More than half of all interruptions in the power supply of consumers usually happen due to the problems in the overhead power lines.

Overhead power line disconnections can be caused by the following factors:

- Overhead power line insulator degradation, developing slowly, over a significant period of time. The degradation can be caused by the internal defects of the overhead power line insulator or surface pollution.
- The problems caused by ambient factors, such as wire icing or insulation pollution moistening. Such problems develop quickly, in several hours.
- The problems of electromagnetic and dynamical effects on the overhead power line. They include overvoltage of different nature and all types of shorting between the wires and the ground.

«DiLin» monitoring system allows decreasing the influence of these factors on the reliability of high-voltage overhead power lines operation and sometimes detecting the defects on early stage of development.

«DiLin» monitoring system is used for:

- Determining the possibility of the overhead power line capacity increasing.
- Effective assessment of the overhead power line insulator condition, defects detection and assessment.
- Measuring the transients in the overhead lines for accurate location of defects along the line; giving recommendations for repair planning and carrying out.
- Forecasting the condition change of the overhead power line as a part of the complex transmission line operation analysis.

«DiLin» system consists of the 3 main elements:

- «DiLin-Sensors» – the primary sensors of the monitoring system mounted on wires of the monitored overhead power line. All the measured and processed information is sent into the monitoring system via radio channel.
- «DiLin-Observers» – the local modules of the monitoring system used for collecting the information from «DiLin-Sensors». The modules are mounted on both the ends of the line; they collect the information and upload it into the system computer.
- «DiLin-inVA» – the software of the top level, set on the system computer. The software collects and unites the information from «DiLin-Observers» and it functions as diagnostic software.

**Smart «DiLin-Sensor»**.

«DiLin-Sensor» is mounted on wires of the overhead power line; the sensor measures and analyzes the data about the overhead power line condition, such as:

- Overhead power line wires temperature.
- Current in the line.
- 3D mechanical oscillations of wires.
- Air parameters – temperature and humidity.
- Wire icing.
- Defect location in the line.

«DiLin-Sensor» is cylindrical, 200 mm in diameter and 300 mm long; it is mounted on wires of the line. There is «DiLin-Sensor/G+» version of the sensor with an built-in pulse generator for wires icing monitoring, it is 400 mm long.

The sensors are fed from the wires load current. For data transmission “to the ground” the built-in radio channel with ZigBee protocol or GSM connection is used.

The built-in transmitter provides reliable connection between «DiLin-Sensors» and «DiLin-Observers» at the distance of up to 1500 meters.

**«DiLin-Observer» module is the information collector.**

The base local module of the monitoring system «DiLin-Observer» is located on the ground and has no galvanic connection to high voltage. It is used for measuring and transmitting information to the main system computer via connection channels of any type.

The base station is power supplied from AC network, or the constant voltage of the substation, or solar batteries and accumulators, if there is no stationary supply. One base module can monitor almost any number of «DiLin-Sensors» mounted on the wires of incoming and outgoing lines of one distribution substation.
**«DiLin» System Diagnostics Algorithms.**

1. **Overhead power line insulator condition monitoring.**
   
   Frequently disconnections of the overhead power lines are caused by the problems with the insulators, often with polymer insulators. The problems arise because of the internal defects or surface contamination. These defects cause the discharge activity growth.

   «DiLin-Sensor» should be mounted on both the ends of the overhead power line. The pulse measurement at the ends of the line is made with high accuracy due to GPS synchronization via the built-in GSM/GLONASS receivers.

   The time of the pulse arrival to both the ends of the line is analyzed by «DiLin-INVA» software. By analyzing the time of the pulse arrival to both the ends of the line, the defects in the overhead line insulator can be located with high accuracy (up to one power transmission tower).

2. **Wire-to-wire short-circuits monitoring.**
   
   Two synchronized sensors on the ends of the line can detect the place of wire shorting in the line. The analysis of the time of pulse arrival from short-circuit to both the ends of the line is the basis of such diagnostics.

   The advantage of this method is that the short-circuit place is located immediately after short-circuit happens. That is why the detection of short-circuit place is made effectively irrespective of whether short-circuit is stationary or self-correcting.

3. **Wires vibration monitoring.**
   
   The 3D accelerometer built into «DiLin-Sensor» allows monitoring all the spatial relocations of wires, i.e. axial, lateral and upright wire vibrations.

   Measuring of wires’ vibration frequency allows monitoring the distance from wires to the ground by using the sensor mounted on wires.

4. **Wires icing monitoring.**
   
   Two «DiLin-Sensors» mounted on the opposite ends of the overhead power line, their work synchronized by GPS, allow solving a very important task – wires icing monitoring. The monitoring is based on measuring the parameters of the high-frequency pulses “flowing” along the overhead power line, and analyzing the changes.

Wires icing is characterized by the appearance of many closed circuits, enveloping the wires in the icing zone. The wider is the icing zone, the more there are the closed circuits and the less is their resistance. It leads to increased signals damping along the line.

Wire icing is also characterized by slowing of electromagnetic waves in the wires. The diagram below illustrates the electromagnetic wave speed during icing and after ice melting.

![Diagram of electromagnetic wave speed during icing and after ice melting.]

«DiLin-Sensors/G» with built-in high frequency pulse generators are the most suitable sensors for these purposes. If «DiLin-Sensor» are used instead, the test pulse generator is mounted separately “on ground” and connected to the line with a coupling capacitor.

![Diagram of «DiLin-Sensors/G» with built-in high frequency pulse generators.]

5. **Detecting the places of one-phase wire-to-ground short-circuit.**
   
   «DiLin-Sensors/G» can also monitor one-phase wire-to-ground short-circuit. In this case the signal from the built-in generator is used for measuring reflectograms of signal distribution along the wires. The analysis of the reflectogram shape allows to detect the wire-to-ground short-circuit and find the place of its origin.

**Delivery set of «DiLin» system.**

The delivery set of «DiLin» system consists of:

- «DiLin-Sensor», 6 pieces.
- «DiLin-Observer» base module, 2 pieces
- Generator of test high-frequency pulses with a coupling capacitor (option), 1 piece.
- «DiLin-INVA» Software.

If «DiLin-Sensors/G» are used in the system, there’s no need in any additional test pulse generator.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage of the line, kV</td>
<td>35 and more</td>
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<tr>
<td>Load current, A</td>
<td>40 and more</td>
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<tr>
<td>Monitored line length, km</td>
<td>Up to 100</td>
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<tr>
<td>Frequency of discharge pulses, MHz</td>
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<tr>
<td>Precision of defect location</td>
<td>±1% of length</td>
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<tr>
<td>Temperature range, °C</td>
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<tr>
<td>«DiLin-Sensor» dimensions, mm</td>
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<tr>
<td>«DiLin-Sensor» weight, kg</td>
<td>25</td>
</tr>
<tr>
<td>«DiLin-Observer» dimensions, mm</td>
<td>520<em>435</em>230</td>
</tr>
<tr>
<td>«DiLin-Observer» weight, in case, kg</td>
<td>25</td>
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