Fermilab

SDC SOLENOID DESIGN REPORT #120

TITLE: Dump Resistors--Slow and Fast--for SDC Solenoid

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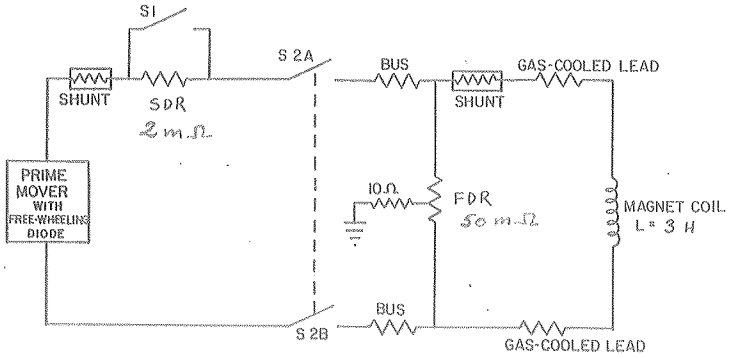
ABSTRACT: The fast dump resistor for a SDC Type-U solenoid at 10 kA is 50 mΩ and is expected to cost between $12,000 and $14,000. The slow dump resistor is 2 mΩ and should cost between $12,000 and $17,000.

CIRCUIT



FAST DUMP RESISTOR

So far in the design of the SDC solenoid, we have required that the value of the fast dump resistor be such that the initial voltage across the terminals of it during a fast dump is 500 V (250 V to ground). Choosing a higher voltage, e.g. 1000 V, would permit the aluminum-stabilized conductor to be somewhat less wide radially and hence the coil would be thinner in radiation lengths. There is not a strong incentive to do this since the radiation thickness is sufficiently low with a 500 V fast dump resistor.

For this note I assumed an operating current of 10 kA for the SDC solenoid and a fast dump resistor (FDR) of 50 mΩ.

The FDR used with the CDF solenoid is an "adiabatic" type, i.e. one which absorbs the magnet stored energy by quickly raising the temperature of a mass of stainless steel alloy. The resistor must then be allowed to cool to some temperature before it can be given another "shot" of energy. This type has worked well at CDF where the FDR has plenty of time to cool down after a fast dump/quench while the refrigeration system is restoring the magnet to operating conditions.

I compared the possible parameters of the FDR for the SDC solenoid to those of that for the CDF solenoid:

Item	CDF	SDR
Operating current (kA)	5	10
Stored energy (MJ)	30	approx. 150
Coil inductance (H)	2.4	approx. 3
FDR resistance (mΩ)	74	50
Initial discharge voltage (V)	370	500
Temperature rise (^{o}F) (^{o}C)	580 320	580 320
Heat absorbing mass (lb) (kg)	300 136	1500 (my guess) 680
Stainless steel alloy	406	406
Over-all size (in^3)	30 x 120 x 30 hi	60 x 72 x 60 hi*
Location	In Assy Hall	Roof of service bldg on surface?
Avg specific heat (J/kg-^{o}C)	500	500
Cost ($)	5760 (9/83)	12000*

* These values were given to me by Tim Bryne on Nov 6, 1990. Tim is with Bryne & Company, 2208 Wellington Ct., Lisle, Il 60532, phone 708-963-1530, the sales representative for Guyan Machinery Company, Logan, W.Va., who supplied the FDR for CDF and DRs for the Tevatron.

SLOW DUMP RESISTOR

The slow dump resistor (SDR) at CDF is not an adiabatic type, it is rated for a steady-state current of 5 kA. I assumed the SDR for the SDC solenoid to be the same type.

The resistance of the SDR for CDF was chosen such that the initial power put into the outer support cylinder by the eddy current during a slow discharge is the same as the power put into it during a constant-voltage charge. This guarantees that the magnet will not quench during a slow discharge.

Since the power, P, put into the outer support cylinder by the eddy current is

$$P = (M^2/R)(di/dt)^2,$$

where R is the circumferential resistance of the outer support cylinder, the equal power criteria is

Charge di/dt = Initial slow discharge di/dt.

The charge di/dt = V/L, where V is the charging voltage and L is the coil inductance.

The initial slow discharge di/dt = $d(i_0 e^{-rt/L})/dt$ at t=0 (r = SDR) = ri_0/L.

The SDR is sized by solving $V/L = ri_0/L$ for r; $r = V/i_0$.

Comparing the parameters of the SDR for CDF and SDC:

Item	CDF	SDC
Power supply voltage (V)	20	20
Operating current (kA)	5	10
Inductance (L)	2.4	approx. 3
Const voltage charge rate (A/s)	8.3	approx. 6.7
Const voltage charge time (s)	600	approx. 1500
SDR resistance (mΩ)	4	2
Steady-state power rating of SDR (kW)	100	200
Cost ($)	5786 (9/83)	12000 - 17000*

*The FDR and SDR for CDF were about the same cost. The estimate given by Tim Bryne for an FDR for SDC was much less than I had guessed from a dollars per pound basis. I would expect the cost of the SDR to go like the current (or power) rating, with some inflation factor. The numbers given here are for no inflation and for 5%/yr for 7 years.