of the hub height thereof.
- Anemometers: Sensors that measure wind speed. Normally several anemometers are installed at various heights in order to record the profile of wind variation with height.
- Weathervanes: Sensors that measure wind direction. Also it is installed more than one side to prevent data loss in case one of them fails.
- Thermometer: To measure the temperature, and on the basis of this air density.
- Barometer: To measure the pressure and on the basis of this air density.
- Data Logger: An instrument that records and stores data, which have been collected by the sensors.
- Other: Lightning rods, solar energy plate to feed the logger, cables, grounding, foundation, tower, etc ...

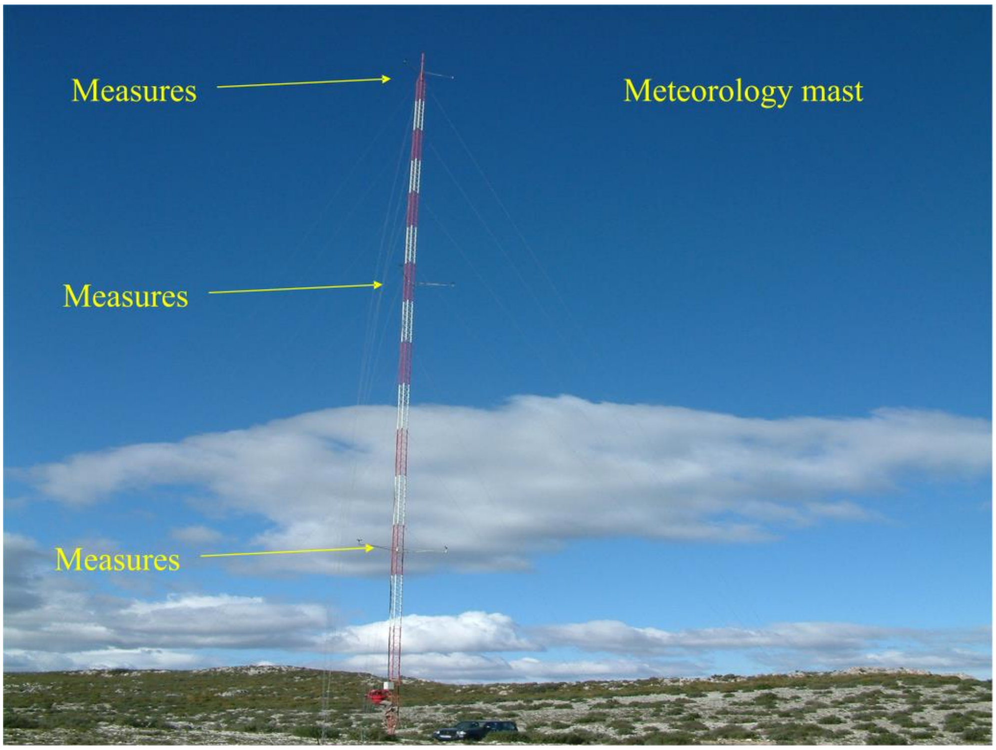


Figure 4.Met tower (Source: Gas Natural)

Figure 5. Sensors and components of a met station. (Source: AEE training course)

A data logger is collecting all the data from the met tower which are saved internal and transferred to the developer using SMS or satellite communication. A typical screen of a data logger is presented in the following illustration.

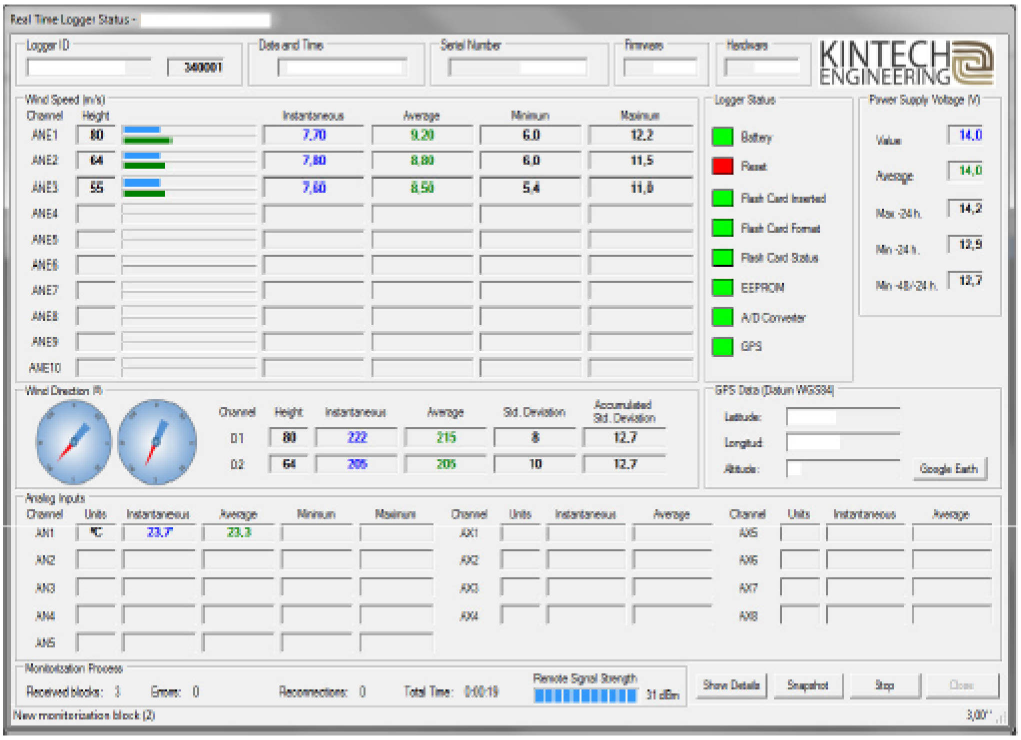


Figure 6. Typical data logger screen (Source: Kintech Engineering)

Some tips on the data collections.

- It´s necessary to know the configuration of the tower:
  - ✓ Measurements of the sensors, which will be in different height.
  - ✓ The distances of the arms where sensors are located, it is important to avoid interferences of the arms.
  - ✓ Point of location.
- It´s necessary to know the durationt of the measurement campaign.
- It´s advisable to visit the site of the tower to check the status of it and possible obstacles or vegetation that may be nearby.
- Having the raw data directly recorded by the logger, filling possible gaps.
- To have certificates of calibration of anemometers. If you have not entered the calibration values in the logger, it can be applied to the raw data rate parameters of the transfer function that appears in them.

- To apply to the corresponding vanes measuring deviation. Normally, the vanes are oriented to north so that the deviation is usually zero. If there are deviations, and these are not known, it can be in a single tower with two different wind vanes rose where there are presented different wind roses, which case you must find out what is the weather vane that marks correctly and correct each other.

The location of instruments must make so that the wind impinges directly on them, preventing them from being shielded by the tower mast or among themselves. Its localization should follow the IEC 61400-12.

The length of the arms should be at least 7 times the diameter of the tubular or tower if 3,75 times the side of the triangle if it is a lattice. If a sensor is placed on top of tower arm at least it should have a length greater than 1 m.

The weathervanes should be oriented to geographic or magnetic north, taking into accounts the magnetic declination of the site.

There also another procedure to evaluate the available wind resource:

Sodar: The device emits a beam of sound waves, which bounce off the airstream and swerves; this deviant wave is collected by the detector system and software analyzes the deviations and deducts the wind characteristics (speed and direction).

Figure 7. Sodar device (Source: AEE)

Lidar: temporary delay of the light beam reflected by aerosols in the air

Figure 8. Lidar device (Source: AEE)

Registered wind data:

The time series data logging station is formed by average values of:

- Average speed.
- Standard deviation of the average speed.
- Direction of wind.
- Temperature and pressure.

Data records have a frequency of 10 minutes. Each record consists of an average value of instantaneous data were taken every 1-5 seconds.

			Anemometer 1 H = 60 m			Anemometer 2 H = 40 m		
Ner	Date	Hour	Speed	Direction	Standar desviation	Speed	Direction	Standar desviation
1	01/01/2009	0000	8,60	64	1,30	8,30	64	1,29
2	01/01/2009	0010	8,70	68	1,21	8,42	68	1,20
3	01/01/2009	0020	7,65	69	1,34	7,56	69	1,34
4	01/01/2009	0030	7,52	68	1,30	7,19	68	1,29
5	01/01/2009	0040	8,55	69	1,03	8,22	69	1,02
52,558	31/12/2009	2330	17,45	290	1,25	18,40	290	1,26
52,559	31/12/2009	2340	18,10	291	1,07	16,51	291	1,06
52,560	31/12/2009	2350	15,90	289	1,21	15,12	289	1,20

Chart 1. Registered wind data

There must be a regular monitoring of the measures contained in the instruments well capturing data remotely via GSM to study centres through the data logger already mentioned.

This analysis is based to prove that obtained data are consistent: the wind logical profile, lack of voids due to malfunction or breakdown in logger instruments, weathervanes with similar values, etc...

The tower must be kept under constant review so that in case of failure it can be resolved as soon as it will be possible.

The wind rose report of the directional distribution of wind frequency, speed and power, and it is critical in the wind farm layout.

The wind rose of frequency represents the percentage of time that the wind blows in a certain direction. The wind rose of speed and power represent the velocity and energy with the wind blowing in each spatial direction.

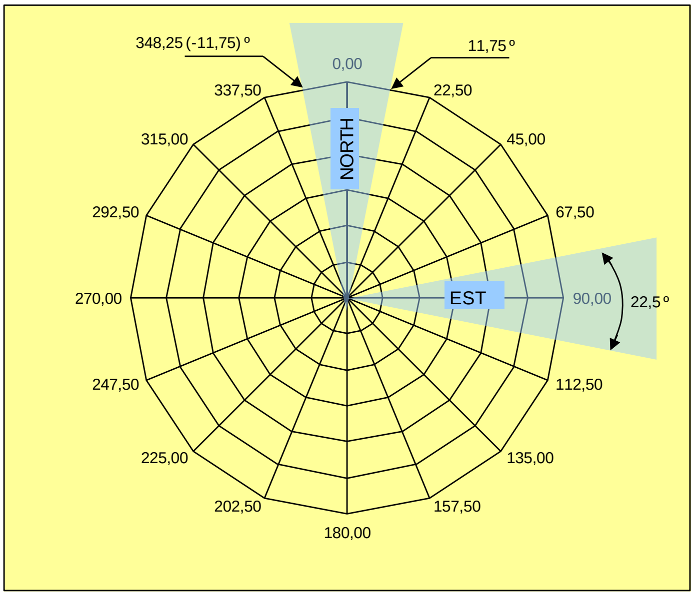


Figure 9. Wind rose (Source: AEE)

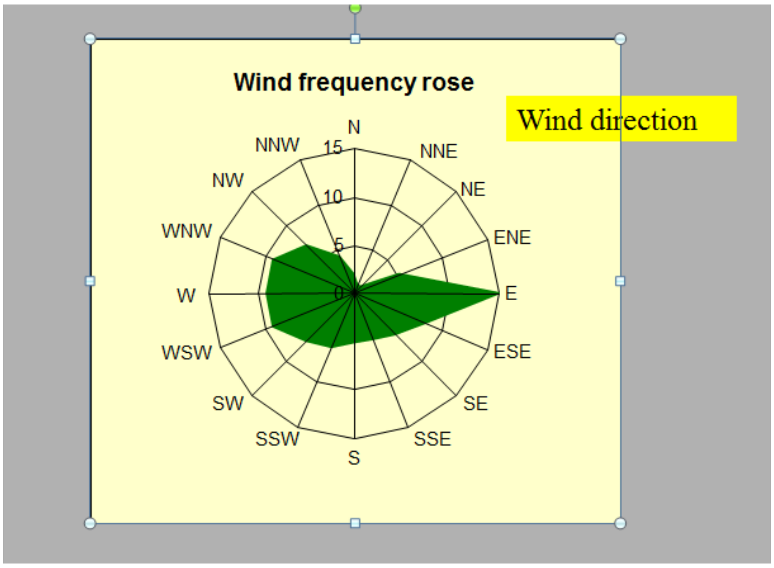


Figure 10. Wind frequency rose (Source: AEE)

The data time series of wind will be obtained at the site for at least a period of one year a descriptive and a statistical analysis is done. The analysis consists of to quantify the main parameters of wind resource.

Direction	Frequency (%)	Average speed (m/s)	Power (w/m2)	Energy (wh/m2)	Energy (%)
Calms	1	0			
N	2	5	76,56	13.413	0,18
NNE	1	4	39,20	3.434	0,05
NE	1	6	132,30	11.589	0,16
ENE	5	10	612,50	268.275	3,66
E	15	16	2508,80	3.296.563	44,98
ESE	8	13	1345,66	943.039	12,87
SE	6	10	612,50	321.930	4,39
SSE	5	8	313,60	137.357	1,87
S	5	8	313,60	137.357	1,87
SSW	6	9	446,51	234.686	3,20
SW	7	9	446,51	273.800	3,74
WSW	9	10	612,50	482.895	6,59
W	9	10	612,50	482.895	6,59
WNW	9	10	612,50	482.895	6,59
NW	7	8	313,60	192.300	2,62
NNW	4	6	132,30	46.358	0,63
Sum	100			7.328.786	100,00

Chart 2. Wind energy analysis

To obtain the wind energy rose from the wind frecuency roses it is necessary to take account the wind speed in each sector that it has to be elevated to the cubic to evaluate the actual energy to be produced in that sector.The densist of power (w/m2) give an approximate overview of each sector with the approach of considering the sector as Rayleigh distribution that it is a Weibull with the factor coeficient k=2.

