CONCEPT OF DIAGNOSTICS OF ENERGY NETWORKS BY MEANS OF VISION SYSTEM

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Summary

In diagnostics of power grids a very important role is played by vision methods. Currently, a relatively new technique is the use of modern, autonomous devices for images acquisition, which are further analysed. The paper presents an overall division of power grids, discussion on the most common damages and effects of failures in these networks. Examples of currently used diagnostic methods of energy networks are presented and examples resulting from a review of modern vision techniques (methods of image acquisition and analysis) are listed. However, it can be noticed that there is still a need of further developing these techniques and striving for automatisaton of the diagnosing process. The paper contains a description of a concept of diagnostic method of energy networks, which includes the application (usage) of an autonomous, unmanned aerial vehicle to obtain the data. Some techniques of artificial intelligence for automated reasoning about the energy networks condition are planned to be applied.

Keywords: energy networks, damage, diagnostics, vision system, UAV, camera

KONCEPCJA DIAGNOSTYKI SIECI ENERGETYCZNYCH Z ZASTOSOWANIEM SYSTEMÓW WIZYJNYCH

Streszczenie

W diagnostyce sieci energetycznych bardzo dużą rolę ogrywają metody wizyjne. Obecnie, stosunkowo nową techniką jest zastosowanie nowoczesnych, autonomicznych urządzeń do pozyskiwania obrazów sieci w celu ich dalszej analizy. W niniejszym artykule przedstawiono ogólny podział sieci energetycznych, omówiono najczęściej występujące uszkodzenia oraz skutki awarii w tych sieciach. Przedstawiono przykłady obecnie stosowanych metod diagnostyki sieci energetycznych i wymieniono przykłady z przeglądu nowoczesnych technik wizyjnych (sposób akwizycji obrazów i ich analiza). Zauważyć jednak można potrzebę dalszego rozwoju tych technik oraz dążenia do automatyzacji procesu diagnostyki. W artykule opisano koncepcję metody diagnostyki sieci energetycznych zawierającej zastosowanie autonomicznego, bezzałogowego statku latającego do pozyskiwania danych. Planowane jest zastosowanie różnych technik sztucznej inteligencji w celu automatycznego wnioskowania o stanie sieci energetycznych.

Słowa kluczowe: sieci energetyczne, uszkodzenia, diagnostyka, system wizyjny, UAV, kamera

1. INTRODUCTION

Energy networks are ones of technical structures which are fundamental to our present daily life. In general, energy networks can be divided into: electric power lines (transmission lines – very high and high voltage and distribution lines – medium and low voltage), fuel networks (gas pipelines, oil pipelines) and heat networks (pipelines transporting hot water or steam). Referring to an example of the power supply infrastructure in Poland, there are several tens of thousands kilometres of energy networks working presently. It is reported that currently, they are not of a good condition. Both electric, fuel and heat networks are outdated and increasingly unreliable [1÷2]. There are many difficulties in their maintenance and proper functioning. These are aspects connected with operating of particular components of these networks, effects of extreme weather conditions or other forces of nature and an everlasting problem of a vandalism or thefts.

2. DAMAGES OF ENERGY NETWORKS

Types of energy networks damages can be various. The most common of them are described below.

As far as electric power transmission lines are concerned, there may occur pylons and foundations damages (these are usually failures of a mechanical or corrosion nature), caused by extreme weather conditions (mainly strong winds, significant falls of temperature) as well as tampering or vandalism. Furthermore, their insulators can be cracked (the ones made of glass or ceramics) or degraded (the polymer ones) as well as corroded (their cores, pins, nuts). Electrical conductors may got torn or broken as a result of a strong wind, heavy snowfall, thick layer of ice, or vibrations [3÷4]. Another important issue is a phenomenon of corona discharges (kind of electric discharges, figure 1), which results in energy loss and accelerated aging of insulators.

Figure 1. Corona discharge effect detected by an UV camera [5]

Damages of fuel and heat networks can be similar due to the fact that in both cases the utilities (gas, oil, water, steam) are transported by pipelines. In such structures failures caused by improper technology or repair performance (defects of a material, welds or an armature) may occur. There may also mechanical damages happen (cracks, indentation) caused by natural forces – lighting, extreme temperatures (especially low), earthquakes, long-term rainfalls, floods etc. as well as vandalism or thefts. Finally, a corrosion (both of an outer and inner surface of pipelines) can also appear. Some of the enumerated cases may lead to pipeline leakages, fires or explosions [6÷7].

