Thyratron Ranging

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Introduction

A major component of a station along the LCLS accelerator is a thyratron. These devices are used as high-power switches for electrical circuits. An advantage of using a thyratron is that it can handle much larger currents than common hard-vacuum tubes. This is made possible because they contain hydrogen or deuterium gas that can withstand megawatts of peak power and can reach switching speeds of under 10 microseconds. However, this convenience comes with a price as the present thyratron replacement cycle used at SLAC is quite expensive. In addition, the system by which thyratrons are ranged for efficiency can be automated to decrease the time in which manual intervention is needed. This project proposes ways in which this problem should be approached for improvement.

Figure 1. A typical deterium-filled thyratron used at SLAC
(Source: MCCWiki/Thyratrons)

Methods/Research

While jitter is inevitable within the LCLS system, steps may be taken to minimize its presence. In order to maintain a reasonable heater current level and acceptable jitter for many parameters including phase, amplitude, beam voltage, and backswing, an increase of the station's reservoir voltage can be applied. In general, there is a direct correlation to the decrease of heater current and the increase of reservoir voltage. This is also true for the previously stated parameters. The problem with this relationship is that, as a thyratron gets older, the reservoir voltage will continue to be raised to account for the jitter problems and eventually become too high and cannot be brought back down.

To detect a past ranging event, one may manually record the start and end times of the occurrence. This can not be easily automated, because each station is unique in that there isn't a strict rule that can implemented to differentiate between a ranging event and a jitter anomaly. This in turn demonstrates why it is difficult to produce a code for this task, however, it is simple to create a way to alert operators that the heater current or jitter data has risen too high. Specifically, for the heater current of a station, it can easily be seen upon inspection that it has risen too high for the linac to run smoothly. While setting the reservoir voltage to a new value is not very time consuming itself, the station does take time to reach the desired voltage. The mean time it takes for a station to reach a new reservoir voltage assigned to it is 54.64 minutes. Although this does not seem large in the long run, it is a significant chunk of time that the jitter of a station is out of control.

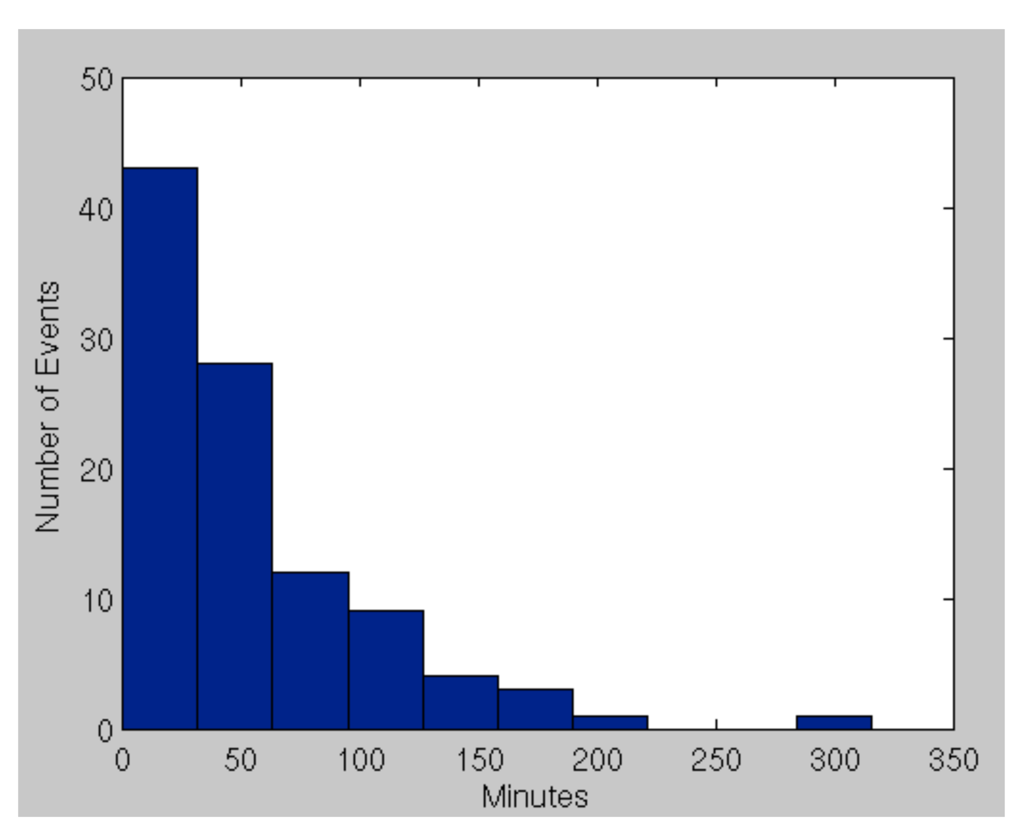

Figure 2. A histogram of thyratron ranging event lengths

Compared to the hour before a ranging event to the hour after, the heater current of a thyratron decreases by -0.0580 A. When the jitter data from the hour before a ranging event and the hour after are compared, all of the parameters in question prove to decrease as well; their differences are tabulated below. This data shows all of the ranging events from March to August 2017.

