Snaking of cables in empty pipes.

Paolo **MAIOLI** (1), Marco **BACCHINI** (2)

1 Prysmian S.p.A, Milan, Italy, paolo.maioli@prysmiangroup.com
2 Prysmian Power Link S.r.l, Milan, Italy, marco.bacchini@prysmiangroup.com

The paper describes the snaking of cables in pipes left empty, modeled with an analytical calculation method developed by the authors. 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.

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 tests.

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

Fig. 1: Snaked cable into a pipe.

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

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

The main conclusions that can be drawn as a result of the mathematical model and verification tests are:

- The cable snakes initially as a cylindrical sinusoid, touching the pipe walls.
- The pitch is created and does not change during the following thermal cycles.
- The sinusoid climbs the pipe walls and allocates an extra-length of cable, thus reducing the thrust that can be computed analytically.
- The fatigue life of the cable sheath is computed on the cylindrical sinusoid configuration, in the position of highest deformation.
- Computation of thrust and fatigue life of the sheath can be done analytically.