# Distance Protection for Electrical Systems

An Online Continuing Education Course for Engineers

**Course Number: E-3061**

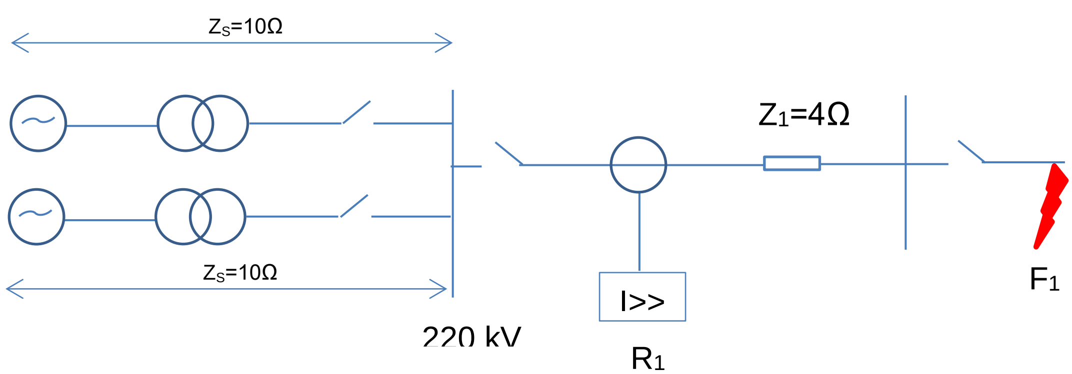
**Credit: 3 Hours / 3 PDH / 3 CPD**

# Distance Protection for Electrical Systems

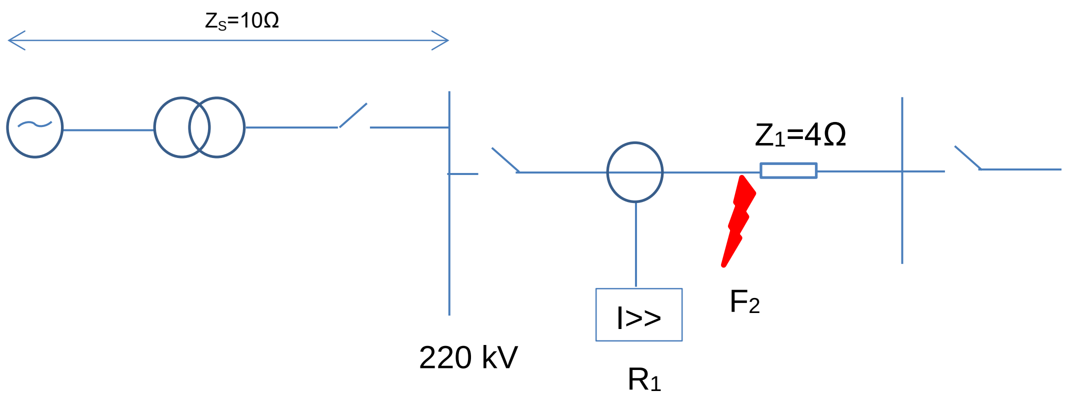
Velimir Lackovic, Electrical Engineer

**DISTANCE PROTECTION FOR ELECTRICAL SYSTEMS**

Combination of fast fault clearance with selective operation of protection element is the main objective for the protection of electrical power systems. To reach these demands, high-speed protection arrangements for electrical transmission and distribution networks that are appropriate for use with the automatic reclosure of circuit breakers are under constant research. Distance protection, is a non-unit protection arrangement providing significant financial and technical benefits. Unlike phase and neutral overcurrent protection arrangements, the key benefit of distance protection is that its short circuit current coverage of the protected element is almost autonomous of source impedance changes. This principle is shown in Figure 1. It can be noted that overcurrent protection cannot be used satisfactorily here. Distance or unit protection is preferred.




$$I_{F1} = \frac{220\times10^3}{\sqrt{3}\times(5+4)} = 14113\ A$$ - Relay $R_1$ setting > 14113 A




$$I_{F2} = \frac{220\times10^3}{\sqrt{3}\times10} = 12702\ A$$ - Relay $R_1$ setting > 12702 A

***Figure 1. Benefits of distance over overcurrent protection (Relay current setting <12702 A and >14113 A).***

Distance protection is relatively simple to use and it can be quick in service for short circuits happening along most of protected elements. It can also provide primary and remote back-up functions in a single operating arrangement. It can simply be adjusted to make a unit protection arrangement when used with a communication link. In this arrangement, it is eminently applicable for usage with high-speed auto-reclosing, for the protection of major transmission circuits.

**DISTANCE RELAY FOUNDATIONS**

Since the impedance of a transmission circuit is relative to its length, for distance measure it is suitable to use a relay able to measure the impedance of a circuit up to a present point (the reach point). Such a protection relay is known as a distance protection relay and is made to function only for faults happening between the protection relay location and the chosen reach point, therefore providing discrimination for short circuits that may happen in different line portions.

