Unit Protection of Feeders

An Online Continuing Education Course for Engineers

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Unit Protection of Feeders

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Introduction

Graded overcurrent protection design, though quite simple, does not meet all the protection demands of an electrical power system. Application issues are experienced for two reasons: firstly, acceptable grading cannot be accomplished for a complex electrical system, and secondly, the protection adjustments may lead to maximum operating times that are excessive and cannot stop faults.

With the unit protection concept, parts of the electrical system are separately protected without reference to other parts of the system. One unit protection concept is widely known as 'Differential Protection.' The foundation of this principle is to detect the difference in currents between the incoming and outgoing terminals of the protected element. Other unit protection concepts can be based on the directional comparison, distance tele-protection arrangements or phase comparison unit protection.

The design of the electrical system may lend itself to unit protection concept. For example, a simple ground fault protection relay used at the source end of a transformer-feeder can be treated as unit protection given that the transformer winding associated with the protected feeder is not grounded. In this example, the protection area is limited to the feeder and power transformer winding because the transformer cannot transfer zero sequence current to an out-of-zone fault.

However, in most situations, a unit protection arrangement requires the measurement of short circuit currents (and sometimes voltages) at each protection zone and the data transfer between the elements at zone boundaries. It should be kept in mind that stand-alone distance protection relay, even though nominally reacting only to short circuits within their setting zone, does not meet the conditions for a unit arrangement because the zone is not clearly specified. The zone is specified only within the accuracy boundaries of the measurement. Besides, the setting of a stand-alone distance protection relay may also extend outside of the protected zone to cater to specific conditions.

Fundamental differential arrangements have established the foundation of many sophisticated protection arrangements for feeders and other system elements. In certain protection schemes, an auxiliary 'pilot' circuit interconnects similar current transformers at each end of the protected zone, as presented in Figure 1. Current running through the zone causes secondary current to circulate around the pilot circuit without generating any current in the protection relay. For a short circuit within the protected zone, the CT secondary currents will not balance, in comparison with the through-fault condition. The difference between the currents will flow in the protection relay. An optional scheme is presented in Figure 2. In this arrangement, the CT secondary windings are opposed for through-fault conditions so that no current runs in the series connected relays. The first protection arrangement is known as a 'Circulating Current' system. The second protection arrangement is known as a 'Balanced Voltage' system. The majority of unit protection systems work through the determination of the relative direction of the fault current. Fault current direction can only be presented on a comparative basis, and such a comparative measurement is the typical factor of many protection systems, including directional comparison protection and distance tele-protection protection schemes with directional impedance measurement.

One of the most important factors of unit protection is the communication method between the protection relays.

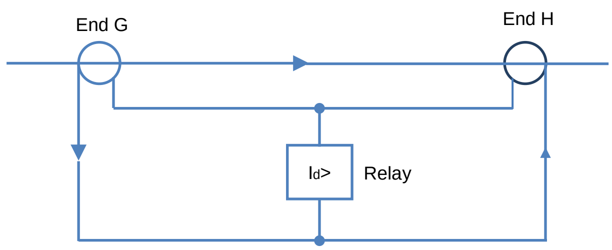

Figure 1: Circulating current unit protection system

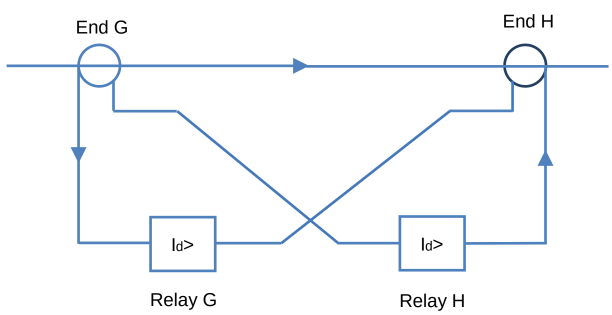

Figure 2: Balanced voltage unit protection system

Direction Convention

It is useful to adopt a direction convention of current flow. In order to accomplish this, the direction measured from a busbar outwards along a feeder is regarded as positive. The notation of current flow is presented in Figure 3. The portion GH transfers a through current which is considered positive at G but negative at H. This feeds to the faulted portion HJ are both positive.

Neglecting this rule typically leads to anomalous equipment arrangements or problems in describing the action of a complex system. When used, the described rule will typically lead to the application of identical equipment at the zone boundaries. This rule is equally appropriate for an extension to multi-ended systems. It also adjusts to network analysis standard methods.

