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Large Hadron Collider Project

PROPOSAL OF A K-MODULATION SYSTEM FOR THE LHC QUADRUPOLES

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Abstract

A method for the precise measurement of the beam position with respect to the magnetic centre of quadrupole magnets installed in particle accelerators has been developed over the last decade. The procedure consists of modulating the field strength in individual lattice quadrupoles while observing the resulting orbit oscillations. This so-called K-modulation provides the precise information on the location of the particle beam and is of particular importance in superconducting accelerators, in which the quadrupole magnets are not provided with a direct optical reference to the magnetic centre. Measurements on the first LHC prototype quadrupole showed that sufficient modulation may be obtained up to a frequency of 40 Hz and that the existing equipment for the modulation of individual lattice quadrupoles in LEP may later on be used in LHC.

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1. Introduction

A method for the precise measurement of the beam position with respect to the magnetic centre of quadrupole magnets installed in particle accelerators has been developed over the last decade [1,2,3]. The procedure consists of modulating the field strength in individual lattice quadrupoles while observing the resulting orbit oscillations. This so-called K-modulation permits the absolute calibration of the associated beam position monitors, thus providing a perfect knowledge of the location of the closed orbit. In addition, it may provide other very useful observations for operation and adjustment of the accelerator. This is of particular importance for superconducting accelerators, in which the quadrupole magnets are not provided with a direct optical reference to the magnetic centre. The field geometry is defined by magnetic measurements and usually transferred to an external reference target. Errors caused by changes of temperature profiles and other phenomena might build up as time passes.

2. Measurement method

Simultaneous K-modulation measurements may be performed in several parts of the accelerator if different modulation frequencies are applied. A difference of about 1 Hz has proved sufficient [2,3]. Local d.c. orbit distortions are then applied in the search for the magnetic centre. The method may be improved by synchronous detection of the oscillation, so that its phase can be identified. The sensitivity of the detection is quite impressive. Experience from LEP shows that a modulation of the quadrupole field of about 300 ppm can be clearly detected. This means that measurements may be taken continuously during a physics run.

3. K-modulation in LHC

The method can easily be applied to the LHC quadrupoles. A small a.c. power supply could be connected directly to the quadrupole winding through the wires foreseen for damping of excitation current oscillations and for the periodic conditioning of the protection diodes. It would thus be connected in parallel to the main excitation current. The a.c. excitation circuit must be designed to support the rather high terminal voltage and common mode voltage occurring in case of quench or fast discharge of the magnet string. This may be obtained by protection resistors, limiting the d.c. current to a few amps.

The system for powering in the LHC tunnel could be very similar to that used for K-modulation in LEP: Two a.c. power supplies located in each of the underground areas may power any of the quadrupoles located in the two adjacent half octants. A possible scheme for powering one half octant is shown in Fig.1. In fact, the existing equipment for the K-modulation in LEP could be reused for LHC. A multicore control cable permits the multiplexing of the magnet excitation in each half octant through a matrix consisting of a simple relay and diode installed near each quadrupole. Simultaneous measurements may then take place in all half octants if different frequencies are applied.

4. Measurements of the quadrupole prototype

Magnetic measurements were performed at CEA-Saclay on the second LHC quadrupole prototype [4] in order to determine its frequency response. The main power supply was modulated with a superimposed a.c. signal at frequencies between 1 and 24 Hz, the upper frequency being limited by the regulation system of the power supply. The harmonic coil used for the systematic magnetic measurements of the quadrupole was placed at a fixed angle providing maximum flux linkage and connected to an analog electronic integrator in order to measure the resulting modulation of the quadrupole field. The amplitude of the modulation was directly compared to the quadrupole field as measured with the same coil and integrator during the ramp of the d.c. excitation current. The result showed that the full frequency range can be comfortably used.

