# APPLICATIONS OF THE MODERN TECHNOLOGIES IN PREVENTIVE MAINTENANCE ON EQUIPMENT IN THE TPG

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**Abstract – This paper presents modern methods that are applied in preventive maintenance of equipment in the Transmission Power Grid. Such methods use special techniques and technologies. It also shows the necessities to applying these technologies in the company and methods for the preparation of the preventive maintenance. This paper will present methods to improve the operating process and increase the quality of services provided by maintenance contractors in high-voltage electrical installations.**

**Keywords:** maintenance, live work, multispectral inspection, electrical network.

## 1. INTRODUCTION

It is well known about the importance of preventive maintenance for high voltage equipments. The efficiency of these maintenance services depends on several factors like correctly applied technologies, costs and training human operators.

The technologies used in maintenance are different. Choosing a technology can be done according to several criteria, such as:

- The parameters of electrical equipments;
- Operating costs of the equipments in terms of organizing maintenance services;
- Operational behaviour of the electrical equipments;
- Importance of those electrical equipments in electrical power grid / power system;
- Risks of applying the technology;
- Costs of the technologies;
- Efficiencies of the technology applied (in technical terms);
- Preparation of human operators and environmental conditions during execution.

Applying conventional technologies, which require the withdrawal from service of the electrical equipments, can lead in some cases to economic losses and decrease operational safety of power grid / power grid area to which it belongs. So, if the application of other technologies are met the other criteria listed above, the efficiency of maintenance will increase.

## 2. MAINTENANCE TECHNOLOGIES

In the maintenance of electrical installations can be applied other technologies, in addition to the classics, such as:

- Multispectral inspection – in spectrum infrared, ultraviolet, visible, audible, laser;
- Live working - live work stick method, Glove and Barrier method, Bare-hand method;
- Monitoring systems.

The preparation and application of those technologies, involve both beneficiary and executants in a more efficient organization, which are based on:

- Statistical data of operational behavior and technical analysis of efficiency of the new solutions;
- Technical analysis for choosing of correct technologies, based on software like GIS, simulation programs, etc.

In electrical installations in the transmission power grid and the management equipment belonging to the distribution power grid those technologies has been applied.

The infrared inspection technologies were used for the following purposes:

- Inspections of overhead transmission lines OHTL in case of the failures;
- Major maintenance for OHTL;
- Site acceptance of investment for OHTL;
- Inspections of equipments in substations in case of the failures;
- Periodic inspections of the substation's equipments;
- Acceptance of minor maintenance of the electrical substation equipments (circuit breakers, disconnectors, measurement transformers, equipment connections and clamps for busbars, chains of the insulators and clamps, power transformers, etc.);
- Acceptance of major maintenance of equipments from substations;
- Monitoring the operating behaviours of power transformers;
- Inspections of cables connections and equipments for auxiliary services, in case of the failures;
- Inspections of medium voltage substation's equipments;
- Determine the condition of in-service equipments for perform analyzes;
- Monitoring the behaviours of new power plants / experimental equipments.

Infrared inspection technologies were archives by using air crafts (helicopters, drones), with hand apparatus, from the ground (in stations and electric lines), or by climbing the tower (on electric line).

Ultraviolet inspection technologies were used for the following purposes:

- Periodic inspections of OHTL;
- Acceptance of major maintenance on OHTL;
- Site acceptance of investment in OHTL,
- Acceptance of minor maintenance, major maintenance and investment in power stations (equipment connections to busbars, busbars, insulators, etc.);
- Monitoring the behaviours of new power plants / experimental equipments.

Ultraviolet inspection technologies were archives by using air crafts (helicopters, drones) and with hand apparatus, from the ground.

Visible inspection technologies were used for the following purposes:

- Inspections of OHTL in case of the failures;
- Acceptance of major maintenance on OHTL;
- Site acceptance of investment in OHTL;
- Periodic inspections of the substation's equipments;
- Monitoring the behaviours of OHTL;
- Determine the condition of in-service equipments for perform analyzes.

Inspection technologies in visible spectrum has made by air crafts (helicopters, drones).

Audible spectrum inspection technologies were used for the following purposes:

- Inspections of power transformers in case of some failures;
- Acceptance of major maintenance to power transformers;
- Monitoring the operating behaviors of power transformers.

Inspection technologies in audible spectrum were made from the ground.

Laser inspection technologies were used for the following purposes:

- Inspections of OHTL;
- Acceptance of major maintenance on OHTL;
- Site acceptance of investment in OHTL;
- Inspections of the substation's equipments.

Laser inspection technologies were conducted using aircraft and ground.

The Live Working technologies have been used for the following purposes:

- Corrective maintenance on OHTL;
- Minor maintenance of OHTL;
- Major maintenance of OHTL;
- Corrective maintenance of substations equipments (disconnectors, busbars, etc.);
- Minor maintenance of substations equipments (disconnectors, busbars, etc.).

