System Protection

An Online Continuing Education Course for Engineers

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System Protection

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The Art of Engineering Relays, Breakers, Reclosers & Fuses

Introduction

System protection is known as the art of engineering, the building block of every utility. We need *proper* protection for the generation, transmission, distribution systems, and renewables: first and second line of defense as well as back-up protection.

Relays represent the brain power that differentiates between normal and fault conditions and trigger the operating muscle, which is the disconnecting devices, such as circuit breakers and reclosers to isolate the faults.

There are key differences between breakers, reclosers & fuses. The consequences of improper protection or relay misoperation are grave.

This course will show the differences between breakers, reclosers & fuses, as well as the consequences for improper protection and relay misoperation. This course will also cover special relay traits, protection zones, common relay types and communication methods, fuse curves and DER impact.

Protection:

We do not have the ability to prevent faults (we cannot stop storms, heavy rains, wind, snow, etc.) We do have the ability to provide adequate and speedy protection schemes to isolate the faults as soon as practically possible to minimize the damage.

There are two conditions that we protect:

- Normal conditions – as the name implies, under normal conditions, the system is whole or 100%: all system components are available and in-service.
    - Overload is simply exceeding the thermal rating/capacity of a circuit, transformer or equipment.
    - Overload may occur under normal conditions, as a result of inaccurate load forecast, extreme heat wave, extremely low temperature, that will result in load exceeding the forecast that the system was planned for. The aforementioned may result in overloads or low voltage conditions triggering relay action. Typically, those conditions will not result in relay operation, unless the relay settings were not preset properly.

- Emergency conditions – mainly as a result of one or more system component(s) being out of service, thus the system is no longer 100% available. Overload or low voltage conditions may occur, triggering relay action(s):
    - Losing a system component: power plant, transmission line, substation transformer, as a result of a fault.
    - During a fault, there are:
        - Much larger than normal current flow.
        - Current flow in directions different from the normal flow.
- When a fault occurs, all neighboring power sources will contribute to the fault location:
    - Voltage is merely a potential difference. At the fault location, the voltage is zero, or close to zero, thus there is a large voltage difference between neighboring circuits & the fault location. As a result, generators, transformers, etc. will contribute to the fault location.
    - They will send thousands of Amps thru various station equipment & circuits that are only designed to carry that large current magnitude for the very short period (else, there is a risk of more failure(s)). Additional relays (primary, secondary and back-up) are monitoring the system as an added reliability to ensure reliable operation in case one or more relays fail to operate as planned.
- Protection systems are there to remove/isolate the faulted equipment as ***fast*** as possible; they are not there to prevent the cause of the failure.

What are Relays?

Relays are ***low powered*** devices that ***trigger*** the operation of several types of equipment when certain ***preset*** values are ***exceeded/violated***. Birds and animals (squirrels, raccoons, and snakes) occasionally find their way onto power lines and transformers, especially in the winter seeking the warmth of the electric wires and transformers. Animal contact can result in either phase to phase or phase to ground short circuit/fault.

Large birds contact power lines all the time (as long as they are only sitting or making contact with one phase only, this should not result in a fault) and may occasionally result in a fault (usually as a result of making contact with two phases). While the animal/bird rarely survives the electric shock, the fact is: a fault occurred, and the corresponding protective relay(s) will initiate a certain circuit breaker(s) to operate isolating the fault(s). The conclusion is that the circuit or equipment tripped/was taken out of service due to the bird/animal contact.

The bulk of the electric distribution system is overhead (OH). Hit-pole is another unfortunate common reason why a circuit or in some cases several circuits (see figure below) may trip due to a car colliding with the utility pole resulting in failures (different phases making contact or even phases from different circuits making contact; in both cases, one or multiple faults will occur).

There are various relay types; traditionally electromechanical relays were utilized (still are), solid-state was the next vintage, and now microprocessor relays are the latest in the protection world.

Hit-poles and animal contact impact the OH system negatively.

Concerning the underground (UG) system, a common reason for UG faults is improper digging (pictures below showing UG construction). This is common in areas with aggressive construction, i.e., Manhattan, where communication/construction companies, environmental agencies, etc. are constantly performing work on their system which may result in improper contact with a utility distribution or transmission cables, again creating a single or multiple faults.