Jitter Parameter	Mean Difference Before/After Ranging
Phase	-0.0398 degrees
Amplitude	-0.0120 V
Beam Voltage	-144.0317 V
Backswing	-0.9872

Table 1. Mean decrease in several jitter parameters an hour after a ranging event compared to the hour prior.

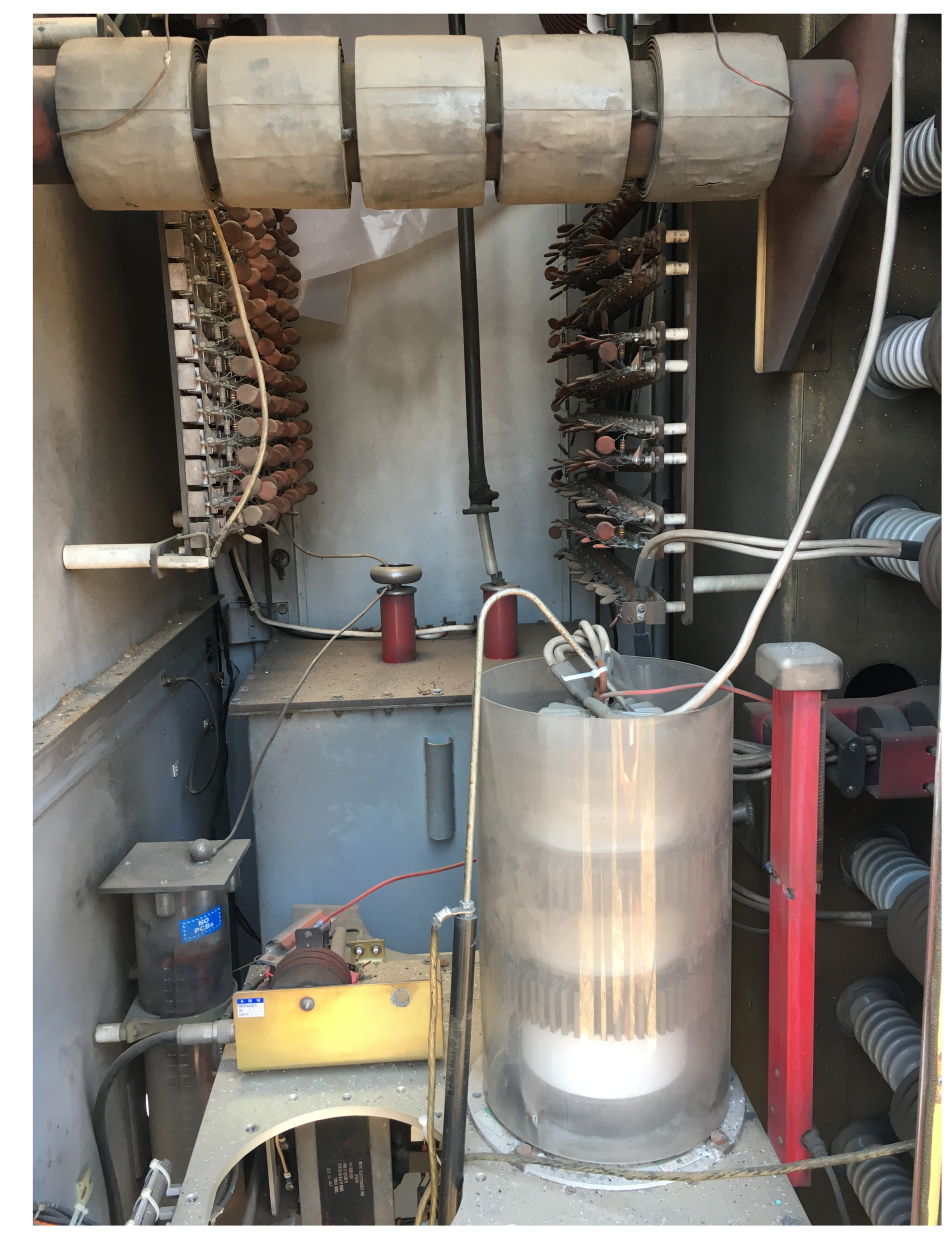

Figure 3. Thyratron inside a Modulator cabinet in an LCLS station

Conclusions

The reasons why a thyratron is ranged depend on many factors including a large increase in heater current or any unexpected rise in a station's jitter data. It is important to catch when a station is experiencing one of these problems to keep the accelerator running at its best, but sometimes only experienced operators are able to notice an alarming change in a station. Unfortunately, as a thyratron grows older, the gas pressure within it cannot be controlled as well and reservoir voltage cannot be infinitely increased to maintain stable heater current levels. This causes problems, because they need to be replaced frequently, have a high price tag, and take time away from LCLS controllers for ranging. However, with the knowledge that we have about the nature of a thyratron, it will be possible in the future to create a program that will range thyratrons automatically using rules found by the data from this project.

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