POWER SUPPLIES FOR INDUS-1

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Abstract

This paper describes the different schemes employed in the power supplies installed for microtron, transport line-1, Booster ring, Transport line-2 and 450 MeV Indus-1 Storage ring presently being commissioned at CAT, Indore. Approximately 130 Nos. of power supplies with ratings ranging from few VA to about 1.0 MVA are used to energise the electro-magnets for generation of magnetic field. The current stability requirement for the power supplies ranges from 1000 ppm to 100 ppm of current set. The schemes followed for power supplies are off line SMPS, linear series pass and SCR controlled power supplies. In booster the power supplies are of ramp type with repetition rate of 1 Hz and these are designed to take care of coupled voltages due to ramping field. All other power supplies are constant DC type.

1 INTRODUCTION

Electrons for storage in 450 MeV Indus-1 ring are generated from the cathode in the microtron, and are transported through Transport line-1 to booster ring and then to storage ring through Transport line-2. In its passage through these stages the electron beam sees magnetic fields that cause bending, focussing, defocussing and chromaticity correction. Large number of electromagnets are used to process the beam. The ratings of main and correction magnet power supplies are listed in Table No.1. The scheme followed for different power supplies are governed by various factors like load power, current stability, load time constant, type of field viz. DC or ramp.

2 POWER SUPPLY SCHEMES

2.1 Thyristor controlled power supplies

These scheme consist of input transformer followed by a SCR bridge and L-C filter. The SCR bridge output is either 6 pulsed or 12 pulsed depending on the stability requirement and load time constant (L/R). Most of the power supplies with current above 80 Amp, load power 2 KW or above and load time constant 0.2 sec to 1 sec follow this scheme with required stability ranging from ± 0.01% to ± 0.1%. Current ripple is attenuated partly through reducing voltage ripple with L-C filter, and partly by the inductance present in the load. The attenuation in the field ripple is further achieved with the vacuum chamber. Booster dipole power supply (Stability during ramp-up time ± 0.1%, in flat bottom and flat top : ± 0.01%) rated for 1000 Amp peak ramp current and peak voltage 1.6 KV follows essentially this scheme with an additional active filter at the output to bring about further ripple reduction and some distinguishing features to be mentioned later. The cathode power supply for microtron uses back to back SCR for AC voltage control on the primary side.

2.2 Bipolar transistor series pass power supplies

In this scheme single phase mains voltage is stepped down, rectified, filtered and control is achieved with a following series pass element. These power supplies are rated at low current (less than 10 Amp) and low load power (less than 200 W) and have stability of ±0.01-0.1% , feeding load with time constant 60-68 msec. This scheme is used for power supplies for Transport line-1 dipole, extraction magnet coil, vertical steering coil and horizontal steering coil in Transport line-1, Transport line-2 booster quadrupoles correction coils, correction coils in storage ring. These power supplies are bipolar in nature and polarity reversal is brought about by mosfet switches or relays following the series pass stage

2.3 Pre-regulator followed by transistor series pass power supplies

In this scheme the input transformer is followed by pre-regulator and series pass element. Required stability for these power supplies ranges from ± 0.05% to ± 0.1% with load time constant of 15 msec to 200 msec. The pre-regulator is mostly SCR bridge with 6 pulsed output or half controlled bridge. Booster dipole correction coil power supplies (peak current 40 Amp ramp, peak voltage 40V) have a DC to DC chopper as pre-regulator. Booster quadrupole tune adjustment secondary coil power supply follow this scheme in ramp mode with pre-regulator SCR bridge, which switches over to inversion mode in the ramp down regime of current cycle, ramp peak here goes up to 150 Amp and peak output voltage is within 50 V.

2.4 Off line SMPS

These power supplies operate in half bridge configuration and are being used at low current (6 Amp)

Table-1

Indus-1 Magnet Power Supplies

Sr. No	System	Power Supply	No.s	Voltage volts	Current Amp	DI/I ± %	Scheme followed category
1.	Microtron	a)Dipole magnet	1	50	280	0.1	2.1
		b)Steering magnets	2	5	5	0.1	2.2
	Field : DC	c) Cathode	1	7	60	0.1	2.1
2.	Transport line-1	a)Q-pole magnet	6	21	10	0.05	2.3
		b)Dipole	1	12	10	0.02	2.2
	Field : DC	c)Steering and correction magnet	11	4-13	0.17-10	0.1	2.2
3.	Booster	a)Dipole and Q-pole magnet	1	1.6 KVP	1000	0.01	2.1
	Field:Ramped	b)Q-pole W-2	2	50 VP	150	0.05	2.3
		c)Steering magnets					
		i)Dipole HSC	6	40	40	0.1	2.3
		ii)VSC	6	25	25	0.1	2.3
		iii)Q-pole W-3	12	5	10	0.1	2.3
4.	Transport-line.2	a)BM-1	1	81	300	0.01	2.1
		b)BM-2	1	60	300	0.01	2.1
	Field:DC	c)Q-poles	8	20	80	0.05	2.1
		d)Steering and correction magnet	15	4-29	5-10	0.1	2.2,2.4
5.	Storage ring	a)Dipole	1	140	800	0.015	2.1
		b)Q-pole	2	120	300	0.04	2.1
		c)S-pole	2	25	250	0.1	2.1
	Field : DC	d)Steering and correction magnets	36	4-40	3-10	0.1	2.2,2.4,2.5

