REALISATION OF SAFE ASSEMBLING OF MIDDLE VOLTAGE OVERHEAD POWER LINES WITH COMPOSITE INSULATORS AT CROSSING THROUGH FOREST

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Abstract: Report consider designation of dedicated equipment for safe construction of middle voltage free aerial power lines at crossing through forest. It was chosen on base of calculations, laboratory tests and functional confirmation by test in natural environment. Presented way of power lines construction with certain equipment ensures essential decrease of damages on power lines in case of extraordinary weather circumstances.

Key words: power line, dedicated equipment, laboratory research

1. INTRODUCTION

Electric distribution companies ensure users safe and uninterrupted delivery of electrical energy with centrally voltage cable and overhead power lines. There are large possibilities for worse injuries on overhead power lines against extraordinary weather circumstances where those power lines cross through forest. On Elektro Ljubljana d.d. initiative in 2003 company Izoelektro d.o.o. started developmentally research project, which goal was to reduce those damages. The purpose of the project was in advance determination of the defect points and to reduce or dispatch worse effects of damages. On the basis of analysis of damage dispatch in the area of Elektro Ljubljana d.d. in years 1998 – 2003 the equipment on which anticipated damage was to be expected has been determined. [8]. These elements have to prevent consequences of extraordinary weather conditions. The damages as:

- **Deformation of wires and SAX conductors**.
- **Deformation of insulation on SAX conductors.**
- **Insulators breakage.**
- **Cross-arms and pillars twisting.**
- **Breakage and pulling of final, suspension and tension poles.**

2. INTERNAL REGULATION

Since 1989 the below described equipment has been used in the area of Elektro Ljubljana d.d. to attach half-insulated conductors [6].

Suspension pole:

- ceramic insulator with or without spring clamp,
- pillars A1, B2,
- upper and down arcing horn,
- SAX conductor 35 ili 70 mm^2,
- suspension cross-arms,
- wooden poles in concrete clamp or concrete holder,
- concrete or steel poles.

Tension pole:

- strain composite or glass insulators,
- arc horns for composite insulators,
- universal tension clamps,
- suspension equipment for insulator strings (for single and double tension strings),
- cross-arms,
- wooden poles in concrete clamp or concrete holder,
- concrete or steel poles.

3. POWER LINE DAMAGES

From 1998 onwards there have been many damages caused by extraordinary weather conditions on overhead power lines which cross through forest. The damage was caused by felling trees, shaking-off snow, sleet and lightning. Consequently the damages on power lines occurred irrespective to equipment that was used. The most common damages are deformation of:

- insulation of SAX conductor,
- cross-arms,
- spring clamp,
- ceramic insulators and
- poles.

In the worst case, power lines collapse. The fact is, that at those collapses in most cases the conductor 35 or 70 mm2 (AlFe or PIV) remains undamaged.

Some photographs of power line alignment damages:

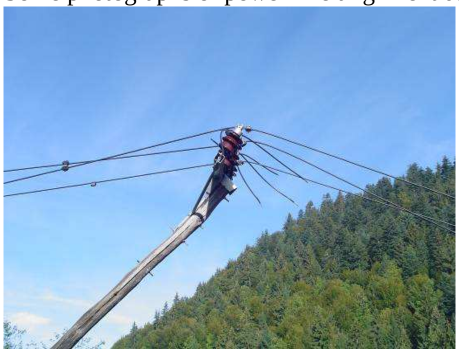

Figure 1: Suspension pole with ceramic insulators.

Figure 2: Pulled out tension pole.

4. LABORATORIAL TESTS

To find a solution IzoElektro d.o.o. performed an experiment of spring clamp collapse at which spring clamp is attached to composite line post insulator. The test was carried out in Laboratory for mechanical elements testing of IzoElektro d.o.o. company on 12th of December 2003 [9]. The aim of the test was to:

- determine the force at which spring clamp looses without causing damage on composite line post insulator, pillar or on SAX conductor,
- determine the type of weakness on spring clamp,
- determine the type of insulator.

