LABORATORIES FOR POWER CABLE DIAGNOSTICS

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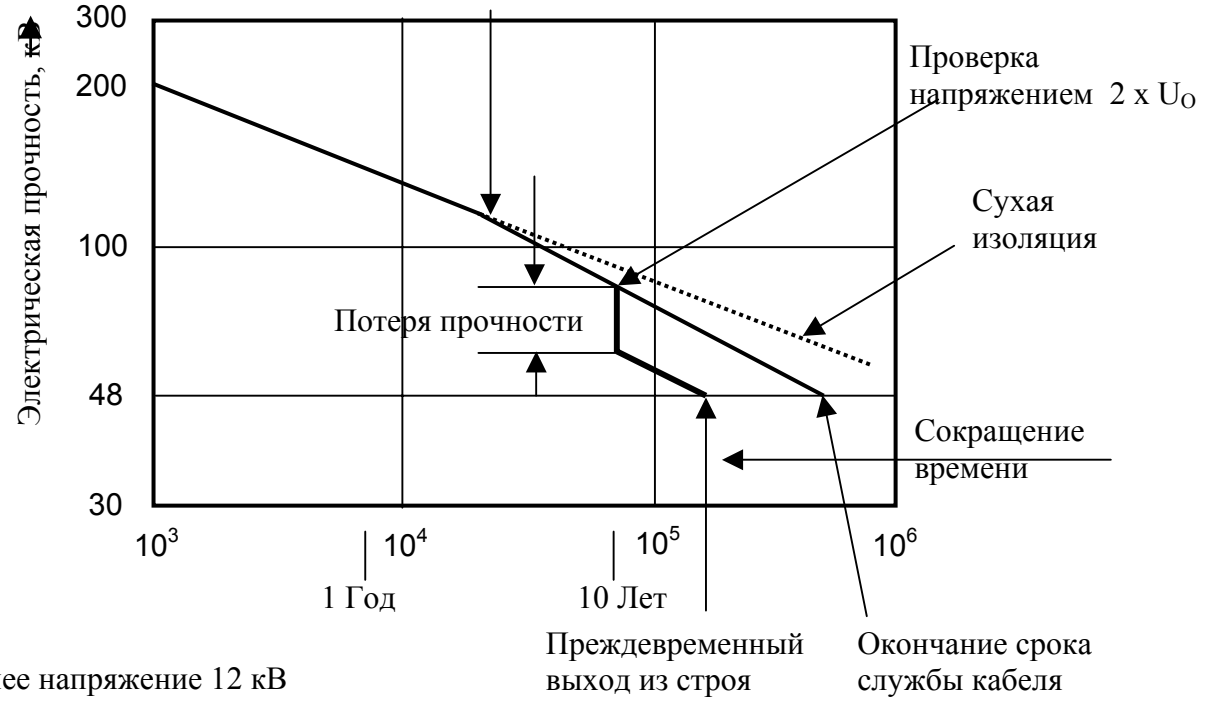
Evaluation of the state of cable line insulation and fittings is the basis for adoption of decisions on continuation of operation, repair or replacement of cable lines.

State of the electric equipment insulation can be determined by the following methods:

- testing under increased voltage in accordance with applicable standards;
- single-time testing under diagnostic methods (diagnostics).

