MULTIPLE CONTROL FOR FEEDBACK TUNING OF THE ADVANCED PHOTON SOURCE STORAGE RING/BOOSTER RF CAVITIES

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Abstract

A method for tuning rf cavities that has fewer rf reflected power conditions and is easier for accelerator operators to use is presented. This method will also prepare the rf cavity tuning for future higher beam currents. The results and installation methods are discussed.

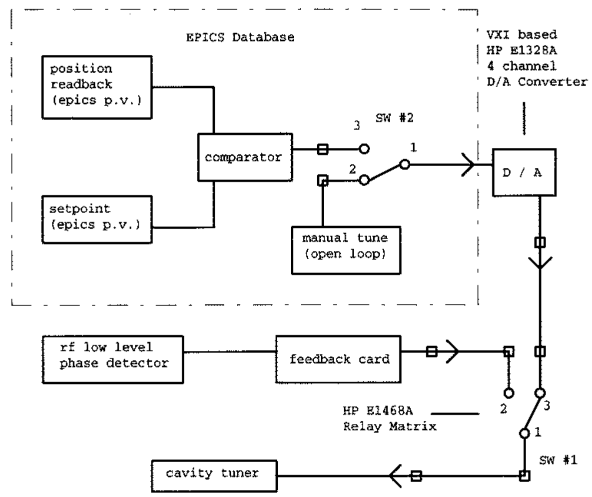
1 INTRODUCTION

The Advanced Photon Source (APS) is a 7-GeV synchrotron radiation facility. The storage ring uses sixteen single-cell rf cavities, and the booster uses four, five-cell rf cavities [1]. These cavities employ a plunger-type tuning system. At present, if the rf drive to these cavities is turned off or tripped off, the tuner movement is electronically inhibited to prevent the tuner from racing to either limit. In the absence of rf, the cavity water cooling system will quickly return the cavity resonance to its original “cold state” condition. When rf is returned to the cavity, the tuner will be at the wrong position and a certain amount of reflected power will always occur until the tuner phase loop can correct the tuner position. A system has been devised using VXI-based relay matrix cards and additional feedback loops that will drive the cavity resonance back to the “cold state” condition when the rf is removed. Several control modes, including a method for manual control of the tuners, have been built into the system. The storage ring single-cell cavities are divided into four sectors (sectors 36, 37, 38, and 40), each employing four cavities. This multiple control feedback tuning design has now been installed in sector 38. The other sectors will be updated in the near future. The following information is derived from the sector 38 data.

2 TUNING CONTROL

The cavity tuner uses a gear-driven potentiometer that varies with the tuner position and can give a voltage readout which corresponds to the tuner position inside the cavity. With the rf off, the tuner could be tuned to a position where the cavity resonance would match the storage ring rf drive frequency and the potentiometer reading noted. This is done for each cavity and the voltage readings are used as *setpoints* in the “cold state” tuning loop (see Figure 1). From this point on, these numbers will hold valid if the cavity volume is not disturbed, the cavity cooling water temperature is held constant, and the storage ring rf drive frequency does not change.

In normal operation (rf on), for each cavity, the output of low-level rf phase detection circuitry indirectly drives the tuning plunger. A VXI-based 8×8 relay matrix card is



	SW #1	SW #2
RF On (Normal Operation)	1 - 2	X
RF Off	1 - 3	1 - 3
Manual Tune	1 - 3	1 - 2

Figure 1: Tuning control for each cavity.

electrically inserted between the rf phase detection circuitry and the tuner input (see Figure 2). Depending upon selection, the manual tune control *or* the output of the cold tuning loop drives one channel of a four-channel, VXI-based D/A converter. This D/A converter will drive the tuner, through the relay matrix, unless the rf low-level phase feedback loop is selected for control.

These selection processes take place in the software via the EPICS control system [2]. *The tuners are never allowed to freerun.* Power levels per cavity are monitored, and if the level drops below a certain adjustable value, normally set at approximately 900 watts, the software will assume the rf is off. This condition will switch the relay matrix to the “cold state,” allowing the cavity tuners to quickly tune to a preset condition and wait for the return of rf. Each cavity is judged individually. If that cavity rf drive level is above 900 watts, the cavity tuner will be instantly controlled by the low-level rf phase loop and tune accordingly, negating the changing cavity resonance effects caused by the rising cavity temperatures.

