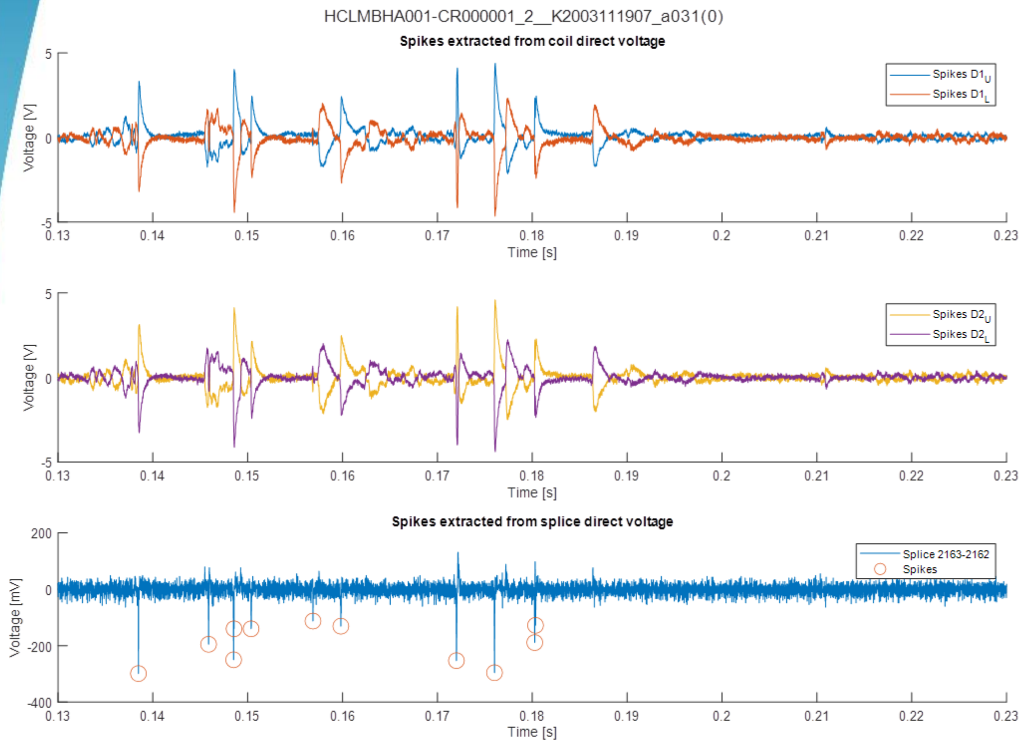
Analysis of the spikes & Simulation of Sudden Flux Variations

B. Bordini, D. Baffari

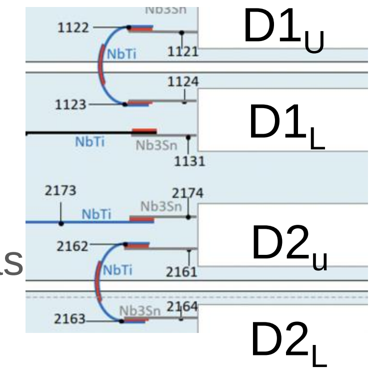
Acknowledgments:
F. Savary, F. Lackner, H. Prin, S. Izquierdo Bermudez, E. L. Gautheron
G. Willering, F. J. Mangiarotti

Different type of Spikes



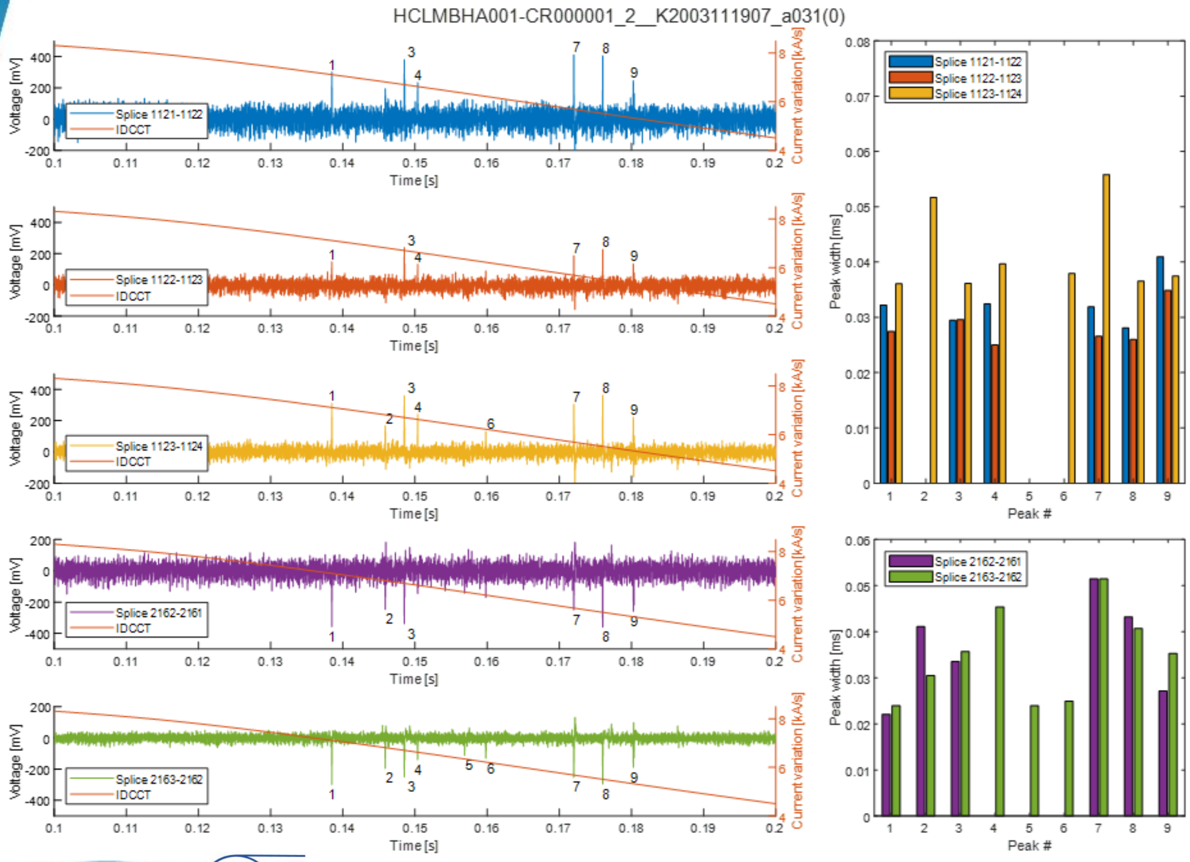
- In the coils the spikes present a rise time of **~ 100 μs** and then an exponential decay with a time constant **~ 500 μs**

