Study Committee B3

Substations and Electrical Installations

Paper B3-10367_2022

Autonomous software and hardware complex for preventing technological defects of the basic substation's equipment based on remote monitoring data

G.K. Gladkovskii, i.L. Arkhipov, D.S. Kapustin, A.V. Koltsov, E.V. Magadeev, A.V. Selikhanovich

PJSC Rosseti, MES Volgi – Rosseti FGC UES, MTK Business.Optima LLC

Motivation

- there are a large number of old electrical substations that require close attention and control, because unplanned failures at any point in the equipment lifecycle have large consequences
- the current level of development of machine vision technologies enables to discuss the possibility of almost complete replacement of tours and visual inspections with automatic controls equipped with a mathematical tool for object selection, character recognition, etc.
- the software and hardware suite allows to check regularly equipment of the controlled substation, which provides a significant reduction in inspection time versus traditional ground surveys
- the use of software and hardware visual control reduces the role of the human factor. The human factor makes a significant contribution to the number of incidents and accidents that occur annually in the power industry, and the elimination of this factor is the key to improvement

Objects of investigation

- complex for automated control of equipment at 500 kV high-voltage substation
- at the substation, there were 187 controlled elements under the control, the number of data collection tools was 108 pcs. (including cameras, microphones, thermal imager)

Experimental setup

- the pilot operation of the software and hardware suite took place within the period from November 2020 to October 2021 at the 500 kV substation – full year onsite tests in continental climate with winds, rains and snow
- the software and hardware suite prototype was operated in the continuous mode and automatically inspected elements of the substation equipment based on hourly scenario
- the experiment for use of an unmanned aerial vehicle (UAV) was conducted as part of the pilot operation

Location of cameras of the visual monitoring system on the auto transformer.

Inspection of the substation using UAV

Study Committee B3
Substations and Electrical Installations

Paper B3-10367_2022

Autonomous software and hardware complex for preventing technological defects of the basic substation's equipment based on remote monitoring data

continued

Method/Approach

The software generates automatically recognition errors for the substation personnel stating the location of the camera and the monitored indication.

Software for the visual monitoring software and hardware suite uses pre-trained neural network image recognition models:

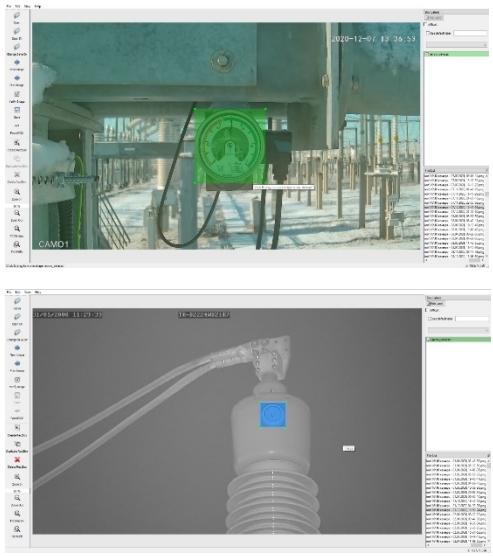
- Fast R-CNN.
- YoloV5
- and others

To train the data set, the labeled data for a certain period, including frames at different times of the day, from different positions and at different times of the year, were used. About 3,000 images, taken during a calendar year, were collected for each type of instrument.

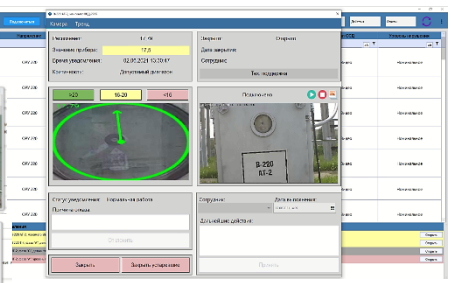
In addition to recognition of the state monitoring instruments based on optical band cameras, the software and hardware suite includes acoustic data analysis and thermal imaging modules.

