

Structure of Wind farm Power Plant

The average modelling method is presented in [19][20][21] to calculate the inverter impedance of a Distributed Generation (DG) source with considering converter control structure.

Typical Single Line Diagram

Figure 5.9 Typical single line diagram

The design of the electrical system is determined by the characteristics of the wind turbine generators and of the network to which the project is to be connected, as well as regulations imposed upon it, notably through Grid Codes. The network operator controls the grid to meet its operational objectives and also requires a degree of control over large generators (which may include offshore wind farms). Additionally, the wind farm must be designed to respond appropriately to grid faults.

Components of a wind Farm Power Plant

The plethora of sub-components, which can number up to 8,000, needed to construct a wind turbine involve myriad manufacturing processes, from metal fabricating and casting to heat treating, machining and grinding.

All of this combines to create a product with a typical life span of 20 years and enough generational capacity to power the equivalent of 750 US homes for a year.

Four parts, however, are vital: The generator, nacelle, tower and blades.

Generator

The generators used in modern wind turbines used the difference in electrical charge to create a change in voltage, which acts as the driving force behind the subsequent electrical current.

This current is then passed through power lines for distribution, powering the turbine's associated grid.

Nacelle

The nacelle houses a wind turbine's generator, and is mostly commonly manufactured as either gear-driven or direct drive.

wind turbine components

A wind turbine's nacelle houses a multitude of sub-components (Credit: Fabricators & Manufacturers Association)

The former can comprise a case as heavy as 150 tonnes, while the latter comprises a rotor hub which directly drives the generator without the need for a gear train arrangement.

Tower

Wind turbine towers are produced at various different heights, with the average being roughly 50m and the tallest surpassing 200m.

They are usually coated with a zinc-based finish and epoxy and urethane layers to provide ultraviolet resistance.

The average weight typically exceeds 40 tonnes, and a tower can often account for more than 10% of the total cost of a wind turbine.

Rotor Blades

Wind turbine blades can reach speeds in excess of 160 miles per hour when in operation and therefore require robust construction.

The component primarily comprises wood, fibreglass, resin and carbon, but can host more than 100 layers of material once complete.

Switchyard Structure of Wind farm Power Plant

Almost in every wind farm a step-up substation is built to collect all the energy generated by the turbines and received through the MV cables. The exceptions are new wind farms or existing wind farms extensions built near a substation that can be upgraded to absorb the additional energy produced: in these cases, only a control center with the SCADA and the medium voltage system is realized.

Although there are different possible technical solutions, normally a substation will be composed by the following elements:

Medium voltage system

High voltage system

Capacitors banks

Auxiliary services

Control, protection and metering system

Communication system

Fire protection and intruders protection systems

Medium voltage system is composed by the general busbar, disconnectors, circuit breakers and current transformer.

High voltage system is made of one or more transformers, together with earthing reactance, surge arresters, current transformer, voltage transformer, circuit breaker and disconnector with earthing switch.

Capacitors banks are installed to comply with the grid requirements regarding active and reactive power.

The auxiliary services supply energy both in AC/DC current, and count with a group of battery that can generate energy for several hours to operate the substation in case of emergency, a rectifier and often a backup diesel generator, with a tank big enough to provide energy for 3 days..

Control, protection and metering system allows the correct operation of the wind farm according to local regulations and grid requirements. Basically they are protection relays for the switchgear and power transformers

The communication system, must guarantee the correct communication with the adjacent substations and with the grid owner control center, in order to make possible the correct operation of the wind farm substation. Normally communications are through optical fiber/carried wire.

Fire protection system is normally composed by optical or infrared detectors, fire extinguisher, external bells or siren, while the intruders protection system are normally a fence plus a closed circuit TV.

Also the SCADA server is normally located inside the substation, together with a parabolic antenna to grant broad band connection.

There are several available solutions to connect with the existing high voltage distribution network: normally a dedicated line is used, while in other situations a tap off (or "T" connection) is used. A third solution is to open the existing line between 2 substations.