At test performed the composite line post insulator with weakened spring clamp and belonging pillar had been used. For extraction 100 cm long parts of half-insulated conductor 70 mm^2 had been used.

4.1. The force of special spring clamp collapse

The experiments were performed on differently formed spring clamps. Collapse of special spring clamp emerges at measured horizontal extraction force of conductor F_{3mak} =3,60 kN [9]. At that force the arcing horn does not damage SAX conductor insulation. Special spring clamp must be attached to composite line post insulator, which due to elasticity, enables anticipated deformation [9]. Figure 3 shows weakness on spring clamp framework.

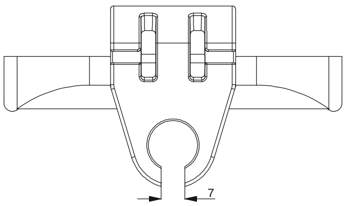

Figure 3: Laboratorial determined shape of spring clamp framework with weakness

5. EXPERIMENTAL POWER LINE

5.1. *Location - generally*

Newly constructed power line stands in the Elektro Ljubljana –control office Grosuplje area. “TP Drenik, 20 kV power line, LV part” facility – figure 11, was built in the period 27.5. – 3. 6. 2004. Before the new power line, “TP Drenik” was built the area obtained electricity from TP Brezje pri Smrjenih through LV electric wire nr. 3, which took total length of 1,2 km up to last user. Due to the length of the electric wire, increased consumption of electric energy and due to bad electric energy circumstances new transformer had to be built. In Drenik village bad electric energy circumstances were fixed by new 20 kV electric wire construction with SAX conductor and new transformer. The users in this area are existent and new tenement houses with households and farms.

To reduce or dispatch above mentioned damages laboratorial determined equipment took test in natural environment. Experimental power line has been planned as follows.

5.2. Suspension pole

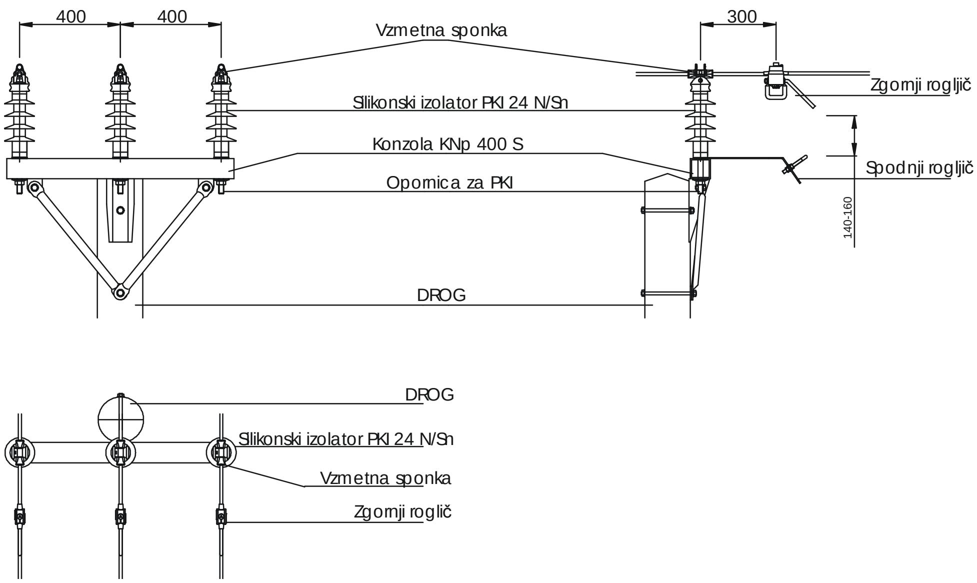

Figure 4: Suspension pole plan

With use of laboratorial determined equipment, the reduction or dispatch of damages on suspension poles is anticipated. At damages, defects should be limited only to special spring clamp that can be replaced fast and easily. To perform a test on the ground (concerning laboratorial measurements) the following items are selected:

- **composite line post insulator with special spring clamp – Figure 3 and 5,**
- **pillar PKI M20/180 – Figure 6,**
- **other equipment specified in the plan.**

Composite line post insulator PKI 24 N/Sn

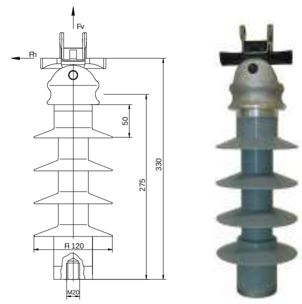

Figure 5: Technical drawing and photograph of composite line post insulator PKI 24 N/Sn with special spring clamp

Technical data of PKI 24 N/Sn type insulator

Rated voltage:	24 kV
Number of ribs:	4
Creepage distance:	493 mm
Arcing distance:	275 mm
Dry lighting impulse withstand voltage:	155 kV
Wet power frequency withstand voltage:	70 kV
Cantilever strength:	12,5 kN
Conductor horizontal pull strength:	0,8 kN
Conductor vertical pull strength:	2,8 kN
Shed material:	silicon rubber
Material of end fittings:	Al-legura
Weight:	1,8 kg

The main elements of composite line post insulator are core, silicon layer and metal connectors. As the core takes carrying function, it is so vital for insulator mechanical features. The core has a pole shape and it is made of glass fibres and special filling. It is extremely resistant to tensile and bending force activities. Withstand tension force equals withstand tension force of steel at 75 % lower weight. Insulators silicon shed is flexible and so insensitive to strikes. Mechanical damages on insulators practically do not happen during transport and set up.

Good characteristics of composite line post insulators, which are at the same time, also the advantages in comparison to ceramic or glass insulators are as follows:

- Low weight.
- Simple transport, handling and set up.
- Higher dielectric strength.
- Self cleaning.
- Higher mechanical stamina (vandalism, thermic load vault),
- Elasticity (at transverse force)
- Higher reliability of functioning.
- No maintenance costs.
- Anti – vibrator.

Pillar PKI M20/180

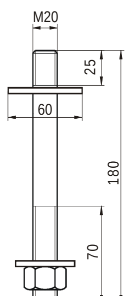

Figure 6: Pillar for composite line post insulator

5.2. Tension pole

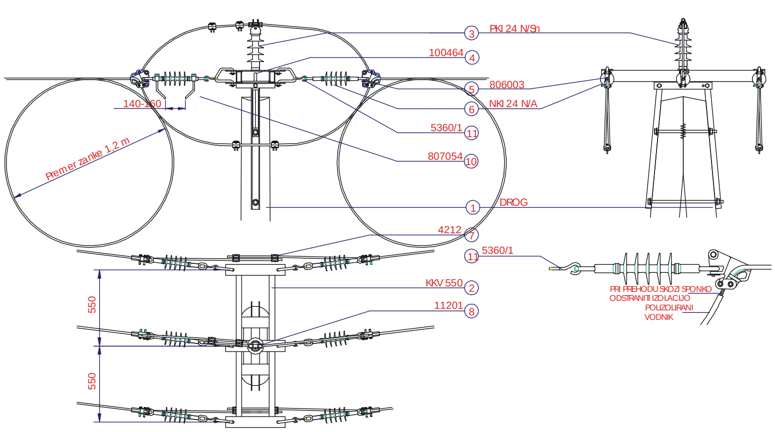

Figure 7: Plan of tension pole with safety arc

Hook with capacity of 6 kN must be built in between composite strain insulator and cross-arm holder. This part represents anticipated point of defect. In this way the collapse of cross-arms and poles is prevented. On tensile field safety arc of SAX conductor with 1,2 m diameter is implemented. To fix safety arc plastic tie of 3 mm width is used. In natural environment test based upon calculations and laboratorial measurements the following equipment and methods were used:

- strain insulator NKI 24 N/A
- safety arc with 1,2 m diameter on each phase,
- hook with 6 kN capacity,
- other equipment specified in the plan.

