Low Voltage Distribution System
Selection Of Circuit Breakers

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Introduction

Reliability of power supply in any network depends on various factors such as :

- A reliable power source
- A strong distribution network with fully coordinated distribution system
- A well maintained and disciplined load management system
- Proper selection of ratings of all devices,viz., transformer, switchgear and loads

Selection of appropriate switchgear ensuring suitable discrimination upstream and downstream plays a very important role in ensuring good performance of the distribution system.

Guidelines for selection of switchgear, especially the circuit breakers, may appear very simple as parameters like rated service voltage, rated current, and frequency are obvious factors considered during selection. However, the short-circuit performance specifications are sometimes ignored/ missed. The price of a circuit breaker of a given thermal rating will vary widely depending on the short-circuit capabilities. In order to keep the project cost under control, there could be a temptation to compromise on the breaking capacity/short time rating requirements of the circuit breakers, without realising its impact on the system reliability and operational efficiency and convenience.

Distribution System

Let us look at a typical distribution system, shown in Fig.1, fed from a grid having a fault level of say, 50 kA.

The incoming circuit breaker A feeds the bus section of Panel 1. One of the outgoing feeders controlled by breaker B feeds Panel 2. The load L1 fed from this panel is controlled by breaker C. There are other outgoing feeders for both the panels 1 and 2. Based on the discrimination scheme envisaged by the consultant or customer, the system may provide complete discrimination or partial discrimination or no discrimination at all.

The term "**Discrimination**" implies '***co-ordination of the operating characteristics of two or more over-current protective devices so that on the incidence of an over-current within stated limits, the device intended to operate will do so while the other(s) does (do) not***

In any good distribution system, it is normally desired that :

- the fault should be cleared immediately on its occurrence by a device closest to the location of fault
- only the faulty section is isolated
- healthy feeders are not unnecessarily isolated due to a fault elsewhere
- the system is stressed least and the extent of outage/power interruption is kept to a minimum.

Fully Rated System With Discrimination

In a fully co-ordinated system, the circuit breaker nearest to the fault is

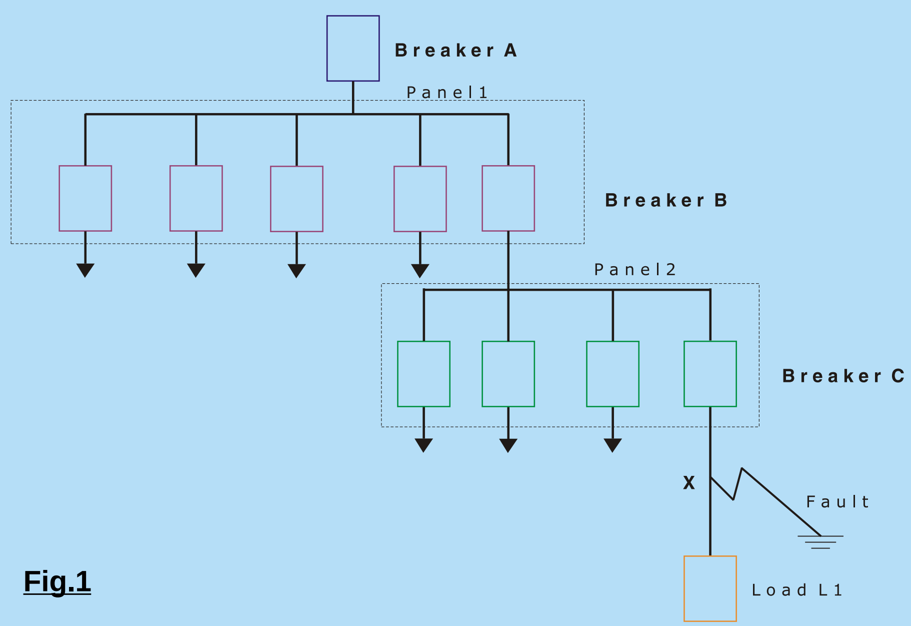

Fig.1

designed to sense and clear the fault. Other feeders connected to the system continue to remain energised. In Fig.1 for a fault at X, the breaker C is expected to operate for clearing the fault. In case this breaker fails to operate for any reason, the upstream breaker B will operate after a pre-determined time delay. Breaker A that is upstream of breaker B will operate after a further pre-set time delay only if both the breakers B and C fail to operate. This scheme will provide total discrimination. Discrimination is achieved by matching the time-current characteristics of the protective devices.

In this system, all the circuit breakers should have breaking capacity equal to or more than the prospective system fault level. The entire bus system should also be designed to withstand the short-circuit stresses till the upstream breaker A clears the fault after its preset time delay as decided by the requirements of co-ordination and discrimination.