The fundamental rule of distance protection includes the division of the voltage at the relaying point by the measured current. The calculated impedance is equated with the reach point impedance. In the case the measured impedance is lower than the reach point impedance, it is presumed that a fault is on the circuits between the relay and the reach point. The reach point of a protection relay is the point along the transmission line impedance locus that is crossed by the boundary feature of the protection relay. Since this depends on the ratio of voltage and current and the phase angle between them, it may be shown on an R/X graph. The loci of electrical power system impedances as detected by the protection relay during faults, power swings and load changes may be shown on the same graph. The service of the protection relay in the presence of electrical system faults and disturbances may be examined, using this method.

**RELAY OPERATION**

Distance protection relay operation is expressed in terms of reach exactness and operating time. Reach exactness is a comparison of the real ohmic reach of the protection relay under real circumstances with the protection relay setting value in ohms. Reach exactness is especially dependant on the level of voltage shown to the protection relay under fault period. The impedance measuring methodologies used in special relay arrangement also have an influence. Functioning times can change with short circuit current, with short circuit position relative to the protection relay setting, and with the point on the voltage wave at which the short circuit happens. Depending on the measuring processes used in a specific relay arrangement, measuring signal transient errors, such as those made by capacitor voltage transformers or saturating CTs, can adversely slow relay function for short circuit currents close to the reach point. It is typical for electromechanical and static distance protection relays to claim both maximum and minimum functioning times. Nevertheless, for modern digital or numerical distance protection relays, the change between these is negligible over a wide range of electrical system operating states and fault locations.

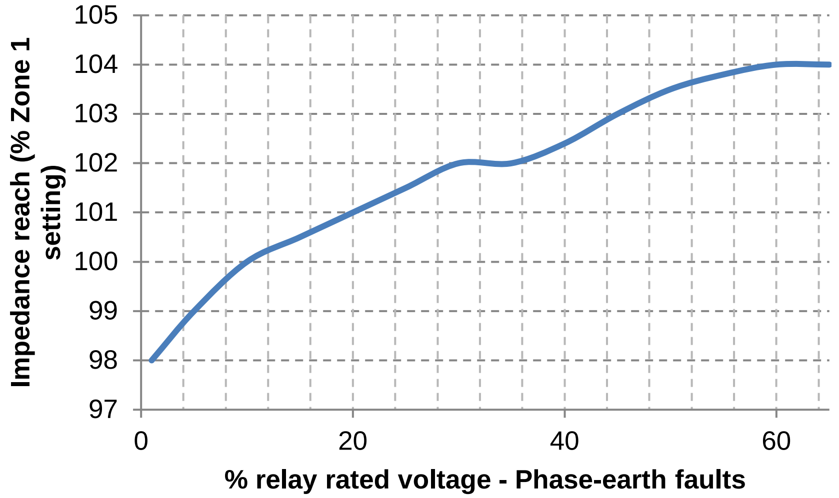
**ELECTROMECHANICAL/STATIC DISTANCE PROTECTION RELAYS**

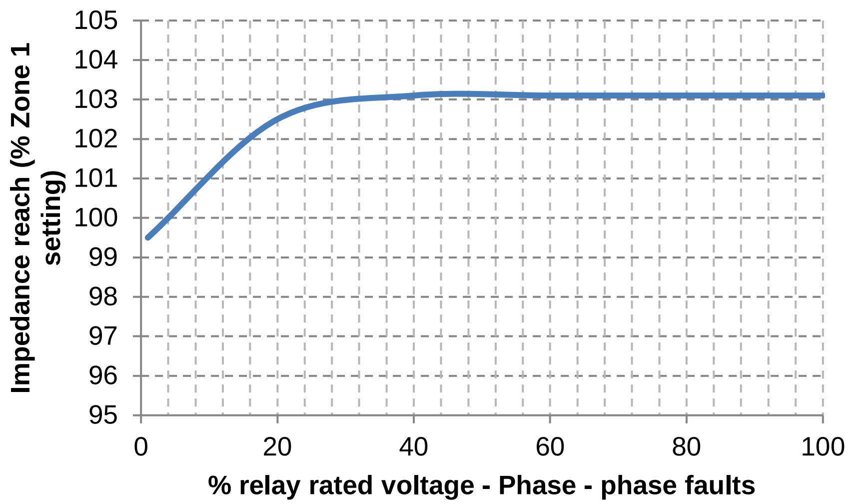
With electromechanical and static protection relay arrangements, the magnitude of input quantities especially determined both reach exactness and functioning time. It was accustomed to show data on relay operation by voltage/reach curves, as presented in Figure 2, and servicing time/fault location curves for different values of electrical system impedance ratios (S.I.R.s) as presented in Figure 3, where:

$$S.I.R = \frac{Z_S}{Z_L}$$

And

$Z_S$ – electrical system source impedance behind the relay points
$Z_L$ – electrical line impedance equivalent to protection relay reach setting


105
104
103
102
101
100
99
98
97
Impedance reach (% Zone 1 setting)
0
20
40
60
% relay rated voltage - Phase-earth faults


105
104
103
102
101
100
99
98
97
96
95
Impedance reach (% Zone 1 setting)
0
20
40
60
80
100
% relay rated voltage - Phase - phase faults

