# Instruments and Mobile Laboratories for NDT and Diagnostics of Underground Communication Lines

Vasily N. KOLTSOV, Joint Venture “Seba Spektrum”, Russia, Moscow
Yrij A. KONDRATIEV , Joint Venture “Seba Energo”, Russia, Moscow
F. PETZOLD, SebaKMT Holding GmbH, Baunach, Germany

**Abstract.** Last decades of the XX-th century were marked by a number of natural and technogenic cataclysms, large accidents at the enterprises, gas mains, on all types of transport, etc. Cases of terrorism acts have become frequent. Last years we are witnesses of frequent failures on the underground communications laid in residential areas of mass building, and sometimes even their switching-off from the user. It is clear, that safety of civilian objects and community facilities, industrial and social spheres is fully defined by their technical condition which in turn depends on a level of modern equipment and the automated means of complex diagnostics functioning in any climatic and weather conditions.
In the paper new information technologies of complex diagnostics of large technical objects of power, communication, housing and communal services, and also the large industrial enterprises are presented.

## 1. Instruments and mobile laboratories for damages search and diagnostics of underground cable lines

Last years the requirements to operation of electric networks, including on revealing and elimination of emergencies in the shortest terms, are shown the most urgent. Today this problem is essentially solved with the help of mobile laboratories equipped with modern equipment, but new methods of search of damages and complex diagnostics of cable lines nevertheless are developed.
A technique of a cable defects location is chosen depending on character of damage. Defects with low electric resistance are expedient for defining by means of reflectometers, working on a principle of measurement of an electric pulse distribution time along the cable from the instrument to defect and back. The cable length can be up to 600km, while accuracy of defect positioning is 0,01 %. Reflectometers present the computerized systems with special software and functionally support connection of various peripheral devices for work results storage, transfers and display. However reflectometers work unstably when defects resistance is some kiloohms or more. A method of transformation of high-resistant damage to low resistant one is based on creation of a voltaic arch with stable parameters in a place of its location. The voltage of up to 32kV is applied to a cable and after voltaic arch forming its parameters are kept for 4 seconds. This time is enough to determine the defect position with the help of reflectometer.
More accurate cable damage detection on site is performed by means of shock wave or a method of sound waves. The shock wave method is used for defects of breakage type, i.e. in case of opened circuit. In this case in damaged place a pulse acoustic signal occurs which is registered from ground surface by the special receiver consisting of a ground

microphone, amplifier and headphones. The working voltage of shock waves generators is adjusted within the limits of 2.5 … 32kV. Such instruments have two start modes – manual and automatic. In a manual mode the pulse is generated after button pressing while in automatic mode the pulse is generated periodically with interval 1.5 … 6 seconds depending on applied voltage and generated pulse energy. The instruments weight is 40 - 96kg.

The sound waves method used for damages of short circuit type, i.e. in case of closed electric circuit. The sound wave generated in the cable propagates in to the place of damage. From a surface it is registered by means of ground microphones or a step voltage probe. When the signal disappears, it means that receiver is positioned above damaged place. Sound signals generators provide automatic matching with examined cable based on maximum power put in cable that reach 500W when the instruments is powered from mains.

After damage is located and eliminated the cable is subject to high voltage tests. For this purpose used are instruments of various performances – in the form of separate units and finished blocks mounted in a vehicle. Those instruments provide Devices provide cables testing by means of dc or ac within limits of 150 to 100kV accordingly.

Developed and introduced in practical use control-computing system realizing technology of the complex examination of underground cable lines, is designed to carry out the preventive tests of electrical equipment with operating voltages up to 35kV, and also for detection of power cables damaged places in case of working voltage up to 10kV. The laboratory where this system is installed is equipped with special automated protection means that save personnel from harm and injury caused by electric current. Switching-off of protection automatically causes switching-off of all high-voltage instruments, and also discharges all high-voltage equipment.

The laboratories can be made on any foreign and domestic cars having sufficient carrying capacity. On heavy haulers it is possible to have utility module comprising soft sleeping berths, mini-kitchen (with washstand, electric stove, refrigerator, etc.).

The basic functions of mobile laboratories:

- Cable lines trace location and their lay depth determination;
- High-voltage tests of electric equipment and cable lines;
- Detection of cable lines damaged places, including detection that does not cause burnings in presence of high-resistant and swimming away damages;
- Burning through the cable lines;
- Detection of damaged places of cable coatings;
- Detection of ground short circuits in not grounded installations;
- Selection of single cable between several.

Lately the new direction is rapidly developing - cable lines diagnostics. This direction is of special importance as provides forecast of cable line residual life evaluation with certain degree of probability. At present developed and successfully used are instruments based on the following methods: examination partial discharge, measurement of isothermal relaxation currents, and measurement of return voltage. These instruments can operate on all cable types including those widely used nowadays with insulation made of cross-linked polythene.

## 2. Devices and mobile laboratories for measurements and installation of fiber-optical and metallic communication lines.

Increasing importance of digital data transfer and occurrence of new transfer technologies, such as ISDN and xDSL impose more strict requirements on transfer parameters of

communication cables. To provide high quality communication it is first of all required to provide, i.e. measure, the following parameters: transient processes at near (transmitting) and far (receiving) ends as well as attenuation value.
One of the most complicated problems facing operators all the time - elimination of damages in cable networks in the shortest terms. This task can be maximally effective be solved with the help of mobile laboratories equipped with modern instrumentation. When designing this type of laboratories the working experience of telecommunication networks operated by leading telecoms operators as "Rostelecom" and Department of telecommunication of Ministry of Communications of the Russian Federation were taken into account.
The basic functions of mobile laboratories:

- Cable lines trace location and their lay depth determination;
- Detection of places of cable lines damages by remote methods;
- Detection of places of cable lines damages by by topographical methods;
- Detection of damaged places of cable coatings;
- Detection of wire pairs in multicore cables.