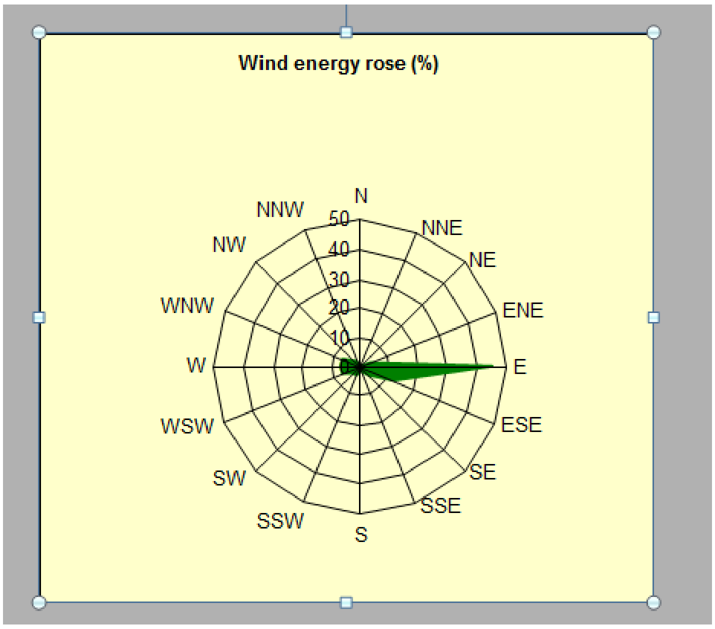


Figure 11. Wind energy rose

The first important task is to verify the quality of the recorded data in order to detect possible time intervals of anomalous data. The verification of data quality or cleaning can be done as following:

- The visual inspection made by graphical representations of trends.
- The statistical methods consisting of applying filters to the data to detect anomalies such as extreme speed work and standard deviation of speed.

In the following figures can be observed some mistakes in the direction data, probably due to ice formation or dust in the van device. Normally the person who treats the information should fill this gap of information with his best criteria.

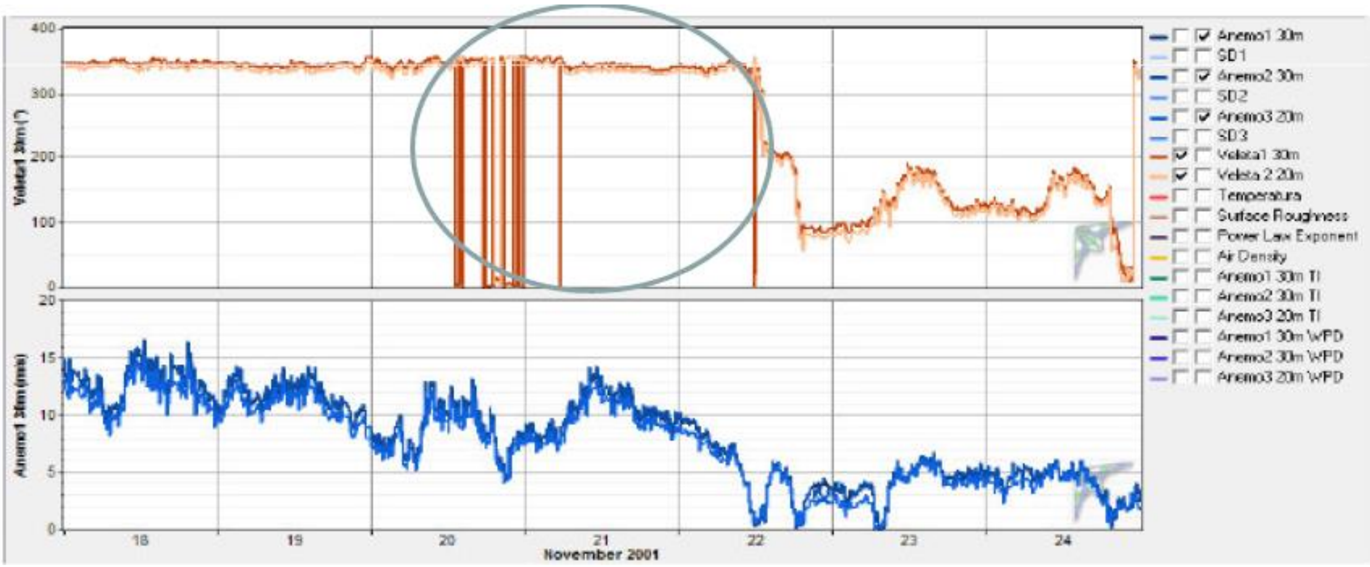


Figure 12. Mistakes in the wind direction data

<u>Descriptive statistical analysis of the wind data.</u>

With this analysis, the next values are obtained: Mean values, maximum, predominant directions, probability distribution frequency speed and direction (wind roses), duration curve (cumulative distribution function), directional distribution of available energy, turbulence and their graphical representations.

- Probability that wind speeds exist between two limits of interest.
- The average wind speed is obtained from the Weibull distribution.
- The standard deviation of the Weibull distribution.
- Turbulence.

Altura sobre el suelo (m)	40,0	20,0
Velocidad de viento: media (m/s)	7,18	6,73
Velocidad de viento: máxima (m/s)	31,31	29,49
Weibull k (factor de forma)	1,985	1,960
Weibull c (m/s) (factor de escala)	8,10	7,59
Densidad de potencia media (W/m²)	418	350
Contenido energético medio (kWh/m²/año)	3.662	3.070
Registros Posibles	456.133	456.133
Registros válidos	326.943	326.943
Registros no válidos	129.190	129.190
Ratio de datos válidos (%)	71,7%	71,7%
Hora de máxima velocidad de viento	6	6

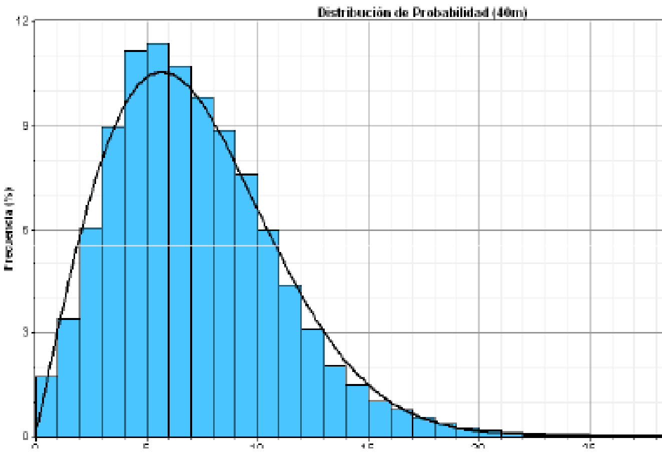


Figure 13. Typical Weibull curve for a specific site (Source:AEE)

It is also imporant to calculate the wind intensity turbulence as the standard deviation of the wind speed with data collected every 10 min. This turbulence will be used to select the type of the WTG for a specific site.

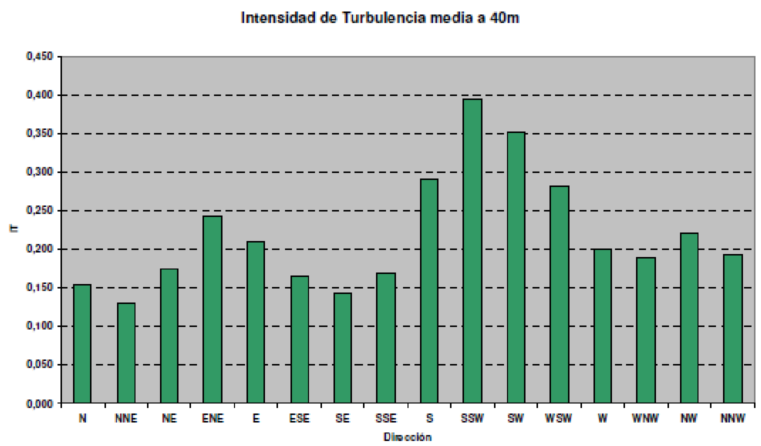


Figure 14. Average turbulence instensity at 40 meters high

With the wind data collected will be also necessary to calculate the dayly and the monthly profiles such as are represented in the following figures.

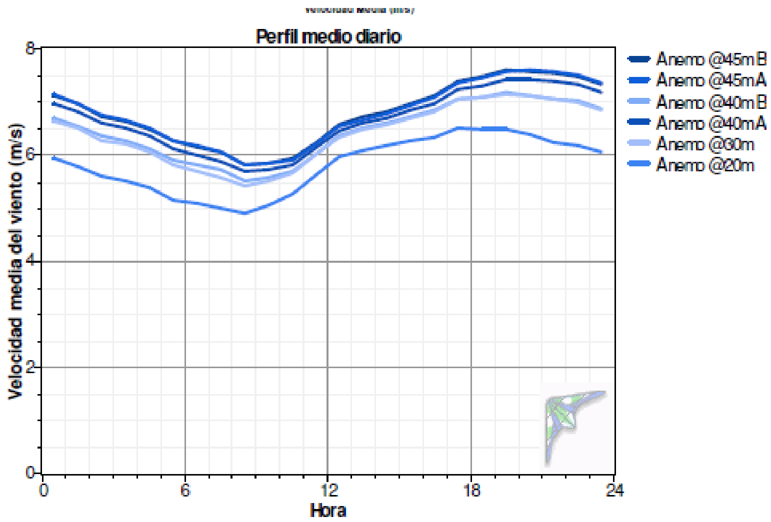


Figure 15. Average daily profile

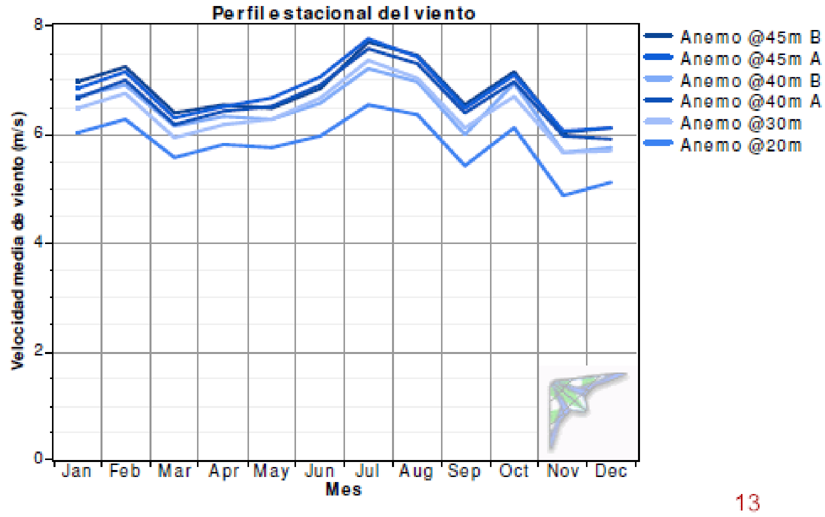


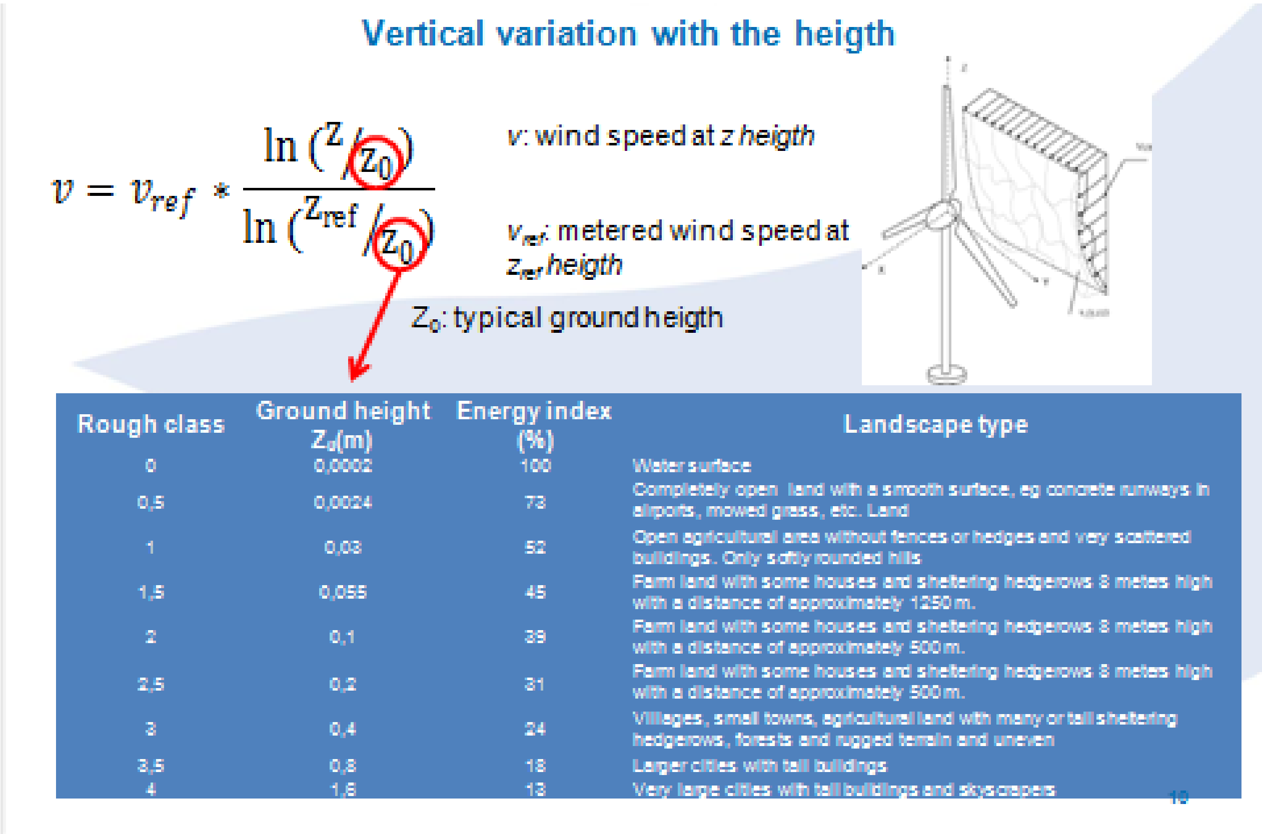
Figure 16. Average monthly profile

For the study of the wind, include:

- To process of the weather station data.
- Calibration of weather stations.
- Evaluation of the local air density.
- Modelling of wind.

- Modelling from measurements of the reference period of the wind.
- Assessments of productions.

