



**Transformer Monitoring, Diagnostic and Control Expert  
System ESMDU-TRANS manufactured by  
PJSC “Zaporozhtransformator”**



**Intelligent Transformers mean transformers and autotransformers that include special electronic monitoring and control devices ensuring the following:**

- ✓ Electrical energy quality registration and analysis of all (high, intermediate, low) voltage sides in steady state processes.
- ✓ Fault and healthy transient processes registration and analysis, including: commutations (switching on, switching off) and short circuit regimes.
- ✓ Electrical, heat and mechanical parameters monitoring of the main parts of the transformer construction with expert estimation of the equipment technical condition and loading capability and life time.
- ✓ Dispatched automatic optimum cooling system control (management).
- ✓ Dispatched automatic optimum tap changers control (management).

Above mentioned functions are realized in Monitoring, Diagnostic and Control Expert System manufactured by PJSC «Zaporozhtransformator» (PJSC ZTR).

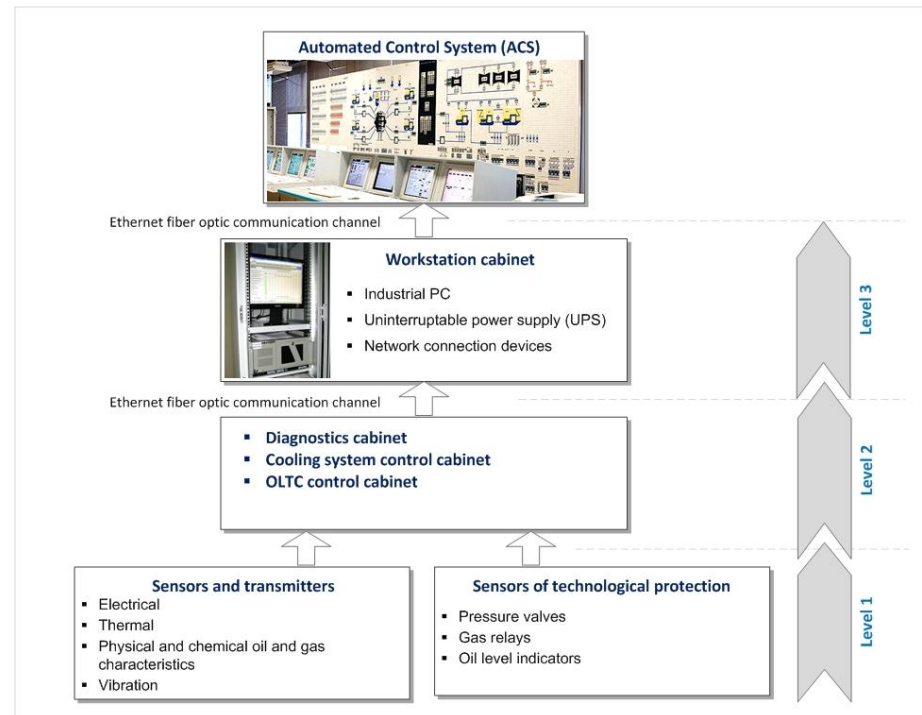


# Monitoring, Diagnostic and Control Expert System ESMDU-TRANS for Transformer equipment.

**Monitoring, Diagnostic and Control Expert System ESMDU-TRANS is purposed for technical condition control of the transformer equipment within operation generation of diagnostic, warning and emergency messages, database maintenance, information transfer of technical condition of the equipment in the automatic control system of substation (ACS SS).**

**Hardware structure of ESMDU-TRANS has three – level system:**

- ✓ **Level 1** – sensors and sensing transmitters. At this level, conversion of measured physical parameters into unitized signals is realized for measured data transfer to level 2.
- ✓ **Level 2** – controllers and input/output devices. At this level, signal processing from level 1, performance of calculations of series of diagnostic parameters and generation of digital bitstream is realized for data transfer to level 3. Constructive arrangement is inside the diagnostics cabinet.
- ✓ **Level 3** – server of data acquisition and expert evaluation. At this level, acquisition and processing of digital bitstreams, archive maintenance, implementation of expert evaluations, information display on monitor screen and informational communication with adjacent systems of higher level is realized. Constructive arrangement is inside the Workstation cabinet.



Monitoring system supply together with transformer equipment experience for PJSC ZTR is more than 10 years. All projects of Monitoring system, sensors and converters (1st level) assortment and installation, control cabinet CS and TC design, diagnostic algorithms and diagnostic parameters expertise in exploitation has been done by 3TP. However, hardware and software for data collection, data transfer to ACS SS has been done by partner enterprise.

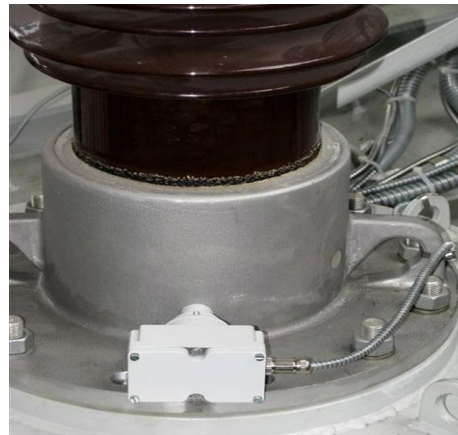
- ✓ 2001 - delivery of the first monitoring system.
- ✓ 2011 - the 100-th delivery of Monitoring system.
- ✓ 2013 - more than 150 deliveries of Monitoring systems.
- ✓ In 2011 on the grounds of previous experience the first version of the ESMDU-TRANS system was developed and implemented in trial operation by “ZTR” PJSC based on Compact Rio controllers and LabView software designed by National Instrument (NI).
- ✓ In 2012 the additional software for user training was developed.
- ✓ In 2013 ESMDU-TRANS successfully passed mechanical, climatic and electromagnetic compatibility tests in the laboratories of GOSSTANDARD of Ukraine and obtained proper reports. System version updated according to test results was implemented for three-phase transformer 1 000 MVA 500 kV and three-phase transformer 63 MVA 35 kV for TPP Berezovskaya, three-phase three-winding autotransformer 125 MVA 330/110 kV (2 pcs.) for Ruchej s/s, single-phase three-winding autotransformer 83,333 MVA 500/150 kV (4 pcs.), single-phase three-winding transformer 83,333 MVA 500/150 kV (4 pcs.) (Uruguay).
- ✓ Since 2011 up to 2013 ESMDU-TRANS was tested with more than 20 transformers at ZTR testing fields during routine tests.

# Monitoring system primary sensors and devices

1. Dissolved gas analysis (DGA) devices
2. Moisture analyzers
3. Bushing isolation quality measuring device with particle discharge electrical technique measurement option.
4. Fiber optic probes for temperature direct measurements
5. Temperature measurements sensors
6. Current transformers for monitoring system on high and low voltage sides
7. Voltage measurements devices on high and low voltage sides
8. Cooling system monitoring gauges and indicators
9. Tap changer monitoring gauges and indicators
10. Technological protection devices
  - buchholz relay
  - shutter valve
  - transformer tank and tap changer tank oil level indicators
  - pressure relief devices
  - tap changer control relay



Temperature measurements sensors



Bushing isolation quality measuring sensor



Device for temperature direct measurements

# Monitoring system Connection (Junction) cabinet

Junction cabinet provides primary sensors, primary devices, technological protection devices signals collection and primary processing and converting, transferring to the diagnostic cabinet, cooling system and tap changer working regimes control. All elements are of industrial performance with temperature effective range -40..+70C

## **Diagnostic cabinet contains:**

- Three door electro technical outdoor cabinet;
- Microclimate supply system;
- Industrial removable connectors for input of incoming signals;
- Automatic switches for commutation of primary equipment supply;
- Secondary electrical supply cells with galvanic commutation;
- Input analog signals normalizing converters with galvanic commutation and frequency converting to 100kHz;
- Industrial controller number 1 Compact RIO by National Instruments, USA;
- Ethernet controlled router



Figure 1 – Example of connection cabinet unit for one phase transformer ORDCI-210 000/1200 installed at ZTR testing field



Figure 2 – Example of connection cabinet unit for three phase transformer TNC-1 000 000/500

# Monitoring system diagnostic cabinet

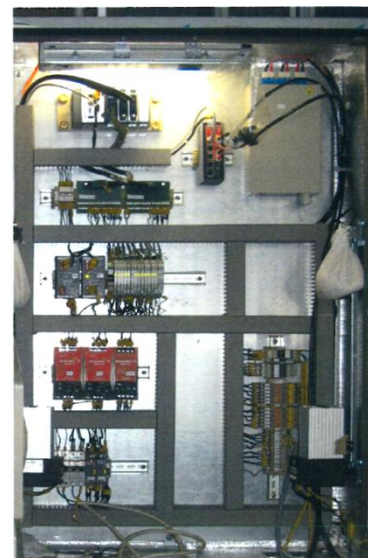
Diagnostic cabinet provides signals reception from primary sensors and devices, mathematical and algorithmically signal processing, calculation of parameters set, data acquiring and data storing, data transferring to the system AWP by the fiber optic communication lines within temperature effective range -40..+70C

## ✓ Diagnostic cabinet maintains

- Electro technical outdoor cabinet from stainless steel;
- Microclimate supply system;
- Industrial removable connectors for input of incoming signals;
- Automatic switches for commutation of primary equipment supply;
- Secondary electrical supply cells with galvanic commutation ;
- Input analog signals normalizing converters with galvanic commutation and frequency converting to 100kHz;
- Input/output relay signals converters with RS-485 output and Modbus
- Industrial controller number 2 Compact RIO by National Instruments, USA;
- Ethernet controlled router



