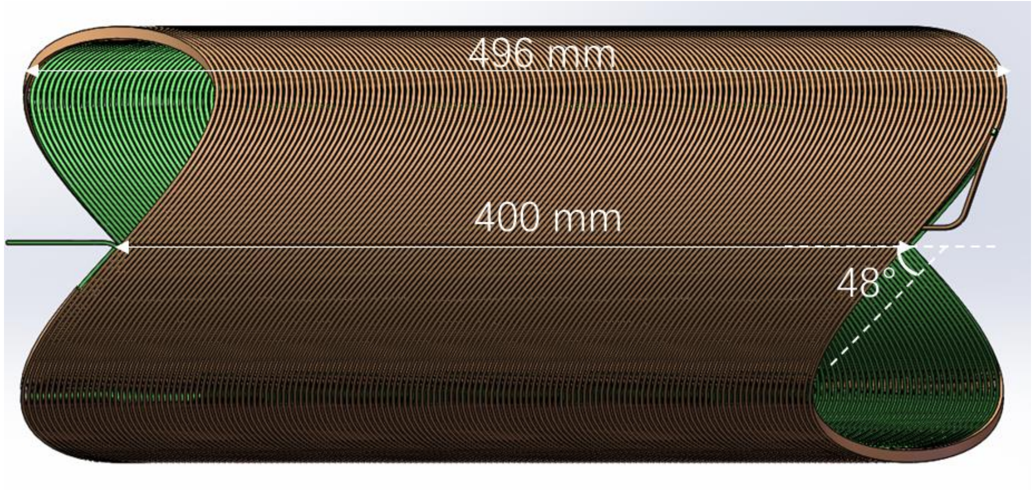
# CLIQ system

The coupling-loss-induced quench (CLIQ) system is an innovative method for the quench protection of highfield, high energy superconducting magnets. With respect to the conventional method based on quench heaters, it offers significant advantages in terms of electrical robustness and energy deposition velocity. It relies on capacitive units that are electrically connected to the magnets and are discharged upon quench detection, hence introducing fast current changes in the coil sections. This results in local magnetic-field changes and generates high coupling loss, which heats up the superconducting strands above its critical temperature and assures a quick magnet discharge. The Superconducting Magnets Group (SMG) in Institute High Energy Physics (IHEP) is developing a Canted-Cosine-Theta (CCT) quadrupole magnet named SCQ-CCT, for which a quench protection system using CLIQ method has been designed. The simulation approach for that magnet with the COMSOL software and the results are shown in this article. Simulation results convincingly show that the CLIQ system can work effectively that it allows a faster discharge of the magnet energy than the conventional energy-extraction resistance. The possibility of applying CLIQ to a developing high field magnet system LPF-3 is also studied.

