Faults
Types & Effects
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IDC Training expresses its sincere thanks to all those who freely made available their expertise in preparing this manual.
1.1 The Development of Simple Distribution Systems

When a consumer requests electrical power from a supply authority, ideally all that is required is a cable and a transformer, shown physically as follows:

![Figure 1.1: A Simple Distribution System.](image)

This is called a RADIAl system and can be shown schematically in the following manner:

![Figure 1.2: A Radial Distribution System.](image)

**Advantages:**
If a fault occurs at T2 then only the protection on one leg is called into operation. The other consumers are not affected.

**Disadvantages:**
If the conductor to T2 fails, then supply to this particular consumer is lost completely.
This disadvantage can be overcome by introducing parallel feeders; however, this uses more copper and is not always the most economic:

![Figure 1.3](image)

*A Parallel Distribution System.*

The RING MAIN system, which is the most favoured, then came into being:

![Figure 1.4](image)

*A Ring Main Distribution System.*
Advantages:
Essentially meets the requirements of two alternative feeds to give 100% continuity of supply, whilst saving in copper.

Disadvantages:
For faults at T1 fault current is fed into fault via two paths in parallel, hence the fault current is much higher.

Protection must therefore be fast and discriminate correctly so that other consumers are not inconvenienced.

We have covered the case of a feeder failing as cables tend to be the most vulnerable component in the network. Not only are they likely to be hit by a pick or alternatively dug-up or crushed by heavy machinery, but cable joints are notoriously weak, being susceptible to moisture ingress etc, amongst other things.

Transformer faults are not so frequent, however they do occur as windings are often strained when carrying through-fault current. Also, their insulation life-span is very often reduced due to temporary or extended overloading, leading to eventual failure.

As it takes a few months to manufacture a Power Transformer, it is normal practice to install two units at a substation to provide continuity of supply.

Busbars on the other hand, are considered to be the most vital component on a distribution system. They form an electrical “node” where many circuits come together, feeding in and sending out power.

On H.V. systems where mainly outdoor switchgear is used, it is relatively easy and economic to install duplicate busbar, but on medium voltage (11kV and 6.6kV) and low voltage (3.3kV, 1000V and 500V) systems where indoor metalclad switchgear is extensively used, it is not practical or economical to provide second switchboards. Even duplicate - busbar switchgear is not immune to the ravages of a busbar fault.

The loss of a busbar in a network can in fact be a catastrophic situation, and it is recommended that this component be given careful consideration from a protection viewpoint when designing networks, particularly for continuous process plants such as mineral processing.

1.2 Faults - Types and their Effects

It is not practical to design and build electrical equipment or networks so as to completely eliminate the possibility of failure in service. It is therefore an everyday fact of life that different types of faults occur on electrical systems, however infrequently, and at random locations.

Faults can be broadly classified into two main areas which have been designated “Active” and “Passive”.
1.2.1 Active Faults

The “Active” fault is when actual current flows from one phase conductor to another (phase-to-phase) or alternatively from one phase conductor to earth (phase-to-earth). This type of fault can also be further classified into two areas, namely the “solid” fault and the “incipient” fault.

The solid fault occurs as a result of an immediate complete breakdown of insulation as would happen if, say, a pick struck an underground cable, bridging conductors etc. or the cable was dug up by a bulldozer. In mining, a rockfall could crush a cable as would a shuttle car. In these circumstances the fault current would be very high, resulting in an electrical explosion.

This type of fault must be cleared as quickly as possible, otherwise there will be:

- Greatly increased damage at the fault location. (Fault energy = $I^2 \times R \times t$ where $t$ is time).
- Danger to operating personnel (Flash products).
- Danger of igniting combustible gas such as methane in hazardous areas giving rise to a disaster of horrendous proportions.
- Increased probability of earth faults spreading to other phases.
- Higher mechanical and thermal stressing of all items of plant carrying the current fault. (Particularly transformers whose windings suffer progressive and cumulative deterioration because of the enormous electromechanical forces caused by multi-phase faults proportional to the current squared).
- Sustained voltage dips resulting in motor (and generator) instability leading to extensive shut-down at the plant concerned and possibly other nearby plants.

The “incipient” fault, on the other hand, is a fault that starts from very small beginnings, from say some partial discharge (excessive electronic activity often referred to as Corona) in a void in the insulation, increasing and developing over an extended period, until such time as it burns away adjacent insulation, eventually running away and developing into a “solid” fault.

Other causes can typically be a high-resistance joint or contact, alternatively pollution of insulators causing tracking across their surface. Once tracking occurs, any surrounding air will ionise which then behaves like a solid conductor consequently creating a “solid” fault.

1.2.2 Passive Faults

Passive faults are not real faults in the true sense of the word but are rather conditions that are stressing the system beyond its design capacity, so that ultimately active faults will occur.

Typical examples are:
- Overloading - leading to overheating of insulation (deteriorating quality, reduced life and ultimate failure).
- Overvoltage - stressing the insulation beyond its limits.
- Under frequency - causing plant to behave incorrectly.
- Power swings - generators going out-of-step or synchronism with each other.

It is therefore very necessary to also protect against these conditions.

1.2.3 **Types of Faults on a Three Phase System**

The types of faults that can occur on a three phase A.C. system are as follows:

![Figure 1.5](types_of_faults.png)

Types of Faults on a Three Phase System.

(A) Phase-to-earth fault
(B) Phase-to-phase fault
(C) Phase-to-phase-to-earth fault
(D) Three phase fault
(E) Three phase-to-earth fault
(F) Phase-to-pilot fault *
(G) Pilot-to-earth fault *

* In underground mining applications only

It will be noted that for a phase-to-phase fault, the currents will be high, because the fault current is only limited by the inherent (natural) series impedance of the power system up to the point of faulty (refer Ohms law).

By design, this inherent series impedance in a power system is purposely chosen to be as low as possible in order to get maximum power transfer to the consumer and limit unnecessary losses in the network itself in the interests of efficiency.
On the other hand, the magnitude of earth faults currents will be determined by the manner in which the system neutral is earthed. Solid neutral earthing means high earth fault currents as this is only limited by the inherent earth fault (zero sequence) impedance of the system.

It is worth noting at this juncture that it is possible to control the level of earth fault current that can flow by the judicious choice of earthing arrangements for the neutral. In other words, by the use of Resistance or Impedance in the neutral of the system, earth fault currents can be engineered to be at whatever level is desired and are therefore controllable. This cannot be achieved for phase faults.

1.2.4 Transient & Permanent Faults

Transient faults are faults which do not damage the insulation permanently and allow the circuit to be safely re-energised after a short period of time.

A typical example would be an insulator flashover following a lightning strike, which would be successfully cleared on opening of the circuit breaker, which could then be automatically reclosed.

Transient faults occur mainly on outdoor equipment where air is the main insulating medium.

Permanent faults, as the name implies, are the result of permanent damage to the insulation. In this case, the equipment has to be repaired and reclosing must not be entertained.

1.2.5 Symmetrical & Asymmetrical Faults

A symmetrical fault is a balanced fault with the sinusoidal waves being equal about their axes, and represents a steady state condition.

An asymmetrical fault displays a d.c. offset, transient in nature and decaying to the steady state of the symmetrical fault after a period of time:
Figure 1.6
An Asymmetrical Fault.

The amount of offset depends on the X/R (power factor) of the power system and the first peak can be as high as 2.55 times the steady state level.
Figure 1.7
Total Asymmetry Factor Chart.