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EQUIPMENT AND MOBILE LABORATORIES FOR NDT AND DIAGNOSTICS OF UNDERGROUND COMMUNICATION LINES.

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Abstract

Discussed and presented is equipment develop and produced by Russian and German companies as well as mobile diagnostic systems designed to solve the following problems in different branches of industry:
Power industry
- testing and diagnostics of power cable lines (high voltage lines testing, trace locators and systems for damaged places locating)
- diagnostics of power transformers health condition
- testing of relay protection systems and electric power stations automatics
- testing of electrochemical protection systems

Communications
- testing and location of the damaged places of communication cables (metallic and fiber-optical)
- cable trace location

Water supply and drainage
- leak detection in water supply and heat pipes
- pipeline trace location
- quality testing of potable water
- testing of non-flow pipes and drainage channels

Presented goods implement latest technologies and used in all CIS countries. Discussed will be practical results and experience of Russian-German cooperation. All measuring instruments got pattern approval certificate of measuring instruments while all other types instruments and installations – certificate of conformity in accordance with Russian standards.

keywords: mobile diagnostic systems, different branches of industry, testing and diagnostics of power cable lines, Water supply and drainage, Russian standards

1. Introduction

Nowadays reliability and continuity requirements for power/water supply of companies, agencies, residential districts, all kinds of transport, postal and telegraph service, construction, mines and other national economy facilities as well as a variety of control and monitoring systems are becoming increasingly stringent. Special emphasis has been placed, therefore, by OOO Seba Spectrum and OOO Seba Energo on the issues related to diagnostics and monitoring of national power and water supply systems.

Among the founders of OOO Seba Spectrum and OOO Seba Energo are internationally recognized Russian and German companies with established extensive expertise in NDT and diagnostics.

Fig.1. Companies' History

Since they were established, the companies have gone a long way from imported equipment sales to development and manufacture of their own complex systems for performance monitoring and diagnostics of power industry facilities as well as fault location all along the processing chain "production – supply – distribution – consumption of power/water".

What follows is a description of instruments and mobile facilities enabling the above tasks to be carried out.

2. Base Van Version for the Mobile Laboratory

Depending on the laboratory type and purpose, the van is divided into functional modules. Any type of laboratory, however, will use the base version which comprises:

Laboratory power supply system

The following power supply options are provided to do the entire range of works:

- from external AC mains 220 V, 50 Hz: external power supply of instruments and equipment will use a cable drum with network supply cable 50 m long and a cable drum with protective earth cable 50 m long;
- from a 2 - 6 kW self-contained gasoline/diesel generating set.

Standard temperature maintenance system

In cold weather the van is heated by a self-contained heater that features a continuously adjustable wattage function to maintain the required temperature inside the van. Due to use of state-of-the-art technologies and their simplified design, the new heaters have a much longer life, better quality and performance, as distinct from the previous generation heaters.

For use of laboratories in the hot season, provision is made for air conditioning systems to be installed in the van's cabin and lab compartment.

Van lighting system

The van's lighting is by lamps powered from the van on-board power system, backup battery (emergency lighting) or AC mains (auxiliary workplace illumination).

Mobile radio communication system

Mobile radio communication system comprises an automobile radio station, manpack radios and, if necessary, a telescopic antenna mast.

"North" version configuration (optional):

- starting preheater;
- fuel heater group (in fine and coarse filters, fuel tanks);
- double automotive glass windows;
- insulated floor;
- self-contained high-wattage heater;
- winch driven from PTO shaft of the van engine;
- increased-capacity fuel tanks.

3. Power Transformer Performance Control Laboratory

Purpose: testing and diagnostics of 110-500 kV power transformers and 110-500 kV high-voltage bushings in accordance with relevant guidelines.

Performance capabilities:

- measuring parameters of winding/bushing insulation;
- DC copper resistance test
- standby loss test
- short-circuit impedance test
- transformer ratio test
- winding connection group test
- power-frequency overvoltage test for windings and bushings;

- measuring time characteristics of undervoltage relay switches;
- circuit-breaker oil analysis;
- automatic presentation of testing results.

