Distribution System Reliability

An Online Continuing Education Course for Engineers

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Distribution System Reliability

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Introduction:

The reliability of the distribution system varies whether the distribution circuits are overhead or underground. The distribution design plays a bigger role: radial, autoloop, buried residential distribution or network. The substation design and the reliability of the substation supply circuit impact the overall distribution reliability.

The utility's reputation is measured by the total number of customers interrupted, total outage duration, and number of interruptions, whether momentary or permanent, in a given time. Typical distribution circuits do not have the same capability/reliability or length as typical transmission circuits.

Distribution System:

The key components of the distribution systems are:

- The inception: distribution systems start at the distribution substation, mainly at the substation bus, which is connected to the secondary side of the substation step-down transformer.
- Unlike power plants and transmission stations, distribution substations are located close to the load center, mainly due to the voltage drop, which is related to the circuit length.
- The end: distribution systems typically end at a small distribution overhead (OH) or underground (UG) transformer that is located very close to a customer's house, or ends at the customer's electric meter.
- Distribution voltage is typically below 69 kV, mainly 5-35 kV class; the 15-kV class is more common.
- It is common for utilities to have several distribution medium voltages. The main reason is that decades ago there were numerous separate utilities operating different medium voltage systems. After consolidation, it was cost effective to maintain some of the various voltages. Load density is another common reason; heavily loaded areas may be supplied via higher medium voltage (higher ratings).

Transmission and distribution substations are similar, with the following exceptions:

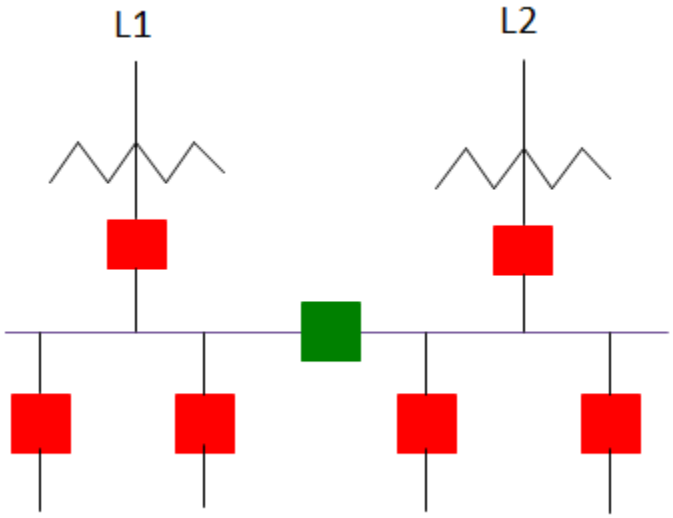
  - Transmission breakers/disconnect switches and other disconnecting devices have higher capabilities, i.e. higher short circuit interrupting capabilities.

- Pumping plants, used to circulate oil for underground transmission cables, are utilized at some transmission substations and not distribution substations.
- Transmission stations typically do not have transformers, unless it is a switching substation; however, distribution stations always have transformers.

Substation Design:

The straight bus design is very common as it is the simplest and cheapest design. There are several possible straight bus configurations, below is a very common design.

The design below shows:



- There are several reasons why straight buses can have a normally open bus breaker:
  - Short circuit capability is a common reason for having the bus split.
  - Prevent breaker failure; if the bus breaker was normally closed and an attempt to open that breaker failed or if there is a fault that required that breaker to open and the breaker failed to open, then all the other breakers will open, thus losing the entire substation.

Distribution Line Design Reliability:

Distribution line design varies whether the line is underground (UG) or overhead (OH). Other than the voltage, there is a major difference between transmission and distribution circuits: the attached equipment.

Weather:

- UG distribution lines are almost weather proof. Wind (exceeding design) has a drastic impact on OH lines, i.e. reducing clearance between phases and nearby objects and/or phases, resulting in flash/fault. The bulk of the distribution systems worldwide are OH, since OH is cheaper by design and easier to construct. UG distribution lines are not impacted by wind.
- Trees: whether due to age or because of storms, tree branches fall on OH lines and result in trip-outs.
- Flood: unfortunately, more common now, affect substations more than lines; however, UG non-submersible transformers will be damaged.
- Lightning: UG is rarely impacted by lightning. With respect to the OH system, lightning/surge arrestors are typically attached to OH transformers, riser poles, etc. The aforementioned was comparing 100% UG lines to 100% OH. Some OH lines transition to UG to cross a highway, bridge, rail tracks, etc. As a result, the OH portion of the circuit will be prone to lightning not the UG portion.
- Snow: snow impacts OH & UG system differently. For the OH lines, they are designed to withstand a certain weight due to the accumulated snow. Significant snow accumulation may result in pole collapse or wires sagging beyond the acceptable limits which may result in a flash.
    - UG distribution lines are impacted by the melting snow that is mixed with the salt that trucks spray all over town. Salt corrodes the cables and result in brownouts, burnouts and manhole fires.

UG distribution systems are the winner from a reliability perspective. Having said that, OH systems have the following characteristics:

- Higher ratings: UG cables may get de-rated (loss of rating) due to their vicinity to other heat resources, i.e. subway, transmission cables and other distribution cables.

- Visible: faults are visible, thus the restoration is quicker, while UG faults are not visible, thus taking longer to restore. Sophisticated fault locating techniques and equipment are utilized in the UG system, while operator patrol is typically all that is required for OH failures.
- Cost: depending on the location, proposed route, river/rail crossing, etc., an UG mile may cost five to ten times the cost of a typical OH mile.

Unlike common transmission cables that are oil filled, distribution cables are not. Few splices may be oil filled and some old cables are filled with Nitrogen. There is an environmental concern with those cable types.

Digging: from the weather perspective, it was clear that the UG system is more reliable. One common issue is unauthorized (non-utility) digging, where a local construction crew may mistakenly dig into a distribution cable (or multiple cables since they run close together) that will fail.

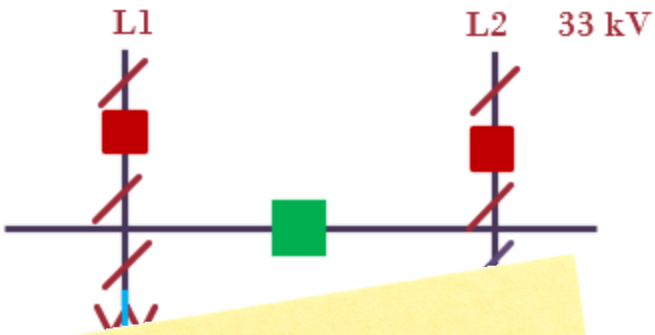
Depending on how heavily populated or crowded the city is, there may be crews replacing or building new gas pipes, water pipes, communication cables, steam systems, distribution circuits, etc., or building a new high rise, thus there are various threats to the surrounding cables.

Utilities exert a lot of effort to ensure proper digging, eliminate improper digging, and provide utility prints when required promptly.

Substation Design Reliability:

The diagram below depicts a common substation design. Below are some key characteristics:

- The supply feeders are 33 kV (known as 35 kV class)
- Both supply feeders are equiped with breakers and disconnect switches (allows isolation/maintenance).
- The 33 kV (high side) & 4 kV (low side) straight buses have a normally open bus breaker.
- The two transfomers are equipped with breakers on the secondary side, i.e. the 4 kV side.
- Three 4 kV feeders are connected to each transformer side.



4 kV

Fault on the secondary side g to isolate the fault; transfomer secondary er operation, all three feeders will be withou