NEW TRUE BIPOLAR POWER SUPPLIES FOR BOOSTER HORIZONTAL STEERING COILS

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Abstract

Particle accelerators use horizontal and vertical steering of the beam to make minor changes in its path to keep it in the centre of the beam chamber. This paper describes the new true bipolar power supplies required to feed controlled current through horizontal steering coils put on the dipole magnets of the Indian booster synchrotron at RRCAT Indore. The new power supplies were required because the existing power supplies were not able to fulfil the requirements due to their topological limitations. After the new power supplies were put into operation, Booster beam current went up to 6 mA from 3 mA.

INTRODUCTION

To achieve horizontal steering of the electron beam in booster synchrotron, 8 turns have been wound on the dipole magnet along with the main winding. This coil needs to be fed positive or negative current in order to achieve +ve or -ve steering of the electron beam in horizontal plane. The value of this current will in general be a function of the main winding current . Also, a time-varying voltage is induced in the steering coil due to mutual coupling with the main coil when the current is ramped in the main coil.

The power supplies described in this paper are specified to feed 500 ppm stable ±40 A ramped current with suitable offset. The corresponding voltage requirement for the power supply comes to be +40 V and -22 V. Six independent power supplies have been put for the six steering coils (one each on the six dipole magnets).

The new power supplies were required to be designed and developed because the old power supplies were not able to control the steering coil current at and near zero current. This shortfall was a limitation of the topology of the power circuit of the old supplies which consisted of an unipolar power stage followed by polarity changing MOSFET bridge. The power and control circuit of the new power supplies is able to control the load current at all values including the vicinity of zero current.

THE POWER CIRCUIT

The power circuit consists of 3-phase, 50 Hz step down transformer followed by a 6-step diode bridge, LC ripple filter and finally a BJT output power stage (Q1 & Q2 in Fig 2) The output stage is of complementary emitter follower configuration which is DC-biased to operate in class-AB. The power transistors in this stage have been paralleled using current equalising emitter resistors. They are all mounted on water cooled heat-sinks.

The load parameters:

Self Inductance : 0.44 mH
Resistance : 0.2 mOhm.
Induced voltage : 28 volt (max)

THE CONTROL CIRCUIT

The control circuit shown in Fig 3,is designed to track a trapezoidal current reference varying at 1 Hz. It takes the load current signal through a stable shunt, the load voltage through a resistive voltage divider and the induced voltage through the sensing winding producing an appropriate drive signal for the output complementary emitter stage. The control system consists of an outer current control loop containing an inner load-voltage control loop. The induced voltage has been fedforward to achieve tight control. This has been achieved using a separate winding on one of the dipole magnets to sense the induced voltage.

The small signal control bandwidth is around 200 Hz for the current loop and around 15 kHz for the load-voltage loop. There is practically no distortion at zero crossing due to class-AB operation of the output stage.

OPERATIONAL EXPERIENCE

The supplies are in operation for more than a year. They are working well mostly without any problem. One problem which we experienced was high tracking error at the corners of the trapezoidal current reference when the main Dipole coil was operated at higher currents to fill INDUS-2 ring. On investigation, we found that the reason was reduction of coupling between the sensing

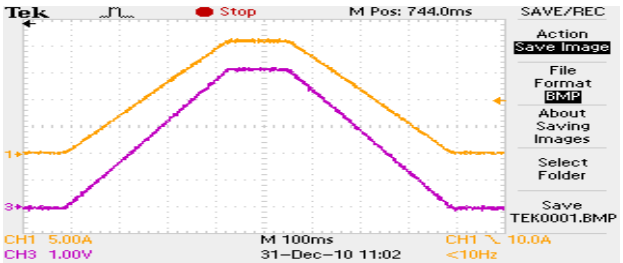

Figure 1: Current reference (lower trace) and steering coil current (upper trace).

