DESIGN AND TESTING OF A LOW COST MODULATING CURRENT SYSTEM FOR DETERMINATION OF SRS QUADRUPOLE MISALIGNMENT

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Abstract

Superimposition of a small a.c. signal onto a quadrupole magnet d.c. excitation can be used to determine the magnitude of electron beam offset in that magnet, thereby providing information on the relative alignment of the beam, the magnet and the bpms in a storage ring. In the Daresbury Laboratory SRS, a 2GeV synchrotron radiation source it is desirable to collect such data for each of its 32 main focusing quadrupoles, since regular checks need to be made around the whole ring in order to preserve good orbit control for the user beamlines. The paper gives a brief outline of the design philosophy of the system and a detailed technical description of the electrical engineering solution, which provides a 5 A modulation at variable frequency 1-8 Hz. A d.c. offset up to 10 A is a valuable additional facility.

1 OVERVIEW

In an ideal storage ring the electron beam on the reference orbit will pass through the centre of every quadrupole. In a practical accelerator this will not be easy; the quadrupoles and beam position monitors will have survey and alignment errors, so that the electron beam will not pass through the centre of each magnet. This is undesirable as it has the effect of applying an unwanted kick to the stored beam at each magnet. It is important therefore that the position of the beam with respect to the magnet is well known, so that steps can be taken to minimise these errors.

The deflection of the beam is proportional to the distance between the beam and the centre of the quadrupole, so this can be used to locate the centre of the magnet with respect to the beam. If a beam is stored and a small alternating current applied to just one of the quadrupoles at a selected frequency, then a beam position signal can be used to monitor the induced displacement at this frequency. As the beam is moved closer to the centre of the quadrupole with a corrector magnet bump the signal will reduce, reaching a minimum when the beam is passing through the centre. The signal will not actually disappear because of the finite beam size of the stored beam. A prototype system provided the example measurement for an SRS quadrupole shown in Fig.1. The error in finding the centre of the quadrupole is about 0.5mm.

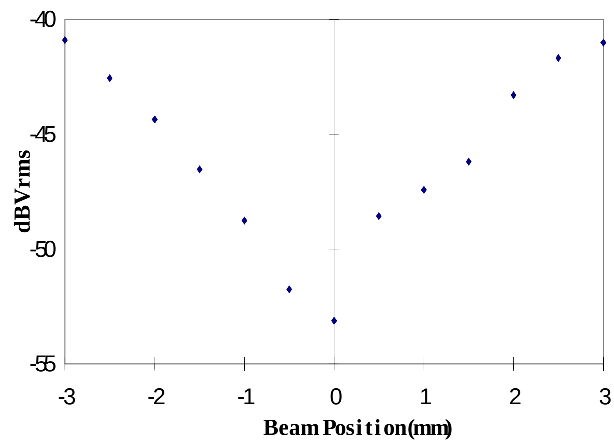

Figure 1: Beam position signal (dBVrms) versus beam position (mm).

2 DESIGN OPTIONS

There are two obvious methods of applying the small alternating field to the quadrupole magnet current. The first is to superimpose an a.c. current on to the stabilised d.c. as shown in Fig.2. This would require an additional power supply and prove costly if all thirty two quadrupoles magnets used in the SRS were to be controlled independently.

If this method were to be adopted then it is necessary for the power supply chosen to have isolated outputs; and it must withstand the maximum output voltage of the quadrupole power converter with respect to earth. In most power supplies the control circuitry is referenced to one of the output terminals and the external control electronics will require the same isolation. The power supply must have sufficient bandwidth to respond to the frequency range selected, this system operates at less than 10Hz, so this is easily achievable. The rating of the power supply will be determined by the inductance of the quadrupole magnet and the required frequency and magnitude of the a.c. signal.

The second method is to use a current shunt in parallel with the magnet and vary the amount of bypass current. This design utilises the power converter feeding the quadrupole magnets and provides a low cost solution, as it requires no additional supply. The frequency and amplitude of the a.c. signal is limited by the voltage dropped across each magnet and its inductance. The design will require the same isolation to the control electronics as was necessary in the previous method.

