FREQUENCY LOSS INDUCED QUENCH PROTECTION SYSTEM FOR HIGH TEMPERATURE SUPERCONDUCTORS

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ABSTRACT

A fundamental problem with high temperature superconductors (HTS) is their high critical temperature (Tc) values and the stability that they impart. Low normal propagation velocities and high stability of HTS wires cause localized damage of magnet coils when there is a quench. Protection of HTS magnets for reliable operation has proven to be a challenge, particularly in Rare Earth Barium Copper Oxide (REBCO) superconductor, with the amount of energy that is required to get enough of the current into the metallic stabilizer to properly distribute the magnetic energy and minimize peak hot spot temperatures. A twist of a relatively new technique that relies on AC losses to distribute energy is Frequency Loss Induced Quench (FLIQ). FLIQ like Conduction Loss Induced Quench system, drives an imbalance in the transport current between two or more sections of a magnet. In order to drive this imbalance, FLIQ uses an H-bridge design with IGBTs, whose gates are driven based on the feedback response of the voltage across the bridge. This system optimizes frequency, as current resonates at the frequency of the LC network across the bridge. This paper will discuss the novel circuit design, its working principle, and present representative data obtained on an insulated REBCO insert magnet coil.

FEATURES OF FLIQ BOX

Remote trigger using TTL Logic
Adjustable activation time
Adjustable frequency
Zero-crossing capability
Current feedback control
Self oscillating