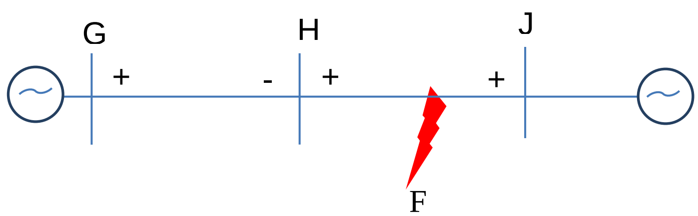

Figure 3: Current direction convention

Conditions for Direction Comparison

The circulating current and balanced voltage protection systems presented in Figure 1 and Figure 2 complete full vectorial comparison of the zone boundary currents. Such protection arrangements can be treated as analogs of the protected zone of the power system. In them, CT secondary quantities represent primary currents and the relay tripping current corresponds to an in-zone short circuit current. These arrangements are simple in concept. However, they are applicable to zones having any number of boundary connections and for any pattern of terminal currents.

Defining a current requires that both magnitude and phase are presented. However it is not always easy to transfer all this information over available pilot channels.

Circulating Current System

The principle of this arrangement is presented in outline in Figure 1. In the case current transformers are ideal, the system operation is straightforward. However, the transformers will have errors developing from both Watt metric and magnetizing current losses. They will cause a deviation from the ideal, and the interconnections between them may have different impedances. This can increase a ‘spill’ current through the protection relay even without an existing fault, therefore limiting the potential sensitivity. An equivalent circuit of the circulating current protection arrangement is presented in Figure 4. If a high impedance protection relay is applied, and unless the protection relay is installed at point J, a current will run through the protection relay even with identical currents I_{Pg} and I_{Ph}. If a low impedance protection relay is applied, voltage FF’ will be insignificant, but the CT exciting currents will be different due to the different burdens and relay current I_R will still be non-zero.

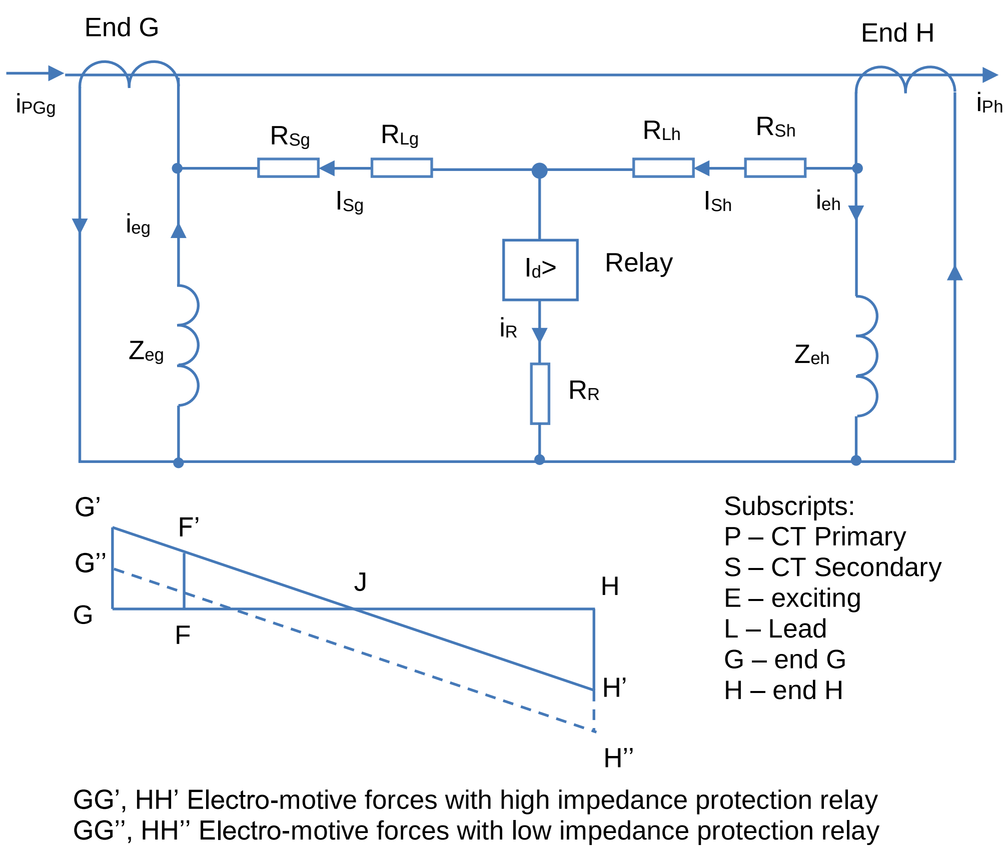

Figure 4: Equivalent circuit and potential diagram for circulating current protection arrangement

