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HV SOLUTIONS

Recommendation For Advanced Asset Management of Paper-Oil Insulated Transmission Power Cables

Background

Remaining Life Management of power cables deals with a complex issue, consisting of a combination of technical, strategic and economic factors. The process of natural ageing strongly depends on the operating mode of the cable system (nominal load or partial load, continuous or short time operation, overloads, number of starts, standstill periods).

The insulation degradation strongly depends on the service conditions such as: load, number and type of defects developed during years of service, repair quality and an environmental factor e.g. soil thermal resistivity, over-voltage conditions.

Aging failures indirectly are the result of cable service stresses. Four major cable stresses can be specified:

- Electrical stresses
- Thermal stresses
- Mechanical stresses
- Environmental stresses

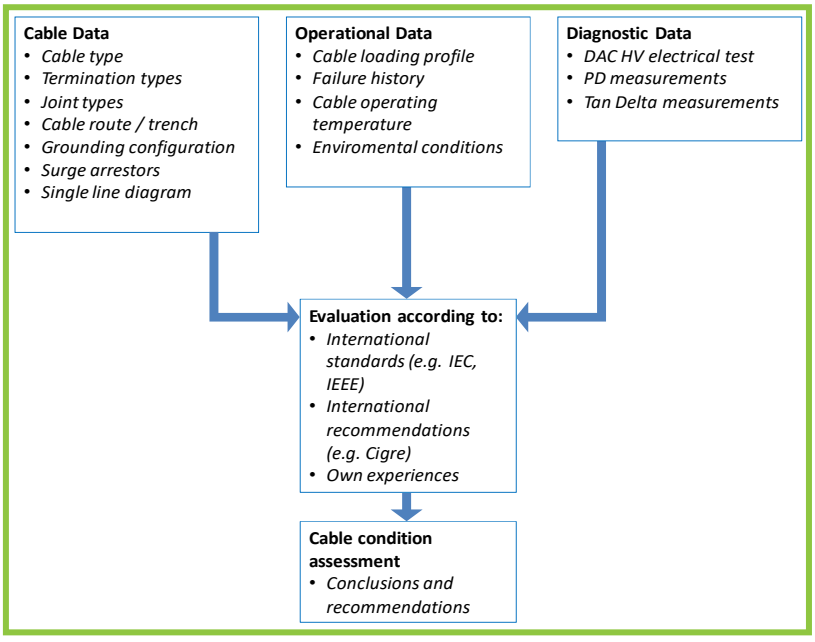
Tracking traces on paper insulation of a 150 kV cable

Insulation Aging

Aging of the paper-oil insulated cables is a complex process. Oil impregnated paper under stresses such as: thermal, electrical and mechanical stresses can have lower electric and the mechanical strength but the process is not constant and predictable. This aging process is not related to one major stress factor, but a combination of the various stresses acting synergistically throughout the cable service life. Aging of the impregnated paper follows basically three different processes:

- Thermal degradation (pyrolysis)
- Oxidation (gasification)
- Hydrolytic degradation

In the case of paper-oil insulated power cables, hydrolytic degradation is the main degradation mechanism leading to lower breakdown strength and irreversible deterioration of the paper-oil insulation.



Cable condition assessment approach

Cable Condition Assessment Approach

To obtain the overall technical condition of the cable circuits and to evaluate the ageing factors for paper-oil insulated cables (as far as detectable with electrical tests) the following diagnostic test will be performed and the results evaluated in relation to international guidelines:

- High voltage damped AC testing
- Partial discharge measurement with localization
- Dielectric losses by the dissipation factor (tan Delta)

Damped AC Insulation Condition Evaluation

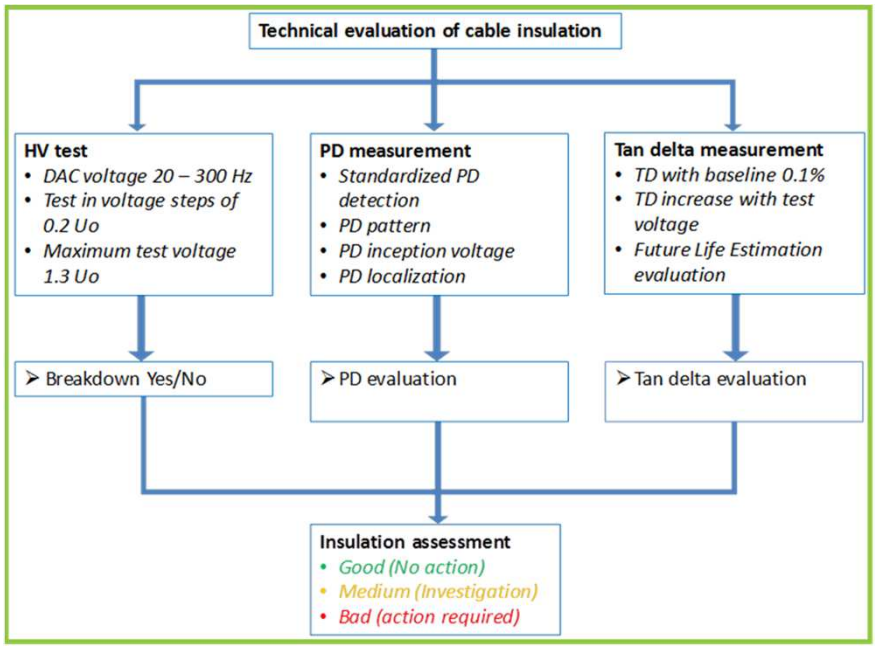
Damped AC (DAC) technology has the advantage of non-destructive testing and the method provides deterministic values of partial discharge (PD) activities in the cable system as well as the dissipation factor (tan Delta) of the overall cable system.

