PSR SWITCHYARD KICKER SYSTEM IMPROVEMENTS

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Abstract

A switchyard kicker system which allows time sharing of beam between the Los Alamos WNR/LANSCE complex and other LAMPF users was redesigned as part of the Proton Storage Ring addition. The system consists of two pulsers providing 1750-ampere, 1-msec pulses to a pair of 1 meter long ferrite magnets. The system was designed to operate at 24-Hz maximum repetition rate. In 1986 a modification was made to the equipment to allow operation at 40 Hz. While the system operated reliably this way some difficulties were observed. A desire on the part of the users to operate the system at 60 Hz coupled with a major system failure led to design changes to load resistors, drive cables, charging system, and cooling system. These changes are described along with an analysis of the difficulties encountered with the original hardware.

1 Introduction

A pair of ferrite magnets, each one meter in length and having an aperature of 9.65 cm by 5.25 cm, are used to switch beam between the WNR/LANSCE complex and other LAMPF experimenters. The magnets are pulsed to 1750 amperes for 1 msec with a nominal risetime of 40 μsec. A pair of modulators utilizing 22-section pulse-forming networks (PFN) provide the current pulse. Fig. 1 is a block diagram showing the modulator configuration [1].

The original specification called for a maximum repetition frequency of 24 Hz, but a desire to send more beam to the WNR/LANSCE users raised the rate to 40 Hz [2]. The PFN is resonantly charged, then an SCR switches current to the magnet. To speed up the charging time the charge inductor was decreased from 16 mhy to 5 mhy and the discharge resistor was removed. It was also necessary to add blowers to the ducts carying the drive cables to keep these cables from overheating.

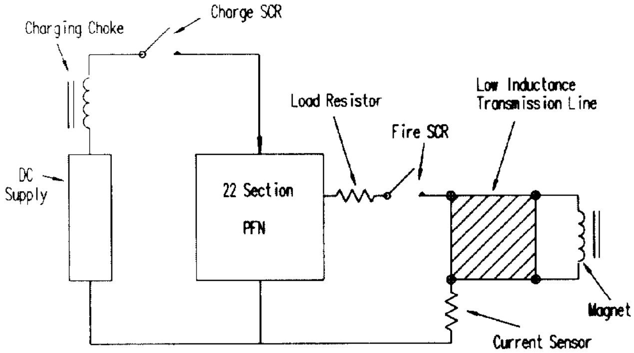

Figure 1: Modulator Block Diagram

Attempts to push the repetition rate to 60 Hz resulted in the marginal failure of a charging system SCR and the loss of a load resistor. Of course the marginal SCR would heal itself before we could find it, so the replacement of the load resistor was the only corrective action taken. We replaced the load resistor many times before we finally were able to find the faulty SCR and replace it. As an interim solution a high-current fast-acting fuse was inserted in the DC feed line to the charging system and at least this saved the load resistor. We also designed a replacement load resistor that could handle the entire DC power-supply capacity.

Having experienced trouble running at 60 Hz we did a thorough study of the modulators, which resulted in fairly major system modifications. Our study showed that the drive cables were very marginal at 60 Hz, cooling for charging SCRs was inadequate, and the charging chokes saturated and overheated. We have replaced the charging chokes and drive cables, redesigned the load resistor, reinstalled the discharge resistor and completely reworked the cooling system.

2 Charging System

Fig. 2 is a simplified drawing of the charging system. Charging is initiated by firing S1 and terminated by firing S2. When S2 is fired, the load resistance (0.1 ohm) and a discharge resistor (1 ohm) are shunted across the charging inductor. For 24-Hz operation the L/R discharge time would be 15 msec. When the system was modified for 40 Hz operation the charging inductor was reduced to 5 mhy

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(the inductor had a 5-mhy tap) and the discharge resistor was jumpered out. For 40-Hz operation the discharge time actually increased to 50 msec, forcing the inductor to carry a high DC current. This is the source of the core saturation. Our solution was to replace the charging inductor with one that can handle the DC component and to insert a small discharge resistor. The present circuit utilizes a 0.5-ohm discharge resistor and a 5-mhy charging inductor for a discharge time constant of 10 msec.

