Bulletin of the *Transilvania* University of Braşov • Vol. 10 (59) No. 2 - 2017
Series I: Engineering Sciences

RESEARCH FOR OVERHEAD POWER LINES MONITORING

A. LASCU[1] D. STOIA[1] B. GHIȚĂ[1]

Abstract: *Quick troubleshooting of overhead electric power lines is an important objective of the electrical system management. In this paper the authors have analyzed the non-conformities in the overhead power lines in a distinct area of the energy system, was determined the percentage of non-conformities and the causes that generated them. Starting from these non-conformities the authors proposed a monitoring system that includes the analysis of each of the factors which contribute to defects and to meet the requirements imposed by overhead electrical line managers.*

Key words: *electrical system, video monitoring, power lines.*

1. Introduction

Overhead power lines are basic components of electrical systems around the world. Transport and distribution of electricity from generating systems to consumers depends directly on the safety of their operation. Components of overhead power lines are exposed to environmental factors (humidity, the wind, extreme temperatures, atmospheric discharges, floods, landslides, uncontrolled vegetation growth in active areas and so on.). In addition, due to the extensive geographic areas on which they are distributed, may be subjected to negative actions such as sabotage, theft of materials or illegal activities in the security zone [7].

Early identification of nonconformities can be done by implementing monitoring systems in their structure and have as consequence semnificative reducing the factors with negative influences on overhead power lines and implicitly to ensure the operational safety [9]. Prestigious world organizations such as CIGRE (Conseil International des Grands Réseaux Électriques) or EPRI (Electric Power Research Institute), do intensive research on this subject [14].

This article is the result of research carried out in a distinct area of the energy system, is based on real elements, taken over by the author, following incidents and damages, in which were involved high-voltage power lines of 400 kV and 220 kV, completed with topical theoretical aspects taken from specialty literature. The overhead power lines are not identical, especially due to the development of the projects for their construction, in the distinct politico-economic situation. Consequently, the applicability of a monitoring system must be assessed according to the individual characteristics of each line. The upward trend in the number of incidents, failures and downtime in recent years, has been the main reason for addressing this issue [15]. Starting from real causes and individual

---

[1] Centre "Advanced Electrical Systems", *Transilvania* University of Braşov.

features, solutions are being sought to reduce the number of nonconformities in overhead power lines by analyzing data from monitoring systems and possibly expanding them. For each type of non-compliance will be identified the elements which will be subject to monitoring, data and the possibilities of acquiring them.

Taking into account the current dynamics in the development of electronics, communication systems and in particular hardware/software elements, designing a performance monitoring system is an achievable and feasible goal over time.

An important objective to be pursued by the management of electrical systems is the conversion of classical electrical networks in smart grids [12]. Until the total replacement of classical networks with modern smart grids, ensuring the quality of electricity is made by monitoring systems with data acquisition. Designing the structure of a complete monitoring system was a challenge for researchers in the field of electrical engineering from folowing resons respectively due to operation in the external environment, due to the criteria imposed by the electromagnetic compatibility and the extensive geographical areas occupied by the overhead power lines.

Overhead lines studied are older than 40 years and the upward trend in the number of incidents and accidents in recent years (Table I), is closely related to their age.

In Table 1 has synthesized the evolution of defects on the electric power lines, in the period 2011 - 2016 for the studied network area.

The development of the defects on the lines Table 1

	2011	2012	2013	2014	2015	2016
Persistent fault	7	7	4	3	8	10
Resolved by auto -recloser	37	15	39	41	30	44
Total	44	22	43	44	38	54

In Table 2 are presented the causes of the defects, the affected elements, the duration of unavailability of an area in the National Energy System in 2016. It is worth mentioning that the long periods of unavailability make the biggest financial losses and the causes have to be drastically reduced.

Causes, affected items, percentage, unavailability Table 2

	Causes	Affected items	Percentage [%]	Out of order [h]
1	Vegetation, sag	Conductors	55	26
2	Structural defects, metal corrosion , cracked foundations	Conductors, line tower	20	590
3	Overvoltage caused by lightning strikes	Conductors, insulators, arresters	10	12
4	Sabotage, theft of materials	Conductors line tower	5	280
5	Nests of birds	Conductors, insulators	5	21
6	Broken insulator	Conductors, insulators	5	17
7	Heated connector	Conductors	2	8

It can be noticed that the greatest length of unavailability time is recorded in the case of structural defects (590 h) followed by sabotage, theft of materials, especially at the metalized parts where corrosion occurs and the most common causes are vegetation and sag (55%).