The wind rises with the height such as it can be shown in the following figure:



Rough class	Ground height Z_0(m)	Energy index (%)	Landscape type
0	0,0002	100	Water surface
0,5	0,0024	73	Completely open land with a smooth surface, eg concrete runways in airports, mowed grass, etc. Land
1	0,03	52	Open agricultural area without fences or hedges and very scattered buildings. Only softly rounded hills
1,5	0,055	45	Farm land with some houses and sheltering hedgerows 8 meters high with a distance of approximately 1250 m.
2	0,1	39	Farm land with some houses and sheltering hedgerows 8 meters high with a distance of approximately 500 m.
2,5	0,2	31	Farm land with some houses and sheltering hedgerows 8 meters high with a distance of approximately 500 m.
3	0,4	24	Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and rugged terrain and uneven
3,5	0,8	18	Larger cities with tall buildings
4	1,6	13	Very large cities with tall buildings and skyscrapers

Figure 17. Vertical wind variation with the height

1.3.1.4. Wind conditions evaluation in a specific site

The analytical speed distribution to characterise a specific site is the Weibull distribution, which is the function of probability density, which is the most used to represent the frequency distribution of wind

- p(v): Statistical probability that a given probability happens.
- C: Scaling factor (speed units).
- K: the form factor.

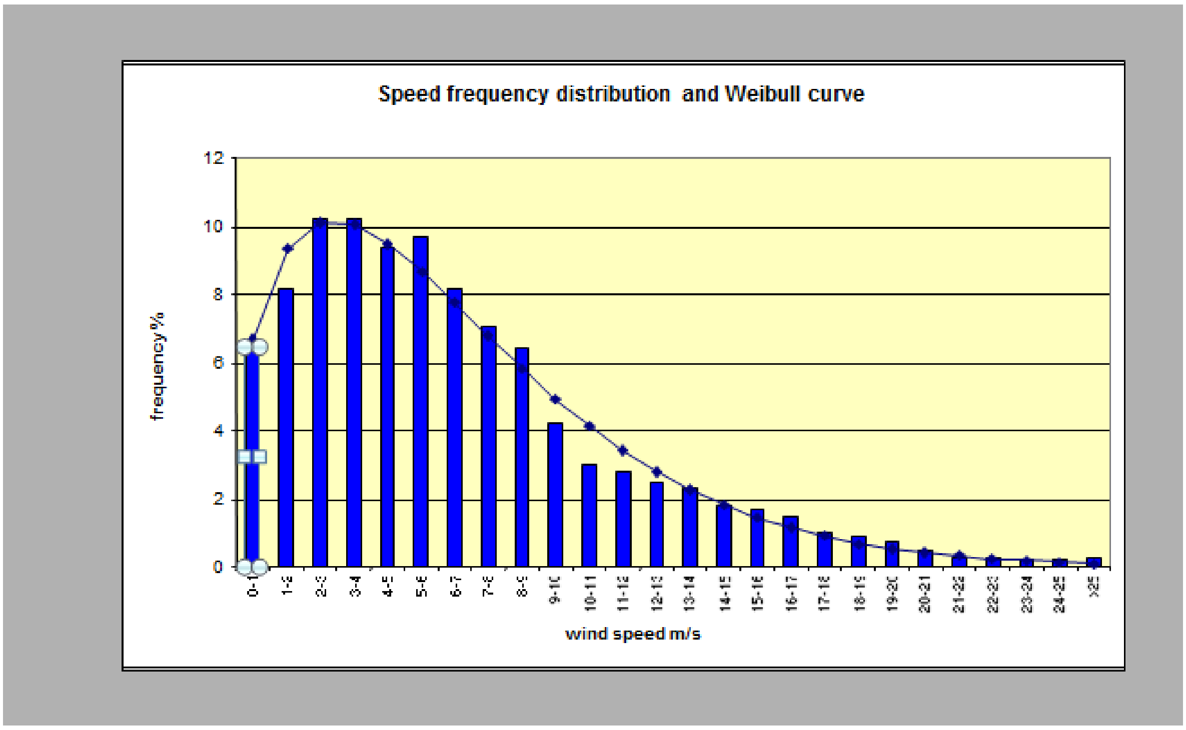


Figure 18. Speed frequency distribution and Weibull curve

The bar graph of each speed interval represents the frequency (number of hours of wind in the bounded range) and the curve is an Weibull approach.

In the following figure it can be observed different Weibull curves with different form factors, is clear that higher ks mean better wind conditions because there is a higher probability concentration in certain values of the wind speed which are normally the site average wind speed.

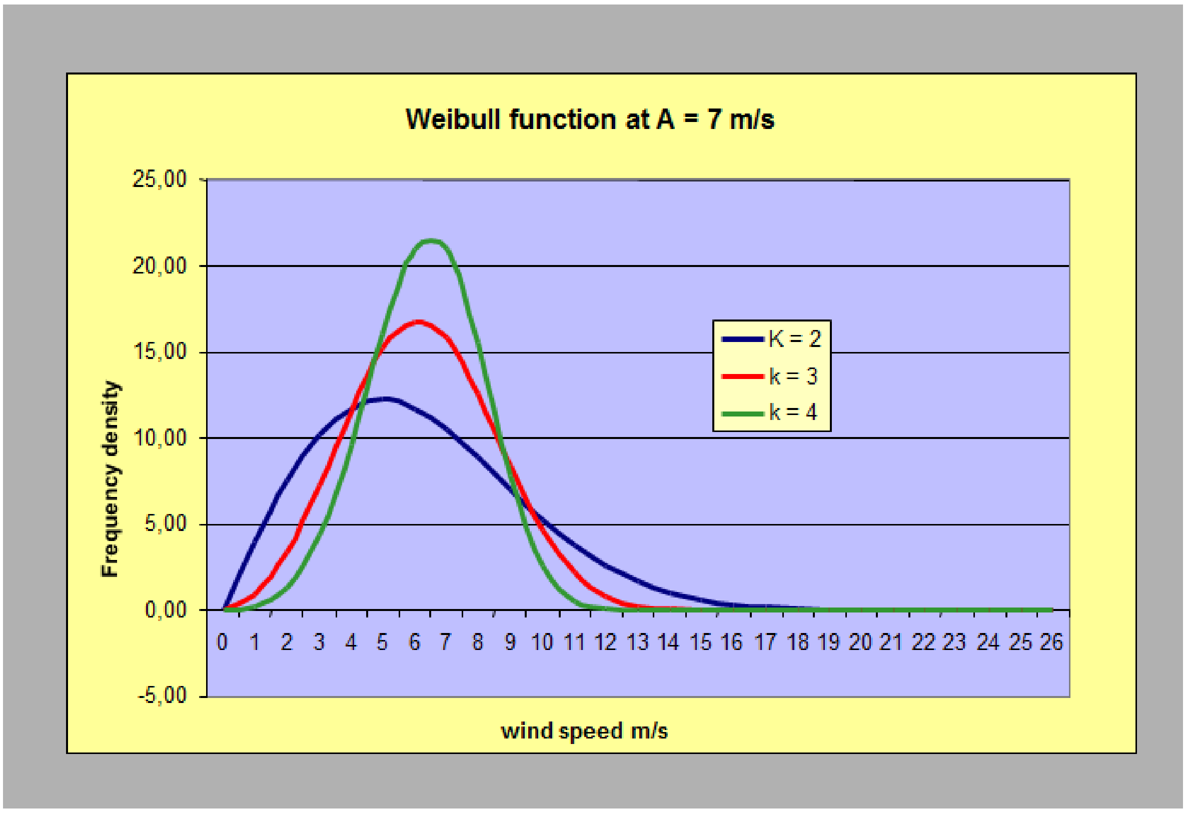
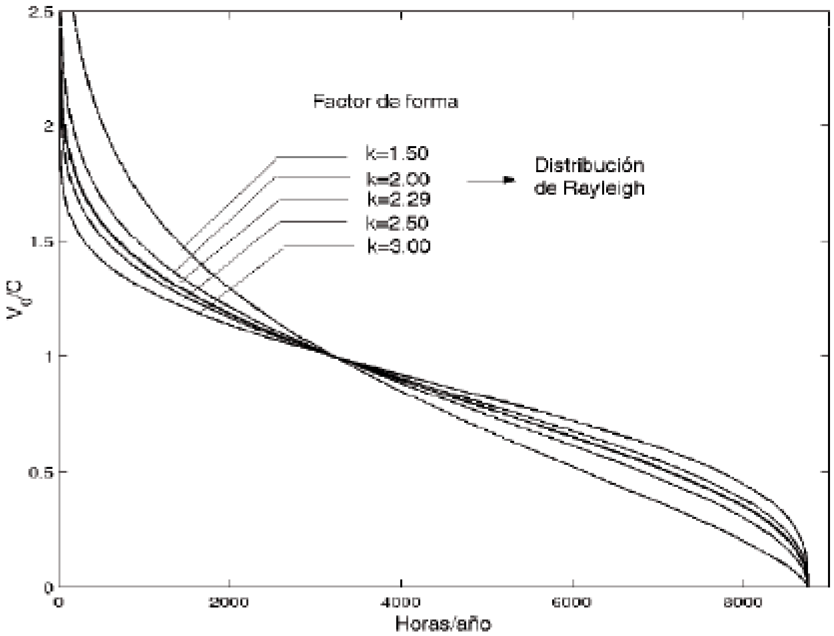


Figure 19. Weibull curves with different form factors

Applications of Weibull distribution:

- Weibull cumulative distribution function: The probability that the speed wind (v) will be above a certain (u).
- If this function is multiplied by the number of hours in a year (8760 hours), it´s possible to obtain duration curve of wind that gives the number of hours the wind speed exceeded a certain value.



Curva de Duración para diferentes valores de los parámetros c y k

Figure 20. Duration curve of wind

The equation of Weibull distribution is:

$$p(v) = \frac{k}{c} \times (\frac{v}{c})^{k-1} \times e^{(-\frac{v}{c})^k}$$

Where:

- c: Scale factor
- k: Form factor

1.3.1.5. Wind generation calculation

The typical power curve of a WTG with changeable pitch is shown in the following figure for a modern wind turbine G80, 80 meters diameter and 2 MW of nominal power.

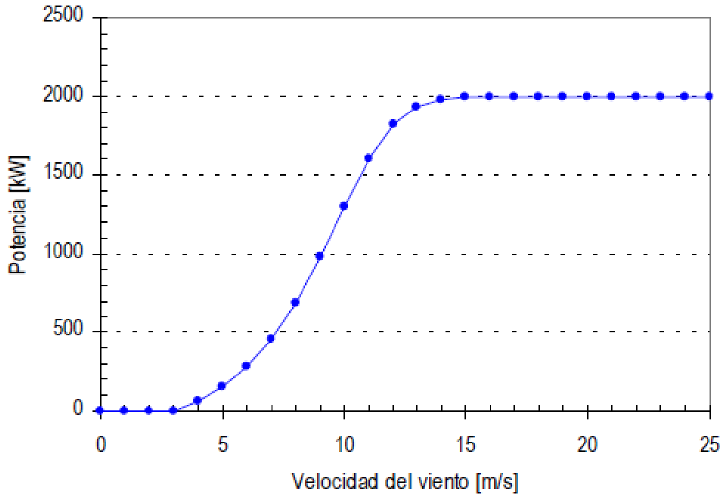


Figura 1a: Curva de potencia del aerogenerador G80 – 2.0 MW-105.1 dB(A) para una densidad del aire igual a 1.225 kg/m³.

Figure 21. G80 Wind turbine power curve

The combination of this power curve with the wind conditions will determine the generation of the WTG but it is important to use the Weibull distribution approach shown previously because the generation will finally be achieved such as it can be observed in the following table for the G80 and the V100, in this case with 100 meters diameter. Generation is very dependent of the rotor diameter according to the following for mule:

$$P_t = \frac{1}{2} \cdot \rho \cdot A \cdot v^3 \cdot Cp$$

Where:

ρ: air density

A: rotor surface in m2

V. wind speed in m/s

Cp: Power coefficient, also included in the manufacturers catalogue.

Ct is the trust coefficient related to the aerodinamical behaviour of the generator and it is especially important for its structural design.

Tabla 3: Valores de C_P y C_t del aerogenerador G80 – 2.0 MW.

Vel. viento [m/s]	C_p	C_t
4	0.336	0.818
5	0.394	0.806
6	0.421	0.804
7	0.432	0.805
8	0.437	0.806
9	0.435	0.78
10	0.420	0.737
11	0.389	0.649
12	0.341	0.571
13	0.286	0.41
14	0.234	0.314
15	0.191	0.249
16	0.158	0.202
17	0.132	0.167
18	0.111	0.14
19	0.094	0.118
20	0.081	0.101
21	0.070	0.088
22	0.061	0.076
23	0.053	0.067
24	0.046	0.059
25	0.041	0.052

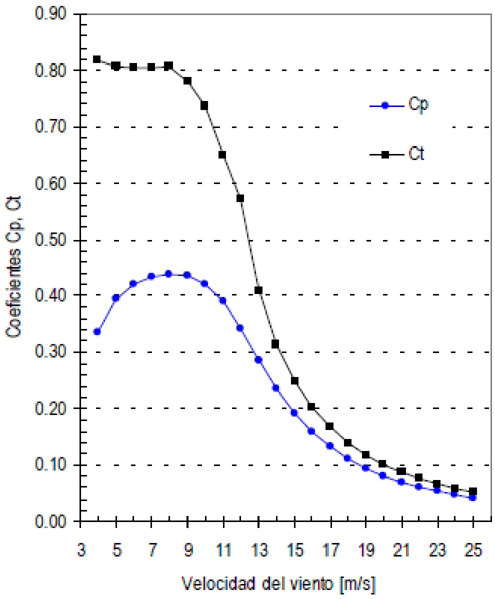


Figura 2:Curvas C_P y C_t del aerogenerador G80 – 2.0 MW.

