

Impedance relays in sub-transmission and distribution networks

Increasing demand for better supply quality and structural changes makes it necessary to revise the traditional use of protective overcurrent relays or differential relays in modern distribution networks. Affordable and uncomplicated impedance relays offers reduced trip delays, better selectivity, reduced communication requirements and improved protection during 11-66 kV network faults.



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Acquisitions and restructuring of power utilities as well as the demands for higher profits have increased the need for low cost operation while still maintaining high reliability and safety. Structural changes in modern sub-transmission and distribution networks are also causing a need to re-evaluate the principles for protective systems.

Extended Radial Networks

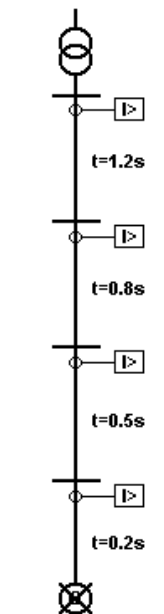
It is common to improve the use of distribution networks by extending existing lines, and by subdividing them by inserting more Ring Main Units (RMU's) or substations in the extended circuit. In this way the supply area is extended at a low cost and with acceptable selectivity. More selectivity steps however results in longer

trip delays at the feeding points and a higher risk of injuries to people or damages to equipment. In radial systems with definite-time overcurrent relays (O/C) the trip delay usually increases 0.3s per step (fig. 1a). Similar increases in trip delays are experienced in inverse O/C systems.

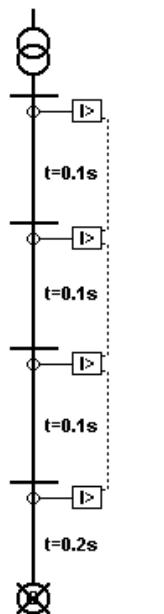
If the starting signal from O/C relays at one level is used to block undelayed trip from the O/C relay at the above level (fig. 1b), then the trip delays may be reduced. This requires signalling between the RMU's or substations, and the solution is useless if there is local generation at distribution level.

A differential relay trips undelayed (fig. 1c), but usually doesn't protect the busbars. So the trip delay at the feeding point will still be too long (O/C main/backup function). Another problem with differential relays is the need for continuous and high quality signalling between the stations

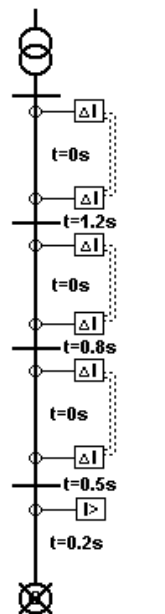
Impedance relays usually protect 80% of a line at high speed. The remaining 20% of the line are usually tripped within 0.3s (fig. 1d). With simple communication (trip logic) between stations the impedance relays may even operate without delay at any point of the line



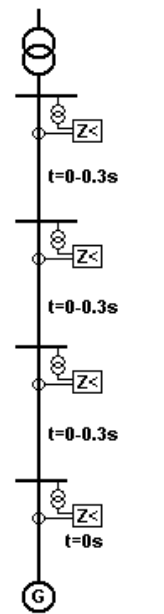
Long trip delays with O/C relays
Fig. 1a



Short trip delays with blocking communication
Fig. 1b



Long bus trip delays with differential relays
Fig. 1c



Short trip delays with impedance relays
Fig. 1d

More Distributed Generation

Untraditional energy sources like wind, waves, tidal power and other sorts of local generation like diesel generation plants are now challenging the structure of sub-transmission and distribution networks. When small distributed generation units are installed, then O/C relays are no longer sufficient.

When distributed generation results in low infeed compared to the capacity of the feeding system transformer, then special problems arise. The transformer O/C relay must allow all load currents, but it will fail to trip by short circuit (SC) on the HV-side of the transformer (fig. 2a) if the SC-current is lower than the load current. In that case the only possible protections are some generator relays like frequency or overload, and that is not really acceptable.

Differential relays could be used instead of the distribution O/C relays, but differential relays are demanding in many ways, and they rarely offer good backup protection.

Impedance relays offers a good combination of selectivity, sensitivity and backup functions.

If an impedance relay is placed on the transformer LV side (fig. 2b) then a sensitive and selective protection is established. This solution has been successful at higher system levels for decades, but it will give great advantages to distribution networks during weak local infeed operation. The availability of inexpensive and uncomplicated impedance relays has now made this solution possible.

