POZNAN UNIVERSITY OF TECHNOLOGY ACADEMIC JOURNALS
No 74 Electrical Engineering 2013

Rafał GASZ*

IDENTIFICATION OF OBJECTS BASED ON METRIC IMAGES AS AN EFFECTIVE DIAGNOSTIC TOOL USED IN POWER ENGINEERING

The paper presents the method for semi-automatic diagnostics of support structures for high voltage lines with use of metrical photographs. Diagnostics of electric power lines is an important component of their operation and consists of determination which components of the support structures need repairs or maintenance. However, it is a very time-consuming and usually really expensive process. Therefore this paper discloses the method that may make it easier to determine current technical condition of poles since it consists in comparison of real photos against virtual patterns that are developed on the basis of 3D models worked out from technical documentation. The proposed method makes it possible to analyze data that have been collected beforehand or can be applied on-line to carry out real-time investigations. However, application of the method in the on-line mode would enable much faster selection of poles for further assessment of them.

1. INTRODUCTION

Electric power lines comprise dozens of support structures and each such structure is made up of hundreds components. Technical soundness of these is one of basic requirements necessary to assure safe operation of the entire system. Breaks in supplies of electricity caused by poor technical condition of power lines, which is usually manifested under harsh weather conditions, can be painful, in worst cases, to even large areas of the country [1]. Therefore it is necessary to provide diagnostics for all components of power lines: support structures, cables and wires, insulators and supplementary equipment.

Electric power poles are particularly exposed to various damaging factors, mostly of mechanical nature, as well as corrosion. Sometimes the defects are caused by human activities, unintentional or purposeful ones. Each of such factors leads to weakening of the structure and, under extreme weather conditions, can be a reason for deflections, falls or even breaks of poles. Thus, reliable and methodical diagnostics of technical condition is essential for assessment of support structures.

* Opole University of Technology.

2. EXISTING METHODS FOR DIAGNOSTICS OF SUPPORT STRUCTURES

Technical diagnostics of support structures is usually carried out during scheduled inspection determined by the inspection timeline. Such inspections may be long-lasting and expensive, depending on facilities and technical means involved. However, even the most expensive diagnostics methods with use of CCTV and thermovision cameras installed on mobile flying platforms are unable to guarantee that all essential information about technical condition of poles is acquired [2]. Sequences of chromatic video images recorded both in visible light and IR bandwidth during flights over electric power lines reach sizes of dozens GB. Even viewing such huge amounts of acquired data within reasonable time limits is time consuming and needs extreme effort and attention from those who are employed as experts in assessment of structures. To cut down expenses and reduce the time of necessary analyzes it is practical to take benefit from various automatic techniques. For the needs of trustworthy analysis it would be sufficient to use the methods of screening surveys for large populations where it is essential to avoid omission of any incorrect result (failures) even if a certain percentage of targeted components are free of real defects. Electric power distributing companies that deal with transmission of electricity and maintenance of power lines usually possess the complete documentation of their infrastructure, including photos of all line components. If quality of photos is satisfying they can be used to determine technical condition of poles.

When a photo of a facility in question is available it is possible to read all necessary information that is shown on it. The readouts may serve for identification of all structural components presented on snapshots and their technical condition.

However, the photos have substantial drawbacks entailed by imperfectness of optical lenses, where distortion of is the major factor that leads to deformation of images and deteriorates quality of photos that are used for measurements. The deformations can be caused by two types of radial distortion, i.e. the barrel and pillow ones.

Distortion is the optical imperfectness that consists in variations of the image magnification with increasing distance from the optical axis of a lens [2, 3]. It leads to disturbance in proportions and deformation of shapes on images. Distortion usually occurs on snapshots that are taken with use of zoom lenses (with variable focal distance). The barrel distortion is manifested by rounding the image to the outside that makes a characteristic shape where the image is mapped around a sphere. It is the imperfection that is typical for wide angle lenses with short focal distances. On the other hand, bowing of the image lines inwards, to the picture centre, is referred to as the pincushion or pillow distortion and is usual for telephoto lenses.