**Figure 1 –**  
Example of  
diagnostic  
cabinet unit for  
one phase  
transformer  
ORDCI-  
210 000/1200



**Figure 2 –**  
Example of  
diagnostic  
cabinet unit for  
three phase  
transformer TNC-  
1 000 000/500

# Monitoring system automatic working place (AWP)

## Automatic working place provides:

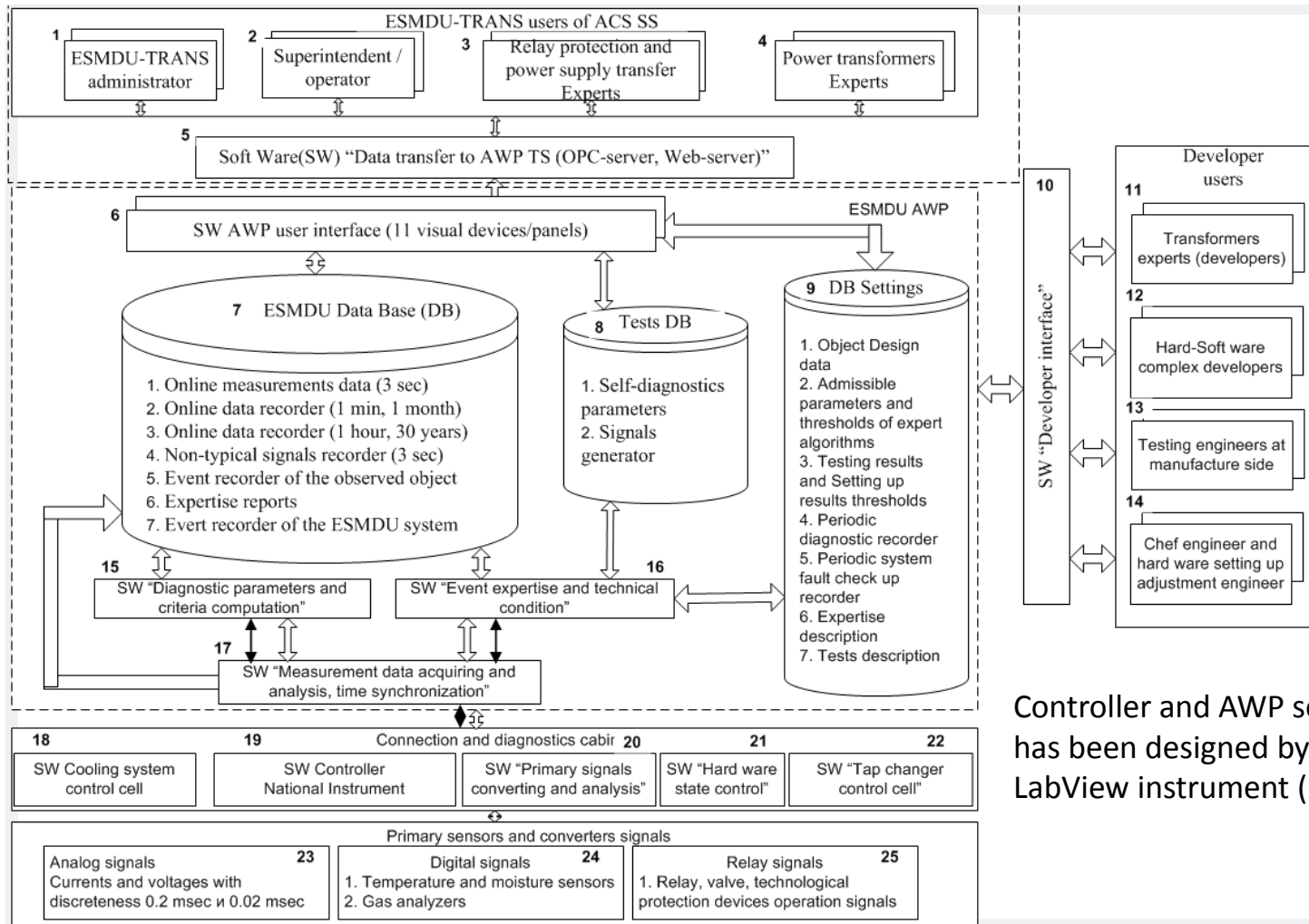
- data acceptance from diagnostic cabinet devices;
- execution of mathematical calculations set and expert diagnostic algorithms;
- keeping of data base archives;
- displaying data concerning technical state of the object in real time scale;
- current and archive data transfer to the higher level systems.

## Automatic working place includes:

- Electro technical cabinet combined with ventilation and conditioning systems;
- Automatic switches for AWP primary hardware supply;
- Secondary electrical supply cell, providing galvanic commutation;
- Ethernet controlled router;
- Liquid crystal display monitor;
- Industrial computer with duplicated hard disc;
- uninterrupted power supply



# Software (SW) and database (DB) structure

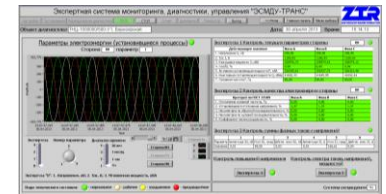


Controller and AWP software has been designed by means of LabView instrument (NI)

- ✓ All parameters registered in the system by functional indication are divided into groups. Each group of parameters is analyzed with a help of certain algorithm (expertise). All expertise in the ESMDU-TRANS monitoring system has been grouped into program modules, which defines technical state of the components or functional subsystems. Further those modules are called virtual devices. There are virtual devices that have been realized in ESMDU-TRANS monitoring system for system total control, for system work control (self diagnostics). There are also virtual devices for visualization of expertise algorithms and diagnostic parameters as follows:

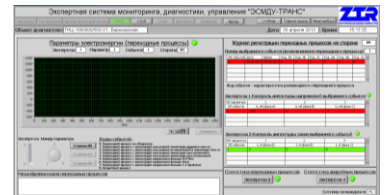
## 1. Power energy parameters (steady-state processes)

- 1.1 Monitoring of chosen side current parameters
- 1.2 Quality control of chosen side electric energy
- 1.3 Monitoring of amount of phase currents and voltages
- 1.4 Monitoring of overvoltage
- 1.5 Spectrum control currents, voltages and powers



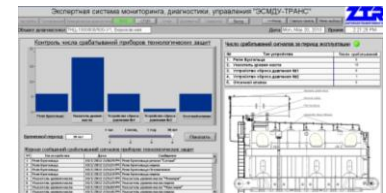
## 2. Power energy parameters (transient processes)

- 2.1 Voltage amplitude of transient processes control
- 2.2 Current amplitude of transient processes control
- 2.3 Transient process statistics
- 2.4 Failure process statistics



## 3. Parameters of technological protection devices of transformer instruments

- 3.1 Monitoring of alarms from technological protection instruments



## 4. 4. Magnetic system parameters

- 4.1 Control of magnetic system thermal parameters
- 4.2 Control of magnetic system electromagnetic parameters

## 5. Windings parameters

- 5.1 Control of windings thermal parameters
- 5.2 Control of windings electromagnetic parameters

## 6. Insulation system parameters

- 6.1 Physical-chemical oil properties control
- 6.2 DGA control of oil from tank
- 6.3 Moisture content in oil control
- 6.4 Control of solid insulation

## 7. Bushings parameters

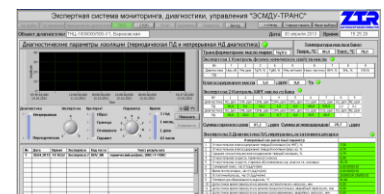
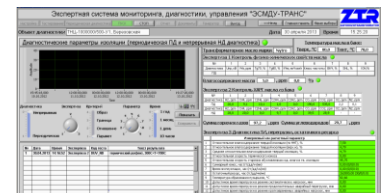
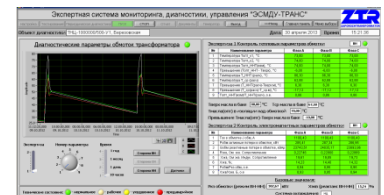
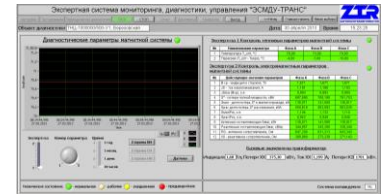
- 7.1 Control of bushings parameters at side
- 7.2 Control monitoring of phase conduction current amount
- 7.3 Control of partial discharge level
- 7.4 Monitoring of bushing parameters acc. to PD data