Live working technologies applied by the Maintenance Company. The technologies, approved by the Live Working Association in Romania ALSTR, are:

- Corrective maintenance on active conductors of OHTL by using ergonomic seat or electrical insulated ladder;
- Corrective maintenance on active conductors of OHTL by using metal ladder or elevating platform truck with insulating arm;
- Changing the insulators of suspension towers on OHTL;
- Preparation and application of protective layer on metal poles, to the crown of tower;
- Checking with live working technologies of the insulating column of disconnectors;
- Replacing the suspension hooks of insulator chains;
- Replacing the insulator chains of busbars in substations with live working technologies;
- Mounting the lighting day and night systems, with live working technologies;
- Mounting the superior protection rings of insulator chains;
- Mounting the monitoring systems of OHTL, with live working technologies;
- Replacement the suspension clamps and mounting the dampers on the conductors of OHTL;
- Replacing the anchor of the suspension anchored towers SAT;
- Replacing from helicopter the dampers and lighting day;
- Technical revision of disconnectors.

## 3. IMPLEMENTATION OF TECHNOLOGIES

By applying the maintenance modern technologies in electrical installations aims to increase the efficiency of maintenance and operating activities and lower costs for the customer.

Below we list some works which used the technologies mentioned in the previous chapter.

The purpose of multispectral inspections is: gather more details about the electrical installations, creating a database and acceptance the maintenance (major and minor) or investments.

The goal of multispectral inspections was to collect information and creating databases for all overhead lines in TPG.

Fig. 1 shows the visible spectrum image of OHTL, which help to obtained background information about the tower in question. The image was made from a helicopter. For a database of all towers of OHTL all other information has been obtained in the same way.

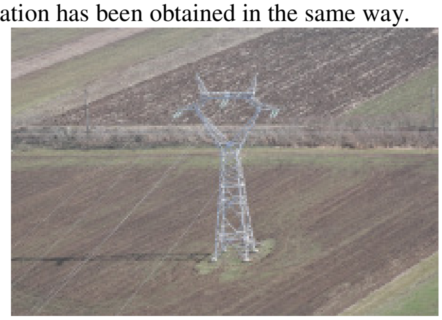


**Fig. 1. An overview from the multispectral inspection of tower of OHTL is shown in the visible spectrum [1].**

**Fig. 2. An overview from the multispectral inspection of crown tower of OHTL is shown in the ultraviolet spectrum [1].**

Fig. 2 shows the ultraviolet image of tower of OHTL, through which information has been obtained about the conductors. The image was made from a helicopter. For a database of all towers of OHTL all other information has been obtained in the same way.

Fig. 3 shows the infrared image of tower of OHTL, through which information has been obtained about the connections between the components of the electric line.

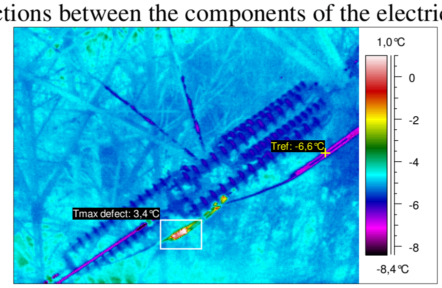
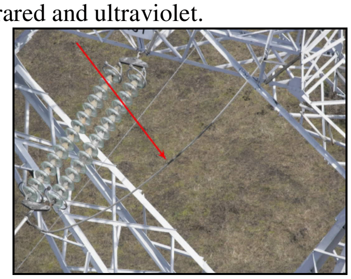


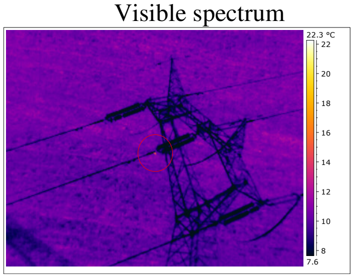

**Fig. 3. An overview from the multispectral inspection of crown tower of OHTL is shown in the infrared spectrum [1].**

At the final of major maintenance of each OHTL, the multispectral inspections were carried out for acceptance.

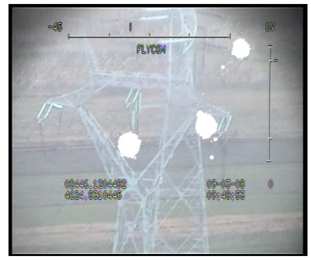
In Fig. 4 are shown images from nonconformities found during the multispectral inspection in the 3 spectra: visible, infrared and ultraviolet.



Visible spectrum



Infrared spectrum



Ultraviolet spectrum

**Fig. 4. The images captured in the multispectral inspection for acceptance of major maintenance of OHTL [1].**

The same methods (multispectral inspection) have been applied to acceptance of maintenance at substations.

Fig. 5 shows the infrared image of a high voltage measure transformer, were nonconformity is visible at clamps in left part to OHTL.