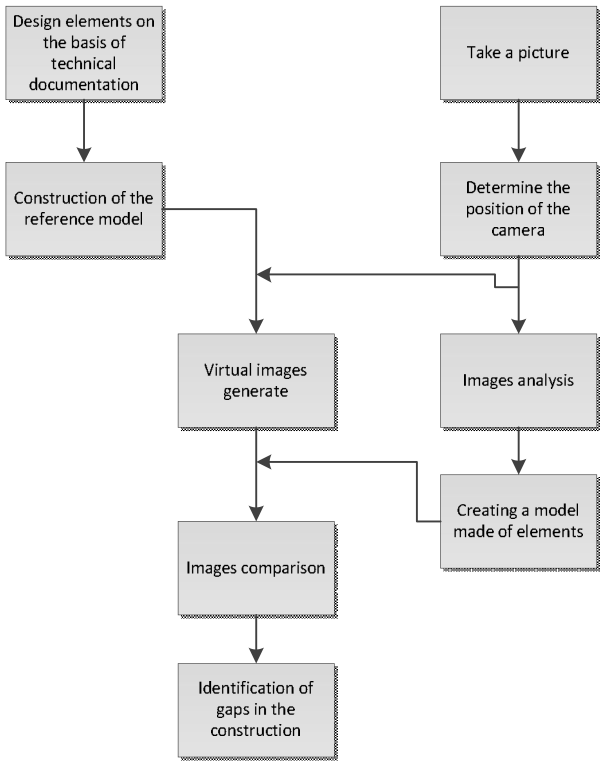

Fig. 1. The method of virtual images algorithm

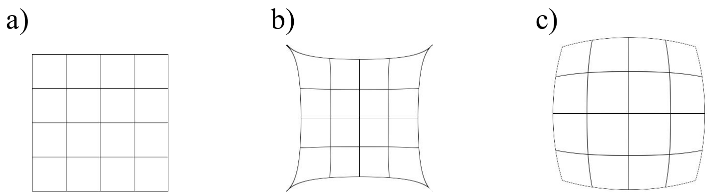

Fig. 2. Image: normal (a), pincushion distortion (b) barrel distortion (c)

Another blurring that frequently occurs is aberration. The most common aberration types are the spherical and chromatic ones. To the more or less significant degree the both aberration types affect readability of images by worsening of sharpness on certain areas of pictures [2, 3]. Eventually, the same points presented on two different photos cannot be mapped on each other.

The spherical aberration consists in the fact that the optical power of lenses varies for light beams in pace with their distance between the central axis and boundaries of the optical system. As a result a blurred photo is obtained with poor readability and with high content of noise, which may make difficult to clearly identify individual parts of images. Another type of image imperfection is the chromatic aberration that consists in focusing variation of incoming beams depending on the light wavelength. The chromatic aberration is manifested on photo images as a colour envelope around contrasting parts of the image, for instance the pole structure on the background of bright sky. To obtain photos that are suitable for the metrical analysis one has to remember about appropriate calibration of the measuring equipment or about appropriate touch-up correction of images taken.

To enable metrical analysis of snapshots it is first necessary to know spatial orientation of each photograph and the camera positioning when the image was taken. The factors for orientation of photographs are classified into the factors of internal and external orientation. The factors of internal orientation include the distance of images also known as the camera constant as well as the main point of photograph. The camera constant is defined as the distance between the projection centre and the projection plane. For ordinary, non-metric cameras it is equivalent to the focal length of camera lens. In turn, the main point of photograph is understood as the perpendicular projection of the projection centre onto the image plane. Location of the main point is defined in a local co-ordinate system for the photo that is referred to as the system of background coordinates. The horizontal axis of the coordinate system is denoted as X whereas the vertical one as Y, where coordinates of the system central point are specified as $\{x_0, y_0\}$. Location of the camera main point is determined during the process of camera calibration.

On the other hand, the factors of external orientation comprise: 3D coordination of the projection centre – location of the projection centre against a field (global) coordinate system XYZ and three angles that define location of the camera axis and the projection plane within the field space – the elevation (tilt) angle ω, the azimuth angle φ and the rotation angle κ. To enable identification of the image components it is first necessary to know the exact position of the photo camera, or more strictly, position of the matrix centre. For that purpose it is possible to implement the method of normal photos that consists in some assumptions that serve as the basis for measurements and are associated with positions and mutual orientation of photographs. But use of trigonometric functions and the principle of the triangle similarity one can calculate coordinates of the camera location where the pictures were taken from.

The presented method [3] with the algorithm outlined in Fig. 1 is intended to check completeness of the structure and benefits from the method of image analysis [4, 5]. It enables to make a preliminary diagnosis in the automatic way and to select the structures for further, more detailed analyzes of their condition. The proposed method uses photographs of support structures and virtual images, i.e. the images that are obtained in a virtual environment as the result from rendering of virtual models for the structure of the same type with consideration to a specific location of the observer. The process consists in comparative analysis of the actual condition of the structure reproduced in the photographs against the models that are developed in a CAD environment.

Virtual images were developed with use of the AutoCAD software environment. Steel support structures, in spite of various design options varying from one structure to another, are rather simple solutions and accurately specified in their engineering documentation, which makes it possible to develop their 3D models in many CAD-type virtual environments. The detailed investigations were focused in the Z52 pole, in particular on the bottom part of the truss. The virtual model of the truss is depicted in Fig. 3 whilst Fig. 4 shows the photo of the real pole support structure.