# background

## SCQ-CCT quadrupole

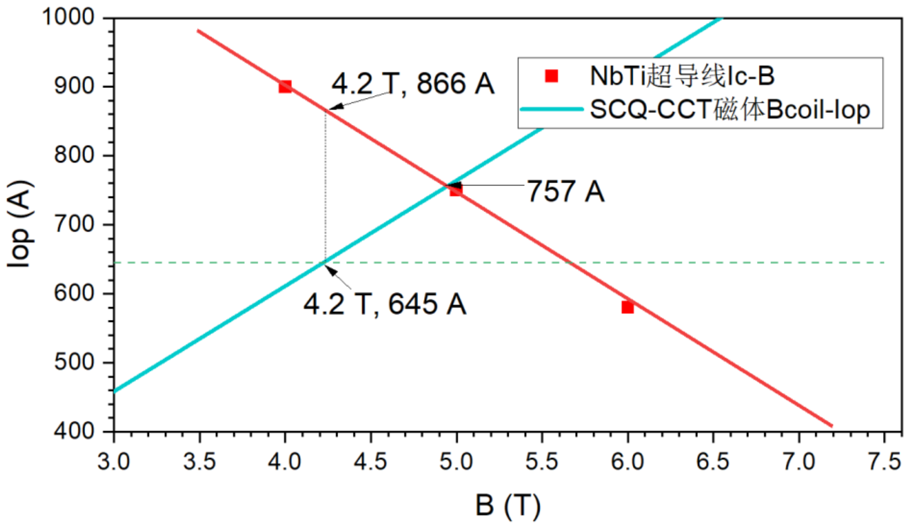



BEPCII-U SCQ-CCT磁体参数

| 内层骨架内径 [mm] | 外层骨架内径 [mm] | 骨架厚度 [mm] | 线槽截面 [mm] | 倾斜角 | 槽间距 [mm] | 槽内线数 | 匝数 | 运行电流 [A] |
|---|---|---|---|---|---|---|---|---|
| 95.1 | 101.6 | 6 | 4.5×1.85 | 48° | 2.9 | 5×2 | 138 | 645 |

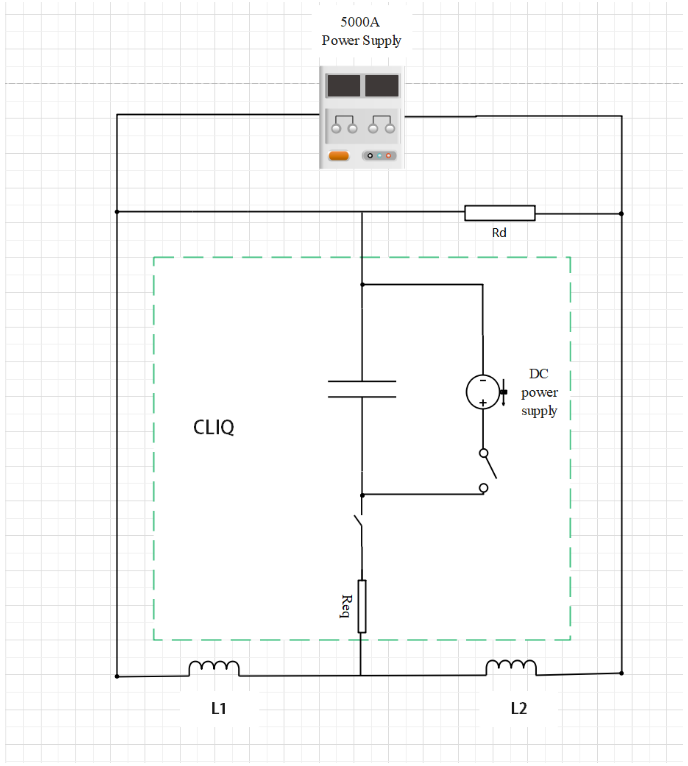
BEPCII-U SCQ-CCT拟用的NbTi超导线参数

| 裸线直径 [mm] | 绝缘后直径 [mm] | 铜超比 | RRR | 芯数 | 4.2 K名义临界电流 | | |
|---|---|---|---|---|---|---|---|
| | | | | | 4 T | 5 T | 6 T |
| 0.825 | 0.88 | 1 | >100 | 708 | >900 A | >750 A | >580 A |