- In the splices connecting the upper to the lower coils, spikes occur at the same time as in the coils

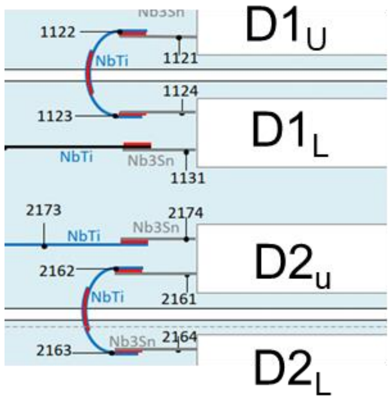


- In these splices, the spikes are **significantly different**: they are **very short** in time **~ 50 μs**

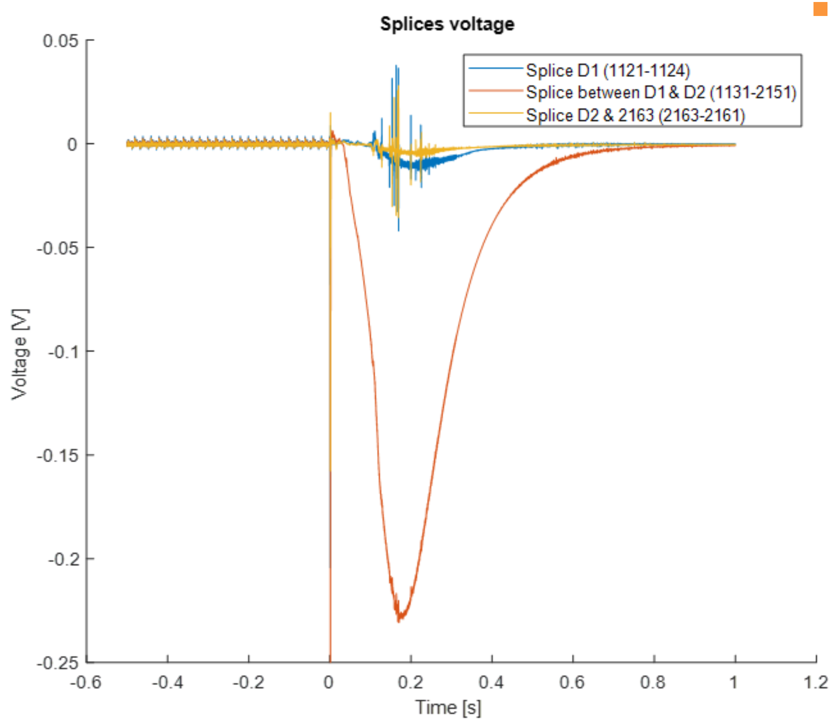
Narrow Spikes in splices between upper & lower coil



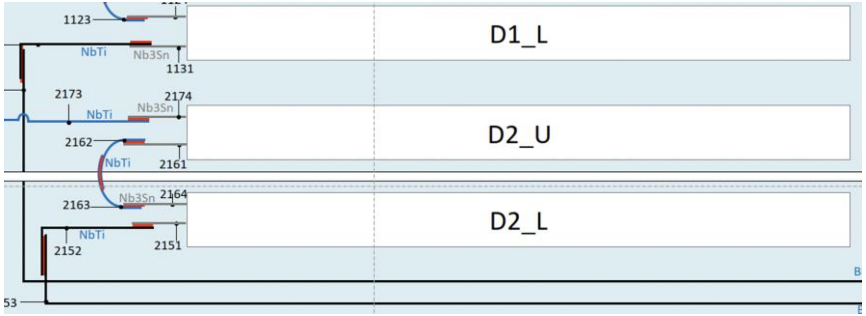
- These spikes are practically identical in the monitored 5 splices
- Different polarities between D1 and D2 splices are associated to the definition of the voltages that follows the path of the transport current