Figure 22. Chart and curves representing the power coefficient C_P and the trust coefficient C_t versus wind speed

P [kW]	*Densidad del aire [kg/m³]*								
Vel. viento [m/s]	*1.225*	*1.060*	*1.090*	*1.120*	*1.150*	*1.180*	*1.210*	*1.240*	*1.270*
3	9.7	6.4	7.0	7.6	8.2	8.8	9.4	10.0	10.6
4	31.2	25.7	26.7	27.7	28.7	29.7	30.7	31.7	32.7
5	78.4	69.3	70.9	72.6	74.2	75.9	77.6	79.2	80.9
6	148.2	130.5	133.7	136.9	140.2	143.4	146.6	149.8	153.0
7	242.7	215.5	220.4	225.4	230.3	235.3	240.2	245.2	250.1
8	368.8	329.5	336.7	343.8	351.0	358.1	365.2	372.4	379.5
9	525.3	468.7	479.0	489.3	499.6	509.9	520.2	530.4	540.7
10	695.0	618.4	632.3	646.2	660.2	674.1	688.0	702.0	715.9
11	796.6	711.0	726.6	742.2	757.7	773.3	788.8	804.4	819.9
12	835.9	768.5	780.7	793.0	805.3	817.5	829.8	842.0	850.0
13	846.8	813.0	819.2	825.3	831.5	837.6	843.7	849.9	850.0
14	849.3	834.4	837.1	839.8	842.5	845.2	847.9	850.0	850.0
15	849.9	844.4	845.4	846.4	847.4	848.4	849.4	850.0	850.0
16	850.0	848.0	848.3	848.7	849.1	849.4	849.8	850.0	850.0
17 → 21	850.0	850.0	850.0	850.0	850.0	850.0	850.0	850.0	850.0

Chart 3. Wind turbine power generation depending on the air densitity and wind speed

Therefore the generation of the different WTGs above mentioned are the following ones:

Vm (m/s)	5,16			
K	2,034			
A	5,82			
ha	8760			
Vestas V100 1,8 MW				
v(m/s)	weibull $P(v_x \le v \le v_y)$	Pi(kW)	hi(horas) weibull $P(vx \le v \le vy)$	producción kWh weibull $P(vx \le v \le vy)$
0	0,68	0	59,19	0
1	5,46	0	478,49	0
2	10,25	0	898,31	0
3	13,49	98	1181,44	115781
4	14,79	245	1295,37	317365
5	14,27	454	1250,18	567583
6	12,42	742	1087,90	807224
7	9,87	1108	864,47	957837
8	7,21	1518	631,98	959353
9	4,88	1752	427,09	748259
10	3,06	1798	267,65	481238
11	1,78	1800	155,89	280609
12	0,96	1800	84,53	152148
13	0,49	1800	42,71	76887
14	0,23	1800	20,14	36245
15	0,10	1800	8,86	15950
16	0,04	1800	3,64	6555
17	0,02	1800	1,40	2517
18	0,01	1800	0,50	904
19	0,00	1800	0,17	303
20	0,00	1800	0,05	95
21	0,00	1800	0,02	28
22	0,00	1800	0,00	8
23	0,00	1800	0,00	2
24	0,00	1800	0,00	0
25	0,00	1800	0,00	0
>25,5	0,00	0	0,00	0
sumas	**100,00**	**sumas**	**8760,00**	**5.526.891**
			MWh/año	**5.527**

Chart 4. Vestas V100 1,8MW Wind turbine generation

Vm (m/s)	5,16			
K	2,034			
A	5,82			
ha	8760			
Gamesa G-80 de 2 MW				
v(m/s)	weibull $P(v_x \le v \le v_y)$	Pi(kW)	hi(horas) weibull $P(vx \le v \le vy)$	producción kWh weibull $P(vx \le v \le vy)$
0	0,68	0	59,19	0
1	5,46	0	478,49	0
2	10,25	0	898,31	0
3	13,49	0	1181,44	0
4	14,79	66,3	1295,37	85883
5	14,27	152	1250,18	190028
6	12,42	280	1087,90	304613
7	9,87	457	864,47	395065
8	7,21	690	631,98	436070
9	4,88	978	427,09	417693
10	3,06	1296	267,65	346876
11	1,78	1598	155,89	249119
12	0,96	1818	84,53	153669
13	0,49	1935	42,71	82653
14	0,23	1980	20,14	39869
15	0,10	1995	8,86	17677
16	0,04	1999	3,64	7280
17	0,02	2000	1,40	2797
18	0,01	2000	0,50	1004
19	0,00	2000	0,17	337
20	0,00	2000	0,05	106
21	0,00	2000	0,02	31
22	0,00	2000	0,00	9
23	0,00	2000	0,00	2
24	0,00	2000	0,00	1
25	0,00	2000	0,00	0
>25,5	0,00	0	0,00	0
sumas	**100,00**	**sumas**	**8760,00**	**2.730.781**
			MWh/año	**2.731**

Chart 5. Gamensa G-80 2MW Wind turbine generation

Such as it can be seen in the two previous tables the generation can be duplicated with only 20 m of increasing of the rotor diameter and decreasing the nominal power of the WTG but this is very dependent of the onsite wind conditions.

Following the wind conditions which are only roughly represented by the average wind speed it can be made a first approach of the generation production.

Wind [m/s]	Energy [MWh]
5.0	6737
5.5	8525
6.0	10300
6.5	12038
7.0	13730
7.5	15293
8.0	16792
8.5	18139
9.0	19396
9.5	20528
10.0	21542

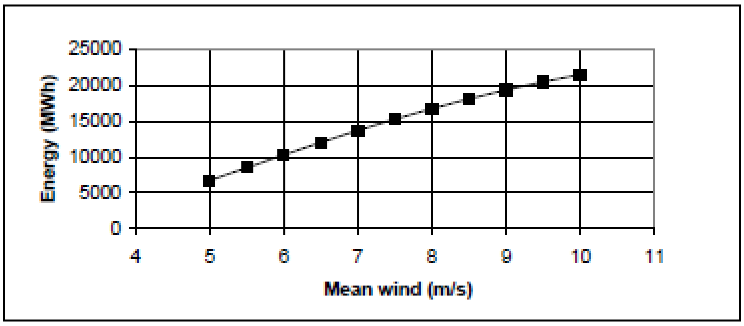


Figure 23. Generation production by average wind speed

The value of production is usually in probabilistic terms using the P50 as a reference value, nevertheless taking into consideration that the production has been less than expected, many financial institutions are claiming to use other probabilistic values such as either P75 or P90, much lower in terms of generation but easily achievable such as it can observed in the following figure:

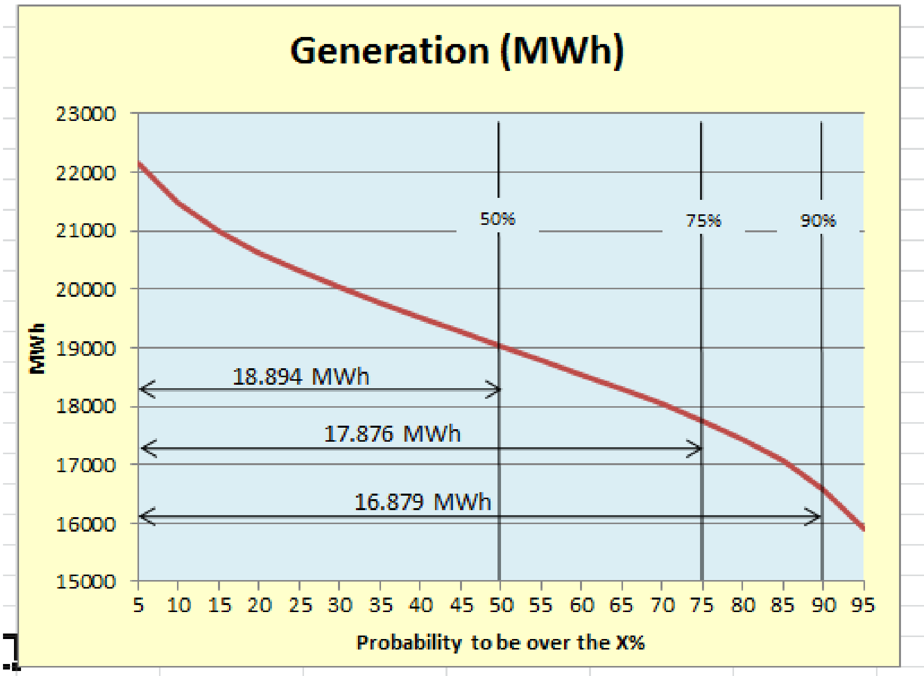


Figure 24. Probabilistic value of production

On the other hand, wind turbine manufacturers design various different types of wind turbine following the design standard IEC-61400-1:

- Classes 1, 2 3 and 4 are based in wind speed limits.
- IEC Class A or B, which is based on turbulence limits.

	IEC Class	I	II	III	IV	S
Wind speed limits	Vmax (m/s)	50	42.5	37.5	30	Designer specifies
	Vgust (m/s)	70	59.5	52.5	42	
	Vavg (m/s)	10	8.5	7.5	6.0	
turbulence limits	IEC Class	A	B			Designer specifies
	I15	0.18	0.16			
	a	2	3			

Fig. 1.1 IEC 61400-1 Wind Turbine Safety Standard

The wind classes are based on the stated wind parameters which are defined as follows:

- Vmax = maximum wind speed over a period of 50 years (averaged over 10 min)
- Vgust = maximum wind gust over a period of 50 years (averaged over 5 sec)
- Vavg = average annual wind speed
- Turbulence intensity = std deviation of wind speed dived by average wind speed of random ten-mi measurements
- I15 = characteristic turbulence intensity at 15 m/s = mean + 1 std deviation of turbulence intensity at 15 m/s
- a = turbulence model parameter

$I = I_{15}\,(a+15/V_{hub})/(a+1)$

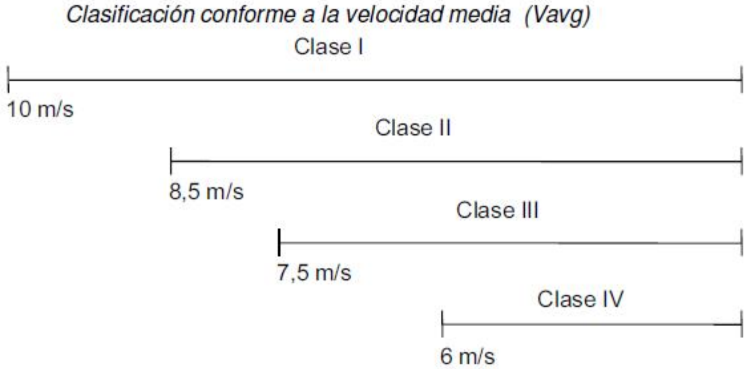
I_{15} : intensidad turbulencia para 15 m/s

I_{15} = 0,18 para a = 2 -----clase A

I_{15} = 0,16 para a = 3 -----clase B

V_{hub}: velocidad a la altura de buje

Clasificación conforme a la velocidad media (Vavg)



Clasificación conforme a la turbulencia (I_{15})

The 2nd edition of IEC 61400-1 defines three turbulence categories based on the **characteristic turbulence intensity** at a wind speed of 15 m/s:

Turbulence Categories defined in IEC 61400-1 2nd Edition

Category	Characteristic TI at 15 m/s
S	> 0.18
A	0.16-0.18
B	0-0.16

The 3rd edition of IEC 61400-1 defines four turbulence categories based on mean turbulence intensity at a wind speed of 15 m/s:

Turbulence Categories defined in IEC 61400-1 3rd Edition

Category	Mean TI at 15 m/s
S	> 0.16
A	0.14-0.16
B	0.12-0.14
C	0-0.12

Figure 25. Different types of wind turbine following the design standard IEC-61400-1

Selecting one or other type of wind turbine depends on the equivalent hours of each site.

Nevertheless, a clear trend is observed in the recent past to increase the rotor size which makes that the above classification needs to be reviewed.

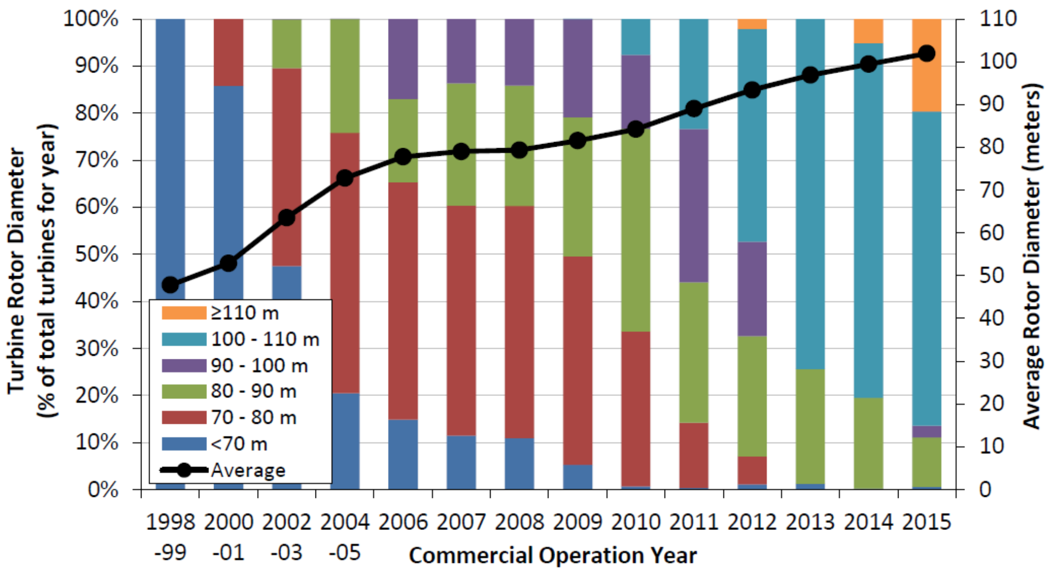


Figure 26. Rotor size increase trend

1.3.1.6. Fitting the WTG to the on-site conditions

In the process of selecting a model it is important to adapt to the characteristics of a site, these are:

- Desert (sand and extreme heat).
- Intense cold (freezing of liquids, ice buildup, cold working conditions, nearby sea conditions, …).
- Customer requests.
- The specific regulator.
- Etc.

All these changes, as others have named above, are reported during the design process of the wind farms area so that they are taken into account during manufacture of the WTGs. From here the wind turbines finally delivered will be associated with the specific location.

Usually, the wind turbines are assembled from components, which have been produced by third parties. These components are manufactured according to the technical design specifications.

The necessary checks are developed to ensure that production is suited to the conditions set by design.

Nevertheless the application of this standard is lately reviewed with the present trend of increasing the diameter maintaining the nominal power, reducing then the power density .

WTGs in Cold Climate Version (CCV) design

Wind turbines with the CCV option are designed for operating at deep temperatures down to -30 °C. Work on the WT, however, is only permitted at temperatures down to -20 °C.

When staying or working inside the WT under extremely low temperatures, do not touch any metallic parts with bare hands because there is the risk of freezing to it. Wear safety gloves.

The tools and accessories must be suitable for use under extreme frost conditions.

WTs in Hot Climate Version (HCV) design

Wind turbines with the HCV option are designed for operating at high temperatures up to +45 °C. Therefore, the surface of some WT components may be very hot. Signs in the entrance area inform you about the hazard of being exposed to hot surfaces.