Fig.2. Functional Chart of the Power Transformer Performance Control Laboratory

Translation of wording in boxes of Fig. 2

Box 1: 220-380 V measuring system
Hand control unit
Transformer phase selection
DC resistance windings/transformer ratio test
Transformer loss test: copper losses, iron losses

Box 2: 5-10 kV measuring system
Measuring the dielectric loss tangent of transformer winding/bushing insulation
Insulation-resistance test and measuring the absorption factor R60/R15

Box 3: 100-130 kV high-voltage measuring system
100 kV AC high-voltage testing system
135 kV DC high-voltage testing system

Box 4: Measuring system for time characteristics of undervoltage relay switches

Box 5: Circuit-breaker oil analysis
Oil electric strength test
Oil **tgδ** test
Analysis of water content in oil
Analysis of gas components in oil

Instrument switching device Specialized software Visualization/documentation facilities
Multilevel safety system

Network cable (50 m) on a drum Instrument/control cables (25 m) on drums Transformer
Earth cable (50 m) on a drum High-voltage cables (25 m) on drums

Fig.3. General View of the Lab

Fig.4. High-Voltage Compartment

Fig.5. Part of the Work Compartment

Fig.6. Part of the Work Compartment

4. Instrument Transformer Calibration Laboratory

Purpose: calibration of instrument current/voltage transformers designed for electricity metering.
Performance capabilities:
- transformer ratio test
- winding resistance test
- insulation-resistance test;
- phase shift test
- high-voltage testing.

Fig.7. HV Equipment Compartment

Fig.8. Operator's Compartment

5. Power Cable Diagnostic Laboratory

Purpose: power cable state evaluation for remaining life forecasting

Performance capabilities:

- cable tracing
- power cable state evaluation
- remaining life forecasting.

The recent trend in the power industry has been a smooth transition from the preventive maintenance system to repairs as required, a system widely accepted in developed countries. Such transition implies introduction of new and improvement of conventional diagnostic techniques.

Integrated diagnostics of power cables may use the principle of measuring reverse voltage and isothermic relaxation currents. After a certain phase during which the tested cable capacity is first charged and then discharged momentarily, data are collected on variations of reverse voltage and isothermic relaxation currents, which characterize the aged condition and moisture content in insulation.

Given that 40% to 50% of primary power facilities in the Russian power industry have served out their design life, diagnostics should focus primarily on extension of equipment life until it is fully used up. In this situation, special attention should be given to on-the-spot status control methods for energized equipment. Measurement of partial discharge (PD) signals is one of the most promising methods for high-voltage insulation control and should be thus applied on a large scale. The real cable insulation differs from the ideal dielectric, above all, in that the insulation body features micropores, especially on the core-insulation interface surface. This often causes electric insulation to deteriorate in use, a process known as dielectric ageing for which partial discharges are largely responsible. Typically, it is AC fields that affect dielectrics in power generation. AC voltage of certain amplitude produces partial discharges in gas and air pores. The proposed laboratory allows a PD source to be located and the remaining cable life to be estimated.

Fig.9. Operator's Compartment **Fig.10. High-voltage Compartment**

6. Laboratory for Fault Location and Power Cable HV Testing

Purpose: fault location and power cable HV testing

Performance capabilities:

- cable tracing
- high-resistance fault burn down
- cable fault location
- DC high-voltage testing
- cable selection from a bunch
- cable core phasing
- insulation-resistance test
- insulation fault location.

Fault location is a task of critical importance in use of power cable lines (PCL). A choice of cable fault location method depends on the nature of fault and transient resistance at the point of fault. There are a variety of faults in three-phase PCLs. A megohmmeter is used for fault type identification, to which end the following should be checked on both ends of the line: insulation resistance to ground of each cable core (phase insulation), intercore insulation resistance (line insulation) and core continuity.

Very often cable fault location requires a minimum possible resistance between cores or between a core and the cable sheath at the point of fault. This transient resistance is reduced to the desired level by burning the insulation with a high-vacuum rectifier, audio frequency generator or transformer. The burn-down process varies depending on the fault nature and cable condition. Normally, resistance decreases by a few tens of ohms in some 15 to 20 seconds. With wet insulation, however, the process tends to take a longer time, allowing resistance to be reduced only to 2,000 to 3,000 ohm. The burn-down process in couplings is extended and, sometimes takes a few hours, with resistance dropping suddenly and rising again until the process is steady-state and resistance starts decreasing.

In case of a PCL fault, the fault area is identified first (relative methods) and then the fault is located along the cable run, using various methods (absolute or cartographic). For pinpointing the fault area, a few methods should be used at one PCL end. Failing this, a single method used at both cable ends can provide a more accurate measurement.

The following methods are used for fault area location: pulse method, oscillatory discharge method, loop method and capacitance method. All the said methods for cable line fault location are implemented by mobile electrical laboratories.

