Chennai and Dr.MGR University Second International Conference on Sustainable Energy and Intelligent System (SEISCON 2011), Dr. M.G.R. University, Maduravoyal, Chennai, Tamil Nadu, India. July. 20-22, 2011.

Effect of Series FACTS Devices on Distance Protection

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Keywords: Distance protection, FACTS, Relays, Zones

Abstract

The increase in the line complexity, configuration and the power transmitted has introduced a number of problems in relation to protection. New techniques have become necessary to tackle these problems. Firstly it has become necessary to see that lines are not unnecessarily disconnected, but at the same time shorter operating times from protective relays are demanded on faulted sections to preserve the system stability. In this paper, discussion is made on the basic needs of protective systems, the various schemes of protection and the importance of distance protection in power system. Next it deals with various distance relay characteristics such as Mho, Ohm, Quadra mho, Quadrilateral, Elliptical, lentical and Ova. The constructional features of each type of distance relay, the behavior and performance of various distance relays had been analysed .The variation in the operation of Distance Relay for multi-terminal configuration, effect of arc resistance, tower footing resistance, resistive reach is obtained. Finally the effect of Series Flexible Alternating Current Transmission System(FACTS) devices on the performance and operational characteristics of the Distance Relays will be observed. The entire simulations are done by using Mipower software to incorporate all the above features and graphical display in transient stability analysis. These studies give us the latest trends in the transmission line protection.

1 Introduction

Coordination in the planning and generation and transmission facilities and the design of an effective protective relaying system is essential for the reliable performance of a power system. The principal performance of the relays is to protect the power system from the effects of faults by initiating circuit breaker operations to disconnect the faulted equipment

The design of a protective relay must assure proper operation so as not to disconnect additional equipment that would aggravate the effects of the disturbances and must assure that faulted equipment is cleared sufficiently fast to mitigate the effects of the fault. In addition the relaying system must not limit the design capability of the generation and transmission facilities. The distance protection operation is based on the measured impedance at the relaying point. There are several factors affecting the measured impedance at the relaying point. Some of these factors are related to the power system parameters prior to the fault instance, which can be categorized into two groups. The First group is the structural conditions, represented by the short circuit levels at the transmission line ends. The second group is the operational conditions, represented by the line load angle and the voltage magnitude ratio at the line ends. Besides the power system parameters, the fault resistance could greatly influence the measured impedance, in such a way that when the fault resistance is equal to zero, the power system parameters do not affect the measured impedance. In other words, power system parameters affect the measured impedance only in the presence of the fault resistance, and as the fault resistance increases, the impact of power system parameters becomes more severe. In the recent years, FACTS devices are introduced to the power systems to increase the transmitting capacity of the lines and provide the optimum utilization of the system capability. This is done by pushing the power systems to their limits. It is well documented in the literature that the introduction of FACTS devices in a power system has a great influence on its dynamics. As power system dynamics changes, many subsystems are affected, including the protective systems. Therefore, it is essential to study the effects of FACTS devices on the protective systems, especially the distance protection, which is the main protective device at EHV and UHV levels. Unlike the power system parameters, the controlling parameters of FACTS devices, as well as their connection points could affect the measured impedance even in the case of zero fault resistance. In the presence of FACTS devices, the conventional distance characteristic such as MHO and Quadrilateral are greatly subjected to mal-operation in the form of over-reaching or under-reaching the fault point. Therefore, the conventional characteristics might not be usable in the presence of FACTS devices.

2 Distance protection

The conventional distance relay uses three distance measuring units, can be three separate units or one unit for the first and second zone with a timing unit to increase the delay of the former and a second unit for the third zone. Figure 1 shows the application of distance relaying. At each end of the line, three separate sets of relays are arranged to provide three protective zones. The first and second protective zones provide primary protection, and the second and third zone provides remote back up for the adjacent line.

2.1 Zone1 Setting

It is normal practice to adjust the first zone relays at A to protect only up to 80% - 90% of the protective line AB. This is a highspeed unit and is used for the primary protection of the protected line. Its operation is instantaneous. This unit is not set to protect the entire line to avoid undesired tripping due to over reach. Over reach may occur due to transients during the fault condition.