## 8. Cooling system parameters





- 8.1 Control of cooling system functioning parameters

## 9. Tap changer parameters

- 9.1 Control of tap changer functioning parameters

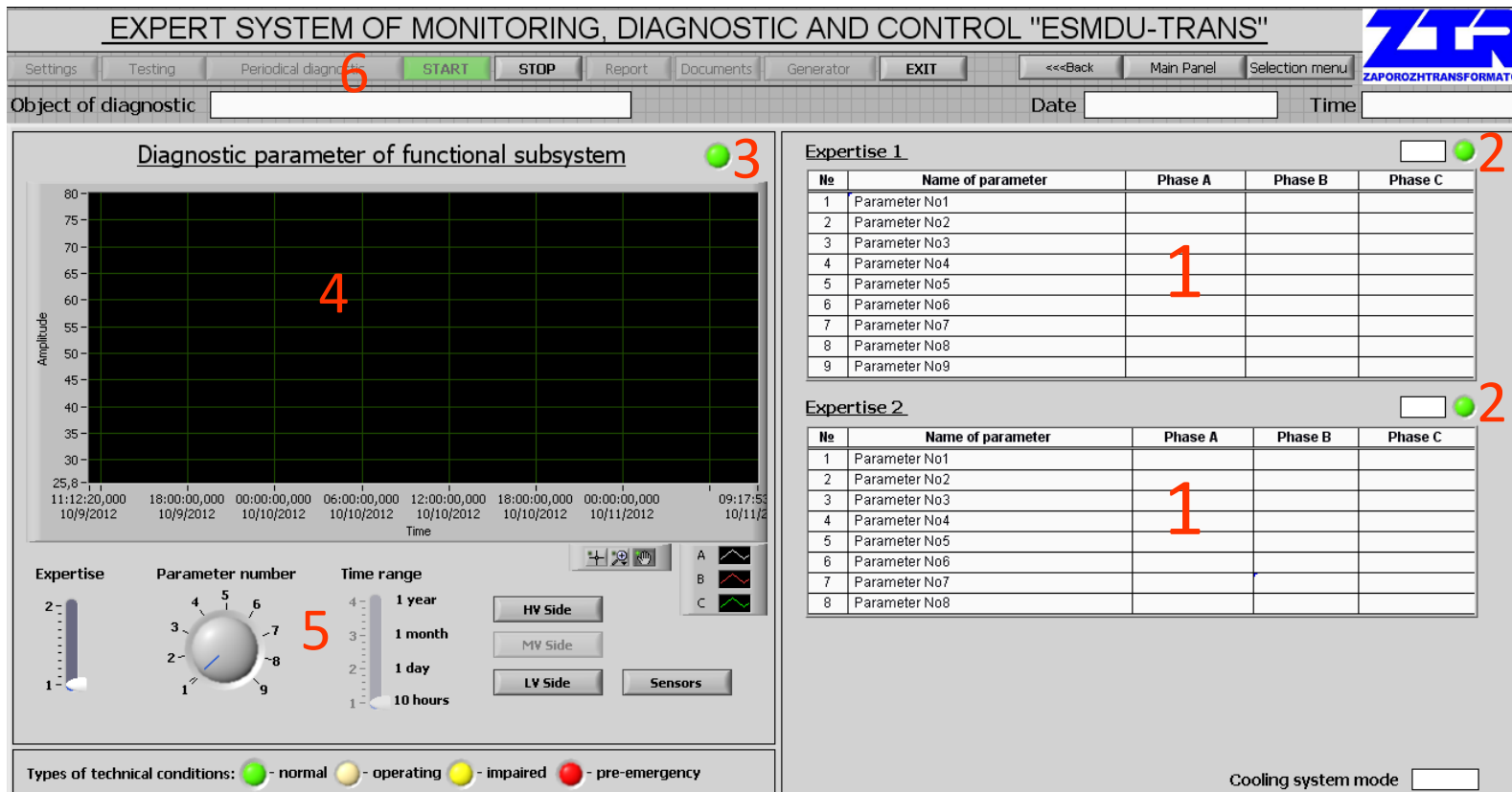


- ✓ Each expertise is held under the group of specially selected diagnostic parameters ( $X_1, X_2, X_3, \dots, X_n$ ). These parameters could be assigned to either monitoring system devices measuring results or special algorithms system calculation results. Calculation algorithms use measuring data, field and manufacture testing results, field periodic diagnostics results.
- ✓ During each expertise it is checked whether diagnostic parameter  $X_i$  within admissible values:  $X_{i.min.adm.} \leq X_i \leq X_{i.max.adm.}$ , and then it is calculated admissible values of deflection and the expertise resulting decision has been reached. Parameters  $X_{i.min.adm.}$  and  $X_{i.max.adm.}$  are admissible values (thresholds) which had been set up by manufacture and could be corrected by the users after expiration of exploitation guarantee period.
- ✓ Special signal indicators of the virtual device are lighting as the result of expertise. The color of indicator is pointing on the technical condition of the diagnostic parameters control set of either system under control or external impact: green color – normal status; beige color – operating status; yellow color – impaired status; red color – pre emergence status.

Технические состояния:  - нормальное  - рабочее  - ухудшенное  - предаварийное

- ✓ As the result of control for the reason of color definition of signal indicator ЭСМДУ-ТРАНС system expertise uses different decisions accepting algorithms.
- ✓ **There are several types of decisions accepting algorithms:**
  1. Algorithm of worse value deviation of diagnostic parameter from admissible value for given expertise:  $\text{Max}(|X_i - X_{i.\text{min.adm}}|, |X_i - X_{i.\text{max.adm}}|)$
  2. Algorithm of maximum deviation of admissible value from (not certain diagnostic parameter) average value, deviation for different phases  $\text{Max}(|Y_i - X_{i.\text{min.adm}}|, |Y_i - X_{i.\text{max.adm}}|)$ , where  $Y_i = (X_{iA} + X_{iB} + X_{iC})/3$
  3. Algorithm of comparison of the parameter maximum deviation between phases with admissible values:  
 $K1 = |X_{iA} - X_{iB}|, K2 = |X_{iA} - X_{iC}|, K3 = |X_{iB} - X_{iC}|$   
 $X_i = \max \{K1, K2, K3\}$
  4. In some virtual devices the expertise algorithms additionally control rate of diagnostic parameters change and ratios between values of different parameters (parameters images) for decision accepting.
- ✓ Algorithm type for decision accepting for each expertise is defined by the manufacture during setting up process and could be corrected by the user after expiring of the guaranty period.

# Virtual device structure for visualization and expertise results

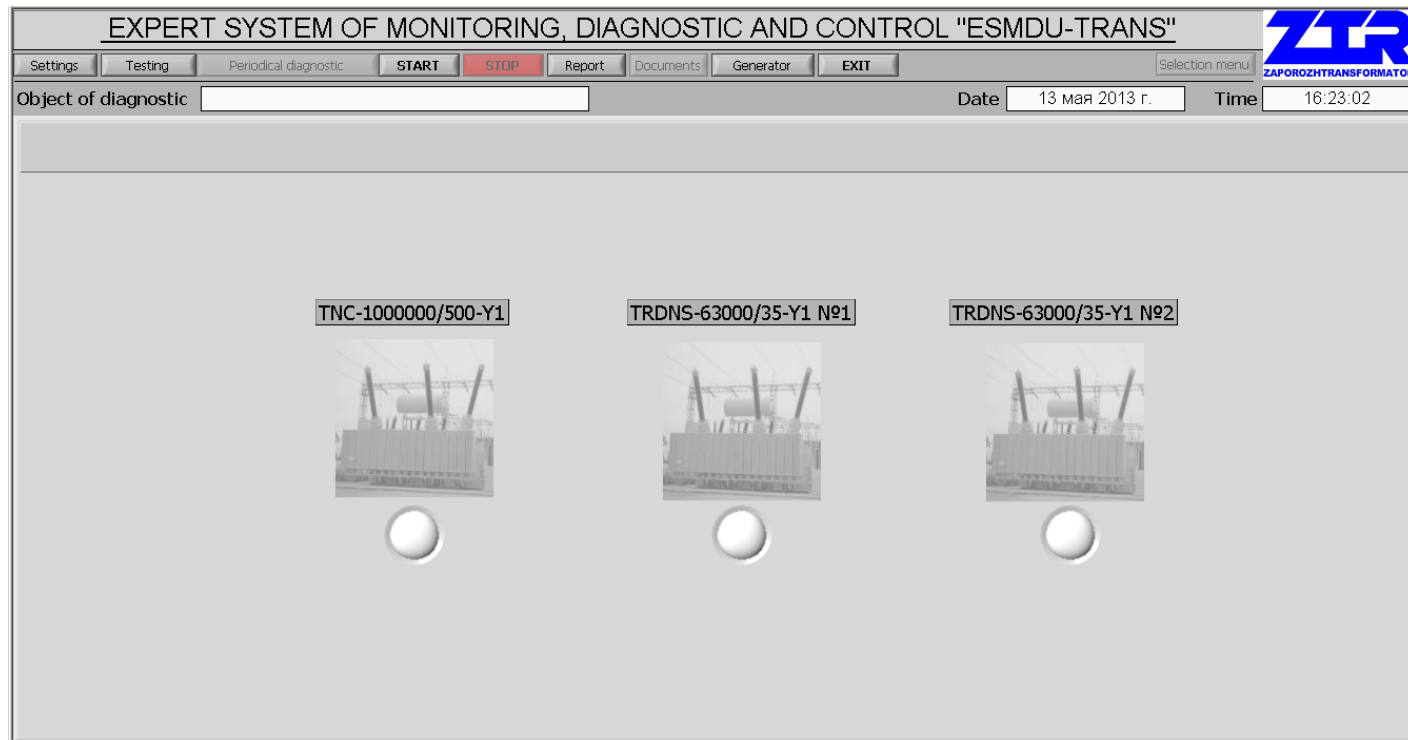


- Each virtual device consists of logical elements: 1. Tables, containing values of diagnostic parameters; 2. Indicators, change in color signalize result of expertise work; 3. Indicator, change in color signalize technical condition of the subsystem (expertise group of virtual device) 4. Trends display (time dependent) of the diagnostic parameters; 5. Display control elements in form of switches and buttons. 6. ESMDU-TRANS monitoring system regime control panel.

# Software starting window of ESMDU-TRANS system



- There is panel (buttons set) located on the starting window which can be used for system operation regime selection, system controlled transformer type equipment selection, signal indicators which characterize technical status of this equipment with its color



- The system is configured by manufacture for each substation object, at which different sensors and devices has been placed. As an example, the monitoring system variant is represented for SRPP Berezovskaya (one transformer unit TNC-1000000/500 and two transformers TRDNS-63000/35).

# ESMDU-TRANS monitoring system working regimes



- ✓ ESMDU-TRANS monitoring system regime control panel is located in upper side of each virtual device at starting panel of the monitoring system. System regime switching is caring out on pushing corresponding button.
1. **“Settings” regime** – designed for system parameters setting up. In this regime configuration of the system software occurs, filling up information data base with information of certain transformer, admissible values of diagnostic parameters and thresholds for expertise).
  2. **“Testing” regime** – designed for automatic control of AWP software in different regimes.
  3. **“Periodic diagnostics” regime** – designed for periodic testing data input to the system which has been provided separately from monitoring system with another devices for the purpose of more accurate expertise result definition.
  4. **“RUN” regime** – in this regime system automatically making continuous request to primary sensors and devices, making computation of the diagnostic parameters, executing expertise, expertise results signalization, output of the corresponding messages and saving necessary information to the data base.
  5. **“Report” regime** – designed for displaying and output to USB thumb drive of the calculation results, diagnostic parameters measurements and expertise results for the given by the user period of time .