The analysis of the background sound makes it possible to track disturbances in the equipment operation associated with changes in the background sound:

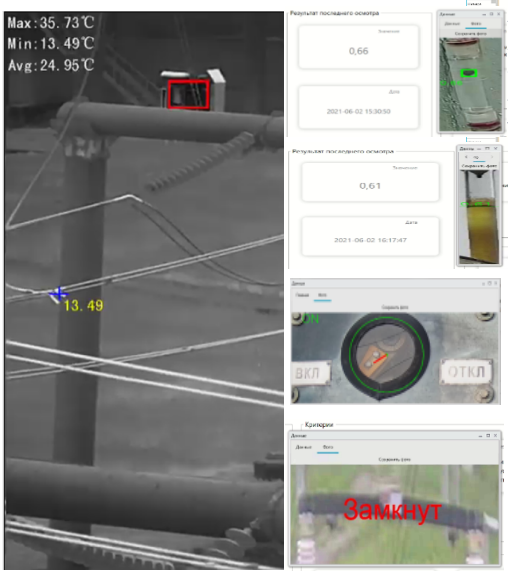
- air leaks from the tanks of air circuit breakers, frequency band of 5-6.5 kHz
- deviations in the operation of the transformer cooling system frequency band of 2-3.5 kHz



Example of selecting an object using the open program "labelImg".



Views of screen forms of the visual monitoring software and hardware suite prototype.



Examples of recognition of controlled elements

The developed software for monitoring of the equipment state based on thermal mapping data makes it possible for the users to determine an arbitrary number of monitored zones with their own warning set points in the visible band.

Being combined with the thermal camera's turning mechanism, it allows to perform automatic inspection of user-assigned spots or zones as well as to automatically inform the user about the revealed anomaly spots.

Study Committee B3

Substations and Electrical Installations

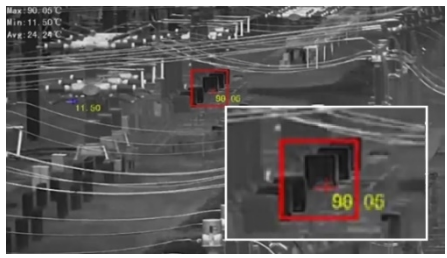
Paper B3-10367_2022

Autonomous software and hardware complex for preventing technological defects of the basic substation's equipment based on remote monitoring data

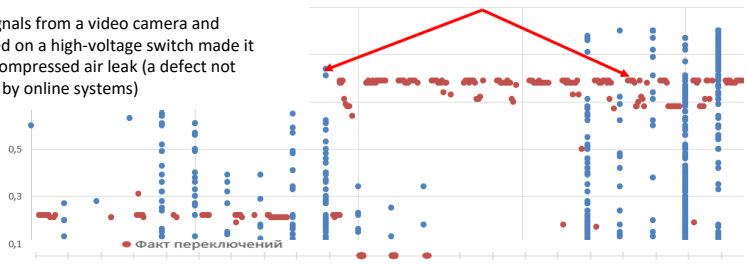
continued

Test results

- during the pilot operation, a sudden malfunction in the operation of the heating system of the 220 kV circuit breaker control cabinet was detected by the prototype of the equipment visual monitoring system
- using the visual monitoring software and hardware suite, it was possible to record a low pressure in the purge indicator on the air circuit breaker and a low temperature in the control cabinet of the sulfur-hexafluoride circuit breaker
- the program proved to be stable in operation. In the event of temporary problems, for example, in the rain, special re-interrogation algorithms are activated, waiting for the situation to normalize, after which the program switches to normal mode



- joint processing of signals from a video camera and microphones mounted on a high-voltage switch made it possible to detect a compressed air leak (a defect not previously diagnosed by online systems)



Conclusion

- the use of visual monitoring software and hardware at the substations of the bulk power system, commissioned decades ago and not equipped with modern systems for collection of information from monitoring instruments, may reduce much the personal efforts for performance of tours and increase the observability of equipment
- the machine vision systems make it possible to replace a person in taking readings from monitoring instruments for almost all the operating conditions and types of instruments
- the use of rotary cameras and cameras with optical zoom may reduce significantly the amount of installation works
- the wireless data transmission systems may be considered as an evolution of the system, which would simplify installation and reduce the cost of the solution
- by the functionality the software can be used both for stationary platforms and for robotic ones, including UAVs

Discussion

- the use of quadcopters for visual inspection is an alluring prospect, this way allows the process to be carried out qualitative and in full; the influence of the electromagnetic environment on the UAV seems to be a solvable issue through the use of LIDAR technology
- in some countries, the use of UAVs without an observer is prohibited