When staying or working inside the WT under extremely high temperatures, do not touch any metallic parts with bare hands because there is the risk of burns. Wear safety gloves and long work clothes. Do not get into contact with hot surfaces for longer than 10 minutes. Observe the heat breaks that are required by national rules and regulations, and drink enough.

Slip hazard due to ice

In icy conditions, there is an increased risk of slipping when approaching the WT, and particularly when using the external staircase.

In this weather conditions, watch your step accordingly when approaching the WT or take actions to avoid slipping on iced floor.

Ice throw

The primary residual risk when operating the WT is the risk of ice throw during the cold season. Where required, the owner is obliged to point out the risk of ice throw by means of suitable signs and labels, e.g., a sign in the access area.

If there is a risk of icing, the owner must ensure that the WT is stopped. It must be restarted only when the owner/operator has assured himself on site that there is no longer a risk of ice throw.

If there is a risk of ice throw, take particular caution when approaching the turbine. In particular, avoid standing or walking below the rotor blades.

Below the design climatic conditions of the SIEMENS SWT 2.3-108 WTG are presented.

Design Climatic Conditions SWT-2.3-108

The design climatic conditions are the boundary conditions at which the turbine can be applied without supplementary design review. Applications of the wind turbine in more severe conditions may be possible, depending upon the overall circumstances. A project site-specific review requires the completion by the Client of the "Project Climatic Conditions" form.

Subject	ID	Issue	Unit	Value
1. Wind, operation	1.1	Wind definitions	-	IEC 61400-1 Ed3
	1.2	IEC class	-	IIB
	1.3	Air density, ρ	kg/m^3	1.225
	1.4	Mean wind speed, V_{ave}	m/s	8.5
	1.5	Weibull scale parameter, A	m/s	9.6
	1.6	Weibull shape parameter, k	-	2
	1.7	Wind shear exponent, α	-	0.20
	1.8	Mean turbulence intensity at 15 m/s, I_{ref}	-	0.14
	1.9	Standard deviation of wind direction	Deg	7.5
	1.10	Maximum flow inclination,	Deg	8
	1.11	Minimum turbine spacing, in rows	D	3
	1.12	Minimum turbine spacing, between rows	D	5
2. Wind, extreme	2.1	Wind definitions		IEC 61400-1 Ed3
	2.2	Air density, ρ	kg/m^3	1.225
	2.3	Maximum hub height 10 min.wind, V_{ref}	m/s	42.5
	2.4	Maximum 3 s gust in hub height, V_{e50}	m/s	59.5
	2.5	Maximum hub height power law index, α	-	0.11
3. Temperature	3.1	Temperature definitions	-	IEC 61400-1 Ed3
	3.2	Minimum temperature at 2 m, stand-still, $T_{min,s}$	Deg.C	-20
	3.3	Minimum temperature at 2 m, operation, $T_{min,o}$	Deg.C	-10
	3.4	Maximum temperature at 2 m, operation, $T_{max,o}$	Deg.C	35
	3.5	Maximum temperature at 2 m, stand-still, $T_{max,s}$	Deg.C	45
4. Corrosion	4.1	Corrosion definitions	-	ISO 12944
	4.2	External corrosion class	-	C3
	4.3	Internal corrosion class	-	C3
	4.4	Internal climate control	-	Yes
5. Lightning	5.1	Lightning definitions	-	IEC 62305-1
	5.2	Lightning protection level (LPL) acc to IEC 62305	-	LPL 1
6. Dust	6.1	Dust definitions	-	-
	6.2	Dust conditions, ground level	-	Normal DK
	6.3	Dust conditions, hub height	-	Normal DK
7. Hail	7.1	Maximum hail diameter	mm	20
	7.2	Maximum hail falling speed	m/s	20
8. Ice	8.1	Ice definitions	-	IEC 61400-1 Ed3
	8.2	Ice conditions	Days/yr	4-7
9. Trees	9.1	If the height of trees within 500m of any turbine location height exceeds 1/3 of (H – D/2) where H is the hub height and D is the rotor diameter then restrictions may apply. Please contact Siemens for information on the maximum allowable tree height with respect to the site and the turbine type.		

Figure 27. SIEMENS SWT 2.3-108 WTG design climatic conditions

1.3.1.7. Wind farm arrangement

In the following scheme is presented the general wind farm layout, based in a previous ortophoto and the specific steaks of the WTGS

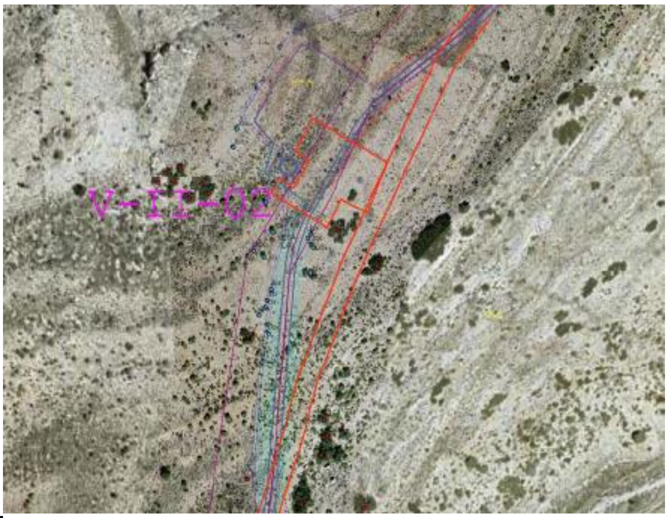


Figure 28. General wind farm layout on an ortophoto

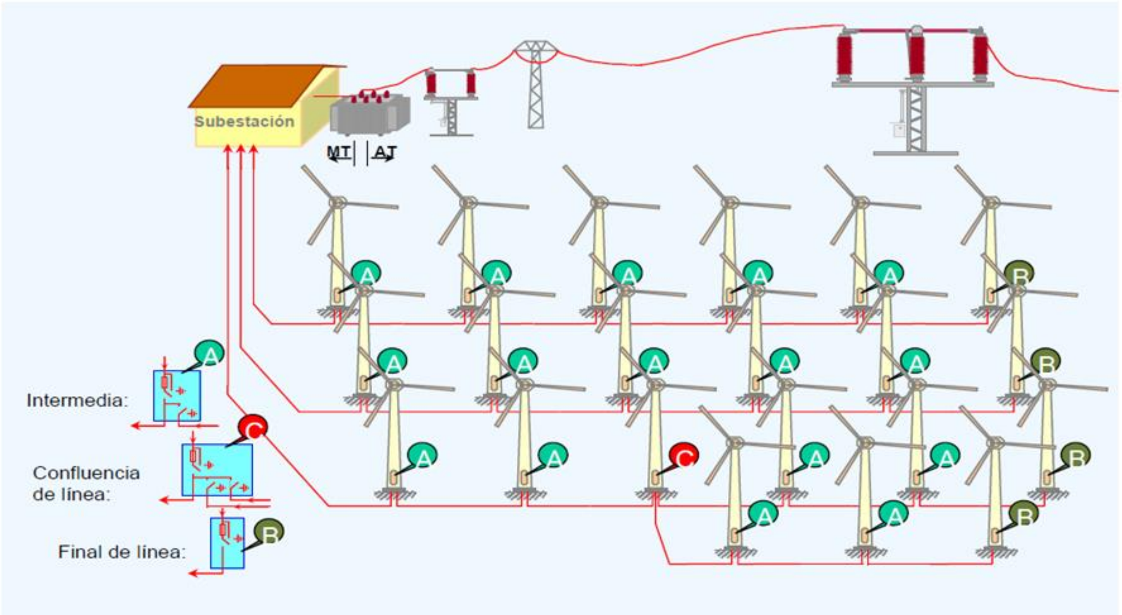


Figure 29. Wind farm layout

And in the follwing figure the wind farm substation can be observed as well as the WTGs which are part of the same Wind Farm.

Figure 30. Wind farm electrical substation and wind turbine generators

The electrical diagram is presented in the following drawing with all electrical components of the wind farm, more complex than the presented in the above figure.

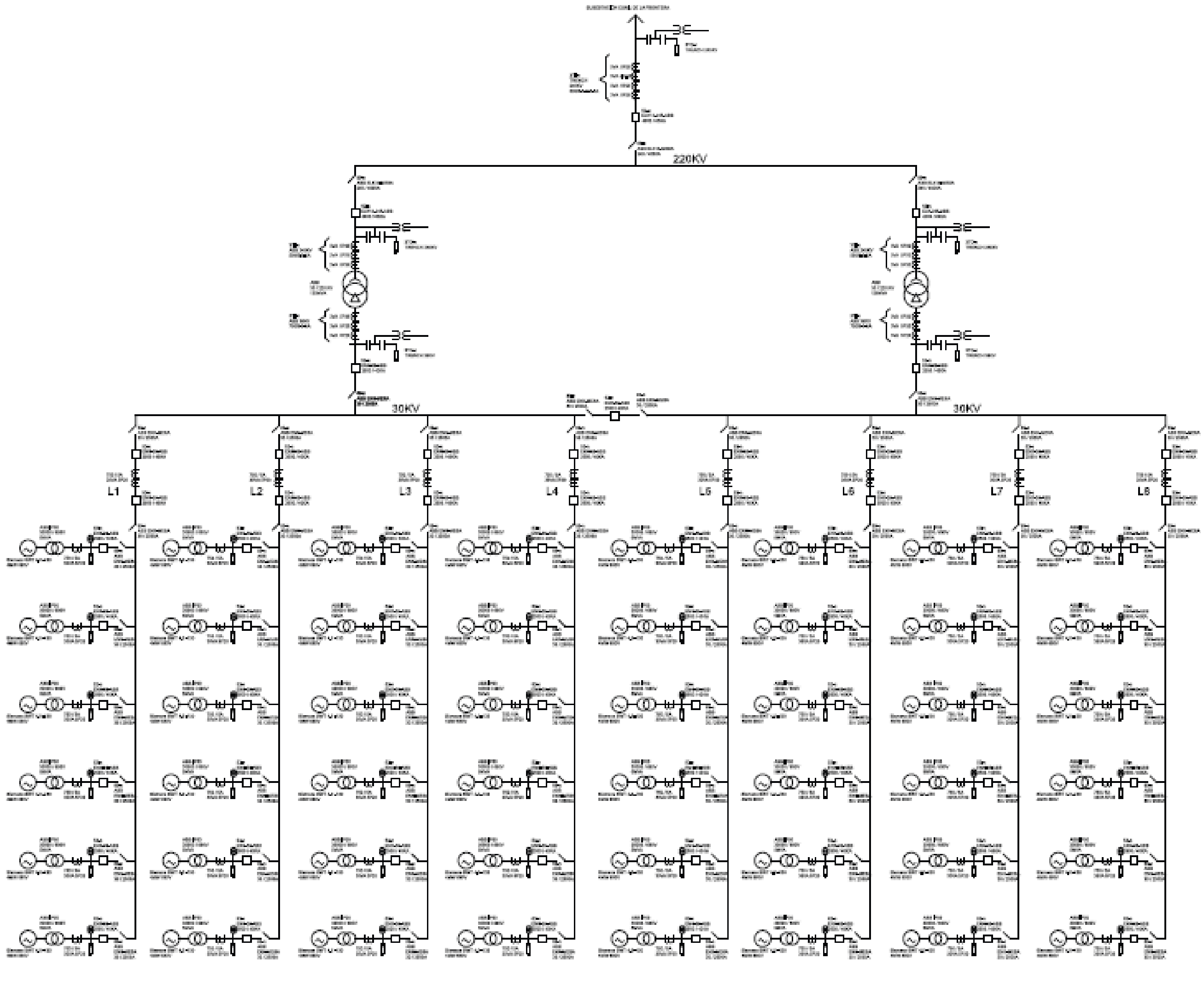


Figure 31. Wind farm electrical diagram

The electrical lines to connect the different lines of the wind farm, in this case 6 WTGs per line, are underground and the ditches are used for both the electrical distribution and the optical fiber for communications. The WTG are serial connected but the have a ground box with a switchgear and disconnector to isolate each for maintenance purpose. The number of WTG connected in the same line are limited because the final section of the cable before to reach the bar has to be big enough to reduce the electrical losses but at the same time no excesively rigid to be handled. Normally the maximum number of WTGs in the same line are between 6 and 8, related to their nominal power.

The Substation connection diagram is presented in the following figure as well as a picture of the electrical substation of a Wind farm:

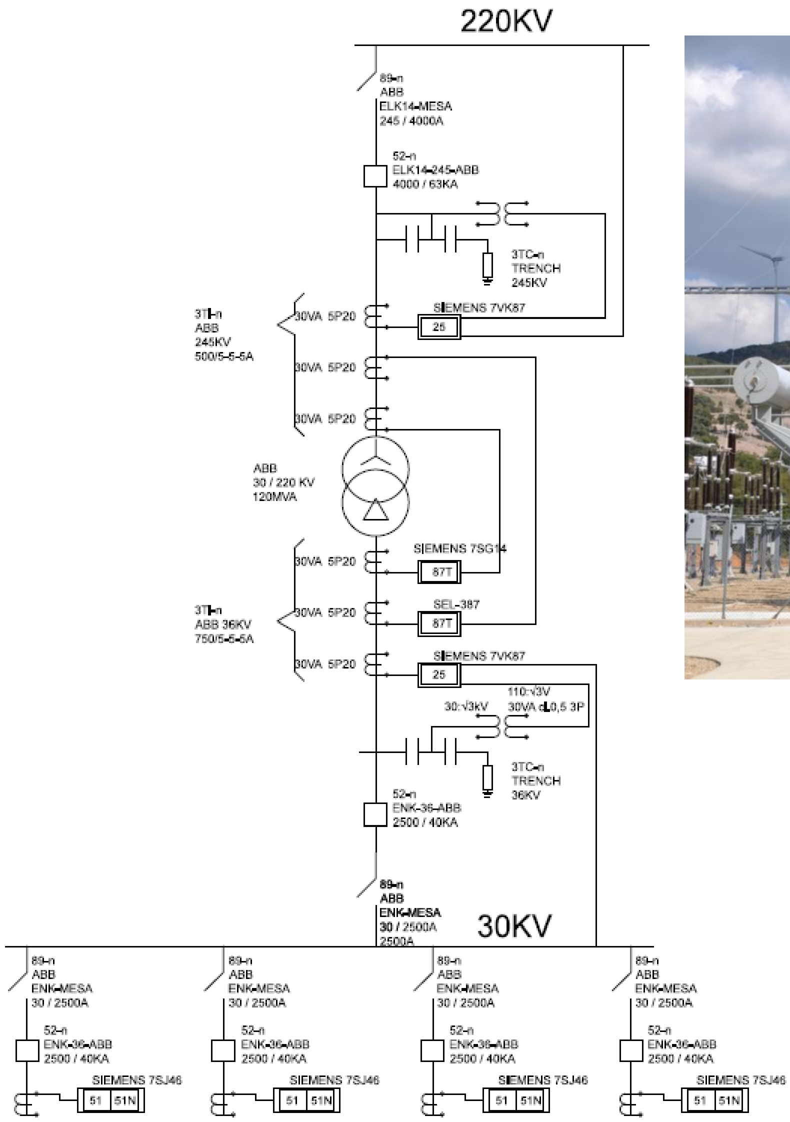


Figure 32. Electrical substation connection diagram

Each position to connect the Wind Farm has its switchgear and disconnector, the first can be used to switch the installation under load conditions and the second, only it the switchgear has already proceeded but it has the necessary function of being visible for the operators. Additionally thre are also the current and voltage transformers to met the generation of the plant.

