MEĐUNARODNO REGIONALNO SAVETOVANJE O ELEKTRODISTRIBUTIVNIM MREŽAMA

REGIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION

Crna Gora, Herceg Novi, 5 - 8. oktobar 2004. / ***Montenegro, Herceg Novi, October 5 - 8, 2004***
* *

HELICOPTER INSPECTION OF HIGH - VOLTAGE AND MEDIUM - VOLTAGE POWER LINES

R. Glavič, Elektro Ljubljana d.d., Slovenska 58, 1000 Ljubljana, Slovenija

INTRODUCTION

After opening the electricity market, and after making the market-associated changes and after new requirements for having the lowest possible quantities of unsupplied electricity have been imposed, it is necessary to use new measuring and diagnostic methods for fault detection when inspecting and maintaining high-voltage and medium-voltage lines. These methods will contribute to high-quality maintenance and earlier defect detection. They should exclude subjective factors, which depended on individual fitters (their conscientiousness, preciseness, specialised knowledge, observation skill levels, etc.) in carrying out previous inspections of power transmission lines.
According to technical regulations governing operation and maintenance of power installations, power transmission lines should be inspected twice a year. Power transmission lines should be in operation during inspection. The inspection norm is 4 km per hour. Revisions are made once a year. The revision norm is 1 km per hour. Glavič (1). When making revision, the power transmission line should be put out of operation. The visible defects on joining elements, insulators, conductors, etc. are detected by climbing pylon bars. However, internal defects, such as overheating, partial discharges and corona, cannot be detected during such inspection. For that very reason, some faults may occur after a certain time. Moreover, they may cause electricity to be unsupplied for many hours.
There is a need for rationalizing the times of putting transmission lines out of operation. Therefore, helicopter-aided inspection of transmission lines is one of the methods, which does not require the transmission to be put out of circuit. By using a helicopter, you can carry out:
- video inspection,
- laser scanning,
- thermographic inspection,
- corona inspection.

PREPARING THE PROJECT

In order to prepare and perform inspections by using a helicopter, the customer must collect the following data on power transmission lines:

- transmission line route plans, which show the route course and the tower numbers, marked with tower or route coordinates in GPS system or there are Gauss-Krueger coordinates that are used in most Geographic Information Systems (GIS),
- data on maximum permissible loads on transmission lines, cross-sections of current conductors, transmission line age, and voltage levels, at which thermographic inspection needs to be conducted. In the event that there is a difference between permissible loads in summer and in winter, these data need to be given as well.

VIDEO INSPECTION

Video inspection provides faster, more accurate and overall inspection (also in hard-to-access places) of transmission line routes and their components.
The helicopter crew consists of a pilot, co-pilot and operator.
The inspection is carried out by using a high-resolution video camera.
When conducting a video inspection, the following objects are recorded:
- tower bases,
- tower / pylon constructions,
- insulators,
- current conductors.

Maximum video inspection speed must not exceed 10 km per hour at a distance of 10 to 15 m from the 110 kV line. The operator shoots the transmission line route and each tower separately by using a stable camera with 24-time zoom lens. Each video recording has GPS data, which deviate from the actual state by 10 to 15 m, depending on the flight distance.
Video inspection report includes:
- DVD-video recording of the entire route with synchronised GPS information,
- short video films about the sections (with GPS data), where mechanical damage or defects on conductors, protective wires, insulators, towers were detected,
- photographs indicating anomalies and having GPS data or Gauss-Krueger coordinates.

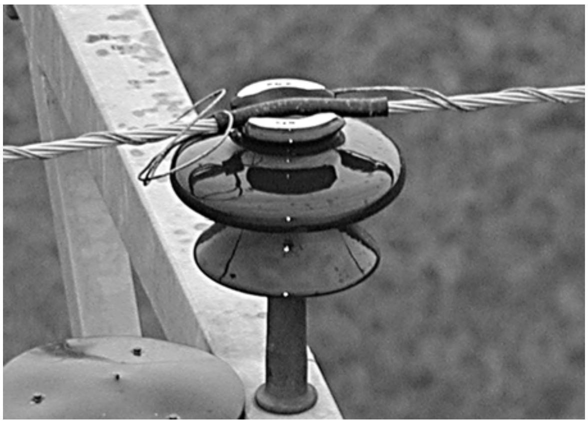

FIGURE 1 - ANOMALY DETECTED BY VIDEO INSPECTION

LASER SCANNING OF POWER TRANSMISSION LINES

Laser scanning of power transmission lines is intended for:
- ascertaining the actual conditions along the route of transmission lines,
- producing a database,
- determining the geometrical and geodetic parameters,
- displaying the parameters, deviating from the values in design documentation,
- determining the level of overgrowing vegetation and displaying the critical spots.