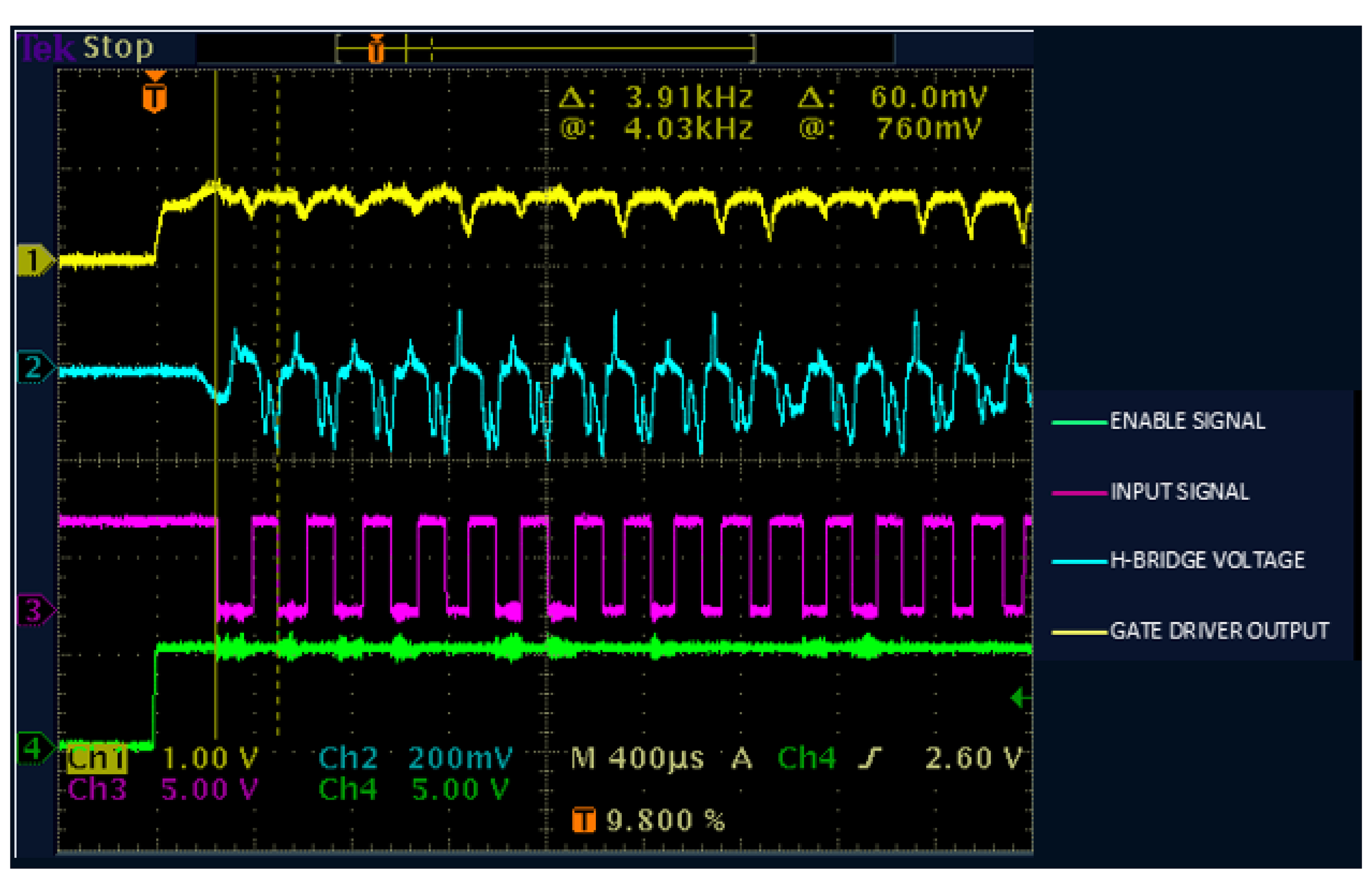

Figure 1. Proof of self oscillation

DESIGN

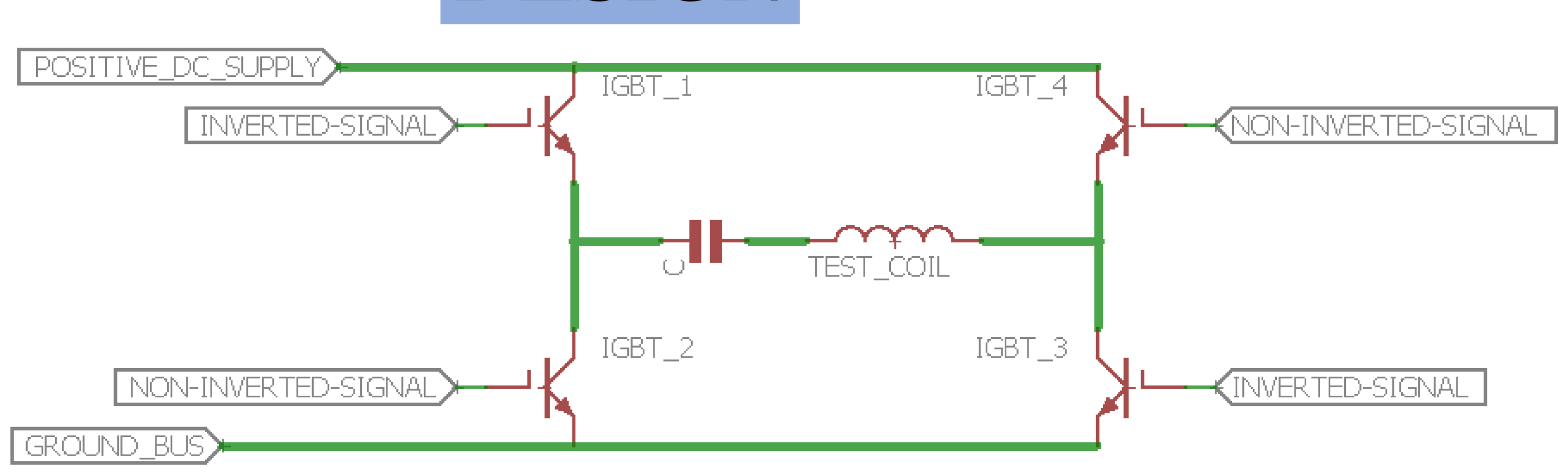

Figure 2. H-Bridge design

HOW IT WORKS

The FLIQ box comprises of an H-bridge consisting of four high current IGBTs and a driving circuit. This design as a self-driving characteristic based on the current feedback output and an enabling pulse. A non-contact current sensor is used to measure the current across the LC load connected across the bridge. This current sensor uses hall-effect measuring method to generate a zero-crossing logic. This logic is serves as input to the gate drivers while a TTL Logic is used actuate the entire system. This system protects superconducting coils by generating energy in form of AC loss by using the frequency of LC network. Basically digital signals are used to control the FLIQ system. The IGBTs are powered with a 12VAC and the driver circuit is powered with a power supply module of ±18V.

	ENABLE	INPUT	OUTPUT
INVERTING DRIVER	0	0	0
	0	1	0
	1	0	1
	1	1	0
NON-INVERTING DRIVER	0	0	0
	0	1	0
	1	0	0
	1	1	1

Figure3. Gate driver logic

HEATING MECHANISM

