UPGRADED LOW LEVEL RF SYSTEM OF THE PLS STORAGE RING *

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Abstract

The upgraded low-level RF system of the PLS storage ring was installed in January 2002. The new system employs dual (inner and outer) amplitude and phase control loops. The inner loop operates mainly for compensation of RF signal phase and amplitude variations of klystron amplifier, and suppression of 60Hz harmonic noise from the amplifier. The inner loop has about 1 kHz bandwidth. The outer loop is active for controlling gap voltage and phase variation of the RF cavity. Bandwidth of the outer loop is about 100 Hz. The new system is consists of many modules that enable us easy maintenance. The new system has many monitoring points of RF and control signals for easy diagnosis. Design concepts and performance of the upgraded low-level RF system will be presented and discussed.

1 INTRODUCTION

The upgraded low level RF system at PLS storage ring consists of dual feedback control loops such as dual automatic phase control (APC), dual automatic level control (ALC), and a automatic tuner control (ATC) circuits. These circuits will ensure the required stability condition for the PLS RF system operation.

low power electronics control circuits use NIM modules. Four independent RF stations provide the RF power for four cavities with a 60kW klystron amplifier system per each station. The output power from each RF station is fed via high power circulator to the RF cavity. In the 2.5GeV operation, the dissipation of the RF cavity is about 20kW for 400 kV of accelerating voltage with a coupling factor of 1.8. The RF cavity dissipation should remain constantly through the entire range of operating beam current from zero to 180mA at 2.5GeV.

When the beam is demanding more power from the RF cavities, the automatic gain control loop should adjust the drive signal of the RF system to provide more power for the beam and keep the RF cavity voltage constant. As the RF signal must go through the low level RF system including three automatic control circuits and finally the klystron amplifier system, the phase of RF signal will vary with the RF output power level. Since the phase variation may give some effects on beam stacking, the phase control circuit has to correct it precisely to keep the phase constantly throughout the whole range of the operating power. In order to keep the four RF cavities on tune during the operation, each RF cavity tuner control loop controls a stepping motor to move the plunger in and out of the RF cavity to keep it on tune.

2 RF FEEDBACK & CONTROL

The upgraded low level RF system in an RF station consists of an automatic level control (ALC) and phase locked loop (APC) of RF signal, a cavity tuning (ATC), an interlock, and various monitor parts. The ALC and APC loops are implemented to stabilize the amplitude level and phase of the klystron output. They reduce phase variations due to cathode high voltage variations and eliminate the power supply ripples and noise around the synchrotron frequency.

Fig.1 shows the photograph of the upgraded low level RF systems for four RF cavities. The low level RF system for one RF station is housed in one 19” rack.

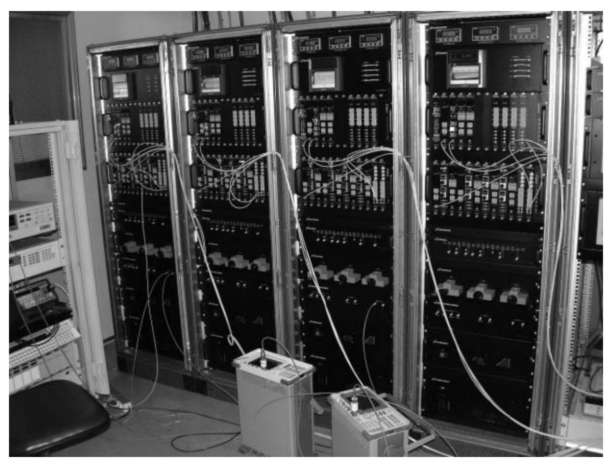

Figure 1: The photograph of the upgraded low level RF system

A block diagram of the upgraded low level RF system for one RF station for RF cavity is shown in Fig. 2. ALC and APC have a function to control klystron output power (inner loop) and cavity voltage (outer loop), and to lock klystron output and cavity phase, respectively. ATC keep the cavity resonating at RF frequency (500.076MHz) with a slight detuning offset by using a movable tuner. An interlock is to protect equipments and human life from break down, beam abort, and radiation