The authors will analyse the most important factors that contribute to the appearance of defects on the power transport lines such as vegetation, sag of conductors or structural defects.

2. Vegetation, Sag of Conductors

Vegetation that is found on the route of overhead power lines produces a significant number of failures (typically single-phase shorts). Based on annual technical revisions vegetations is regularly cut and there are situations where the level of vegetation associated with sag of conductors growth produce shorts (Table 2). Sag of conductors growth is due to dilation of conductors because of increasing the temperature in external environment or overhead power line operation in overload regime [12].

Some of the defects are transient (at the place of failure the vegetation burns during the producing of an electric arc) and the line is automatically switched on by means of fast automatic restoration devices (RAR). The location of the short circuit is identified by line protection systems, which have implemented defective locator functions. If the defect repeats a control on the line route is made. Line control is a difficult task due to the distribution of line on varied and extensive geographic areas.

The fall of the trees on the line conductors occurs due to unfavorable weather conditions or due to illegal actions. It is a serious nonconformity and all components of the power line can be affected.

Failures caused by electrical lines on the route of vegetation or sag of conductors growth because of producing the electric arc may initiate fires with negative effects on the power line and environmental.

The monitored elements are the vegetation in the line's safety zone, the dimension of sag, beginning of a fire. Monitoring of vegetation on overhead power lines can be done through video systems.

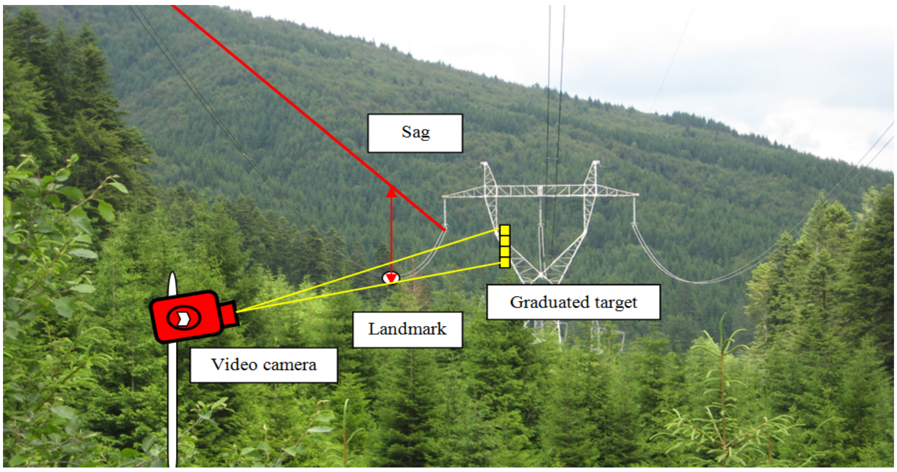

Fig. 1. *Sag position of overhead power line*

The sag height conductors can be directly monitored by measuring the position of a beacon which will be mounted at the maximum point of the sag compared with a fixed point (Figure 1), or indirectly by measuring the conductor temperature and the calculation of the dilatation coefficients [1-2], [5], [10].

Fire smoke and flame sensors are used to prevent fire. For data acquisition at this level, an interface compatible with local sensors and transducers, an energy source, a communication medium between the interface and the server located at the level of the electrical system manager is required.

The implementation of this monitoring structure will be done in areas with vegetation and in areas where the sag grows excessively. The challenges in this case are mounting the beacon on the conductor in point with maximum sag, mounting the camcorder in a fixed point, measuring the temperature of the active conductor.

3. Structural Defects - Corrosion of Metal and Cracks in Pillars Foundation

The elements of the pillars, due to its operation in the external environment are subject to corrosion. To the concrete foundations, especially due to low temperatures, cracks may occur which extend over time. Structural defects occur in association with special weather phenomena (seismic activities, strong wind) lead to the deformation of the pillars or their fall to the ground [8]. A relevant image is made in Figure 2. These are the most serious defects in overhead power lines, the period of unavailability being in the order of tens of days.