# "Settings" regime

**SETTINGS**

Settings for steady-state processes

Settings for rules ay steady-state processes

Settings for PCA and DGA

Reference data for subsystem "Windings"

Diagnostic parameters of magnetic system

Diagnostics of bushing technical condition

Settings for monitoring of cooling system parameters

Settings for archiving

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

**Reference data for subsystem "Windings"**

Browse the running settings

BROWSE

Upload from file with settings

UPLOAD

**Expertise 1 Monitoring of winding thermal parameters**

	HV (base)	LV (base)	Arch HV	Arch LV	LimHV_2	LimHV_3	LimHV_4	LimLV_2	LimLV_3	LimLV_4
Temperature Tfo_turn1, °C	98,0	98,0	1,0	10,0	50,0	10,0	15,0	5,0	10,0	15,0
Temperature Tfo_turn2, °C	98,0	98,0	1,0	10,0	5,0	10,0	15,0	5,0	10,0	15,0
Temperature Tfo_HST(meas), °C	98,0	98,0	1,0	10,0	5,0	10,0	15,0	5,0	10,0	15,0
Temperature rise (Tfo_HST-top oil), °C	41,1	44,2	1,0	40,0	20,0	40,0	60,0	20,0	40,0	60,0
Temperature T_HST (calculated), °C	98,0	98,0	1,0	10,0	5,0	10,0	15,0	5,0	10,0	15,0
Temperature T_av (calculated), °C	85,0	85,0	1,0	10,0	5,0	10,0	15,0	5,0	10,0	15,0
Temperature rise (T_HST - top oil), °C	41,1	44,2	1,0	40,0	20,0	40,0	60,0	20,0	40,0	60,0
Overgeat (T_av(calc) - T_av(oil), °C	32,3	28,8	1,0	40,0	20,0	40,0	60,0	20,0	40,0	60,0
Tfo_HSP(meas)/T_HSP(calc), r.u.	1,0	1,0	1,0	15,0	10,0	15,0	20,0	30,0	40,0	50,0

**Expertise 2 Monitoring of winding electromagnetic parameters**

	HV (base)	LV (base)	Arch HV	Arch LV	LimHV_2	LimHV_3	LimHV_4	LimLV_2	LimLV_3	LimLV_4
Current in winding Jwind, A	1110,0	13889,0	15,0	15,0	10,0	15,0	20,0	10,0	15,0	20,0
Pwind active losses in windina. kW	302,7	233,7	15,0	15,0	10,0	15,0	20,0	10,0	15,0	20,0

## Example of diagnostic parameter setting up for the virtual device "Windings"

- In terms of the given regime user with special rights can correct the list of diagnostic parameters, set of algorithms and expertise models, admissible values of diagnostic parameters and criteria for technical condition. Initial setting and system correction is carried out by manufacture by virtue of modeling, testing and industrial exploitation experience results of the system at Customer site.

**Monitoring system Control**

Power energy parameters (steady-state processes)

Power energy parameters (transient processes)

Instruments of technological processes

Diagnostic parameters of transformer windings

Diagnostic parameters of transformer magnetic system

Diagnostic parameters of insulation

Diagnostics of bushing technical condition

Diagnostic parameters of cooling system

Diagnostic parameters of auxiliary transformer

Enter

Enter

Enter

Enter

Enter

Enter

Enter

Enter

Switch ON all

Switch OFF all

Switch ON record in data base

Switch OFF record in data base

User

Date of last changes

**Diagnostics parameters of transformer windings**

**Expertise 1 Monitoring of winding thermal parameters**

	BH (a)	BH(5)	HH(a)	HH(5)
1. Temperature Tfo_turn1, °C	0	1	0	1
2. Temperature Tfo_turn2, °C	0	1	0	1
3. Temperature Tfo_HST(meas), °C	0	1	0	1
4. Temperature rise (Tfo_HST-top oil), °C	0	1	0	1
5. Temperature T_HST (calculated), °C	0	1	0	1
6. Temperature T_av (calculated), °C	0	1	0	1
7. Temperature rise (T_HST - top oil), °C	0	1	0	1
8. Overgeat (T_av(calc) - T_av(oil), °C	0	1	0	1
9. Tfo_HSP(meas)/T_HSP(calc), r.u.	0	1	0	1

ON

OFF

Archiving

ON

OFF

**Expertise 2 Monitoring of winding electromagnetic parameters**

	BH (a)	BH(5)	HH(a)	HH(5)
1. Current in winding Jwind, A	0	0	0	0
2. Pwind active losses in winding, kW	0	0	0	0
3. Qwind reactive losses in winding, kW	0	0	0	0
4. Req, Ohm eq. Resistance, r.u.	0	0	0	0
5. Xeq, Ohm eq. Resistance, r.u.	0	0	0	0
6. Xeq, %	0	0	0	0

ON

OFF

Archiving

ON

OFF

## Example of expertise algorithms for the virtual device "Windings"

## “Testing” regime

- There are specified 8 tests corresponding for different transformer working regimes for checking correct work of monitoring system algorithms of AWP software. During testing of mentioned regimes system generate testing signals, viewing it with help of virtual devices and checks correct work comparing with inputted into the data base admissible values. Signal testing, 2nd level controller software, data transfer channels is caring out with additional special virtual device “Monitoring system self diagnostics”

Testing

☒ Load 1000MVA,  $\cos \varphi = 1$

☐ Starting at no-load (engaging point - maximum of A phase voltage (0,0233s)).

☐ Short-circuit at phase A at the moment of A phase current maximum (0,372s) at the second period, and self-elimination after 2 periods at the moment 0,0972s with following operation acc. to cl. 1.

☐ Short-circuit at phase B at the moment of zero crossing of phase B current (0,0288s) at the second period, and self-elimination after 2 periods at the moment 0,0688s with following operation acc. to cl. 1.

☐ Short-circuit at phase C at the moment (0,033s) at time moment 0,033s at the second period, and self-elimination after 2 periods at the moment 0,073s with following operation acc. to cl. 1.

☐ Two-phase short-circuit to ground (A and C) at time moment 0,033s with following operation acc. to cl. 1.

☐ Three-phase short-circuit to ground (A and C) at time moment 0,033s at the second period, and self-elimination after 2 periods at the moment 0,073s with following operation acc. to cl. 1.

☐ Phase-to-phase short-circuit with shortiong between phase A and B at time moment 0,033s at the second period, and self-elimination after 2 periods at the moment 0,073s with following operation acc. to cl. 1.

Test

Browse

Stop

Close

Test selection dialog window

## “Periodic diagnostic” regime

Periodical diagnostics

Sample fo oil physical and chemiscal parameters

Oil sample for DGA from the transformer tank

Oil sample for DGA from the transformer bushings

Oil sample for DGA from the transformer OLTC

Select

Select

Select

Select

Dialog window for selection of input data type

№	1	2	3	4	5	6	7	8	9	10
<b>Diagnostics</b>	Ubr, kV	W <sub>la</sub> , ppm	Tg70, %	Tg90, %	OxN, mg*KOH/	Purity class	Impurities	SHL, %	ION, %	<b>Date</b>
<b>PD</b>										

List of controlled physical-chemical features of transformer oil parameters

№	1	2	3	4	5	6	7	8	9	10
<b>Diagnostics</b>	H <sub>2</sub> , ppm	CH <sub>4</sub> , ppm	C <sub>2</sub> H <sub>6</sub> , ppm	C <sub>2</sub> H <sub>4</sub> , ppm	C <sub>2</sub> H <sub>2</sub> , ppm	CO, ppm	CO <sub>2</sub> , ppm	O <sub>2</sub> , ppm	N <sub>2</sub> , ppm	<b>Date</b>
<b>PD</b>										

List of controlled parameters during chromatographic dissolved gas analysis

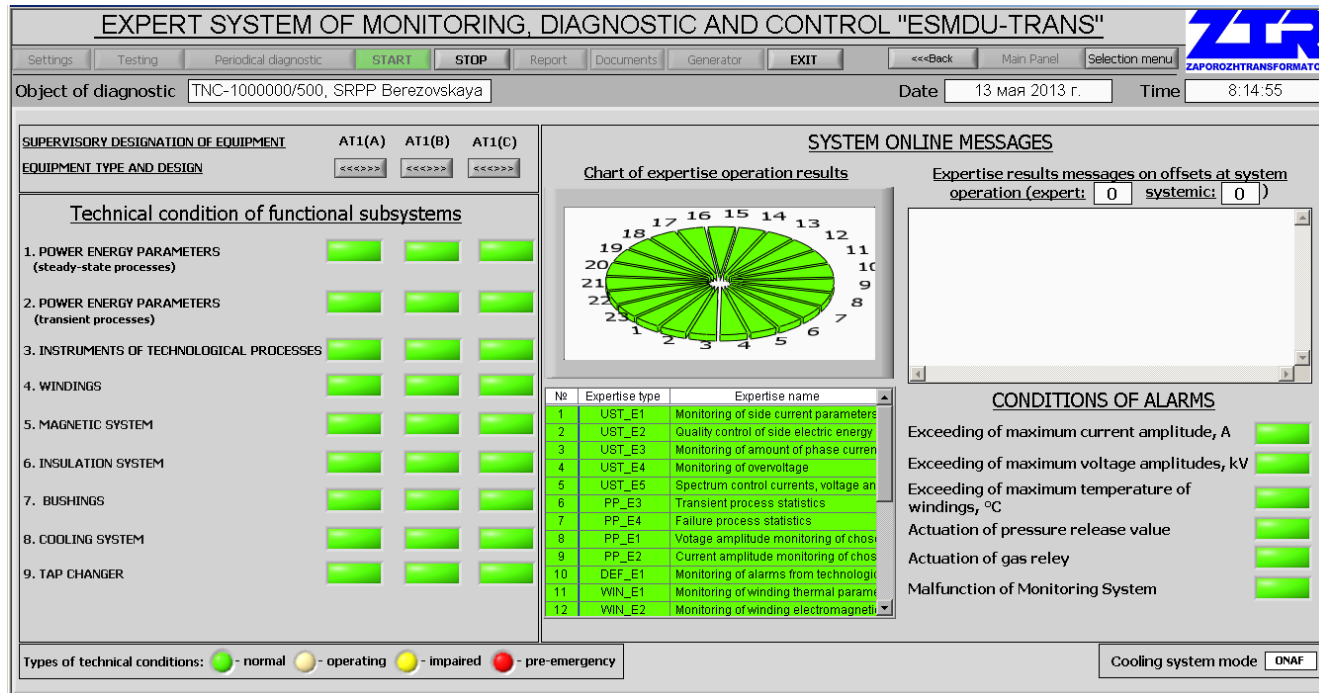
- There is specified input of the periodic diagnostics results of oil sampling carried out by Customer independently from monitoring system (periodic diagnostics). The results of chromatographic analysis of this oil, given from laboratory are compared with results measured with continuous control devices, placed on transformer. This effects on increasing precision of taken decision.

