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SOFTWARE DEVELOPMENT FOR AUTOMATION OF NICA MAGNETS TRAINING AND DYNAMIC HEAT RELEASES MESUREMENT

B. Kondratiev*, V.V. Borisov, A.V. Bychkov, H.G. Khodzhibagiyan, S.A. Kostromin, A.V. Kudashkin, D.N. Nikiforov, M.V. Petrov, A.V. Shemchuk
LHEP, JINR,141980, Dubna, Moscow Region, Russia

Abstract

Training and measurement of dynamic heat releases is assumed for each NICA SC magnet. The software for automation of these processes is described. The results of training and the results of measured dynamic heat releases in the NICA booster dipole and quadrupole magnets at series tests are presented.

INTRODUCTION

For performating SC magnets training and the measurements of dynamic heat releases the software for controlling the power supplies, the energy evacuation switch[1], DAC, ADC modules and signaling equipment is necessary. LabView from National Instruments was used as the development environment for this software.

MAGNETS TRAINING

After the manufacturing of a SC magnet the training of quench current must be performed. This process implies the feeding of SC magnet with gradual increase of current altitude. Quenches are detected by the quench detector [2]. Training of magnets continues until the moment when the quench current altitude reaches plateau or the target value. For booster SC magnets it corresponds to 12100 A that includes the altitude of booster operating cycle [3] that equals 9680 A with the 25% reserve.

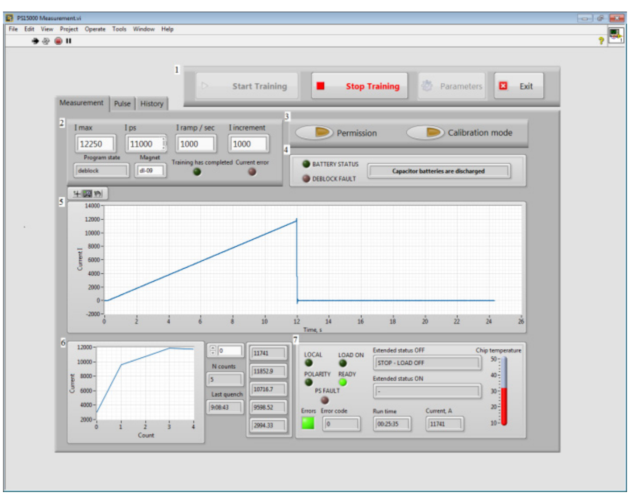

Figure 1: The main window of the training automation program:1 - Controlling buttons 2 - Training status bar, 3 - Buttons for permission of training resumption and for calibration of the detector, 4 - Status of energy evacuation switch, 5 - Current graph, 6 - Quenches quantity, 7 - Status of power supply.

Power supply PS15000 [4] is used for the training of dipole and quadrupole magnets. The maximum current altitude of this power supply is 15000A. The NI-PXIe4461 module is used as the ADC and DAC equipment for generating and measuring of current pulse signal. Commands for manipulating and for state monitoring of power supplies, energy evacuation key and signaling equipment are transmitted by the RS485/RS232 interface via the Moxa NPort 5650 converter.

Software for automation of magnets training (see Figure 1) includes processes of power supplies equipment manipulating, operating with DAC/ADC equipment, detecting of quench events, logging the data and events during SC magnets training. The training of SC magnets is performed by triangular current cycle. The standard current parameters of the training are listed in Table 1.

Table 1. The Standard Current Parameters of Training

Starting altitude, A	1000
Step current increment, A	1000
Final current altitude, A	12250
Current rate, A/s	1000
Time of pause, s	>3
Time of table, s	0
Time of transition areas, s	0.03

After the quench the program is waiting for the permission of training resumption. This permission comes to the program when the magnet achieves the required temperature.

THE RESULTS OF BOOSTER DIPOLE AND QUADRUPOLE MAGNETS TRAINING

Each SC magnet was trained before magnetic measurements and dynamic heat releases measurements. The resulting quantities of quenches are shown below. Some of quenches happened due to the false triggering of the quench detector.

Quenches quantity at the quadrupole doublets are presented in Figure 2.

