PROPOSAL TO SYMMETRIC QUENCH DETECTION AT SUPERCONDUCTING ELEMENTS BY BRIDGE SCHEME USAGE

E.V. Ivanov, A.O. Sidorin, A.L. Svetov, JINR, Dubna, Moscow Region

Abstract

In the frame of the NICA project [1] two new superconducting accelerators will be constructed – the Booster and the NICA collider. Specialized facility for manufacturing and testing of the SC magnets for the NICA and FAIR projects is under development at JINR [2]. Proposal to quench detection system for these and similar facilities is described in this paper.

INTRODUCTION

Currently to detect the active phase on the superconducting elements of modern accelerator complexes widely used method of active phase voltage selection out of the total voltage drop at the controlled element and further analysis to meet the criteria of the quench.

The voltage on the inductive superconducting element is described by the formula:

$Vm = Lm\frac{dI}{dt}$, where Vm – voltage at inductance element, Lm – inductance of a magnet. Voltage at the beginning of quench is Vsm=Rq*I+$Lm\frac{dI}{dt}$ =Rq*I+Vm, where Rq- is resistance of a region with active phase.

Selected quench voltage is Vq=Vsm-Vm is analyzed by the detector logic to meet the criteria of exceeding the voltage threshold Vth by amplitude during predefined time Tv. Exceeding of these thresholds is a condition to turn protective systems on and start energy evacuation from the magnetic system of the accelerator.

It should be noted that the quench voltage Vq is typically ≈100÷200 mV, and voltage Vsm and Vm change dynamically during acceleration cycle in the range from –10V to +10V depending on the rate of change of the magnetic field and of the element inductance.

Thus, the detection scheme must reliably identify the voltage Vq over a wide dynamic range regardless of the instantaneous voltage on the element at each moment of time [3].

Basically bridge scheme is used to select quench signal Vq. This method of detection is widely used due to its undeniable advantages that are missed in other solutions. So, the bridge is completely passive element, so it can detect the signal of any dynamic range in amplitude. The signals from the magnetic elements in the bridge scheme are differential, thus making the bridge scheme insensitive to induced noise. And moreover the bridge scheme is pretty simple, cheap in realization and very robust.

While using the bridge scheme, it is very important that arms of the bridge – that is controlled inductance - have a minimum length. Otherwise due to phase shifts to obtain the bridge scheme being balanced is possible only at one fixed frequency. Herewith any change of the voltage (rise and/or decline) will result in short-term dynamic disbalancing.

So the optimal usage of the bridge scheme to protect quench of a superconducting accelerator elements is to use it in schemes with mid-point connection. In such a solution the scheme logic compares signals from two halves of a magnet. Such a bridge scheme should use the minimum possible inductance, and the shortest linear connections.

Some publications (TEVATRON [4], LHC [5], and the latest SIS 100 documents) indicate the possibility of the so-called "symmetric quench" to occur while using the protection system with mid-point connection scheme. That is the appearance of the active area at the mid-point connection and its symmetric uniform propagation resulting in the bridge scheme disbalancing not happened. Earlier to exclude this situation the sensors with group of magnets bridging were mostly used. Recently some attempts are made to measure the quench by non-bridge sensors.

Unfortunately, the comparison of signals without using the bridge scheme implies necessity to use a very accurate differential amplifier with large dynamic ranges of input voltage and low drift in both measurement channels. Today such devices appear in catalogues of some manufacturers, although usage of these amplifiers in real accelerators is still very difficult to be widely used. In addition, for comparison of the real and reference signals you need to have the reference signal exactly copying the controlled signal and having no phase shift and noise. This fact is the main difficulty to implement such methodology. Realization of such a reference signal is quite difficult structurally.

As an alternative, at the LHC obtaining the derivative is implemented by measuring the current in the circuit before and after the controlled magnet with the subsequent differentiation and averaging. This method is very complex and expensive, and is used in circuits with currents less than 700A and very large (~1V) threshold.

SIS 100 proposes to use one supplementary superconducting filament as a reference winding. The method is also very complex and difficult in design.

In this paper we propose a solution for a problem of the symmetric quench detection while using a bridge detector for the magnetic elements of the NICA accelerator complex, LHEP, and the like [3].

