© November 2018 | IJIRT | Volume 5 Issue 6 | ISSN: 2349-6002

Magnet protection using derivative of the current

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Abstract- **quench detection system (QDS) for the LHC 600A corrector magnet circuits and 6KA individual powered quadrupole (IPQ) is described. A direct current derivative method is mainly proposed in order to improve the dependability of QDS. The system uses a numerically derived current derivative. The current derivative is highly filtered in order to have a stable calculation. This leads to rise of a phase shift and thus the operational range of the circuit parameter is restricted. Transformer based current derivative sensors are in the process of development and they use cut cores which helps in easy prototyping, control in the performance and also in the installation process. An improved method was adopted to find the best arrangement of the sensing element, air gap in the cut core to give high mean sensitivity and to reduce the PQF.**

Index Terms- control equipment, defense, current quantification, transformer cores, super conducting magnets.

1. INTRODUCTION

In order to protect the superconducting magnets the quench protection system of the LHC is the basic part. Aside from the existence of passive protection elements like cold by-pass diodes and cold parallel extraction resistors, the quench detection system organize and performs the working of the active protection components as the quench heater releases the power supplies and vitality extraction systems.

Based on the lap layout and the numeral and type of superconducting elements, the super conducting circuits oversee by the active protection will have different protection arrangements and the protected circuits will have a real current ratings which is in a range from 550A to 11870A.

For the quench protection of 600A corrector magnet circuits of LHC, it uses the magnet and circuit protection and finds the resistive voltage using a compound arithmetical calculation. Thus the finding of derivative of current is very important and at the same time it also produces some systematic faults which lead to limiting the operational range of criterion like acceleration. Thus the procedure which have described in this can helps to solve the problem, enhancing the working of the circuits. The 6 kA IPQ magnet protections could detriment from the direct current derivative measurement as a harmonious method utilising In order to protect the superconducting magnets the quench protection system of the LHC is the basic part. Aside from the existence of passive protection elements like cold by-pass diodes and cold parallel extraction resistors, the quench detection system organize and performs the working of the active protection components as the quench heater releases the power supplies and vitality extraction systems.

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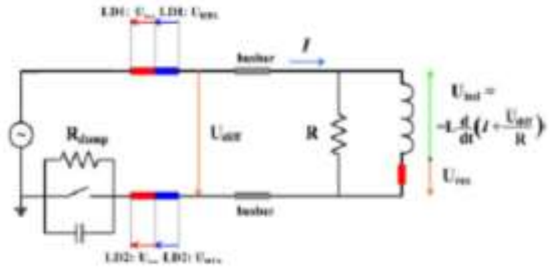

Fig. 1. Protection circuit for 600 A corrector magnets.

2. QUENCH DETECTION METHOD FOR 600A CORRECTOR MAGNET CIRCUITS

Based on the type of magnet used and energy stored the quench protection mainly offered to this type of circuits is given by the power converter crowbar, external energy extraction systems. Whenever a quench occurs the detector will detect it and will stop the power converter and will operate the energy removing system thus enabling the enegy to safely disappear. The system mainly uses a voltage drop across the cold part Udiff and the current measured by the hall sensor which uses as an input signal and thus finding out the resistive voltage Ures using the formula

$$U_{res} = U_{diff} + L(I)\frac{d}{dt}\left(I + \frac{U_{diff}}{R}\right)$$

The arithmetical resolution of derivative of current requires a digital filter, which institutes an phase shift with respect to Udiff . This leads to a hike of an evident resistive voltage during acceleration. It does not make any problems or cause in the protection process, but it is an draw back as it will reduce the high speed for the accelerator working. The current algorithm will reduce the power converter speed to a peak value of 1A/s^2 and also the ramp value to 5A/s.

3. LHC MAGNET PROECTION METHODS

Analog quench detection method

The analog quench detection is mainly based on the analog design which consists of developing a Wheatstone bridge having magnet coils and balancing resistors. For the reduction of number of defective triggers each board is provided with a redundant input and the detection stage using a two out of two evaluation plan. It is also provided with an data acquisition system.

