THE GENERATION OF A REFERENCE DESIGN FOR TRIUMF KAON FACTORY BOOSTER MAGNET EXCITATION

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Abstract

This paper deals with the generation of a reference design for Dual frequency DC biased resonant magnet excitation for the Booster ring magnets of the Triumf KAON factory. It will discuss the interrelation of various parameters and their optimization resulting in a design which is to be implemented. Of primary concern is power system efficiency, as well as isolation of the AC grid from the cyclical power requirements of the accelerator ring magnets. Magnet and DC bypass choke characteristics need to be carefully specified for the resonant circuit to be viable.

Introduction

Resonant magnet excitation is generally used as a convenient method of isolating the AC grid from the cyclical nature of the forcing function required by the AC excited magnets. This results in the suppression of harmonic interaction with the mains, and reduces the power requirements for the facility as most of the required energy is stored in the inductive components of the resonant system. If the resonant system has a sufficiently high Q, the power requirements and hence the operating costs are kept to a minimum.

Reference Design

Magnet excitation is achieved via the series connection of a number of resonant cells as shown in Fig. 1, with the result that with the exception of leakage currents via stray reactances the excitation for all magnets is the same. The total number of resonant cells should be kept to a minimum, and is defined by the peak magnet voltage to ground during the reset interval after extraction. This voltage for practical purposes should be limited to less than 15 kV peak or about 10 kV rms. Once the required ampere-turns for each magnet has been established, it becomes a matter of selecting a practical upper limit of the peak magnet current which in our case appears to be 5000 A. This figure is determined by considering the total rms current required for the desired magnetic field variation, and the desire of using only series strings of thyristors in the capacitor disconnect switch. This is as opposed to a series and parallel combination which is seen to be an unnecessary complication which serves to reduce system reliability and adversely affects the cost. Once the peak magnet current has been selected, the minimum practical magnet inductance is defined. The resulting magnet inductance along with the required di/dt then gives the peak voltage per magnet and dictates the number of magnets which may be used in each resonant cell.

As may be seen in Fig. 1 only one point of the magnet ring is connected to ground while a number of virtual ground points are distributed around the ring. This permits a layout where the peak cell voltages are not cumulative around the ring, but limited to each resonant cell. As one of these virtual ground points is to be found at the center of the DC bypass choke, it is possible to place magnets symmetrically on either side of the choke, effectively doubling the number of magnets for each resonant cell.

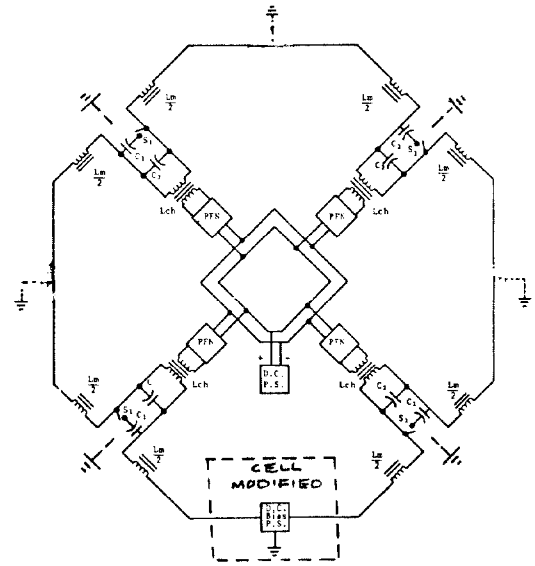

Fig. 1. Typical cell interconnection.

DC bias is provided by a large central DC bias power supply. which acts as a precision DC current regulator. The total voltage requirement of this supply configuration is determined by the DC resistance of the magnets and of the DC bypass chokes. Due to the placement of the supply at a high AC impedance point in the ring virtually none of the AC component of the magnet/choke current is seen by the supply and therefore it's current rating can be limited to the maximum DC bias current.

A large central supply is preferred for economic reasons as the supply cost is necessarily lower than for a number of lower voltage high current units distributed about the ring. This reduces system complexity through a reduction of the total number of components both in terms of power supplies as well as the amount of auxiliary equipment required.

For a distributed resonance system to be viable, the components of this resonant system in terms of inductance and capacitance must be carefully controlled. The magnets and the DC bypass choke must be manufactured in a way which achieves the desired inductances to a close tolerance. Individual cell tuning is then achieved by adjusting the required resonant capacitors in each cell during commissioning. Further trimming is then required to achieve a constant resonant frequency within acceptable tolerance limits for the machine. The choice of DC bypass choke inductance is of consequence, because it's inductance in parallel with the effective magnet inductance per cell defines the resonant capacitance required as well as the peak current that the capacitor disconnect switch needs to interrupt. A value of inductance about equal to the effective magnet inductance appears to be the optimum based on the relative cost of the resonant capacitors and that of the transformer wound DC bypass choke.

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As may be seen from Fig. 1 the AC losses are replenished using distributed pulse forming networks which are powered by a single large high voltage supply. The output of this supply is highly filtered resulting in essentially a DC current being drawn which further isolates the AC power grid from the pulsed load-

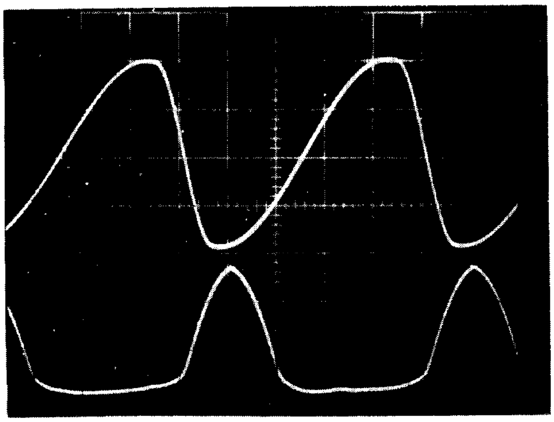

Fig. 2. Magnet current and cell excitation.

ing. AC power loss makeup is supplied during the acceleration period of the magnet ramp up waveform to reduce the voltage requirement to 1/3 of that required during the reset interval. This appears to be feasible without adversely affecting the rising magnetic field. This will be verified during full power tests on a prototype Booster magnet which is under construction. The distributed nature of the pulse forming networks as well as the DC bypass chokes is dictated by the AC losses for the booster Dipole ring which are estimated to be of the order of 2 MW. A single multiple primary – multiple secondary central choke does not appear to be feasible.

Selected circuit parameters:

Booster dipole	L = 5 mh
Magnets per cell	5
Magnet inductor/cell	25 mh
Number of cells	5
DC bypass Choke	L = 25 mh
DC bias current	3500 A
Peak current	5000 A
Cap switch	30 kV working @ 1415 Arms/leg
Total Cap/cell	1820 UF
DC bias supply	600 VDC @ 3500 ADC 0.01% CI reg
PFN supply	2500 VDC @ 800 ADC 0.1% CV reg

The various circuit parameters are being investigated at power using a test stand designed for 1000 A peak magnet current excitation. Dual frequency excitation at 33.3 Hz rising and 100 Hz falling having so far been achieved to 400 A peak to peak with a 400 A DC bias level. Further work is proceeding with the aim of powering two series resonant cells, and ultimately to test the prototype Booster dipole magnet at full power. Figure 2 shows the magnet current excitation waveform achieved to date.

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