Письма в ЭЧАЯ. 2016. Т. 13, № 5(203). С. 939–944



# THE THERMOMETRY SYSTEM OF SUPERCONDUCTING MAGNETS TEST BENCH FOR THE NICA ACCELERATOR COMPLEX

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Precise temperature control in various parts of the magnet and thermostat is one of the vital problems during cryogenic tests. The report describes design of the thermometry system, developed at LHEP, JINR. This system is the operational prototype for the NICA thermometry system. Besides, the report describes generic software tools, developed for the TANGO-based control system web client software design.

PACS: 84.71.Ba

## INTRODUCTION

Superconducting magnets for the NICA accelerator complex are being manufactured in Dubna. To perform the vacuum, cryogenic and magnetic tests of these magnets, a superconducting magnets test bench [1] is being developed at LHEP, JINR. Precise temperature control in various parts of the test bench is one of the vital problems during cryogenic tests. The report describes a thermometry system, developed at JINR. This system is also a prototype for the NICA thermometry system.

## SUPERCONDUCTING MAGNETS CRYOGENIC TEST BENCH

Superconducting magnets cryogenic test bench general view is shown in Fig. 1. It consists of three satellite refrigerators, each will have two experimental shoulders. While one shoulder is being assembled, the other one is operating, and vice versa. Now one refrigerator with two shoulders is operational.

## SPECIFICATION

The main goal is precise temperature control in the different parts of test bench during cryogenic tests. The resistance temperature sensors are being used as thermometers. The quantity of sensors, their location and characteristics depend on a type of the test session. The exemplary scheme of test session and sensors positioning is shown in Fig. 2.

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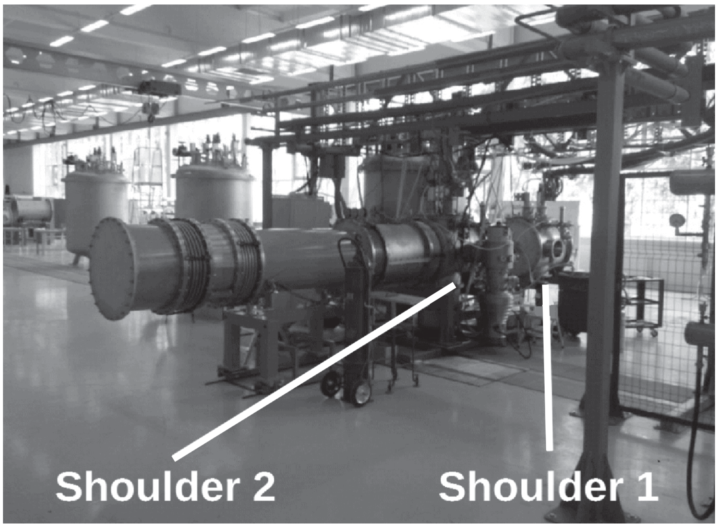


Fig. 1. Superconducting magnets cryogenic test bench general view

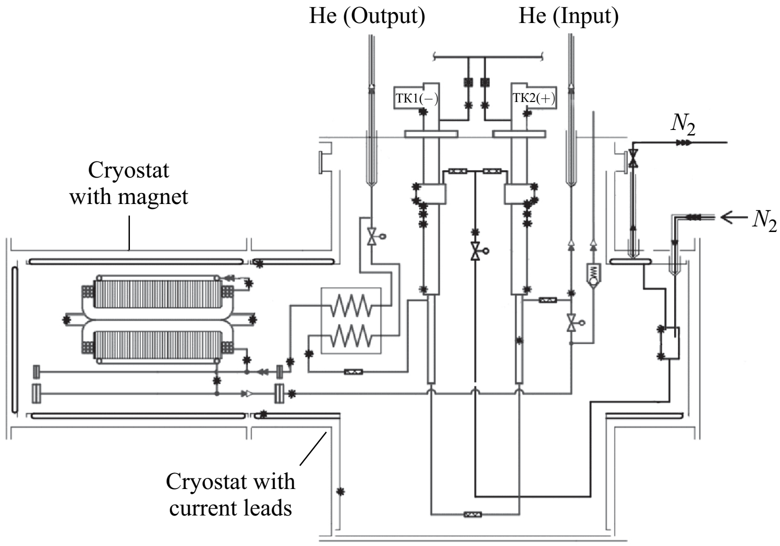


Fig. 2. Example of test session thermometry scheme. Sensors positioning

The thermometry system should provide:

1. Temperature data acquisition and storage in the $24 \times 7 \times 365 \times 5$ mode.
2. Temperature data mapping in the graphs, tables and mnemonic diagrams.
3. Stored temperature data viewing and exporting.
4. Easy configuration.