The FLIQ box employs AC loss heating mechanism to generate its energy by applying electrical current oscillating at the frequency of the load. It uses induction heating methods which changes the properties of the conductor. Based on Faraday's law, change in current induces voltage caused by the created magnetic field. The change in magnetic field results in eddy current loss which increases the temperature of the material and generates the needed heat energy. Heat is also deposited through hysteresis loss as the magnetizing force causes molecular friction when magnetic field changes. With eddy current loss, current density reduces with penetration depth which implies that deposited heat energy reduces with depth of the material. This mechanism causes current to decrease with penetration depth given as

$\delta = \sqrt{\frac{1}{\omega\mu\sigma}}$

Where, w=$2\pi f$
σ= conductivity
μ= magnetic permeability
f=$frequency$

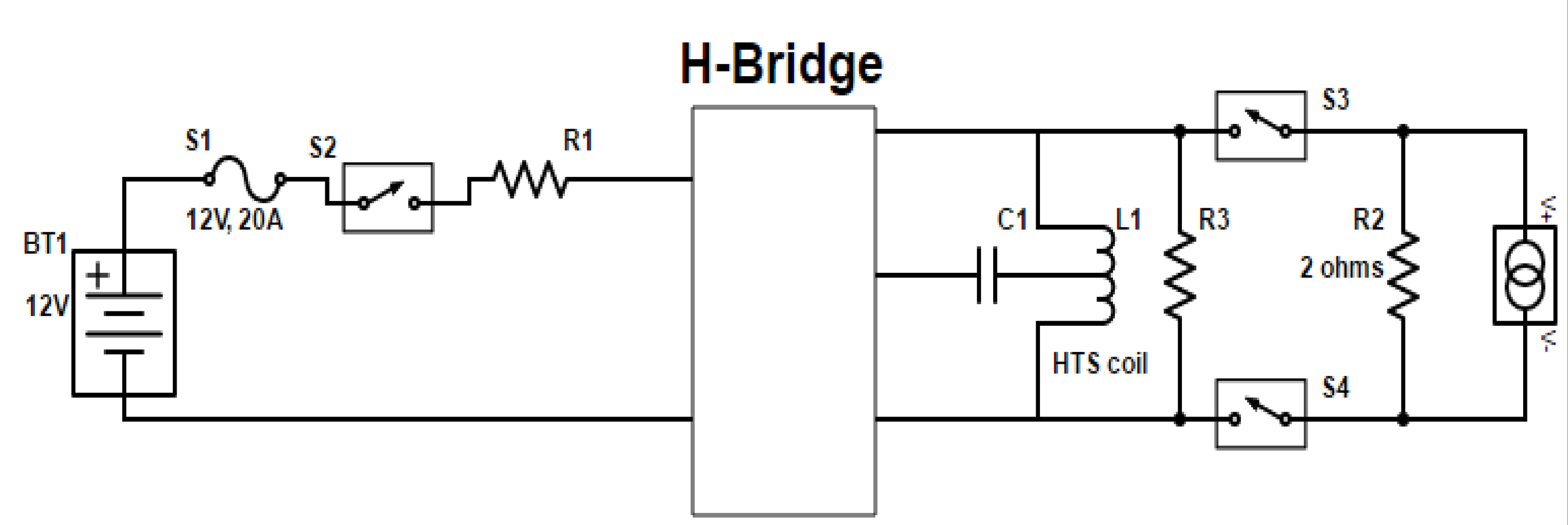

Figure 4. Electrical block diagram

RESULTS

The test was carried on a REBCO coil in Liquid Nitrogen at 77 with frequency of 50Hz.