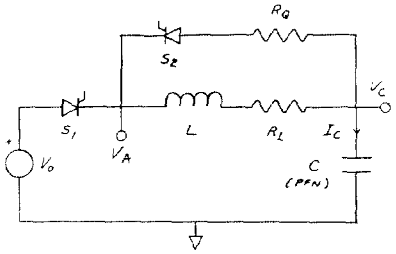

Figure 2: Simplified Charging System Diagram

Fig. 3 is a photograph showing the discharge resistor. It consists of a series of 0.04-inch-wall 3/8-inch-diameter stainless steel tubes. With 5 GPM of water flow each segment can dissipate 5kW. The tubes are bent back on themselves to minimize inductance leaving about 1.6 μhy per element; however, in this application low inductance is not important.

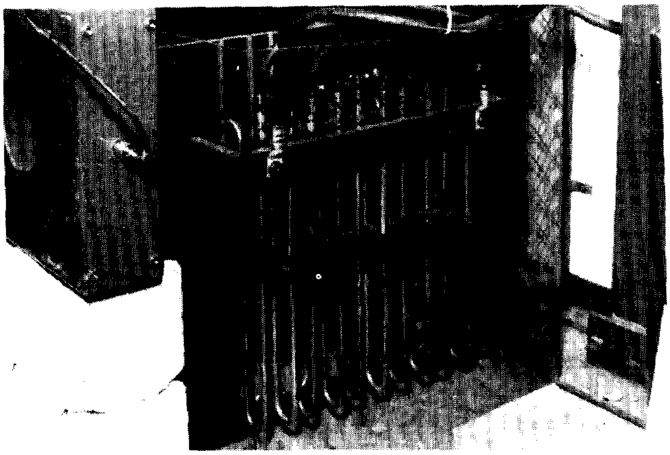

Figure 3: Discharge Resistor

Fig. 4 shows the charging inductors. Nominal inductance is 5 mhy with tap points every 0.5 mhy down to 2 mhy. The core is sized to cary 500 amperes maximum DC with a clipped sinusoidal AC component of 200 amperes peak-to-peak covering 14 msec of a 16.6-msec period (60-Hz repitition rate).

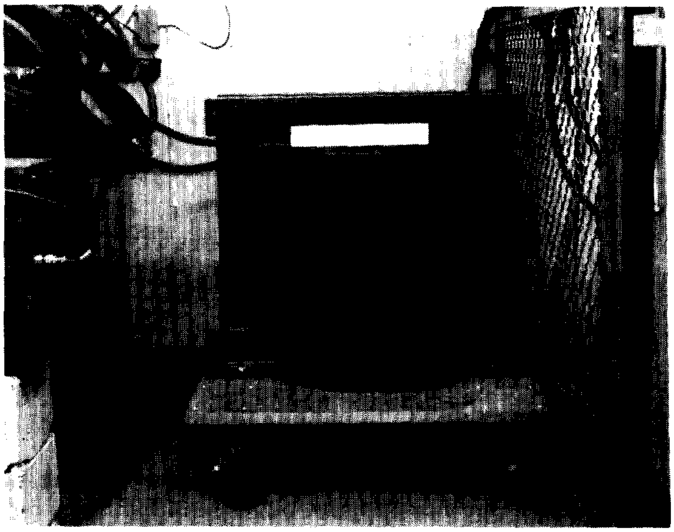

Figure 4: Charging Inductors

3 Transmission Lines

The switchyard kicker pulse modulators are located in a remote location out of the radiation area where the magnets reside. Eighty feet of power transmission line connects the modulators to their magnets. The single-turn ferrite kicker magnets appear electrically as a 3 uhy inductance with about 1 milliohm of series resistance. The magnets are pulsed to 1750 amperes with a rise time of about 40 μsec. In order to achieve this rate of rise with reasonable voltages the power transmission lines must have as low inductance as possible. One does not want to drop all the voltage in the transmission lines. A multi-layer parallel-strip line cable was developed to meet this low inductance requirement. The original design called for a line formed from 20 strips of 12-mil copper sheet and electrically connected with each strip alternating in polarity [3]. This results in 20 transmission lines effectively connected in parallel to provide a composite line with a high frequency characteristic impedance of 0.07 ohms and an inductance of 0.28 nhy per meter. In practice this line was reconfigured to appear electrically as 6 parallel transmission lines for a characteristic impedance of 0.23 ohms and an inductance of 0.9 μhy per meter.

The line was assembled from 1.9-inch-wide copper strips with a plastic insulating jacket bonded to both sides. Individual strips were then taped together and an outer braided jacket was slid over. An external layer of rubber tape was placed over the braid. With this geometry it is important to keep the individual conductors as close together as possible and many layers of tape were needed to accomplish this. 450 watts is dissipated in this cable at the 24 Hz pulse rate. Thermal conductivity of the various layers of tape is quite poor but is adequate for operation at 24 Hz. To operate at 40 Hz, blowers were installed at the opening of the ducts the cables are fed through. The cable was very marginal at 60 Hz even with the blowers.