Fig.11. Functional Chart of the Laboratory for Power Cable Fault Location and High-Voltage Testing

Fig.12. Operator’s Compartment

Fig.13. High-Voltage Compartment

7. Laboratory for High-Voltage Testing of Polyethylene-Insulated Power Cables

<u>Purpose:</u> high-voltage testing of polyethylene-insulated power cables with 0.1 Hz ultra-low frequency voltage

<u>Functional capabilities:</u>

- cable tracing
- high-voltage testing with 0.1 Hz ultra-low frequency voltage
- cable selection from a bunch
- insulation-resistance test
- insulation fault location.

High-voltage testing equipment for power cables with paper-oil insulation is part of the above systems. It should be noted, however, that polyethylene-insulated power cables are tested with a 0.1 Hz ultra-low frequency voltage.

In rectified voltage testing, cables are subjected to increased loads. A very-low frequency testing method may be considered as an alternative. Based on the classical AC testing procedures, this method uses very low frequencies.

Consistent testing results may be obtained by use of rectangular testing voltage with polarity inversion within a 50 Hz cosine half-wave of 0.1 Hz. Standards recommend a testing voltage value U_{rated} and a test duration between 30 and 60 minutes. This will correspond to the voltage crest level used for 50 Hz (2 U_{rated}) AC testing. Yet in practice, it is recommended that the voltage crest level be set depending on the actual situation.

The VLF mobile testing units offered by our company implement this method.

Application of the patented rectangular-cosine shape of voltage allows fast breakdown of faulty sections of cables with plastic and paper-oil insulation, while cable insulation is not loaded unless necessary.

8. Water Leak Detection Laboratory

The present-day technological level enabled development of equipment ensuring fast location of a leak point accurate within a few centimeters.

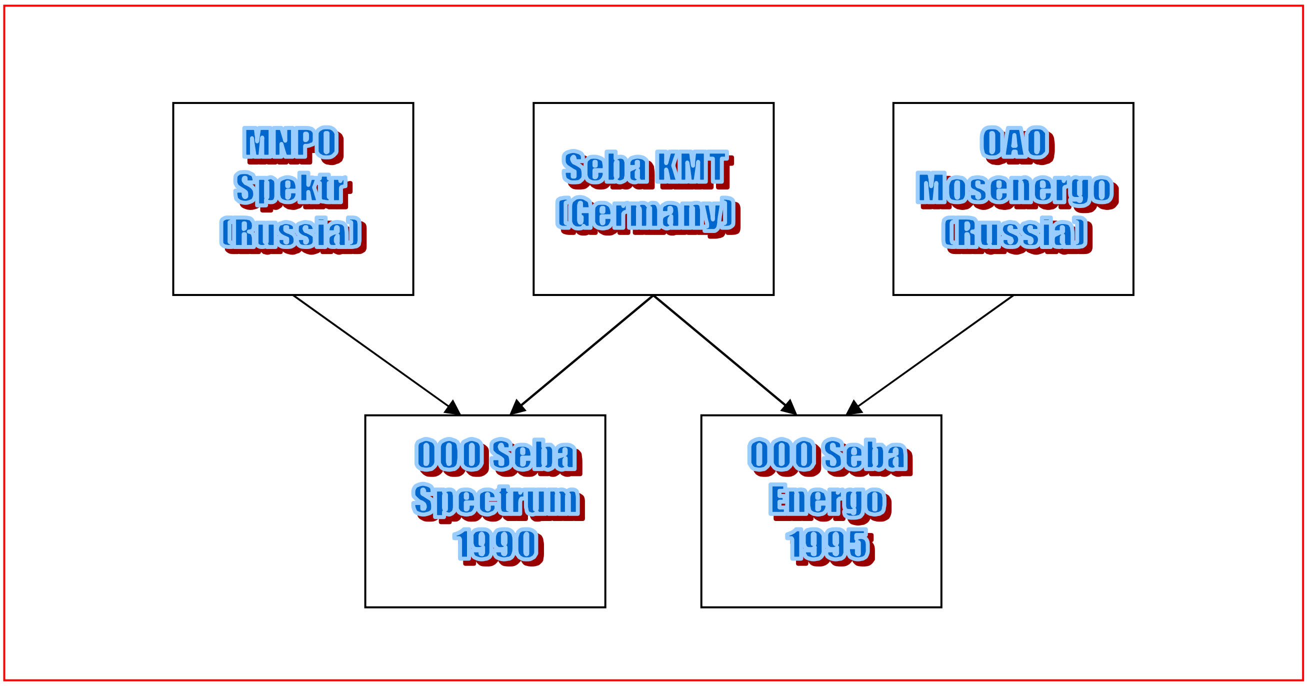
The primary tools for fast and accurate leak detection are piping tracers, correlation and acoustic leak detectors.