Laser scanning is based on a combination of laser technology, modern navigation and positioning technologies, and also high-resolution digital photography.
The helicopter crew consists of a pilot, co-pilot and operator.
The helicopter flying speed is 40 km per hour. The flying height is 250 m above the ground. The laser device is capable of determining the distances to objects on the path of a laser ray with an accuracy of

10 to 20 cm. It is about the registration of the first and last reflections of a laser ray and about determining the distance between them. The first reflection belongs to the object, which is nearest to the transmitter. The last reflection, however, belongs to the object, which is an absolute barrier to the laser ray (the ground, roof, buildings, etc.). When scanning the forest terrain, the laser image shows both reflections: the reflection from the ground and a partial reflection from vegetation. By using special software, the points referring to the vegetation are eliminated and only the ground relief remains.
The report on laser scanning of power transmission lines includes:
- geodetic coordinates of towers,
- transmission line angles,
- distances between towers,
- a list of intersection types,
- distances between the lower wires and the ground or objects,
- absolute height of points of fastening the phase wires and lightening conductor;
- bends measured in conductors, and bends calculated according to additional load,
- data on vegetation and gradation in height.
The data, obtained by means of laser scanning, provide quick designing of new transmission lines. The data are also extremely useful for the maintenance of the existing transmission lines.