# System user interface in “Run” regime

Virtual device VI\_0



## «System superintendent (operator) panel»



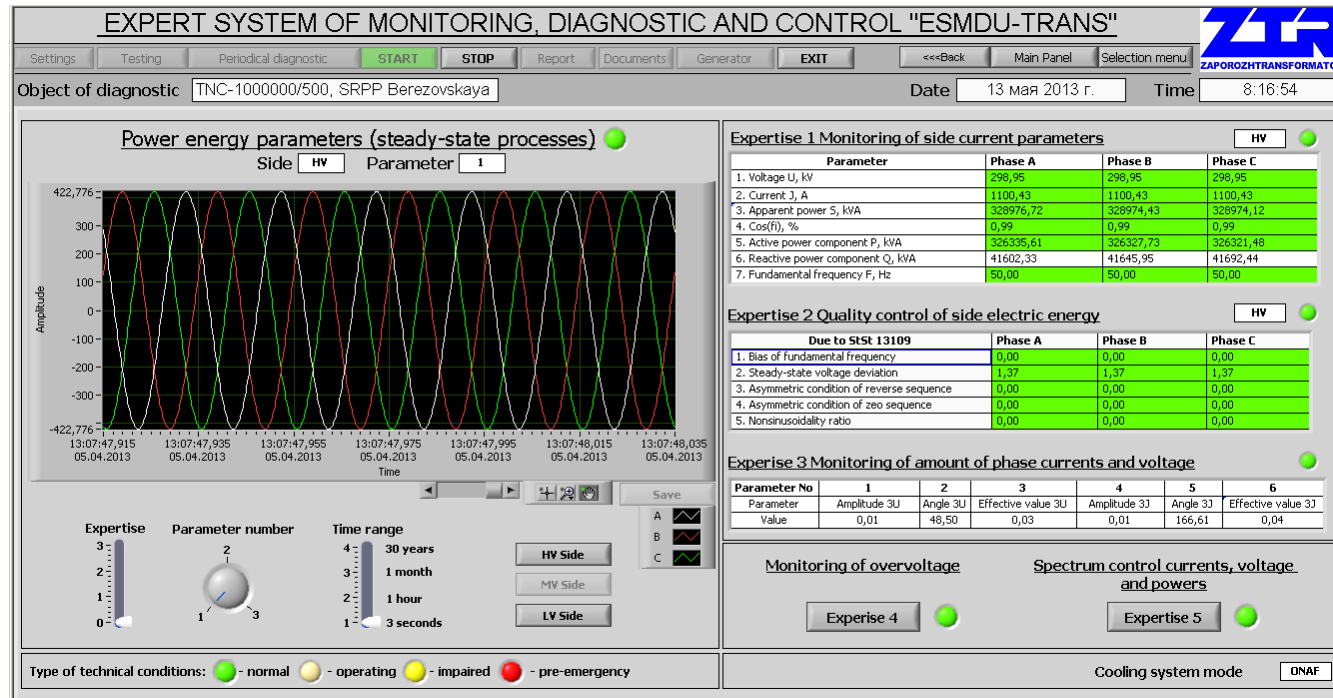
- Virtual device VI\_0 is specified for visualization of the expertise work results of all virtual devices. Buttons in the left side pointing technical condition of the subsystems for all phases of transformer. Those buttons are designed for calling additional panels and corresponding virtual devices. Diagram with list of expertise with a help of color defines results of the work of each expertise. Messages of the expertise results are defined in right upper part of the device in online system messages recorder. Most dangerous (fault) signal conditions are viewed by color of indicators in right lower part of the device.

# System user interface in “Run” regime

Virtual device VI\_1



## Functional subsystem “Electrical energy parameters (steady state processes)”



- Virtual device VI\_1 is designed for electrical power parameters of the network in steady state. At this state parameters of measured instantaneous current and voltage values of all phases (A, B, C) and sides (LV, IV, HV) are analyzed. The following is calculated using this measured values : instantaneous and real values of linear and phase powers, parameters that characterize network energy quality and non symmetry of phase signals, overvoltage statistics, harmonic compounds of the all steady state signals (amplitudes, phases, active and reactive components).

# System user interface in “Run” regime

Virtual device VI\_0



## Additional information panel of virtual device “System superintendent (operator) panel

**EXPERT SYSTEM OF MONITORING, DIAGNOSTIC AND CONTROL "ESMDU-TRANS"**

Settings Testing Periodical diagnostic **START** STOP Report Documents Generator EXIT <<<Back Main Panel Selection menu

Object of diagnostic TNC-1000000/500, SRPP Berezovskaya Date 13 мая 2013 г. Time 8:15:47

**Equipment type and design**

Type of transformer (reactor)	TNC-1000000/500
Manufacturer	ZTR
Serial number	-
Date of production	2012
Number of transformer assembly drawing	-
Rated powers of sides, MVA	1000/1000
Rated voltages of sides, kV	525/24
Frequency, Hz	50
Number of phase	3
Diagram and winding vector group	Y(n)/D11
Type of regulation (side, type)	None
Regulation parameters (number of steps, %)	None
Type of tap changer	None
Type of magnetic circuit design	core-shell type
Winding arrangement on the main core	LV - HV
Winding arrangement on lateral core	-
Type of cooling system	ONAF
Capacities of cooling system switching	-
Date of commissioning	2013
Oil class	Nytro 11 gx

**Transformer electric circuit diagram**

**List of primary sensors**

1 Built-in current transformers	Transformer HV and LV bushings
2 Voltage transformers	Alarms from substation
3 Sensors of moisture and gases dissolved in oil	At cooling system inlet branch pipe
4 Top and bottom oil temperature sensors of windings and active part	Tank cover and bottom part of transformer, respectively
5 Fiber-optic temperature sensors of windings and active part	Transformer windings and active part
6 Temperature sensors (Pt100) of oil and water at oil coolers inlets and outlets	Inlets and outlets of oil coolers
7 Sensors of oil and water pressure at oil coolers inlets and outlets	Inlets and outlets of oil coolers
8 Oil flow indicators	Outlet of oil pumps
9 Sensors of water and oil leakage	Oil cooler
10 Temperature sensor (Pt100) окружающей среды	Connection cabinet
11 Sensor of bushing insulation quality instrument	HV bushing measuring taps
12 Devices of transformer technological protection	Set according to Contract on transformer delivery

Next

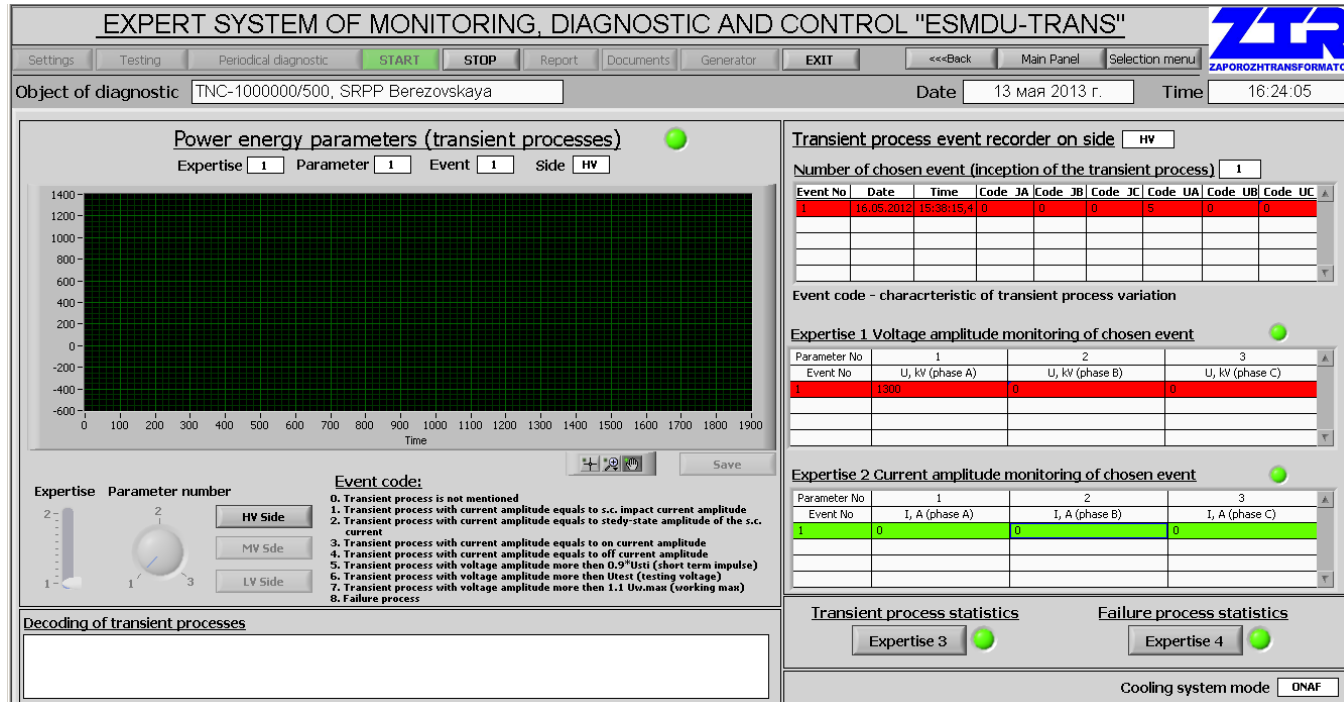
- ✓ For convenient work there are additional information panels in virtual device “System operator panel”, such as “Construction type of the equipment” panel. It is called by pushing the button AT1, AT2, AT3 on the operator panel. It is mentioned at the panel : functional parameters, winding connection scheme, list of primary sensors and devices, fiber optic probes installation scheme