The main consequence of these failures is cutting local citizens off from the media, such as warm water, heating and electricity. Serious accidents may even lead to huge disasters. The threat of the highest scale is characterized by events like: evacuation of local population, loss of species and of the environment, large leaks of VOCs (volatile organic compounds) or toxic gases and even, unfortunately, fatalities [8]. This danger as well as an extensive length of the lines lead to a need of their regular diagnosis and early detection of potential defects to minimize the risk of various forms of losses (including also the financial ones).

3. REVIEW OF ENERGY NETWORKS DIAGNOSTIC METHODS

Nowadays, numerous techniques of energy networks diagnosing are used.

Among others, there are applied methods based on acoustic and vibration measurements, procedures focused on electrical parameters measurement and vision methods. The vision diagnostics is conducted for instance with use of a regular camera (operating in the visible light) or thermal imaging camera (acquiring images in the infrared light) but mostly they are ordinary inspections based on observation by a human "naked eye". Besides, an airborne laser scanning is used to verify whether the lines are not overgrown with vegetation [4].

Considering the fuel and heating networks, vision methods are also often used. Such lines are inspected by thermal imaging cameras, which are for example held in inspector's hands or fixed to a small plane. That allows us to detect a leak from pipelines or, in case of the heat networks, notice a concentration of heat losses (as seen in figure 2). Furthermore, simple human observations are commonly performed (verification of a presence of corrosion or mechanical damages, checking out a condition of insulators, welded joints etc.). The tightness of welded joints is also checked i.e. with an ultrasound method or with use of a suction cup. The fluid leakage can be detected by means of measuring and comparing a water flow through appropriate points of the network [9÷10].

Summing up the enumerated methods one can conclude that the most common and very important method being applied to each of these kinds of the energy infrastructure diagnostic ways is the vision inspection.

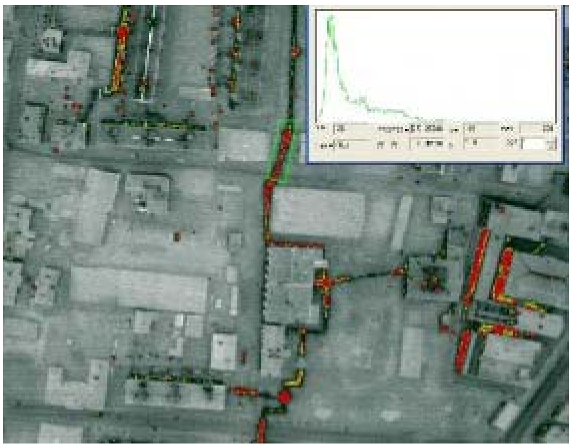

Figure 2. Aerial thermography of district heating networks [10]

3.1. Modern methods in vision diagnostics

Until recently, most of vision inspections were performed by a human - from the ground, a crane or from a manned helicopter or an airplane, controlled by a pilot. One observed that recently a variety of modern ways of energy networks vision diagnostics was reported. Regarding the ways of data acquisition (photographs or images of the lines) it is recently used to be performed by unmanned aerial vehicles (UAVs), remotely controlled or autonomous, also called drones. The camera (or a set of cameras) is usually fixed to a bottom part of these drones. The example of such a modern vehicle is a drone of Aibotix GmbH company presented in figure 3.

Such autonomous devices can be guided on the lines using a known map of the power grids and the system integrated with the GPS (global positioning system).

Figure 3. The Aibot X6 drone [11]

An interesting alternative is the use of the GIS (geographic information system), which allows collecting and storing all kinds of geographical data, such as, in considered case, the position of energy networks units [10]. Another possibility is guiding the vehicles with own-designed system, which recognize the lines "on-line". Authors of [12÷14] performed the research on detecting the power lines based on the Hough transform and other methods of image processing, like filters and morphological operations application. The Hough transform is a method of detecting straight lines and other regular shapes in the image. Such the transform was invented by Paul Hough and patented in 1962 [15]. An example of this application [14] is presented in figure 4 (the red lines represent the detected power transmission lines).

Figure 4. Detected power lines with use of Hough transform [14]

In case of power transmission lines, there are also robots moving on electrical conductors. Among others, authors of [16÷20] carried out the research on such or similar kinds of robots. These robots are autonomous and equipped with sensors so that they can overcome all kinds of obstacles and carry out the inspection tasks. The example of such the robot and the acquired image presenting a damaged electrical conductor [20] is shown in figure 5.

Figure 5. The LineScout robot and the image of a damaged conductor [20]

Regarding fuel pipelines, there are similar robots applied (one of these examples is the IPEK vision camera, shown in figure 6), which are put inside the pipes. The IPEK was designed to be adapted to work in hazardous environments with a danger of explosion, so that they are safe to be used for pipelines with a gas or oil. Another example of the research devoted to such kinds of devices were systems introduced by the authors of [21÷23].