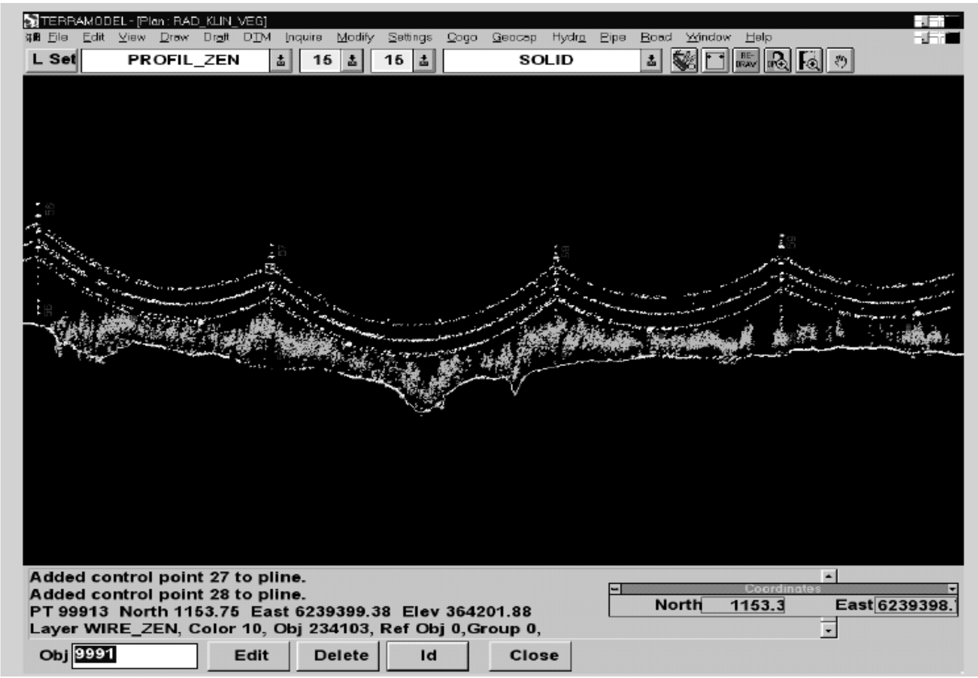

FIGURE 2 - LASER IMAGE SHOWING VEGETATION

THERMOGRAPHIC INSPECTION

Overheating in certain spots of the transmission line might be caused by poor contacts, damaged current conductors, damaged and poor materials, oxidation, etc. Such spots primarily depend on load. Therefore, they are critical regarding fault occurrence. Up until now these spots have not been detected before the actual fault occurrence. The faults cause large amounts of electricity to be unsupplied, and additional costs.
The thermovision method for defect detection is based on the principle of measuring infrared radiation within the range between 5 and 13 μm. The camera for monitoring the radiation of electric power devices measures the radiation in the range of infrared light with a wavelength between 8 μm and 13 μm, because the radiation in a wavelength between 5 μm and 8 μm gives no accurate results due to excessive external impacts.
The requirements for carrying out thermographic inspection: loading the conductor with at least a 30 percent nominal load.
In order to achieve even better results, it is recommended to have:
- cool atmosphere,

- cloudy weather,
- minimum wind,
- low relative humidity.

The overheated spots can be detected on poor current conductors, current connections, terminals, etc.

The helicopter crew consists of a pilot, co-pilot and operator.

The helicopter flying speed is 25 km per hour at a distance of 20 to 25 m from the conductor. The entire route with GPS data is recorded with a thermocamera, having a 20° x 13° wide-angle lens and a 0.6 mrad field of view. Digital photograph camera has an automatic temperature scale, from which all deviations can be read out.

The route data are stored on a laptop computer.

The spot overheated above 30°C at 50% load is considered as a fault. The helicopter slows down and circles above the location of the fault in order to enable the camera to record the area with a narrow angle 5° x 3.3° lens and a 0.15 mrad field of view. This provides a zoomed view of the overheated spot and its location. The area is photographed in one-second intervals.

After the flight, the recorded data are processed by means of the program, given by the equipment manufacturer.

The overall inspection report includes:
- temperature values of overheated spots,
- thermographic report on the actual conductor load,
- thermographic report and analysis of defects at a 100% conductor load,
- a compact disc with report content and the program for viewing the report,
- a video cassette with recorded route.

The thermographic report shows actual conductor loads and the location of the fault in video and infrared images. The images have the date and the time of recording, the parameters of the atmosphere; the distance, from which the pictures were taken; emissive power of the material the elements are made of; conductor load.

The thermographic report and analysis of defects at a 100% conductor load theoretically show the status of the location of defects at a 100% conductor load, where the necessity of eliminating the defects is seen.

CORONA INSPECTION

The corona effect is caused by:
- pollution,
- damaged clips,
- loose bolts and joints,
- damaged insulators,
- incorrect installation,
- poor earthing connections,
- sharp edges.

Due to the factors listed above, a high electric field is created. It ionises the air. The consequence of the increased air ionisation is discharge called corona.

Corona causes
- noise,
- radio and TV interferences,
- mechanical damage to components,
- accelerated corrosion of components,
- decomposition of polymer insulators,
- corrosion of cement and metal caps of porcelain insulators.

Corona depends on voltage and not on conductor load.

Corona is accompanied by UV radiation within the range of 230 mm to 405 mm. The measurement of the entire UV radiation spectrum can be conducted in the field only at night. Since also the sunlight consists of UV radiation, it would distort the measurements during the day.

The sunlight radiation has no impact within the range of 240 mm to 280 mm, because it is absorbed by the ozone layer. Therefore, it is possible to measure corona in this range also during the day.

The helicopter crew consists of a pilot, co-pilot and operator.

The helicopter flying speed is 25 km per hour at a distance of 20 to 25 m from the conductor. When the operator detects corona, the helicopter slows down and the operator records corona with a digital camera, having 14-time zoom lens to achieve an accurate photograph of the corona source.

The measurement is carried out by a camera, which has an additional OFIL filter (2). The field of view is 5° horizontally and 3.5° vertically. Camera view range is 150 m. The camera consists of UV and visible channels with automatic focus. The UV channel detects corona. The visible channel, having GPS coordinates, ascertains the location of corona source. The camera detects the corona size of 30 pC at a distance of 6 m or 100 pC at a distance of 50 m.
There is a report on the overall inspection of the route. The report includes video image data on the route and photographs of coronas with GPS coordinates.