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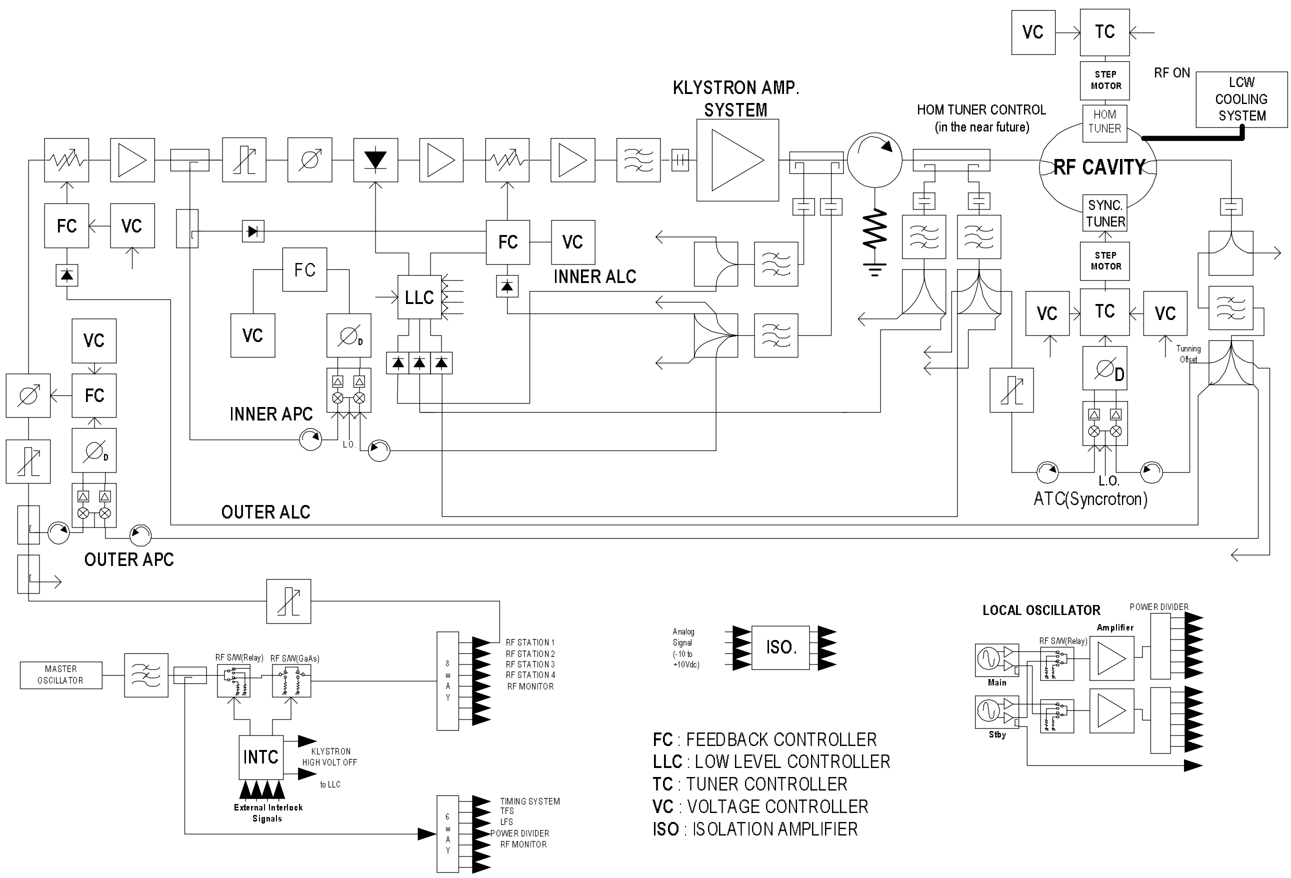

Figure 2: A block diagram of the upgraded Low Level RF System

safety. Various monitor ports are to measure the running condition and to respond to system failure

Low level control & monitor parts in low power electronics modules have manually inputs on the module too. Another role is to monitor the status of each high power circulator and cavity such as reflection power from the cavities and vacuum pressure. The upgraded low level RF system incorporates NIM type modules, which enable the easy maintenance of each module, and provides a large number of diagnostic points for the RF and control signal monitoring. At present, the upgraded low level RF system has been working well. The upgraded low level RF system is ready to control through Ethernet port using microprocessor with a flash memory and VME I/O. Then it is capable to input control values such as RF power, phase through Ethernet using personal computer.

The RF system will be operated by the computer control system based on EPICS in the near future. The computer through network monitors the operating parameters such as the RF power, cavity gap voltage and phase of every part, and takes appropriate action to keep the system working properly. For example, it can detect phase differences among the RF stations from unbalanced beam loading and will correct a phase of each station so that the balance can be restored. the computer interface also monitors the operating environment of the klystrons, circulators, cavities and so on.