To provide operation at 60 Hz we have replaced the original transmission lines with a modified design. Fig. 5 shows the construction of our new lines. The individually insulated single conductors have been replaced with pairs of conductors with a dielectric layer bonded between them and an insulating layer bonded over the outside surfaces. Since the individual lines are complete in themselves there is no real need to insure close spacing. We covered our lines with a woven plastic mesh which is quite open, allowing good heat transfer to the cooling air. In addition to removing the thermal barrier we increased the thickness of the copper strips to 16 thousands of an inch and increased their width to 2.75 inches. Our 80-foot lines have a characteristic impedance of 0.06 ohms, a DC resistance of 3.7 milliohms, an inductance of 7.7 nhy and a capacitance of 2.2 mfd.

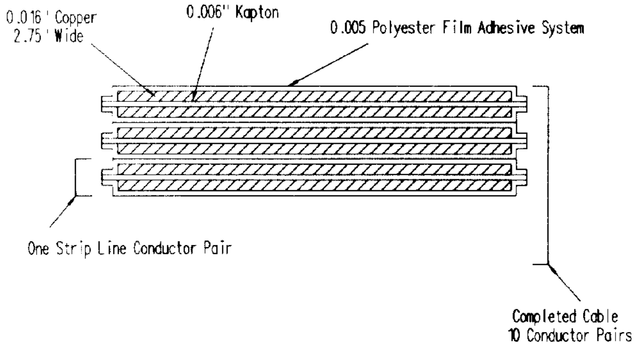

Figure 5: Low-Inductance Transmission Line

4 Load Resistor

During our early attempts to operate the system at 60 Hz we encountered difficulty with a charging SCR (see Fig. 2). When this SCR shorted, 4kj, the entire stored energy of our DC charging supplies, was sent through our load resistor. The original load resistor design consisted of a meandering strip of manginin placed in a water jacket such that the water would flow across the resistor material. This load-resistor design exhibited quite low inductance and easily dissipated the normal 400j of energy. We have replaced this load resistor with 120 inches of stainless steel tubing bent back on itself to reduce its inductance to about 0.3 μhy. Fig. 6 is a photograph of this load resistor. With 5 gpm of cooling water flow we can dissipate 5000 watts with only a 10-degree maximum temperature rise.

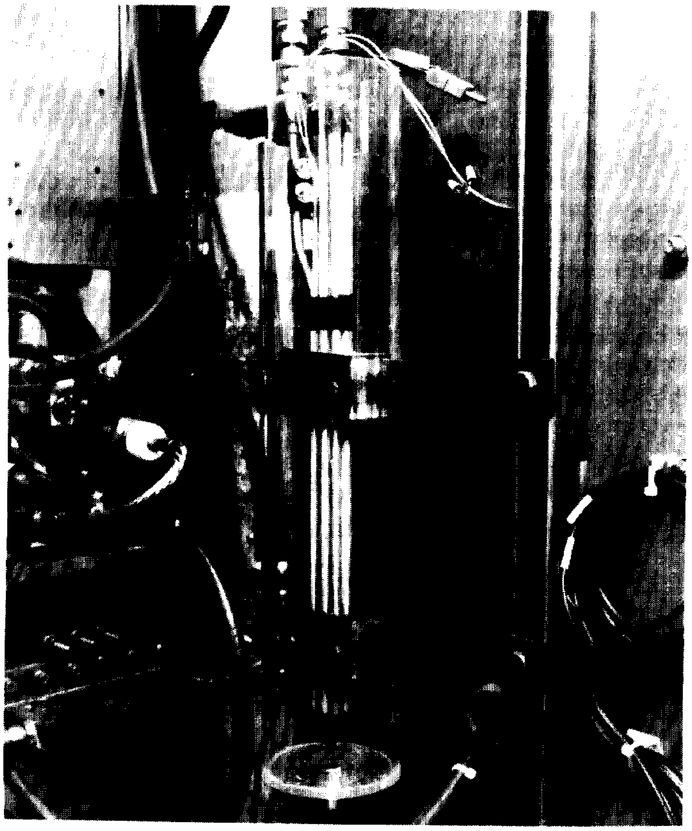

Figure 6: Load Resistor

5 Acknowledgements

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References

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