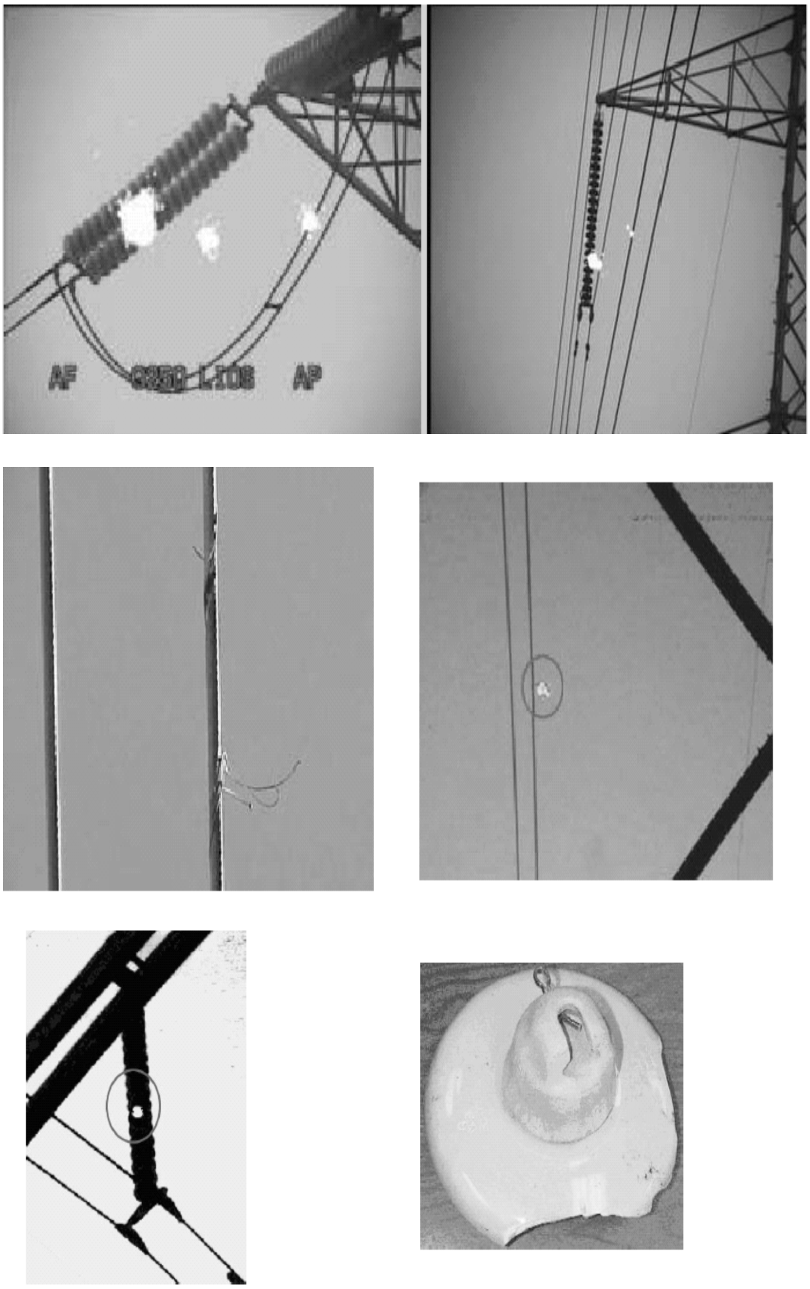

FIGURE 6 - DEFECTS DETECTED BY CORONA INSPECTION

REPORT ON THERMOGRAPHIC AND CORONA INSPECTIONS MADE IN ELEKTRO LJUBLJANA REGION IN 2003

Thermographic inspections

The following transmission lines were inspected in the Elektro Ljubljana region in 2003:

- Nineteen 110 kV transmission lines, having an overall length of 210,3 km, were inspected. 14 overheated spots on connecting terminals and one overheated spot on a current conductor were detected,
- Four 35 kV transmission lines, having an overall length of 61,2 km, were inspected. One overheated spot on a connecting terminal was detected,
- Twelve 20 kV transmission lines, having an overall length of 213,3 km, were inspected. 15 overheated spots on connecting terminals and 3 overheated spots on path switches were detected,
- Twenty-six 110/x kV distribution and transformer stations (DTS) were inspected. 9 overheated spots on junctions of measuring current transformers and 3 overheated spots on junctions of 20 kV busbars were detected,
- Fifteen 20 kV distribution stations were inspected. A fault was detected on the connecting terminal in a cell.