Optionally the lab can be equipped with utility module for shift teams.

## 3. Devices and mobile laboratories for search and diagnostics of underground pipelines and sewer channels.

The structure of modern pipeline communications is extremely imperfect. There are still prevail short-lived metal pipes (in average across the CIS - 70 % of such type communication). Occurrence in walls of the pipeline of through holes (occurred due to corrosion and wandering currents) leads to great losses of transported water. For example, through 3 mm diameter hole and at pressure of water in the pipeline 5 atm. it is lost more than 13 cubic meters of water a day. To reduce water losses it is necessary to operatively find out damaged place and provide its repair.
The developed acoustic control-computing systems for pipelines complex diagnostics take a special place in a row of leak detectors. They are simple and reliable, do not require any sophisticated devices, do not violate the technological processes and are safe for user's health.
At present several groups of instruments for leaks detection are available, each of which corresponds to the certain method.
The first group – noise detectors designed for monitoring and preliminary leak places localization. The detectors automatically register and record to the built-in memory the noise generated by pipeline, including noise generated by leak if it takes place. For this task the detector is equipped with highly-sensitive sensor that is in advance programmed for operation during night time. Picked up signals are kept in the memory, and afterwards read out by the receiver installed onboard of mobile laboratory. From the receiver the information transferred to computer where it is processed and conclusion is made about leak presence.
The second group comprises ultrasonic flow meters with the surface measuring transducers that are placed on pipeline surface. The given flow meters are portable microprocessor instruments equipped with removable ultrasonic transducers providing measurements of water flows' velocities in the range 0.1 … 20km/s and flow volumes in the range 5 … 1000000 L/min with accuracy not more than 3 %. The main advantage of such flow meters – on-line possibility (without necessity to cut-in the pipeline) to measure liquid flow.
The third group of instruments consists of correlation leak detectors with set of piezoelectric transducers. Transducers have magnetic elements to fix them directly on the

pipeline in such a manner that leak is located between them, thus the correlator calculates the distances from transducers to leakage. The amplified signals are transferred via radio channel from probes to processing block where their mutual correlation function is calculated. The place of correlation function peak value corresponds to leakage location. The correlator has variable filters of the upper and lower frequencies as well as variable rejection filter and has option of results presentation in 2D and 3D from. The advantage of correlation leak detectors consists in their ability to localize leakages in pipelines consisting of 10 various construction parts, i.e. from pipes of different diameter or material.

The fourth group presents the acoustic leak detectors. Such detectors comprise a ground microphone and amplifier. The operator, walking along the ground over the trace route registers acoustic noise generated by leaks. This leak detector has eight acoustic filters with operation band of 60 … 20000Hz that provides external disturbing noises tune-out. The instrument has built-in memory in which values of eight acoustic signals' levels measured in 8 points are stored. While the statistical processing of picked up signals is carried out in the electronic block of instruments; this option essentially improves the instrument noise immunity. For convenience of operation the complete set of delivery consists of the transducers to be used on soft soils, on hard soils and the contact transducer to be used for listening through stop valves for preliminary localization of a place of leakage.

The most efficient procedure of pipelines' damages localization, as practical instruments use showed, based on use of the control-computing systems integrating all above mentioned equipment.

To detect places of sewage channels clogs as well as for tracing of non-metal sewage channels used is the set of instruments comprising the electromagnetic transmitter fixed at the end of fiber-glass rope and receiver registering electromagnetic oscillations generated by above transmitter. The transmitter is pushed through the pipe to the clogged place and its position is controlled from the ground surface by means of the receiver. The most efficient instruments for sewage channels examination are TV installations which chambers are placed on the self-propelled trolleys travelling inside the pipeline. The operator of mobile laboratory receives the image of an internal surface of the pipeline in real time.

## 4. Line tracing equipment

Trace locators are must have equipment for all mentioned above laboratories. However they are used by many users (builders, repairmen, geodesists) independently, therefore it makes sense to review these instruments as separate group.

Trace locators provide direct measurement of depth of a cable or the pipeline burial. The depth value is presented on digital display. Modern trace locators have several active frequencies, option to transfer the information on a computer and work with GPS receivers.

The basic functions of modern trace locators:

- Cables location;
- Pipelines location;
- Measurement of depth of burial;
- Detection of places of a cable damage;
- Selection of required cable from a bundle;
- Detection of places of cable insulation damage;
- Detection of illegal pipeline cutting-ins.

In addition to location and burial depth determination some models of trace locators provide search of: couplings and coils, cable wires twisting, cable sheath defects, location of nonmetallic pipelines routes.

The control-computing systems of mobile laboratories designed for such application as a

rule are equipped by trace locators.

## Conclusions

Developed and introduced in practical use are the following instruments and mobile laboratories, which provide:

1. On-line detection of faulty places of underground communications that reduces time of these faults elimination and save resources.
2. Prevention of accidents and incidents initiation on underground communications and, as a result, saving of energy resources transported through pipelines and electric cables.
3. Prevention of possible pollution due to breaks of sewage channels, i.e. improvement of ecological conditions and environment protection.
4. For the period from 1990 to 2006 it has been developed some 400 mobile laboratories which are introduced in practical use in various regions of Russia and other CIS countries.