ISBN 978-3-95450-181-6

BRIDGE SCHEME OF THE QUENCH DETECTION WITH ADDITIONAL SENSOR

Usually, talking about usage of the bridge scheme with the mid-point connection means a circuit as in Fig. 1:

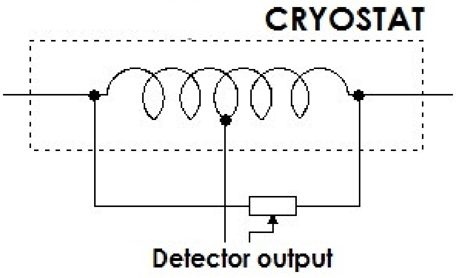

Figure 1: Idealized scheme with mid-point connection.

It is assumed that may be such a situation when the active phase appears and the bridge scheme with mid-point connection does not disbalance. True, it is really so. But in practice the real implementation of the bridge scheme looks like this (Fig. 2):

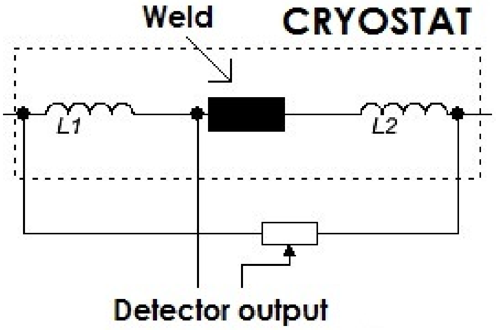

Figure 2: Real scheme of mid-point bridge connection.

There is a weld at the junction point of magnet winding halves. And the mid-point of the bridge is connected to one of the weld edges. It is hardly possible to imagine a situation when the active phase there will be symmetrically and evenly spread through a pure superconductor and the weld. With that any fears of a "symmetric quench" is unlikely to have any reason. Moreover the publications mentioned above clearly state that such cases have never been observed.

Despite the optimism of this view, the theoretical possibility of such a situation still remains. Additionally, there may be a real situation when the magnet completely loses superconducting state. In this case the bridge does not work either.

So we propose the solution to this problem of the symmetric quench as shown in the Fig. 3.

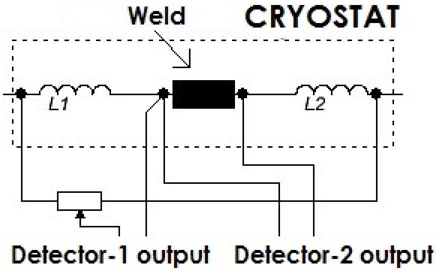

Figure 3: Scheme of total protection for a magnetic element.

A separate sensor is connected to both sides of the weld between winding halves to monitor superconductivity at the weld by absolute value.

Thus, with such an arrangement of the detection scheme a quench, wherever it occurred, will be clearly detected. Even in case of total loss of superconductivity inside controlled volume this separate sensor will show quench, because it compares voltage at weld with absolute value “0 V”.

From the design point of view this solution will require only some extra sensors to be installed. All sensors in this solution are designed identically. Their work has already been tested many times in practice at NUCLOTRON accelerator runs [6].

CONCLUSION

In this paper we propose a solution for a problem of the symmetric quench detection while using a bridge detector with one additional sensor connected to both sides of the weld between winding halves. The sensors required for such a scheme was designed and tested at JINR.

REFERENCES

[1] G.Trubnikov, NICA project, these proceedings.
[2] H. Khodzhibagiyan et.al, The Progress on manufacturing and Testing of the SC Magnets for the NICA Booster Synchrotron, these proceedings.
[3] Ivanov E.V. et al, “System of Quench Detection in Superconducting Magnets of the Nuclotron Accelerator Complex”, Physics of Particles and Nuclei Letters, 2013, Vol. 10, No. 4.
[4] Robert H. Flora et al, “Doubler-TEVATRON mP Quench Protection System”, https://accelconf.web.cern.ch/accelconf/p79/PDF/PAC1979_3451.PDF
[5] K. Dahlerup-Petersen, et al, “The protection system for the superconducting elements of the Large Hadron Collider at CERN”, http://accelconf.web.cern.ch/AccelConf/p99/PAPERS/THP105.PDF
[6] E.Ivanov et. al. Quench Detector for Superconducting Elements of the NICA Accelerator Complex, Proceedings of RuPAC-2014, Obninsk, Russia.

ISBN 978-3-95450-181-6