LOW LEVEL CONTROL RF SYSTEM FOR SSRF

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Abstract

The low level RF control system is an essential component of the RF system for Shanghai Synchrotron Radiation Facility (SSRF). In the R&D of SSRF, one set of low level control system was developed. It consists of a 500MHz signal generator, three feedback loops, an interlock and protection system. This paper addresses the design of this system and mainly introduces the three feedback loops.

1 INTRODUCTION

In the current RF system design, 8 normal conducting RF cavities are used to provide 4MV RF voltage to the beam, each cavity will be powered by a 180kW klystron power amplifier and controlled by a low level RF system. The related parameters of the storage ring are shown in table 1.

Table 1: Storage ring parameters related to RF system

Beam energy	E	3.5	Gev
RF frequency	f_{rf}	499.65	MHz
Harmonic number	h	660	
RF voltage	v	4.0	MV
Beam current	I	300	mA
Energy loos/turn	U_0	1256	keV
Synchrotron frequency	f_s	6.9	kHz
Natural bunch length	σ	4.6	mm

In the R&D of SSRF, a high power RF system has been established, which contains a klystron and its power supply from THALES and THOMCAST, a circulator from AFT, a copper cavity borrowed from PF/KEK and low level RF control loops developed at SSRC.

The low level RF system consists of three feedback loops, a signal generator, an interlock and protection system. The design is basically similar to those of many other electron storage rings in the world, and is based on the use of conventional, well proven equipments.

2 FEEDBACK LOOPS

In the RF control system, the reference RF signal is generated by a master oscillator (HP4437B), which is located at the central control room. This system is comprised of three loops and an interlock system. The frequency loop keeps each cavity in a precision, which can be set to 150Hz. The amplitude loop keeps the cavity gap voltage stable within 1%, which acts on the driving power of the plant. And the phase loop keeps the phase stability of the output power of the RF plant within 1 degree at any power level. The interlock system is comprised of a fast vacuum protection, a RF switch and an arc detector. It can ensure the high power RF system work safely. The schematic diagram of the low level RF control system is shown in Fig.1.

2.2 Tuning Loop

The tuner is driven by an AC motor, to compensate the thermal detaining and react beam loading. The tuning scheme is as follows. First, make the loop open and search for the tuner position of the minimum power reflection by moving the tuner manually, since when the beam is absent, the tuner condition of the cavity corresponds to the minimum reflection. Secondly, adjust the output of the phase detector to zero by adjusting the machine phase shifter to the minimum reflection tuner position. And at last, close the loop for the actual operation. The loop

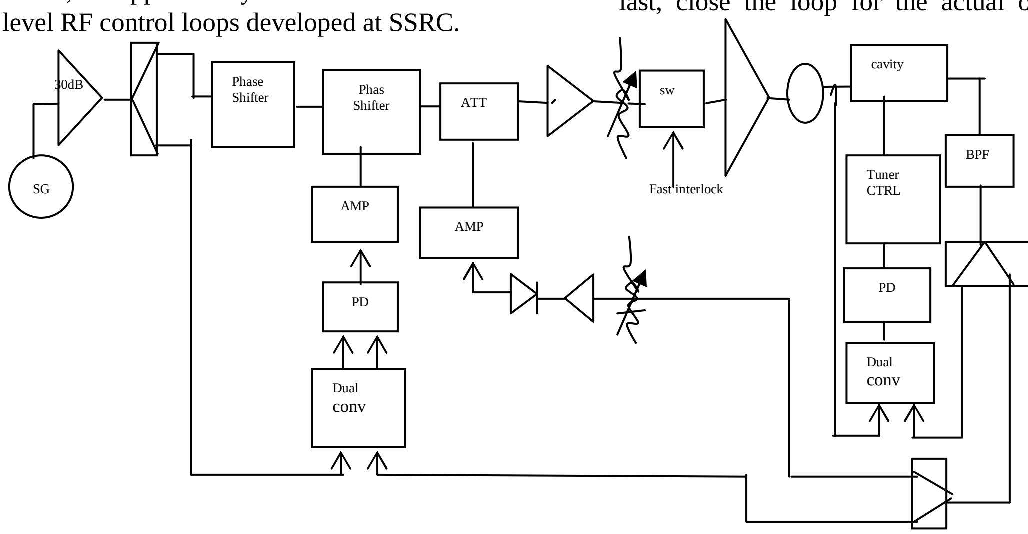

Fig.1 Block diagram of low level control RF system

measures the phase between the cavity voltage and the input RF voltage, which drives the motor to move the tuner. The bandwidth of this loop is around 1 Hz. The maximum tuning speed is 1kHz/s. 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 fact, this machine operates at 3 degrees phase offset. The cavity tuning is performed by a deformation of the cavity in the direction of its axial length. The frequency loop controls the AC motor, which drives the tuning cage. The tuning signal is offered by a 1MHz phase detector. The range of the tuner is 92mm. The sensitivity of tuning frequency of the tuning plug is about 50kHz/mm. The nominal speed is 1kHz/sec. Actually, the speed can be set by the PLC, and the speed is only limited by the motor and the driver. In the test, we tried changing the frequency of the cavity through changing the environment temperature or just sticking something into the cavity. The result of the test is shown in table 2.

