Redundancy strategy and ampacity considerations during a fault with multiple cables per phase

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ABSTRACT

Multiple cables per phase are widely used in electrical installations to adequately satisfy the ever-growing demand of electric current. Unequal current distribution between the cables is often encountered, which could have an adverse impact on the cable life expectancy and can lead to its premature failure. Finding and fixing a faulted cable may require a combination of substantial electrical and civil work, which can be extremely costly. To avoid these drawbacks, the usage of one or more spare cable(s) can be beneficial.

The purpose of this paper is to explore a redundancy strategy based on the utilization of a spare cable during an underground cable failure. Another objective of this paper is to present the importance of phase orientation in the ampacity calculations, considering the fact that IEC standards assume a specific phase sequence, when in reality, phase rotations can substantially affect the ampacity calculations. Numerous phase arrangements are explored using two cables per phase with directly buried and ductbank installations. The obtained results provide sufficient impetus for the usage of this approach to all possible cable installations.

KEYWORDS

Multiple Cables Per Phase, Cable Ampacity, Phase Orientation, Cable Arrangements, Complex Impedance Matrix, Current Distribution, Cable Fault, Spare Cable.

INTRODUCTION

With the ever-growing demand of the power consumption, the usage of concentric cables has significantly increased for transporting electric power to the end consumers. In the urban areas, the underground power cables are preferred in distribution lines for secure operation and ensuring safety of life. The cable circuits composed of identical single conductor cables are often used. When single conductor cables are positioned in a triangular or in a symmetrical arrangement, the currents in each conductor are usually equal. Considering the assumptions in [1], the current ratings are assumed to be balanced in parallel circuits and the analysis primarily focusses on the thermal criteria. The condition of equal conductor currents is not met in every situation of cable arrangement. One such situation arises with the use of a number of cables per phase in a cable circuit. In the situations when a large amount of power is to be transmitted in a restricted corridor, multiple cables per phase are often preferred over traditional single cables per phase.

A three-phase circuit with multiple cables per phase, can permit an extensive amount of electric power to be transmitted as well as provide enhanced reliability and more stable power operations. In the case of multiple cables per phase, the locations of individual conductor and spacing between the cables can play a vital role in determining the load currents in the conductors as well as the induced currents in the other metallic components, like sheath, armour etc. The methodology used in computing the current in each conductor and sheath in the circuit is based typically on the method of complex impedance matrix (CIM). The CIM method is mentioned in [2,3] where parallel single-core cables are analyzed to evaluate the current distribution in the conductors as well as the circulating currents in the sheaths, while considering the mutual induction effects.

The impedances of conductors and sheaths are calculated from their self and mutual reactances. These reactances depend on the relative positions of the cables and their distances from all other conductors and sheaths within the circuit. This results in varying impedance of each conductor and sheath and can eventually cause unbalanced cable impedances. Although the cables used in multiple cables per phase circuit are identical and the phase currents are expected to be equal, the current sharing between cables in the same phase can be quite dissimilar. An inappropriate cable arrangement would result in an extremely unbalanced current distribution between the parallelly placed cables in the circuit. This can allocate load currents beyond the limit to some of the power cables within the circuit. Due to the unequal current distribution phenomenon, the overloaded cables can experience excessive temperature rise. This can eventually reduce the life expectancy of the insulation in the cable. The cable sheaths can also degrade due to excessive heat or cold and even when exposed to chemicals. The above conditions along with water ingress, mechanical failure and ageing can consequently result in cable failures.

This paper discusses the approach of using a spare power cable in the electrical network to overcome every hindrance encountered during a cable failure and ensure uninterruptable power supply. The spare cable(s) resembles exactly the original ones in the installation, in both size and materials but carries no electric current under normal operation. During a cable installation, the spare cable is often placed in parallel with the original cables, simply as a reserve in the cable circuit and is utilized in the event that any one of the functional cable or a phase is damaged and needs to be repaired or replaced. Moreover, the presence of the spare cable(s) does not hinder the normal operations as well as the heat dissipation process of the original power cables in the system.

An additional aim of this paper is to show the importance of phase orientation in ampacity calculations. When it is necessary to connect multiple cables in parallel within the same phase, it is extremely challenging to ensure that the current flowing though these cables are in close proximity. The IEC standards in [1, 2] assume a specific phase rotation in the ampacity calculations; whereas in real