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Tutorial Sheet 3.

Ques 1. Explain the method for estimating the cost for voltage sag events.

Ans 1. **Method for Estimating the Cost for Voltage Sag Events :**

The costs associated with sag events can vary significantly from nearly zero to several million dollars per event. The cost will vary not only among several industry types and individual facilities but also with market conditions. Higher costs are typically experienced if the end product is in short supply and there is limited ability to makeup for the lost production. Not all costs are easily quantified or truly reflect the consequences if a voltage sag is not urgently avoided. The cost of a power quality disturbance can be captured primarily through three major categories :

(1) Product-related losses, such as loss of product and materials, lost production capacity, disposal charges, and increased inventory requirements.

(2) Labor-related losses, such as idled employees, overtime, cleanup, and repair.

(3) Ancillary costs, such as damaged equipments, lost opportunity costs, and penalties due to shipping delays.

Focusing on these three categories will facilitate the development of a detailed list of all the costs and savings associated with a power quality disturbance. One can also refer to appendix A of IEEE 1346-1998 for a more detailed explaination of the factors to be considered in determining the cost of power quality disturbances.

Costs will typically vary with the severity (both magnitude and direction) of power quality disturbance. This relationship can often be defined by a matrix of weighting factors. The weighting factors are developed using the cost of the momentary interruption as the base. Usually, a momentary interruption will cause a disruption to any load or process that is not specifically protected with a type of energy storage technology. Voltage sags and other power quality variations will always have an an impact that is some portion of this total shutdown.

After the weighting factors are applied to an event, the costs of the event are expressed in per unit of the cost of a momentary interruption. The weighted events can then be summed and the result is the total cost of all the events expressed in the number of equivalent momentary interruptions.

Ques 2. Describe Overcurrent coordination Principles.

Ans 2. Overcurrent coordination Principles :

It is important to understand the of the utility system during fault conditions. There are certain limitations to interrupting the fault current and restoring power.

This places certain minimum requirements on the loads that are expected to survive such events without disruptions. There are also some things that can be done better on the utility system to improve the power quality than that on the load side. Therefore, the issues related to both the end user (or load equipment designer) and the utility engineers relevant to utility fault clearing are addressed.

There are two fundamental types of faults on power systems:

(1) Transient (Temporary) Faults:
These are faults due to such things as overhead line flashovers that result in no permanent damage to the system insulation. Power can be restored as soon as the fault arc is extinguished. Automatic switchgear can do this within a few seconds. Some transient faults are self-clearing.

(2) Permanent Faults:
These are faults due to physical damage to some element of the insulation system that requires intervention by a line crew to repair. The impact on the end-user is an outage that lasts from several minutes to a few hours.

- The chief objective of the utility system fault-clearing process, besides personnel safety, is to limit the damage to the distribution system. Therefore, the detection of faults and the clearing of the fault current must be done with the maximum possible speed without resulting in ~~false~~ false operations for normal transient events. The two greatest concerns for damage are typically:

(1) Arcing damage to conductors and bushings

(2) Through-fault damage to substation transformers where the windings become displaced by excessive forces, resulting in a major failure.

A radial distribution system is designed so that only one fault interrupter must operate to clear the fault. For permanent faults, that same device, or another, is operated to sectionalize the feeder, i.e, the faulted section is isolated to restore the power to the rest of the loads served from the sound sections. Orchestrating this process is referred to as the coordination of the overcurrent protection devices. While this is simple in concept, some of the behaviours of the devices involved can be quite complex. Remarkably, all of the process is performed automatically by autonomous devices, employing only local intelligence.

Overcurrent protection devices appear in series along a feeder. For permanent fault coordination, the devices operate progressively slower as one moves from the ends of the feeders towards the substation. This helps in proper sectionalizing of the feeder, so that only the faulted section is isolated. However, this principle is often violated for temporary faults, particularly if fuse saving is employed. The typical hierarchy of overcurrent protection devices on a feeder is as given below:

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(1) Feeder Breaker in the Substation:
This is a circuit breaker capable of interrupting typically 40 KA of current and controlled by separate relays. When the available fault current is less than 20 KA, it is common to find reclosers used in this operation.

(2) Line Reclosers Mounted on Poles at Midfeeder:
The simplest are self-contained with hydraulically operated timing, interrupting and reclosing mechanisms. Others have separate electronic controls.

(3) Fuses on Many Lateral Taps off the Main feeder:
This is the most common form of installation for protection of power system.

Ques 3. Write the effects of Capacitor Switching, Lightening, Ferroresonance on transient over voltages.

Ans 3 (1) Effects of Capacitor Switching:

(1) Capacitor switching introduces oscillatory transients in the power system.

(2) Tripping of adjustable-speed-drives and malfunctions of other electronically controlled load equipment that occur without a noticable blinking of the lights, or impact on other, more conventional loads.

(3) Switching of grounded-wye transformer banks may also result in unusual transient voltages in the local grounding system due to the current surge that accompanies the energization.