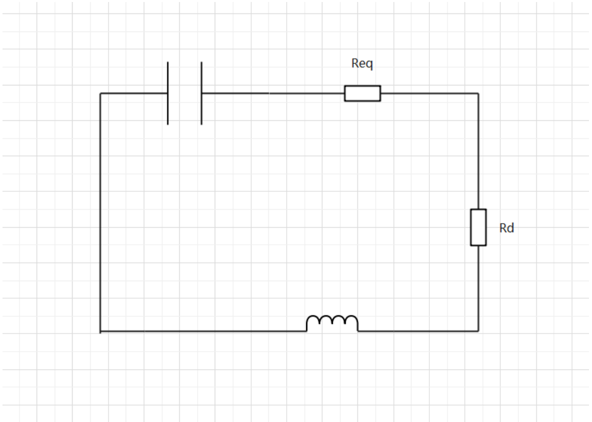



SCQ-CCT
Iop/Ic~74%, load line~85%

# Governing equations




one CLIQ method




another CLIQ method

$$\begin{cases} (L_1 + M_{12})\dot{I}_1 + (L_2 + M_{12})\dot{I}_2 + R_{CA}I_1 + R_{CB}I_2 + U_D = 0 & [V] \\ U_c = L_1\dot{I}_1 + M_{12}\dot{I}_2 + R_{CA}I_1 + \left(R_C + R_{CL_1} + R_{CL_2}\right)I_c + U_{RE} & [V] \\ I_1 = I_2 + I_c & [A] \\ I_c = -C\dot{U}_c & [A] \end{cases}$$

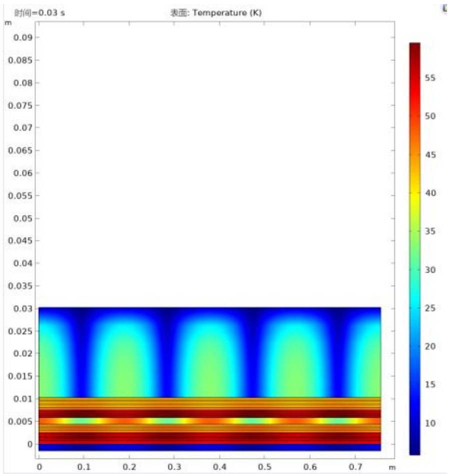
$$\begin{cases} I_1(0) = I_2(0) = I_0 & [A] \\ I_c(0) = \dot{U}_C(0) = 0 & [A] \\ U_c(0) = U_0 & [V] \end{cases}$$

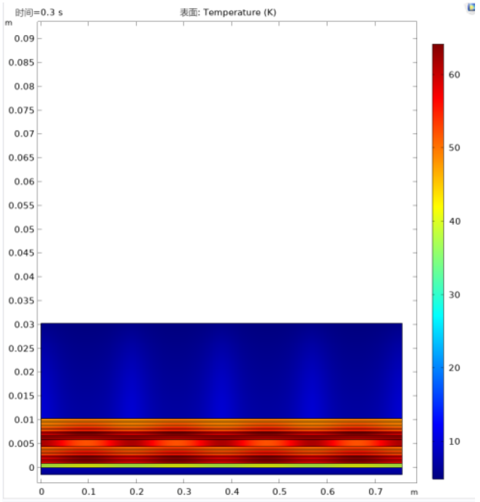
$$\begin{cases} I_1(t) = I_0 + \dfrac{L_2 + M_{12}}{L_1 + L_2 + M_{12}} I_C \\ I_2(t) = I_0 - \dfrac{L_1 + M_{12}}{L_1 + L_2 + M_{12}} I_C \end{cases}$$

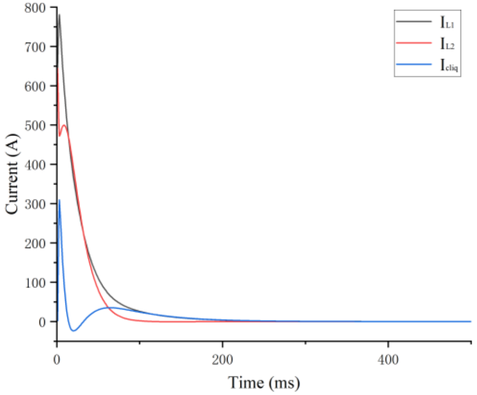
$$L_{eq} = \frac{L_1 L_2 - M_{12}^2}{L_1 + L_2 + M_{12}} \quad [I$$