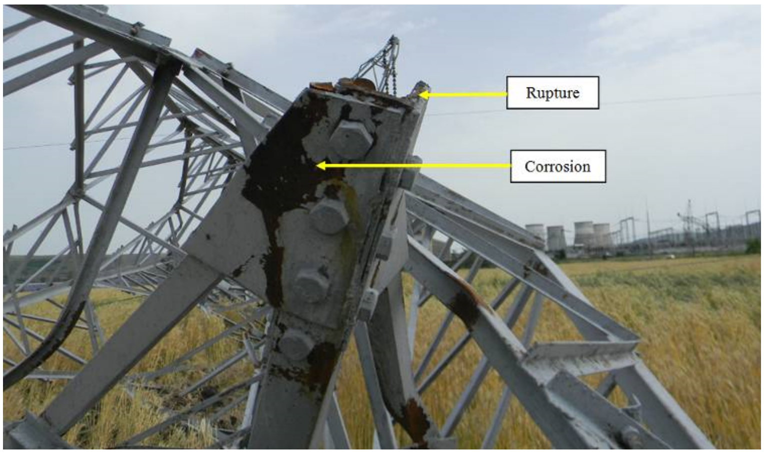

Fig. 2. *Elements of the pillar affected by environmental conditions*

The monitored components are the metallic structures and the foundation of the pillars.

Metallic elements and concrete foundation are included in the inspection and technical inspection programs.

On-line monitoring of structural deformations can be done through laser-wired optical systems. It is an idea of authors and is based on the verification the positions of at least 3 fixed points, located on neighboring collinear pillars (Figure 3). Optionally, the system may include elements for measuring environmental factors (temperature, humidity, wind speed and so on).

The displacement of a fixed point is equivalent to a structural deformation of one of the pillars. The method can also be adapted to monitor the sag of conductors. In hard-to-reach areas, this monitoring proposal will be very useful, especially at critical times where environmental factors reach extreme values.

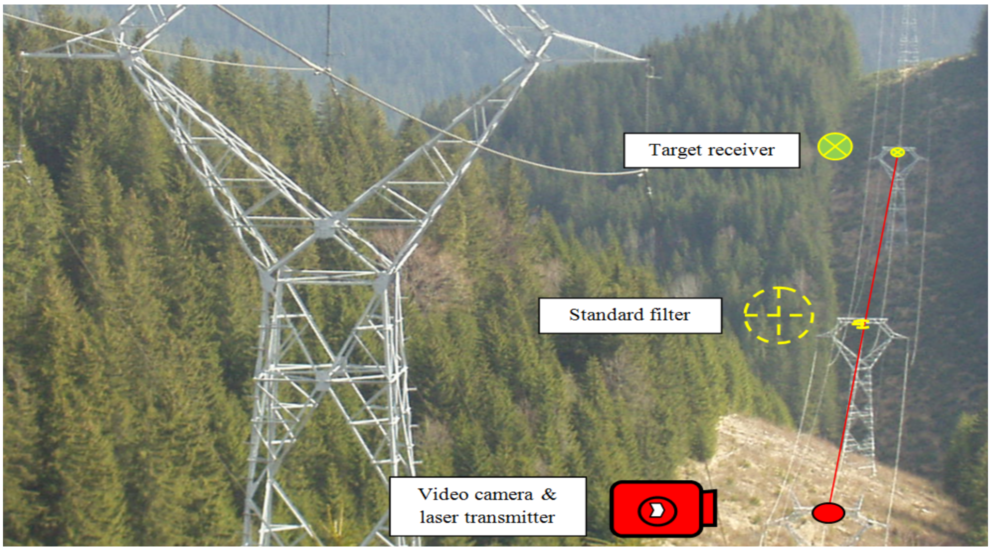

Fig. 3. *Proposal for verification of structural deformations*

To overhead electrical lines of strategic importance is possible to be adapted systems that have special scanning devices with ultrasound, infrared or high-frequency waves. Monitoring environmental factors is done through dedicated sensors. For data acquisition, an interface compatible with sensors and transducers and communication medium is required [11]. The challenge is the installation and calibration of the optical wave laser system to verify structural deformations.

4. Atmospheric Overvoltage

The overhead power lines for protection against atmospheric overvoltages are provided with earth conductors located at the top of the pillars and variable resistance arresters. Usually, after the breakdown of the insulation into the air between active conductors and protective conductors, dielectric rigidity is restored [6]. Where atmospheric overvoltages are frequent, the lines are provided with dischargers and can irreversibly breakdown at high amplitudes (Figure 4). Electric arc associated with electrodynamics forces produced by shorts can affect or damage the insulators, fittings, clamps or line conductors.

