AN IMPROVED PNEUMATIC FREQUENCY CONTROL FOR SUPERCONDUCTING CAVITIES*

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Abstract

The ATLAS (Argonne Tandem Linear Accelerator System) superconducting cavities use a pneumatic system to maintain the cavity eigenfrequency at the master oscillator frequency [1]. The present pneumatic slow tuner has a limitation in the tuning slew rates. For some resonators, the frequency slew rate is as low as 30 Hz/sec. The total tuning range for ATLAS cavities varies from 60 kHz to as high as 450 kHz depending on the cavity type. With the present system, if a cavity is at the extreme end of its tuning range, it may take an unacceptable length of time to reach the master oscillator frequency. We have designed a new slow tuner system that increases the frequency slew rates by a factor of three hundred. This improved system is directly applicable for use on RIA (Rare Isotope Accelerator) cavities. This paper discusses the design of the system and the results of a prototype test.

INTRODUCTION

There are forces, some internal and some external, that can affect the eigenfrequency of superconducting cavities. Some type of tuning device must be employed to compensate the affects of these forces and maintain the cavity frequency at the Master Oscillator frequency. The superconducting cavities in the ATLAS accelerator use a pneumatic control system (slow tuner system) to adjust the cavities frequency. The scheme is to vary gas pressure in a bellows, mounted to an end wall of a cavity. Changing the position of the end wall, changes the cavity frequency. The tuning range for ATLAS cavities varies from 60 kHz to as high as 450 kHz depending on the cavity type. When turning on a cavity there is some time needed for the slow tuner system to bring the cavity frequency to the Master Oscillator frequency. The goal of this development project is to reduce the time for the slow tuner to reach the Master Oscillator frequency.

SLOW TUNER SYSTEM

The original slow tuner system was developed in 1978. The complete system is comprised of an RF Control module, which generates the phase and frequency error signals, a slow tuner feedback controller, which processes these signals and supplies the control voltage to the valves, and a valve-containment unit, which houses the control valves and a pressure transducer (see block diagram in Fig1). The frequency slew rates were limited to 30 Hz/sec to 500 Hz/sec, by installing flow restrictors with flow rate 700-800 SCCM in series with the control valves, as shown in Fig. 2. This limit was considered necessary to insure a stable control loop operation.

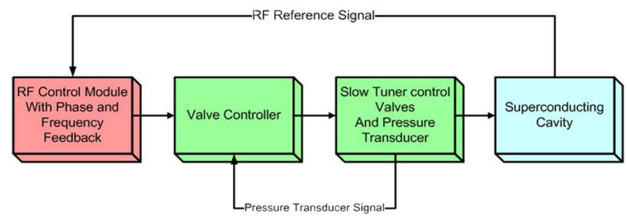

Figure 1: Block Diagram of the slow tuner system.

The original valve configuration employed one proportional valve on the pressure line and one on/off valve on the vacuum line. In addition, there was a fixed leak rate of 60 SCCM between the pressure manifold and the vacuum line; this is shown in Fig. 2 in dashed lines. In the steady pressure condition the proportional valve remained slightly open to balance the effect of the leak rate. This system works well but we felt that improvements in the slew rates could be made.

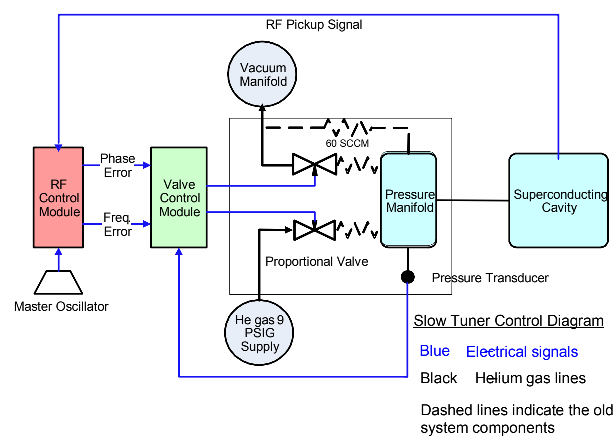

Figure 2: Slow tuner system detailed diagram. Flow restrictors and bypass leak shown in dashed lines.

NEW DESIGN

To achieve faster system response flow restrictors were removed from the system, which gave flow rate increase up to 5000 SCCM, as limited by the control valves. On/off valve in vacuum line was replaced with the proportional valve identical to the one in pressure line. Also, dc valve control scheme was changed to a Pulse Frequency Modulation (PFM) control scheme, where valves are controlled by a 12 V, 12 msec width rectangular pulse with variable from 10 to 100 Hz repetition rate. This scheme allowed us to drastically reduce the control valve hysteresis, as shown in Fig. 3 and 4.

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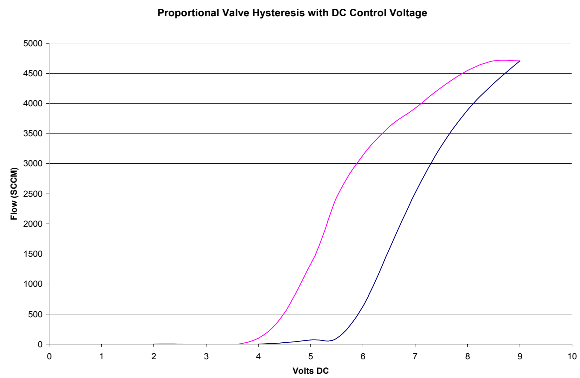

Figure 3: Valve control curve in DC mode.