The inspections have shown that there are 7,1 faults per 100 km line at the 110 kV level; there are 1,.6 faults per 100 km line at the 35 kV level; and there are 7,5 faults per 100 km line at the 20 kV level. Bernard (3).There are also 0,46 faults in DTS and 0,07 faults in distribution stations. Bonča (4).

Corona inspections

The following transmission lines were inspected in the Elektro Ljubljana region in 2003:
- fifteen 110 kV transmission lines, having an overall length of 125,8 km, were inspected. 12 defects were detected on insulators,
- fourteen 35 kV transmission lines, having an overall length of 59,9 km, were inspected. Three defects were detected on insulators, and two defects on path switches,
- eight 20 kV transmission lines, having an overall length of 157,4 km, were inspected. 10 defects were detected on insulators,
- sixteen 110/x kV distribution and transformer stations (DTS) were inspected. 4 defects on insulators and 7 defects on sharp edges of screw couplers, mounted on the current conductor, were detected.

The inspections have shown that there are 9,5 defects per 100 km line at the 110 kV level; there are 8,3 defects per 100 km line at the 35 kV level; and there are 6,3 defects per 100 km line at the 20 kV level. (3). There are also 0,42 faults in DTS (4).

ANALYSIS OF THERMOGRAPHIC AND CORONA INSPECTIONS MADE IN ELEKTRO LJUBLJANA REGION IN 2003

Thermographic inspection analysis has shown that defects on compression terminals arise due to:
- insufficient force, used in making a junction,
- the presence of dirt.

Defects on measuring transformer junctions and on cable terminals arise due to inadequate dimensions of junction elements.

Corona inspection analysis has shown that defects arise:
- on all sharp-edged parts of high-voltage equipment due to current conductor's non-uniform cut in making a junction; the cut needs more precise treatment,
- on bolted connections due to the bolts of various lengths,
- on current conductors, because single wires are damaged.

COST COMPARISON

For carrying out inspections and revisions of transmission lines, having an overall length of 3840 km in the Elektro Ljubljana region, we spend approximately 19200 hours per year on them, which cost around 77 million SIT. By using a helicopter and for this amount of money the inspection of 1800 km of lines would have been carried out faster and with greater precision. Also the inspections would not be necessary every year.

Thanks to diagnostics, we could carry out thermovision and corona inspections once in a five-year period or more.

By using the classical method of inspections over a five-year period we would spend around 385 million SIT and by using a helicopter, we would spend 325 million SIT.

CONCLUSION

The need for introducing the new methods for ascertaining the condition of transmission lines is increasingly greater due to urgent requirements for reducing the amounts of unsupplied electricity. Staff reduction in inspectorates also forces us to do so. By using the above-mentioned methods, the inspections are carried out faster and more accurately. There is no need for transmission lines to be in voltage-free condition, when they are inspected. The existing IR technology has been upgraded with UV technology. IR technology enables us to detect defects, caused by high resistance. UV technology allows us to detect defects that are yet in formation process.
It would be necessary to select the inspections and the frequency for carrying them out. Some inspections could be combined, i.e. thermographic and video inspections or corona and video inspections could be conducted simultaneously. By having accurate photographs of transmission line routes, we could produce a database for ensuring more precise planning, monitoring the chronology of events, ascertaining the material quality in order to increase reliability of transmission lines.

LITERATURE USED

1. Glavič R, 1994, “Standards for performing maintenance work in electric distribution system at Elektro Ljubljana”, “Power devices maintenance in electric power distribution system, Sloko CIGRE Consultation”
2. Prospekt OFIL Ltd.DayCorII, 2001,”The most Advanced Daytime Corona Imager”
3. Bernard R, 2003, “Record of undertaking work under Contract No. 11/03 referring to thermographic and corona inspections of transmission lines in Elektro Ljubljana region in 2003” “Flaycom, d.o.o., Žirovnica”
4. Bonča T, 2003, “Report on thermographic and corona inspections of DTS and DS in 2003” “High-voltage equipment maintenance department, Elektro Ljubljana”