2.3 Amplitude Loop

RF signals picked up from the end of the cavity, which belong to one control unit, are sent via phase stable coaxial cable to the control loops. The measured data of relative phase of these RF signals show that the deviations are small. The signals can be adjusted at the RF combiner using attenuators, whose attenuation accuracy is 0.1dB, and a machine phase shifter, whose accuracy is ±1°. The amplitude loop keeps the gap voltage constant by measuring the magnitude of the cavity field, comparing it to a reference voltage, and adjusting the electronic control attenuator in the main signal circuit. In the complicated condition, the power dissipated on the cavity surface will have to remain constant. The result of the test is listed in table 2. The bandwidth of this loop is also of the order of 1 kHz.

The RF amplitude linear detector works within±1% error over a range of 35dB, from the maximum 20dBm down to -15dBm. The gain of this feedback loop is between 20 dB and 40dB depending on the RF output level as mentioned in the previous section.

2.4 Phase Loop

This loop is to keep the phase of the fields in the cavities locked with the master signal generator. And in fact there is an error of phase shifter. The control precision should be less than ±1°. The phase loop will also compensate the phase change with the RF power variance, due to the power amplifier, the circulator, the klystron, the driving electronics and so on. The components of the driving electronics are designed to have a small phase variation over a wide operating range. The Phase Detector (PD), which convert the signal from 499.65MHz to 1MHz.is the key component. The sensitivity of the PD is 50mV/degree.The range of the detector is ±180°. The PD is a device with rather constant sensitivity against large power variations. The phase detection system work within ±1° error for the input power level between 0dBm and -35dBm.This will prevent the effect of amplitude modulations on the operation of the loop. Although the low level control RF system is designed to work with a close loop mode, the operation with open loop is also tested. This is useful during the final commissioning period. Now we have completed the bench test for every loop individually, and the last acceptance test has been done too.

All the components of the system, including the cables, connectors and so on, are completely tested to certify the specifications. For each plant, the low-level system is hosted in three racks. Two of these racks contain the frequency loop, and the phase loop. The third rack contains the remaining component of the low level RF control system .The system will be built in a modular way, which eases installation, maintains and operation.

Table2: low level performance

Loop	Design performance			Test performance		
	Resolution	Dynamic range	Dynamic response	Resolution	Dynamic range	Dynamic response
F_loop	~150Hz (adjustable)	±30°	Tuning speed>1kHz/s	~150Hz (adjustable)	±30°	Tuning speed> 1KHz/s
A-loop	1%	Phase ±30° Power 10dB	Recovery time (20%step)<10ms	1%	Phase ±30° Power 10dB	Recovery time(100%) <1ms
P-loop	±1°		Recovery time (20% step)<10ms	±1°	<0.5°	Recovery time (±30°)<1ms

3 INTERLOCK SYSTEM

This system is required to turn off the RF driver and high voltage power supply in the event of arcing in the cavity windows, the klystron window, or the circulator, which are very essential and expensive. Infrared photodiodes receive arc signals through radiation resistant optical fibre. A PLC implements the basic control function .A PC computer communicants with the PLC by a RS-232 port, and it also connects the local network. Various sensors and gauges are installed to measure the following factors: the temperature (cooling water, cavities, windows, circulators, water load, tuners), the pressure and flow (cooling water and air), the position of tuners, and connected with the I/O unit of PLC. The fast interlock runs in parallel and shuts down the system when a major fault occurs, independent on each other.

4 FAST PROTECTION

4.1 Arc detection

A 10m long fibre optic cable brings the arc detection light to the fast Interlock module. The detector is a Honeywell HFD-3854 PIN photodiode with a peak response wavelength of 850nm. Each channel has both adjustable gain and bandwidth setting jumpers. The fastest response time is about 1us. The slowest can be up to 10us.Slower settings enable controlled timing of the trip. The photodiode output is amplified in two stages to achieve a gain of about 135dB. Each channel has slow DC removal (>1ms) to allow the use of high gain without regard to the offsets that would normally restrict such a gain. Only fast transient light events are triggered. The unbiased response time of the photodiode is fast enough that no reverse biasing is required. The resulting speed increase from reverse biasing would be small compared to overall response time anyway, and dark current noise would increase. The noise equivalent power is approximately 0.05uW. The preamp output is buffered and available at the front panel of the external chassis for testing and monitoring purposes.

4.2 Fast vacuum protection

Fast protection is very important for system's safety at high power. Some high power components are expensive and sensitive, such as ceramic window, circulator and klystron. When some parameters of the system states (cavity voltage, forward power, reflection power, vacuum, etc.) exceed threshold or major failure occurs, it switches off the drive signal in prevent breakdown of components or paralysis of system. Arc Detectors for ceramic window fast Vacuum detector with 2-7ms speed are also included in this part.

5 CONCLUSIONS

The result of high power test is as follows: the performance of low level system is good in the range of 185kV~420kV.The peak power in the cavity is greater than 20kW,and the peak input power is greater than 25kW. We foresee to get a better operating condition of the control system when the three control loops and the interlock system are commissioned as a whole in the extensive test on the cavity. The problem how to ensure the whole system, including three low level control loop, to wok stably at high beam current, will be researched and solved in the near future. The 50Hz noise caused by the power supply and AC interference of harmonics will directly influence the control precision of the loops. So, independent power supply system is adopted for the low level RF system to avoid common line with magnet power supply, injector system and control system. One point ground and good shield are adopted in the system, and the interference between the stages and loops are avoided.

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