Estimating Voltage Sag Performance -Transmission System Sag Performance Evaluation

The voltage sag performance for a given customer facility will depend on whether the customer is supplied from the transmission system or from the distribution system.

For a customer supplied from the transmission system, the voltage sag performance will depend on only the transmission system fault performance. On the other hand, for a customer supplied from the distribution system, the voltage sag performance will depend on the fault performance on both the transmission and distribution systems.

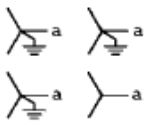
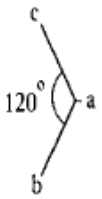
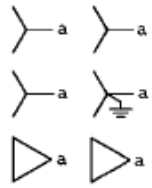
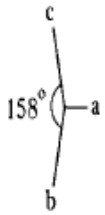
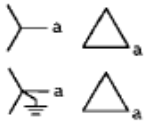
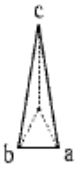
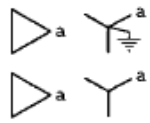
Transmission line faults and the subsequent opening of the protective devices rarely cause an interruption for any customer because of the interconnected nature of most modern-day transmission networks. These faults do, however, cause voltage sags. Depending on the equipment sensitivity, the unit may trip off, resulting in substantial monetary losses. The ability to estimate the expected voltage sags at an end-user location is therefore very important.

Most utilities have detailed short-circuit models of the interconnected transmission system available for programs such as ASPEN (Advanced Systems for Power Engineering). These programs can calculate the voltage throughout the system resulting from faults around the system. Many of them can also apply faults at locations along the transmission lines to help calculate the area of vulnerability at a specific location.

The area of vulnerability describes all the fault locations that can cause equipment to mis-operate. The type of fault must also be considered in this analysis. Single-line-to-ground faults will not result in the same voltage sag at the customer equipment as a three-phase fault. The characteristics at the end-use equipment also depend on how the voltages are changed by transformer connections and how the equipment is connected, i.e., phase-to-ground or phase-to-phase.

Table 2.1 summarizes voltages at the customer transformer secondary for a single- line-to-ground fault at the primary.

TABLE 2.1 Transformer Secondary Voltages with a Single-Line-to- Ground Fault on the Primary

Transformer connection (primary/secondary)	Phase-to-phase			Phase-to-neutral			Phasor diagram
	V_{ab}	V_{bc}	V_{ca}	V_{an}	V_{bn}	V_{cn}	
	0.58	1.00	0.58	0.00	1.00	1.00	
	0.58	1.00	0.58	0.33	0.88	0.88	
	0.33	0.88	0.88	—	—	—	
	0.88	0.88	0.33	0.58	1.00	0.58	

The relationships in Table 2.1 illustrate the fact that a single-line to-ground fault on the primary of a delta-wye grounded transformer does not result in zero voltage on any of the phase- to-ground or phase-to-phase voltages on the secondary of the transformer. The magnitude of the lowest secondary voltage depends on how the equipment is connected:

* Equipment connected line-to-line would experience a minimum voltage of 33 percent.
* Equipment connected line-to-neutral would experience a minimum voltage of 58 percent.

This illustrates the importance of both transformer connections and the equipment connections in determining the actual voltage that equipment will experience during a fault on the supply system.

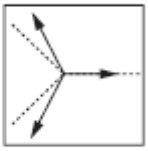
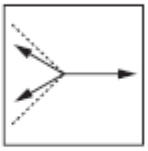
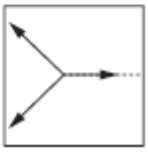
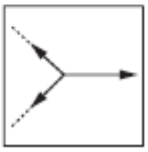
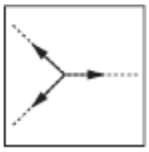
Phase Shift	Number of Phases		
	1	2	3
Angle	 Sag Type D One-phase sag, phase shift	 Sag Type C Two-phase sag, phase shift	Note: Three-phase sags should lead to relatively balanced conditions; therefore, sag type A is a sufficient characterization for all three-phase sags.
None	 Sag Type B One-phase sag, no phase shift	 Sag Type E Two-phase sag, no phase shift	 Sag Type A Three-phase sag

Figure 2.5 Voltage sag types at end-use equipment that result from different types of faults and transformer connections

Math Bollen developed the concept of voltage sag –types‖ to describe the different voltage sag characteristics that can be experienced at the end-user level for different fault conditions and system configurations. The five types that can commonly be experienced are illustrated in Fig.2.5. These fault types can be used

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