The structure of the monitoring system will consider that atmospheric overvoltages can affect variable resistance arresters and other components of the power line (insulators, fittings, conductors, clamps, metal structures) [4].

Measurement of current in the active earthing circuit of the arresters through a dedicated transducer provides information about their status and number of operations [3]. The armatures, clamps, insulators and line conductors can be monitored using video information.

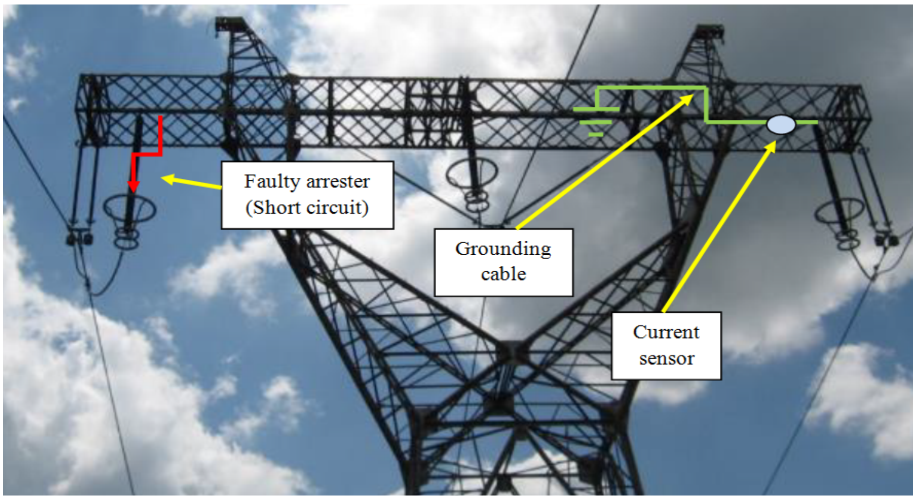

Fig. 4. *Shorts because of isolation breakdown*

Possible heating of the active elements of the line due to damage of the clamps or due to overvoltages, can be monitored by infrared cameras through an interface to retrieve data from the transducers of arresters. A voltage source is also required to power the system elements locally.

5. Broken Isolators

Elements of insulators made of glass or porcelain can break due to temperature variations, due to the electrodynamic forces produced by shorts or as result of vandalism. Partial destruction of the isolator can cause deformation and breakdown of the element (Figure 5). One-phase short are produced and the line remains unavailable until the defective isolator is replaced.

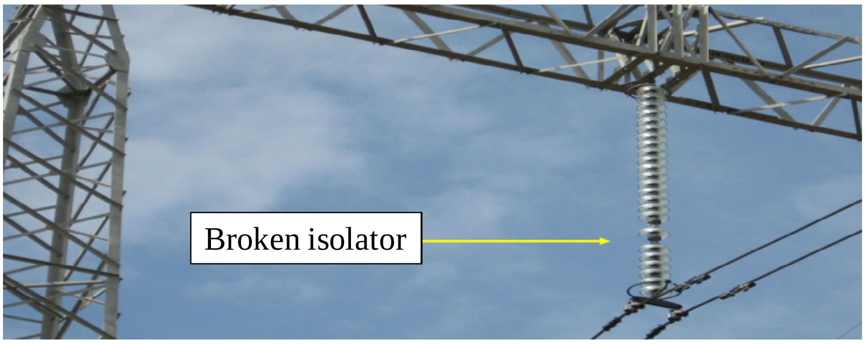

Fig. 5. *Broken isolator*

Checking the condition of the isolators can be done by checking the partial discharges on their surface through ultraviolet [3] or infrared cameras [13]. Where there is an applicable video monitoring system, it will integrate into its structure and will monitor the isolators. Video surveillance systems dedicated to isolators will only be mounted on strategic airlines. In other cases, faulty isolators will be identified during periodic technical inspections. For effective control of defects of any kind and their prevention, it is necessary to implement video monitoring systems [16].

6. The Structure of the Monitoring System

The structure of the monitoring system that the authors propose includes local data acquisition elements and specialized numerical terminals, usually located on power lines, communication media, data storage servers, workstations and software.

Local data acquisition elements consist of diversified sensors and transducers. Specialized numerical terminals take the quantities from sensors and transducers, convert the retrieved sizes and provide the interface with the communication medium.