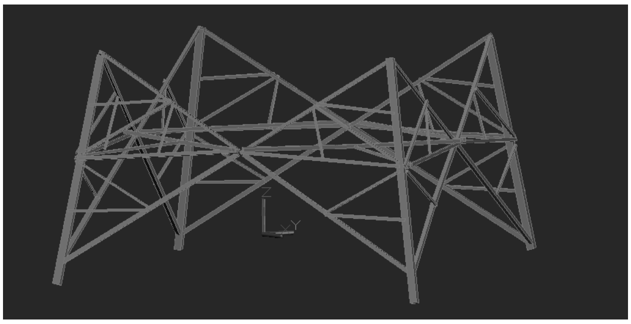

Fig. 3. Model of part of the truss

Fig. 4. The truss

The information that is indispensable to acquire from each photograph is location of the camera, i.e. its relative coordinates, which can be obtained by photogrammetric engineering (backtracking). Prior to use of the image it is necessary to process it accordingly to eliminate all geometrical deformations caused by distortion of the lens. For that purpose one can use a test chart and dedicated specialized software. The camera location can be found out on the basis of direct measurements, e.g. by means of a range-finer that measures distances to the characteristic points of the pole. When camera coordinates are known it is possible to develop a virtual image within the CAD software. For that purposes also other parameters of the camera are necessary, such as its focal length (VxH angles) and resolution of its matrix.

Upon determination of the camera position a virtual image was developed by application of the rendering process with the result as shown in Fig. 5. As one can easily see, the image produced by the rendering process if free of the background that exists on the real photo. Obviously, the background can be added, but removing it from the real photo seems to be a better solution.

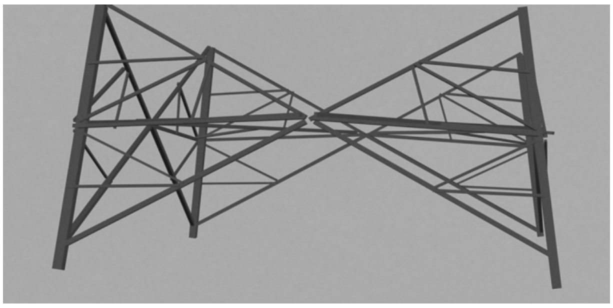

Fig. 5. The virtual image

For that purposes one can use either a mask that is created on the basis of chromatic spectrum of the photo (colour of the truss should differ from the background colour) or a thermovision photo taken from the same location (depending on the solar illumination, season of the year and time of the day the steel structure temperature is clearly different than its surroundings). It is also possible the benefit from the virtual image from the rendering process but in such a case it is necessary to use the chromatic spectrum of the real photo. The product (superposition) of the mask (as a binary image) and the real photo is shown in Fig. 6. Regardless that fact that the outcome image has been converted into a black and white picture the structure of the pole truss is perfectly seen on the processed image.

Fig. 6. The result of the conjunction of two images

Processing a real photo with use of a virtual image makes it possible to achieve the picture where one can see all the existing structural components that should be in place on a real object according to the engineering documentation. Therefore it is easy to detect whether any part is missing or not. Such a detection process can be carried out when any difference between a virtual image and a processed real snapshot is fond out. To demonstrate the outcome of the presented method a certain fragment was removed from the real photo marked with a red circle (loop) (Fig. 7). The photo was that subjected to the foregoing process of analysis and, after the image processing was completed, the missing fragment was distinguished by blue colour. Such a result should suggest that the structure condition should be thoroughly inspected.

Fig. 7. The image of a piece of truss removed

3. RECAPITULATION AND CONCLUSIONS

The proposed method can be an efficient tool meant for preliminary, automatic analysis of acquired snapshots in order to verify completeness of support structures. Since some structural component can be invisible on a single image the complete analysis should be based on several snapshots taken from various locations. Further progress of the studies should comprise automation of the entire process, in particular automatic development of virtual images. It is also essential to draw up a method for automatic determination of the camera location on the basis of typical components within the investigated structure.

Obviously, electric power lines are not made up merely of support structures. The proposed method can be also used for diagnostics of other components, e.g. protective equipment, insulators or verification of correct layout of wires. Capabilities of the detection algorithms can be enhanced by application of the chromatic analysis tools, e.g. for detection of visible corrosion spots or chipped appearance of porcelain insulators.

REFERENCES

[1] Bartodziej G., Tomaszewski M., Problems of extensive power grid failure, Nowa Energia, 2010 (in Polish).
[2] Głuch I., Krzyżanowski J., The diagnostic power of geometry objects, Pomiary Automatyka Kontrola nr 9bis/2005 (in Polish).
[3] Gasz R., Zator S., Virtual images use for diagnostic elements of power lines, Nowa Energia, 2/2012, pp. 133-134 (in Polish).
[4] Tadeusiewicz R., Computer analysis and image processing, Wydawnictwo Fundacji Postępu Telekomunikacji, Kraków 1997 (in Polish).
[5] Woźnicki J., Basic techniques for image processing, Wydawnictwa Komunikacji i Łączności, Warszawa 1996 (in Polish).

Stypendia doktoranckie - inwestycja w kadrę naukową województwa opolskiego.
Projekt współfinansowany przez Unię Europejską w ramach
Europejskiego Funduszu Społecznego.

KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

UNIA EUROPEJSKA
EUROPEJSKI
FUNDUSZ SPOŁECZNY