# System user interface in “Run” regime

## Virtual device VI\_2



### Functional subsystem “Electrical energy parameters (transient processes)”



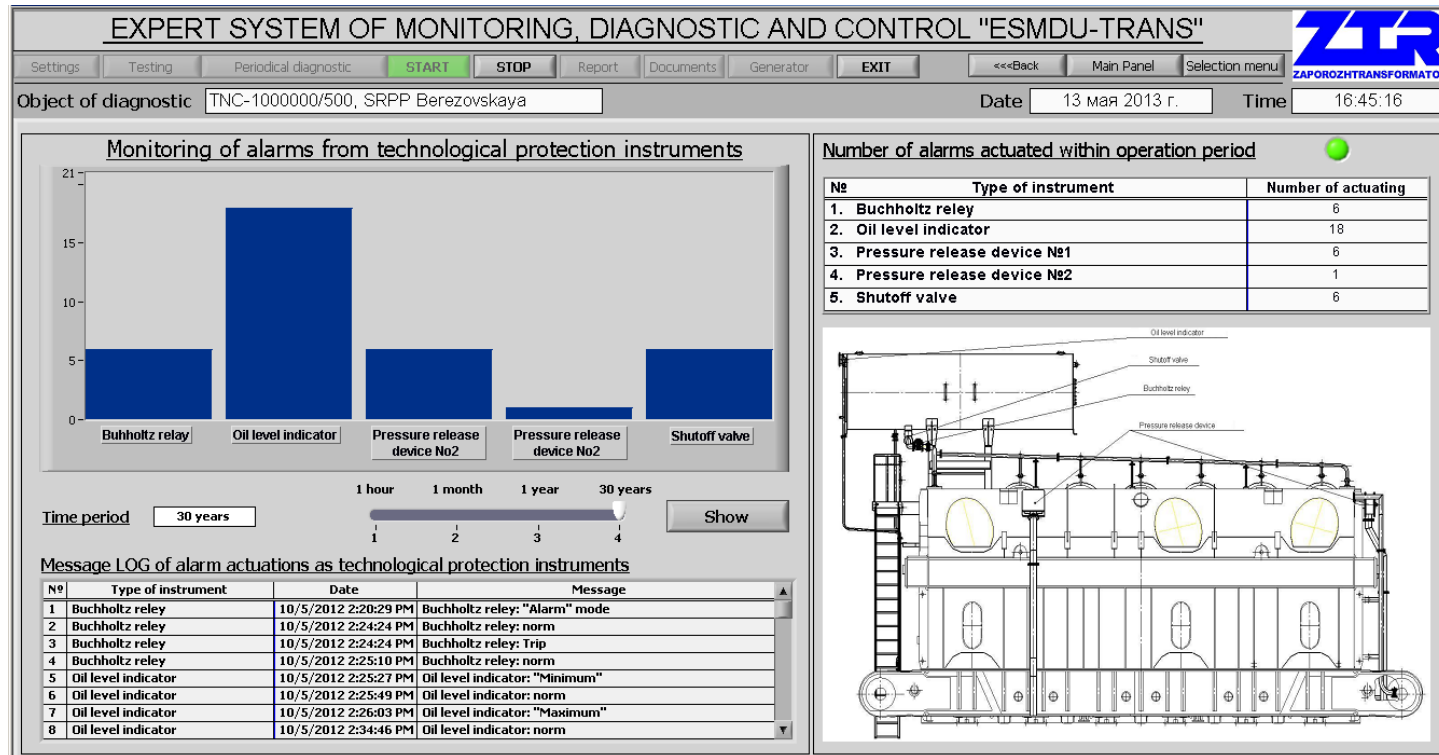
- Virtual device VI\_2 is designed for electrical power parameters control of the network in transient processes. At this state all events parameters (transient processes) are registered and appending into data base: oscillograms of instantaneous values of currents and voltages, exceeding values of admissible thresholds of parameters of currents and voltages for all phases and sides. It is possible to restore and display selected parameters within selected date period. Date of certain event and transient process type are mentioned in recorder at right side of virtual device.

# System user interface in “Run” regime

Virtual device VI\_3



## Functional subsystem “Alarms and protection devices”



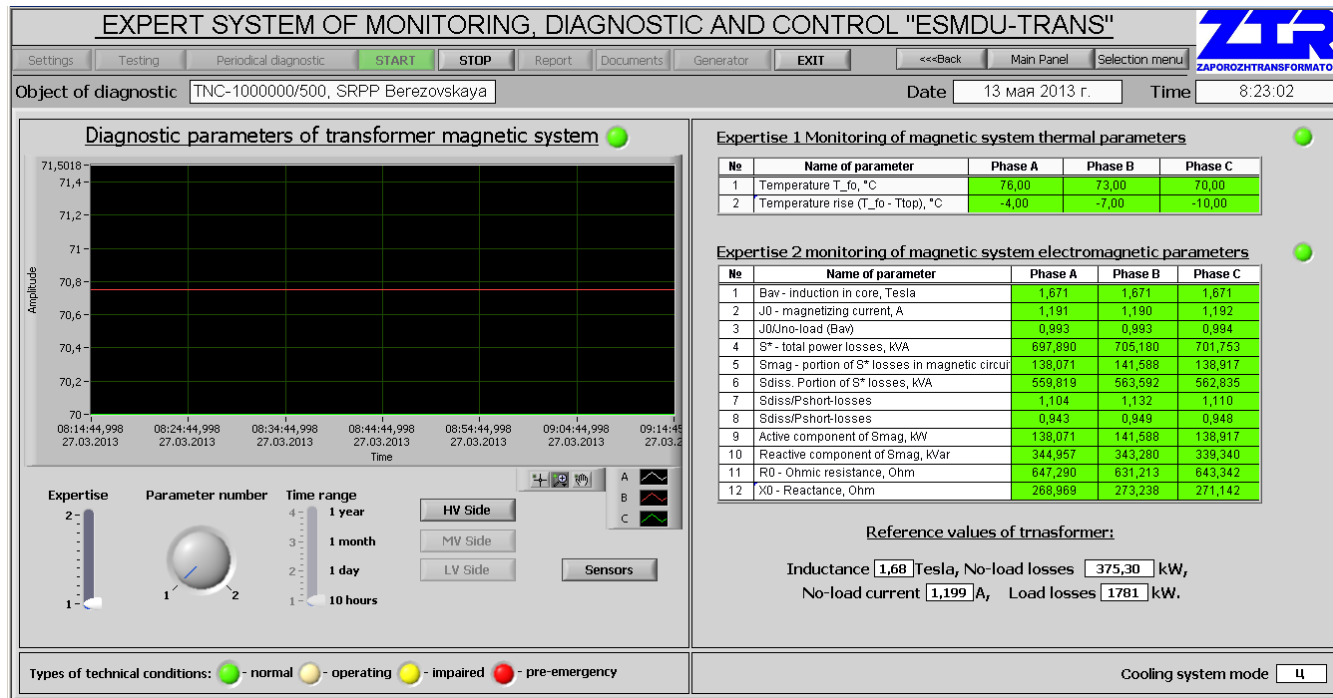
- Virtual device VI\_3 is designed for signal control of technological protection devices, mounted on the transformer equipment. Including : gas relay operation signals, pressure release devices, rapid pressure rise relays, oil indicators and oil flow indicators in the tank etc. The positions of the installation of technological protection devices are shown at picture in the bottom of the virtual device.

