COUNTRY : Germany
REGISTRATION NUMBER : 608

GROUP REF. :
PREF. SUBJECT : 2
QUESTION N° : 2.13

Probabilistic safety concept in OHL construction

Question 2.13: In which other areas of the energy grid can the probabilistic safety concept be applied?

In addition to the adequate safety of the steel construction of overhead line pylons in relation to the possible consequences of damage, the same question also arises for other components of overhead lines.

Foundations of overhead line pylons

In this context the probabilistic analysis of pylon foundations is obvious, thus the whole pylon can be verified. A lot of experience is already available on the external safety of overhead line pylons. Frequently used foundation types are single foundations, pile foundations, slab foundations and wood sleeper foundations. Due to the large dimensions of a 380 kV pylon, split foundations are typically used for each corner of a pylon. Depending on the force occurring in the integrated corner of the pylon, these are subjected to vertical tensile or compressive stress. Single foundations are usually dimensioned for maximum tensile forces. The resulting bottom joint area is usually large enough, so that the bottom joint pressures arising under the compressive force can be kept below the limit value depending on the type of foundation. The resistance to tensile forces results from the sum of the concrete body weight of the circular or rectangular steps and the weight of the foundation soil body activated by the lower step. The weight of the foundation body is approximately twice the weight of the concrete body. Thus, the dimensions of the concrete body as well as of the foundation soil, which are idealised by a truncated pyramid in the calculation model, have an influence on the resistance. The decisive factor for the weights is whether they have to be reduced by buoyancy due to the presence of groundwater. While the dimensions of the concrete body are well known (represented in the stochastic context by constants), the earth loading angle, which is decisive for the size of the ground pyramid stump, varies comparatively.

The limit state function for geotechnical failure mechanism can be formulated in the same way as for steel verification. Impacts on foundations are support forces from the pylons, which therefore depend on the same variables as the limit state functions for steel verifications. In particular, these are the gust wind speed and ice loads. Both variables influence the magnitude of the conductor tension forces, which has a significant influence especially on angle pylons. The resistance in the limit state function depends on the weights of the materials involved and the angle of the earth load. The earth loading angle is physically limited in the lower range by 0° (vertical fracture joint) and in the upper range by 90° (horizontal fracture joint). A beta distribution in the interval of 0° to 90° is used to capture this characteristic. The high uncertainty regarding the magnitude of the earth loading angle can be seen in coefficients of variation around 0.30.

Compared to the probabilistic calculations of the steel constructions, foundations tend to achieve higher reliability indices. This effect can be explained by strongly scattering soil properties and the determination of characteristic values significantly below the mean value for semi-probabilistic verifications. Furthermore, if the resistance is composed of several summands, the probabilistic concept captures the probability that all of them realise a low value at the same time.

Portal constructions of substations

Another possible application of probabilistic verification is the portal construction of substations. These are often constructed by L-sections in a steel lattice construction. Several supports in a row are connected to a gantry with crossbars. The effects are similar to those of overhead line pylons. However, the lower height of the portals results in lower wind speeds and thus smaller loads. The conductors usually have a smaller distance to each other and in the event of a short circuit the result is high mechanical forces act on them. For this reason, in addition to climatic effects, conductor tension due to short circuits must be taken into account. The load application here does not necessarily take place in truss nodes, so that chord members can be influenced by bending moments. These must be taken into account in the corresponding verifications. The standard EN 1993-1-1 requires in the case of interaction of compressive force and bending moment (for the non-double-symmetrical L-sections) a check according to 2nd order theory using an initial imperfection. For steel lattice transmission line towers with negligible bending moments, on the other hand, a verification according to 1st order theory with slenderness-dependent reduction of the yield strength is sufficient.

The limit state function consists of the yield strength on the resistance side, which is reduced on the action side by the described bending stress according to 2nd order theory. In the probabilistic verification, the challenge is that when calculating the design point coordinates, the most likely variable realisation to cause failure, compressive forces can occur in some iteration steps that are above the ideal critical force. In this case, these must either be included in the limit state function as a reduction of the yield strength or the mean value of the initial imperfection must be increased.

Conclusion:

The method of probabilistic calculation can be technically transferred to the verification of foundations of a lattice tower and to portal constructions of substations.