Piping tracers are special instruments designed to locate a pipeline (route and depth).

Correlation leak detectors are special devices based on fast Fourier transformations. Two sensors of a correlation device are mounted at two points of a pipeline, for example, on the gate valves. The sensors "listen" through the pipeline and communicate information via the communication channel to the correlation device receiver. Data on the pipeline type, material, diameter and length are preset in the receiver. Using such data, the correlation device calculates the exact leakage location by the time difference between incoming signals from each sensor.

Acoustic leak detectors are devices that feature electronic (digital or analog) sensory input filtration and analyze the acoustic spectrum of the leak water signal at various pressures and fault sizes. The main purpose of filters is signal extraction in loud urban noise conditions. The higher is the filter order, the more efficient is interference elimination. The basic specifications of such devices are a filtration level as well as the number of filtration ranges and availability of sensors for various soils – asphalt, grass, clean ground and snow.

Fig.14. Operator's Compartment Inside the Water Leak Detection Laboratory



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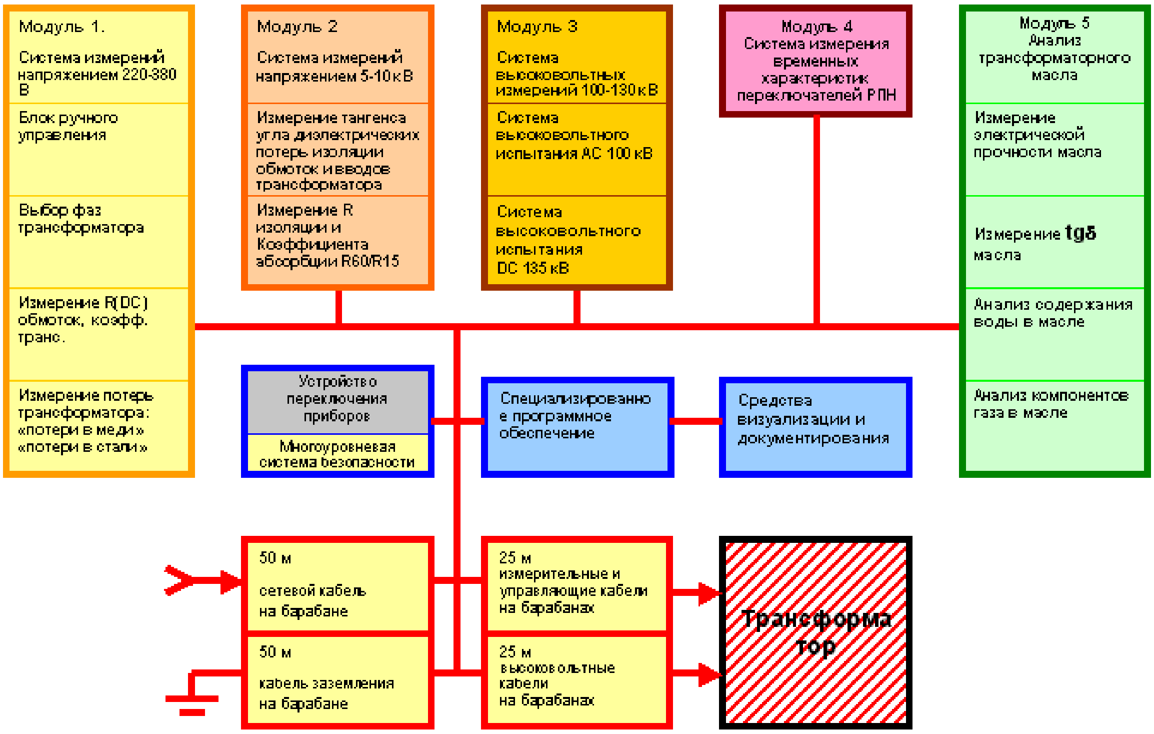

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Fig.10. High-voltage Compartment

