Estimating Voltage Sag Performance - Area of Vulnerability

It is important to understand the expected voltage sag performance of the supply system so that facilities can be designed and equipment specifications developed to assure the optimum operation of production facilities.

The following is a general procedure for working with industrial customers to assure compatibility between the supply system characteristics and the facility operation:

- Determine the number and characteristics of voltage sags that result from *transmission system faults*.
- Determine the number and characteristics of voltage sags that result from *distribution system faults*.
- Determine the *equipment sensitivity* to voltage sags. This will determine the actual performance of the production process based on voltage sag performance calculated in steps 1 and 2.
- Evaluate the *economics of different solutions* that could improve the performance, either on the supply system (fewer voltage sags) or within the customer facility.

2.2.1 Area of Vulnerability

The concept of an *area of vulnerability* has been developed to help evaluate the likelihood of sensitive equipment being subjected to voltage lower than its *minimum voltage sag ride-through capability*.

The latter term is defined as the minimum voltage magnitude a piece of equipment can withstand or tolerate without misoperation or failure. This is also known as the *equipment voltage sag immunity* or *susceptibility limit*. An area of vulnerability is determined by the total circuit miles of exposure to faults that can cause voltage magnitudes at an end-user facility to drop below the equipment minimum voltage sag ride-through capability.

Figure 2.5 shows an example of an area of vulnerability diagram for motor contactor and adjustable-speed-drive loads at an end-user facility served from the distribution system. The loads will be subject to faults on both the transmission system and the distribution system. The actual number of voltage sags that a facility can expect is determined by combining the area of vulnerability with the expected fault performance for this portion of the power system. The expected fault performance is usually determined from historical data.

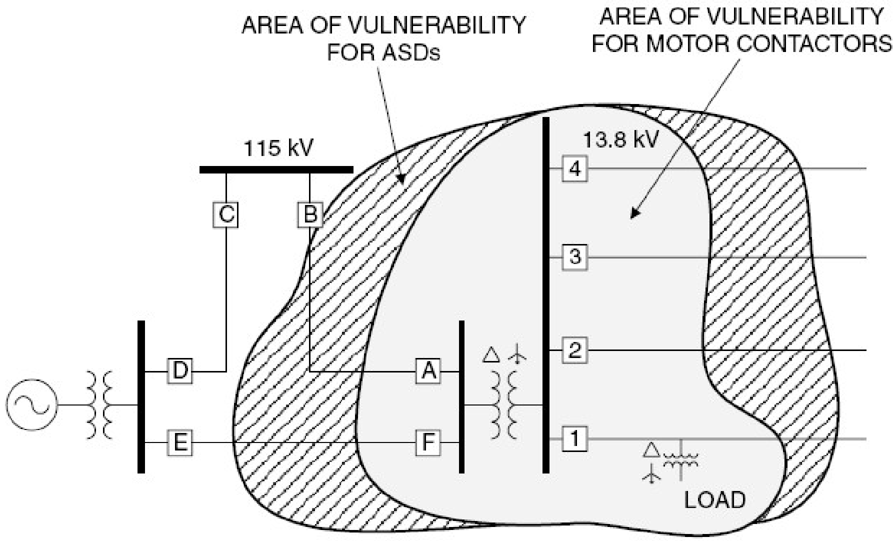

Figure 2.5 Illustration of an area of vulnerability.

2.2.2 Equipment Sensitivity to Voltage Sags

Equipment within an end-user facility may have different sensitivity to voltage sags. Equipment sensitivity to voltage sags is very dependent on the specific load type, control settings, and applications. Consequently, it is often difficult to identify which characteristics of a given voltage sag are most likely to cause equipment to mis-operate.

The most commonly used characteristics are the duration and magnitude of the sag. Other less commonly used characteristics include phase shift and unbalance, missing voltage, three-phase voltage unbalance during the sag event, and the point-in-the-wave at which the sag initiates and terminates.

Generally, equipment sensitivity to voltage sags can be divided into three categories:

* **Equipment sensitive to only the magnitude of voltage sag.**

This group includes devices such as under voltage relays, process controls, motor drive controls,6 and many types of automated machines Devices in this group are sensitive to the minimum (or maximum) voltage magnitude experienced during a sag (or swell). The duration of the disturbance is usually of secondary importance for these devices.

* **Equipment sensitive to both the magnitude and duration of a voltage sag.**

This group includes virtually all equipment that uses electronic power supplies. Such equipment mis-operates or fails when the power supply output voltage drops below specified values. Thus, the important characteristic for this type of equipment is the duration that the rms voltage is below a specified threshold at which the equipment trips.

* **Equipment sensitive to characteristics other than magnitude and duration.**

Some devices are affected by other sag characteristics such as the phase unbalance during the sag event, the point-in-the wave at which the sag is initiated, or any transient oscillations occurring during the disturbance. These characteristics are more subtle than magnitude and duration, and their impacts are much more difficult to generalize.

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