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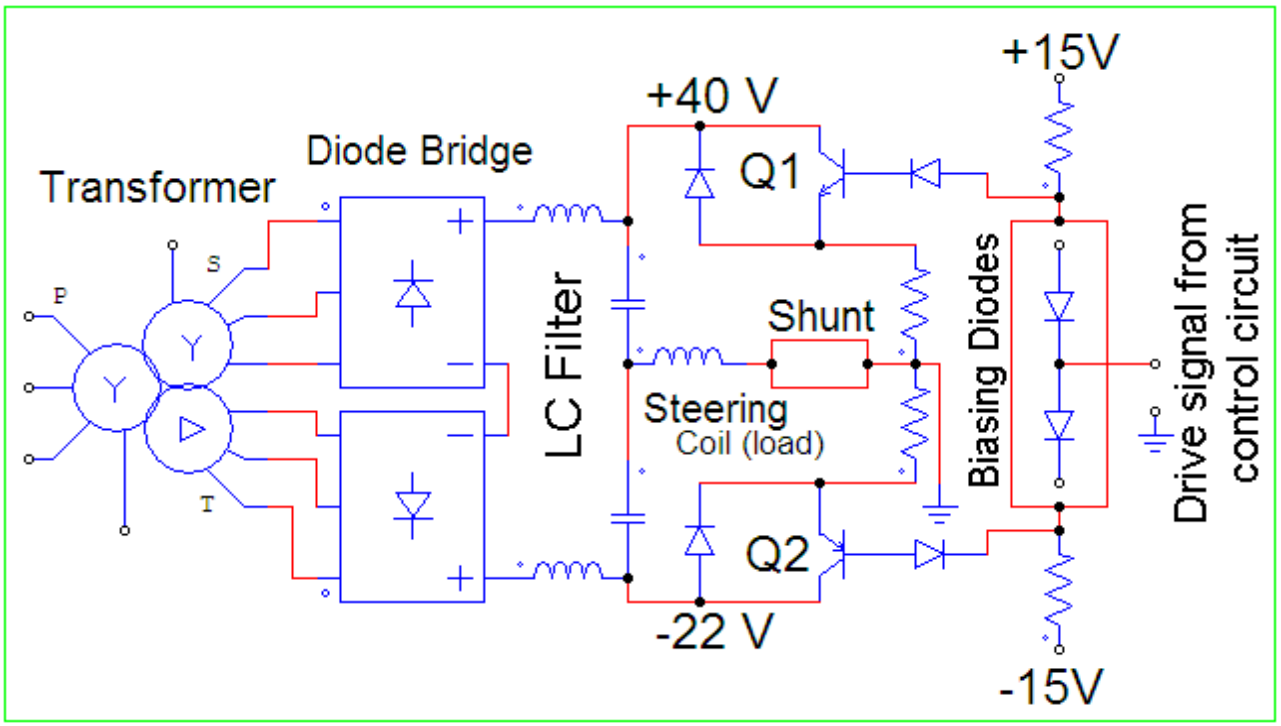

Fig 2 : Schematic diagram of Power Circuit

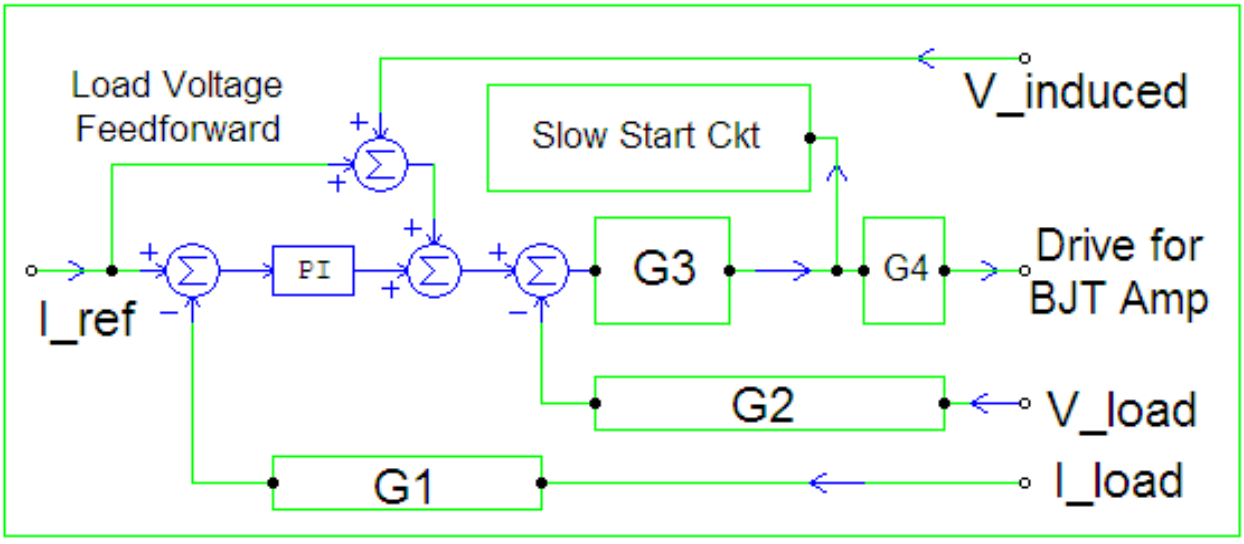

Fig 3: Schematic diagram of Control Circuit

winding (for sensing the induced voltage) and the steering coil. Due to this, the induced voltage was not being sensed faithfully. We increased the number of turns in the sensing winding and laid it more close to the steering coil which solved the problem.

REFERENCES

[1] Power Supplies for Indus-1; S.R.Tiwari, A.C.Thakurta, A.P.Thipsay and others; Centre for Advanced Technology, Indore - 452 013 India