The communication medium is usually made of OPGW (optical ground wire), which exists in the structure of power lines or wireless systems.

Servers have increased storage and data processing capabilities. At this level, according to well-established criteria, varied calculations are made and significant amounts of data are stored. By means of the communication elements, these data are accessed from the workstations.

The PC located at the operator's workstations will communicate with the servers via local (LAN) or intranet networks.

Software items include external software for test, software com through which the communication between the elements of the system is realized and db-software for database management.

7. Conclusions

Overhead power line monitoring systems represent a necessity for the management of electrical systems. This article represents the current state of the transmission system of high voltage line and has as objective the identifying of factors responsible for the failures and propose a monitoring system to quickly remedy the nonconformities.

Decision making for the maintenance of overhead power lines must be made on the basis of objective criteria established according to their actual technical condition. Although the implementation of monitoring systems requires an average initial investment, the benefits of a technical nature result in their rapid depreciation.

In addition, by implementing monitoring systems in the structure of classical overhead lines, an important step towards converting them into smart electric grids will be made.

References

1. Fu, Y., Rong, S., Zhao, W., Shen, H.: *Research on Monitoring Device for Indicating External Damage Risk of Overhead Line Based on Image Recognition Technology with Binocular Vision Cameras.* In: Condition Monitoring and Diagnosis (CMD), 2016 International Conference on, 25-28 Semtember, Xian, China, 2016.
2. Gupta, S.D., Kundu, S., Mallik, A.: *Monitoring of Sag & Temperature in the Electrical Power Transmission Lines.* In: International Journal of Recent Technology and Engineering (IJRTE), Volume-1, Issue-4, October 2012.

3. Levinzon, A., Kottick, A., Knijnik, R., Frenkel, L.: *On-Line Wireless PD Monitoring System for Contamination Detection on High Voltage Overhead Transmission Lines Insulators* - CIGRE (2012) - B2-205, p. 11.
4. Moldoveanu, C., Brezoianu, V., Vasile, A., et al.: *Intelligent System for the On-Line Real Time Monitoring of High Voltage Substations.* In: Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES, Sweden.
5. Needham, J., Dash, B.: *Dynamic Deformation Monitoring of a Transmission Tower Undergoing Failure Testing by Close Range Terrestrial Photogrammetry*. In: FIG Working Week 2012, Knowing to manage the territory, protect the environment, evaluate the cultural heritage - Rome, Italy, 6-10 May 2012.
6. Popovici, D., Lolea, M.: *High Voltage Technic.* University of Oradea, 2011.
7. Skarbek, L., Zak, A., Ambroziak, D.: *Damage Detection Strategies in Structural Health Monitoring of Overhead Power Transmission System.* In: European Workshop on Structural Health Monitoring, July 8-11 (2014), Nantes, France.
8. Skarbek, L., Zak, A., Ambroziak, D.: *Structural Health Monitoring of Overhead Power Transmission Lines.* In: The XV-th International PhD Workshop OWD, 19-22 October 2013.
9. Stephen, R., Seppa, T., Douglass, D., et al: *Guide for Application of Direct RealTime Monitoring System.* In: CIGRE Working Group B 2.36, June 2012.
10. Weibel, M., Sattinger, W., Rothermann, P., et al.: *Overhead Line Temperature Monitoring.* In: Pilot Project - Offprint of paper SC B2-311 published at CIGRÉ 2006 Session Paris, 27th August - 1st September 2006.
11. Zhaia, S.L., Sheng, D., Wang, Z.Z., Zhang, Y.: *Research of Communication Technology on IOT for High-Voltage Transmission Line.* In: International Journal of Smart Grid and Clean Energy **1** (2012) No. 1, p. 85-90.
12. *** ANRE: NTE 011/12/00: *Technical Rule for the Design of Secondary Circuit Systems*.
13. *** Bulletin of verifications emitted by National Power Grid Company - Infrared Scanning of the 400 kV Overhead power lines.
14. *** Electric Power Research Institute: *Future Inspection of Overhead Transmission Lines.* Report no. 1016921, 2007.
15. *** National Power Grid Company: *Updated Incident Report,* 2017.
16. *** Systems with Intelligence (SWI) 1215 Meyerside Drive, Unit #7 Mississauga, Ontario, L5T-1H3 Canada: *Intelligent Video Surveillance Solutions for the Protection of Critical Infrastructure.*