Other Splices do not show the narrow Spikes



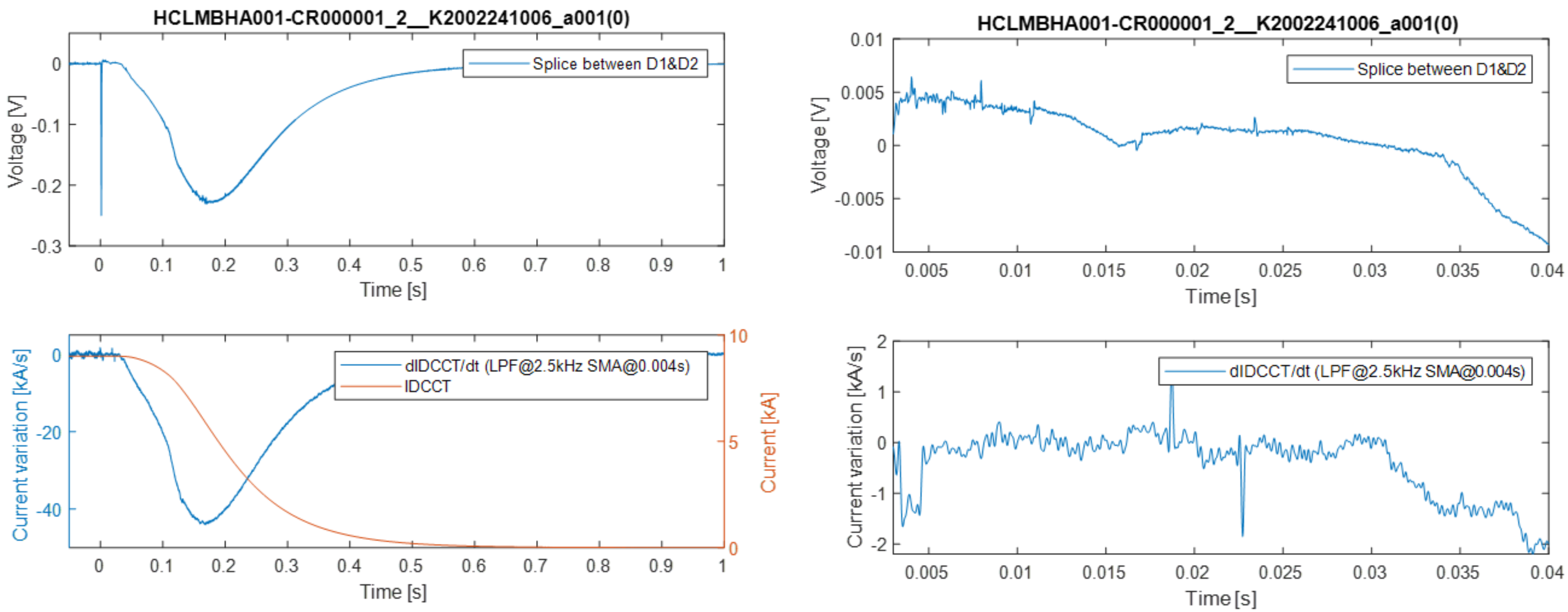
- The connection between the two dipoles (1131-2151) does not show narrow spikes – the larger inductance might be associated to the longer length of the circuit



A Possible Interpretation

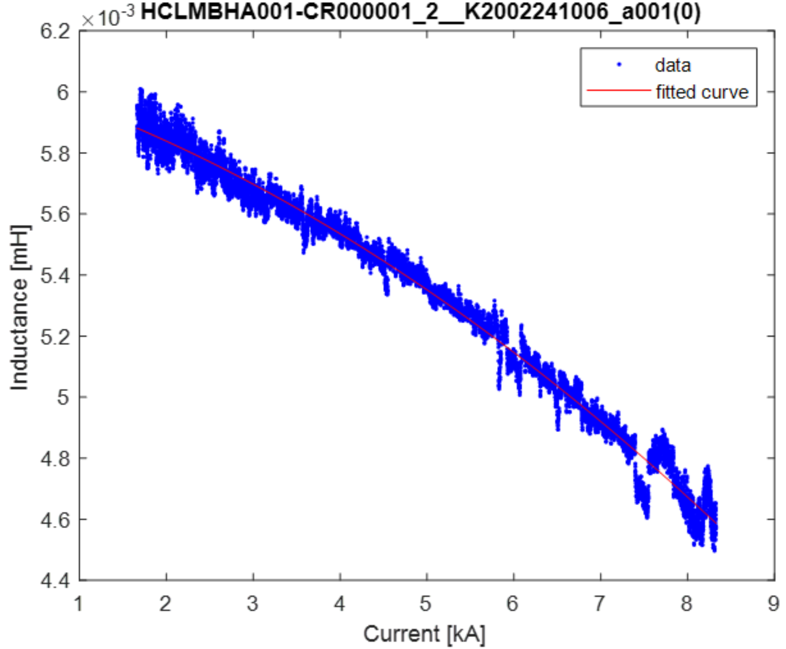
- The narrow spikes are due to a **sudden variation** of the magnetic **flux** (flux jumps, which are much faster than the variation of the transport current)
- The **flux jumps** most likely occur in the connections between the upper and lower coils
- These flux jumps are also ‘seen’ by the coils who react with a variation of the **transport current**:
  - The **coil signals** are a **composition** of the **flux jump** and of ***L dI/dT***

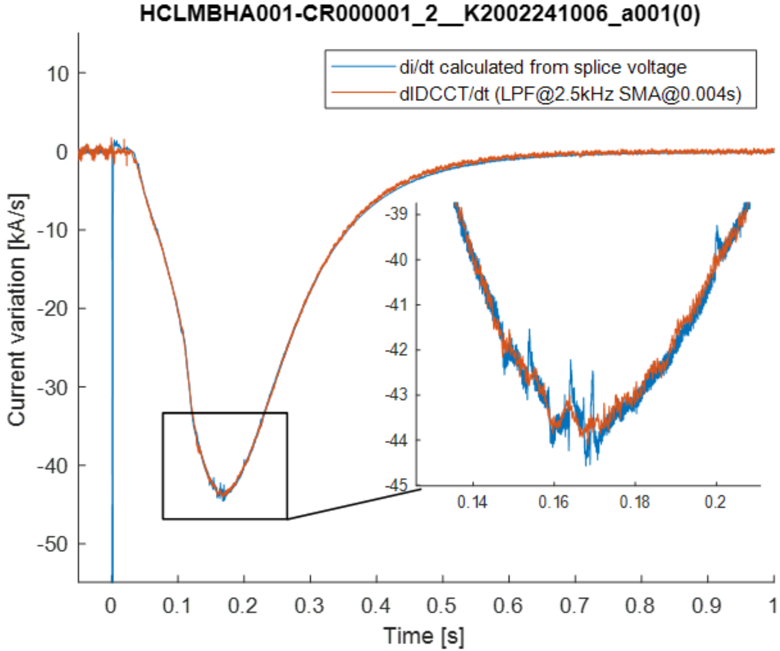
Signal in the connection D1-D2



- After the heaters discharge, the signal gets immediately resistive (~ 5 mV), then, about 30 ms latter, the resistive behaviour disappears and the signal looks dominated by *L dI/dT*

