The most common problem in operating of high voltage cables with cross-linked polyethylene (XLPE) insulation is the defects in the insulation of terminations and joints, which is the most often cause of the old and relatively new cables failure. Cable insulation condition monitoring is also important, and gets more and more critical towards the end of the cable life.

There are two practical methods of HV terminations and joints insulation condition monitoring; they are temperature measurement and partial discharge (PD) measurement and analysis. The latter is more effective, as insulation defects in HV cables are always accompanied by partial discharges and voltage failures, whereas the thermal changes are much rarer, and also accompanied by PD.

«CSM-1» (Cable Sleeve Monitor) device is used for termination and joint insulation condition monitoring.

«CSM-1» allows:
- PD measuring in the insulation of terminations and joints by UHF sensors of up to 1 GHz.
- PD measuring in high-voltage cable insulation by HF sensors in the frequency range of 0.5 - 15.0 MHz.
- PD measuring in the insulation of terminations and joints by acoustic sensor of up to 100 kHz.
- Locating defects in cables by measuring the reflectogram of PD pulse distribution.
- Temperature monitoring of joints (cables) in the place of «CSM-1» device installation.
- Measuring power current in cable shield which is an additional reason of cable heating.

All the data from the sensors is processed directly in the device and as a result the following information is available:
- terminations and joints insulation condition;
- the cable section condition;
- the types of insulation defects;
- location of the insulation defects.

PD Measuring in Terminations, Joints and Cables.

For insulation monitoring of XLPE cables to be reliable, partial discharges (PD) should be measured in a wide frequency range - from parts of MHz to GHz. It is obligatory for cables and joints insulation condition comprehensive diagnostics.

On the first stage PD pulses in XLPE insulation are very high-frequency. While moving through the cable, the pulses change their characteristics: they become longer and decrease in amplitude.

If PD source is in a joint near the sensor, then its frequency is very high - hundreds of MHz, that is why PDs in joints are measured in UHF range. If PD source is far from the sensor, then its frequency can be “only” hundreds of kHz. The longer the cable is, the lower the frequency can be of PD pulses measured in it. That is why HF sensors are used for cable insulation monitoring.

This is the reason why defect location in cable insulation is done on the basis of the reflectogram measured in HF frequency range.

The «CSM-1» Sensors.

For PD measurement in joints and cables insulation by «CSM-1» the sensors of three different types can be used: either all the three together, or two, or one in dependence on the monitoring system purpose. The sensor choice is mostly determined by the installation capabilities.
allows monitoring joint and termination insulation condition quite reliably. RFCT and HFCT high frequency current transformers are used as HF sensors.

Acoustic sensors can be used with the device when UHF and HF sensors are impossible to use. High directed and local sensitivity, as well as low noise rejection are the shortcomings of these sensors. Usually acoustic sensors are fixed on the surface of the monitored joint by resilient mounting or they are installed near the joint.

**«CSM-1» Power Supply**

If «CSM-1» device is used for high voltage cables termination monitoring, then it can be fed from the power supply or any other power source.

If devices are installed on joints, or if there is no voltage on the terminations, there are three ways of power supply:

- «CSM-1» device can be supplied together with PST power supply module, which presents a steel split ring core with winding. This module installed around the cable with the shield current from 50 A can give the energy enough for the device operation. While there is shield current, the device functions.
- If long cables are laid underground, then power supply cable should be laid near it, and all the devices should be successive connected to the power supply cable. This cable will serve two functions: it will provide both power supply and data transition to cables condition monitoring control panel - that will pay all the costs of its laying.
- «CSM-1» device power supply can be carried out from a high-capacity battery; the battery capacity is enough for the device operation during one year.

Such a solution has two major drawbacks - annual maintenance of all equipment is necessary and not all the functions of the device will work in full due to the limited power supply.

**Interfaces.**

«CSM-1» device has the interfaces for integrating into SCADA system.

«CSM-1» can provide:

- Connection to Ethernet for data transmission by fiber optic or a copper cable.
- Connection to ZigBee local network by radio channel for creating data network between the devices.
- Data transmission by the power line using LAN protocol.
- Connection by RS-485 interface.

«CSM-1» memory is sufficient for storing the measurement and analysis results for several years, so the information can be periodically collected through the radio channel.

**Delivery Set of «CSM-1»**

The standard delivery set of «CSM-1» device includes:

- «CSM-1» device;
- PD sensor for UHF frequency range;
- Software;
- Documentation on CD.

Optionally the following PD sensors and power supply modules can be supplied together with «CSM-1»:

- RFCT-7 sensor for HF frequency range;
- Acoustic sensor for PD measuring;
- PST module for the monitoring device power supply from the power frequency currents running through cable shield;
- The module for the device power supply from battery.

**«CSM-1» Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable rated voltage, kV</td>
<td>10 ÷ 500</td>
</tr>
<tr>
<td>Type of insulation condition monitoring</td>
<td>PD monitoring, t°C</td>
</tr>
<tr>
<td>Number of the cables (joints) monitored by one system</td>
<td>1</td>
</tr>
<tr>
<td>Length of the cables monitored by one device, m</td>
<td>Up to 4000</td>
</tr>
<tr>
<td>PD range, MHz</td>
<td>0.1 ÷ 1000.0</td>
</tr>
<tr>
<td>Amplitude of high-frequency pulses, mV</td>
<td>From 1.0</td>
</tr>
<tr>
<td>SCADA interface</td>
<td>ZigBee, RS-485, Ethernet</td>
</tr>
<tr>
<td>Temperature range without heating, °C</td>
<td>-40 ÷ +60</td>
</tr>
<tr>
<td>Supply voltage, V AC/DC</td>
<td>120 ÷ 260</td>
</tr>
<tr>
<td>Device dimensions, mm</td>
<td>200 * 180 * 60</td>
</tr>
</tbody>
</table>