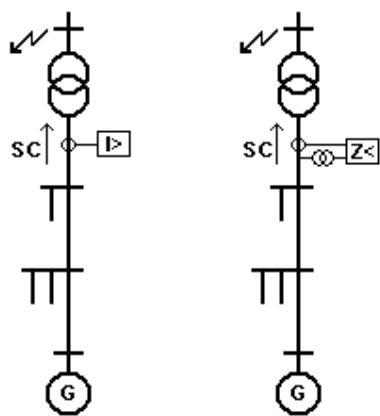


Fig. 2a

Fig. 2b

The SC current is less than I> setting (load). The I> relay cannot trip during faults at the HV side of the transformer

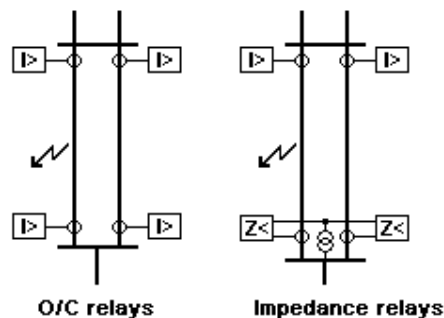
Limited Short Circuit Currents

The short circuit currents during line failure may be low for a number of reasons. Arcing faults, or dry trees across the line are examples of high impedance/low current faults. An O/C protection must operate above the load current and it can usually only trip at SC-currents exceeding 1.2 times the load current. An impedance relay can operate at currents down to 10% of the CT rated current. An impedance relay is therefore over 10 times more sensitive than an O/C relay.

During faults at the far end of long lines the SC-current may be low due to high SC-impedances. The SC-current may easily become less than the load current in the supply point, and then the OC-protection is useless. Here an impedance relay with its high sensitivity and long reach will solve the problem.

Parallel Operation

In large distribution systems parallel connections are common to increase capacity and reliability of supply. To avoid that both the parallel lines are tripped during fault on one of them, special protection systems are needed.



O/C relays

Impedance relays

Fig. 3a

Fig. 3b

Ordinary O/C relays cannot be applied because they are unable to distinguish between fault locations on either of the lines (fig. 3a). During fault on one line both O/C relays will trip, and the supply is completely disconnected.

Directional O/C relays at the line-ends may solve part of the problem, but they still have limited sensibility and offer extremely poor backup in the remaining part of the system. The cost for these relays is almost identical to the cost for corresponding impedance relays.

The main problem using directional overcurrent relays in sub-transmission networks is however strongly related to the natural expansion of such systems. Experience has demonstrated that most sub-transmission and distribution networks will quickly develop from ordinary radial systems into more advanced interconnected networks. The directional O/C principle cannot be applied in multiple infeed systems, or in systems where the network configuration is changing with the daily operation of the interconnected system.

Impedance relays (fig. 3b) offer a far higher sensitivity than directional O/C relays. In addition to protecting the line, an impedance relay may also protect the busbars, and offers sensitive and selective backup protection at far-end faults in the distribution network. The main advantage is however that the impedance relay can be set to operate in a well coordinated way, even if the system configuration changes during the day due to operational needs. Traditionally this solution has not been applied in sub-transmission networks because impedance relays used to be expensive and complicated to operate. This problem has now been solved by uncomplicated and less expensive impedance relays that have been designed especially to be applied in such networks.

Differential relays will trip selectively during faults on the parallel lines, but needs an advanced communication system. Differential relays are not suited as a backup protection for the other system components. Even with an integrated overcurrent backup function they will be less sensitive and less selective during faults on the busbars or the network beyond the cables.

Interconnected networks

In large or growing distribution networks it is common to close the usually open ring systems. In larger towns there often is a need to run sub-transmission systems in an interconnected configuration. The purpose is to reduce losses and to improve the reliability of supply. Such systems cannot be protected by O/C relays of any kind. They will not be selective, and the backup functions are extremely poor. Using O/C protection here will certainly result in widespread disturbances, system breakdowns, or missing backup trip functions.

Good co-ordination, sensitivity and acceptable backup functions can be obtained by using impedance relays. This is also confirmed by the fact that impedance protection is dominating in most interconnected high voltage networks.

With the present availability of inexpensive and uncomplicated impedance relays it is possible to run more distribution networks as interconnected networks, and to accept local generation without further changes to the existing installations of protective relays.

Measuring systems

Directional and selective relays like for instance impedance relays are increasingly likely to be used in distribution systems. To be prepared for future systems, and to make the best out of these relays 3-phase current and 3-phase voltage measurements are needed. When building new substations it is therefore recommended to install 3-phase current measurement in all cells, and at least 3-phase voltage measurement at the station busbars.

New possibilities

In the early days impedance relays were expensive and complicated to set and maintain, and specially trained personnel were needed to set and maintain the relays. Impedance relays were therefore not used in distribution networks. Differential relays were less expensive and easier to apply and that is probably the reason why these relays were widely used in sub-transmission networks.

Directional O/C modules were added to extend the lifetime of the existing OC solutions, without having to install new and usually more complicated impedance relays.

Today impedance relays are inexpensive and easy to use, and the communication requirements are far less than for differential relays. Therefore there are good technical and financial reasons to reconsider impedance relays for distribution networks, and to mainly reject both overcurrent and differential relays as protection in interconnected distribution networks.

The possibilities available by using impedance relays in distribution networks have not been exploited. Many opportunities are present to further improve safety and reliability, and to operate distribution networks in more favourable configurations.

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