## HARDWARE

Two types of resistance temperature detectors are used in the thermometry system. Pt100 sensors with a range from 100 Ω at room temperature to 7 Ω at 4 K are used for temperature measurements in a range from 77 to 300 K on the superconducting current leads. TVO sensors with a range from 1 kΩ at room temperature to 4.5 kΩ at 4 K are used for temperature measurements in a range from 4 to 300 K in various parts of the thermostat and the examined magnet. The general scheme of the thermometry system is shown in Fig. 3.

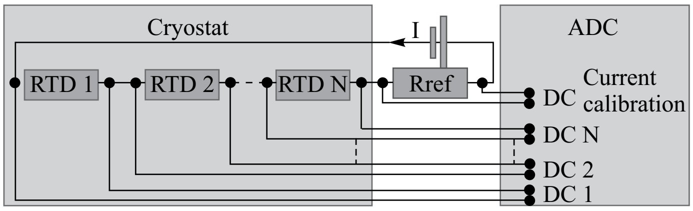


Fig. 3. Thermometry system hardware general scheme

Detectors of each type are connected in series, and powered by reference current sources — 20 $\mu$A for TVO and 500 $\mu$A for Pt100 sensors. Each sensor is connected via a twisted pair to differential input of the data acquisition module to measure voltage drop. It allows us to eliminate crosstalk. The detectors resistance is calculated using reference current value. To take the deviation of current from the nominal value into account, precise currents values are continuously measured through the voltage drop on separate reference resistors. Temperature dependence of the resistance in the range of 0–300 K is approximated by a 6 deg polynomial for sensors TVO and 5 deg polynomial for sensor Pt100.

The data acquisition system hardware consists of a few PXI modules from National Instruments: one NI PXI-8820 system controller and a few NI PXIe-4357 data acquisition modules for RTD measurements (24 bit, 20 channels). The advantages of these modules are: high precision and high level of interference suppression of 50 Hz. It is very important because of the great number of high-power equipment in the test bench. Achieved precision of the voltage drop across the sensor measurement is $\sim 10$ $\mu$V per 80 mV scale ($\sim 0.0125$%).

## SOFTWARE

**Database.** The sensors passport data, configuration of measurement channels data and measured values of temperature are stored in MySQL database. The system configuration for the new test session can be performed by the operator through the special configuration tool.

**TANGO.** The software was developed using the TANGO [2] control system framework. It consists of several TANGO device-servers: ADC data acquisition module (PXI module control, data acquisition and data filtering), temperature calculation module (polynomial approximation of the temperature), database storage access module, data export module (data export to Excel or SQL), system configuration module and TANGO modules for web access (REST, WebSockets, WebAuth). The advantages of using TANGO are easy management, extension and implementation to the NICA control system in the future.

**Client Application.** The client application to provide user-friendly operator interface is shown in Fig. 5. It has been developed as a web page using Sencha ExtJS framework [3]. It

