ADAPTIVE DISTANCE PROTECTION RELAYS: AN OVERVIEW

Ahmad Farid Bin Abidin, Majid Al-Dabbagh, Azah Mohamed
Department of Electrical, Electronic and Systems Engineering
Universiti Kebangsaan Malaysia

ABSTRACT

This paper presents an overview of adaptive techniques used for distance protection in power systems. The concept of distance protection is elaborated to bring a clear picture of the relay operation principles. The problems faced by conventional distance relays are summarized in order to reveal their limitations under certain conditions. Finally, recent studies related to the application of adaptive techniques are elaborated with critical analysis to provide recommendations for further improvement in the relay technology.

Keyword: Distance Protection, Adaptive Techniques, Relays

INTRODUCTION

Distance protection relays are widely used as the main protection for transmission lines in power systems. These relays operate based on the measured impedance seen by the relays known as the apparent impedance trajectory. The voltage and current signals are used as the parameters to calculate the corresponding apparent impedance trajectory. The setting of distance relays operating zones is obtained from line impedance. Basically, the relay will initiate a trip signal to the associated circuit breaker when a fault occurs within its operating zone. During the fault, the apparent impedance trajectory falls inside the operating zone, and as a consequence, the trip signal will be activated by the relay.

Amongst the problems facing distance relays operation are the inaccurate settings of the operating zones, their mal-operation and transient signals during fault. Extensive studies have been carried out by researchers and manufacturers to improve the reliability of distance relays operating scheme for a more accurate and selective operation. The adaptive technique is one of the popular techniques used to improve the reliability of relay operation. This paper presents the development of the different adaptive techniques used in distance protection relays.
DISTANCE RELAY CHARACTERISTICS

The distance relay operates in three different operating zones, namely, Zone 1, Zone 2 and Zone 3, which is referred to as multi-zone distance protection. Zone 1 provides instant tripping for faults along a transmission line and used as primary protection. This zone covers about 80%-90% of the protected lines. The relay will send trip signals instantaneously if a fault occurs within Zone 1 coverage. Zone 2 distance relay provides protection coverage to the remaining part of a transmission line not covered by Zone 1 reach and extends into the neighboring transmission line. In order to ensure selectivity of relay operation, the operation of Zone 2 operating time will be delayed by a certain time referred to as zone 2 operating time. Often, Zone 2 operating region is designed to cover 100% of the protected line plus 10-20% of the adjacent line. Zone 3 operating zone is the longest zone available for the distance relays mechanism and theoretically can extend to the remaining part of a transmission line in the forward reach plus 2-7% of reverse reach. Zone 3 operating zone in the forward reach covers 100% of a line and the remaining part of the adjacent line which is not covered by Zone 2 coverage. The time delay for Zone 3 operating scheme is made greater than Zone 2 operating time by additional time delay. Zone 3 is used as a back up protection when faults are not cleared by the primary protection of each transmission line within the reach of the relay. Figure 1 shows the reach of distance relay zones with different time settings.

![Diagram of distance relay zones](image)

FIGURE 1 Transmission line time setting at Zone1, Zone 2 & Zone 3

The relay operating characteristics are commonly drawn in polar coordinates which form a circular shape in R-X complex plane. The R axis corresponds to the real part of an impedance Z, while the X axis corresponds to the imaginary part of impedance Z. The apparent impedance as seen by a distance relay, Z_a, is calculated from the following equation:
\[ Z_a = \frac{|V|^2 (P + jQ)}{P^2 + Q^2} \]

where,
- \( V \) is the line voltage
- \( P \) is the active power flow in a line
- \( Q \) is the reactive power flow in a line

During normal conditions, the measured apparent impedance is outside the relay operating zone. Once a fault occurs at one of the points covered by relay operating zone (point X in Figure 1), the apparent impedance enters the relay operating zone. In this situation, the relay will send a trip signal to a breaker to trip a transmission line. Figure 2 illustrates the polar characteristics of a three-zone Mho type distance relay.

![Figure 2 Mho type distance relay during fault](image)

OVERVIEW OF ADAPTIVE DISTANCE PROTECTION RELAYING

Adaptive protection principle can be defined as a protection philosophy which permits and seeks to make adjustments to various protections operating coverage in order to make them more attuned to prevailing power system conditions (Horowitz et al 1988). During the last decade, adaptive protection concept has been an attractive possibility due to the advancement of computers and communication systems. The development of computer relaying allows more advanced protection techniques, such as adaptive relaying, advanced signal processing and artificial intelligent to be applied to improve relay performance. The characteristics and adaptation of relay operation is discussed in this paper.