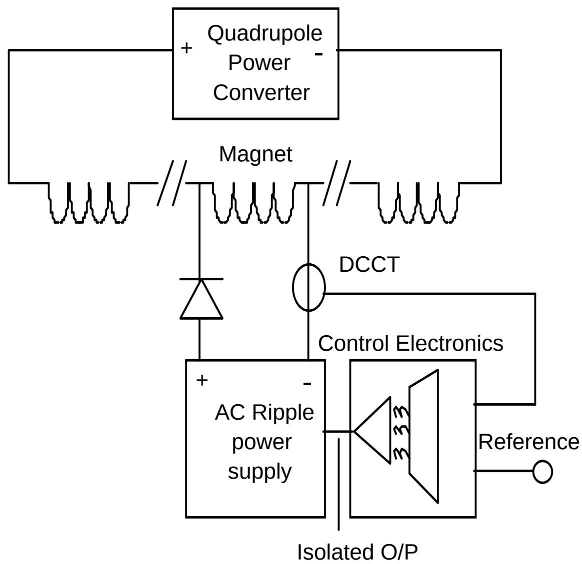

Figure 2: Superimposing a.c. ripple onto the d.c. excitation

3 PROTOTYPE RESULTS

The original prototype experiments were performed by superimposing the a.c. signal onto the d.c. magnet current. These results showed that a frequency of between 1 and 8Hz is the optimum range. A frequency higher than this increases the voltage required to achieve the di/dt and is not necessary to produce the desired results. The magnitude of the signal required is less than 10 amps, but to avoid beam loss the signal needs to be increased slowly to the value chosen.

The accuracy of the experiment depends on three main features:

- actual stored beam size - the beam diameter will effect the results; ideally the beam size should be a as small as possible:
- magnitude of stored beam current - the signal generated by the beam position monitor is directly proportional to the beam current; this should be a minimum of 100mA to achieve good resolution:
- bandwidth of the main quadrupole power converter - if the response time of the power converter is not sufficient, then a small alternating field will be seen in the other quadrupole magnets.

The best result would be to generate a minimum signal which is close to that of the background noise when the beam passes through the centre of the magnet.

4 DESIGN SELECTION

A prototype version of the shunt design was also constructed and test results proved that both designs were equally viable. The reason for choosing the shunt design was based mainly on cost and simplicity of design.

As the experiment can only be performed on one quadrupole at a time, a single shunt system per quadrupole family would be sufficient.

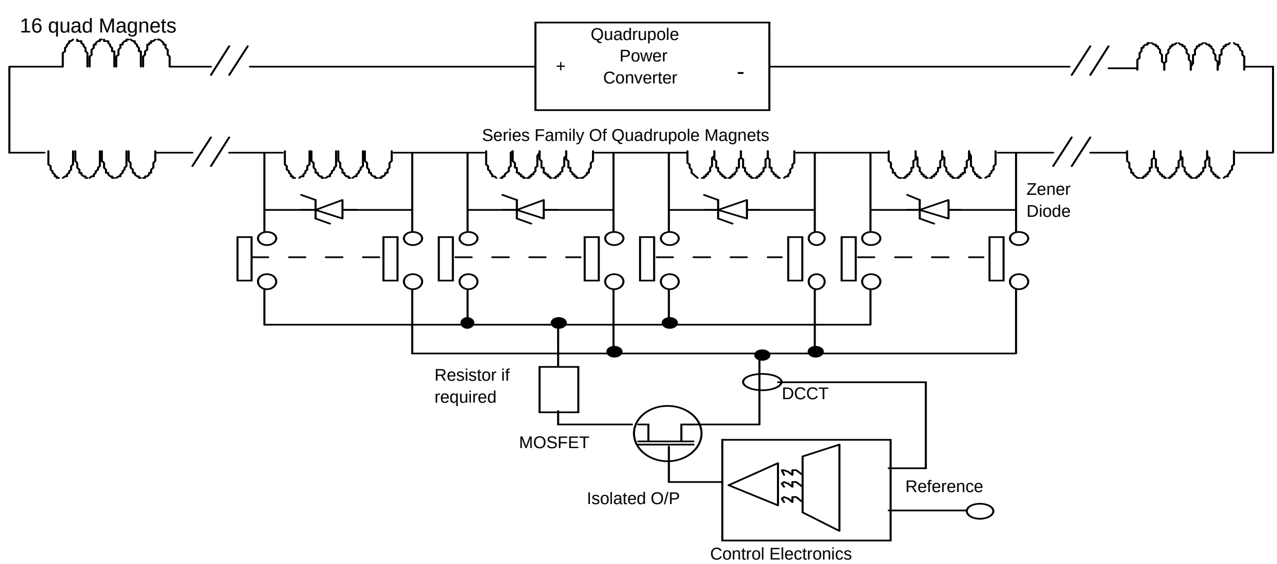

Figure 3: a.c shunt design with common power and control electronics for four quadrupole magnets

