Renewable energy is consistently increasing its penetration into the electrical power market; while fossil fuels such as coal are beginning to lose their share in the power generation market. Distributed energy resources (DERs) such as wind turbines and solar panels are the leading power generation technologies behind renewable energy and its expanding market share capture. Many governments across the world (including the USA) are setting mandates and/or futuristic goals to have a certain percentage of electricity generated by renewable energy resources. There are even tax incentives and subsidies to foster growth and attract manufacturers to build wind and solar farms. As with all newly constructed power generation facilities, numerous feasibility studies must be performed to verify their viability within the existing power grid. This includes, for example, understanding and planning of how the DERs will be connected to, or interfaced with the existing power grid and completing computer simulations of the DERs operation within the existing power grid. Once the new installation is approved, construction then begins and additional detailed electrical studies are performed.

Detailed power system studies, typically consist of a short-circuit study, a protection coordination study, a load flow study, and an arc flash hazard assessment. Modeling a wind turbine itself typically includes the main circuit breaker at the base of the tower and the doubly-fed induction generator located in the head of the wind turbine, otherwise known as the nacelle, but there are many other electrical systems, equipment, and electrical cabinets throughout the wind turbine.

Unfortunately, the level of detail required to properly model and label these components inside the turbine is often overlooked. The information contained on the arc-flash label results from a detailed arc-flash evaluation of the turbine’s electrical system based on the available short-circuit energy at the incoming switchgear used to protect the electrical equipment within the nacelle. The label attached to an electrical device generally provides the required level of personal protective equipment (PPE) and other key items of information (see Figure 1). Often it is assumed that this arc flash assessment will cover all of the equipment within the nacelle; however, this assumption is likely inaccurate, as the arc flash hazards may differ between the different electrical systems within the nacelle.
Exponent was retained to perform a detailed arc flash hazard analysis of the electrical equipment within the nacelles of multiple turbines. These analyses were completed in part to meet applicable Occupational Safety and Health Administration (OSHA) regulations and provide improved information regarding the arc flash hazard, along with the level of PPE required when performing electrical work on the turbine. Exponent’s analysis involved modeling the internal electrical components of the wind turbine; including circuit breakers, fuses, disconnect switches, the doubly-fed induction generator, transformer, electrical converters, and power cables. The power cable interface included the connection between the switchgear and metering compartments at the base of the tower up in the nacelle. Detailed wind farm site information and wind turbine internal component information was provided to Exponent for input into an electrical engineering software package which bases its electrical calculations on recognized industry standards such as IEEE 1584 – Guide for Performing Arc Flash Hazard Calculations.1,2

The results of the arc flash analysis confirmed that the equipment in the turbines was not optimally protected and the original arc flash label for the switchgear was not consistent with all of the electrical equipment within the nacelle. For example, a particular fuse was shown to have little to no effect on the incident energy calculated during the arc flash simulation study. In general, fuses do not effectively limit incident energy except when using specially designed fuses or triggered current limiters. The results also suggested a few circuit breakers installed inside the nacelle had their respective protection settings set at sub-optimal values. The existing settings of these circuit breakers did not minimize the arc flash hazard, which then resulted in that specific breaker’s not being the primary protection device. In this case, an upstream breaker was the actual device that would have interrupted the arcing fault current flowing in the circuit during the simulated worst-case conditions. An upstream protective device that clears an electrical fault before the protective device that is located closest to the fault is an example of improper coordination and indicates sub-optimal protection settings.

Exponent helped determine recommended optimal settings, which were then implemented in the electrical engineering software; the power system studies were then re-calculated. With the new recommended settings, the simulations showed that the potential incident energy level was reduced and the closest protection device cleared the arc flash, as the system was originally intended. This result highlights how simulating the equipment throughout the turbine can reduce the electrical hazard to which a worker may be exposed when working on live electrical equipment. Additionally, by optimizing the protective device coordination in the event of a fault, the damage to the electrical equipment may be limited and repair times decreased.

Arc flash labels specific for the equipment throughout the turbine were also created. These labels provide the required information for the specific electrical equipment and inform the electrical worker on the most appropriate personal protective equipment to wear for the job. This allows workers to knowledgably work on the electrical equipment with a better understanding of the specific electrical hazard associated with each item of electrical equipment.
Credibility for the individual arc-flash/PPE evaluation for each piece of equipment is established, by virtue of the device-by-device analysis, as compared with the results of a general study, detrimentally applied to the aggregate of the devices lumped together. The worker is thus able to maximize safety, dexterity, and comfort on the job.

![Warning](image)

**Figure 1. Arc Flash Label Example**

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