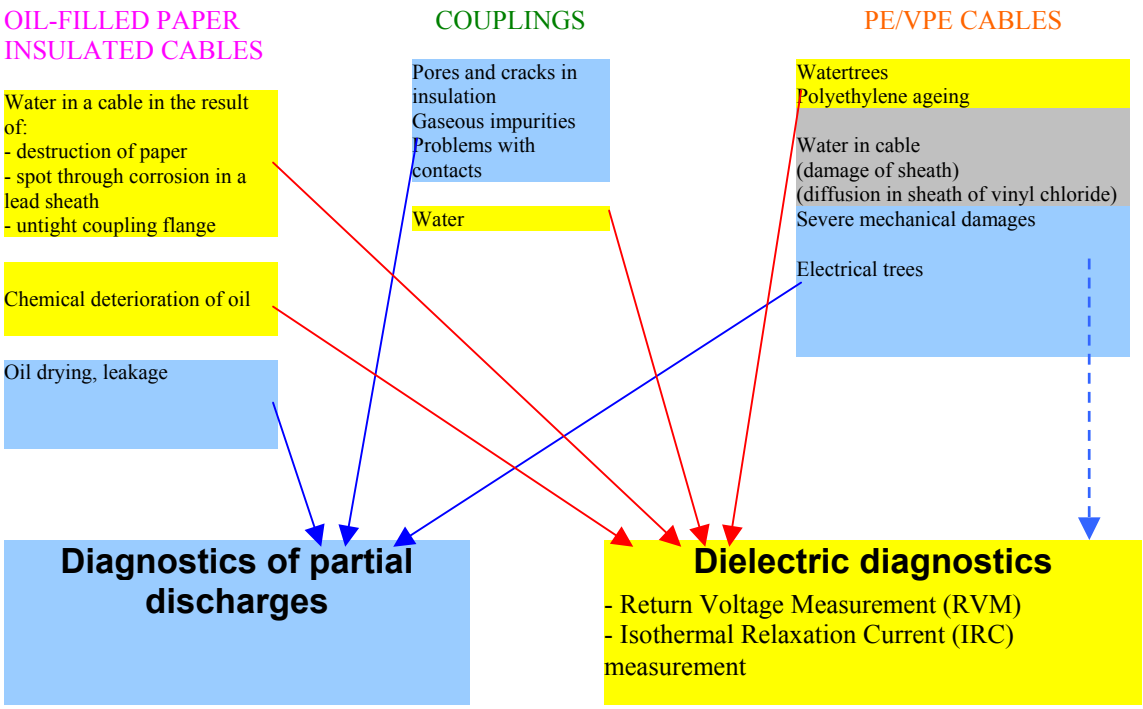
From practice of operation of high-voltage cable lines, it is known that positive results of tests under increased voltage do not guarantee at all subsequent accident-free operation of electric equipment. Thus, for example, cable lines come out of function often within nearest months following their successful testing under increased voltage. It is established that reason of this phenomenon consists in the intensive destruction of insulation by partial discharges in problem points, which results in reduction of cable line service life. Tests under increased voltage are mostly dangerous ones for cable lines with large service life or low quality of installation and already having high level of partial discharges in problem points.

Diagram below demonstrates reduction of service life of operated cable during testing under increased voltage.



Objective data on technical state of electric equipment can be obtained by modern diagnostic methods. Diagnostic tests of electric equipment are performed, as a rule, by methods that do not damage insulation. They make it possible not only to determine technical state of an object, but to localize available problem points as well. Performance of combined diagnostic tests under various nondestructive testing methods allows also evaluation of the degree of insulation ageing and cable remaining life.

Combination of methods of integral and local diagnostics is the most optimal way to obtain the most trustworthy and complete information on the state of cable insulation and fittings. Testing of the cable line operability by application of increased DC voltage is justified following installation or repair and in the absence of technical ability to apply diagnostic nondestructive methods.



Let's consider in more details problems occurred in the process of operation of cable systems and methods of their detection.

Problems with cables with insulation of polyethylene (PE) and cross-linked polyethylene (VPE)

Considerable ageing effect of cables with PE/VPE insulation is caused by appearance and growth of watertrees. They occur with time under action of water, heat and electromagnetic field strength. They expand gradually and, finally, result in short circuit and cable failure due to formation of electric trees. Other ageing effects appear under thermal overload of PE/VPE insulation. Expanding of watertrees is contributed especially by moisture in cables with defects in sheath. Since watertrees conditioned by physical laws do not demonstrate partial discharges, described processes of ageing can be detected and evaluated only by means of **dielectric diagnostics**.

Problems with cables with impregnated-paper insulation.

- water in cable

Moisture content in insulation increases due to damage of sheath (corrosion opening; cracks in the result of cable movement) and disintegration of cellulose caused by ageing. At the same time, electric strength of insulation continues to decrease gradually until achieves working voltage value and cable becomes unreliable for operation. Service life of such cables depends strongly on manufacturing quality and conditions of layout. Therefore, it is impossible to provide any information on insulation quality on the basis of the cable service life only. Determination of wetness requires application of **dielectric diagnostic**. As experience shows, partial discharges do not occur in the wet paper-oil insulation.

- drying

Mass leakage and insufficient impregnation results in drying of these places and formation of hollow spaces in cable insulation filled with gas. Due to decreased electric strength, partial discharges (PD) occur in such places, which can lead to carbonization of paper and destruct insulation. Such PD's can be detected and localized by means of **PD diagnostics**. Often, localization of such PD's does not reveal local concentrations and, at the same time, there is no direct threat of damage, but distribution along more extended sections of a cable.

Problems in couplings and sealing ends.