The cheapest solution available is to construct one unit which is portable and can be connected to any quadrupole magnet. The procedure for this system would be as follows; connect the equipment to the appropriate magnet, achieve stable stored beam and apply the a.c signal. It is not possible to apply the a.c. signal before injection as this effects the orbit. Unfortunately the duration of the experiment would be excessive and is not a practical solution.

The preferred method is to house the equipment outside the storage ring tunnel, and design the system with the capability of switching the a.c. signal to any one magnet during stored beam. This will allow the experiment to be performed on multiple magnets without refilling.

5 DESIGN PRINCIPLES

The design philosophy is simple, a transistor (Mosfet) with its base drive controlled to generate the alternating field is used to shunt current from the magnet. The control electronics are isolated from the Mosfet as its potential can vary between earth and 200V which is the nominal output of the quadrupole supply. Generally a low quality direct current current transducer (DCCT) can be used, as long term stability is not critical. As this system is also used as a d.c. shunt then the DCCT specification will need to be improved.

The a.c. signal can be applied manually or automatically. If set on automatic the current is ramped to a preset amplitude and frequency to prevent beam loss.

The actual design used will incorporate four shunts per magnet family of sixteen units, so that one shunt will be switched between four quadrupoles as shown in Fig.3. This decision was influenced by utilising the system to shunt d.c. current which allows some flexibility to reduce unwanted beta function modulation around the storage ring. This additional functional offers a low cost solution compared with the procurement of a power converter for each quadrupole magnet.

To reduce cable lengths these will be distributed around the storage ring, with a cable size sufficient to minimise voltage drop and standardise the design.

When using a common shunt it is important that only one magnet is connected at any time, multiple connections would result in a magnet being short circuited. To prevent this, a programmable logic controller is included in the design. This allows activation of the outputs only when the input conditions are satisfied. Each connection to the magnet must be individually fused as close to the magnet as possible. As long as the reverse voltage is minimised by providing a alternative path for current flow during fuse activation, the fuses do not necessarily have to be d.c. rated.

A zener diode connected across the magnet is sufficient to provide a path for the alternating current and limit the reverse voltage. It is important when selecting the zener diode voltage, that it is high enough not to effect the di/dt of the quadrupole magnet power converter during ramps from injection to final operating energy.

This simple a.c. shunt design can be achieved with readily available low cost components. The low magnet voltage and shunt current, combined with operating frequencies of only 1 to 8 Hz enables general purpose components with low technical specifications to be used. This is evident in the procurement of the mosfets and DCCTs.

If the design is used for a.c. applications only the control electronics will not require integrated circuits with ultra low drift and temperature stability, as the a.c. system will only be operated for the duration of the experiment approximately 1 to 2 hours. As this system is also used for d.c. applications these parameters will need to be taken into consideration.

6 CURRENT DEVELOPMENTS

The a.c. ripple system is required to check the alignment of the quadrupole magnets in preparation for the installation of the multipole wigglers as part of the SRS upgrade [ref.1,2]. The vertical aperture of the storage ring will be reduced as a consequence of this upgrade and this makes the positioning of the quadrupoles more critical.

The first module designed to shunt current from four quadrupole magnets has been successfully manufactured and tested. The installation of the entire system is scheduled for completion during the July 98 shutdown.

The initial system will be configured for manual control only, via the front panel of each module, although the system is designed to operate remotely. This will not be available until the interface to the Daresbury control system is completed.

If required in the future the design can be easily upgraded to provide 32 individually controlled quadrupole shunts.

REFERENCES

[1] J.A. Clarke, et al, “Progress with SRS upgrade project”, these proceedings.

[2] J.A. Clarke, M.W. Poole “Upgrading the SRS with additional insertion devices and its implications to the storage ring layout”, EPAC 96, Pg. 623