Phase servo tuner control system of SSRF 500MHz cavity

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Abstract Eight 500 MHz cavities are applied in the storage ring of the Shanghai Synchrotron Radiation Factility (SSRF). In order to tune the cavities for different changing parameters and operation modes, the control system is essential for operations. The tuning is achieved by synchronizing the drive signal and the cavity probe signal. The error signal defined as their subtraction is amplified and used to drive a stepping motor, which in turn moves a metallic plunger in or out of the cavity by programmable logic controller (PLC). The tune speed is set to be 1kHz/s.

Keywords Cavity, Tuner, Programmable logic controller

CLC numbers TL594, TL503.6

1 Introduction

There are eight cavities in the SSRF storage ring. For each cavity, the tuning is controlled using a phase servo tuner control module. The tuner, a metallic plunger, is driven by a stepping motor and programmable logic controller (PLC). The driver accepts a bipolar input signal derived from phase detector in the phase servo tuner to determine speed and direction of rotation of the motor. The resolution of the stepping motor is 0.5 degree of rotation per step.

Fig.1 shows the block diagram of the control module. Most controls have been implemented with the capability of operating under local controls. All circuits are inserted into a standard 19 inch rack mount unit.

2 Tuner position control

The tuner attached to each of the accelerating cavity is driven simultaneously by a motor to compensate the thermal detaining and react beam loading. The tuning scheme is as the following: when beam is outside the cavity, the tuner condition of the cavity corresponds to the minimum reflection condition. Firstly it is to make the loop open, and second to search for the position of the minimum reflection by moving the tuner manually. Third, it is to adjust the output of the phase detector to zero by adjusting the machine phase shifter to the minimum reflection tuner position. Then the loop is closed for the actual operation. The loop measures the phase between cavity voltage and the input RF voltage, which drives the

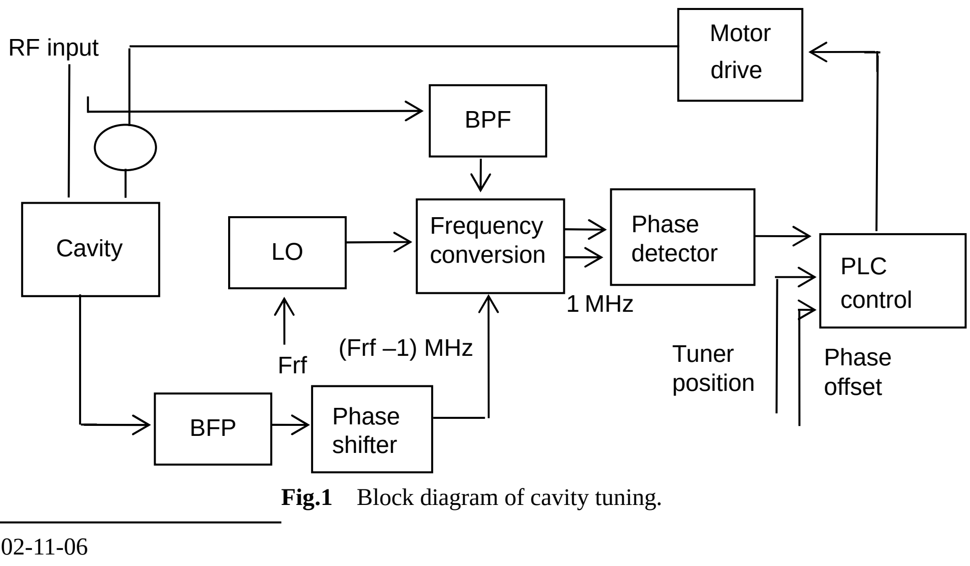

Fig.1 Block diagram of cavity tuning.

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motor to move the tuner. The bandwidth of this loop is of the order of 1 Hz. All of these requirements are essential for the entire accelerator RF system. Also known as, the individual RF system needs tighter control margin than that. In the actual this machine is operating at 3 degree phase offset.[1] The cavity tuning is performed by a deformation of the cavity in the direction of its axial length. The frequency loop controls the step motor, which drives the tuning cage. The tuning signal is given by a 1 MHz phase detector. The large distance of tuner is 92 mm. The sensitivity of tuning frequency for tuning plug is about 50 kHz/mm. The tuner speed is 1kHz/s. In fact the speed can be set by the PLC, and the speed is just limited by the motor and the driver. In the test, we tried to change frequency of the cavity through changing the environment temperature or just sticking something into the cavity. The results of the test are shown in Table 1.

