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Application of a proposed overcurrent relay in radial distribution networks

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ABSTRACT

This paper contains the application criteria and coordination process for a proposed overcurrent relay in a radial power system with feed from one or multiple sources. This relay uses independent functions to detect faults and to calculate the operation time. Also this relay uses a time element function that allows it to reduce the time relay operation, enhancing the backup protection. Some of the proposed approaches improve the sensitivity of the relay. The selection of the best approach in the proposed relay is defined by the needs of the application. The proposed protection can be considered as an additional function protection to conventional overcurrent relays.

1. Introduction

The overcurrent relay is widely used in many protection applications throughout power systems. These devices provide fast operation at high current and slow operation at low current and, as the fault current is a function of the fault location the coordination with other overcurrent devices is possible. This behavior is characteristic of overcurrent relays, and it has been demonstrated that it is appropriate for the protection of electrical systems in which operation above the nominal values is frequent but temporary. This situation is not as convenient when it occurs in backup protection; due to the nature of the overcurrent relay, operating times are long, forcing the system to tolerate non-permissive currents, resulting in thermal and mechanical stress that could be minimized.

The growing load-ability of the electrical systems require the relay pickup settings to be increased, so that the need for greater sensitivity of the relays during an operational state of low demand is more significant. The short circuit current has a growth limited by the lack of investment in new generation power stations and/or by the reconfiguration of the electrical system in less meshed topologies with the intention of reducing the short circuit levels, avoiding the replacement of switches and other primary equipment. However, the load current is subject to the dynamics of industrial and commercial development, population growth and increase of electrical consumption. These factors require setting the protection to be carried out in low levels of short circuit and with high values of load current, jeopardizing the sensitivity of the relays during conditions of low demand because the increased load levels of the electrical systems have resulted in elevated settings of the pickup current. The appearance of distributed generation (DG) and unconventional sources in low voltage networks may result in a change of the fault response [1,2]. The operation times of the overcurrent relays (primary and backup) can be rendered excessive by the topology diversity of the network.

The applications of overcurrent relays in distribution networks have been reported [3–8]. Various methods are proposed to solve the functional limitations of overcurrent relay. The use of relays based on differential phase to phase currents is proposed. The information containing distorted current signals is used to offset the saturation effect of the CT. An overcurrent directional relay based on ANN is proposed. Symmetrical components are used to improve selectivity. And at last, a methodology based on voltage overlapping signals to improve awareness of protection in radial distribution systems is presented.

There are interesting proposals for the introduction of communication channels for changing the settings of relays close to real time for low voltage networks [9,10]. However, in radial networks with one or two sources, such communication systems or other principles of protection imply an economic cost, amplified by the significant number of radial networks in power systems.

The pickup current of an overcurrent relay serves two different functions, the detection of the fault condition and the determination of time of operation. In the current electrical systems that present unequal increases in load levels and the short circuit ability, the task of discriminating between a condition of overload and a fault is hardly obtained with a single setting. In this paper, we propose to separate the functions of fault detection and to calculate the operation time in specific functions. The adaptive principles reported [11,12] are applied for radial systems with one supply source or more than one supply source (directional relay). The proposed relay does not represent a global solution to the problem of

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overcurrent relay application but nevertheless it offers functional advantages that allow obtaining another functional approach of the protection.

The proposed relay has a functional platform that is coherent with the operational state of the system. The functional structure of the proposed relay is not affected by the load current. Thus the proposed relay improves the protection performance in its locality. The proposed relay does not require communication channels since the process is handled with the information at the relay location. The proposed relay can be implemented in several ways, allowing functional flexibility and response to the particular protection requirements of the electrical system. All applications presented are transparent to the user since only off-line data for the primary device is needed. Finally, the proposed relay is obtained with a minimal change in the relay's firmware and without change of relay hardware.

2. Proposed relay functions

2.1. Sensitivity

The pickup current for the overcurrent relay is calculated from the maximum load current, but this is present for only a few minutes per day; for the remaining time the load current has lower values. Thus, the pickup setting is fixed while the power system is dynamic.

We suggest [11] that the pickup current I_{pickup} for the proposed overcurrent relay will be a function of the load current I_{Load} (Fig. 1), where ΔI represent a safety margin, with a proposed value of 15% of the maximum load current, Δt is the sample period and N must be selected in such a way that the interval $N{\cdot}\Delta t$ lasts between one and several minutes as the integration time used in demand measures. Previously, functions that implied an increase in the computational resource represented a disadvantage; at the present time the relays have the hardware to make the measurement functions, and also to execute the proposed functions.

