Development of a new type of conductor car from design to assembly

Dr. Gábor GÖCSEI, Dr. Bálint NÉMETH, Bálint Gergely HALÁSZ, József MEIXNER, József KISS
Department of Electric Power Engineering
Group of High Voltage Technology and Equipment
MAVIR Hungarian Transmission System Operator Company Ltd.

contact: gocsei.gabor@vet.bme.hu, +36 1 463 3236
New type of conductor car: main benefits

• Made of extra light, cost-effective, non-conductive material
  • Novel approach compared to the existing (conventional) conductor cars
• Ability to pass suspension insulators
Development of a new type of conductor car

- Analysis of existing tower – insulator – conductor configurations
- Design of the prototype
- Tests of new materials, adhesives, accelerated aging
- Electrical tests of the conductor car
- Mechanical tests of the conductor car
- Complete risk analysis
- Manufacturing of the prototype
Application of new materials

• Completely new design
• New principle of operation: made of insulated material
• All components are made of plastic
• New materials - new way of fastening
• Different adhesives have been tested
• Besides the chemical binding plastic sticks are used at all linkages through the connecting materials to ensure proper mechanical parameters
Aging tests

• Several types of aging test to determine the best kind of adhesive
  • Permanent heat test
  • Permanent cold test
  • Permanent water ingress test
  • Permanent UV-test
  • Permanent water boiling test

After aging:

• Determination of mechanical strength of the aged samples by breaking
• Selection of best adhesive
• Vibration stress (new samples with best adhesive)
• Sample breaking
Mechanical vibration and breaking test
Mechanical breaking curve – example

- Load versus strain
- Determination of breaking force
- Determination of safety factors
- Evaluation of results, selection of best design
Material and design tests - summary

• Best adhesive and design has been selected based on the results of mechanical breaking after several ways of aging

• Grooves on the surface increase the efficiency of contact, so the mechanical loading capabilities of the adhesives

• While applying the optimal adhesives and surface handling, average mechanical safety factor of plastic-plastic contacts is 4.27 (2.87 in worst case)
  • Application of plastic sticks through the adhesive increase the efficiency of the contact
Mechanical inspections

- Complete 3D CAD model of the new structure
- Finite element method analysis
  - Critical forces
    - Amplitude
    - Direction
  - Critical torques
    - Amplitude
    - Direction
  - Determination of safety factors
  - Comparison with the results of breaking tests after aging and vibration stress
Mechanical inspections

- FEM torque and force calculation for each connecting element
  - Determination of maximal values and critical points
  - Validation of design by calculation and laboratory measurements
Example: mechanical FEM simulations („T” and „L” shaped elements)
Example: mechanical FEM simulations

- Investigation of the effect of mechanical loads in case of different scenarios (elastic modulus, load position)
- Examination of local forces and torques
- Examination of deformation
FEM results: forces and torques

Torques in directions of $x$, $y$ and $z$

- Case 1 $M(x)$
- Case 1 $M(y)$
- Case 1 $M(z)$
- Case 2 $M(x)$
- Case 2 $M(y)$
- Case 2 $M(z)$
- Case 3 $M(x)$
- Case 3 $M(y)$
- Case 3 $M(z)$
Mechanical inspections – summary

• Asymmetric loads cause the highest force and torque values

• The maximal mechanical force affecting to the adhesives in the system is 1445 N, which is below the nominal design value (1500 N)

• In case of symmetrical mechanical loading conditions, none of the local forces exceed the nominal design value
Electrical inspections

- Inspection of tower geometries
  - Identification of critical air gaps
- Complete 3D CAD model of the new structure
- Finite element method analysis
  - Potential distribution
  - Electric field distribution
    - Analysis of critical stresses by electric field
    - Risk analysis of the technology
- Simulation of worker in different positions
Electrical inspections: 3D CAD model

• Mannequin by IEC 62233
• Tower geometry: common Hungarian type „Ipoly-OT”
  • Critical clearances
Risk analysis

• Determination of critical arrangements (tower vs. conductor)
• Electrical potential and electric field distribution analysis of critical arrangements
  • Identification of risks and dangers
  • Increasing the safety of the work
Simulation results

Electric potential distribution

Electric field distribution
Simulation results

Electric field inside the tower window

Electric field in the vicinity of the worker
Simulation results

- Comparison of results without and with the conductor car
Electric field simulation – summary

• In case of the most critical geometries, peak value of electric field is about 55 kV/m between the energized parts and the grounded tower structure.
• Theoretical dielectric strength of air is 2000 kV/m (homogeneous electric field distribution). Practically consideration of an inhomogeneity factor of 10 (and above) is a good approximation of real working conditions.
• Based on the simulation results inhomogeneity factor is around 11 in this case (maximal values around the worker, minimal values around the tower).

Even in case of critical geometries safety factor from electrical aspect is 3.3.
Risk evaluation

- ISO 12100: Safety of machinery - General principles for design - Risk assessment and risk reduction

Step 1: identification of all hazards
Step 2: reduction of all hazards to acceptable level

**Determination of risk level**

- **Volume of damage**
- **Probability of occurrence**

Step 2: reduction of all hazards to acceptable level
Laboratory tests: first steps
Video: on-site tests
Thank you for your attention!