# System user interface in “Run” regime

## Virtual device VI\_4



### Functional subsystem “Magnetic system”



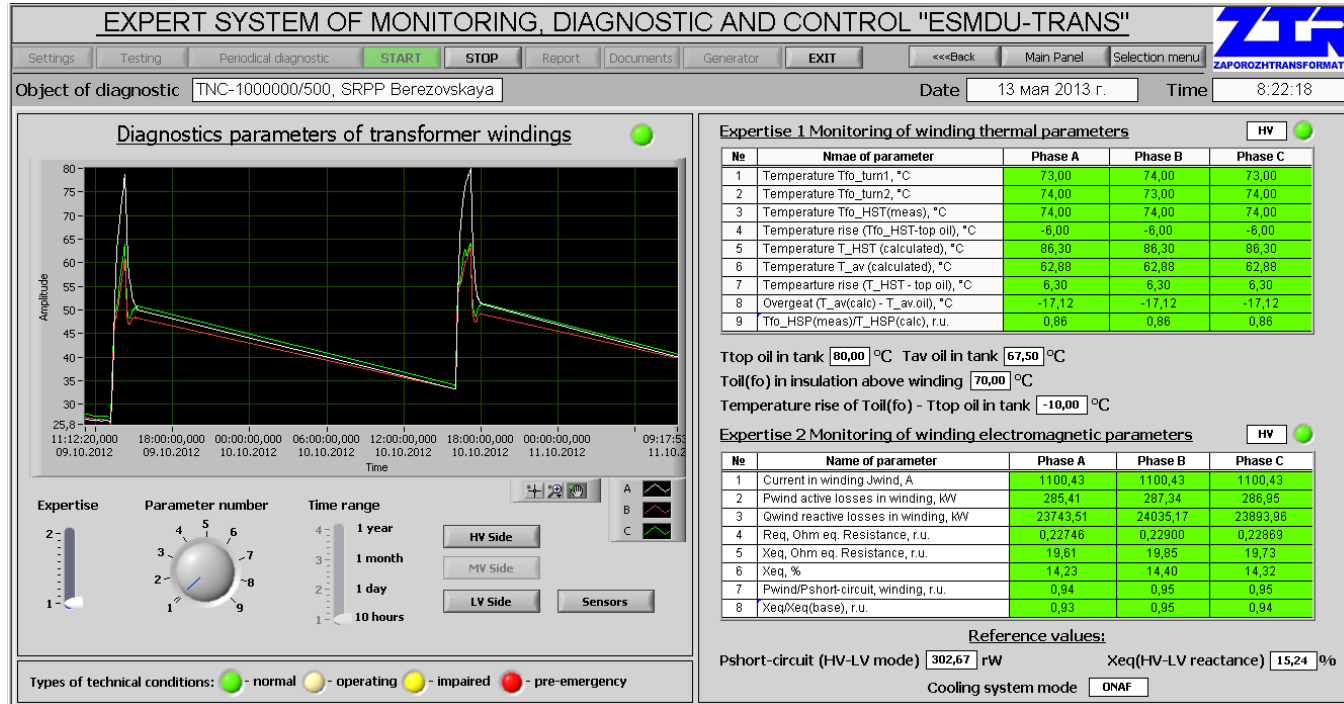
- Virtual device VI\_4 is caring out expertise for electromagnetic and heat parameters of the magnetic system, using fiber optic probes measurements (T<sub>fo</sub>). Electromagnetic parameters corresponds to parameters for magnetizing brunch in equivalent circuit of transformer (R0, X0). Besides, it is defined: average inductance of limb, magnetizing current, loss share in loading regime inside and outside (leakage) of the magnetic circuit (Smag, Sdiss) with respect to shirt circuit and open circuit losses.

# System user interface in “Run” regime

## Virtual device VI\_5



### Functional subsystem “Windings”



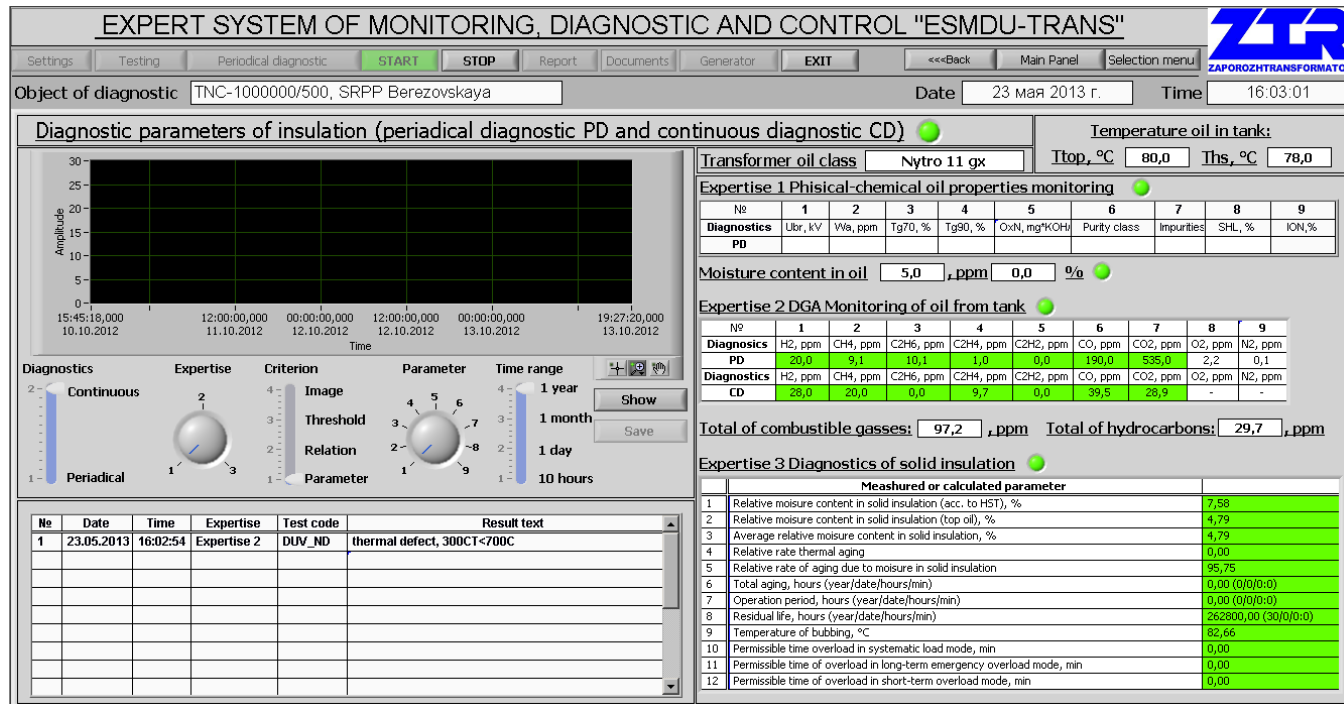
- Virtual device VI\_5 is carrying out expertise for electromagnetic and heat parameters of the windings simultaneously for all phases, using fiber optic probes measurements (Tfo), calculated values (Tcalc) for average temperatures (T\_av) and hot spot temperatures (T\_hst). Electromagnetic parameters corresponds to parameters for windings in equivalent circuit of transformer. These parameters are calculated on basis of measured values of currents and voltages in the given operating regime under the load, including: active and reactive components of losses and resistances (Req, Xeq). Parameters of the equivalent circuit are compared with values, given from testing results

# System user interface in “Run” regime

Virtual device VI\_6



## Functional subsystem “Isolation system”



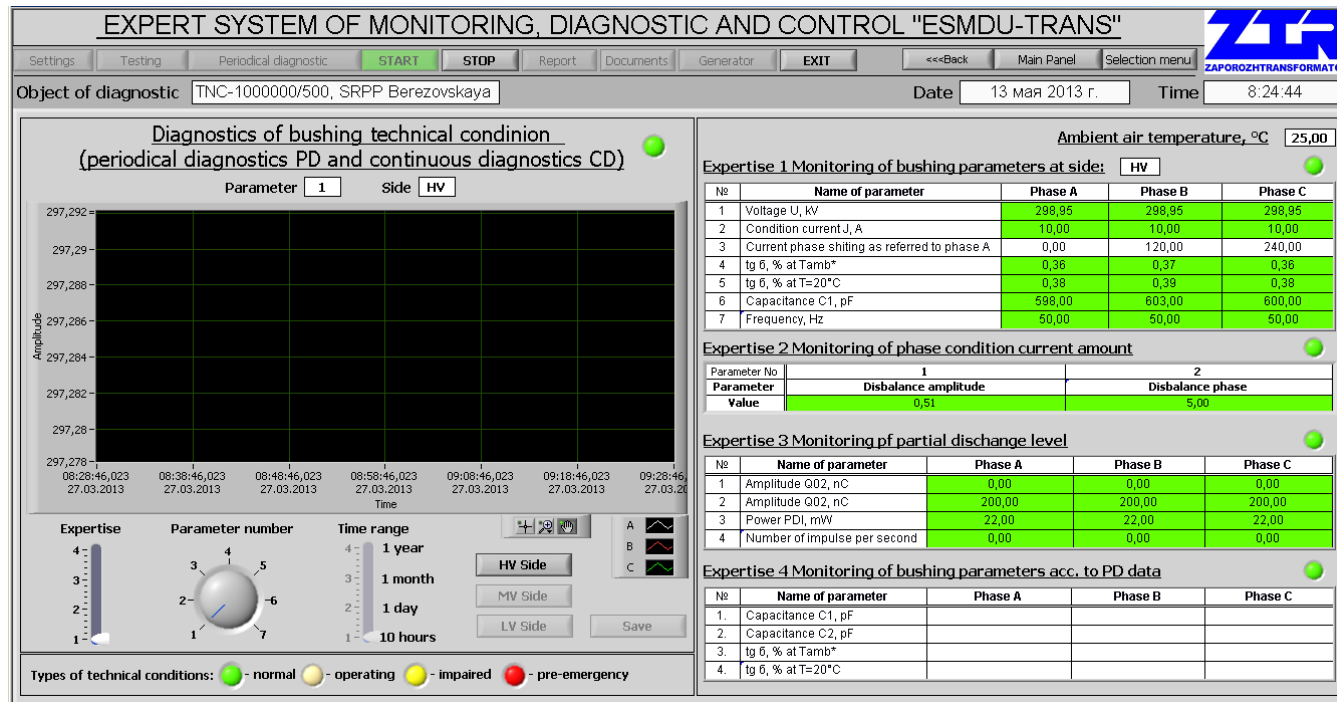
- Virtual device VI\_6 is designed for solid isolation and transformer oil diagnostic parameters control. It is calculated life time (residual life) and rate of aging for solid isolation. It is also carrying out physical-chemical features expertise and DGA by results of periodic diagnostics with moisture expertise and DGA by results of system devices measurements for the transformer oil. DGA expertise are carrying out with following standards (ГОСТ, МЭК, IEEE), Duval method, Toshiba technique (gas images)

