LOW LEVEL RF SYSTEM FOR THE ANKA STORAGE RING

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Abstract

For the storage ring of the synchrotron light source ANKA, under construction at FZK Karlsruhe, Germany, an RF system composed of two 250 kW power plants, each one powering two 500 MHz ELETTRA type cavities, is foreseen. The low level system, based on ELETTRA experience, will include a frequency loop for each of the four cavities, an amplitude loop and a phase loop for each RF plant. The frequency loop will keep each cavity tuned with a precision which can be set either to 100 or 500 Hz. The cavity resonant frequency can be offset in comparison to the generator frequency to prevent Robinson instabilities. The amplitude loop will keep the sum of the two cavity gap voltages stable within 1 % acting on the driving power of the plant. Finally, the phase loop will keep the phase stability of the output power of the RF plant within 0.5 degrees at any power level. A general description of the system and the status of the design and construction is reported in this paper together with some considerations on the effects of the beam-cavity interaction on the whole RF control electronics.

1 INTRODUCTION

ANKA is a new 2.5 GeV synchrotron light source under construction at FZK, Karlsruhe, Germany [1]. Two 250 kW RF plants will provide the required RF power for the four cavities in the storage ring [2]. The low level RF system is composed of three feedback loops (frequency, amplitude, phase) along with the usual phasing and interlock systems. Beam is injected in the storage ring at 500 MeV and then ramped to the operating energy. Cavity effective gap voltage will be set at maximum at 600 kV, which means that the maximum wasted power will be 52.9 kW. Beam power for the design 400 mA beam current will be 66 kW per cavity. Beam loading strongly affects the operation of the RF plants. Amplitude and phases of the cavity fields must be kept stable during different steps of machine operation (injection, ramping, beam storage), which require different power levels from the klystrons and different tuning of the cavities. These beam loading effects will have to be compensated by the low level RF system. This system will be derived from the ELETTRA one [3], [4].

2 FREQUENCY LOOP

Four frequency loops, one for each cavity, will keep the cavities tuned by compensating for both beam loading and temperature effects. The calculated frequency shift for 400 mA and cavity effective gap voltage set to the minimum value (315 kV) is 54 kHz. If the voltage is set to the maximum value (600 kV), this decreases to 28 kHz. Cavity tuning is performed by an elastic deformation of the cavity in the direction of its axial length. The frequency loop controls a low inertia dc motor which drives the tuning cage. The nominal speed is 700 Hz/sec (i.e. 3.5 degree/sec), which could eventually be increased up to 1 kHz/sec. With the nominal speed, the maximum injection rate in the storage ring allowed by the RF system is larger than 5 mA/sec.

A block diagram of the frequency loop is shown in figure 1. The reference signal is taken from a waveguide directional coupler before the cavity input coupler. This is phase compared with two other signals (with 180 degrees phase difference) taken from the cavity. The sensitivity of the phase detector will be 10 mV/degree. The output of the phase detector is then filtered and amplified before being applied to the motor control unit. The sensitivity of the system (defined as the difference between cavity and generator frequency requiring an intervention of the tuner) can be set at either 100 or 500 Hz. To prevent Robinson instabilities, the resonant frequency of the cavity can be offset with respect to the generator by some kHz. Protection of the system is assured by window detectors which will stop the operation of the motor if the error signal exceeds some pre-set limits. In this case also an interlock signal is generated which will be sent to the interlock switch of the plant. Limiting blocks are also used as a further safeguard in case the window detector fails. The operation of the tuner is inhibited until the error signal exceeds a pre-set threshold level: this avoids undue operation of the tuner. Operation of the loop is also inhibited in the absence of RF drive or if the cavity is not in operation. The position of the tuning system is also provided both locally and remotely: this will provide an indication of the working frequency of the cavity. The open loop 3 dB bandwidth will be 200 Hz and dc gain will be 36 dB (100 Hz option) or 23 dB (500 Hz option). The choice of the frequency loop working parameters is very much related to the operation of the cavity cooling system. In fact the time constants involved are comparable and hence this could lead to an unstable operation. Obviously, uncompensated detuning of the cavity means a decrease in the wasted power and consequently a fast decrease in the cavity temperature and vice versa a change in the cavity temperature requires an intervention of the cavity tuner. The cavity cooling system is similar to the ELETTRA one and also the frequency loop working conditions. For this reason no problems coming from the interaction of the cavity cooling system and frequency loop are expected. Of course a fine optimisation has to be done when the cavity will be installed. This will determine the final settings of the cavity cooling rack.

