north american WINDPOWER®

Reprinted with permission from the December 2006 issue

Design Considerations For Large Collector Systems

Since no two large wind farms are exactly the same, the collector system for every site must have a unique design.

BY ERNST CAMM

When it comes to designing collector systems for large wind farms, it is safe to say that no two sites are exactly the same. As a result, every large wind farm collector system needs to have a unique design performed. There are many considerations that must go into a large wind farm collector system design. The following provides a high-level overview of some of the most significant design considerations involved in the development of collector systems for large wind farms.

The collector system of a large wind farm (i.e., wind farms rated more than 20 MW) consists of a network of cables collecting the power output from the individual wind turbine generators spread out over the entire wind farm, the wind turbine generator step-up transformers, and the collector substation where the power is delivered to a single point for delivery to the interconnecting utility's transmission system.

The location and terrain of the wind farm site is a significant factor when designing collector systems. Good wind regimes typically are in mountainous areas, presenting a number of challenges, including accessibility, construction of roads and electrical grounding.

These challenges affect the installation methodology and constructability of the collector system. The composition of the land and ice throw from wind turbines will, in large part, determine whether the collector system is installed overhead or underground. If the decision is to install underground, trenching and grounding practices will be influenced greatly.

The collector system cable circuits for large wind farms typically are long due to the required distances between towers, terrain conditions and wind characteristics. Long cable circuits result in increased voltage drops, copper losses and expenses associated with the cable installation. Long cable runs also complicate cable testing procedures and increase testing equipment requirements, particularly for fault detection.

Long circuit lengths can make locating and isolation of faults difficult. Recommendations include providing sectionalizing points for circuits that do not exceed the capabilities of fault locating equipment, while also providing sectionalizing points for isolation and restoration. In addition, the use of directional fault indicators at wind turbine generator (WTG) step-up transformers can cut down in fault-locating time significantly.

Common voltage levels for collector systems in North America include 15 kV, 25 kV, 35 kV and 46 kV (primarily in Canada). The most common system voltage for large wind farm collector systems is 35 kV because of the long circuit lengths and loading requirements. Collector system cable design considerations include the conductor size (based on system ampacity requirements) and the insulation type and level.

The two common insulation types are tree-retardant, cross-linked polyethylene (TRXLPE) and ethylene propylene rubber (EPR). EPR-insulated cables are easier to install (which is particularly beneficial for large conductor sizes) but are more expensive than TRXLPE-insulated cable. The insulation level (100%, 133% or 173%) depends on the system grounding as well as the magnitude and duration of temporary phase-to-ground overvoltages under fault conditions.

The industry standards for determining the appropriate insulation level are ICEA S-94-649 and AEIC CS8. For wind farm applications, the specifications of the most common cable type used include:

- aluminum conductors,

- 133% TRXLPE insulation,
- bare copper concentric neutral wires, rated 1/3 the ampacity for return current,
- linear, low-density polyethylene (LLDPE) jackets, and
- manufacture in accordance with ICEA S-94-649 and AEIC CS8.

Cable ampacities, and therefore the conductor size, are directly related to five major factors including:

- number of circuits,
- cable installation geometry and method,
- thermal resistivity and temperature,
- cable shield voltages and bonding method and
- load factor.

Understanding and controlling the thermal installation conditions is the overarching goal to prevent thermal run-away. Loaded cables naturally produce heat, so the number of circuits (i.e., the number of cables) installed together will reduce the amount of ampacity per cable. Therefore, cable ampacity is inversely proportional to the number of circuits.

Cable installation geometry and method affect the amount of heat produced under loaded conditions. For example, direct buried cables have higher ampacity levels than cables buried in ducts because ducts and duct banks reduce the ability to dissipate heat quickly.

The spacing of cables is an important consideration as well. Cables installed in a triplex, or trefoil, configuration produce less heat versus cables installed in parallel because the number of eddy currents induced on the metallic shield is reduced in a triplex configuration.

A significant source of potential problems with underground circuits is the improper selection and installation of thermal backfill materials to obtain the required thermal resistivity. Thermal run-away of cables will occur if the thermal resistivity is not higher than the designed level (typically 90 degree C-cm per W).

Finally, the metallic shield bonding method affects ampacity due to induced shield currents. Single point bonded shields, solidly bonded and grounded shields or cross bonded shields generally are used. The second method typically is used as it is the simplest solution to the problem of induced shield currents, reducing the amount of heat generated by the cable.

National Electric Safety Code section 9, rule 92C recommends "4 grounds per mile," as well as grounds at transformers and splices. A bare copper conductor (parallel grounding conductor) usually is included and bonded to the shields at regular intervals.

The last factor to consider is load factor, which is the average power divided by the peak power over a period of time (usually 24 hours). It is common to use 4/0 aluminum conductors near the ends of feeder strings, while 500 kcmil aluminum conductors are used closer to the collection substation and 1,000 kcmil aluminum conductors are used for the "home runs" to the collection substation. Cable ampacity, system loss and voltage drop calculations are required to size the cable properly for the wind farm collector system.

Designs for transient and temporary overvoltage protection typically involve the installation of surge arresters at the last pad-mounted transformer on each feeder string of a collector circuit. Application considerations of surge arresters include the location of arresters and type of mounting, the system grounding method and the circuit length.

Transient analysis and insulation coordination may be required to determine surge arrester placement to minimize transient overvoltages during feeder breaker closing or other switching events. Short-circuit and coordination studies typically are performed during the design phase of the project to address overcurrent protection requirements.

Several collector system design aspects influence overcurrent protection, including:

- long circuit lengths may not allow for easy detection of ground faults,
- system grounding (grounded versus ungrounded or systems grounded through grounding transformers on each feeder),
- selective coordination of collector system circuits can be quite challenging, as it is often difficult to distinguish faults on feeders when grounding transformers are used,
- selective coordination with fuses in downstream pad-mounted transformers at WTGs,
- unfaulted phases can be elevated to phase-to-phase voltage levels with respect to ground during ground faults,
- loss of phase during faults with single-phase tripping and reclosing on the transmission system or downed conductors and
- WTG may feed faults for several cycles (even though the feeder breaker tripped open) if sympathetic tripping of WTGs is not implemented.

There are many challenges associated with large wind farm collector systems, which must be addressed during the design phase. Realizing these challenges need to be addressed and having the expertise to identify and implement design solutions are critical to the success of every large wind farm. NP

Ernst Camm is a Senior Engineer in S&C Electric Company's Power Systems Services Division.