Introduction to Microgrids

An Online Continuing Education Course for Engineers

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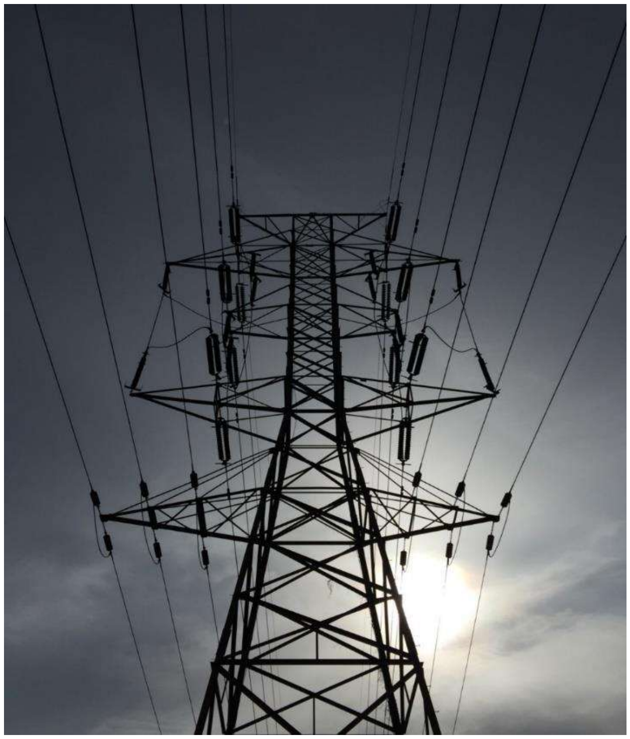
Ahmed Mousa, Ph.D.

Introduction:

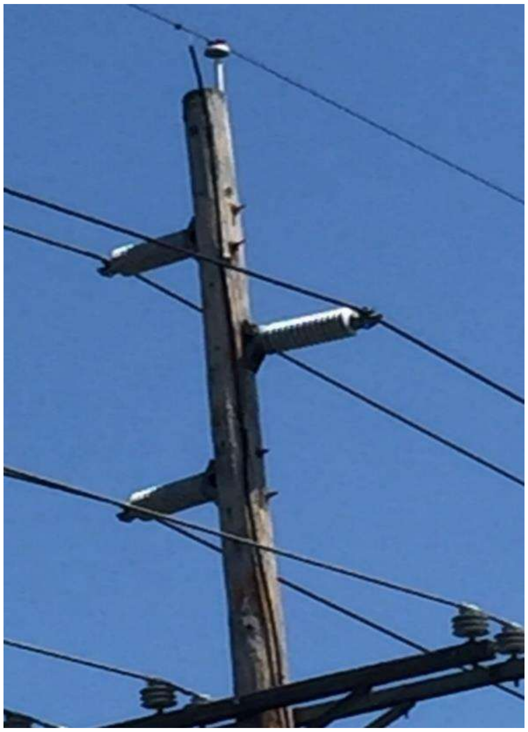
A “micro” is a unit of measurement that is equal to 10^{-6} or 0.000001. With respect to the electric grid, a “microgrid” is an electrical system where a large customer, i.e., a university provides their own generation and distribution system, instead of relying solely on their local electric utility. The customer acts as a mini utility. There are two common microgrid modes of operation:

- Blue-sky day operations, 24/7 operation while being connected in parallel to the electric grid (macro grid).
- Black-sky day operations, where the microgrid only operates when the electric grid (macro grid) is not available (i.e., storm-related, local contingency, blackout).

Sometimes, the microgrid mode of operations varies based on available financial incentives and energy/capacity markets, and utility programs. Typically, there are no transmission components involved in the microgrid world, since the primary purpose for having a transmission system is to transmit the large, generated power (typically in the hundreds and thousands of MWs) from power plants to the load center (long-distance transmission of power). The transmission system was designed to mitigate the I^2R losses (I is the current and R is the resistance), and since power, P = VI; the efficient way to transmit a large amount of power over a long distance is to lower the current and raise the voltage.



Although microgrids are not common (due to many issues that will be discussed later), they tend to be more common among large educational institutions, i.e., universities/colleges, since they are traditionally supplied via medium/sub-transmission feeders, own their substation, and responsible for their local distribution system/design (not the utility), i.e. utilities supply the customer-owned substations with medium voltage, i.e. 33 kV and the customer will build their own distribution feeders/switchgear, etc., from the substation to all the buildings, offices, residences, etc.



The Island Setup

For many decades (since electricity was created), the electric utility (utility for short) has been the sole source of power. On very rare occasions, some small cities or large residential complexes chose to generate their own power and distribute the generated power to their residents. This electric setup is not a true microgrid since that residential complex is not physically connected to the utility electric system (macrosystem). The customer is mainly islanded from the grid; there are no electrical ties between the utility and the customer. In the event there is a major disturbance at the customer's generating facility or distribution switchgear, all customers supplied by this generator will lose power, most likely for a prolonged period until the issue(s) has been resolved (depending on the reason for the disturbance and damage). Some new developments are constructed in remote areas, far from any utility assets, thus it is cost-effective to set up a semi-microgrid design instead of paying their local utility for a long extension.

Most likely, the predominant reason for this mode of islanded operation is that the developer/investor determined that it is cost-effective to operate isolated instead of getting supplied via the local utility or that location is far from the nearest utility supply; thus, it was cost-effective to operate that way.