The overall cable condition evaluation is performed by:

- Condition Based Maintenance (CBM):
  - DAC HV tests and diagnosis and the evaluation of diagnostic parameters
- Cable condition index:
  - Partial discharge values and the PD evaluation together with the tan delta values (TD) are evaluated according to knowledge rules and statistical evaluation to obtain an overall condition index.
- Future Life Estimation (FLE):
  - Diagnosing the life consumption and future life estimation of Paper-oil insulated cable is based on thermal ageing and the diagnostic parameters (TD and PD).

Cable Condition Index

The measured tan delta values (TD) and PD analysis are used as input for statistical analysis to obtain TD boundary values for a particular type of cable insulation.



Damped AC cable insulation condition assessment

These boundary values can be used for cable condition indexing. To obtain these values the fitted statistical distribution of tan delta values from measurements on comparable cable types are evaluated . The boundary values are used to provide a condition index that is indicated with number and color:

- Index 9; very good (green)
- Index 8; good (light green)
- Index 6: moderate (yellow)
- Index 3: poor (orange)
- Index 1: very poor (red)

For each phase of a cable circuit at the different voltage levels the condition indexing can be obtained for the measured values. Eventually these values are combined to obtain an overall condition index per phase.

	Phase		
Condition parameter	**L1**	**L2**	**L3**
PD evaluation	3	6	9
Tan δ at 0.5 Uo	9	6	9
Tan δ at 1.0 Uo	8	6	8
Tan δ at 1.4 Uo	6	6	9
Δ Tan δ	1	3	3
Overall cable rating	**6**	**6**	8

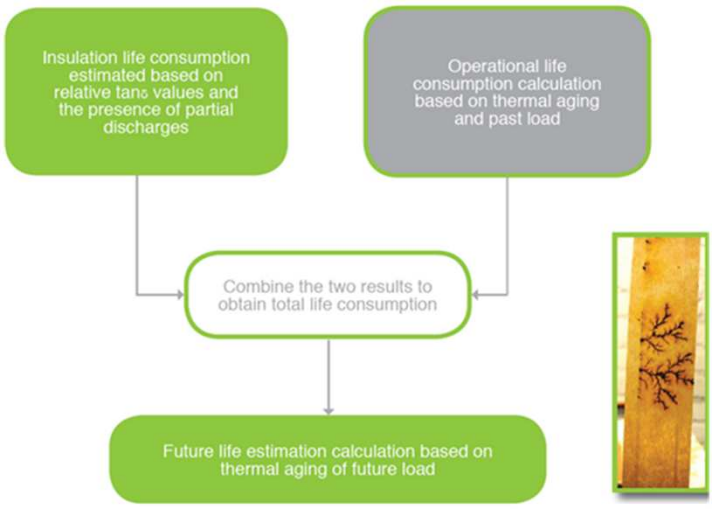
Example of statistically obtained condition indices for the PD evaluation and the tan delta values at 0.5 Uo, Uo and 1.4 Uo with the condition indexing levels for an oil-filled 230 kV cable

Future Life Estimation

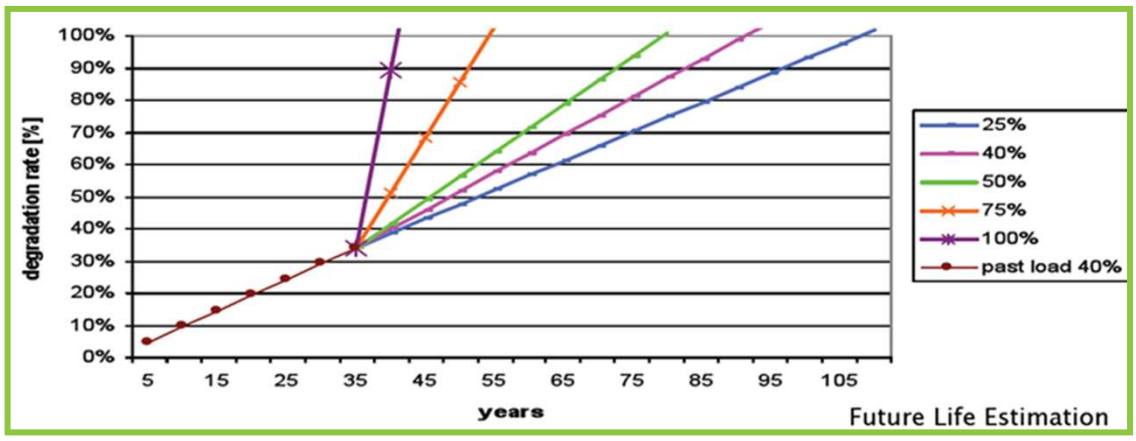
Diagnosing the life consumption and future life estimation of oil-impregnated paper insulated cable can be performed with a special ageing model. The FLE is obtained by combining:

- Insulation Life Consumption ILC), based on the actual measured tan delta values
- Operational Life Consumption OLC), based on thermal aging

Together with the future load, the life estimation can be estimated.



Flow chart of life consumption and future life estimation calculations



Future life estimation example of bad condition cable based on 40% average loading in the past

Conclusion

- The application of damped AC technology with on-site diagnosis of transmission power cables provides the essential information to evaluate your cable condition.
- PD detection is an adequate method to get insight into discharging insulation defects in both XLPE and paper-oil insulated cable insulation.
- The measurement of tan delta at various voltage levels provides valuable information regarding the overall paper-oil insulated cable insulation ageing.
- The diagnostic information as obtained using onsite DAC testing contributes in the overall cable condition assessment.
- The obtained experiences in the past years provided the information to develop our own specific knowledge rules to support maintenance and replacement activities of transmission power cables.

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