Complementary of all electrical swichtgear, condensators can also be found for voltage control in both sides of the Substation Transformer.

1.3.1.8. Assembly tasks of the wind turbine energy facilities

In this section the different tasks for the erection of the wind farme are subsequently presented.

The construction of wind farm. Civil Works :

To design the appropriate installation platforms each model of turbine depending on the height of the tower and some sites for regulatory, environmental or road needs require adaptations of the wind turbine sitting.

The civil work is carried out according to the project, taking special care with:

- Width of paths, elevation changes of the paths, camber, and widening turning radius curves.
- Compaction and quality of the paths.
- Do not exceed the maximum on the established slope in the instructions with or without treatment of concrete.
- To install relevant animals paths, if it´s necessary.
- It´s necessary an access road and a few interior roads to access the wind farm. The radius of curvature shall be of 30 meters, with the corresponding envelope width. The maximum slope should be between 14% and 17%. If the slope is greater than 14%, the road must be paved.
- The firm of vials will be made by tiers properly graded aggregate compacted with a thickness of between 20 cm and 40 cm depending on the available esplanade.
- The works, which have to do, both new execution vials and conditioning and reinforcement of existing roads, are as following:

– Clearing the trace, in areas of new execution.
– Excavation of topsoil.
– Excavation in compact ground mechanically.
– Excavation in rock slopes.
– Fill with material from the excavation.

- Extended a top layer of gravel or crushed artificial boulder.
- Compacting of the top layer.
- Concrete pipes drain diameter 80 cm.
- Extended topsoil.
- Sowing.

The required space for the construction and installation of wind turbines is determined by the surface, which is occupied by cranes and the required space to perform all maneuvers during assembly and collection of materials. In the assembly of wind turbines, it is necessary to have a surface where it is possible to park the crane, which lifts the different parts of the machines.

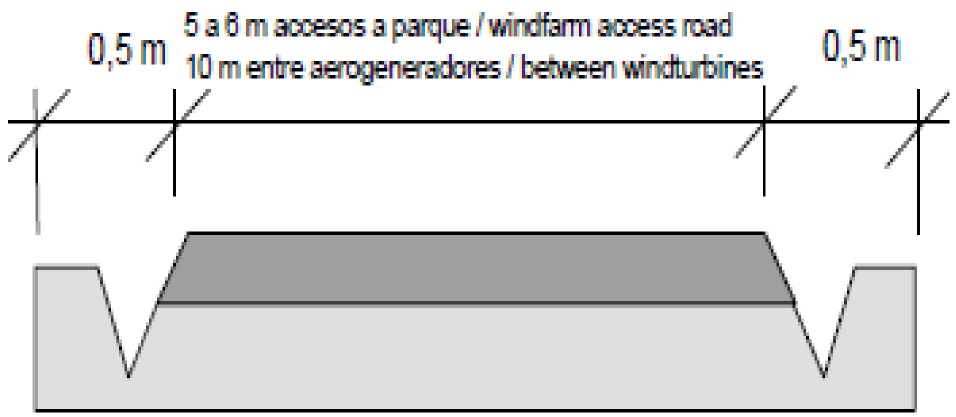


Figure 33. Wind farm access road

Figure 34. Stone agregate base for the Wind farma access road

Figure 35. Wind farm access road works

The foundation design of wind turbines must be adapted to the geotechnical characteristics of the soil where they are located.

The types of foundations that have been carried out for the support of wind turbines are mainly: shallow foundations and shallow foundations with piles.

The shallow foundation is characterized by a large area on the ground, based on transmitting and receiving loads and its own weight to the ground. Its geometry is always circular or polygonal and the used material is concrete.

The loads are transmitted to it through the interface connection to the tower are mainly those produced by the weight of the structure (tower, nacelle and blades) and the thrust of the wind. The weight is a vertical action, while wind thrust action is a horizontal operating in different areas: the area swept by the blades and the shaft of the tower.

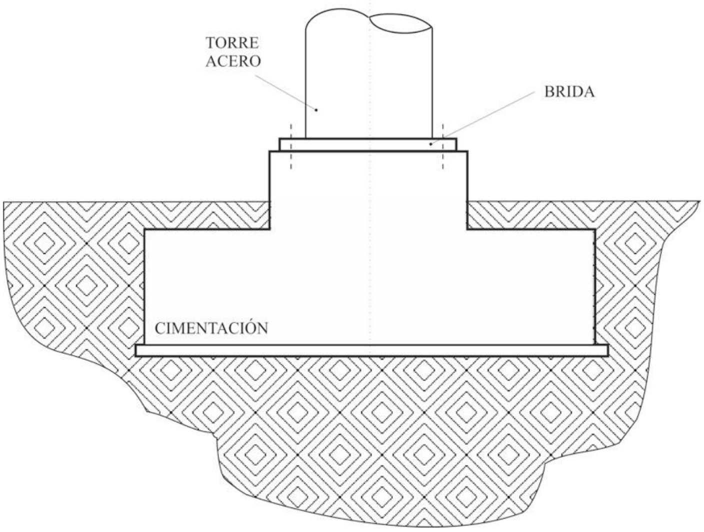


Figure 36. Wind turbine shallow foundation

Loads should be driven to the ground without exceeding the carrying capacity. For this reason, the shoe-contact surface area must be enough large since, the higher, the lower the pressure to be carried on the ground but, in turn, the greater the economic cost of the foundation.

Once the foundation comes in charge, it must ensure an appropriate response to their requests. On the one hand, you must ensure the stability of the wind turbine avoiding overturning and slipping because of the horizontal actions. On the other hand, when the reaction terrain is transmitted its loads, which will generate a pressure distribution in the shoe and it will cause cutting and bending stresses in the concrete, being essential the place of steel bars.

Depending on the terrain where the foundation will be placed, it is advisable to remove the surface layer thereof provided support shoe on a better quality. In many cases, even it´s necessary to dig certain depth before constructing the shoe and then fill the gap. If this is the case, the fill weight on the foundation helps reduce the possibility of overturning.

The latter type of foundation is suitable for rigid floors offering small settlements; hence they are used especially in areas with high angle of internal friction and not on clay, organic or low modulus of elasticity soils.

- Running shoes is the most critical point in the assembly of wind turbines.
- Dimensions and shapes of shoes: they don´t have definite shape but it is usually for a 2MW wind turbine, a dimensions of foundation 15m x 15m x 2m.

Figure 37. Wind turbine shoe works

<u>Interconnection ditches</u>

Pipes interconnection between wind turbines to 20/30 KV consist of trenches dug 1.2 m deep and 0.6 m minimum width, which may be higher depending on the number of triples to install.

Then a layer of 300 mm of land is extended in 100 mm coats without stones and rubble and it is compacted mechanically. All the way, two tapes of signaling warn the existence of medium voltage cables underneath. Finally, above the tape of signaling extends another layer of soil to reach the ground surface.

Figure 38. Pipes interconnection between wind turbines

In cases where the ditches cross the road inside the Wind Farm, It ´s necessary to place polyethylene tubing double layer of 160 mm diameter for cable protection, as well as polyethylene tube double layer of 90 mm in diameter for communications cables, and concreting thereof with HM-15.

The WF is designed based on the best use of each turbine wind at each position. It must prevent wind turbines do shadow each other.

The best model for each site depending on the quantity and quality of wind turbine studied site is selected.

The route of the evacuation lines is the most optimal possible, reducing the lengths.

1.3.1.9. Road transport:

That tracks access to the site and the site itself is accessible throughout the year.

Overall, this transport will be used to bring the elements of wind turbines to the wind farm. For this form of transport, the selected truck must have sufficient capacity to carry the assigned load by the tracks and the roads leading to the installation points, which can have up to 12% slopes.

You can use three types of trucks:

- Truck with fixed platform: This type of truck is used to transport some loose components or medium volume elements such as transformers, or nacelles small and medium power.
- Extensible platform truck: This is used to transfer components of medium or large volume. This truck comprises a mechanically bonded through a chassis which can be shortened or lengthened trailer as the length of the load.
- Dolly truck (trailer) Independent: It transports some components structurally, which do not need support.

The main feature of the sites to which loads are transported is that they are locations where there is some wind, which are very often seated either in mountains and rough ground.

Figure 39. Rotor blade transport

Figure 40.Mistakes in the tower transport (Source: CIER traning cours)

There are several types of cranes, which will be selected as appropriate, taking into account its location and characteristics of the park.

To select the crane must be taken into account:

- Table of loads to be arisen.
- Height at which you have to lift the load.
- Tables of characteristics cranes.
- The width and load capacity of the slopes of the park.

The types of cranes are:

- According to the support system:
  - ✓ Caterpillar cranes.
  - ✓ Tyre crane.
- Depending on the type of height arm:
  - ✓ Hydraulic Extendable.
  - ✓ Lattice.
  - ✓ Mixed.

Figure 41. Caterpillar Crane

Figure 42. Cranes hoisting the Wind turbine tower

CRANES TO USE				
Rotor height	56 m	60 m	70 m	80 m
Main crane	**500 t**	**500 t**	**500 t**	**550 t**
Minimum height under hook	70 m	70 m	80 m	90 m
Auxiliary crane	**120t**	**120 t**	**180 t**	**225 t**
Minimum height under hook	60 m	65 m	75 m	85 m

Chart 6. Cranes to use depending on the rotor height

1.3.1.10. Tasks involved in the assembly sequencing them and describing the tools and equipment to be used.

It´s important to have the information and documentation about wind farm.

Instruction Manual Manufacturer: commissioning, initial maintenance tasks...

The installation can be done by downloading the various elements on the floor before they will be hoisted, or from the truck directly, depending on the park planning, the supply flow or environmental conditions.

The installation of the various elements of the wind turbine in field (Sections of the tower, nacelle, rotor and / or blades) is made according to the technical design specifications and operating facilities.

It is recorded in the control document quality after to make the necessary technical inspections by the quality control team of the work.

The construction of civil works finishes when the installation is completed because it is necessary to make an overhaul and review of the paths when the installation is completed and cranes, hoisting and transport equipment are removed.

Figure 43. Wind turbine installation completed

There is also important to adapt the commissioning area to its adequate size. These will be re-built if it is necessary to make a corrective maintenance. Earlier start-up team develops the necessary controls for the pre-operational testing and the conditions are set by design, establishing the corresponding records.

The pre-operational testing and start-up are carried out according to the technical design specifications. Such testing and start-up, first performed on non-factory-tested components and subsequent especially the wind turbine.

Figure 44. Wind turbine commissioning area

Sections assembly

This section describes the procedures for the assembly of the sections of the tower or the corresponding structure, establishing the alignment requirements, verticality and support

Since of course wind farm sites are selected for their good wind potentials, this limit the installation in terms of available time window for safe crane operations. That’s why different installation concepts were developed to reduce time.

There are five methods that are commonly being applied in wind farms installations:

- "Bunny ear" and Tower in two pieces: Nacelle, hub and two of the blades are assembled together which shapes like a bunny head hence it is called "bunny ear". The tower is carried in two pieces. Therefore one turbine is transported in four pieces to the site. This configuration is called "bunny ear with two pieces of tower" and requires four offshore lifts at the construction site.

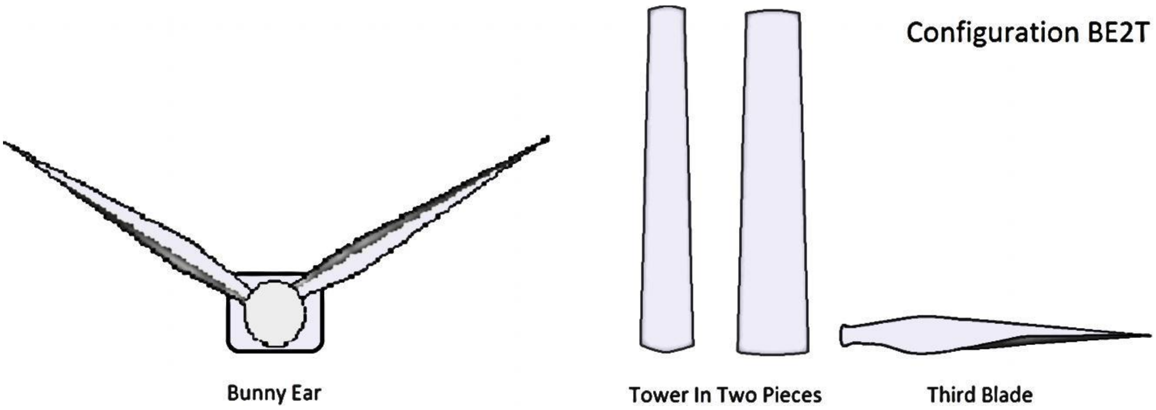


Figure 45. Bunny ear and tower in two pieces configuration

- "Bunny Ear" and Tower in one piece: Nacelle, hub and two of the blades are assembled to shape the "bunny ear". The tower is also assembled to be carried in one Therefore one turbine is transported in three pieces to the site. This configuration is called "bunny ear with tower in one piece" and requires three offshore lifts at the construction site.

