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GROUP REF. : B1
PREF. SUBJECT : 2
QUESTION N° : 3

**PS2-Q3: To what extent do enhanced test methods, perhaps including more variable environmental scenarios offer benefits to enhanced reliability and system integrity? What possible further recommendations and guiding documents are needed to standardise procedures of enhanced tests?**

TB 852 already considers two types of installation conditions for Pre-Qualification Test (PQT), one mimicking the operational installation with to freely changing ambient temperature and one where the test object is kept in a controlled environment.

The first setup poses the problem of uncontrolled $\Delta T_{MAX}$: the current needed to keep $T_{cond} \geq T_{cond,MAX}$ with varying ambient temperature may lead to exceed or fall short of $\Delta T_{MAX}$.

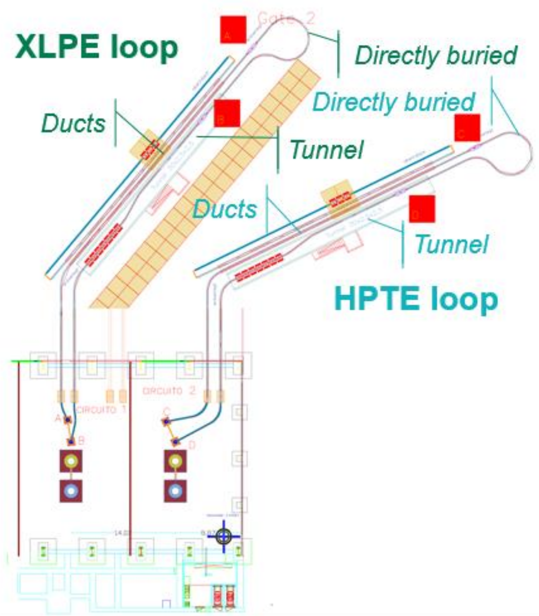
This can be explained by looking at the formulas governing the two parameters:

$$\vartheta_{cond} := I^2 \cdot \left[ R \cdot \left( T_1 + T_2 + T_3 + T_4 \right) \right] + \vartheta_{amb}$$

$$\Delta\vartheta := I^2 \cdot R \cdot T_{1is}$$

where $\theta_{cond}$ is the conductor temperature, $R$ is the conductor resistance, $T_1$, $T_2$, $T_3$ and $T_4$ are respectively the thermal resistances between conductor and sheath, between sheath and armour, of the external serving and of the surrounding medium, $\theta_{amb}$ is the ambient temperature, $\Delta\theta$ is the temperature drop on insulation and $T_{1is}$ is the insulation resistance without the semiconductive screens.

To maintain $\theta_{cond}$ above the maximum conductor temperature when $\theta_{amb}$ changes, it is necessary to increase the conductor current, being all the other parameters fixed. This has a direct impact on $\Delta\theta$, which is proportional to the square of the current. Also, in case of operational installation conditions there is less certainty about $T_4$, which may vary along the year due to soil humidity content or in case of unfilled ducts. On the contrary in laboratory conditions, it is less likely the two situations above will occur, as ambient temperature of the laboratory building can be controlled and external thermal resistance is obtained by the application of low thermal conductivity tapes of known and stable characteristics.




Very high $\Delta T_{MAX}$ resulting from the first setup can be seen as a stressful condition due to electric field inversion, however new HVDC materials are less sensitive to temperature gradient. On the other hand, it isn't the worst condition to capture

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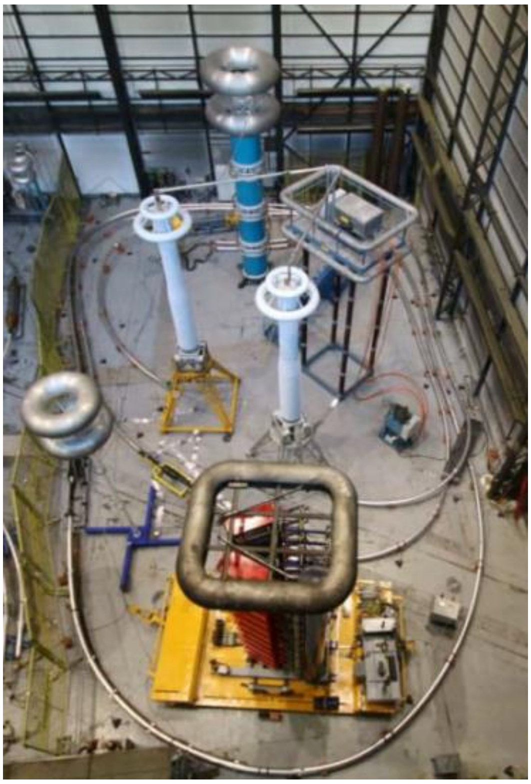
thermal instability phenomena, as the insulation average temperature is lower (hence insulation resistivity is higher). This is also addressed by TB 852 which introduced a new Thermal Stability Test (TST) and the concept of $\Delta T_{min}$.



On top of theoretical considerations, it is possible to draw some conclusions looking at how three different 525kV test loops performed under different installation conditions.

Two 525kV PQTs on land systems insulated with XLPE and HPTE were successfully completed mimicking the installation conditions. As PQT lasts 1 year, in the coldest months it was necessary to increase the heating current, leading to a $\Delta T_{MAX}$ of 40 K across insulation in certain loop locations. This condition isn't representative of the cable operation, as during cold months the conductor temperature is lower than $T_{cond,MAX}$ and consequently $\Delta T_{MAX}$ as well.

A different test setup in laboratory condition was used on a submarine 525kV XLPE cable. $T_{cond,MAX}$ and $\Delta T_{MAX}$ are controlled by means of current and thermal insulation in accordance with TB 496. However, TB 852 allows to control $\Delta T_{MAX}$ also by external heating or cooling, allowing for a better control of the two design parameters. In parallel to the PQT, a TST was also setup to verify any thermal instability phenomena not captured by controlling $\Delta T_{MAX}$ during PQT.

In conclusion, both setups are feasible and there seem not to be different test outcomes based on the setup used. The setup mimicking the installation conditions can lead to uncontrolled test parameters, not necessarily testing the system for the worst conditions. The setup in laboratory conditions allow for better control of the test parameters, especially considering new TB 852 allows not only for external thermal insulation, but also for external heating or cooling, giving additional degrees of control over the test parameters. There may were concerns that, by applying external heating or cooling, some failure modes like thermal instability may not be captured, however the introduction of Thermal Stability Test (TST) in TB 852 test scheme is specifically addressing this point.