However, some additional damping might occur due to eddy currents in the thin copper layer inside the beam screen. The measurements were therefore repeated at an extended frequency range and at a lower temperature inside an early prototype of the beam screen. This tube had an internal copper layer with a thickness of about 50 microns. The measurements were carried out, using a pair of standard search coils [5] placed on the inside wall of the beam screen. The magnet was excited by a power converter of same type as those used in the LEP K-modulation scheme, including the protection resistors which would be needed in LHC. No significant damping was observed in the frequency range up to 100 Hz. The useful modulation frequency will therefore be limited only by the protection diode fitted in parallel with the quadrupole magnet. So the minimum modulation of 300 ppm peak-to-peak can be obtained in a frequency range up to about 40 Hz.

5. Concluding remarks

It would seem useful to repeat these measurements in Test String no. 2. This could be achieved, using the same search coils which will serve for the field tracking experiments, again placed on the inside wall of the beam screen. The functioning of the proposed powering scheme, including the protection diodes could be verified and the possible interference with the main excitation circuit could be studied.

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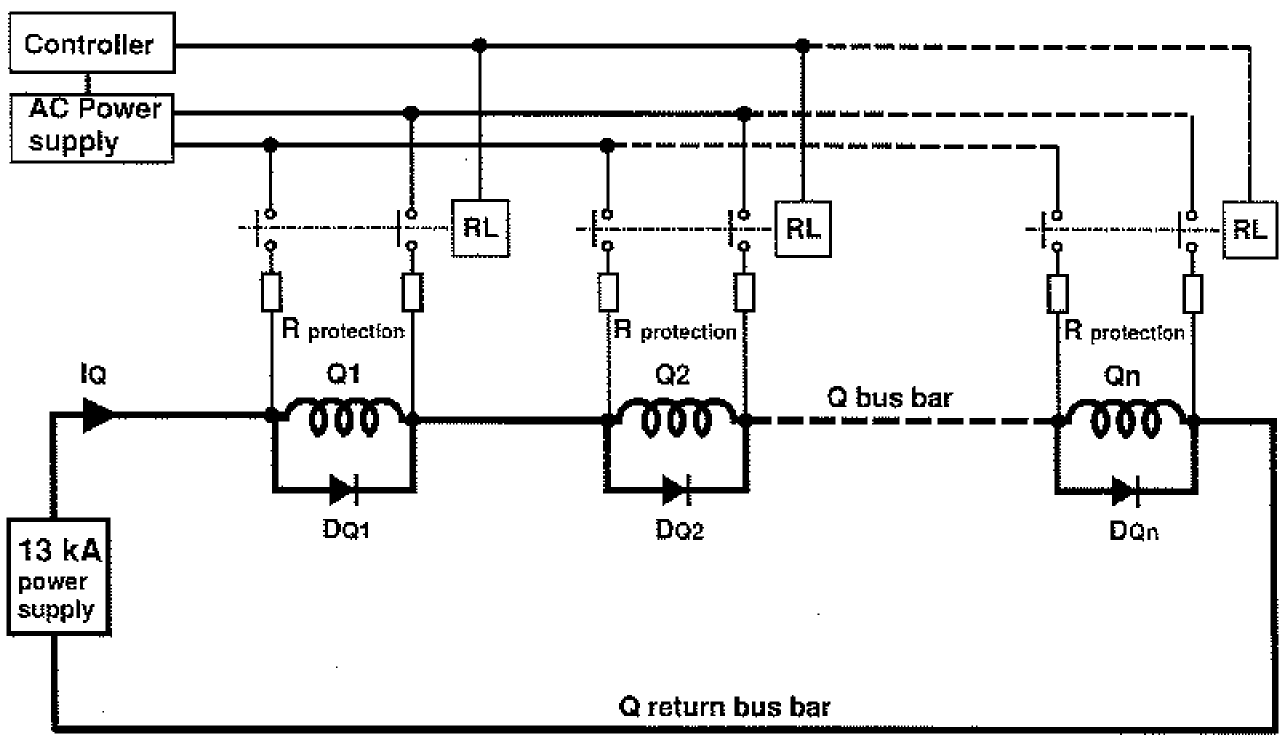
FIGURE 1



K - Modulation connection for LHC Quadrupoles