- damaging by partial discharges

As a result of incorrect installation, ionized, gas-filled cavities and gaps, as well as sections with increased electromagnetic field strength occur and result in partial discharges partially at rated voltage

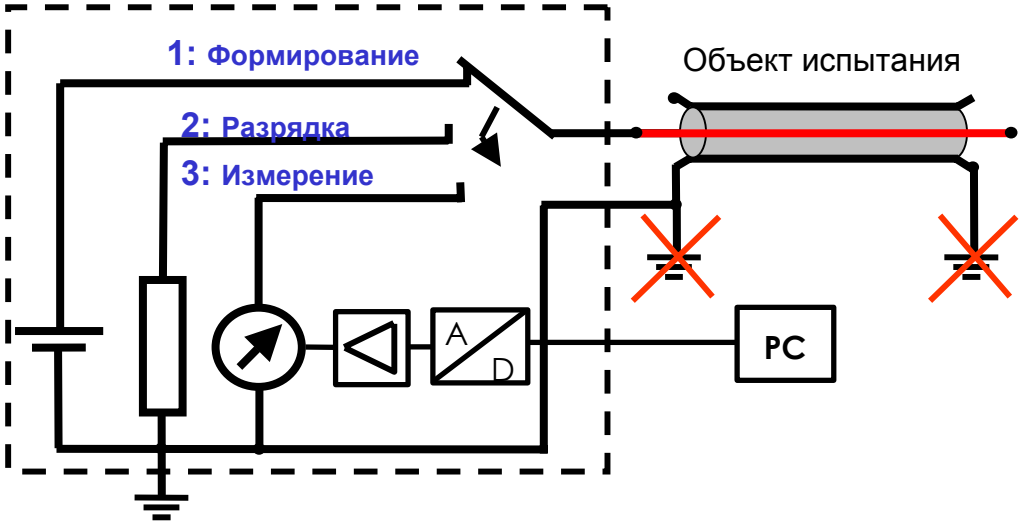
already. Afterwards, thermal processes of degradation in couplings with unduly performed connections of conductors can also affect sections, where PD's can form. Such places damaged by partial discharges can be detected and localized by means of **PD diagnostics.**

- water in couplings

Detection of wet couplings is not the paramount objective of diagnostics. However, during diagnostics, this information is often "auxiliary" one. Wet couplings do not cause partial discharges, but attract attention due to increased and unstable charging current during **dielectric diagnostics** of cable sections. In this case, it is recommended, as a rule, to carry out VLF tests with subsequent localization by means of reflectometer.

Dielectric diagnostics

Cables must be disconnected and discharged completely. Prior the beginning of diagnostics, it is necessary to ensure earthing by means of ground connection cable or measuring cable from the side of measurement. Minimal earthing and short circuit time must amount to 30 minutes. In unfavorable conditions, longer short-circuit time can be required. It is necessary to disconnect voltage transformers and to clean contaminated sealing ends.



- PE/VPE-cables

Combined lines with sections of PE- and VPE-cables can be diagnosed together. In order to perform diagnostics, main conductor and cable screen must be disconnected completely at both sides from distributing device in order to eliminate in guaranteed manner noises and polarization effects of distributing installation.

- cables with impregnated paper insulation

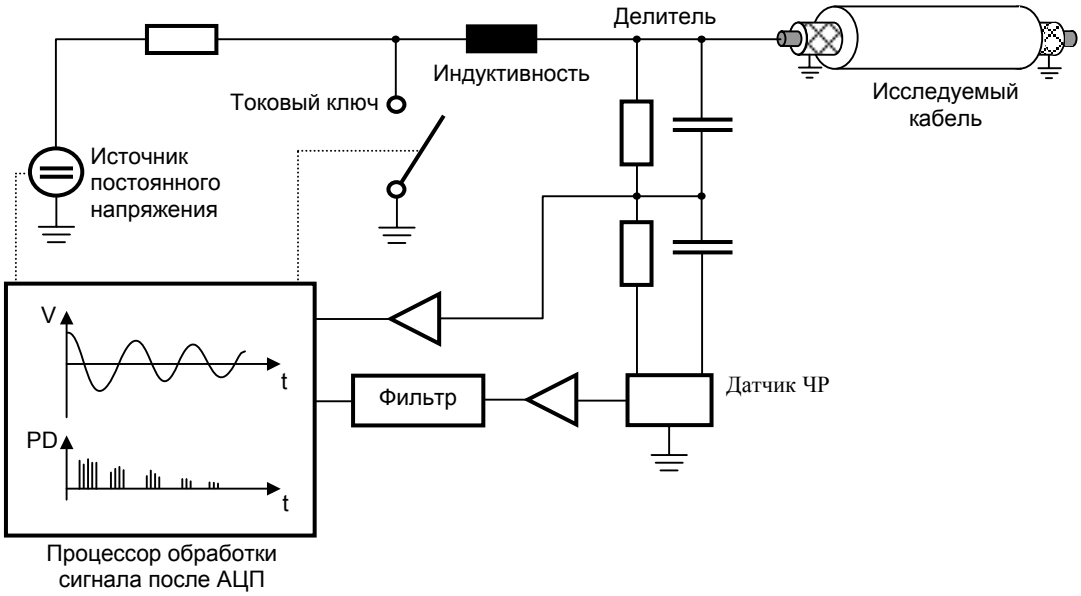
In order to perform diagnostics, conductors must be disconnected completely at both sides from distributing device. In the point of measurement, metal sheath/earthing of substation remains connected. At other end of cable, this connection should be disconnected as far as possible from distributing installation in order to eliminate influence of noises on measurement results.