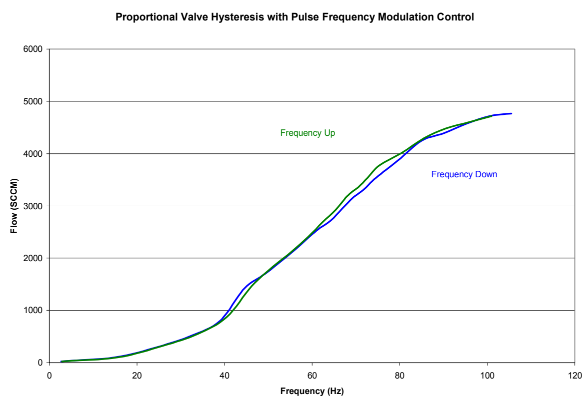

Figure 4: Valve control curve in PFM mode.

In addition to improving the hysteresis, we eliminated the need for the fixed 60 SCCM leak rate by setting a minimum control frequency on the vacuum valve. This emulates the fixed leak and insures that in the steady state pressure the control is being accomplished with the pressure valve. This concept is important because it minimizes the amount of helium gas that is recovered by the refrigerator system during normal operation.

FEEDBACK ANALYSYS

For the prototype, all of the flow and response characteristics were measured to calculate the optimal settings for the control loop parameters. Fig 5 shows the slow tuner feedback control block diagram. The valves and valve controller transfer characteristics are represented as dFl/dU, where Fl is the helium flow rate, U is the valve control voltage. The transport delay in our case was measured to be close to 100 msec.

The resonator helium pressure manifold can be considered as an integrator, where the pressure changes linearly with time as

$$dP = K \cdot t \cdot dF$$

Changes in the pressure result in resonator frequency changes dFr/dP.

The RF control module generates the frequency dU/dFr and phase dU/dPh errors by comparing resonator rf frequency and phase with the master oscillator rf signal.

Fig 6 shows the slow tuner open loop Bode plot for the stable operating region.

Fig. 7 shows the improvement in the frequency slew rates between the old system and the new prototype system.

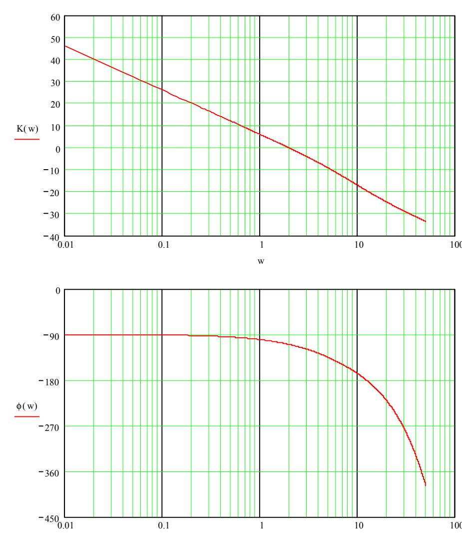

Figure 6. Slow tuner system open loop Bode plot for the stable operating region.

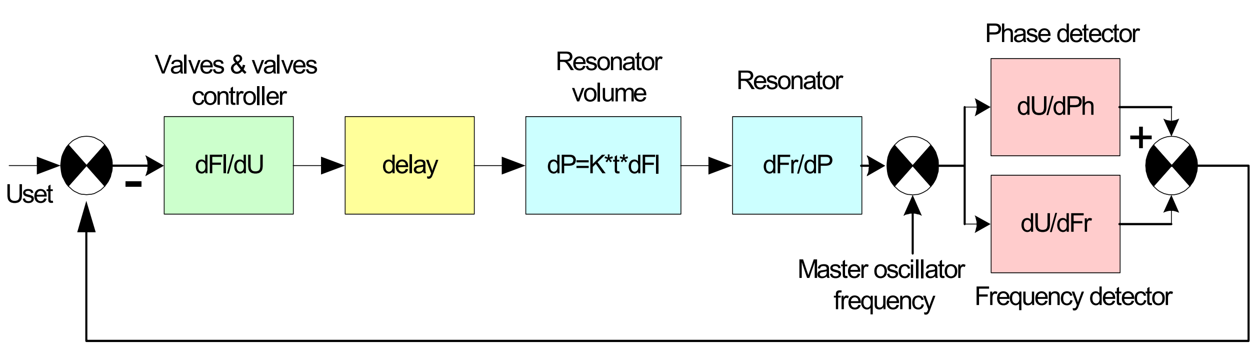

Figure 5. Slow tuner system control block diagram

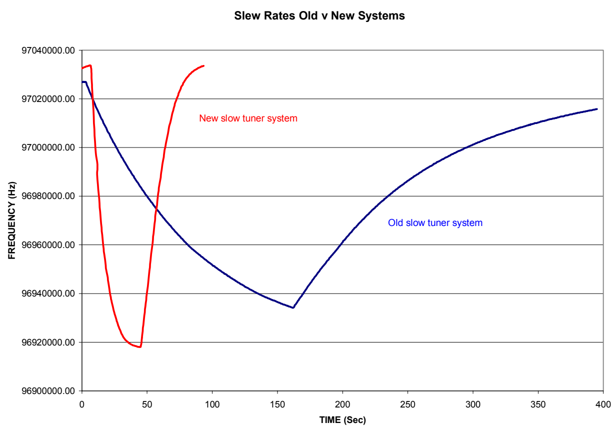

Figure 7: Improvement in the frequency slew rates between the old system and the new prototype system.

CONCLUSION

The prototype control system was demonstrated using an on-line superconducting cavity. It operated stably during this test period. Installing this new system on all of the ATLAS cavities will dramatically reduce the time to lock up the cavities. This type of tuner control is applicable to any superconducting cavities that require an active tuner.

REFERENCES

[1] Internal Laboratory document, “A Proposal for a Precision Heavy Ion Accelerator at Argonne National Laboratory” Feb. 1978, p.35