# System user interface in “Run” regime

## Virtual device VI\_7



### Functional subsystem “Bushings”



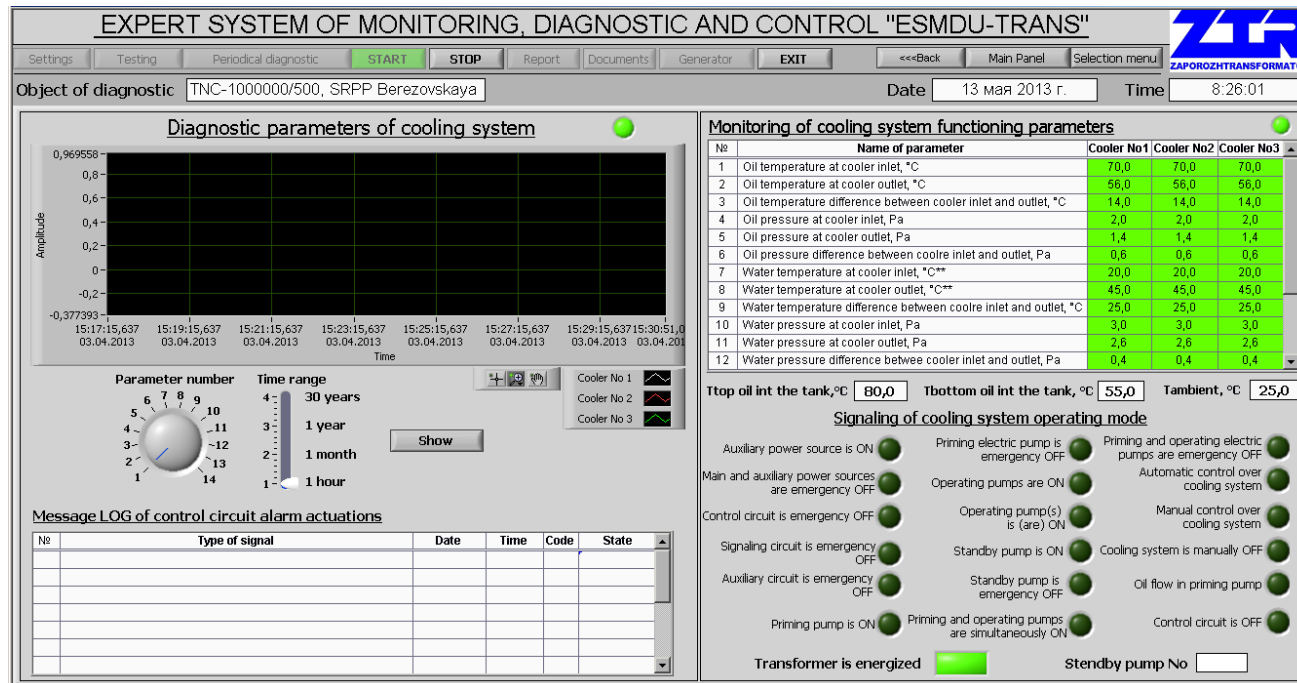
- Virtual device VI\_7 is designed for bushings diagnostic parameters control including: bushing isolation capacity and tangent delta, bushing isolation leakage current, particle discharges parameters given by measurements of the sensors which are placed on bushing pins. It is foreseen additional rate of change analysis of bushing parameters for different phases for the purpose of excluding false operation in expertise

# System user interface in “Run” regime

Virtual device VI\_8



## Functional subsystem “Cooling system”



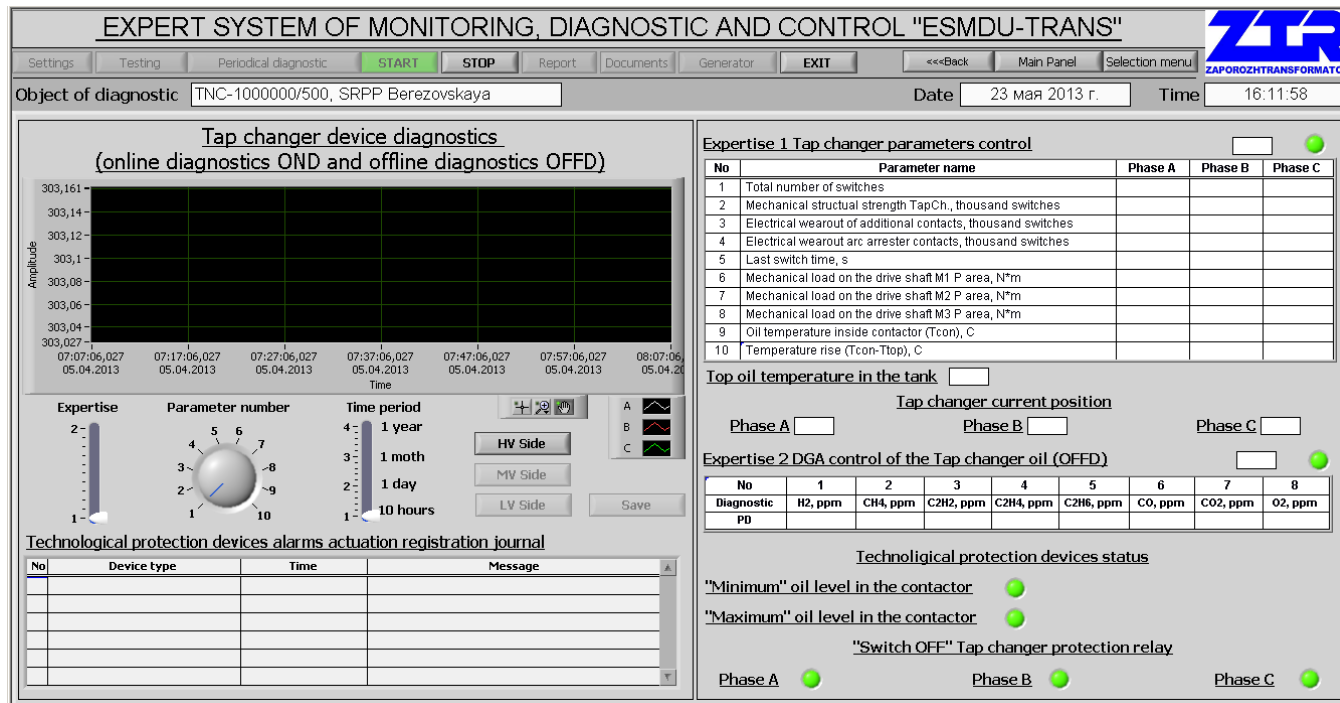
- Virtual device VI\_8 is designed to control diagnostic parameters and regimes of cooling system work. Set of diagnostic parameters is individual for the different types of cooling system (ONAN, ONAF, OF, OFAF, ODWF). For example it is shown parameters of the cooling system type ODWF. During this process it is defined: output and input oil temperature of the coolers (radiators) of the cooling system; number of runs and spent electrical motors hours; cooling system condition (control regime, coolers (radiators etc.) group on/off state).

# System user interface in “Run” regime

## Virtual device VI\_9



### Functional subsystem “Tap changers”



- Virtual device VI\_9 is designed for tap changer diagnostic parameters control. During this process it is defined: mechanical life of the tap changer, electrical wear out of the contacts, last switch time, mechanical load on the drive shaft, current flowing through the tap changer during last switching



# Monitoring system testing process

- Since 2011 ESMDU-TRANS system hardware and software has been installed at ZTR testing fields. This equipment allows carry out monitoring system compatible testing with any transformer produced at the plant which has primary sensors or single-phase testing transformer 210 MVA 1200 kV which has been placed at testing field. The measurements of the monitoring system are compared with stationary equipment and devices of the testing station during given testing



Testing transformer 210 MVA 1200 kV



Room with diagnostic cabinets and AWP

# Monitoring system testing process



- ✓ The example of ESMU-TRANS system testing with three-phase transformer 1000 MVA 500 kV at ZTR testing field. By the end of 2013 is carried out more then 20ty compatibly testing of monitoring system with transformers

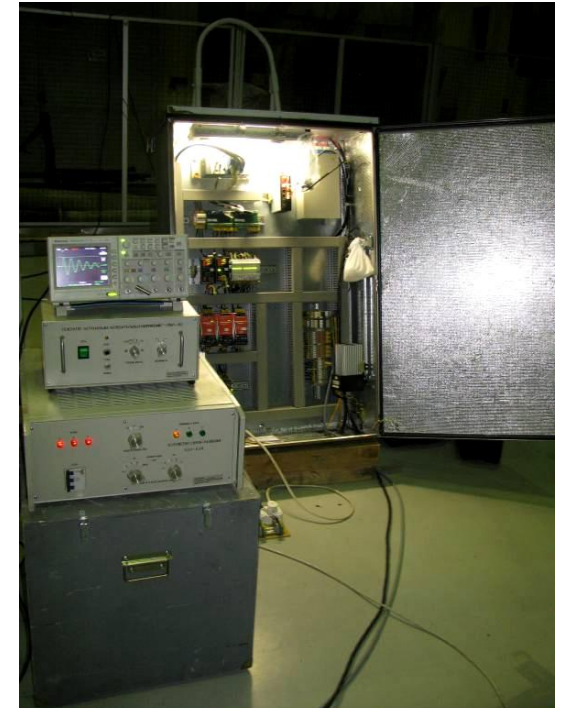
# Attestation of the ESMDU-TRANS system



Electromagnetic compatibility of the  
AWP cabinet



Electromagnetic compatibility of the  
connection cabinet



Electromagnetic compatibility of the  
diagnostic cabinet

- ✓ In 2013 it was carried out set of mechanical, climatic and electromagnetic compatibility testing at State Standard Laboratory of Ukraine, which approved reliability of hardware and software of ESMDU-TRANS system.
- ✓ Given system is recommend by ZTR transformer manufacture for exploitation

# Thank you!



## Contact

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