The most critical elements of power transformers are:
- High-voltage transformer bushings – OIP and dry bushings;
- Transformer windings insulation;
- Local overheating of windings, cores and magnetic shunts inside the transformer;
- Problems with transformer OLTC condition;
- Problems with windings dynamic resistance to short circuit currents.

At the same time, many functions of transformer monitoring and diagnostics used at present could be excluded without any loss of monitoring efficiency. Here we mean the monitoring of slowly changing parameters (for example, insulation ageing), and duplication (for example, protection relay monitoring and cooling system monitoring).

The unjustified monitoring functions enhancing by some producers could one day discredit the idea of on-line monitoring itself.

«TDM-3F» diagnostic monitoring system is one of the standard configurations of TDM complex diagnostics system. It is based on the minimum sufficiency principle and provides the efficient monitoring of the most critical power transformers subsystems. It allows considerable decreasing of the monitoring system introduction costs without losing the monitoring efficiency.

The following diagnostic functions are realized in «TDM-3F» system:
1. Condition monitoring of 3 or 6 high-voltage bushings – according to the type of the transformer. The monitored parameters are: the insulation leakage current, \( C_{3} \) capacity and dissipation factor (relative or absolute, optionally). For that DB-2 complex sensors are installed on the test taps, which allows insulation parameters monitoring and high-frequency pulse (PD) measuring in the wide frequency range – up to several GHz.
2. PD level and distribution in the insulation of bushings, windings and cores. The unique function of «TDM-3F» system is the synchroic PD measurement by six channels and in two frequency ranges (HV and UHF). It allows almost 100% corona pulses rejection. The build-in expert system defines the defect type and evaluates its danger to the transformer operation. Processing the data of PD measurements and dissolved gases analysis gives the most accurate information on the transformer condition.
3. The supplementary function of PD measuring in «TDM-3F» system is transformer windings’ deformation monitoring. Corona discharge pulses of the HV and LV ends of the winding are used as probe pulses for frequency response analysis (FRA).
4. It is necessary to monitor the moisture content in oil of transformer tank for all power transformers with rated voltage of 100 kV and more. This is the most important oil diagnostic parameter, which influences the transformer operation reliability in the whole. Monitoring of dissolved hydrogen in oil is also necessary for high-power transformers. Greater number of combustible dissolved gases should be monitored in the power transformers with the rated voltage of 220 kV and more.
5. OLTC monitoring. The use of «OLTC-Monitor» external module allows monitoring OLTC location, assessing the power of the driving motor during commutation and analyzing the diagram of contactor operation at every commutation. The presence of arch discharge in OLTC is revealed by vibration sensors.
6. The assessment of transformer cooling system efficiency is made by measuring and analyzing of the transformer tank top and bottom temperature and transformer rated load. A simplified heat model of transformer is used in these calculations.

TDM-3F system sensors are installed as follows:
- «DB-2» sensors for leakage current and PD pulse measurement are installed on the test taps of high-voltage bushings. If there are no test taps on output isolators of the power transformer LV winding (which is usual for voltages of 6-35 kV), then coupling capacitors are used instead of the sensors.
- «IFCT-5» sensors for load current monitoring in transformer primary winding phases are installed on cables of secondary circuit in measuring current transformers.
- The temperature sensors are installed at the top and bottom of a transformer tank.
- «LTC-Monitor» for OLTC condition monitoring is installed inside of OLTC enclosure. It is connected to «TDM-3F» monitoring system through RS-485 interface.
- «SMF» water in oil sensor (SMFD + DGA + oil pressure) is installed on drain valve in the bottom of transformer tank and is connected to the monitoring system through RS-485 interface.

The connection of «TDM-3F» system to SCADA can be done as follows:
- By isolated «RS-485» interface.
- By optical connection line.
- By radio channel.

Protocol ModBus RTU or protocol IEC 61850 could be used for information communication to SCADA system.

Signals of GPS/GLONASS system can be used for «TDM-3F» measurement synchronization on several objects, which adds to the information validity. GPS/GLONASS signals receiver is installed in the TDM-3F module. Besides, several TDM-3F systems can be connected with optical connection line.

### «TDM-3F» Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The mounting enclosure dimensions, mm</td>
<td>600x700x250</td>
</tr>
<tr>
<td>Operation temperature range (with heating system), °C</td>
<td>(-55 \div +60)</td>
</tr>
<tr>
<td>The modules’ power supply, V</td>
<td>80 ÷ 265 AC/DC</td>
</tr>
<tr>
<td>The enclosure power supply (with heating system), W</td>
<td>250 - 300</td>
</tr>
</tbody>
</table>