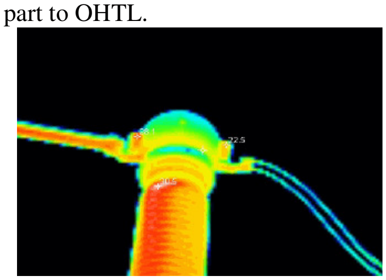


**Fig. 5. Infrared view of a 400 kV measure current transformer was taken during the multispectral inspection in a substation.**

The laser inspections were performed to obtain detailed information, creating the databases and acceptance of major maintenance on electrical equipments. Pilot project was done for both a transmission line of 220 kV and a substation. The inspection of 220 kV OHTL was made by a plane and the inspection of station was made from ground.

Fig. 6 shows how to perform laser inspection with the helicopter.

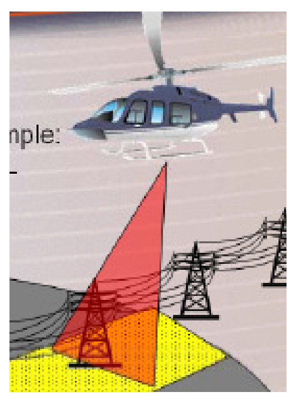


**Fig. 6. Laser inspection used in the substation and OHTL [2].**

To have a complete database of information is necessary to supplement data from: monitoring systems and information processing, maintenance, operations, multispectral inspection, monitoring systems and works with modern technologies.

The monitoring systems were installed for power transformers on rehabilitated / renewable works. A pilot project was implemented in substation 400/110 kV to monitor the primary and secondary equipment.

Also a pilot project was implemented for installing a temperature monitoring system for active conductor of a 220 kV OHTL. This system is shown in Fig. 7.

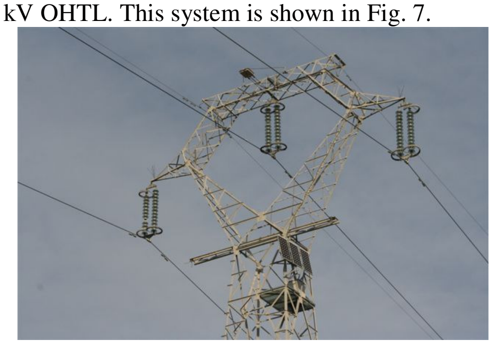


**Fig. 7. Monitoring system on OHTL is shown [3].**

A part of multispectral inspection data and GIS system was transpose on a Google Earth map. This mixture is shown in Fig. 8.

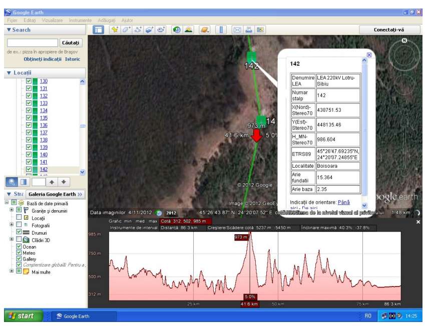


**Fig. 8. Multispectral inspection data transpose in Google Earth [4, 5].**

The data obtained by different methods (inspection, monitoring, etc.) were processed to obtain more information about the power losses in TPG.

For this purpose we used data from SCADA, the data from measuring system and the data from monitoring systems. This data was use together with the simulation method of OHL, estimation method of active power losses, estimation method of power reactive losses and corona losses (EdF method supplemented by Russian VNIIE and forecast meteorological data, predicted by computer program COSMO [6]):

$$P = K * P_n(E_{MED}/E_{critic}, m) \qquad (1)$$

where,

$K=(n\ r_{conductor})*(2{,}52-\log_{10}r_{echivalent})*(\log_{10}\rho-\log_{10}r_{echivalent})\ /\ (2{,}52-\log_{10}\rho)$

$\rho$ - the radius spatial load [cm]

$r_{echivalent}$ - the equivalence radius of fascicle [cm]

$E_{critic}$ - the critical field [kV/cm]

m - the status coefficient of conductor's surface

[6]

The inspection of power transformers was performed in additional by verification in audible spectrum, which verifies the behaviour of mechanical components.

The live working technologies were applied both to maintenance of 220-400kV OTHL and substation's equipments.

In Fig. 9 are presents a live working method. Live working technologies have been applied to preventive and corrective maintenance (replacement of insulation, removal of foreign bodies, technical inspection canopy, etc.) and major maintenance (replacement clamps, replacement anchors, protective coatings metal elements, and so on).

**Fig. 9. Live working method – bare-hand method use insulating arm elevating platform truck with insulating arm, presented by SC SMART SA [7].**

## 5. CONCLUSION

By applying modern technologies were obtained:

- Increase operational safety of the TPG;
- Decrease the operational costs;
- Decrease the maintenance costs;
- Reduce the power losses;
- Increase efficiency of maintenance and operations.

The application of these technologies and methods will be extended to other facilities and will be used with high priority in the maintenance and operation of electrical installations.

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