- combined lines with sections of cables with impregnated paper insulation and PE/VPE-cables

Under physical laws, diagnostics of combined cables can provide information only on cables with impregnated paper insulation. Certainly, cable line must consist mainly of cable with impregnated paper insulation; share of PE/VPE-cables must amount to max. 20% of the total length of cables. It is often the case during repair of individual sections and inputs at substations. Preparatory works are the same as ones for cables with impregnated paper insulation.

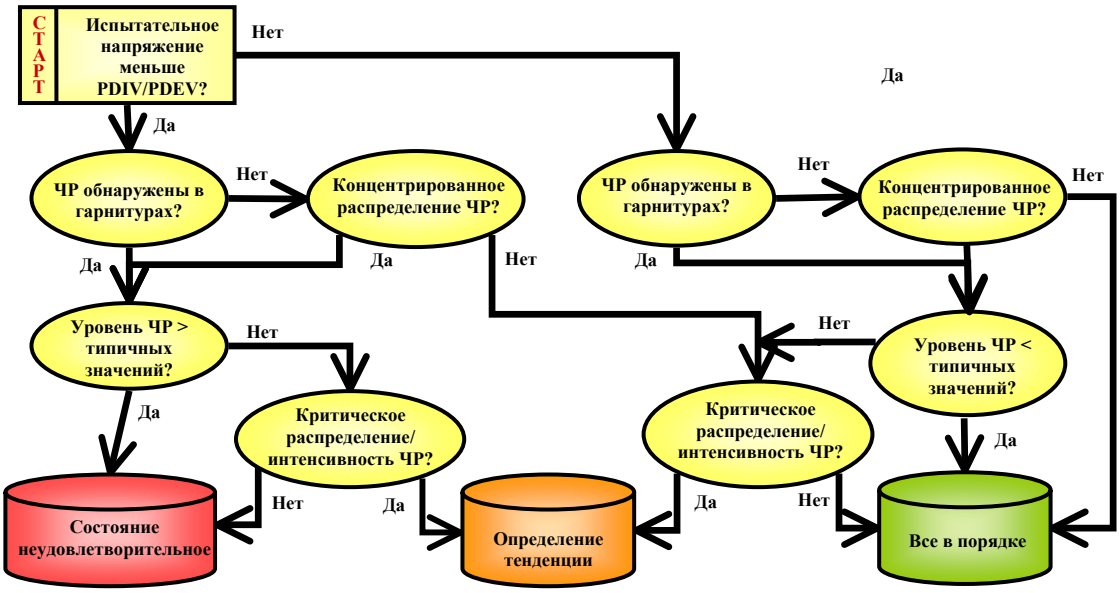
Diagnostics of partial discharges (PD)

For such diagnostics, cables must be disconnected and discharged completely. In the event of gas-insulated switching devices, measuring adapters should be prepared in advance. For accurate localization of PD damaged points, accurate diagrams of cable lines and couplings are of special importance.



Characteristics of partial discharges depend on the defect type, size and location; insulation material; applied voltage; cable temperature; and vary with time. PD caused damages depend on the number of factors and can vary from insignificant to dangerous ones resulting to failures within the range from few nearest days to several years.

Interpretation rules for the results of PD-diagnostics of power cables



* **PDIV** and **PDEV** – partial discharge inception and extinction voltage.

Diagram of installation for measurement of return voltage

Diagram of installation for measurement of partial discharges