The 3 solutions are shown on the following diagrams:

Transformers

Each turbine in a wind farm is equipped with a step-up transformer, which boosts (steps up) turbine generator output voltage from a few hundred volts to the collector system's medium voltage distribution levels. These wind turbine step-up transformers are failing at an alarming rate and developers and operators of utility scale wind farm projects are scrambling to identify the most likely causes for this widespread failure.

The root cause of the failure is not hard to find: conventional distribution transformers that typically are used simply cannot stand up to the severe duty requirements of a wind turbine step-up transformer. To guarantee the future reliability of this valuable renewable energy source, wind turbine step-up transformers must incorporate these unique requirements, which include variable loading, harmonics and non-sinusoidal loads, transformer sizing and voltage variation, low voltage (LV) fault ride through, as well as protection and fire behavior, step-up duty, switching surges and transient over-voltages, loss evaluation and gassing.

Transmission Lines

Wind energy has demonstrated to be a clean, copious and absolutely renewable source of energy, and the large penetration of it into the power grid indicates that wind energy is considered an effective means of power generation. Transmission of wind energy from remote locations to load centers necessitates long transmission lines. Series compensation is a proven and economical transmission solution to address system power transfer strength, grid stability, and voltage profile issues of long transmission lines. In this paper, a programmable approach to determine the capacitive reactance of series capacitor and optimum location for its placement to achieve maximum power transfer has been presented. The respective program with sample solutions has been provided for real-time applications.

Cost Analysis of Wind farm Power Plant

The installed cost of a wind power project is dominated by the upfront capital cost (often referred to as CAPEX) for the wind turbines (including towers and installation) and this can be as much as 84% of the total installed cost. Similarly to other renewable technologies, the high upfront costs of wind power can be a barrier to their uptake, despite the fact there is no fuel price risk once the wind farm is built. The capital costs of a wind power project can be broken down into the following major categories: figure 4.1: capital cost breakdown for a typical onshore wind power system and turbine. Source: Blanco, 2009.

- »» The turbine cost: including blades, tower and transformer;
- »» Civil works: including construction costs for site preparation and the foundations for the towers;
- »» Grid connection costs: This can include transformers and sub-stations, as well as the connection to the local distribution or transmission network; and
- »» Other capital costs: these can include the construction of buildings, control systems, project consultancy costs, etc.

For the turbine, the largest costs components are the rotor blades, the tower and the gearbox. Together, these three items account for around 50% to 60% of the turbine cost. The generator, transformer and power converter account for about 13% of the turbine costs, with the balance of “other” costs being made up miscellaneous costs associated with the tower, such as the rotor hub, cabling and rotor shaft. Overall, the turbine accounts for between 64% to as much as 84% of the total installed costs, with the grid connection, civil works and other costs accounting for the rest (Blanco, 2009 and EWEA, 2009). The reality is that the share of different cost components varies by country and project, depending on turbine costs, site requirements, the competitiveness of the local wind industry and the cost structure of the country where the project is being developed. Table 4.2 shows typical ranges for onshore and offshore wind farms.

The Wind Energy Technologies Office (WETO) works to understand and mitigate barriers to wind power deployment by conducting research and development activities aimed at addressing siting and environmental issues. When properly sited, wind projects provide a net environmental benefit to the communities in which they operate and to the nation overall. To see a full listing of projects supported by WETO, see the Projects Map and select Program Area: Environmental Impacts and Siting.

As with all energy supply options, wind energy can have adverse environmental impacts, including the potential to reduce, fragment, or degrade habitat for wildlife, fish, and plants. Furthermore, spinning turbine blades can pose a threat to flying wildlife like birds and bats. Due to the potential impact that wind power can have on wildlife, and the potential for these issues to delay or hinder wind development in high-quality wind resource areas, addressing impact minimization, siting, and permitting issues are among the wind industry’s highest priorities.

To address these issues and support environmentally sustainable development of wind power in the United States, WETO invests in projects that seek to characterize and understand the impact of wind on wildlife both on land and offshore. Furthermore, WETO invests in activities to collect and disseminate scientifically rigorous peer-reviewed research on environmental impacts through centralized information hubs such as Tethys. The office also invests in scientific research that enables the innovation and development of cost-effective technologies that can minimize wildlife impacts at land-based and offshore wind farms.