The maximum voltage and current of the klystron power supply is 27kV and 6.5A, and AC power line frequency is 60Hz. Each power supply is a twelve-phase rectifier circuits (with ripple noise occurs at multiples of 720Hz): and the klystron power supplies in the four RF stations are phase-shifted by 7.5° from each other at their input transformer. Therefore, if each station is finely tuned and the four stations are balanced, equivalent 48-phase rectifier could be expected (with ripple noises in multiples of 2880Hz). In fact, there are some causes that disturb the balances, so that the extra harmonic components are excited in the power supply. During the test with beam, the amount of phase variation of the system is more than 5 degrees between operating power level of 20kW and 60kW. Low level RF system of the storage ring employs two pairs of amplitude and phase control loops. One is for the variation of the klystron high voltage power supply, called the inner loop, which is a fast loop with the bandwidth of below 1kHz. The other is for the gap voltage and phase variation in the RF cavity, which is a slow loop with the bandwidth of below 100Hz. With the automatic phase feedback loop, the phase variation is reduced to less than ± 0.5 degrees. With an automatic level control feedback loop, the amplitude variation of RF power into the RF cavity is measured to be less than ± 0.5% (0.039dB). At the initial phase, the operating power for the four cavities is 80 kW without beam. With beam current of 180mA at 2.5GeV, the total RF power required is about 180kW with transmission loss.

3 INSTABILITY PROBLEM

The primary function of low-level RF feedback system is to constantly control the amplitude and phase of cavity voltage even under perturbations from the components inside the loop. The perturbations are slow or fast. Fast fluctuations of cavity voltage occur, for example, due to gap transient. The low level RF system is designed to control only the slow perturbations such as beam amplitude change during beam injection and klystron power supply ripples etc. In control of the phase of cavity voltage, it is important to minimize the phase noise of RF signal, that is the klystron output. The low level RF system can reduce this phase noise by adjusting the gain and bandwidth of feedback electronics. The phase noise amplitudes in the range of 30 Hz - 35 kHz are below 60 dB from the main RF signal. Figure 3 shows the BPM signal spectrum when the phase is big or small. When the phase noise is big, shown in (a), and very large phase oscillations are observed in the frequency range to 1 kHz. By adjusting the feedback electronics, these oscillation amplitudes are reduced by factor of 4 as shown in (b)

The low level RF system is not able to maintain the amplitude of cavity voltage when the klystron output power approaches saturation, which is due to power gain reduction in klystron tube. This is observed in our system. We are investigating how to compensate the gain reduction of klystron tube with the feedback electronics. If the feedback loop fails to damp the perturbations, a big phase noise arises. This makes the amplitude of cavity voltage quite smaller than the setting cavity voltage because the pickup signal in RF cavity that is fed to feedback loop is polluted with these noise signals. This causes a reduction of effective cavity temperature and change of frequency tuner position. As a result, the frequencies of unwanted higher order modes in RF cavities approach the beam revolution frequencies so that the coupled bunch instabilities grow.

4 SUMMARY

The low level RF system was successfully commissioned in January 2002. And its stability and reliability was proven.

As the stability of RF system was greatly improved, beam availability was improved to more than 95% from 91% in this year.

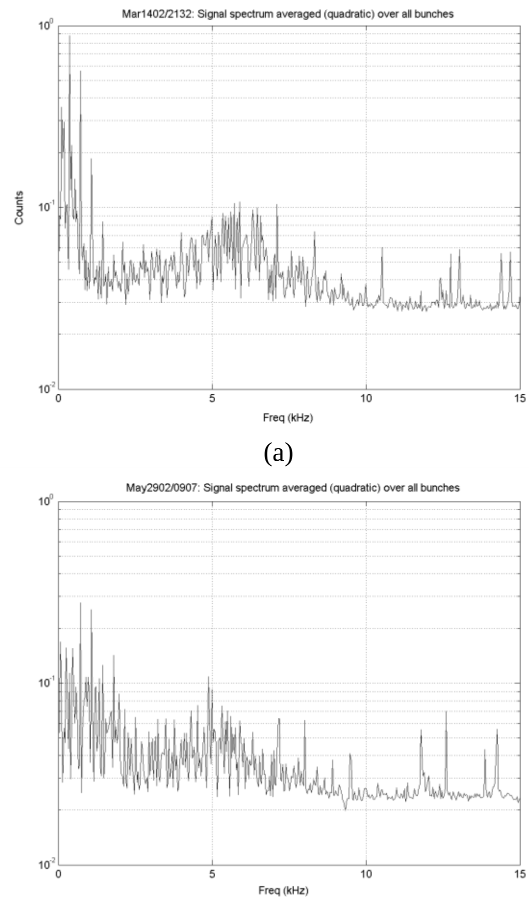

Figure 3: BPM signal spectrum when the phase noise is big (a) or small (b).

5 ACKNOWLEDGMENTS

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