Clearance of OHL taking into account correlation between weather conditions and lightning strike probability

Air clearance of OHLs to earthed objects are determined for summer weather conditions, i.e. 35°C ambient temperature, 0.6m/s wind speed, 900 W/m^2 solar radiation, a typical maximum conductor temperature of 80°C, and it is based on lightning impulse withstand voltage (LIWV) in accordance with EN 50341-1 and IEC 60071-1. However, at these weather conditions, which lead to the highest conductor sag under high load conditions, no lightning events are to be expected. Therefore, from the insulation coordination point of view, dimensioning with regard to slow front overvoltages (SFO), only, would be sufficient under these conditions (**Figure 1**). The surplus can be exploited for increasing the ampacity under normal weather conditions corresponding with lower conductor temperatures.

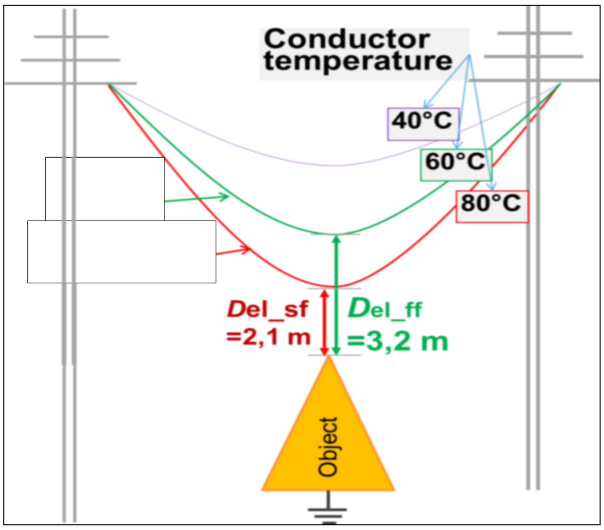

Figure 1 : Change of conductor sag due to different conductor temperatures and electrical clearance resulting from different voltage surges

The approach is based on statistical data, which covers 30.000 lightning strikes over a time period of 10 years along the transmission line corridor. Along this line several weather stations were available, providing records of all relevant environmental parameters at time intervals of 5 minutes. A typical example of the corresponding statistical evaluation is presented in **Figure 2**. Two load situations, 100% and 75% load are assumed. Due to an approaching thunderstorm, around 1.5 h before any lightning strikes, the ambient temperature drops rapidly by some 10 °C. As the sky gets cloudy, the global radiation decreases as well. In connection with the updraft thunderstorms the wind speed also increases. However, this effect only takes place during the early stadium of thunderstorm. The main reason why the conductor temperature is lower in comparison to a time instant 4 h before the lightning strike event, is the lower ambient temperature. Most presumably, the cooling effect would still be improved by the rain, but it was disregarded because of missing precise data. In total the better cooling leads to a decrease of the conductor temperature for about 20°C and this in turn causes a reduction of the conductor sag for about 46 cm…70 cm depending on the span length of 200 m… 500 m, at which longer span lengths are more of interest. This surplus can be utilized for improvements in ampacity.