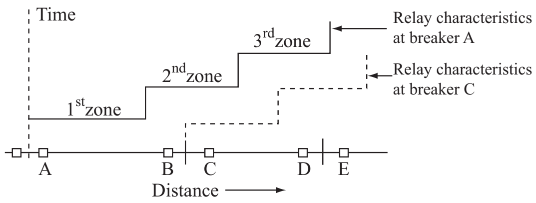

Figure1: Distance relay protection

2.2 Zone2 Setting

Zone2 unit is set to cover about 25% of the second section. The main object of the second zone unit is to provide protection to the end zone of the first section which is beyond the reach of the first unit. The setting of the second unit is so adjusted that it operates the relay even for arcing faults at the end of the line. To achieve this, the unit must take care beyond the end of the line. In other words its setting must take care of under reach caused by arc resistance. Under reach is also caused by intermediate current sources, errors in C.T, and P.T and measurement performed by the relay. To take into account the under reaching tendency caused by these factors, the normal practice is to set the second zone reach up to 50% of the shortest adjoining line section. The protective zone of the second unit is known as the second zone of protection. The second zone unit operates after a certain time delay. Its operating time is usually 0.2 to 0.5sec.

2.3 Zone3 Setting

The third zone of protection is provided for back-up protection of the adjoining line. Its reach should extend beyond the end of the adjoining line under the maximum under reach, which may be caused by arcs, intermediate current sources and errors in C.T, P.T and measuring unit. The protective zone of the third stage is known as the third zone of protection. The setting of the third zone covers the first line i.e. the protected line plus the longest second line plus 25% of the third line. The time delay for the third unit is usually 0.4 to 1sec. For example consider the operating characteristics of mho type distance relay which has inherent directional characteristics as shown in Figure 2.

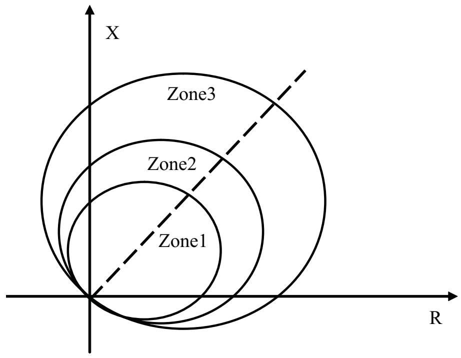

Figure2: Operating Characteristics of mho type distance relay

The circles associated with the three units are labeled as zone1, zone2, and zone3. When a fault occurs and the value of impedance seen by the relay falls within the zone1 and above, the zone1 contacts will close and trip the circuit breaker immediately. In this case all the units will operate because zone1 is the smallest circle. When the impedance falls only with in zones 2 and 3, or zone3, the contacts of the associated units will close and energize a timer. At a specified time setting, the timer will close a second set of contacts associated with zone2. If the first set of contacts associated with zone2 is closed, the circuit breaker will be tripped. If the zone2 contacts are not closed the impedance seen by the relay is not within zone 2, then the timer at a later specified time, will close a second set of contacts associated with the zone 3. If the first set of contacts associated with zone 3 is closed then the circuit breaker will be tripped. The time delays for zone 2 and zone 3 can be set independently. Zones 1 and 2 provide primary protection for a transmission line section, where as zones 2 and 3 provide backup protection in the event relays or circuit breakers of adjoining facilities fail to operate properly[1].

3 Concepts on Distance Relay

In this section some of the advanced concepts on the distance relays are studied. The effects of Arc resistance, tower footing resistance, resistive reach, multi terminal, performance of the distance relays on series FACTS compensated lines are discussed.

3.1 Multi Terminal Effect on Distance Relay Operation

A multi terminal line introduces intermediate current source which is the source of current between a distance relay location and a fault for which distance relay operation is desired.

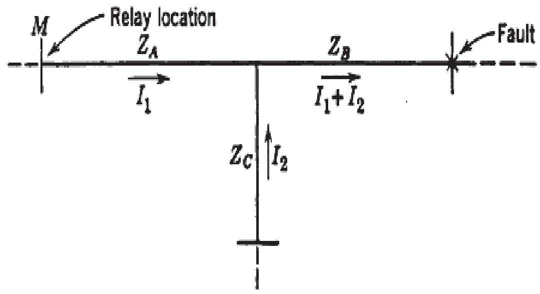

Figure3: Multi terminal line

From the Figure 3, if Z_A, Z_B, Z_C are the impedances of the three terminals A, B, C respectively. When fault occurs at K_2, the true impedance to the fault is Z_A+Z_B , but, when the intermediate current Ib flows, the impedance appears to the distance relays as $Z_A+Z_B+(I_2/I_1)Z_B$; in other words, the fault appears to be farther away because of the current I_2. This effect has been called the "mutual impedance" effect. It will be evident that, if I_1 and I_2 are out of phase, the impedance $(I_2/I_1)\ Z_B$ will have a different angle from Z_B. If the distance relays are adjusted to operate for a fault at a given location when a given value of Ib flows, they will operate for faults beyond that location for smaller values of Ib. Therefore, it is the practice to adjust distance relays to operate as desired on the basis of no intermediate current source. Then, they will not overreach and operate undesirably. Of course, when current flows