SNAKING OF CABLES IN EMPTY PIPES.

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ABSTRACT

The paper describes the snaking of cables in pipes left empty, modeled with an analytical calculation method specifically developed. The theory has been verified with experimental tests that demonstrates its validity. The paper provides a presentation of the theory, experimental tests and indications for cable designer.

Different HV cable types have been tested with different material of conductor and metallic sheath.

It has been demonstrated that the cable snakes with a pitch that does not change during the following thermal cycles. The mathematical model provides the deformation of the cable inside the pipe; the thrust and the fatigue life of the cable sheath can be computed analytically.

KEYWORDS

Cable Snaking – Empty pipes – Fatigue life - Thrust Modelling – Installation – HV cables – Energetic model.

INTRODUCTION

The theory is based on the following main observation and principles:

1 – Cables in empty pipes may change their configuration from rigid to a snaked configuration if the conductor temperature increase above certain defined critical value.

2 – The configuration of the cables in empty pipes is the one which implies the minimum energy for the cable itself (Energetic model).

It is possible to formulate the total energy of the cable, as the sum of Axial, Bending and Gravitational Energy, for any configuration of the cable. It is possible to find the analytical equation of cable snaking with minimizing the value of the total energy.

Analytical formulas are complex but can be easily imputed into a personal computer and solved.

Comparison of total energy computed for straight, sinusoidal and helical configuration, allows determining the deformation preferred by the cable. The solution of the equations provides also the critical temperature which triggers the passage of the cable from the straight configuration to the snaked configuration.

One of the most important results of the developed theory and experimental tests is that the pitch of the first snaking is kept during all the following load cycles. This basic result of the pitch conservation allows the calculation of the various parameters such as cable thrust and sheath strain and fatigue along the whole life of the cable.

For low thermal rise the only existing configuration is the straight configuration, but above a critical temperature the sinusoidal configuration becomes possible and most probably the cable will tent to assume this configuration; for very high thermal rise and stiff cables, the helical configuration becomes possible.

EXPERIMENTAL SET-UP

The theory and the calculation model have been verified by means of full scale experimental tests, based on the installation of a cable inside a long rigid transparent pipe.

Different HV cable types have been tested with different materials of conductor and metallic sheath: the cables have been blocked to the ground at the two extremities, just outside the pipe.

Load cycles at 90°C of conductor temperature have been executed, but temperature up to 200°C have been also tested, to verify the cable behavior at short circuit extreme conditions.

The following picture reports the snaking of a cable inside the empty pipe, taken at high temperature during the thermo mechanical tests.

Fig. 1: Snaked cable into a transparent pipe.

The real scale experimental set-up has been realized using a transparent plastic pipe 33.5 meters long and with internal diameter of 192 mm and a thickness of 4 mm, to withstand the lateral force of the HV cable, when diverts from original rectilinear configurations. Various pieces of the pipes are connected together and firmly fixed to the ground with special "U" clamps (Fig.2).

Mechanical characteristics of the cable have been measured in laboratory on cable samples: axial rigidity, bending stiffness and thermal expansion coefficient.