(2) Effects of Lightening:

(1) Generation of very short, single impulse transient, or a train of impulses due to quick changing of interwinding capacitances.

(2) Many times, a longer impulse, which is sometimes oscillatory, is observed on the secondary when there is a strike to a utility's primary distribution system.

(3) They raise the potential of the local ground above other grounds in the vicinity by several kilovolts. Sensitive electronic equipment that is connected between two ground references, can fail when subjected to the lightning surge voltages.

(4) They induce high voltages in phase conductors as they pass through cables on the way to a better ground.

(3) Effects of ferroresonance:

(1) Audible Noise:

During ferroresonance, there may be an audible noise, often likened to that of a large bucket of bolts being shook, whining, a buzzer, or an anvil chorous pounding on the transformer enclosure from within. The noise is caused by the magnetostriction of the steel core being driven into saturation.

(2) Overheating:

Transformer overheating often results due to ferroresonance, which is especially true when the iron core is driven into saturation. This may damage solid insulation structures beyond repair.

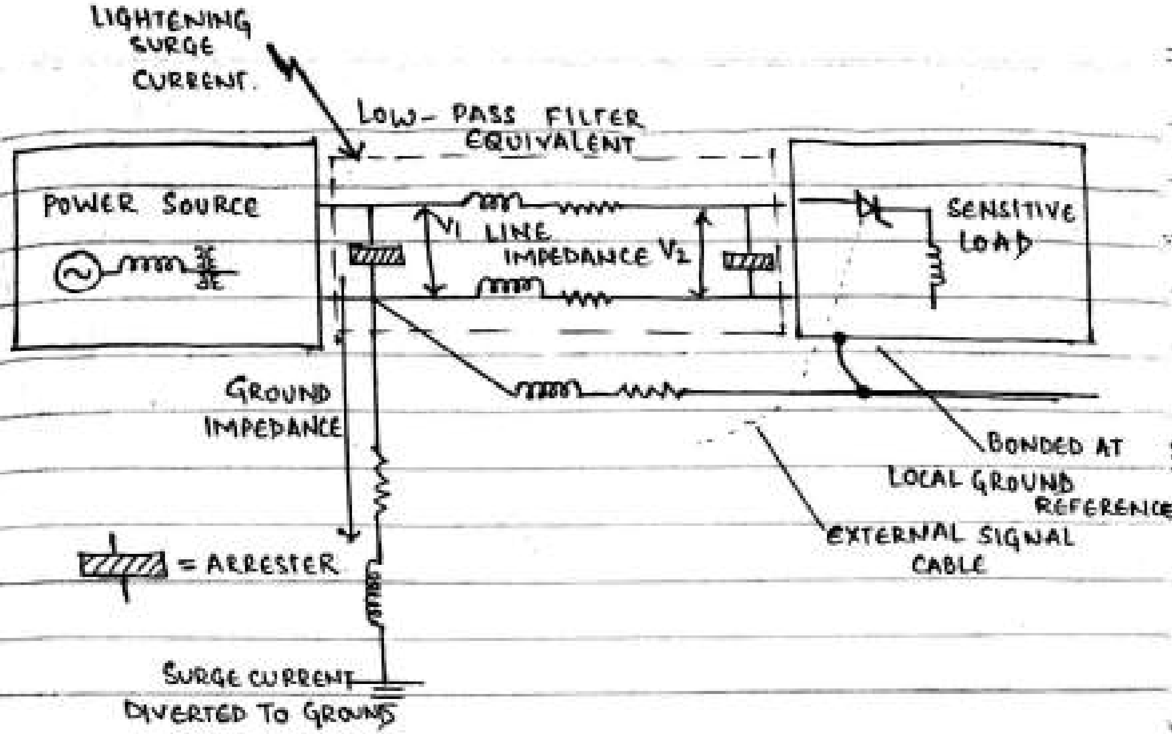
(3) High Overvoltages and Surge Arrester failure:
Ferroresonance accompanied by overvoltages leads to electrical damage to both the primary and secondary circuits. Surges arresters are common casualties of the event.

(4) Flicker:
During ferroresonance, the voltage magnitude may fluctuate wildly. Some electronic equipments may be very susceptible to such voltage excursions. Prolonged exposure can shorten the life of the equipment or may cause immediate failure.

Ques 4. What are fundamental principles of protection? Explain in detail.

Ans 4. Principles of Overvoltage Protection:
The fundamental principles of overvoltage protection of load equipment are:
(1) Limit the voltage across sensitive insulation.
(2) Divert the surge current away from the load.
(3) Block the surge current from entering the load.
(4) Bond grounds together at the equipment.
(5) Reduce, or prevent, surge current from flowing between grounds.
(6) Create a low-pass filter using limiting and blocking principles.

These protection principles are explained in the figure given alongside:



The first arrester is connected from the line to the neutral ground bond at the service entrance. It limits the line voltage V_1 from rising too high relative to the neutral and ground voltage at the panel. In this situation, most of the surge energy will be discharged through the first arrester directly into the ground. In that sense, the arrester becomes a "surge diverter."