Transient Instability

An asymmetrical current applied to a current transformer will generate a flux that is higher than the peak flux corresponding to the current steady state alternating component. It may bring the CT into saturation, decrease dynamic exciting impedance and highly increase the exciting current.

When the unit protection balancing current transformers differ in excitation features or have different burdens, the transient flux build-ups will be different and an increased 'spill' current will occur. There is a subsequent risk of protection relay operation on a healthy line under transient conditions, which cannot be accepted. Potential solution includes installation of a stabilizing resistance in series with the protection relay. The stabilizing resistor calculation procedure is usually included in the instruction manuals of all protection relays. When a stabilizing resistor is installed, the protection relay current setting can be decreased to any practical value. The protection relay is now being a voltage-measuring instrument. Apparently, there is a lower limit, below which the protection relay element does not have the sensitivity to pick up.

Bias

The 'spill' current in the protection relay generated from different sources of error depends on the magnitude of the through current. It is negligible at through-fault current low values but occasionally reaches a disproportionately large value for serious faults. Defining the protection operating threshold above the maximum level of spill current creates poor sensitivity. By making the differential setting roughly proportional to the short circuit current, the low-level fault sensitivity is highly improved. Figure 5 presents a common bias characteristic for a modern protection relay that solves the problem. At low currents, the bias is insignificant, thus allowing the protection relay to be sensitive. At higher fault currents that are experienced during inrush or through fault conditions, the used bias is higher. Therefore, the spill current needed to start operation is higher. It can be concluded that the protection relay is more tolerant of spill current at higher short circuit currents and therefore less likely to maloperate. It is still sensitive at lower short circuit current levels.

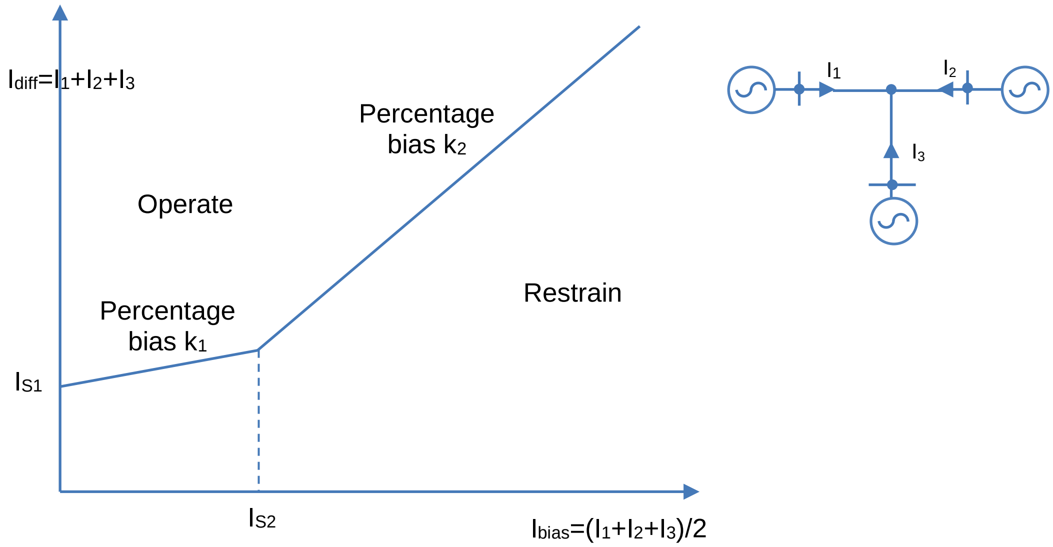

Figure 5: Common bias protection relay characteristic

Balanced Voltage System

This paragraph is presented for historical reasons since the number of such protection arrangements is still found in service. Circulating current schemes are almost exclusively used for new installations.

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device is known as transact ... equivalent circuit is presented in Figure 6.