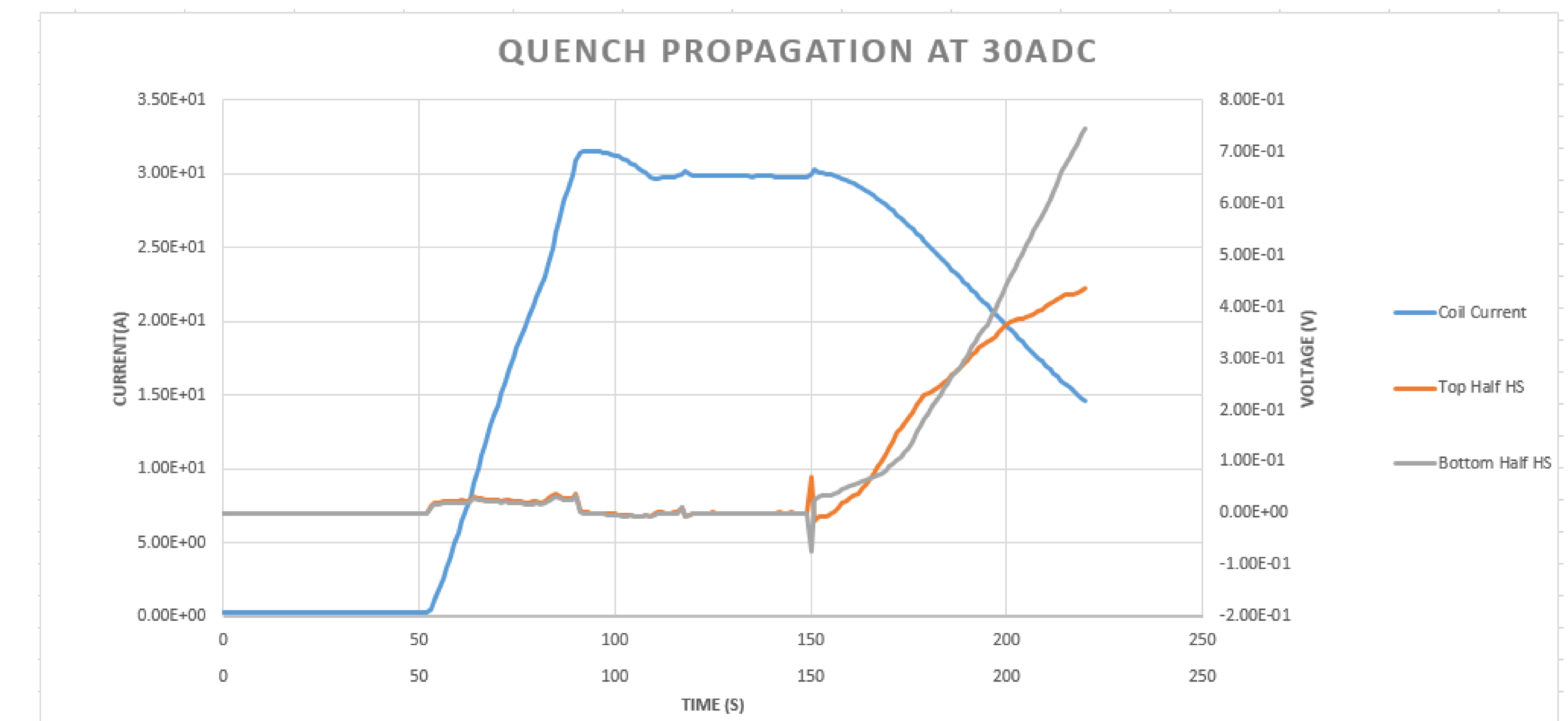

Figure 5. Quench Propagation of the HTS coil

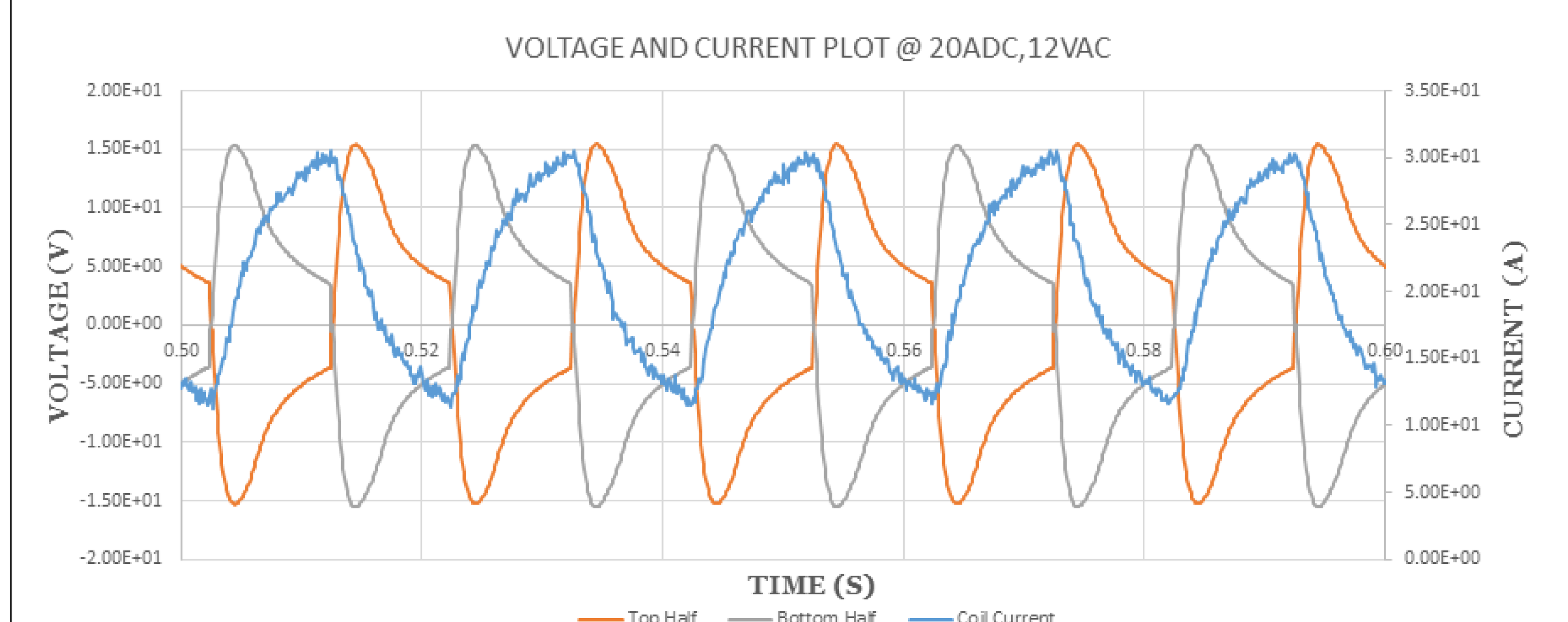

Figure 6. Voltage and Current plot

CONCLUSION

The goal of this project is to build a protection box capable of quenching HTS coil. The intent of this system is to advance protection technology for High Temperature Superconducting coils and have a protection system that can deposit high energy needed when it quenches as fast as possible. This development is in its early stages of development and will require possible optimization in the nearest future.

ACKNOWLEDGMENT

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