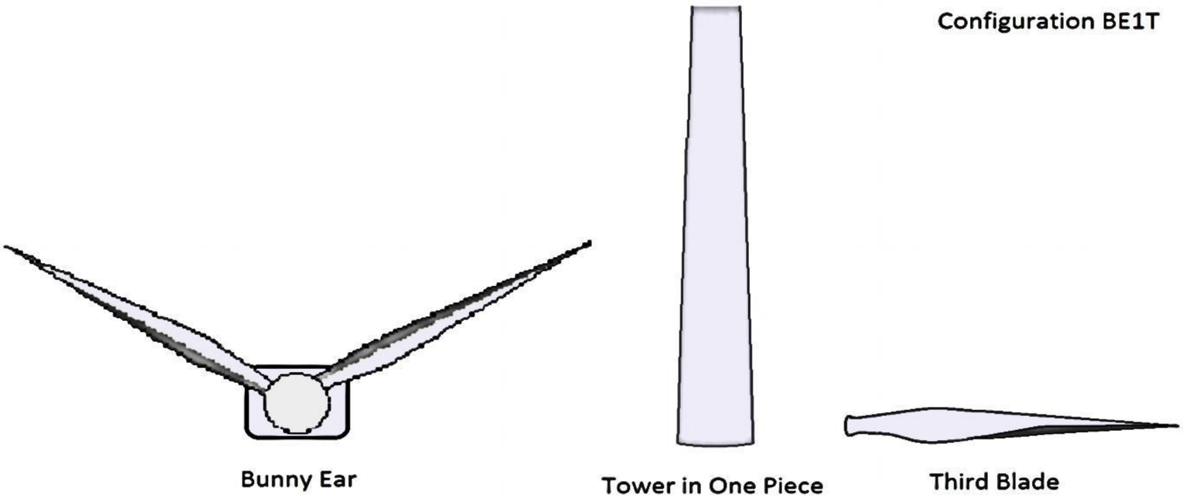


Figure 46. Bunny ear and tower in one piece configuration

- Pre-assembled Rotor: Hub and three blades are assembled to shape the complete rotor. Therefore one turbine is transported to the site in four pieces. This configuration requires four offshore lifts at the construction site.

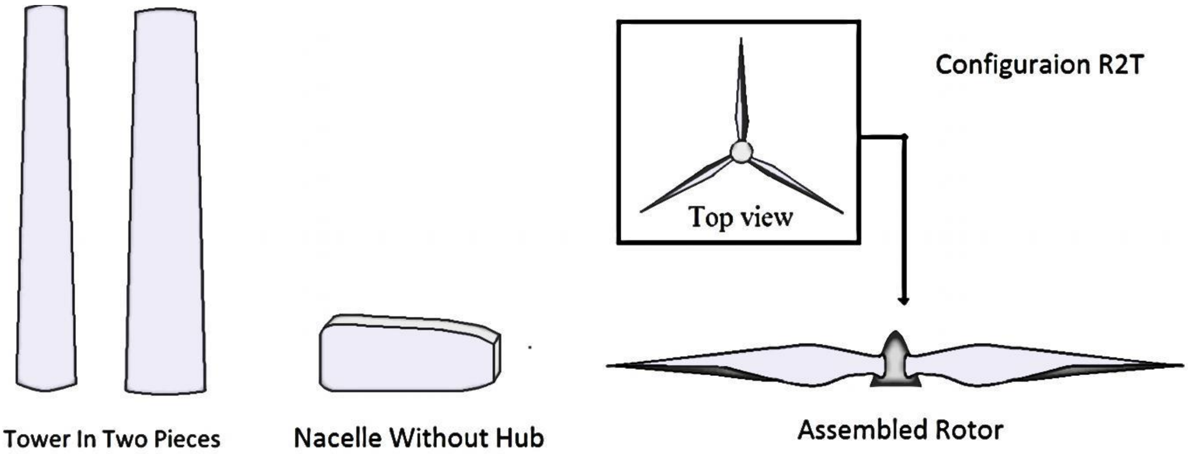


Figure 47. Pre-assembled rotor configuration

- Five Pieces Separately: The tower is assembled in one piece. The blades are left separately and placed in the “blade stacker”. Therefore one turbine is transported to the site in five pieces. This configuration is called “Separate Pieces, 5” and requires five offshore lifts at the construction site.

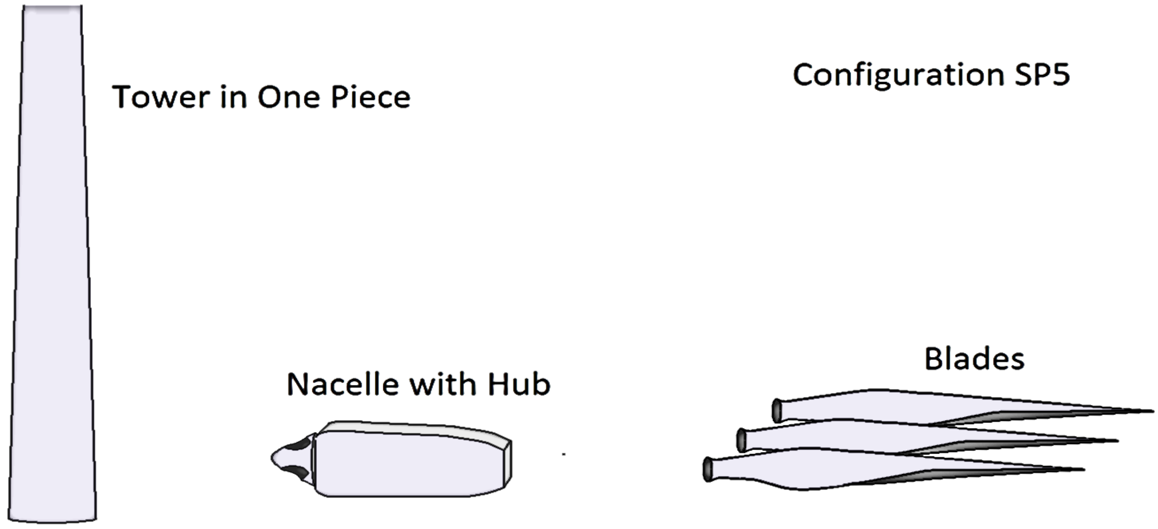


Figure 48. Five piece configuration

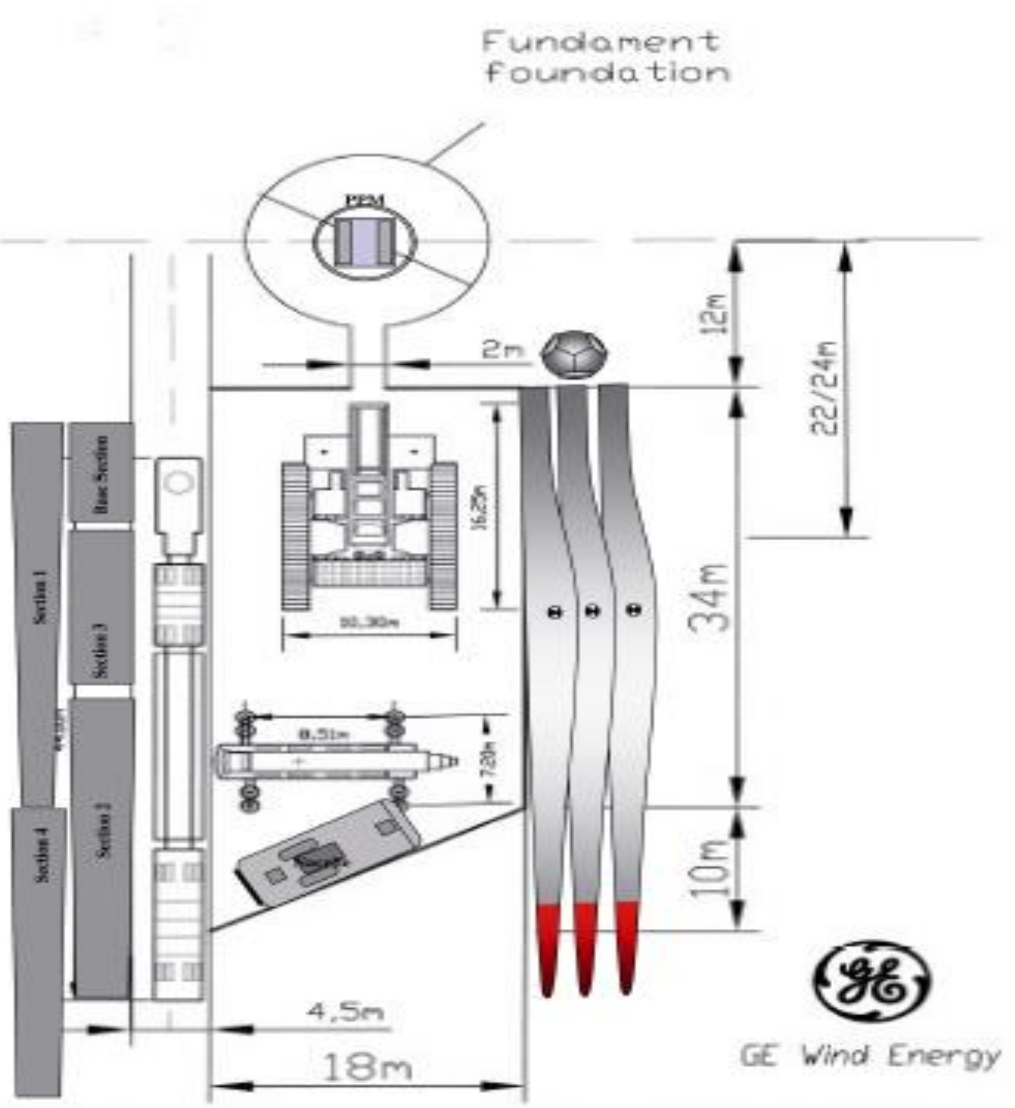


Figure 49. Commissioning area diagram

- Six pieces Separately:. The tower is carried in two pieces and the blades are placed in the stacker separately. Therefore one turbine is transported to the site in six pieces. This configuration is shortly called “separate pieces 6” (shortly S6P) and requires six offshore lifts at the construction site.

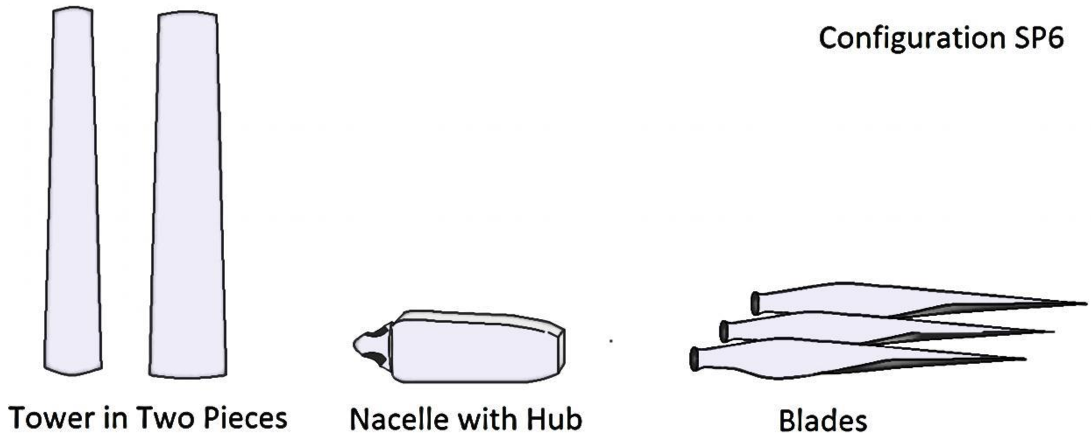


Figure 50. Six piece configuration

Design of the commissioning/assembling zone related to the WTG size:

- Method 1: This type of installation is usually slower, but it requires less equipment and personnel. The wind turbine is supplying all items at once, in the following order: tower sections T1, T2, T3, Nacelle and Rotor. It requires a main and an auxiliary crane. Based on the foundation, the process would be as follows:
  - ✓ If necessary, previous finishes are made on the platform or truck.
  - ✓ To position of main and auxiliary crane.
  - ✓ To rise cell medium and cupboards in the lower platform of the tower.
  - ✓ To rise tower sections and tightening torques to the joints.
  - ✓ To install the transformer in a tower section.
  - ✓ To rise the gondola and give the torques to joints.
  - ✓ To fit rotor and torques to the joints.
  - ✓ To finish, to install and to connect the power cables.
  - ✓ To finish assemblies installed indoor machine.
- Method 2: In this case the supply of towers is in two parts. The first sections, T1 and T2, together and subsequently the final section T3, nacelle and rotor separately. The process would be as follows:
  - ✓ Finishes previous platform or campa.
  - ✓ To position of auxiliary cranes.
  - ✓ To ride cell medium and cupboards in the lower platform of the tower.

- ✓ To install sections T1 and T2.
- ✓ To position of main and auxiliary crane.
- ✓ To install the last section of the tower and give torques to the joints.
- ✓ To ride the nacelles and giving the torques to joints.
- ✓ To finish, to install and to connect the power cables.
- ✓ To finish interior assemblies with installed machines.

1.3.1.11. Professional activities in the assembly of the wind farm

This section describes the procedures for the assembly of the sections of the tower or the corresponding structure, establishing the alignment requirements, verticality and support

To describe the procedures for assembling the tower sections or corresponding structure, alignment requirements, verticality and support are established.

The tower consists of three sections:

- Section 1 or lower
- Section 2 or intermediate
- Section 3 or higher

These sections are bolted together by flanges located at its ends together to form the tower. The bottom flange of the first section is screwed to the line of foundation bolts described above and the upper flange of the third tranche of the yaw bearing, fixed to the nacelle.

The supporting structure of each tower section consists of curved plates welded together, called ferrules, and upper and lower flanges, also welded to the ferrules.

For hub height of 100 m tower there are two variants: a multipurpose for CI / CII and other specific classes for CIII class.

The differences between the mentioned towers consist of different length of its sections and different sheet thicknesses that are thicker for CI / CII given the higher strength requirements, motivated by conditions more demanding work in those classes.

The surface treatment of the tower ensures a virtually unlimited service life and maintenance free.

Access to the interior of the tower is possible via a metal door at the bottom.

Inside the tower there are some series of electrical components and control to be described later. Also, the interior of the tower is illuminated at the required points.