Composite strain insulator type NKI 24 N/A

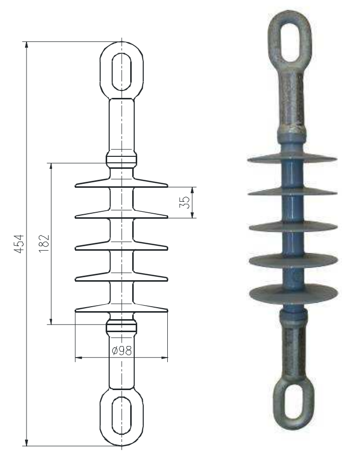

Figure 8: Technical drawing and photography of composite strain insulator type NKI 24 N/A

Technical data of insulator type NKI 24 N/A:

Rated voltage:	24 kV
Number of ribs:	5
Creepage distance:	520 mm
Arcing distance:	230 mm
Dry lighting impulse withstand voltage:	155 kV
Wet power frequency withstand voltage:	60 kV
Breaking tensile strength:	80 kN
Shed material:	silicon rubber
Material of end fittings:	Hot deep galvanized steel
Weight:	1,0 kg

Safety arc

Calculation of safety arc_diameter was made without data for exactly determined extension. Instead, the average data for extension on 20 kV power line was used. At determination, we used general formula for sag calculation at same heights of poles. For exact calculation of conductor length, we would have to use formula for sag calculation at different heights of poles as well as data for exactly determined extension. On basis of simplified calculation the average diameter of safety arc has been determined, which is 1,2 m – figure 7 [8].

Hook

Hook has been used as safety fuse between G–bolt and composite strain insulator (Figure 9).

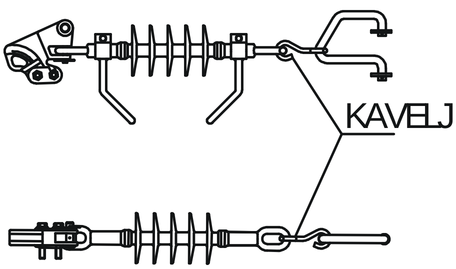

Figure 9: Position of hook (figure 7 detail)

Measures and technical data of hook

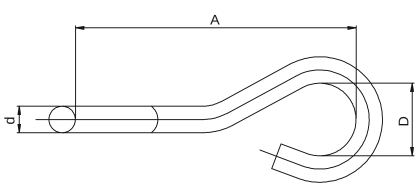

Figure 10: Hook turned for 90°

A……………	80 mm
D……………	22 mm
d…………….	10 mm

The maximum load of the hook is 6 kN.

6. ANTICIPATIONS BEFORE TESTING

After tree, falling on power line SAX conductors 20 kV the following is expected:

- SAX conductor in special spring clamp would be pulled out,
- elastic deformation of composite line post insulator,
- long term deformation at the point where arc horn hits the special spring clamp,
- safety arc of SAX conductor would unroll,
- long-term hook deformation.

Extension of conductor on other suspension poles will be enabled by spring clamp. Tree is going to pull SAX conductors all the way to the ground. Conductors and other equipment are going to stay undamaged. To establish primary conditions conductors will have to be strained again. As well, hooks and special spring clamps with riders will have to be replaced.

7. TEST IN NATURAL ENVIRONMENT

Test in natural environment with fallen tree was carried out on 24th of September in 2004. For testing, we used tree between pole nb. 6 – tension A pole and pole nb. 7 – suspension pole. The tree was closer to tension pole. Diameter of the tree in lower area was 75 cm and it was 30 m high. It stood 7 m away from alignment.

