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<u>Question 2.14</u>: How did determine circuit sections, when applied the DLR system to the whole circuit? How can be considered the application of low-cost temperature measurement DLR sensors?

<u>Contribution</u>: BME's philosophy is twofold in the application of DLR system for the whole circuit. A possible opportunity is the so-called critical span analysis, which results in some spans or tension sections where the line monitoring sensors should be installed in order to get comprehensive information about the whole condition of the power line. The other possible solution is covering all the tension sections with sensors in order to monitor the longitudinal thermal profile of the power line and in this way ensure the safe operation. Detailed information from both methods is available in the following paragraphs.

For the critical span analysis, BME offers two different methods. One is the critical span identification algorithm. The basis of this method is the sag simulation, which takes into account the elevation profile and objects under the line. In this way not only the sag of the spans, but the ground clearance level and clearance level from other objects under the line are also available. The spans are ranked by the clearance reserve values which is the difference of the clearance at maximal conductor temperature and the legally required clearance level from the given object or ground. According to the TSO's safety request the spans with less clearance reserve than the limit value are chosen for installation places.

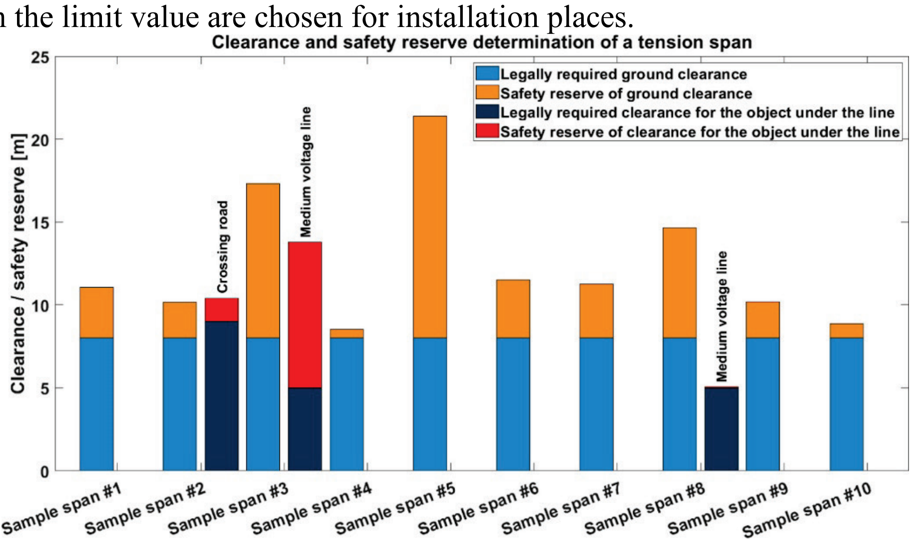

Figure 1. Clearance level results for a given tension section during the application of BME's critical span identification algorithm

Another possible solution to identify critical spans is the risk-based, distributed sensor installation concept. Besides the ground clearance level, it also takes into consideration the electric- and magnetic field under the line at maximal conductor temperature. If violation possibility of electric- or magnetic field arises in a given span it should be covered by line monitoring sensors on which measurement basis conductor temperature and sagging limitation may be applied. Moreover, the prevailing weather parameters along the line route as distributions are also taken into account in this method. Monte Carlo sampling method is used to determine the conductor temperature and ampacity distribution from this data set. By this simulation the conductor annealing phenomenon is also eliminated. The advantage of this model, that it applies distribution function to simulate the above-mentioned parameters, in this way the risk taken can be optimized on the basis of implementation cost.

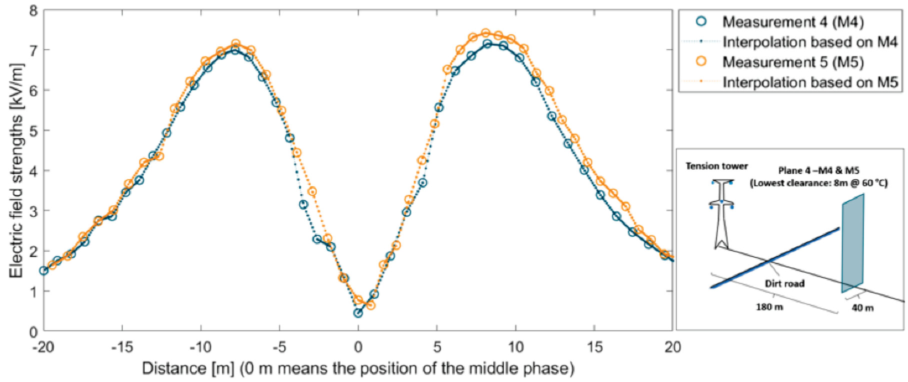

Figure 2. Electric field strength validation for critical span analysis purpose

The other approach to achieve a DLR system which covers the whole power line is to install line monitoring sensors in every tension section. Basically, this would be a very expensive solution, with the application most of the DLR sensors available in the international market. In order to handle this challenge, BME's High Voltage Laboratory developed a low-cost DLR sensor for that purpose. This cost-efficient sensor has only one functionality, namely the conductor temperature measurement in order to keep the production cost low. Moreover, other cost-efficient technologies (such as the house of the sensor is 3D printed) were chosen in order to obtain efficient series production. On the other hand, the conductor temperature measurement was realized with high precision by the application of A-type Pt100 temperature sensor. For the power supply module, a current transformer-based energy harvesting system was chosen, which main advantage that it is maintenance free. The data collection and transfer are realized with an IoT based central processing unit, which is also responsible for GSM communication. Two prototypes of the sensor are in operational in the Hungarian transmission system on 400 kV voltage level. Next to the prototypes other line monitoring sensor is also installed in order to have measurement result for validation purposes. The first results from more than half year of operation show promising results for further application.

The main advantage of the proposed DLR system implementation with low-cost sensors, that the longitudinal temperature profile of the line is available from sensors measurements. Therefore, the local thermal overload of the conductors can be avoided, which contributes to the lifetime extension of the conductors. Moreover, conductor temperature measurement is enough to implement a complex DLR system, as it can be used for ampacity calculation and sag simulation also.

Figure 3. Low-cost sensor under field test on a 400 kV power line