Leaks Location of Micro Leaks in FFLP by Hydraulic Model

PART 1 "A Formal Ergodic Approach"

Geraldo R. de Almeida ; TECHSYS , (Brazil), geraldo.almeida@tagpower.com.br

Paulo Deus de Souza, ENEL, Brazil, paulo.deus@enel.com

ABSTRACT

The micro oil leaks in FFLP cables occur naturally after 40 years of use of these cables due to exhaustion of the mechanical creep of welds of splices and terminals. Any type of leak location method must have certain attributes: (i) they are methods that are non-invasive to the oil of the cables, (ii) they do not require the cables to be disconnected while the location is in progress, (iii) they have a good accuracy of location and (iv) naturally be low cost for FFLP cable operators. The method formalized with ergodic theory fits into the group of dynamic systems modeling, with energy and mass functions within complete and measurable metric spaces. This work is a hydraulic frame, with a statistical mechanics platform, with measuring devices, capable of measuring dynamic variables during the oil loss process and applicable in rheometry of any Newtonian fluid.

KEYWORDS

FFLP Cables, Underground Cables, Leaks Location, Ergodic Approach, Assets Management.

INTRODUCTION

Paper cables impregnated with insulating oil have been used commercially in networks and underground lines since 1923 [01] and several of them have already surpassed the mark of more than 50 years of use and are still in service. The vast majority of defects in these cables are due to the intervention of external agents in civil works, where the location of an oil leak is purely visual. However, after so many years of performance, these have some oil leak points that need to be located and repaired.

Figure 1 Typical leak on FFLP cable

The oldest method, but one that many utilities still use today is the so-called freezing method [02]. From 1970 onwards, an effort to develop alternative methods to freezing began due to its cost and time required for an effective location [03], [04] and [05].

Even simpler methods were prospected and some of them were used successfully, however interfering in the performance of the line with necessary maneuvers for its execution [06].

There are currently 4 approaches under development: (i) The old and effective freezing method [02], (ii) Hydraulic methods with flow measurement [03], [04] and [05], (iii) Pressure pulse method [06] and (iv) method by tracers [07].

The previous work [08] showed the potential of the approach, however, without the formal modeling now presented and with several applications of the method for locating leaks in various types of underground transmission lines with FFLP cables, as an intensive presentation in part 2 of this paper.

The approach with formal ergodic theory frames the class of hydraulic methods with flow and pressure measurement as its measurable functions, in a statistical mechanics platform, with thermodynamic reductionism for applying the problem to any Newtonian fluids.

FFLP CABLE AND THE UTL

FFLP (Fluid Filled Low Pressure) cables are an electrical system supported by a conductor insulated with paper impregnated with insulating fluid. Figure [2] shows the geometry of single and three core constructions. The three-core construction has been used for cables in class 138 kV (Uo=80 kV) and conductor cross-sections less than or equal to 1 square inch (□630 mm²). The unipolar construction has been used for any AC or DC voltage level and conductor section limited by mechanical stiffness or economy.

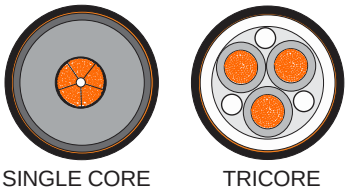

Figure 2 FFLP cables

Figure [3] shows a UTL (underground Transmission Line) of single core cables installed in the trefoil formation in two circuits spaced by 500mm at a depth of approximately 1500mm. In the same figure, the Altimetric profile is shown, where one can see a difference of 33 meters between the ends of the line, each cable of the line has 4 splices along 2736 meters in length and naturally two external transition terminals at the ends. The leak meters were installed at the ends, the line performs since 1968 and this case was addressed in part 2 of this work.

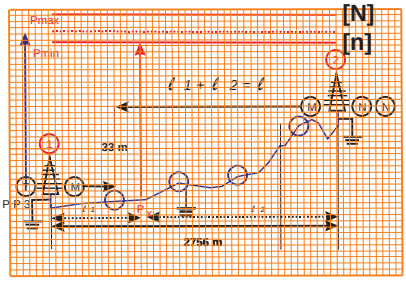

Figure 3 FFLP in the UTL installed in trifoil formation

Figure [3] shows a line of single core cables installed in the trefoil formation in two circuits spaced by 500mm at a depth of approximately 1500mm. In the same figure, the Altimetric profile is shown, where one can see a difference