Wind Power System SYSTEM COMPONENTS

The wind power system comprises one or more wind turbine units operating electrically in parallel. Each turbine is made of the following basic components:

- Tower structure
- Rotor with two or three blades attached to the hub • Shaft with mechanical gear
- Electrical generator • Yaw mechanism, such as the tail vane
- Sensors and control

Because of the large moment of inertia of the rotor, design challenges include starting, speed control during the power-producing operation, and stopping the turbine when required. The eddy current or another type of brake is used to halt the turbine when needed for emergency or for routine maintenance. In a modern wind farm, each turbine must have its own control system to provide operational and safety functions from a remote location. It also must have one or more of the following additional components:

- Anemometers, which measure the wind speed and transmit the data to the controller.
- Numerous sensors to monitor and regulate various mechanical and electrical parameters. A 1-MW turbine may have several hundred sensors.
- Stall controller, which starts the machine at set wind speeds of 8 to 15 mph and shuts off at 50 to 70 mph to protect the blades from overstressing and the generator from overheating.
- Power electronics to convert and condition power to the required standards.
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A. TOWER

The wind tower supports the rotor and the nacelle containing the mechanical gear, the electrical generator, the yaw mechanism, and the stall control. Figure depicts the component details and layout in a large nacelle, and Figure shows the installation on the tower. The height of the tower in the past has been in the 20 to 50 m range. For mediumand large-sized turbines, the tower height is approximately equal to the rotor diameter, as seen in the dimension drawing of a 600-kW wind turbine Small turbines are generally mounted on the tower a few rotor diameters high. Otherwise, they would suffer fatigue due to the poor wind speed found near the ground surface. Figure 4.5 shows tower heights of various-sized wind turbines relative to some known structures. Both steel and concrete towers are available and are being used. The construction can be tubular or lattice. Towers must be at least 25 to 30 m high to avoid turbulence caused by trees and buildings. Utility-scale towers are typically twice as high to take advantage of the swifter winds at those heights. The main issue in the tower design is the structural dynamics. The tower vibration and the resulting fatigue cycles under wind speed fluctuation are avoided by the design. This requires careful avoidance of all resonance frequencies of the tower, the rotor, and the nacelle from the wind fluctuation frequencies. Sufficient margin must be maintained between the two sets of frequencies in all vibrating modes.

TURBINE

Wind turbines are manufactured in sizes ranging from a few kW for stand-alone remote applications to a few MW each for utility-scale power generation. The turbine size has been steadily increasing. The average size of the turbine installed worldwide in 2002 was over 1 MW. By the end of 2003, about 1200 1.5-MW turbines made by GE Wind Energy alone were installed and in operation. Today, even larger machines are being routinely Department of Electrical Engineering, Veer Surendra Sai University of Technology Burla Page 89 installed on a large commercial scale, such as GE's new 3.6-MW turbines for offshore wind farms both in Europe and in the U.S. It offers lighter variable-speed, pitchcontrolled blades on a softer support structure, resulting in a cost-effective foundation. Its rated wind speed is 14 m/sec with cut in speed at 3.5 m/sec and the cutout at 25 m/sec.

C. BLADES

Modern wind turbines have two or three blades, which are carefully constructed airfoils that utilize aerodynamic principles to capture as much power as possible. The airfoil design uses a longer upper-side surface whereas the bottom surface remains somewhat uniform. By the Bernoulli principle, a "lift" is created on the airfoil by the pressure difference in the wind flowing over the top and bottom surfaces of the foil. This aerodynamic lift force flies the plane high, but rotates the wind turbine blades about the hub. In addition to the lift force on the blades, a drag force is created,

D. SPEED CONTROL

The wind turbine technology has changed significantly in the last 25 yr.1 Large wind turbines being installed today tend to be of variable-speed design, incorporating pitch control and power electronics. Small machines, on the other hand, must have simple, lowcost power and speed control. The speed control methods fall into the following categories: No speed control whatsoever: In this method, the turbine, the electrical generator, and the entire system are designed to withstand the extreme speed under gusty winds. Yaw and tilt control: The yaw control continuously orients the rotor in the direction of the wind. It can be as simple as the tail vane or more complex on modern towers.

SYSTEM-DESIGN FEATURES

When the land area is limited or is at a premium price, one optimization study that must be conducted in an early stage of the wind farm design is to determine the number of turbines, their size, and the spacing for extracting the maximum energy from the farm annually. The system trade-offs in such a study are as follows:

TURBINETOWERS ANDSPACING

Large turbines cost less per megawatt of capacity and occupy less land area. On the other hand, fewer large machines can reduce the megawatt-hour energy crop per year, as downtime of one machine would have larger impact on the energy output. A certain turbine size may stand out to be the optimum for a given wind farm from the investment and energy production cost points of view.

TYPES OF BATTERY

There are at least six major rechargeable electro-chemistries available today. They are as follows:

• Lead-acid (Pb-acid)

• Nickel-cadmium (Ni-Cd)

• Nickel-metal hydride (Ni-MH)

• Lithium-ion (Li-ion)

• Lithium-polymer (Li-poly)

• Zinc-air

New electro-chemistries are being developed by the United States Advanced Battery Consortium for a variety of applications, such as electric vehicles, spacecraft, utility load leveling and, of course, for renewable power systems. The average voltage during discharge depends on the electrochemistry,. The energy densities of various batteries, as measured by the Wh capacity per unit mass and unit volume, are compared in Figure. The selection of the electrochemistry for a given application is a matter of performance and cost optimization.

LEAD-ACID

This is the most common type of rechargeable battery used today because of its maturity and high performance-over-cost ratio, even though it has the least energy density by weight and volume. In a Pb-acid battery under discharge, water and lead sulfate are formed, the water dilutes the sulfuric acid electrolyte, and the specific gravity of the electrolyte decreases with the decreasing SOC. Recharging reverses the reaction, in which the lead and lead dioxide are formed at the negative and positive plates, respectively, restoring the battery into its originally charged state.