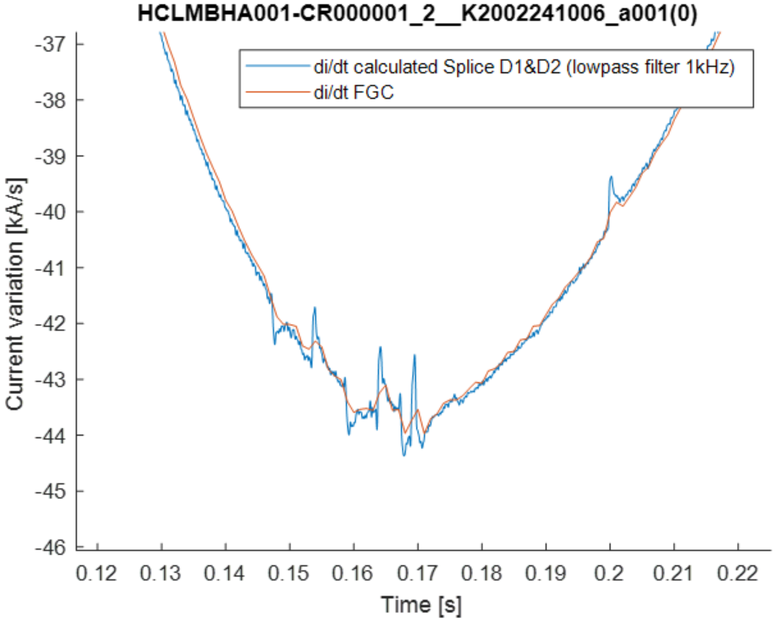
Using the D1-D2 signal to derive *dI/dt*

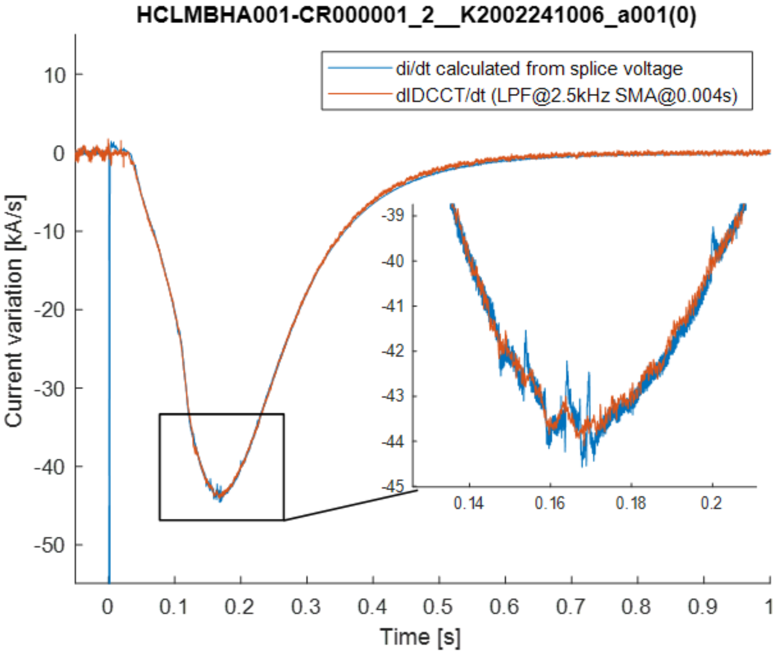




- The inductance of the splice can be calculated using the postprocessed dIDCCT/dt and the voltage in the splice. The inductance is then fitted against the current and finally used to recalculate the instantaneous *dI/dt*