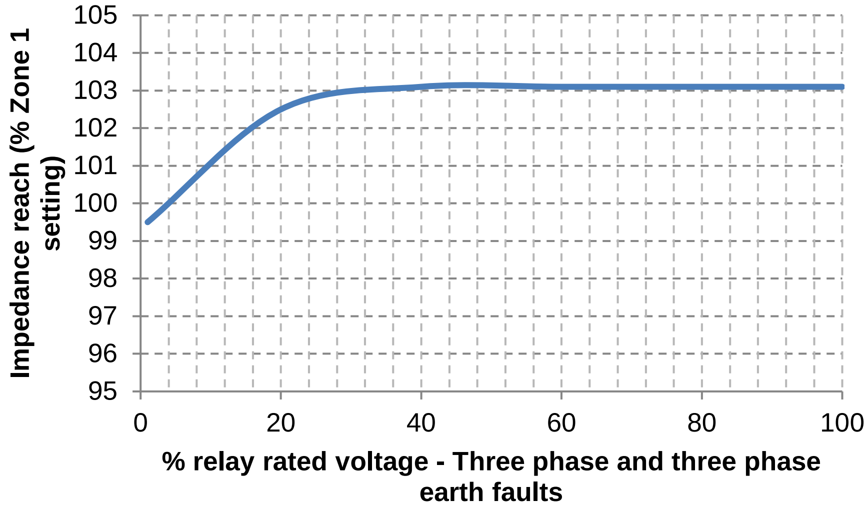
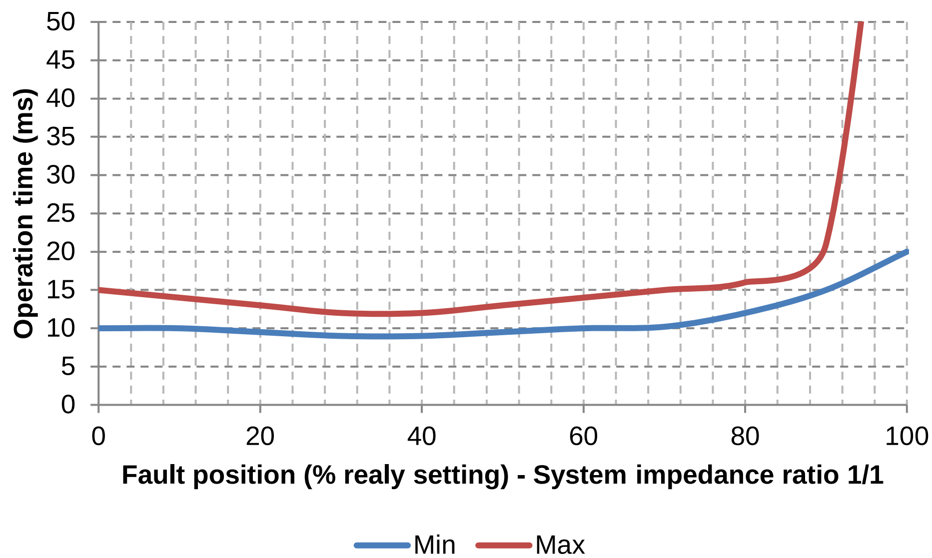



*Figure 2. Common impedance reach exactness characteristics for Zone 1*



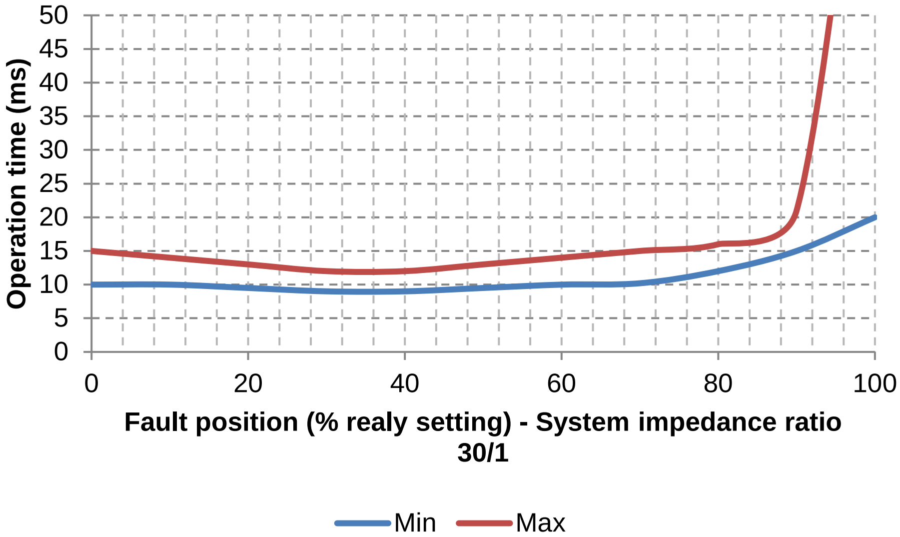



*Figure 3. Common functioning time characteristics for Zone 1 line-line faults*

Instead the above data was mixed in a family of contour curves, where the short circuit current location given as a percentage of the protection relay setting is presented against the source to line impedance ratio, as shown in Figure 4.