The selection of manual tuning control will be used infrequently and for experimental purposes. The manual tuning of an rf cavity at high power could easily result in a high reflected power condition, the tripping of an rf system, and the loss of beam in the accelerator. It is the

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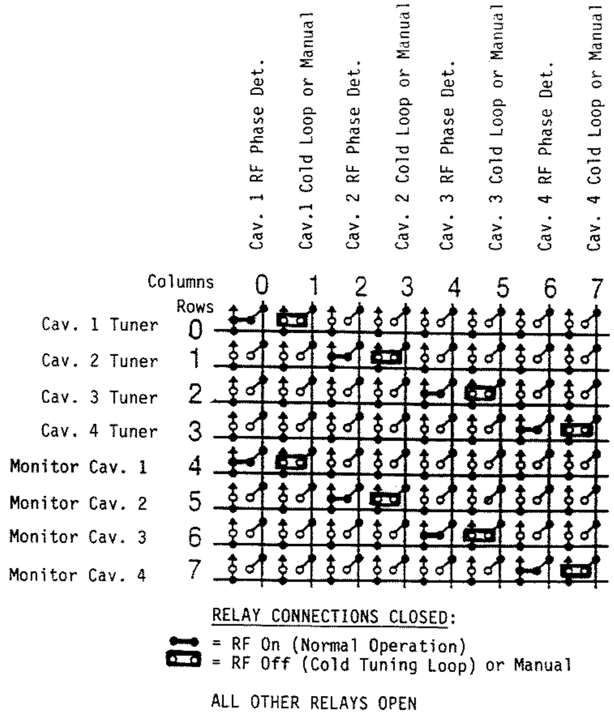

Figure 2: Relay matrix connections.

responsibility of the person selecting manual tuning to guard against this situation. To prevent operators from selecting manual tuning for cavities under power and accidentally leaving these cavities unattended, the following processes have been implemented in the software to aid against possible high reflected power conditions:

1. If rf is on (rf phase detection loops active), when rf is turned off or tripped off, all manual tuners will be automatically put back into auto, reset by the cold tuning loop, and wait for the return of rf.
2. If rf is off (cold tuning loop active), when rf is turned on, all manual tuners will be automatically put back in auto and tuned up properly with the rest of the sector.

3 CONTROL SCREENS AND OPTIMIZATION

Excluding the manual control, the changes in the tuning control in sector 38 have gone basically unnoticed to the operators since the rf phase loops and the cold tuning loops switch automatically. An existing operator screen has been modified for the addition of the manual tuning capability (see Figure 3).

An engineering screen for each cavity was added to make the parameter adjustments required for a timely stable lock up of the cold tuning loop (see Figure 4). A two-speed adjustable system is used for controlling the tuners. The setpoint is predetermined and stored in the database. The tuner position voltage is constantly monitored from the gear driven tuner potentiometer. The difference between the tuner position and the set-point is constantly calculated, and when it is above the fast range setting, the tuner will move in fast speed.

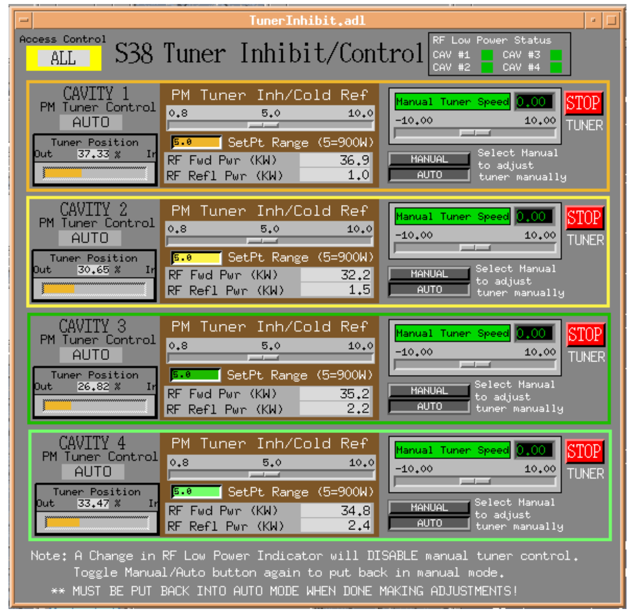

Figure 3: Operator screen for manual adjustments.