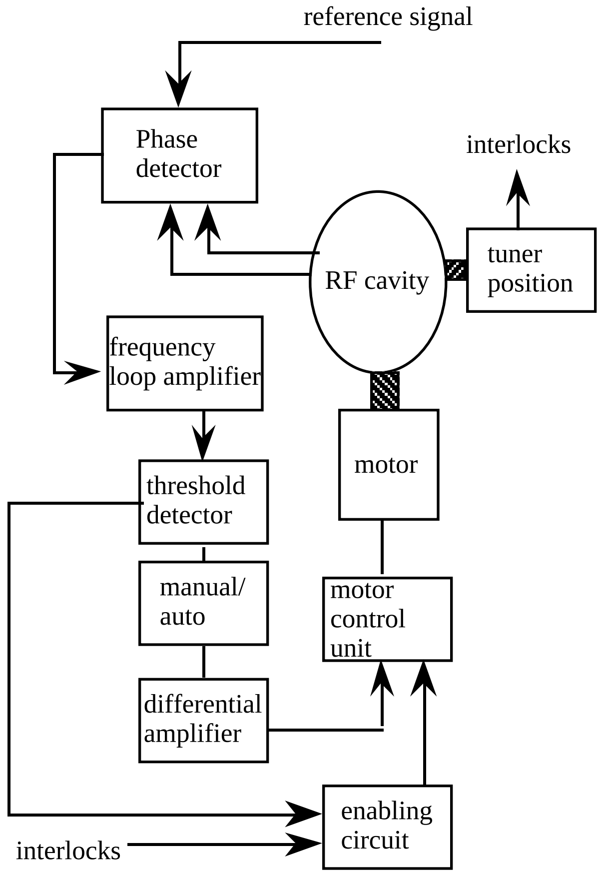

Figure 1: Block diagram of the frequency loop

3 AMPLITUDE LOOP

Two amplitude loops, one for each plant, will be installed. The amplitude loop will keep the sum of the two gap voltages constant in a 1 % range counteracting the beam loading effects, through the entire operating range of beam current and energy. It must be remembered that in ANKA the beam will be injected in the storage ring at 500 MeV and then ramped to the final 2.5 GeV energy. The RF power that each cavity will have to provide to the beam (400 mA) will then vary from a few hundred watts at injection to 66 kW when reaching the final energy. Then it will decrease according to beam decay. In all these conditions, the power wasted on the cavity surface will have to remain constant.

A block diagram of the loop is shown in figure 2. The gap voltage samples are taken with an inductive pick-up in each cavity. These signals are fine amplitude regulated to compensate for differences in the pick-ups and in the cavities. The amplitude detectors are full wave rectifiers. The detected signals are then sent to the amplitude loop board where their sum signals are compared to the reference voltage provided by the control system. The output of the amplitude loop board will drive a variable attenuator which regulates the input power to the klystron. Klystron working parameters are not varied by the loop. The variable attenuator is voltage controlled, linearised, with minimised phase variation over the entire attenuation range (±1.5 degrees over 20 dB, ±2.5 degrees over 30 dB). The open loop bandwidth will be adjustable in eight steps from 30 Hz to 4 kHz. The maximum bandwidth is actually limited by the synchrotron frequency of the machine (41.8 kHz in ANKA), so that there will be minimum interference with the operation of the loop. The open loop dc gain will be 30 dB and the recovery time will be less than 6 msec. The amplitude loop board will also provide a signal proportional to the difference between the two detected voltages which will be used for interlock purposes.

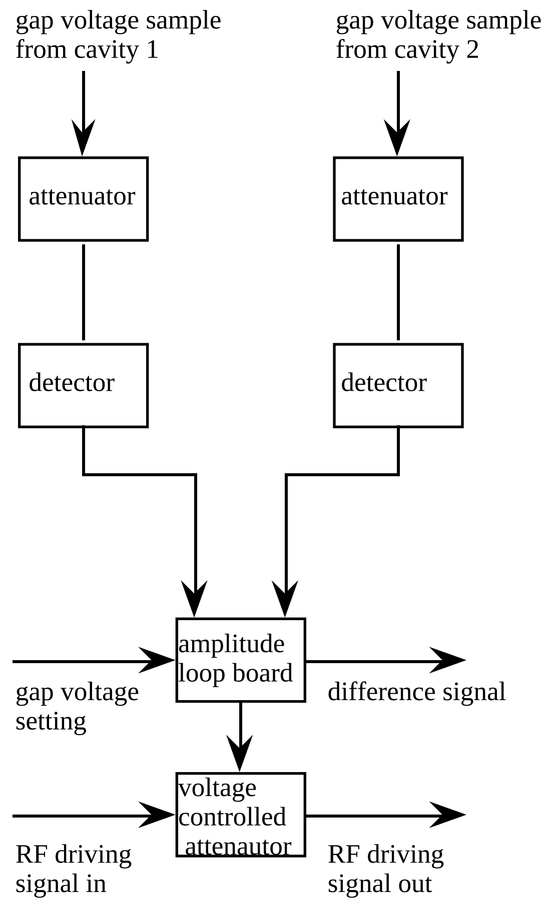

Figure 2: Block diagram of the amplitude loop

4 PHASE LOOP

For each of the two plants, one phase loop will compensate for phase changes in the RF power due to the power amplifier, the circulator and the driving electronics. The components of the driving electronics are designed to have a small phase variation over a wide operating range. The klystron will have a phase stability of ± 0.5 degrees at each point within the operating range of output power achieved. Therefore the main contribution to phase changes comes from the variation of the RF power required depending on beam current and energy. Phase variation can have some effects during beam accumulation: the phase loop will keep the phase constant within ± 0.5 degrees through the entire range of operating power.