Calculated dI/dt vs FGC comparison

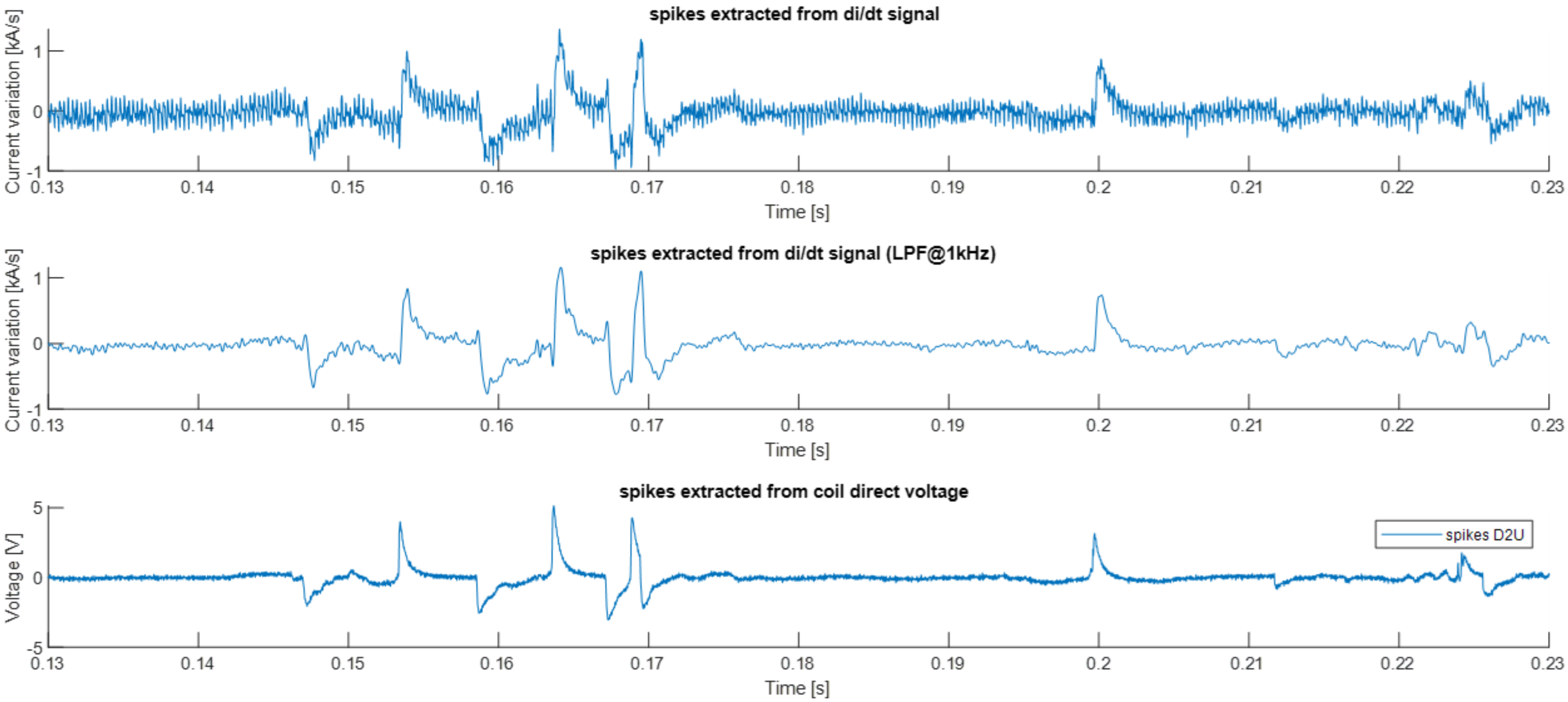




- The obtained dI/dt presents some spikes in the discharge phase, similar spikes can be observed in the dI/dt calculated from the data obtained from FGC readout (High-precision 1 kHz FGC readout, see Gerard's slides from 03/03/2020 meeting)

Spikes extracted from the signals

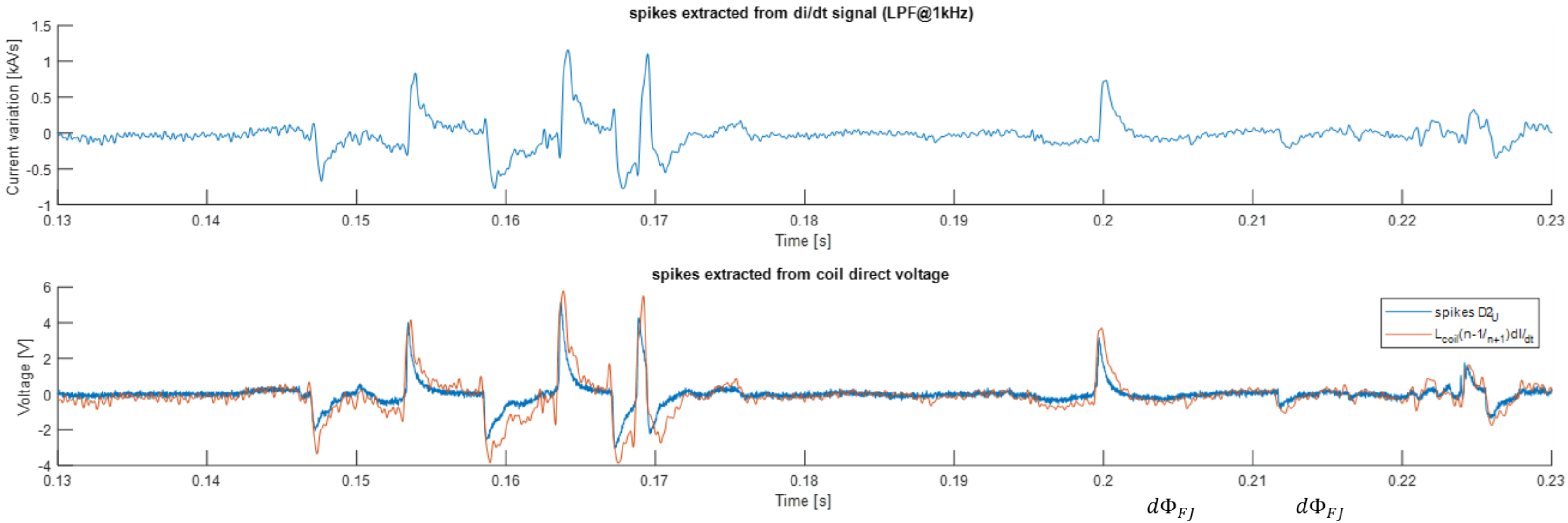
HCLMBHA001-CR000001_2__K2002241006_a001(0)



- Spikes extracted subtracting a heavily smoothed version of parent signal from itself

Spikes extracted from the signals

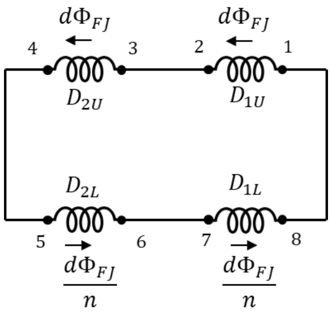
HCLMBHA001-CR000001_2__K2002241006_a001(0)