Cascade system

Though the good engineering practice calls for all breakers used in a network to have breaking capacities equal to or more than the prospective system fault level, some customers may use breakers of lower breaking capacities for certain special applications. This practice existed in certain countries, especially in the North America till the recent past (may be due to technology limitations at that time), but today it is not preferred by most consultants and customers. Modern handbooks on Electrical Engineering do not recommend this practice for new installations. **The National Electrical Code (of USA), i.e., NEC 1999** as well as **IEC on Electrical standard Installations of Building-IEC 60364** lay down special requirements for such applications. Relevant details are extracted and reproduced below:

(i) Reference:- NEC 1999 National Electrical Code-Chapter 2
<u>*Cl.240.86*</u> *Series ratings - Where a circuit breaker is used on a circuit having an available fault current higher than its marked interrupting rating by being connected to the load side of an acceptable over current protective device having the higher rating, the following shall apply:*

(a) Marking - The additional series combination interrupting rating hall be marked on the end-use equipment, such as switchboards and panel boards

(b) Motor Contribution - Series ratings shall not be used where

(1) Motors are connected on theload side of the higher rated over-current device and on the line side of the lower rated over-current device, and,

(2) The sum of the motor full load currents exceed 1% of the interrupting rating of the lower-rated circuit breaker. (This clause, i.e., Cl. 240.86 was added in the NEC as an amendment in 1999)

(ii) Reference:-IEC 364 Part 4 Chapter 43. Electrical Installations of Building
<u>*Cl. 434.3.1*</u> *The breaking capacity (of the switching device) shall not be less than the prospective short-circuit current at the place of its installation, except where the following paragraph applies.*
A lower breaking capacity is admitted if another protective device having the necessary breaking capacity is installed in the supply side. In that case, the characteristics of the devices must be coordinated so that the energy let through by these two devices does not exceed that which can be withstood without damage by the device on the load side and the conductors protected by these devices.

(iii) Reference:- Switchgear and Control Handbook edited by Robert. W. Smeaton and published by McGraw-Hill Book Company
.....The cascade system, once considered acceptable is no longer recommended by the standards.......... (Text authored by MAX. E. EVERETT, Senior Engineer Allis-Chalmers Corporation)
...... Note that small moulded-case circuit breakers or fuses and circuit breakers should not be cascaded to achieve adequate short-circuit interrupting ability unless the combination is specifically approved for that purpose. Small moulded-case breakers tend to open more quickly than larger frame sizes of moulded-case breakers and therefore attempt to perform the job of interrupting fault currents prior to the operation of the larger breakers with which they might be cascaded. .... (Text authored by W. B. PERKINS & D. E. MAXWELL, Distribution Equipment Division, Square D. Company)

A careful analysis of these recommendations will highlight the points listed below regarding the cascading of devices:

- In a cascaded system, the customer is compromising on discrimination requirements for a cost. For a fault downstream of the breaker with the lower breaking capacity, the upstream breaker will trip along with the down-stream breaker cutting off power supply to other healthy feeders as well. This will reduce the useful life of the upstream device.

- The specific combination of the upstream and downstream breakers should be tested for the required fault level before selection. NEC recommendation implies that thecombination may not have abreaking capacity equal to that of the upstream or downstream device.

- If more inductive (motor) loads areadded to the system on a future date, a combination, consideredadequate till then, may suddenly turn out to be non-acceptable as per the NEC Code due to the increased motor contribution considerations.

- While faults upstream and also downstream of the cascaded system are taken care of, the protection for an internal fault at a location between the two devices is not verified and guaranteed.

- Any system upgradation or replacement of any of the protective devices, on a future date, can cause havoc unless extreme care is exercised. E.g. replacing one 100A MCCB by another 100A MCCB as part of maintenance can lead to a safety hazard unless the replaced breaker is *identical* to the old breaker in *all respects*.

Referring to Fig.1, if the breaker C does not have the breaking capacity equal to the system fault level, for a fault at X, breakers B and C may have to operate in cascade to clear the fault. This will result in an undesired power outage for the other healthy feeders connected to Panel 2 as the system is not, in this case, designed for discrimination between breakers B and C.

There are some similarities between SCPD of contactors/ motor-starters and the cascade system of circuit breakers in a distribution feeder. It is well-known that the contactors/motor-starters have making and breaking capacities of only 6-8 times the operational current rating which may be far lower than the system fault level. In these cases a SCPD is selected so that in case a current above the breaking capacity of the starter is to be broken, it will be the SCPD and not the starter that will operate. This is ensured by proper co-ordination of the upstream SCPD and the downstream starter. The feeder to be isolated in this case is only a single motor feeder unlike in a distribution network where multiple loads fed by the upstream feeder will also get isolated causing large and undesired power outages.

In a cascade system, both the upstream and downstream devices are expected to operate simultaneously so that the fault energy is shared by the breaking devices. Unless the combination is tested for the required fault level, the performance of the combination cannot be guaranteed in the field. After a major fault is cleared both the devices of the combination need to be thoroughly examined and replaced if necessary to ensure safe operation during any future fault in the system.

Comparison between distribution systems

A balance sheet analysis of the pros and cons of **fully rated system with discrimination** versus **cascade system** will look as given in the chart.

Conclusion

It is up to the consultant who in consultation with the end user should make the choice of systems and devices after assessing the real cost of the cheaper-looking option and its impact on the long-term service performance, operational convenience and efficiency of his installation. In most cases, the final decision will be obvious.

Fully rated system with discrimination	Cascade system
Total discrimination possible	Only partial discrimination can be expected
Only the device closest to fault needs to operate	Larger outage in case of fault
As only one device needs to operate for a given fault, life of upstream devices not affected	In case of any fault tripping, all devices have to be thoroughly inspected and serviced before re-commissioning.
Minimum disruption in case of any fault	Short-circuit rating of the combination has to be assessed by testing prior to use
All devices are fully rated and hence no safety hazard in service	Will appear economical (on initial cost considerations only), but will work out more expensive if total cost of outages and the cost of lost opportunity are properly computed.
Could be marginally more expensive, though extra service reliability/less outage will be more than off-set the extra cost	Future system upgradation/equipment replacement needs **extreme** caution
High reliability	Less reliable