Effect of the Fault Impedance on the Performance of Directional Over Current Relays in Medium Voltage Power Cables- A Case Study

Ahmed Mohamed **AMIN HUSSEIN**
DAR Engineering, KSA, ahmed.amin@dar-engineering.com

I- Abstract

One of the most effective techniques for protection of medium voltage cables is Directional Over Current relays (DOC). However, the fault impedance that results from gradual deterioration of the insulation materials between cable cores and sheath may lead to mal-operation of these relays if it is improperly set. In this paper, the effect of the value and nature of fault impedance (resistive or inductive) is illustrated for different medium voltage network's configurations. After that ***ETAP*** software is used for validation of these results on a real case study in **Saudi Arabia**. The directional over current relay settings of 13.8 kV incomer feeders with the possibility of parallel operation of two 115/13.8 kV transformers are calculated for **Royal Commissioning JUBAIL** substation.

II-Introduction

Power underground cables are widely used in High Voltage transmission and Medium Voltage distribution applications. The main cable types used in power systems are High-Pressure Fluid- Filled (HPFF) Pipe-Type, Self-Contained Fluid-Filled (SCFF) Type, and Solid Dielectric Type. Due to its great advantages over the other types, the solid dielectric cable with cross linked polyethylene (XLPE) or Ethylene propylene rubber (EPR) insulation has increasingly been utilized in power systems [1]. As a matter of fact, Underground cables types have a great effect on the cable fault characteristics. Actually, one of the most important reasons of faults in underground cables networks is the gradual deterioration of the insulation material between core and sheath that causes internal failure in these cables [2]. The insulation material can contain voids and impurities that initiates a process called treeing leading to insulation breakdown [1-3].When the insulation breaks down, an electric arc forms a low impedance path between the cable's core and sheath. The arc typically burns until the protection system disconnects the cable after the fault is initiated. However, the fault path and nature in most cases are more complex to be analyzed. The value of fault impedance can vary from zero ohms to many mega ohms. This degree of variation may be unpredictable and an accurate calculation to the fault impedance during the period of the fault could be deeming impossible. Sometimes, the fault impedance may be a voltage dependent one [4]. Moreover, the bonding and grounding methods of the cable sheath do have a great influence on the zero-sequence impedance that is seen by the protection relay in case of ground faults. The fault path impedance can also be affected by several factors such as the resistivity of the cable trench backfilling, the presence of parallel cable circuits, the presence of parallel metallic pipes in the vicinity of the under-ground cables and the resistivity of the ground where the cables are laid. In recent years, a lot of researchers have discussed the differences between overhead transmission lines and underground cables from the protection point of view. In their research, they focused on the challenges that face the Distance relays in high voltage networks in protection of underground cables compared to overhead transmission lines [5]. Little attention was pointed to the performance of Directional over current phase and earth relays in the protection of medium and high voltage networks. In this paper, the ETAP software was successfully used to analyze the different types of faults in underground cables for different configurations of medium voltage networks in Saudi Arabia. The effect of fault impedance on selecting the settings of directional over current phase and earth relays was identified and recommendations of settings of such relays were proposed. After that, the same effect was applied on a real case study of 13.8 kV incomer feeders of two parallel 115/13.8 kV transformers for Royal Commissioning JUBAIL substation in the eastern region in Saudi Arabia.

III-Different reasons for unpredicted fault impedance for underground cables

In this section, the different types of faults that are caused in power cables are illustrated, moreover, the reasons for the great variation in fault impedance are explained.
Types of cable faults are studied from two different points of view: the cable insulation resistance during faults and the power system. According to the insulation resistance, the cable faults are classified to:

- Bolted Fault:
Bolted fault occurs when the insulation burns to such a degree that the cable conductor and cable sheath are in contact. In this case insulation resistance is zero to only a few ohms.

- Blow out of cable conductors:
Blow out of a conductor usually occurs due to a high fault current, or a failure in cable splicing. Cable cores connection to ground may occur and if the fault and ground is dry, a high insulation resistance is predicted; while when ground is moist the resistance value may be moderate or low.

- Corroded concentric:
Corroded or open concentric will present several issues during a fault locate. The concentric is designed to carry fault current. If the integrity of the concentric is endangered due to open strands or high levels of corrosion, the concentric may no longer provide the lowest resistance path of the fault current. In this case the fault current will follow the least resistant path which may be fence posts, phone shields, cable TV shields, gas tracer wires, other utility cables or the ground itself.