Digital quench detection system

Digital quench detection system is mainly used for the protection of of corrector magnets, insertion region magnets, superconducting bus-bars and high superconducting current leads. All these systems are mainly placed in the underground areas in protection so that the radiation during the working of LHC is smaller than that on the inside of tunnel.

Fast DSP system

This is mainly used for the protection of LHC superconducting insertion region magnets, inner triplets which have an ultimate current value of 600A,a two channel digital detecting system is developed. The core of the system consists of an digital processor using 14 bit analog-digital converter mainly used for the assessment of two analog input channels.

4. SUGESTED METHODS

A. Direct current derivative sensor

The transformer related configuration is mainly used for executing the direct current derivative measurement. This has an advantage of low complication design and the prototyping process is very easy. The performance can be increased by making changes in the air gap of transformer cut core.

For the requirement of fitting the sensors, there is no need of any further moderation of present circuit and also no need of trimming the power cables.

B. MAGNETIC CIRCUIT MODEL

Sensor replica is a form of principle of power transformer. Applying faradays law to the sensing element.

Magnetic flux change in the core produces a voltage:

$$U(t) = n_2 \frac{d\Phi(t)}{dt}$$

Total current flowing through the magnetic path Ic is identical to the magneto motive force Fc, H(t):

$$F_c = H(t)l_c = n_1 I_1(t) = I_1(t)$$

$$H(t) = \frac{\Phi(t)}{A_c \mu}$$

Using khirchoff's magnetic law, it gives as:

$$U(t) = \frac{\mu A_c n_2}{l_c + 2\mu_r l_a} \frac{dI_1(t)}{dt}$$

With the help of the saturation current produced in the core, the current rate of the sensing element is given as:

$$I_{sat} = \frac{B_{sat} A_c}{n_1} (R_c + R_a)$$

5. PROTOTYPING

Transformer cut core configuration is mainly used for the prototyping. The first priority given for the prototyping is about the selection of top quality core matter. Electrical steel and the lamination steel of having relative permeability of 4000 and a saturation field of 0.3T are the two core matter tested. The result of core magnetization reduces as the air gap increments. This results an increase in the range of sensors. After choosing the good core matter and the arrangement of sensor the prototypes for the required magnet ie…600A and 6KA is known. For the stretching of two cut cores, sensors are in the form of sandwich like shape.

6. PERFORMANCE DEFINITIONS

The allowance of the sensor depends on the two factors: mean sensitivity and arithmetical performance quality factor. Mean sensitivity is nothing but the ability of the sensors reaction to the ramp value. Performance quality factor is mainly based on the standard deviation and the mean value of di/dt

$$U_{mean} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} U(t)dt \ [V]$$

Mean sensitity is given by:

$$S_{mean} = \frac{U_{mean}}{\frac{dI}{dt}} \left[\frac{V}{\frac{A}{s}} \right]$$

To find PQF, standard deviation is found out:

$$\sigma_{(t_1,t_2)} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (U_i - U_{mean})^2} \ [V]$$

PQF is given by:

$$PQF = \frac{\sigma}{U_{mean}} * 100 \ [\%]$$

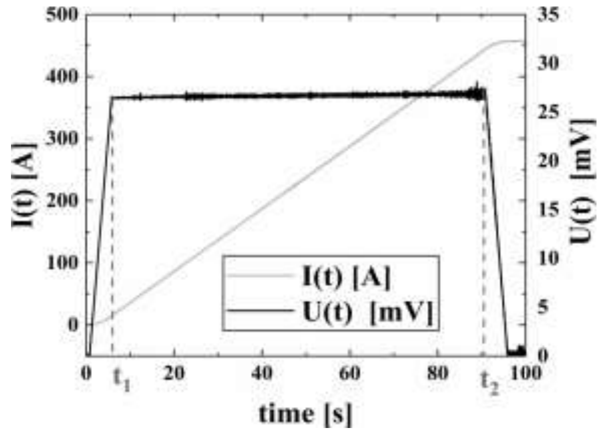

FIG 1.Sensor voltage (black) recording during a current ramp (gray line).start and stop points

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