$$V = L\frac{dI}{dt}\left(\frac{n-1}{n+1}\right)$$

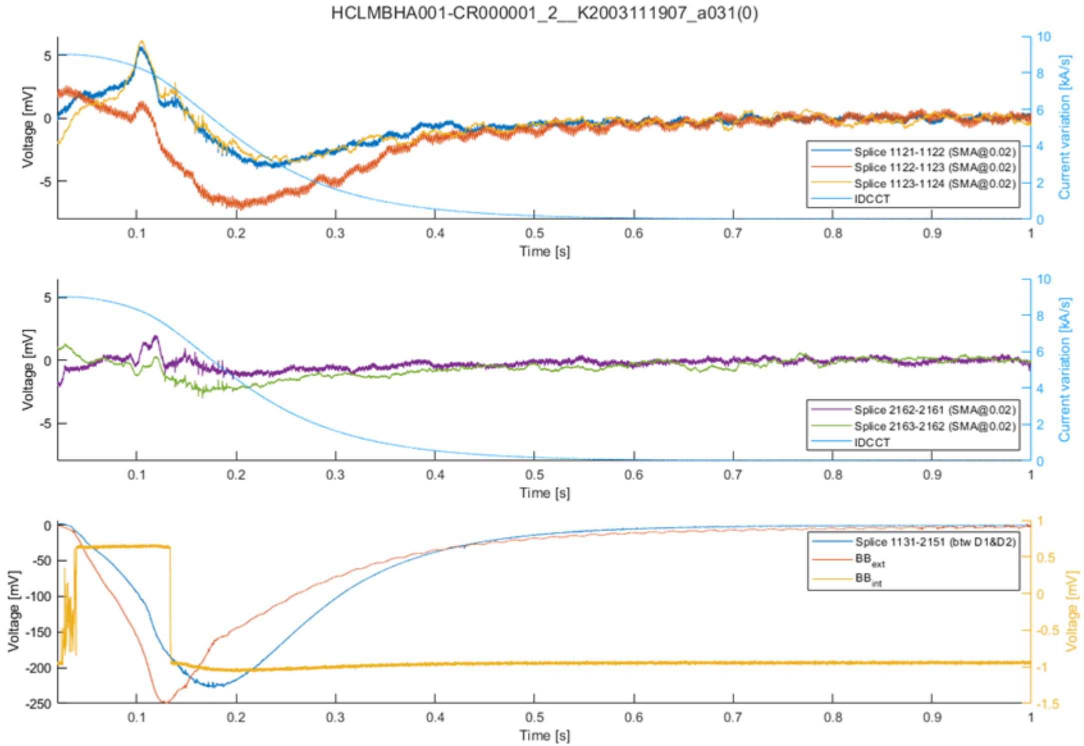
$$L_{coil} \sim 15\ mH$$

$$n = 2$$



Splices Quenching ?

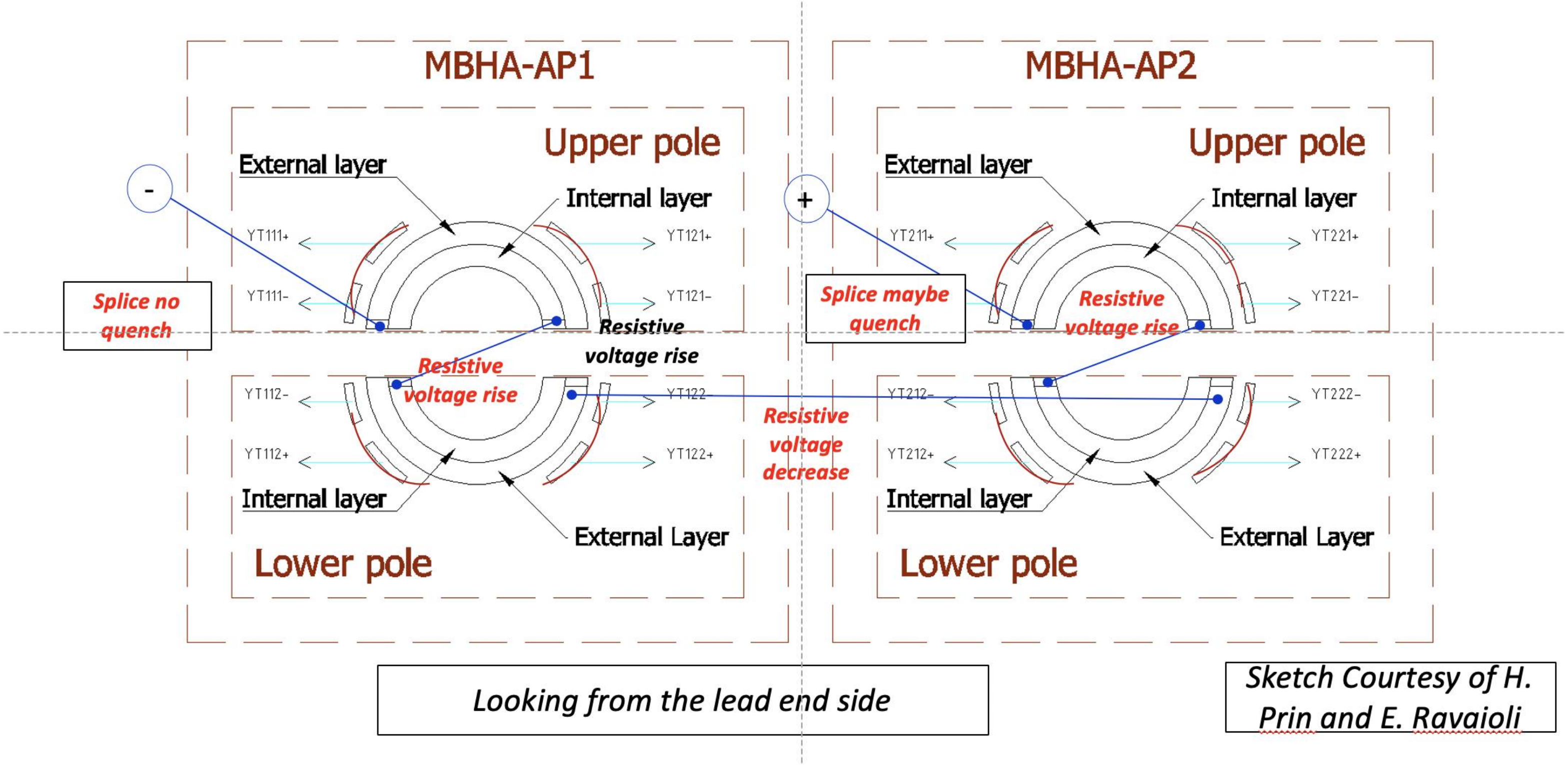
HCLMBHA001-CR000001_2__K2002241006_a001(0)