The decision for some customers to install a large generator onsite is mainly driven by economic and/or reliability reasons, i.e., making use of available power markets (to be discussed later), cheaper to generate own power compared to relying on the grid, or due to the local utility's poor reliability record, wherein some geographical areas, the proposed setup would be more reliable than the utility's (back-up power as well).

On the other hand, some campuses and large customers that are normally supplied by their local utilities choose to install a large generator (not utility-scale of course) onsite to supply:

- Their full load
- A portion of their load
- Reduce their load consumption during the peak day (rates related, i.e., reduce consumption during peak hours when the electricity prices are the highest).
- Their full load and export excess generation to the grid
- Their full or partial load when the utility supplies are not available.

Back-up generation may be a federal/state mandate for certain critical customers, such as hospitals, retirement homes, prisons, etc. in the event the utility supplies are not available.

Customer supply:

There are many reasons why utility supplies become unavailable. Typically, we refer to the utility supplies as circuits or feeders; based on the customer's load, criticality required level of reliability, and utility design, the customer may only require one feeder from their load demand perspective; however, the utility will provide the customer with two or more circuits to meet their reliable contingency design (n-1 or n-2) → thus customers located in utilities with reliable designs will benefit without bearing additional cost, while in other locations, critical customers, i.e. data center will have to pay for the additional supplies/reliability.

The supply to the customer premises may be:

- Overhead (OH)

- Underground (UG)

OH construction is much cheaper to construct than UG; a UG mile may cost up to ten (10) times the typical OH mile. It is common to perform the comparison on a per-mile basis.

Some cities mandate all utility assets to be constructed UG, thus the utility has no choice but to bury all their transmission and distribution assets below ground. Think about Manhattan or downtown Chicago, how will both cities look like if the transmission and/or distribution systems were OH instead of UG?

From a reliability perspective, there are numerous benefits to UG systems; the main drawbacks are cost, and the longer time required to restore UG cables after failures (we refer to UG circuits as cables) compared to the OH system.

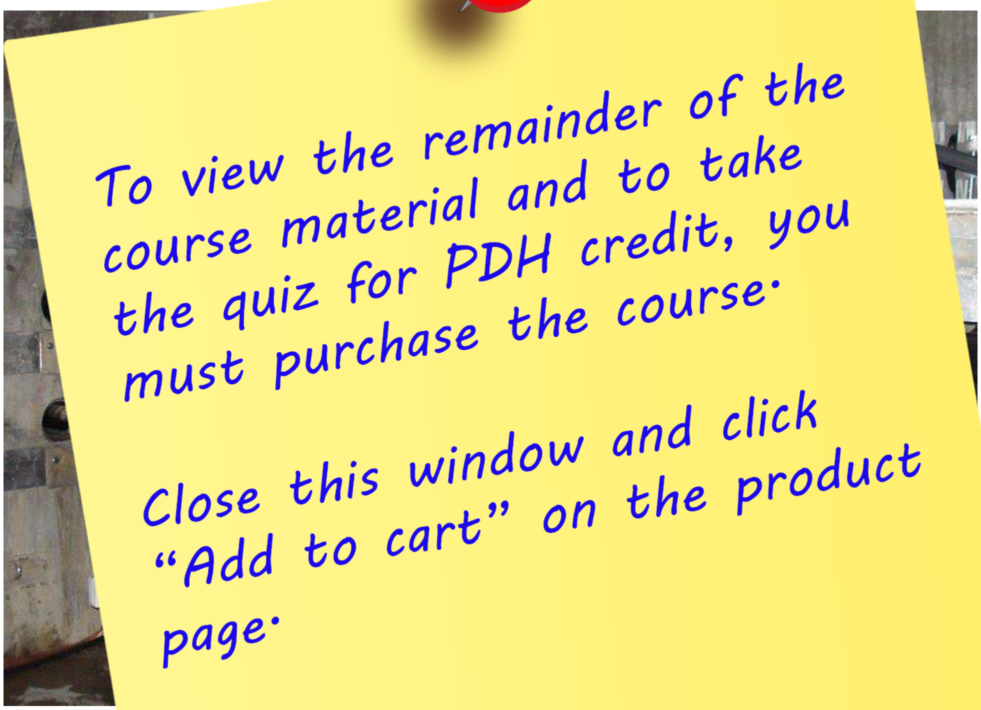
Below are common reasons for OH circuit failures:

- Animal contact
- Mylar balloon/kite contact

- Hit-poles
- Tree contact
- Storms
- Relay misoperation
- lightning

Below are common reasons for UG cable failures:

- Unauthorized digging
- Workmanship (human error during splicing and/or cable pulling)
- Cable degradation due to the wide usage … (after a snowstorm)
- UG transformer failure



OH circuits and ca… …streets to customers. Major storms can c… …If the substation is damaged, most or all circuits from that substatio… (loss of power source to the substation). Over the past few years, there were two major events on the east coast, the 2003 blackout and superstorm Sandy that reshaped the electric grid.

Currently, there are numerous seminars, papers, etc. related to the causes of the 2003 blackout and how the electric grid changed after. We will not be discussing blackouts; it suffices to state that the transmission system in the U.S. after the 2003 blackout is completely different from the transmission system before 2003, whether due to the major transmission expansion and/or due to the SCADA (Supervisory Control and Data Acquisition) and digitization upgrades. In addition, different regional