The tuner position can be set either locally or remotely by the PLC. The total travel of the tuner is approximately 100 mm. A pot attached to the tuner provides the feedback signal for the control module. The two electronic limit switches of the tuner are set by two adjustments in the control module, which shuts down the drive to the motor below 20% and above 80% of the travel. A drive signal is able to put the tuner back in the normal operating range by activating one of these switches. The two mechanical limit switches in the tuner provide additional insurance to protect the tuner from ramming the end points of the travel. The tuner can be restored to the operating range by two push button switches with a logic circuit, if these mechanical switches are activated by accident.

A retuned position setting has also been implemented to bring the tuner back to the tuned position at any time by activating the retuned switch; this is particularly useful in case the tuner is at some arbitrary position during an interrupted operation.

3 Tuning the cavity

A reference signal and a RF sample signal from the cavity are required to produce a tuner correction signal with a phase detector (PD). The PD is a key component, which, designed and made by us domestically, converts the RF frequency 499.65 MHz to intermediate frequency 1MHz. The sensitivity of PD is 50 mV/degree. The detector range is $\pm 180^{o}$.The cavity tuning is performed by a deformation of the cavity in the direction of its axial length. The frequency loop controls a step motor, which drives the tuning cage.

In the reference signal path, a mechanical and an electronic phase shifter together with an attenuator are put in series for phase and amplitude offset and adjustment purposes. The RF signal for the signal port is derived from the cavity monitor. And proper attenuators are used to bring the signal level down to a range of +3dBm to +20dBm with the nominal level center around +13dBm at the signal input ports of the phase detector.

4 Phase detuning of cavity

An electronic phase shifter is used to adjust the phase of the reference signal in the case of closed loop operation either to fine tune the phase detector or to detune the cavity by offsetting the tuner to resonate the cavity at a lower frequency of approximately 10 kHz.[2] The detuning is used mainly to counteract instability due to beam loading. The detuned phase and detuned phase angle transfer functions were measured by observing the phase angle between the waveguide signal and the cavity signal while changing the detune bias.

The detuned frequency is calculated by the following expression:

$$\Delta f = \frac{a}{Q} \cdot f_0$$

where Δf is detuned frequency, a is a constant obtained from the universal resonance curve, Q the quality factor of the cavity and f_0 the resonant frequency.

The cavity in the storage ring has been operating

Table 1 Design performance and test performance of the tuner loop

Resolution (Hz)		Dynamic range		Dynamic response	
Design	Test	Design	Test	Design	Test
150	150	±30º	±30º	Tuning speed>1 kHz/s	Tuning speed>1 kHz/s

with a detune bias voltage of approximately 0.4V. The Q of the cavity is approximately 40,000. The best operating range of the phase shifter was found by selecting the proper bias voltage range. The local phase bias is set at the mid range of the phase shifter to provide enough room on both sides for the phase detune to work properly. However, under normal operation, the phase angle only needs to be detuned to the lower frequency side. Because the phase shifters used in the servo control modules have different transfer functions, it is expected to use different phase of the phase shifter for different case of detune, different case of detune voltages and for different control modules. However, all these can be solved by computer automatically.

5 Conclusion

One phase servo tuner controller module has been operating in the cavity test stand for over one year. The capability of PLC tuning of the cavity has been implemented. The result of high power test is as follows: the performance of low level system is good in the range of 185 ~ 420 kV. When this loop operates for more than 8 hours at one time, the stability of phase is less than 1 degree. The peak power in the cavity is greater than 20 kW, and the peak input power is greater than 25 kW.We foresee to get a better operating condition of the control system when the control loop and the interlock system are commissioned as a whole in the extensive test on the cavity. The problems, such as how to ensure the whole system, and to work stably at high beam current, will be researched and solved in the near future. Since the 50 Hz noise caused by the power supply and AC interference of harmonics are possible to directly influence the control precision of the loop, we will make more efforts to work out a solution.

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