



2D Electromagnetic Model of Fast-Ramping SC Magnets

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- Fast-ramping SC magnets are a challenge for designers as well as for design-tool makers.
- → The FAIR project at GSI requires R&D in the field.
- → CERN is investigating fast-ramping alternatives to PS and SPS rings.
- → ROXIE as well as other tools are preparing for the new challenges.



→ We present:

- the basic layout of the ROXIE electromagnetic model of fast-ramping magnets.
- measurement- and simulation-data for the GSI001 dipole.





Nonlinear Iron Eddy Currents

High Saturation and Fringe Fields

Persistent Currents

Interstrand Coupling Currents

Interfilament Coupling Currents



Models





Boundary Elements





ISCC Network Model























Interfilament

Interstrand

Coupling Currents

Persistent Currents

Coupling Currents

Boundary Elements

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Block sp	y Run Iron lec. (Peak fields.	Forces, F	EM pl	ots)						
Plotting Information 2D										
Interface	e Options									
Time Tra	ansient Effects									
IFCC (V	álson) (LIFF)				C (Wilson ana	lytic) (LICCA)	📕 ISCC (netw	vork model) (LICC)		
LICC +	mut. inductances	(LICCINE))	Non	linear Inner It	erations (LITER	NL) _ Plotting Ma	agn. Fields Only (LPCONLY)		
PC: 0:None; 1,3:1D; 4:Vector 1					Symmetry: 0:gen, 1:1in1, 2:2in1 0					
Start Time for Loss Calculation 4 Start Time for Multipole Variation 4				4 End time for Loss Calculation 8						
					End Time for Multipole Variation 8					
Maximum	Number of Itera	tions	0							
No	Ts	Te	Steps	8						
1	0	4	4	$\overline{\Delta}$						
2	4	4.1	3							
3	4.1	4.4	5							
4	4.4	5.9	5							
5	5.9	6	2	_						
	6	6.1	2							
6	6.1	7.6	5							
6 7	7.6	7.9	5							
6 7 8		8	3	X						
6 7 8 9	7.9				A	В	C	D Blocks,Layers	8	
6 7 8 9 No	7.9	Te	unctio	n			0 472	2 1-4		
6 7 8 9 No 1	7.9 Ts 0	Te F	unctio	n 5	0.01	0.05	0.110	and the second	- And	
6 7 8 9 No 2	7.9 Ts 0 4	Te F 4 8	unctio	n 5 5	0.01	0.05	0.472	2 1-4		
6 7 8 9 No 1 2	7.9 Ts 0 4	Te F 4 8	unctio	n 5 5	0.01	0.05	0.472	2 1-4		





At Brookhaven National Laboratory a test magnet was built for GSI.
It uses RHIC coil design with cored cable to control ISCC losses.
[A. Jain et al., *Measurements of the Field Quality in SC Dipoles at High Ramp Rates*, PAC 05]





- → Ramp rate up to 4T/s.
- ➔ Peak field 4T.
- Validate a new measurement system for fast multipole analysis.
- ➔ Measure losses per cycle.
- Measure field distortions.





ROXIE



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Persistent Currents





$$M_{i} = \frac{4r\xi}{\pi} \int_{q_{i}}^{q_{i+1}} j_{c}(B(q))(1-q)^{2} \,\mathrm{d}q = \frac{4r\xi \mathcal{F}}{\pi} \int_{q_{i}}^{q_{i+1}} \frac{(1-q)^{2}}{\sqrt{B(q)}} \,\mathrm{d}q$$







Interfilament Coupling Currents



















$\{I\} = -[M]([M][R][M]^{T})^{-1}[M]\{\partial_t A\}$





Iron Saturation and Coil Field











Bringing the Models Together







ΔB3 (Tesia)

Т





ISCCs









→ We do not predict B5 and A2 correctly.



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- ➔ Does an up-down asymmetry in adjacent resistance account for A2?
- Is a factor 5 between upper and lower coil realistic?





- ➔ And where does B5 come from?
- ➔ The presented work points to an unidentified conductive body in vicinity to the magnet aperture.
- ➔ Investigate eddy currents in the yoke structure.
- ➔ Look out for more conductive parts in the magnet.