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CHARGED-PARTICLE TRANSPORT SYSTEM

Warren L. Dexter

January 29, 1969

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TRANSPORT SYSTEM

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Summary

A novel automated magnet switching system has been devised whereby power for beam-transport magnets of multiple-beam arrays can be supplied by common power supplies, thereby reducing the power-supply cost to that of a single beam line. The heart of the system is compact and inexpensive computer- or punched-card-operated reversing and selector switches that can switch kiloamperes. The complete system and the switches are described in detail.

Introduction

Most modern accelerators have a number of beam-transport lines so that when one beam line is in operation it is possible to work on experimental setups on the others. Each transport line usually has a complete magnet system so that it is only necessary to energize the magnets to make the line operational. In small installations it has been considered economical to provide a power supply for each magnet. In large experimental transport systems, bolted links are provided to allow switching from a number of magnets to common power supplies. However, if the beam line is complicated and contains say 60 magnets, it would take over an hour to make the switchover. In high-cost-per-hour machines, such a change-over is prohibitively expensive. Also, it is necessary in many cases to reverse the polarity of the power supplies.

In order to overcome these problems, a reversing switch and a four-pole transfer switch have been developed that can switch kiloamperes and be remotely operated. The main criteria for such devices is they be compact, inexpensive, and reliable. Figure 1 shows a compact motor-driven reversing switch rated at 2000 A. Figure 2 shows a 4-pole, 4-position motor-driven selector switch rated at 1000 A.

In order to fully utilize the capabilities of these switches, control circuits operate the transfer motor of these switches for impulses from a card reader or a computer. Figure 3 shows a small representative beam-transport system suitable for four experimental areas. This schematic shows two bending magnets, B1 and B2, and four quadrupole magnets: Q1, Q2, Q3, and

Q4. This arrangement requires only two power supplies, one reversing switch, and two selector switches.

To utilize the high-speed virtues of such a system it is also desirable to set the current in each magnet to its operating value by means of the same reader or computer. The system for achieving this is described in another paper in this conference.¹

Description of Reversing Switch

The schematic diagram for the high-current circuit of the reversing switch is shown in Fig. 4. Four stationary switch contacts are arranged in quadrantal relation and spaced apart with narrow gaps. Two sets of contacts are mounted on movable carriages that provide bridging electrical connection across the gaps between selected pairs of adjacent stationary contacts. Switching is accomplished by withdrawing the movable contact carriage, by means of a motor-driven leadscrew, from the first two pairs of stationary contacts and then advancing the other movable contact carriage toward the stationary contacts to provide connection between the other two pairs of stationary contacts. Limit switches are provided at each end of the carriage travel to prevent the motor from driving the carriages beyond their range. These limit switches also provide a signal to the power supply control circuit to ensure that the power supply is de-energized during switching.

Description of Selector Switch

Figure 5 shows the high-current wiring of the selector switch used to switch the power to four quadrupole magnets: Q1, Q2, Q3, and Q4. Only one triplet quadrupole magnet is shown, for clarity. The switch is constructed with eight stationary contacts arranged in radial relationship with two stationary common central switch contacts with gaps between them. Two sets of contacts on an insulated movable carriage provide bridging electrical connections between the common contacts and the radial contacts. Switching is accomplished by withdrawing the movable contacts from a first set of contacts and rotating and advancing the movable contacts to provide a bridging connection between the

*Work done under the auspices of the U. S. Atomic Energy Commission

common contacts and a different set of radial contacts. A single motor and leadscrew arrangement advances and retracts the movable contact carriage. This leadscrew also rotates the carriage by means of a friction nut. An arrangement of four electrical solenoids with catches that engage notches on the circumference of the contact carriage provides means for remotely determining which radial contacts the movable contacts will bridge. The switch shown in Fig. 2 has two sections but, of course, it can be built with as many sections as required. Microswitches are provided at each radial position to provide a feedback signal to the control circuit to verify that the switch has actually advanced to the position the punched card or computer had specified.

Switch Current Rating

The current rating of the bridging contacts is dependent on many factors^{2, 3} but the predominant ones are contact pressure, copper cross section, and cooling. The current rating assigned to any particular switch was determined by temperature measurements while the switch was carrying current. A 35°C temperature rise over 20°C ambient was considered acceptable. For convenience in scaling up or down the existing switches, Fig. 6 can be used to estimate the losses of each contact at different currents and contact pressures.⁴

Cost

The reversing switch described has been built in outside job shops for \$350 each in quantities of ten. The selector switches cost about \$950 each.

Drawings

Complete shop drawings for the switches are available from the Lawrence Radiation Laboratory:

2000-Ampere Reversing Switch, drawing No. 5V 7174
1000-Ampere Selector Switch, drawing No. 5V 8735
Selector Switch Control, drawing No. 5V 9095.

References

1. J. W. Davis, W. L. Dexter, and B. H. Smith, Application of Telephone Crossbar Relays to Computer Control of a Particle Accelerator, Lawrence Radiation Laboratory Report UCRL-18493, February 1969.
2. Ragnar Holm, *Electric Contacts Handbook* (Springer-Verlag, Berlin/Gottingen/Heidelberg, 1958).
3. Proceedings of the Third International Research Symposium on Electric Contact Phenomena, June 1966, University of Maine, Orono, Maine.
4. C. W. Park, Lawrence Radiation Laboratory, private communication.

Fig. 1. 2000-Ampere reversing switch.

Fig. 2. 1000-Ampere, 4-pole, 4-position selector switch.

XBL 692-195

Fig. 3. One-line electrical diagram of beam-transport system.

XBL 692-196

Fig. 4. Wiring diagram of reversing switch.

XBL 692-197

Fig. 5. Wiring diagram of selector switch.

XBL 692-198

Fig. 6. Copper-to-copper contact loss versus contact pressure for various currents.

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