In this figure, the signal cable may be another possible path for the surge current. As a result, damaging voltages can be impressed across the load. The first arrester at the service entrance is electrically too remote to provide adequate protection. Therefore, a second arrester is applied at the load, again, directly across the load to be protected. It is connected line-to-neutral so that it only protects against normal mode transients.

A load may be in an environment where it is close to another loads and operators or sensitive equipments are routinely in contact with both loads. This raises the possibility that a lightning strike may raise the potential of one ground much higher than the others. This can cause a flashover across the insulation that is in between the two ground references or cause physical harm to operators. Thus, all reference conductors should be bonded together at the load equipment. The principle is to tie the references together so that all power and signal cable references in the vicinity rise together.

Efforts to block the surge current are most effective for high-frequency surge currents. Since power frequency currents must pass through the surge suppressor with minimal additional impedance, it is difficult and expensive to build filters that are capable of discriminating between low frequency surges and power frequency currents. Blocking can be done relatively easily for high frequency transients by placing an inductor, or choke, in series with the load. The blocking function is frequently combined with the voltage-limiting function to form a low-pass filter, in which there is a shunt connected voltage limiting device on either side of the series choke

The amount of current flowing between the grounds may be reduced by improving all the intentional grounds at the service ~~and~~ entrance and nearby on the utility system. This will normally reduce, but not eliminate entirely, the incidence of equipment failure within the facility due to lightning.

Ques 5. Write short notes on:
(1) Ferroresonant Transformer
(2) Magnetic synthesizer
(3) Active Series Compensator
(4) UPS
(5) Superconducting Magnetic Energy storage Device.

Ans 5. (1) Ferroresonant Transformer :

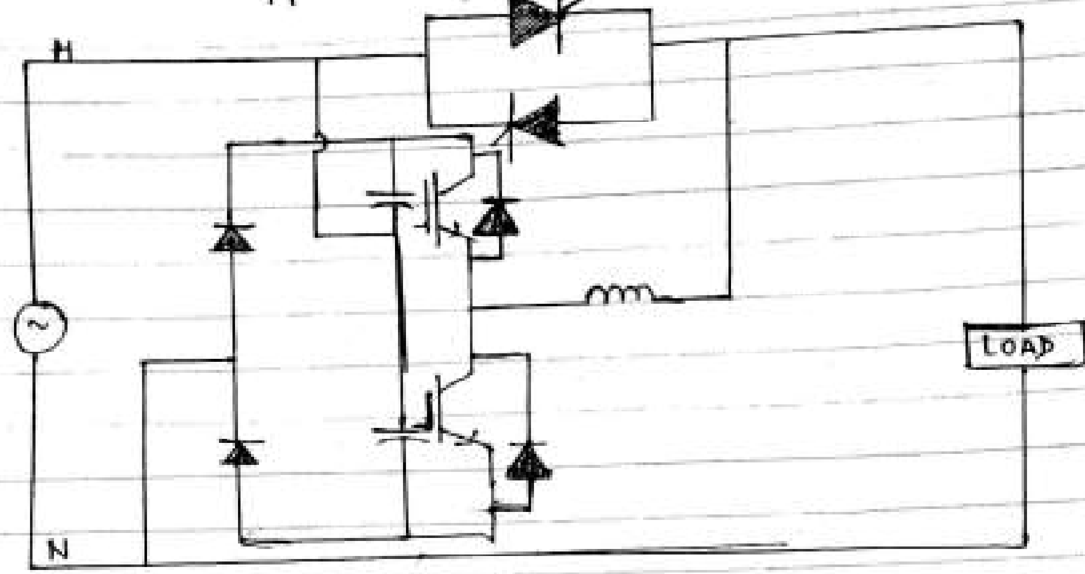
Done in Tutorial sheet 2, Ques 3.

(2) Magnetic Synthesizer:

Done in Tutorial Sheet 2, Ques 4.

(3) Active Series Compensator:

An active series compensator is a device that can boost the voltage by injecting a voltage in series with the remaining voltage during a voltage sag condition. They are available in size ranges from small, single phase devices (1 to 5 KVA) to very large devices that can be applied on the medium voltage systems (2MVA and larger). When a disturbance to the input voltage is detected, a fast switch opens and the power is supplied through the series connected electronics. This circuit adds or subtracts a voltage signal to the input voltage so that the output voltage remains within a specified tolerance during the disturbance. This is fast enough to avoid problems with almost all sensitive loads. The circuit can provide voltage boosting of about 50 %, which is sufficient for almost all voltage sag conditi



Active Series Compensator

(4) Uninterrupted Power Supply (UPS):

Done in Tutorial sheet 2, Ques 5

(5) Superconducting Magnetic Energy Storage Device (SMESD):

Done in Tutorial sheet 2, Ques 6 ; Part (3).