The Design of a Resonance Control System for the IOTA Storage Ring

Gerrit Bruhaug, Idaho State University

Background

The Integral Optics Test Accelerator (IOTA) storage ring is being constructed in conjunction with the Fermilab Accelerator Science and Technology (FAST) electron LINAC and the HINS RFQ Proton Source at the New Muon Laboratory (NML). These machines will be used to study non-linear beam dynamics, which will assist in the construction of new accelerators around the world.

A Beam Position Monitor (BPM) will be used to detect the beam position in the IOTA ring. This device requires a bunched beam to work properly, thus a bunching cavity was devised[2] to prevent beam bunch smearing. This cavity requires continuous tuning to keep it on resonance. My project was to design, build, and test the controls system necessary to properly bunch both electron and proton beams

Design

The controls system needed several pieces to function properly.

1. A way of detecting if the cavity was on resonance.
2. A way of changing the resonant frequency of the cavity.
3. A system to actively use the inputs, change the resonant frequency, and integrate with the Fermilab ACC-Net controls network.

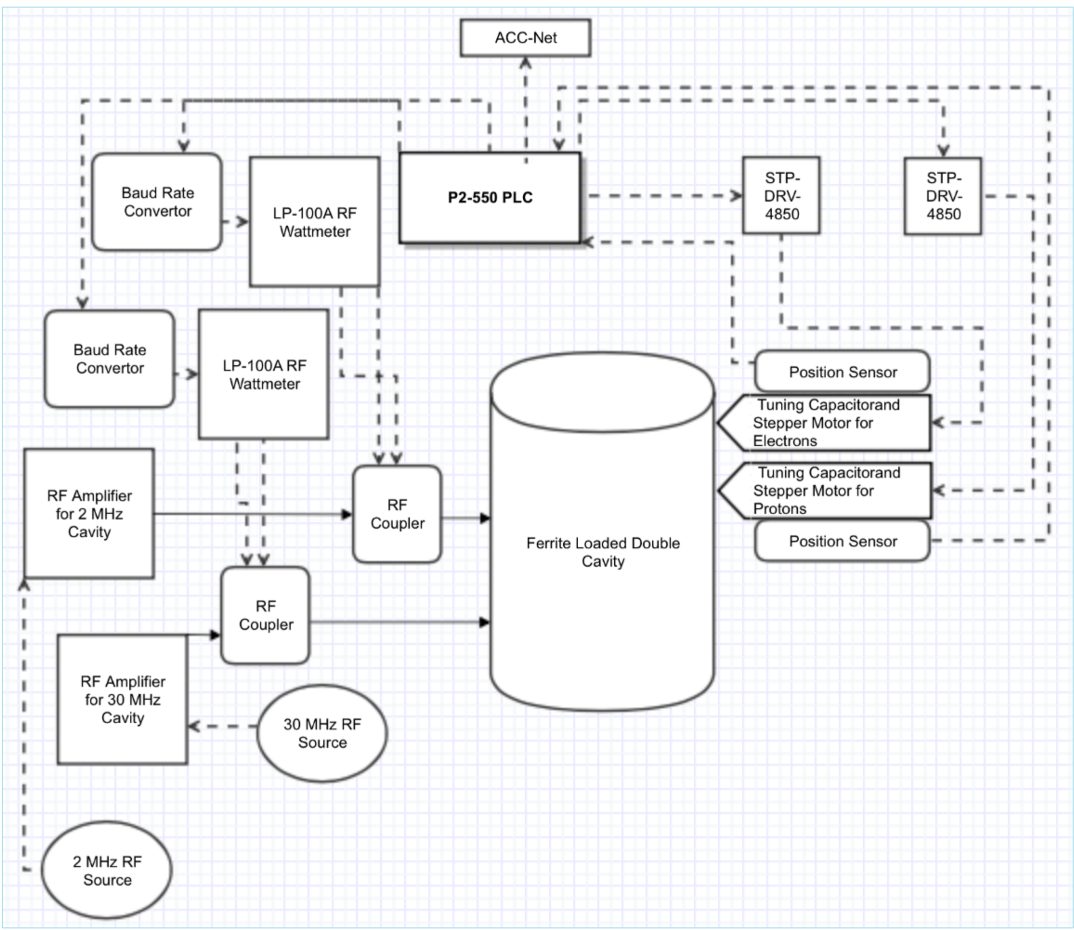
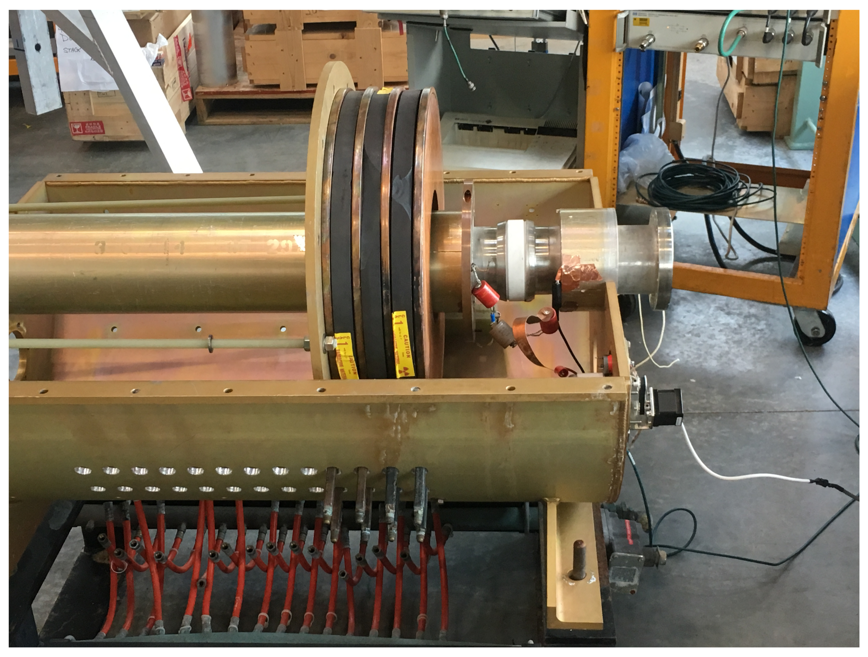