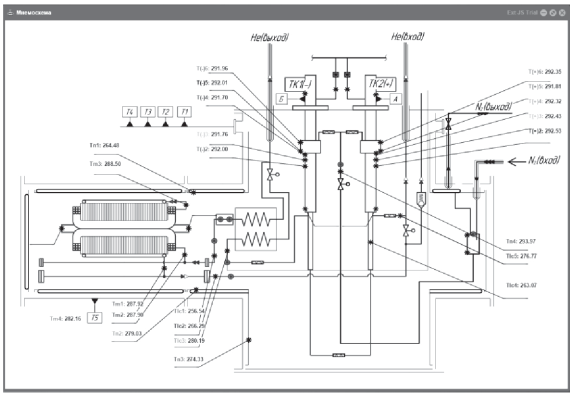


Fig. 4. Mnemonic diagram

Таблица — Ext JS Trial

| Датчик ↑ | Темпера | Модуль | Тип | Диаг | Описание |
|---|---|---|---|---|---|
| T(+)1 | 3.455 | thermostat2 | TVO | He | Токоввод (+) гел. часть |
| T(+)2 | 73.385 | thermostat2 | PT100 | N2 | ВТСП (середина) |
| T(+)3 | 72.84 | thermostat2 | PT100 | N2 | Азотный бачок (низ) |
| T(+)4 | 73.251 | thermostat2 | PT100 | N2 | Азотный бачок (верх) |
| T(-)1 | 3.867 | thermostat2 | TVO | He | Токоввод (-) гел. часть |
| T(-)2 | 73.347 | thermostat2 | PT100 | N2 | ВТСП (середина) |
| T(-)3 | 72.233 | thermostat2 | PT100 | N2 | Азотный бачок (низ) |
| T(-)4 | 73.056 | thermostat2 | PT100 | N2 | Азотный бачок (верх) |
| Tm1 | 4.595 | magnet0004 | TVO | He | Вход в обмотки дуплета |
| Tm2 | 3.631 | magnet0004 | TVO | He | Выход из обмоток (вход в ярмо 1) |
| Tm3 | 3.924 | magnet0004 | TVO | He | Выход из ярма 1 ( вход в ярмо 2) |
| Tm4 | 3.559 | magnet0004 | TVO | He | Выход из ярма 2 |

Fig. 5. Table

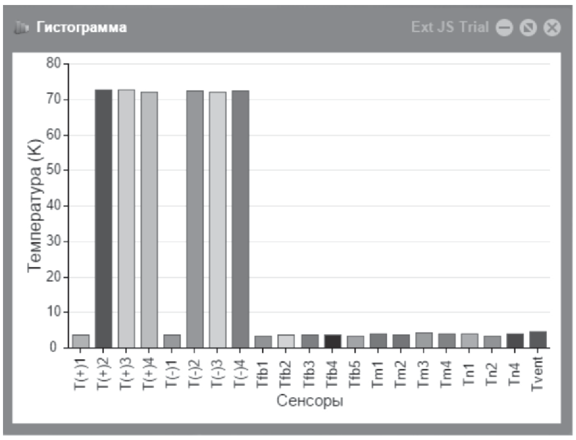


Fig. 6. Column chart

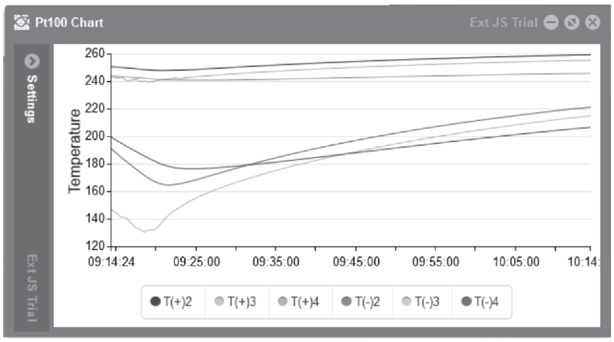


Fig. 7. Line chart

allows us to create a web desktop with a flexible design. An operator can access it from any device in local network (PC, tablet). No additional software is needed (only a web browser). Several widgets for the data mapping have been developed: mnemonic diagrams (Fig. 4), tables with sorting and filtering (Fig. 5), column charts (Fig. 6), line charts (Fig. 7), stored data viewing, stored data exporting, logbook and tango devices management.

## TANGO WEB TOOLS

While creating a web-based client several modules [4] for the TANGO-based control system web client software design have been developed:

1. WebSocketDS device-server serves to read TANGO attributes through WebSockets.

2. RestDS designed to provide access to the TANGO control system units through http(s) requests (Ajax).

3. TangoWebAuthDS designed to provide a web access control (in addition to a standard TANGO access control and our custom TangoAuth control).

These modules are cross-platform generic Tango device-servers, developed in C++ with Boost library. It includes built-in web servers. No additional software is needed. The client web pages could be developed in html with any JavaScript framework (JQuery, ExtJS).

## SUMMARY

1. Standalone thermometry system for superconducting magnets test bench has been developed.

2. This system is also a prototype for the NICA thermometry system.

3. Precision of the voltage drop across the sensor measurement $\sim 10\ \mu$V per 80 mV scale ($\sim 0.0125\%$).

4. User-friendly flexible web client application has been developed.

5. Toolbox consisting of the TANGO web tools (WS, REST) with JavaScript web framework (like ExtJS) can be used for developing other control system client applications.

## CURRENT WORK

1. To extend the system up to 6 experimental shoulders (currently 2 are operational).
2. To set up the new powerful server Supermicro for data storage.
3. To develop a new configuration tool.

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