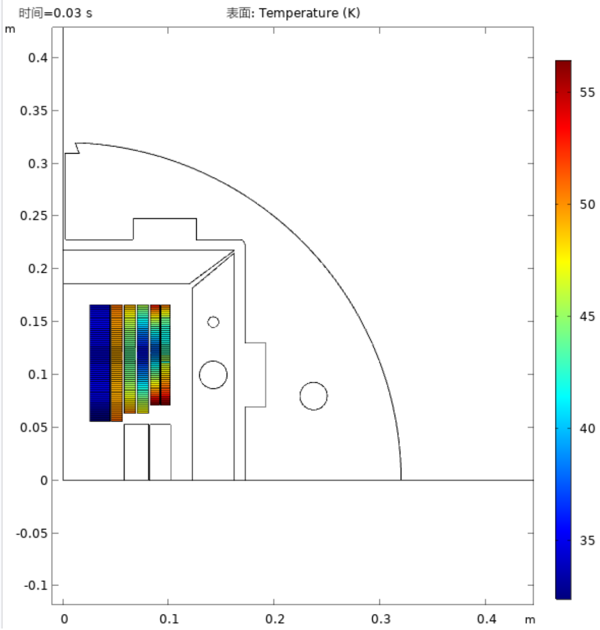
To get the key parameter – Mutual Inductance

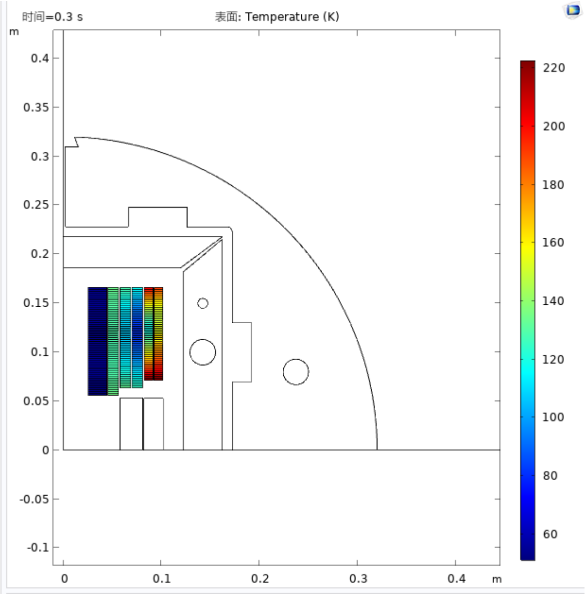
# results

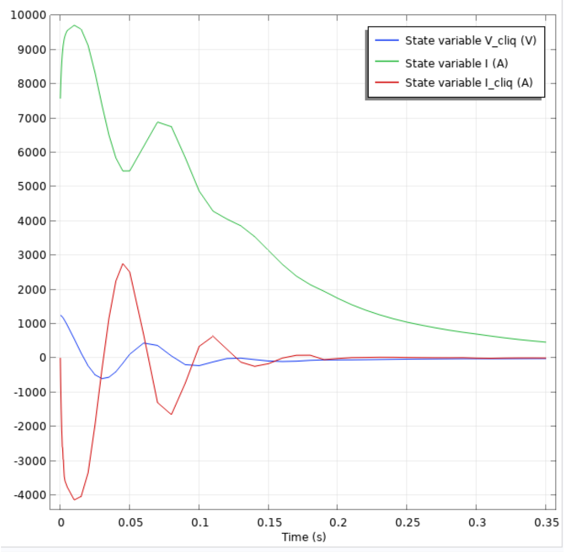

时间=0.03 s
表面: Temperature (K)
m


时间=0.3 s
表面: Temperature (K)
m


Current (A)
Time (ms)
$I_{L1}$
$I_{L2}$
$I_{cliq}$


时间=0.03 s
表面: Temperature (K)
m


时间=0.3 s
表面: Temperature (K)
m


State variable V_cliq (V)
State variable I (A)
State variable I_cliq (A)
Time (s)