Diagram of Controls System

Construction

I built the system from Automation Direct components along with two LP-100A RF Vector Wattmeters. In addition, I programmed the Programmable Logic Controller (PLC) with the Productivity 2000 software. This ladder logic program contains two Proportional, Integral, Derivative (PID) control loops for accurate RF tuning without oscillations about the set-point. However, to properly tune the PID loops I would need to attach the controls system to a real RF cavity.

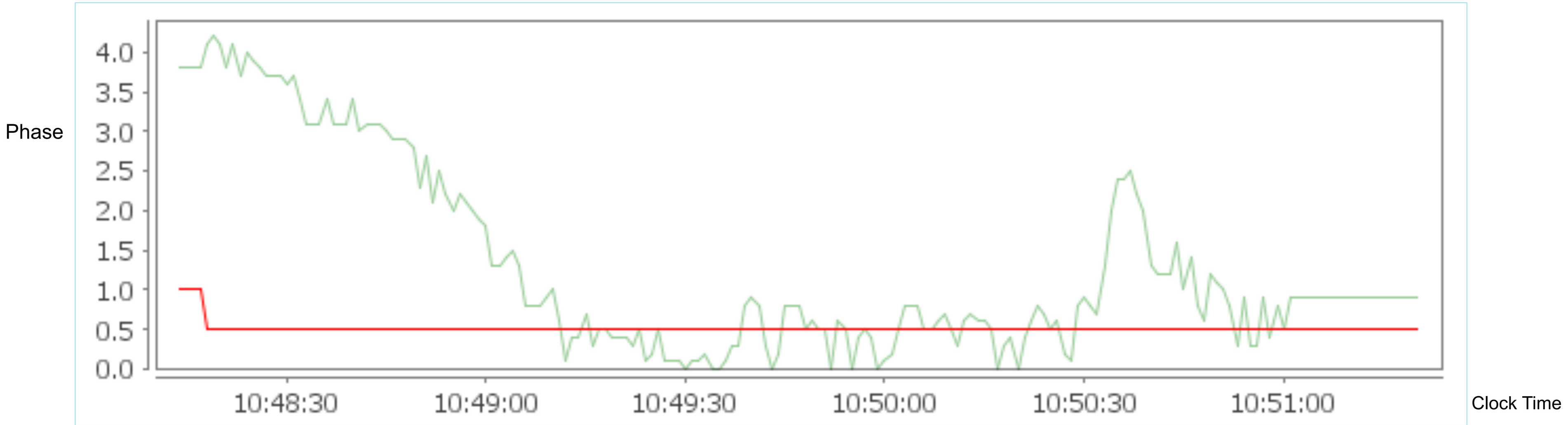


Test ceramic break with RF tuning motor and sensors installed on front face.

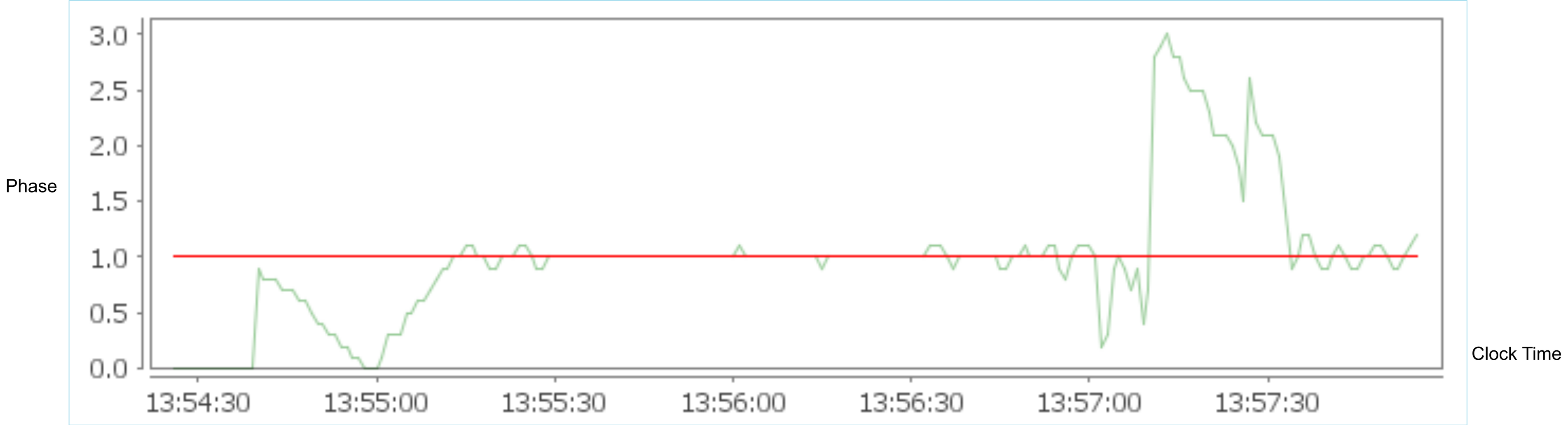
In addition, the system was successfully integrated with the Fermilab Accelerator Controls Network (ACC-Net), via Modbus.

Tuning of the PID Loop

To test my controls system a dummy system was set up with an older ceramic break beam-pipe so as to not risk the new system. In addition, a left-over tuning capacitor was attached to this older ceramic break and connected to one stepper motor control system at a time. This allowed for very precise tuning of the PID loops with out needing large amounts of RF power, or risking the new double ceramic break and tuning capacitors. The pictures below show the result of this tuning.



Untuned PID Loop Response to Excursion



Tuned PID Loop Response to Two Excursions

References

[1] Prebys E., “RF Capture of Protons at the IOTA Ring at Fermilab”, Batavia, Illinois, January 2015

[2] Kazakevich G., Carlson K., “IOTA Cavity Engineering”, Batavia, Illinois, December 2015

Acknowledgements

I would like to thank my mentor, Kermit Carlson, for his guidance and help throughout this project.