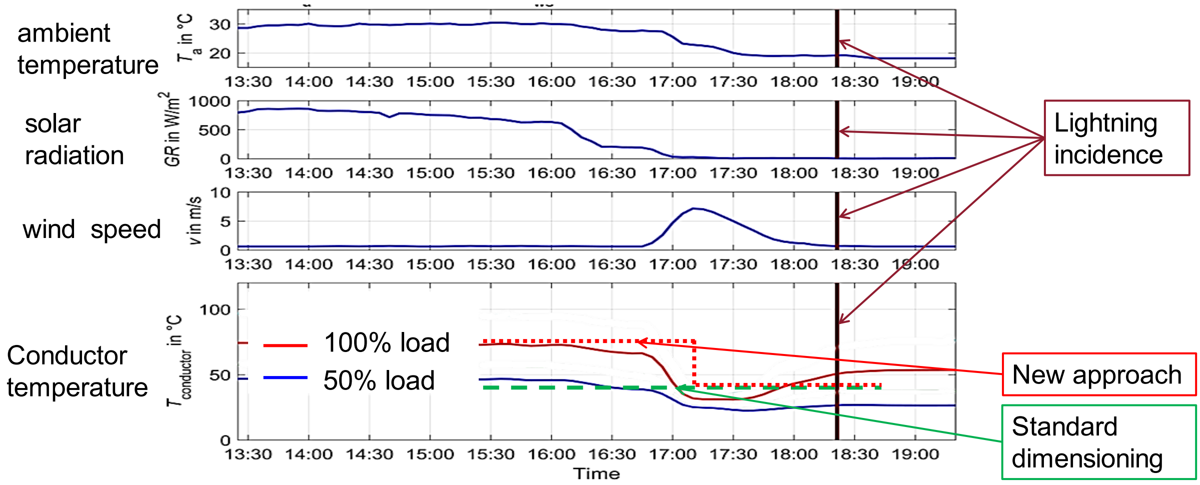

Figure 2 : Conductor cooling at period during lightning incidences

However, further improvements can be achieved by a more sophisticated insulation coordination (IC) based on statistical consideration for adjustment of air clearance to earthed objects, i. e. required air clearance for SFO, D_{el_sf} and for FFO, D_{el_ff}.

With regard to the required air clearance for SFO, the distribution of SFO has to be considered. For this purpose, numerous simulations of three phase line energisation were carried out. The cumulative probability function of the slow front overvoltages for line lengths of 50 km, 100 km and 200 km is presented in **Figure 3**.

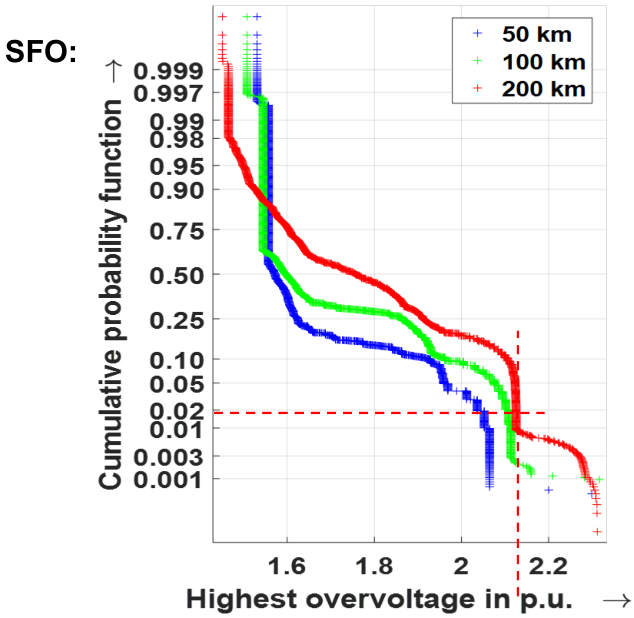

Figure 3: Cumulative probability function of slow front overvoltages due to three phase line energization; line lengths: 50 km, 100 km & 200 km

From this figure a SFO with a 2% probability of U_{e2} = 2.1 p.u. can be derived. U_{e2} is taken for determination of the required air clearance for SFO D_{el_sf}. According to IEC 60071-2, this results in a required air clearance for SFO of D_{el_sf} = 2.1 m.

For determination of the required air clearance for FFO D_{el_ff}, the shielding failure flashover rate (SFFOR) and the back flashover probability (BFR) for a given OHL configuration are studied by means of the EGM. Based on the previous considerations a clearance of 2.1 m corresponding to D_{el_sf}, plus reduction of conductor sag Δs = 46 cm…70 cm due to conductor temperature drop can be assumed for the FFO air clearance D_{el_ff}. In the case under consideration, a worst-case estimation was carried out, assuming a FFO air clearance D_{el_ff}. of 2.1 m corresponding to SFO air clearance D_{el_sf} with the following result:

SFFOR	0.06 1/100km*a	N_g=2.5 1/km²*a
BFR	0	tower footing impedance $R_f \leq 10\Omega$

That means, in a time period of 17 years, one lightning strike would hit the conductor of a line 100 km in length and cause an overvoltage amplitude equal to or larger than the withstand voltage of the 2.1 m air gap. Taking into account that the lightning strike must hit the line in the vicinity of the relevant span with the minimum clearance to generate a flashover, the flashover probability is negligible.

To resume, the consideration of the correlation between weather conditions and occurrence of FFO can be applied for optimisation of the design of OHLs, their ampacity and their insulation coordination.