Figure 6. The IPEK vision camera with anti-explosion system [24]

4. CONCEPT OF VISION METHOD

Since the requirements related to the maintenance of energy networks are high reliability, efficiency and safety, there is a need of developing some specific diagnostic techniques. The paper deals with a concept of a method based on the application of a mobile device, which is universal and easily adaptable to perform inspections in all kinds of the listed above networks.

4.1. UAV

Due to the common features of the mentioned energy networks, i.e. the length of their elements and their repeatability along the entire lines, the most convenient way of acquiring data which has to be taken into consideration is the UAV with cameras.

Moreover, in order to automatize the diagnostic process, the vehicle is required to be autonomous and the GIS would be applied to guide the vehicle on the lines.

4.2. Cameras

In order to detect as much failures as possible at least three types of camera are supposed to be implemented. One of them should be a regular, high resolution camera to take photographs in the visible light. This camera should let us find damages, which are of a mechanical or corrosion nature as well as the abnormalities, such us trees encroachment into the lines area. The second one, thermal imaging camera (used to get images in the infrared light) let us detect all damages, which are characterized by excessive generation of heat. Taking into consideration the power transmission lines, another camera is advisable. Additionally, an ultraviolet camera can be used for detection of the corona discharges.

4.3. Image stabilisation

One of very important problems related to the application of the vision systems is an image stabilization. Quite old but still current and effective method in this field is the use of gyroscopic stabilizer. One of researchers who considered a problem of gyroscopic stabilization was Louis Brennan who succeeded in issuing the patent in 1905 [25]. A general principle of the gyroscope operation which is described in this patent is the use of a mass that rotates and prevent a working monorail-type train from falling over. Many modifications were later introduced. Nowadays, the stabilization based on the gyroscope is commonly applied in many systems.

4.4. Data transmission

Regarding the way of data transmission (video or photographs acquired by UAV with cameras), there would be three scenarios taken into consideration. One of them is to collect images and transfer them after the whole procedure of the flight finishes (off-line transmission). Another proposal is to transfer the data systematically during the UAV flight (on-line transmission) via one of the wireless technologies (e.g. Wi-Fi, Infrared, Bluetooth). In these two cases, the data could be analysed in any other place, outside the area of carried research and at any time. The last proposition requiring a very high capacity of the software is the image analysis "on board", during the flight and with immediate information about detected faults sent to the user.

In case the off-line method is applied, there is a need of implementing the software which synchronize the gained data with the information about precise localization of the objects seen in the relevant image.

4.5. Image analysis

The next and the most important step is to process the obtained images and recognize the components and their (if any) damages.

To perform this step, the knowledge base of networks failures is required to be developed. The base will be a fundamental source used for reasoning about the energy networks condition on the basis of recognizable symptoms.

As far as the image processing is concerned, there may occur a few problems to be solved. Firstly, the objects (elements of the lines) have a complex background (fields, trees, buildings, roads, birds etc.), and is changeable all the time (different background in every picture). It may cause some difficulties in objects identification. Secondly, with example of power transmission lines, there are many types of pylons, insulators (they vary in sizes and shapes) and electrical conductors (cross-sections dimensions), what requires to implement advanced approaches. Furthermore, various obstacles such us branches covering the objects of interest may occur. This problem should be taken into account in case of algorithms of image processing. The same refers to a situation when an object is strongly damaged and its shape deviates greatly from the undamaged one.

The system should send a report to a user about detected and localised damages of the energy networks.

4.6. Tests

Because we must not do any simulations of damages in energy networks during their operation, tests of the accuracy of the algorithm are needed to be performed in a laboratory environment. For this aim, the experimental setup (shown at in figure 7), available in the Institute of Fundamentals of Machinery Design of Silesian University of Technology, could be used. The device was constructed by a graduate of Silesian University of Technology within his master's thesis [26]. This experimental setup allows us to set the camera in movement by any trajectory and different velocities and take photographs of e.g. models of object with simulated damage.

After that, the experimental tests (of the images acquiring and the algorithm working) would be performed on the real networks (after identifying their real damages).

Figure 7. Experimental setup for testing vision systems [25]

5. SUMMARY

Because of many difficulties in proper functioning of energy networks, as well as a big amount of different and dangerous possible damages, there is a need of diagnosing them regularly. Many of these failures can be detected by vision diagnostics methods. A huge part of currently performed vision inspections of energy networks is executed by a human. The main disadvantage of such the approach is disability to notice everything what might be significant. Additionally, such procedures take some time to be performed. In order to obtain better quality of the inspections the automatisation of this process is necessary. The paper deals with a conception of automation not only the process of acquiring data (images) but also automation of reasoning about the power grids condition by means of methods of image processing.

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