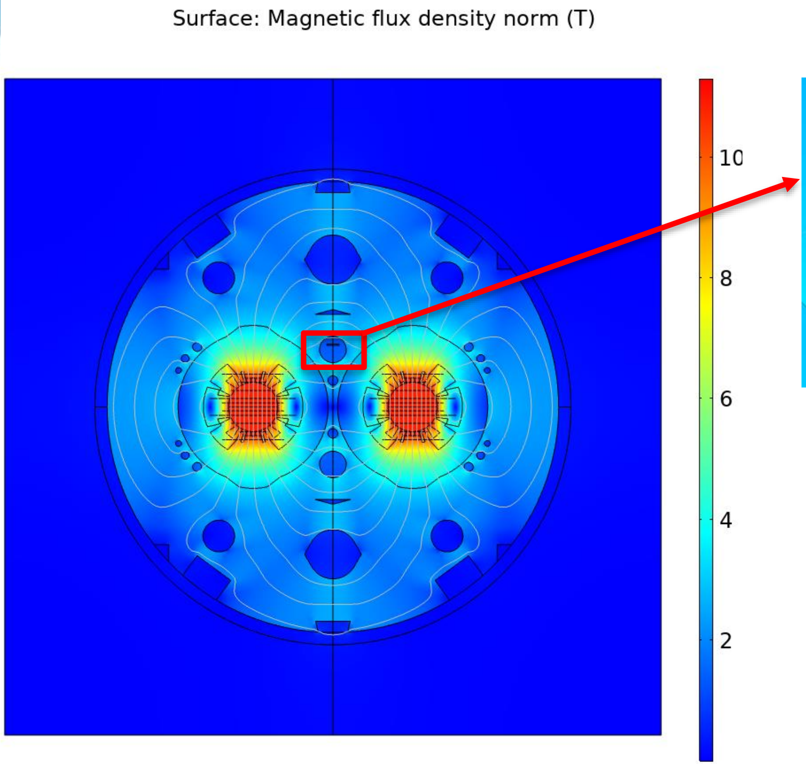
- In the Nb_3Sn splices connecting the upper to the lower coils a resistive signal increases at least up to 0.1 s – propagation of the quench
- In the connection between the two dipoles (1131-2151) the signal gets immediately resistive and then seems to recover
- **Work in progress….**

Splices Quenching?