Li et al (1999) proposed the use of a new Bowl shape impedance relay to overcome the disadvantage of conventional shape distance relay such as small coverage of fault resistance. The new Bowl shape impedance relay theoretically
changes the shape based on the load state and transmission line parameters. This relay combines the characteristics of the Mho relay and the reactance relay. However, the detail implementation of the adaptive technique is not explicitly discussed in this paper.

A new adaptive data window for distance relay operation has been introduced by Tarlochan et al. (2002) to cater the problem of slow response of conventional microprocessor based distance relay. The fixed data window during monitoring process is one of the factors leading to the relay slow response and therefore a new windowing technique is developed so that the relay can perform faster. The proposed technique by Tarlochan et al. (2002) utilized a window of different lengths for voltage and current phasors, to measure the impedance trajectory. The data windows adaptively change from a few data sample to one cycle. The proposed technique reduces the transient response time delay and provides converge estimates of the impedances. Further improvement needs to be investigated since the voltage and current phasors are not sufficient to trigger the relay during power swings and high impedance faults.

A novel adaptive scheme for distance protection operation has been introduced by Jonsson (2003) to block false trip signals during voltage instability. The developed scheme is based on the rate of change of voltage as an additional criterion along with impedance trajectory and zone of operation. The adaptive scheme needs the support from communication devices to avoid undesired operation due to load shedding event and fault clearance issues.

Transient stability and voltage stability may violate the reliability of zone 3 distance protection and therefore Kim et. al. (2005) proposed the concept of a new state diagram using the steady state component and transient component of voltage signals as the criteria to improve the security of Zone 3 relay. This approach prevail the shortcoming of the conventional relay by clearly distinguishing different events such as three-phase fault, load encroachment and voltage instability.

The installation of Static Synchronous Series Compensator (SSSC) in power systems has significantly violated the distance relay setting. The control parameters of SSSC such as output phase angle and voltage modulation index affect the measurement of apparent impedance seen by a relay. Since these parameters are dynamically changed in accordance with system conditions, the measured apparent impedances would also change accordingly. This situation may lead to under reach and overreach situation by the corresponding distance relay. Hence, an adaptive technique is required to overcome such undesired effect. Rastegar (2006) studied this issue and proposed the use of neural network based relay as a tool to modify the relay setting according to the SSSC control parameters.

An indicator based on the derivative of voltage has been used to differentiate between a fault and other events (Jonsson, 2003). However, this indicator may fail to activate a relay when a power system is close to voltage collapse. Verbic (2006) proposed the use of the System Status Indicator (SSI) to overcome the above problem. An new algorithm which utilizes the principle of adaptive scheme and SSI has been developed to adapt the local phasor measurements.
The performance of conventional distance relay can be affected by ground fault resistance, prefault system conditions, mutual effects of parallel lines and shunt capacitances influence (Bhalja, 2007). To overcome this problem, Bhalja (2007) proposed the use of an adaptive distance relay scheme using radial basis function neural network (RBNN). The relay setting resistance and the change of active and reactive powers are chosen as the RBFNN inputs and the output of the RBFNN is the reactance setting for the relay. The shape of distance relay setting can be changed depending on the corresponding output. The observation under different types of faults needs to be investigated since only single-line-ground faults have been investigated.

Adaptive protection technique has been proposed by Lim et al (2008) to discriminate between fault and overload. The sensitivity factor based on line distribution factor has been utilized as an important element to decide between fault and overload. The factor also provides the margin between measured power flow and estimated power flow. The threshold of the margin is the criteria to decide whether the relay should be blocked or not. Nevertheless, this approach does not clarify the mechanism of clearing a fault during overload condition.

In practice, a major problem faced by distance relays is that the apparent impedance may enter a protective zone not due to the faults. Load encroachment is amongst the culprits that contribute to this circumstance. In order to resolve this problem, a new adaptive load encroachment prevention scheme based on steady-state security analysis and adaptive Anti Encroachment Zone (AEZ) is proposed by Jin et. al (2008). The scheme integrates real time security analysis and online design of AEZ to prevent undesired tripping of relays. The dependability of the protection relays is assured by allowing operation of AEZ only when needed. Nonetheless, the unblocking mechanism during faults is not discussed in this technique.

CONCLUSION
The reliability of proper operation of distance relays is vital in order to mitigate the adverse effects experienced by power systems. Adaptive concepts have been developed to improve the reliability of distance protection schemes. Different adaptive approaches have been introduced in order to overcome the different problems faced by conventional distance relays. The paper provides brief discussions on the ability of different techniques to address overreach problems of distance relays. It concludes that based on the current literature published on adaptive distance protection schemes; there is a need for more research and development to further improve such techniques for reliable and selective operation of distance protection relays.

REFERENCES