and load power up to 250 watts for Transport line-2 steering coil and Storage ring sextupole steering coils. Bipolar operation is possible with polarity change over mosfet switches. Required stability of these power supplies is± 0.1.%.

2.5 Bipolar power amplifier type power supply

There power supplies are rated for current less than 10 Amp and load power less than 100 watts. Bipolar operation is provided by the power amplifier itself working in class AB mode. No additional stage for polarity reversal is required. These are being used to feed. Vertical steering coils of SRS sextupoles. Stability required is about ± 0.1.%.

3 BOOSTER POWER SUPPLIES

Power supplies in microtron, Transport line-1 Transport line-2 and storage ring see passive R-L as load, while the power supplies in booster (viz. for correction and adjustment coils) have loads with coils coupled to some other coil energised by a separate power supply. In booster dipole and Q-pole power supply, trapezoidal current passes through the main coils with a repetition rate of 1 hertz. Current is ramped up from 20 Amp to 1000 Amp, in 200 msec., held there for 50 msecs and forced to decrease faster thereafter so that injection for the next cycle is possible within given time. Because of time varying currents in these coils, induced voltages appear at the load, rendering it effectively active. In booster dipole and Q-pole magnet power supply four SCR bridges are put in series with 2 bridges having bypass SCR'S across them. Turn-off of bypass SCR'S in conjunction with impressing of precharged filter capacitor voltage across the highly inductive load (L/R=1 sec) brings about transition from ramp start to flat top beginning. The ramp starts with all the bridges put on, control being achieved with 2 bridges while the other two are operated at fixed firing angle. This takes place in synchronism with impressing voltage of another precharged capacitor across load, with these switchings, steep voltage changes across the load are brought about. In the current decay regime, the SCR bridges are operated, in inversion mode and energy is allowed to flow back to mains. These features distinguish this power supply from other under category.

4 CONTROL SCHEME

All the power supplies feeding inductive loads have two basic control loops ; current loop, a slow one, and a voltage load which is quite fast, whenever fast changes in voltage (including that due to mutual coupling) at the output are required, this fast loop is made use of and the change is introduced by way of feed forward control. Fast changes in voltage become necessary when load current enters from one regime into another showing different trends in magnet current cycle e.g. a flat current changing to ramp and vice-versa. While for medium power supplies, these fast changes can be accommodated in a series pass element, for high power this is not practicable. The unity gain bandwidth for SCR based power supplies is about 60-80 Hz for voltage loop and 8-10 Hz for current loop. For series pass and SMPS a unity gain band width of 5-7 kHz for voltage loop is easily achieved.

For current sensing, almost in all power supplies shunts made of low temperature coefficient (± 3 ppm /°C) zeranin alloy are used. Sensing stages up to the error amplifier in some of the power supplies (Stability better than (± 500 ppm) have been enclosed in temperature controlled oven, so that amplifier gain and offset drifts are checked. In booster dipole power supply current sensing has been done with a DCCT having output stability of ± 10 ppm. The output voltage of DCCT is sufficiently high and the problem connected with obtaining a voltage, proportional to output current, particularly for range extending to low currents are well taken care of. Operation of all power supplies is possible in both local mode and remote mode from the main control room.

5 COOLING OF POWER COMPONENTS

Cooling of heat dissipating components viz semiconductors, transformers, chokes in high current power supplies has been done with low conductivity water, so that heat is carried out of the room. This avoids warming of air inside the cabinets and the surroundings, thereby reducing the load on air conditioning unit. Also the weight and size of water cooled heat sinks reduces drastically. With epoxy potting facility available locally, water cooled transformers (800 KVA) fed by 11 KV on primary were fabricated with epoxy potted coils. These transformers are being used for booster dipole magnets. Chokes and transformers for medium range power supplies were fabricated with OFHC hollow copper conductors.

6 CONCLUSION

All the power supplies for Indus-1have been installed and are being used for beam storage and optimization. Though the schemes followed for power supplies are large in number considerable experience has been gained with different types of schemes and these may help us to choose the best for future requirements. It is further planned to modify booster dipole magnet power supply to cope up with nonlinearities of dipole magnets at higher currents and for better repeatability of field from pulse to pulse.

7 REFERENCES

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