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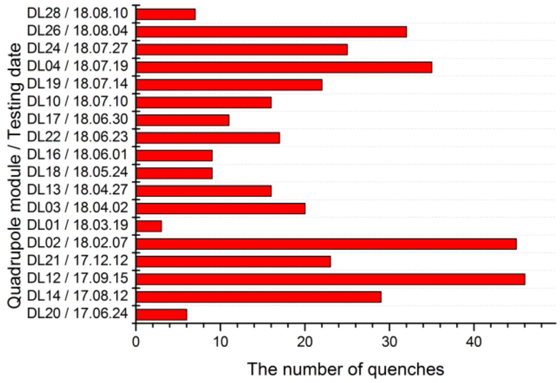

Figure 2: Quenches quantity of the quadrupole doublets.

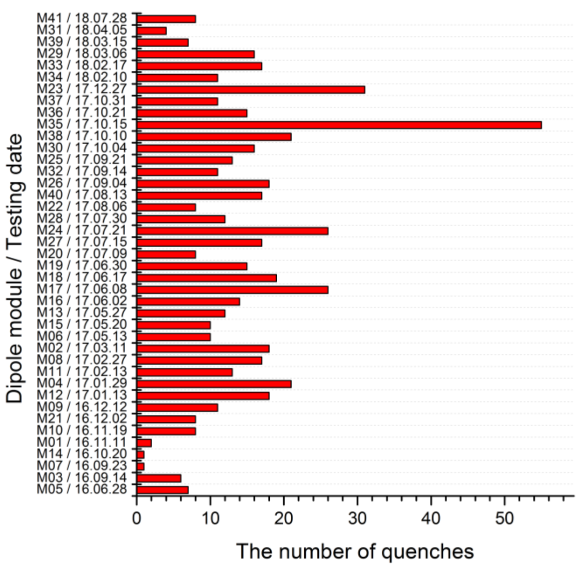

Figure 3: Quenches quantity of the dipole magnets.

The number of quenches for the NICA booster dipole magnets is shown in Figure 3. The current altitudes of quenches for some SC magnets are given in Figure 4.

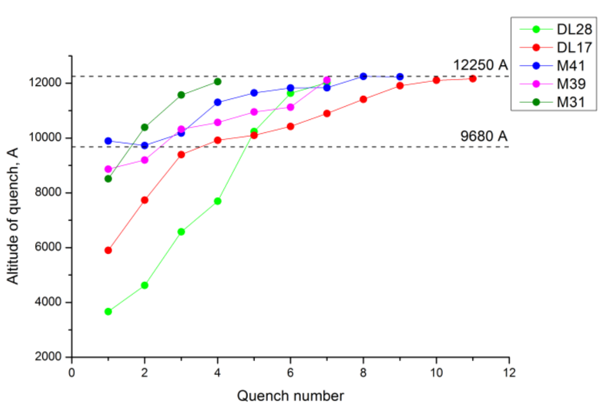

Figure 4: The current altitudes of quenches at SC magnets DL28, DL17, M41, M39, M31.

DYNAMIC HEAT RELEASES MEASUREMENT OF BOOSTER DIPOLE AND QUADRUPOLE MAGNETS

One of the parameters measured during the cold testing of superconducting magnets for the NICA project is the dynamic heat releases at pulse operation mode. These losses are due to eddy currents, hysteresis losses and other effects.

The system for measurement of dynamic heat releases (see Figure 5) by electrical (V-I) method [5] is comprised of two high-accuracy digital multimeters Keithley DMM 7510. The first multimeter is connected to the current sensor LEM ITZ-16000, and the second one to a superconducting magnet under testing. The maximum voltage value from the current sensor 10V corresponds to the maximum measuring current 16000A and varies linearly with the current that flows through the sensor. The voltage taps are connected to the starting point and endpoint of the superconducting coil. The multimeters acquire data at digitize mode simultaneously by the trigger signal from NI-PXIe 6682. PC is connected to the Keithley multimeters by GPIB interface and interacts with testers via the LabView program.

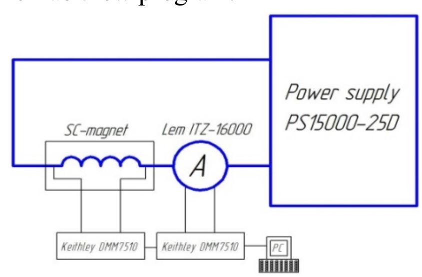

Figure 5: The scheme of dynamic heat releases measurement.

Software for the measurement of dynamic heat releases (see Figure 6) may control two power supplies simultaneously to feed the quadrupole doublet and dipole corrector magnet at the same time.