Tests were performed with a variety of adjustments, and a position showing the best overall speed and stability was obtained (see Figure 5). Figure 4 shows sector 38 cavity #1 in normal feedback control (rf phase loops on). If rf was turned off or tripped off, the cold loop would drive the tuner, and the tuner position would match the setpoint in approximately 2.5 seconds.

Figure 5 is one second per division and shows the lockup time of the cold tuning loop to be approximately 2.5 seconds. This time will change slightly with different power levels in the cavity. Channel 1 is a measurement of when the rf drive power leaves the cavity, prompting the cold tuning loop to begin. Channel 1 is the trigger for this measurement. Channel 2 is a measurement of the signal applied to the tuner input. The tuner is in fast speed for 1.3 seconds, slow speed for 0.8 seconds, and shows a tuner ini-

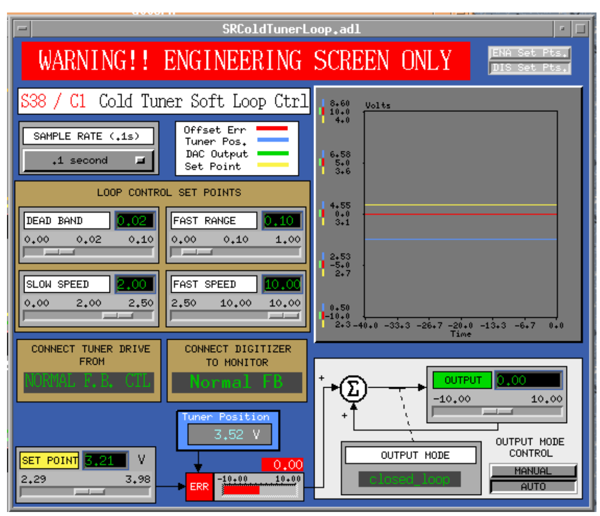

Figure 4: Cold tuning loop engineering screen.

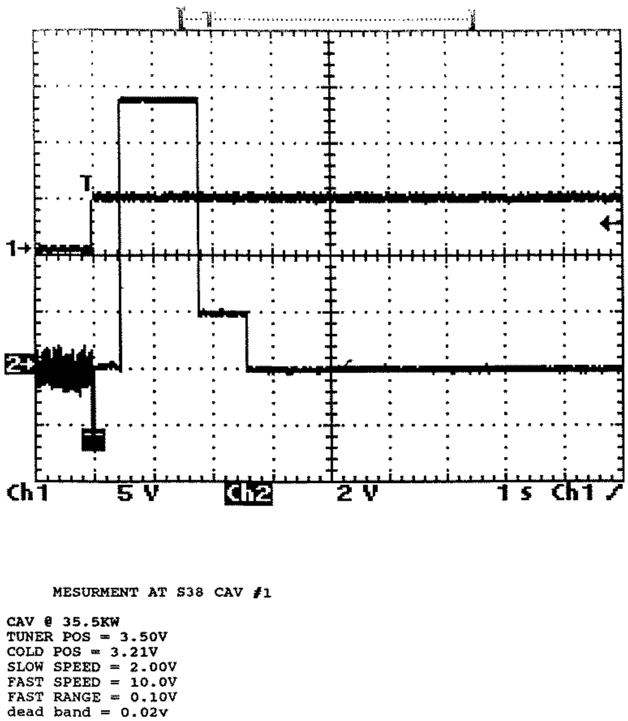

Figure 5: Lockup time of cold tuning loop.

tial response time of 0.4 seconds. This lockup time seems to be adequate, but a faster and more stable time could be acquired if more accelerator studies time was dedicated.

4 DISCUSSION

At the present time, the maximum beam current used in the APS is approximately 100 mA. The rf systems are running at high power levels to sustain this beam current. If the rf is turned off or tripped off in sectors 36, 37, or 40, the tuners will inhibit. When the rf is turned back on, some tuners will lock after a period of time and some will require manual help (by adjusting setpoints) to achieve phase lock. This problem will become increasingly more apparent as the accelerator beam current improves from 100 mA toward 300 mA.

At present in sector 38, all four cavities will automatically lockup and tune immediately upon the return of any level of rf.

5 ACKNOWLEDGMENT

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