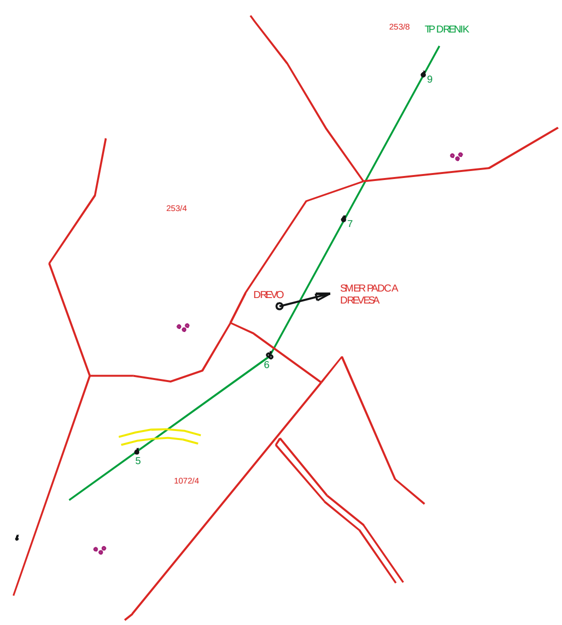

Figure 11: Position of the tree regarding to power line.

7.1. *Course of test*

As anticipated, at tree fall composite line post insulators compensated first thrust due to their elasticity. After that special spring clamp on composite line post insulator (which was built in tension pole) gave in and so disabled tearing of conductor as well as defects on half-insulated conductor insulation. Because of big force safety hooks on tension pole gave in which caused the extension of safety arc.

Damages:

Figure 12: Special spring clamp after test carried out

Hook:

Figure 13: Straightened hook after test carried out.

When damages on poles were surveyed, it was observed that poles and cross-arms remained unharmed. Only special spring clamp on composite line post insulator and safety hooks on tension poles would have to be replaced. Poles nb. 6 and nb. 7 were 6^o out of vertical position.

Figure 14: Undamaged tension pole.

Points of destruction:

- Special spring clamp.
- Hook.
- Safety arc with plastic tie.

8. CONCLUSION

8.1. Technical part

Test in natural environment has confirmed the calculations and experiments carried out in laboratory. Safe operating of power lines that cross through forests is ensured by following:

- **Standard equipment for power line building with no regard to type of conductor.**
- **Composite line post insulator with special spring clamp.**
- **Hook.**
- **Safety arc with plastic tie.**

8.2. Economic part

The price of new elements regarding to standard building presents less than 1% of the costs of attach equipment for conductors. On basis of time spent for repair of tested power line it is possible to say that repairs of damages will take more than 80 % time less. Except for safety elements, other equipment after damages does not have to be replaced.

Building of power lines that cross through forest with insulators made of composite material and with anticipated points of destruction is justified technically and economically.

REFERENCES

[1] Plaper M., Električna omrežja II, Založba FE, Ljubljana, 1976

[2] Članek – S. Vižintin: Uporaba kompozitnih izolatorjev za nadzemne vode, 1997.

[3] M. J. Owen, Silicone Polymers for High-Voltage Insulators, Rubber World, Vol. 217, št. 3, jan 1998.

[4] Vižintin S., Električno in mehansko dimenzioniranje podpornih kompozitnih izolatorjev za SN nadzemne vode, jun. 2001

[5] Kompozitni izolatorji, IzoElektro d. o. o., Jan. 2004-10-28.

[6] Elektro Ljubljana d. d., Tipizacija daljnovodov DV 20 kV z polizoliranimi (PIV) vodniki na lesenih drogovih, marec 1998.

[7] Elektro Ljubljana d. d., Projektna dokumentacija – TP DRENIK, 20 kV vod in NN razvod, december 2002.

[8] Stane Vižintin, Stane Rozman, Boris Sterle, Marjan Drolc, Jože Hrastnik: - Poročilo o izvedbi varne montaže PIV vodnika na 20 kV DV s kompozitnimi izolatorji na prehodu skozi gozd, oktober 2004.

[9] Jože Hrastnik, Peter Osterveršnik: - Določitev porušitvene sile na vzmetni sponki podpornega kompozitnega izolatorja PKI 24 L/S-M20, 19. 12 .2003.