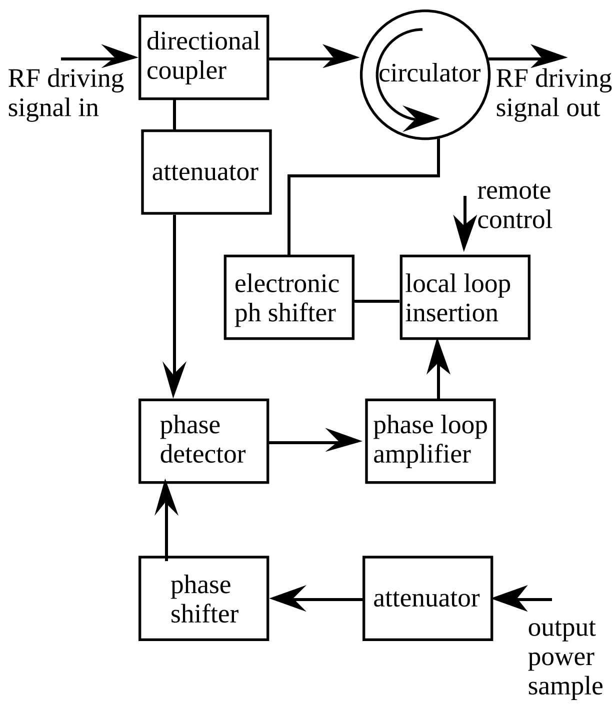

Figure 3: Block diagram of the phase loop

A block diagram of the loop is shown in figure 3. The phase detector is a mixer device with rather constant sensitivity against large power variations. This will prevent the effect of amplitude modulations on the operation of the loop. The reference signal for the phase detector is a sample of the plant driving signal taken with a low power directional coupler. The other input is a sample of the forward output power taken with a waveguide directional coupler in the power transmission line after the circulator. A phase shifter in this path is provided for fine regulation, so that the phase detector will work in the correct range. Two fixed attenuators are provided for fine regulation of the amplitudes to fit the operating levels of the mixer. The output of the phase detector drives an electronic phase shifter developed with minimised insertion loss. The open loop 3 dB bandwidth will be 1.4 kHz. This value has been chosen so to damp the klystron power supply ripple, being insensitive to the synchrotron frequency (41.8 kHz). In this way no interference with the loop is expected. The open loop dc gain will be 30 dB. Although the system is designed to work always in closed loop configuration, the operation with open loop is also foreseen. This will be useful during the first commissioning period.

5 OTHER COMPONENTS

The relative phasing of the plants will be achieved by means of a 500 degrees (at 500 MHz) mechanical phase shifter placed on top of each plant. The phase shifter will be remotely controlled and the movement will be achieved by means of a stepper motor. A coaxial mechanical RF switch will be used to enable the supply of the driving signal to each power amplifier. The switch will be connected to interlock signals for safety purposes. Vacuum interlocks from the cavities and the out of range interlocks from the frequency loops will be connected to this switch. Other interlocks signal will come from the power plant. For each plant the low level system will be hosted in three racks. Two of these racks will contain the frequency loop of each cavity. The third rack will contain all the remaining components of the low level system. The system will be built in a modular way, which eases installation, maintenance and servicing.

6 CONCLUSIONS

The construction of the low level system for the ANKA storage ring is in an advanced state and is proceeding according the scheduled plan. The electronic circuit boards have all been manufactured and the mounting of the components is now in progress. The first frequency loop is now under bench test. All the electronic components have been ordered and a large part of them already delivered. Each of the components is completely tested to certify the specifications. This will allow to have a complete characterisation of each component that will be part of the low level system. The acceptance test of the first frequency loop is foreseen for the beginning of November 1998. The acceptance test of the first amplitude loop and phase loop and the second frequency loop is scheduled for the beginning of January 1999. The last acceptance test is planned for the beginning of May 1999.

Although some optimisation could be possible during the construction phase, the parameters of the system can be considered quite definitive. They have been chosen by carefully taking into account the parameters of the machine, considering that the operation of the RF system is strongly affected by the loading due to the circulating current.

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