Figure 6: The program for automation of dynamic heat releases measurement: 1 - Controlling buttons, 2 - Measurement status bar, 3 - Status of energy evacuation switch, 4 - Data graph, 5 - Cycle parameters, 6 - Heat releases power graph, 7 - Status of first power supply, 8 - Status of second power supply.

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The cycle parameters for the measurement of dynamic heat releases are listed in Table 2.

Table 2: Parameters of the Current Cycles

Parameter	Dipole	Quadrupole	
Coil	Dipole	Quadrupole	Dipole Corrector
Current altitude	9680A	9680A	40A
Current rate	6453 A/s	6453 A/s	26.7 A/s
Pause	0(1) s	0(1) s	0(1) s
Cycle duration	3.004 (4.004) s	3.004 (4.004) s	3.004 (4.004)s

Each SC magnet tested by the cycle with a pause and the cycle without pause. Shape of the cycle for quadrupole doublet with dipole corrector is shown in Figure 7.

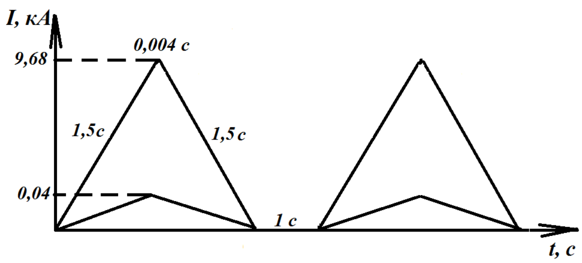

Figure 7: Quadrupole magnet's current cycle.

Switching between the cycles is performed by the "Next button".

THE RESULTS OF AC LOSSES MEASURENTS FOR THE SERIES MAGNETS

The measurements of dynamic heat releases were made at the series dipole and quadrupole magnets for the NICA booster by V-I method and calorimetric method.

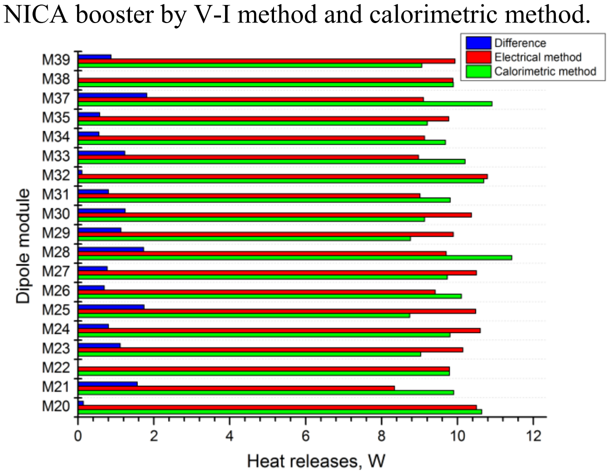

Figure 8: Power of heat releases for the dipole magnets.

Results of AC-losses measurements for the dipole magnets are shown in Figure 8. These values were corrected for the booster cycle. Results of AC losses measurements for the quadrupole doublets are shown in Figure 9.

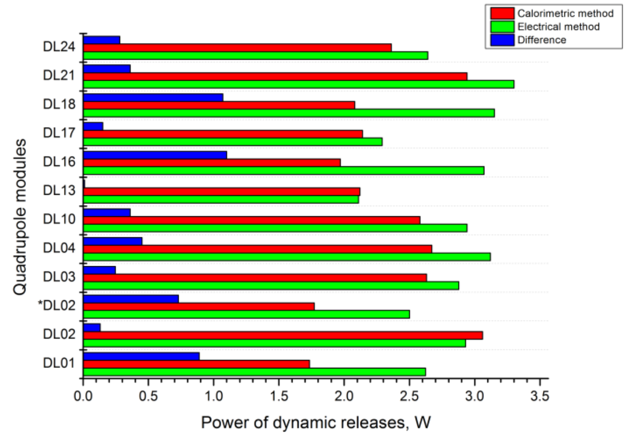

Figure 9: Power of heat releases for the quadrupole doublets.

The average values of AC Losses power for SC magnets that was measured by the V-I method and calorimetric method are listed in Table 3.

Table 3: Average values in Watts of dynamic heat releases for the NICA booster magnets

Dipole magnets		Quadrupole doublets	
Calorimetrical	Electrical	Calorimetrical	Electrical
10.00	9.82	2.82	2.57

CONCLUSION

The software for training and dynamic heat releases measurement of SC magnets vastly decreases staff time and required time for these processes as well as exclude human factor in the process of power supply control.

ACKNOWLEDGMENT

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