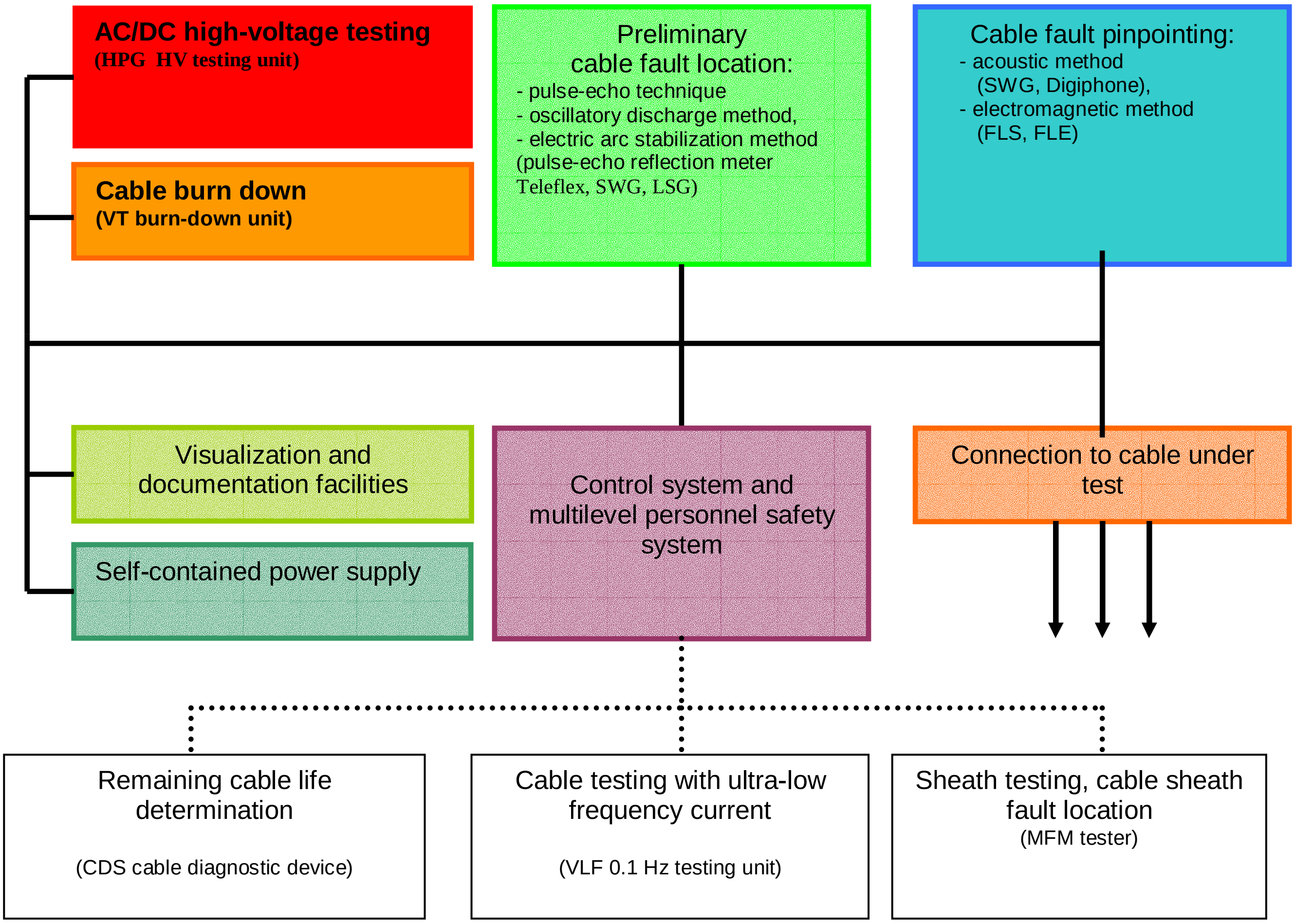

Fig.11. Functional Chart of the Laboratory for Power Cable Fault Location and High-Voltage Testing

Fig.12. Operator’s Compartment

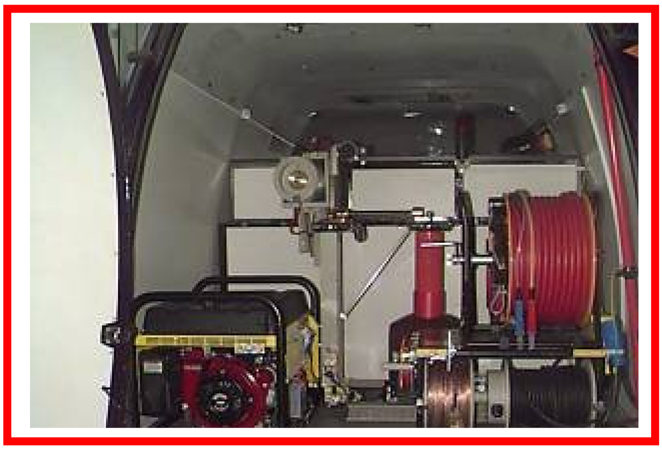

Fig.13. High-Voltage Compartment

Fig.14. Operator’s Compartment Inside the Water Leak Detection Laboratory