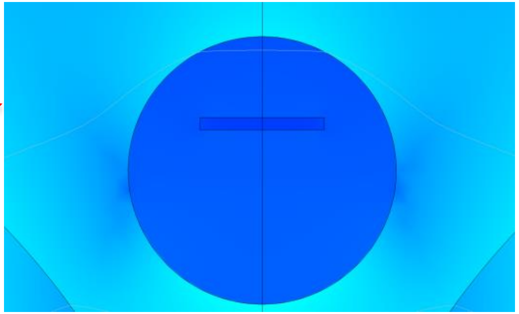
- **Work in progress...**



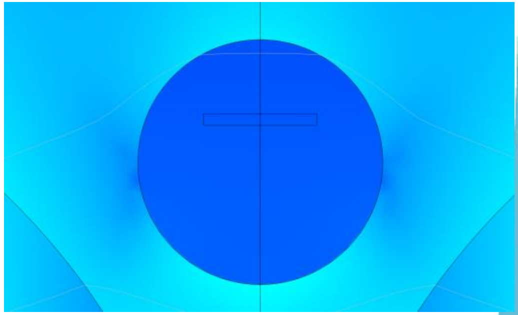
Effect of a Flux Jump in 2 D



Before Flux Jump

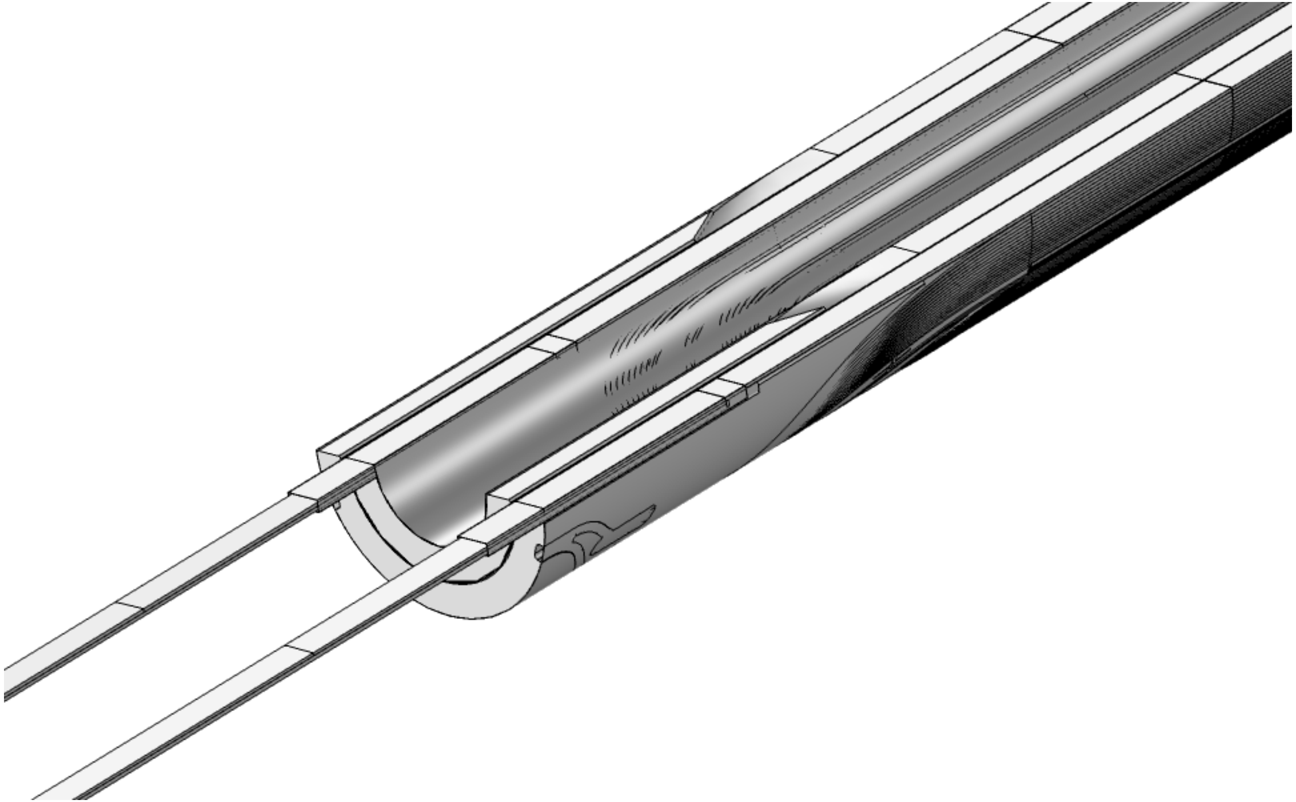


After Flux Jump

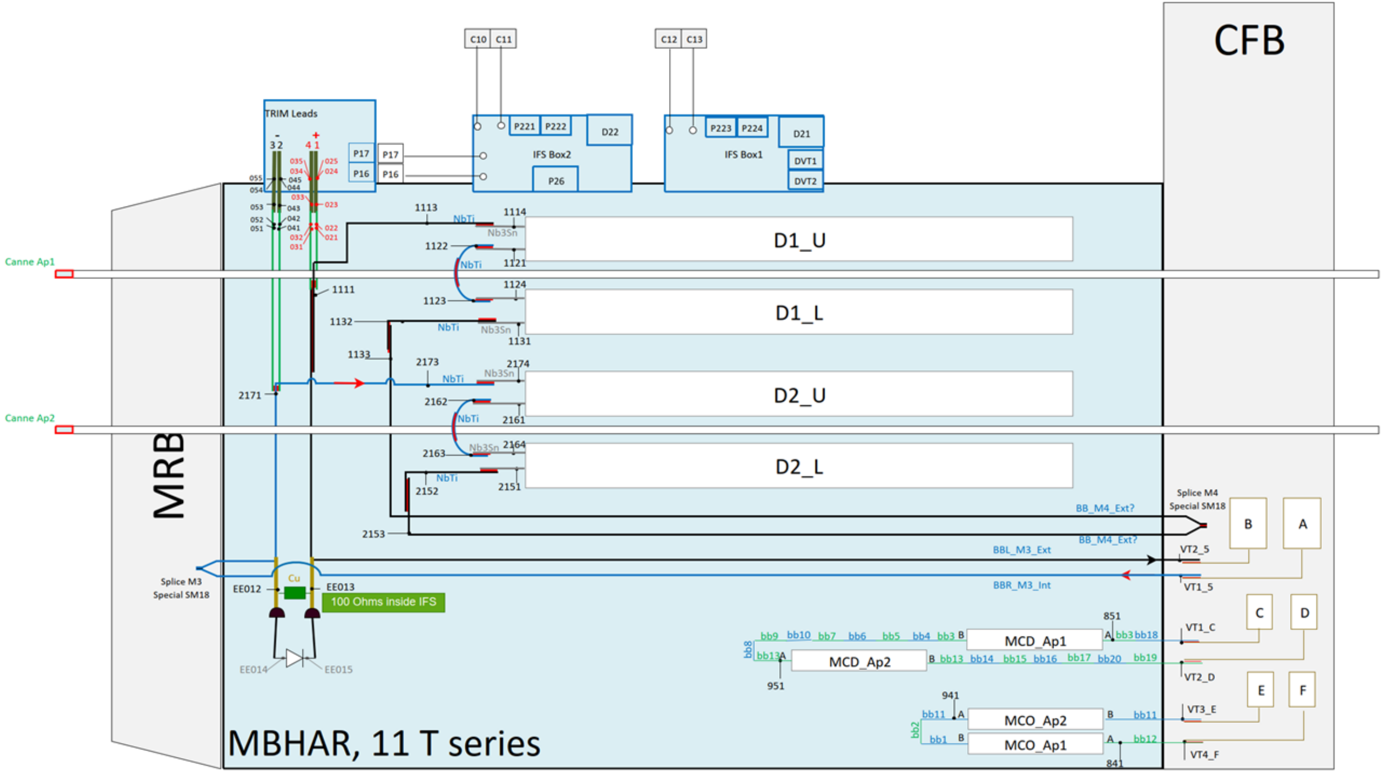


A variation of the field (due to a flux jump) by 300 mT in the cable above produces a variation of flux equal to 4.8*10^-4 Webber/m in the upper coil and; 3.4*10^-4 Webber/m in the lower coil

Plan: Study Effect of a Flux Jump in 3D



APPENDIX



Courtesy of G. Willering, F. J. Mangiarotti

Effect of a Flux jump External to the Coils

$$V_{12} = \frac{d\Phi_{FJ}}{dt} + L_{12}\frac{dI}{dt}$$

$$V_{34} = \frac{d\Phi_{FJ}}{dt} + L_{34}\frac{dI}{dt}$$

$$V_{56} = \frac{d\Phi_{FJ}}{dt}\frac{1}{n} + L_{56}\frac{dI}{dt}$$

$$V_{78} = \frac{d\Phi_{FJ}}{dt}\frac{1}{n} + L_{78}\frac{dI}{dt}$$

$$L_{12} = L_{34} + L_{56} + L_{78} = L$$

$$V_{12} + V_{34} + V_{56} + V_{78} = 0$$

$$\frac{d\Phi_{FJ}}{dt} = -2L\frac{dI}{dt}\left(\frac{n}{n+1}\right)$$

$$V_{12} = V_{34} = -V_{56} = -V_{78} = L\frac{dI}{dt}\left(\frac{1-n}{n+1}\right)$$