This pickup function provides increased sensitivity, because the value of I_{pickup} is also small due to minimal demand conditions. During a complete demand interval ($N \times \Delta t$), the I_{pickup} value is fixed in the relay at the end of the previous interval. The action of low-pass filtering that is inherent in the demand concept simplifies the logic of the proposed relay. In situations in which a large load is added to a feeder, the relay has fault confirmation logic [11] to supervise I_{pickup}. This logic discriminates between a large load and a fault.

The proposed pickup current is not advisable for computation of the operation time; because the backup time will be dynamic [11]

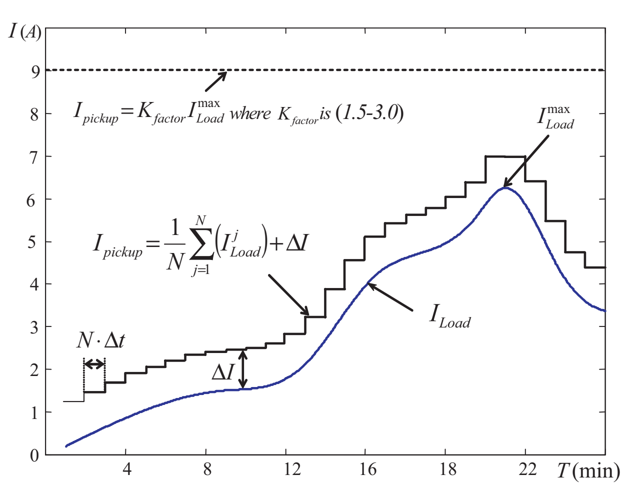

Fig. 1. Pickup current proposed.

and it will be difficult to coordinate it. Accordingly, the time curve relay will be dynamic, moving in horizontal direction to the present value of the operation current. This behavior is not desirable. It is necessary to implement a time function that does not depend on the proposed pickup current.

2.2. Time

The main purpose is to find a time element function T_{backup} that ensures that the backup relay operates with a constant time delay relative to the primary device, for any fault current. In order to obtain this, it is necessary that the operation time of the backup will be determined from the time curve of the primary; then the backup must emulate the operation of the primary and the operating current used by the given relay must correspond to that of the primary. The current used to determine the time of operation of the proposed relay will be the pickup current of the primary relay.

The equation of the proposed relay is obtained. The operating current was calculated using the pickup current of the primary device and the fault current $I^{primary} = I_{shortcircuit}/I_{pickup}^{primary}$:

$$G_k = \Delta t \sum_{k=1} H_{backup} \quad \text{where}: H_{backup} = \frac{1}{T_{primary}(I^{primary}) + CTI} \tag{1}$$

where G_k is the representation of the accumulated value of the integrator or, analogically, the position of the induction disk of an electromechanical relay at any sample k. $T_{primary}(I_k^{primary})$ is the time curve of the primary overcurrent device, CTI is the coordinating time interval and H_{backup} is the non-linear function of the backup relay.

The operation condition is achieved when [13]:

$$G_k = \Delta t \sum_{k=1}^{k_{operation}} H_{backup} = 1 \tag{2}$$

The behavior of this process is the reduction of primary and backup time in the overcurrent relays during poor fault current conditions. For the proposed coordination, it is necessary to obtain the time curve of the primary device. The analytical expression is obtained and included in the dynamic equation of the time overcurrent relay [12]. The time curve of the proposed relay is asymptotic to the pickup current of the primary relay, and this result in a minimum backup time for all fault currents. For the highest fault current (coordination current) the time operation of the proposed relay is similar to a conventional relay. The data necessary for coordination of the proposed relay is the time curve and pickup current of the primary device.

Thus, the pickup current of the proposed relay is not used for the time calculation; it is a fault detector only. This fault detector, because it depends on the magnitude of the load current, is very sensitive to minimum load conditions. Another option is not to use the dynamic pickup current but a fixed value like a conventional relay; this also results in a fault detector.

We wish to point out that the basic principles of the actual relays are similar in the proposed relay, but we suggest a change in the computation of the time curve, and use the pickup current of primary relay instead of the pickup current of the self-relay. Then the proposed relay emulates the dynamics of the primary device to obtain a fast backup time operation; we do not need to know the fault current and do any setting of this time curve, the coordination process is not necessary because the time curve is similar to the primary device protection (fuse, relay or recloser), so this time curve is independent of future system changes (such as topology, generation and load).