Analyzing Acoustic Data From Quench Training

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Introduction and Purpose of Study :

Superconducting magnets have a physical process called quench. A quench is when the magnet heats up, becomes resistive, and drives the shut-off of the magnet to avoid damage. The details of individual quench precursors are poorly understood. Studies have shown that using piezoelectric sensors to acquire acoustic data could be useful for investigating what causes a quench. Finding differences in arrival times allows one to find the acoustic event location. Using acoustic data in this study, we attempt to automate tasks such as event detection, time difference, and event location. We also investigate events close to quench, how strong they are, and what insights we could get for the quenches characterized by other methods.

MDPTC1 Magnet Setup and Acoustic data :

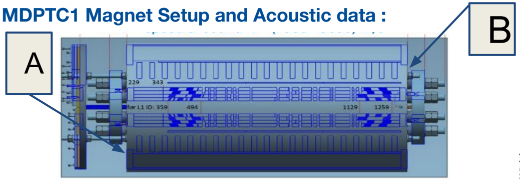

Fig 1: This figure shows a side view of the MDPTC1 magnet and the configuration of the piezoelectric sensors. In this figure, the sensors labeled 0 and 1 are on sides A and B, respectively.

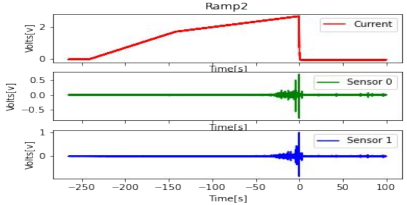

Fig 2: This figure show acoustics data from one of the ramps. Note that current units are not volts they are abstract units. The highest point is where the magnet quenches.

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Methodology :

Using python, we built tools to help us automate the analysis tasks like event detection, time difference, event location, and investigating the acoustic data close to quenching. These tools were built from scratch and used on a dedicated analysis computer.

Event Detection :

The first major analysis tool that we built was the event detector. The event detector used is a combination of the source code from Obspy and our own, and we did this so that the Obspy package would intake our rolling R.M.S data. ***The code works kind of like an oscilloscope. The user sets two R.M.S thresholds called ON and OFF. The ON threshold needs to be larger than the OFF. Once the acoustic signal goes above the ON threshold, we have found the approximate start of the event. When the signal goes below the OFF threshold, we consider that the end of the event. From this, we extract the approximate start and end times of events.***

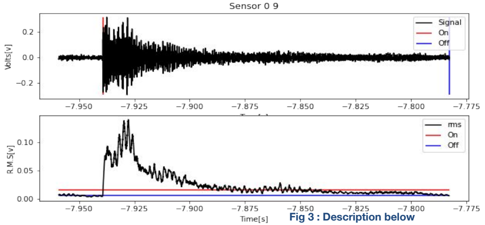

Fig 3 : Description below

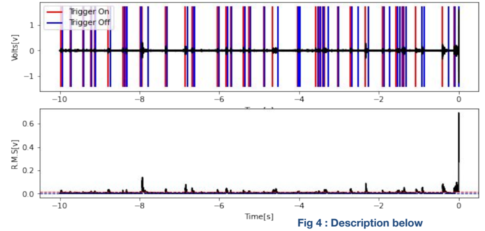

Fig 4 : Description below

Fig 3 & 4 : This figure above shows the capture of a single event. The threshold used are .015 volts(ON) and .005 volts(OFF). The figure below is the events captured in the last 10 s of a ramp at the same threshold used above

Finding the Time Difference :

Finding the time difference between arrival times in two sensors is an essential part of analyzing acoustic data because the time difference allows us to find the longitudinal location of the acoustic event. The location can then be compared to voltage tap data of well know quenches. The way we automate this task is by searching for amplitudes above a defined threshold that have three consecutive points above 3 times the noise level. The amplitudes must also be behind the approximate start time from event detection.

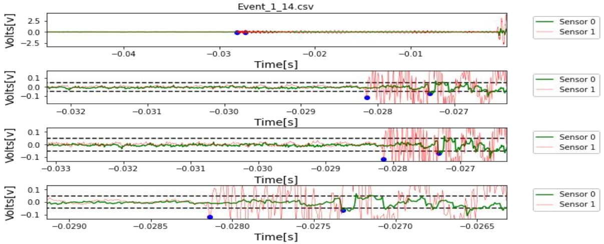

Fig 5 : This figure shows the start times found by our algorithm. This gave a time difference of .82 ms with an uncertainty of 1.7 ms. This is really not good because this means our algorithm has failed. Also, it means we can not reliably find the location of an event.

Events Close to Quench :

Visualizing acoustic events near the quench is another essential aspect of analyzing acoustic data from magnet training. We have plotted the ramp number vs. the time from the quench, with the color bar representing the max amplitude of each event.

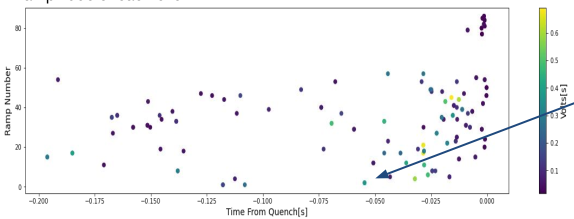

Fig 7: This shows the ramp number vs. time from quench. The color bar is the max amplitude for each event.

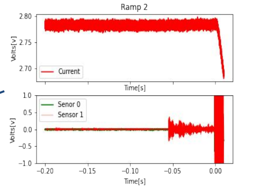

Fig 8 : This figure shows the event represented by the green dot in Fig 7. Note that here again, the current units are abstract units, and the max value is where the quench happens.

Conclusion :

In our attempt to automate the analysis of acoustic data from quench training, we were successfully able to detect events and visualize events near the quench. With the event detector, we can quickly find acoustic events, making finding events to investigate more efficient. Visualizing events near the quench allow us to see how large events near the quench are and compare them to events far from the quench. Automating for the time difference worked only for a handful of situations, which means the algorithm needs more work.

Scources :

[1] Obspy. (n.d.). *Home · obspy/Obspy Wiki*. GitHub. Retrieved November 26, 2021, from https://github.com/obspy/obspy/wiki#installation.
[2] Stoynev, S. (n.d.). *Summary of quench performance analysis*. Lecture.