The tower design allows installation (optionally) of an elevator inside the tower for facilitating access to the nacelle and maintenance.

However, in all cases there is the possibility of manually access ladder to the top of the tower. This staircase is provided with a lifeline and other security features.

There are mainly two methods to install a wind turbine.

Method 1.

This type of installation is usually slower, but it requires less equipment and personnel.

The wind turbine is supplying all items at a time, in the right order, T1, T2, T3, Nacelle and Rotor. It requires a Principal and an Assistant crane. To start from the buried section, the process would be as following:

- To position of main and auxiliary crane.
- To assemble the cell middle and cupboards at the bottom platform tower.
- To ride the tower sections and to tighten torques to the joints.
- To install the transformer in a tower section.
- To ride the gondola and to give the torques to joints.
- To fit rotor and torques to the joints.
- To finish, to install and to connect the power cables.
- To finish the installed assemblies indoor machine.
- Location of auxiliary cranes.
- To fit the cell medium and cabinets on the bottom shelf tower, to give the torques to joints.
- To fit sections 1 and 2. To move the auxiliary cranes to assemble all the first sections, tightening torques to the joints (flanges) and mount the transformer if applicable throughout the site.
- Location of main and auxiliary crane.
- To mount the last leg tower and to give the torques to joints.

- To ride the gondola and give the torques to joints.
- Mount rotor, and to give torques to joints.
- To finish installing and connecting the power cables.
- To finishing assemblies installed indoor machine.

A nacelle is accessed from inside the tower through a trapdoor and ladder access. From inside this there is also access to the hub to perform testing and maintenance work on it without going outside.

Method 2.

In this case, the supply of towers is in two parts, the first sections T1 and T2 together and then the final stretch T3, nacelle and rotor. We set the first sections with two auxiliary cranes and subsequently the rest of the elements with the main crane and auxiliary crane. The process would start from the buried section:

- To position of auxiliary cranes.
- To assemble the cell middle and cupboards at the bottom platform tower, give the torques to joints.
- To fit sections 1 and 2. To move the auxiliary cranes to assemble all the first sections, to tighten torques to the joints (flanges) and to mount the transformer.
- To position of main and auxiliary crane.
- To install the last leg tower and to give the torques to joint.
- To ride the gondola and to give the torques to joint.
- To install rotor and to give torques to joint.
- To finish, installing and connecting the power cables.
- To finish installed assemblies indoor machine.

<u>Place the nacelle or turbine on the tower with a safety and quality criteria required.</u>

To place the turbine nacelle on tower with safety criteria and required quality.

The nacelle contains all the necessary to transform the rotation into electrical energy. It consists of gears that regulate the speed to get the most performance, a generator to create electricity and a braking system capable of stopping the rotation in case of excessively strong winds or any other failure. The wind turbine also incorporates an active guidance system, which turns the nacelle so that the rotor remains facing the incoming wind.

<u>Make the electrical connections of the equipments, the generator and the transformer.</u>

- Medium voltage electrical system:
  - ✓ The voltage generation output of the wind turbine is usually 20 KV but now it is increasing up to 30 kV
  - ✓ Losses.
  - ✓ Interconnection of wind turbines in groups of five to eight turbines in series, transporting energy in common sets of three cables to substation.
  - ✓ Medium voltage cells in each wind turbine: 3 cells, a lift, a wind turbine sectioning and one output to the next turbine.
  - ✓ Output cables each turbine.
- Connection collector substation:
  - ✓ Buried wiring to the substation.
  - ✓ To trench, with the following dimensions:
    - Width: 80 cm.
    - Depth: 1 m.
  - ✓ The stones in the excavation must be removed to prevent damage to the wiring. It must be added a fine sand to protect the driver in case of overweight.
  - ✓ Trenches must be drawn parallel to the paths of wind turbines.
  - ✓ Finally, the ditches are clogged and topsoil is added.
- Electrical Substation:
  - ✓ Arrival of the different lines of wind farms in 20 KV.
  - ✓ At the substation, it distinguishes:
    - Medium voltage area: 20 KV cells.

Wind Farm in the open, where the power transformer and the connection positions to the high voltage line is located.

Output voltage: 66 KV - 220 KV, and in some cases to 400 KV.

- If the output is at 220 KV or 400 KV substations should be a property of the owner corresponding to the transport network.
- The high voltage line from the collector substation to the connection point end has to pay special attention to environmental processing.

Perform initial and offline network shares.

1.3.1.12. Professional activities in the assembly of the wind farm

This section analyzes the different professional activities in the assembly of a wind turbine to be installed in a wind farm, identifying risk situations and classifying them by type and importance

Assembly phase of a wind farm is one of the most complicated and dangerous in its lifecycle, as it involves installations, heavy lifting and transition of major components. Moreover the installation stage is the most personnel intensive one. Finally, it is important to remember that these activities take place in windy and isolated areas. The safety implications of working at height and the exposure to these high wind conditions need to be carefully considered throughout the construction phase.

Analyzing in deeper details the different activities and milestones in the assembly stage we can highlight the following that of course will vary depending if we are talking about onshore or offshore farm:

Onshore substation development

- Earthworks and screening mounds
- Construction of access roads
- Construction of control room
- Delivery of transformer
- Internal concrete roads and paving
- Electrical and mechanical installation
- Substation commissioning
- Installation of export cables
- Construction completed

Onshore wind farm

- Construction of access road
- Excavation of foundation
- Steel reinforcement and base
- Turbine base and transformer housing completed
- First tower section and nacelle installed
- Blade fitted
- Cable routing to substation

Possible hazards during the construction phase of wind farms

- Falling structures, loads or objects during lifting operations.
- Falls from heights.
- Mechanical hazards, such as contact with moving parts.
- Offshore — marine operations and transportation, for example ship collisions or man overboard.
- Electrical — short circuits, overcharge, electrostatic phenomena or falls due to shock.
- Fire or explosion of turbine (use of combustible materials) or vessel.
- Manual handling.
- Ergonomics — physiological effects as a result of heavy lifting and repeated movements, fatigue from climbing ladders or working in confined spaces.
- Working with dangerous substances.
- Working in confined spaces — the configuration of all nacelles will classify them as confined spaces.
- Environmental effects — wind, wave and currents, or lightning.
- Organizational — time pressure, insufficient or lack of safety equipment, lack of competence or skills for wind energy sector, different actors/companies all involved in the same operation.
- Exposure to noise and vibration.
- Evacuation of persons from wind turbines as a result of changing weather conditions and locations may be challenging.

The development of onshore and offshore wind facilities requires extensive planning and thorough knowledge of site conditions, for example location, topography, ground conditions and other factors.

The traceability of specific components of the start-up is incorporated into the technical specifications of the wind turbine. When the start-up was successful, the reception of the WF is produced by the property. At this point begins the maintenance of the WF.

The maintenance is performed according to:

- Technical design specifications.
- The technical specifications of each component.
- The maintenance manual (specific for each model and series).

1.3.2. Lesson 2: WTGS Start up.

The aim of this lesson is to give the students the needed tasks to start up and to energize the WTGs as well as the evacuation components of the Wind Farm.

To successfully complete this Lesson, students shall be aware of:

(1) Safety requirements before WTGs start up..
(2) Conditions
(3) Criteria to select the most appropriate WTG
(4) Civil works and foundations characteristics
(5) Principal activities for the transport and assembling of the WTG

Preconditions:

This start-up procedure must be followed before the turbine can be put into operation and produce power.

At the same time, it is a final check of the cable mounting and of the correct function of the assembled system.

For security reasons, at least two persons must be present during the entire start-up procedure.

Safety requirements:

- The blades must be fully feathered.
- Lock blades with locking bolts.
- The rotor locking system is not locked when the turbine is ready for start-up, but the locking system must be locked when entering the hub or working on moving parts like slip rings, main shaft, etc.

Start-up conditions:

The following conditions must be met before beginning the star-up procedure:

- Main isolator switches to transformer open.
- Switches of the ground disconnected. Check the rating of the automatic circuit breakers.
- All motors protectors and automatic circuit breakers of the top and ground disconnected.
- Connection of the cables of the rotor and the stator – top connected according to diagrams. Ensure that no rotor cables are connected to the stator.
- Check that it is not possible to manually switch the relay that connects the stator to the grid and the relay that is stator connection contactor.

Energization with generating set:

If this point is applied, skip next point.

The generating set must be 690 V_{AC}:

- Remove the relay that connects the stator to the grid from its base. It will not reconnect until the auxiliary generator becomes removed and the MV transformer powered.
- Earth the MV switchgear and lock it. It will remain opened and earthed until the auxiliary generator becomes removed. The key will be kept by the person in charge of start-up.

- Disconnect, in the not protected zone of Ground Cabinet busbars, the power cable of the LV Inlet from the transformer and insulate them by means of plastic tube in the terminals covered with insulated tape with and insulation higher than > 1 KV.
- Connect the power supply cable of the generating set in direct sequence in the not protected zone of Ground Cabinet busbars.
- Load the application “workshop_1” into the PLC, where communications are cancelled onscreen.
- Supply relay directly with 24 VDC. Ensure that the elements of the emergency series are correct.
- Place a bridge over terminals 14 and 16 of the digital outputs.
- Reset the emergency series and start the tests from Point 3 onwards.

Energization:

Before energizing the tower to be started-up, the earth connection must be removed and the power earth connection must be removed and the power supply switch to the transformer from the switchgear of the given tower must be closed.

Once this has been done, the tower is energized from the previous power or from the substation, and never with personnel inside the tower. By doing this, the process of directly energizing the transformer for the first time is avoided, with the consequent risk of exploding bottles, or any other risk.

Transmission and Communications.

Program of transmission to top and ground

As a general rule, the program is loaded at the manufacturing plant. If not, communication between the Top PLC and the Ground PLC will not be activated.

Loading the program

- Turn on all the thermal magnetic and automatic circuit breakers of both the Top and the Ground.
- Run the System loader using the icon on the desktop. Connect the computer to the PLC using the icon displaying a cable with two plugs.

Communications

Check that no crosses appear on any texts on the touch-screen terminal, that the data are updated, and that the top – ground communication is correct.

Start-up parameters

Before beginning the start-up tests, it is necessary to check and, if necessary, change certain parameters:

- Wind turbine type.
- Load type.
- Tower height.
- Controlled emergency series.
- Anemometer type.
- Gearbox type.
- Wind turbine serial number.
- Wind farm identify code.
- Wind turbine number.
- Station number.

Alarm reset

Reset the existing alarms by pressing the "Reset" buttom.

Emergency circuit test from the top

Emergency pushbuttons

Controlled emergency activation

Emergency series trip due to battery failure

Reset the VOG by removing it from its socket.

Vibration sensor.

Activate the vibration sensor. The alarm will appear on the display, and if the wind turbine is in any other state, it will change to the Stop state.

Optical sensor mirror

Place the mirror opposite the optical sensor, making sure that the power cables are completely untwisted. Stick with silicon.

Hydraulic system check

Preparation for the test.

The rotor must be on the wind turbine and must be locked.

Previously, adaptors must be checked (well tightened).

To carry out this test, enter the “Hydraulic” test. This screen will allow us to activate, deactivate and place the hydraulic unit into automatic, as well as at all times view the pressure of the unit.

Check direction of motor rotation

Visually check that the direction of rotation of the motor is correct. If correct, the unit will build up pressure.

If the direction of rotation of the motor is not correct, check that the power supply cable of the motor is correctly connected, ensuring that the direction of rotation of the remaining motors is correct.

Pressure difference between manometers – display.

Maximum pressure difference between manometer and display = 4 bar.

Hydraulic pump test.

During this initial test, pay special attention to any possible leaks in the hydraulic system.

Connect the digital manometer at position M3.

Start the hydraulic unit pump on automatic, and check that the start-up pressure of the hydraulic unit pump is 180 bar, and that its cut-out pressure is 200 bar.

Stop the pump, and move the digital manometer to position M6. Reset the pressure of the unit, and check the brake pressure.

Pitch accumulator test

Measure and, if necessary, refill the accumulator with nitrogen according to ES420003 document.

To prevent the system from cutting out due to maximum pumping time, it is recommended to stop and start the pump within one minute.

Pitch System

Press the desired option, and the test calculates the negative or positive limits. The values must be between 0,040 ± 0,010 V_{DC}. If not, calibrate the sensor.

In the Pitch and Brake test, enter the required pitch degrees in the pitch reference value, and check that it responds correctly.

Gearbox

The oil level must be check, as well as for any possible leaks.

Cooling pump. Check the direction of rotation of the electric oil pump by pressing “Run” in the corresponding test:

- Auxiliary filter: Check the direction of rotation of the filter by pressing “Run” in the corresponding test, and check for leaks.
- Bleed the auxiliary filter.
- Check that all the adaptors are well tightened.
- Pressure switch setting: Check the gearbox manifold block pressure switch setting.

Wind vane and anemometer

- Check that the wind and anemometer operate correctly.

Fibreglass protection

- Check for any possible damage, and that there are no loose bolts in the shells of the nacelle and the hub.

Fan and heater test

- Top ventilation: Decrease the temperature on thermostat until the top fan comes on. If it is already in operation, increase the temperature setting until it stops.
- Top heating: Increase the temperature on thermostat until the heating element comes on.

Generator

- To carry out the tests, unlock the rotor and check that the generator turns freely. Grease the bearings in case of it is necessary, while turning the generator

General, energization of the wind turbine:

- The electrical connections have to be verified:
  - ✓ Visually.
  - ✓ Tighten of the connection screws .
- The energization of the transformer and power cabinet is made.
- The test firing of the cell is performed via:
  - ✓ The relay connection.
  - ✓ The temperature control unit transformers.
- The results of the checks and tests are recorded:

The energisation of the elevators, in case the wind turbine it is made available, should be also tested. The certification of the implementation of the elevator must be performed by authorized personnel for this purpose.

Pre-operational tests:

- To be verified:
  - ✓ The wiring (connectors and cables).
  - ✓ Electrical ground.
  - ✓ Isolation circuits.
  - ✓ The various elements of the generator and the control.
  - ✓ Extinguishers and safety equipment.
  - ✓ The lifeline close to the stairs.
  - ✓ Change blade pitch is set.
  - ✓ Sensors and actuators.

- The checks performed are:
  - ✓ Visual.
  - ✓ Continuity.
  - ✓ Insulation.