THE IMPACT OF THE LOCAL FEEDBACK SYSTEMS ON THE PERFORMANCE OF THE RACETRACK MICROTRON LINAC.

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Abstract.
Local feedback loops (LFL) of RF field amplitude and phase in accelerating section (AS) ensure safe and stable operation of the linac and quality of the beam, necessary for experiments. Modes of the LFL operation are controlled by front end computer of the computer control system (CCS). Digital feedback loop of AS temperature is closed through the CCS. In order to minimise ineffective operation of the RTM, a feedback system design cycle has been developed. Due to this procedure, we have find optimal parameters of the regulators as a result of a computer simulation of the feedback systems. An accuracy of the simulation permits a relative stability and a dumping ratio of real systems in the operating mode of the RTM as soon as LFL are placed. It is possible to change elements of the systems quickly in spite of system's transmittance parameters can differ strongly. The results of the testing of the linac operating conditions with open and closed LFL are represented. The main internal and external sources of disturbances were analysed. Respects for future improvement of the system on the basis of digital signal processors are discussed.

INTRODUCTION.

Modern accelerator - cw racetrack microtron (RTM) is under construction in the Institute of Nuclear Physics of Moscow State University. The first stage of the accelerator - 6 MeV linac have been successfully started in operation a few years ago. A confirmation that the linac is ready to operate was supported by accurate measurements of the beam quality [1]. The parameters of the injector beam are: maximum beam energy - 6.2 MeV; relative energy spread $\pm 3x10^{-3}$; normalised transverse emittance less than 5 mm x mrad [2]. Nuclear fluorescence experiments have been provided last year on the output beam of the RTM linac [3].

RTM LOCAL FEEDBACK SYSTEMS.

The quality of the output beam in RTM depends on an accuracy of computer simulation and manufacturing of different accelerator's parts and reliability of CCS, including top and bottom levels, hardware and software.

Local feedback systems form bottom level of CCS and ensure safe, reliable and exact operation of RF system of the linac [4].

Three main RF parameters: RF field amplitude, phase shift between RF reference and RF field in AS and self frequency of AS cavites, influence the process of the particles accelerating. Therefore, there are three different local systems that adjust the parameters during the operation of the accelerator.

The self frequency of the section should be equal to the frequency of RF reference. Amplitude level and phase shift should be fixed and constant. The accurate performance of these conditions is impossible, therefore, it is necessary to determine an exaptable error for the RF parameters stabilizing. The error of RF amplitude may be approximately 10^{-3} of a relative error. The error of RF phase shift may have a deviation of approximately 1° from optimal phase shift. Possible self frequency shift depends on a quality of the cavities and ability of the RF system to stand up a high level of reflected wave.

BANDWIDTH OF FEEDBACK SYSTEMS.

Local control systems could be observed as different dynamic systems with internal bindings. A behaviour of any dynamic system should be observed in static and dynamic mode. Therefore, it is necessary not only fix the exaptable errors of parameters but to define bandwidth of closed and opened feedback loops. The bandwidth depends on physically realised disturbances in the systems, ability of sensors to fill and actuators to control the object and really existing disturbances in the system.

The first type of the bandwidth depends on a quality of the cavities (Q=7500) and is in the range of 1.5 MHz for amplitude and phase error.

The second type of the bandwidth depends on a construction of microstrip channel - RF detectors, attenuators, phase shifters and phase detectors and is in the range of 0.5 MHz.

The third type of the bandwidth has been the subject of many investigations. The experiments on studying of real disturbances have been performed during test operation of the accelerator and nuclear physics experiments. Computerised test bench has been designed for studying the dynamic parameters and behaviour of stabilising systems.

The general principle of the feedback system development is an identification of the plant or object and generating adequate mathematical model. Controller with definite control algorithm is designed on the next stage of development. The feature of RTM construction resides in impossibility to start up the RF supply system (one section or the whole accelerator) without proper feedback loops and computer control. Therefore, it was necessary to develop stable feedback system without previous accurate identification measurements. Some of the measurements of static characteristics and bandwidth of actuators and sensors, have been performed on the special RF test bench.

A synthesis of feedback loops has been done on the base of computer simulation of the plant and controller. We have received optimal behaviour of the systems immediately after starting up procedure. The feedback systems have been optimised under consideration of real disturbances during the accelerator's adjustment and the nuclear physics experiments preparing.

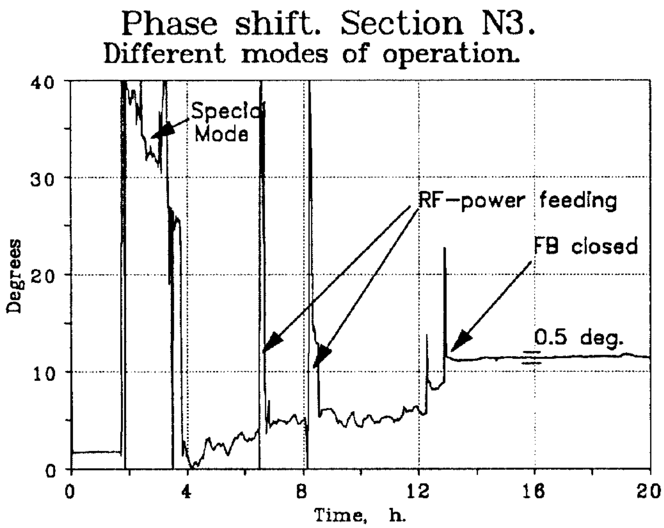

Fig. 1. Phase shift behaviour in time.

DISTURBANCES IN THE SYSTEMS.

To fix the demands for necessary bandwidth of disturbances suppressing, long time trends of parameters, average statistic characteristics and short time instabilities have been studied. Process of RF parameters restoring after short time emergency stopping have been investigated. An example of the phase shift behaviour in time on the section number 3 is shown on the Fig. 1. The "special mode" area corresponds to operation of the section in safe autoexitation regime. "RF power feeding" picks correspond to the procedure of RF power feeding in autoexitation regime and switching on external RF reference [5]. Point of "FB closed" means the closing of feedback loop and the beginning of normal accelerating of the particles.

The necessary bandwidth according to technical demands is 1.5 MHz. But all possible disturbances have a bandwidth with cut-off frequency not higher than 50 kHz. High energy harmonics of disturbances correlate with main frequencies of power supply sources - 50 and 300 Hz. Examples of RF amplitude low frequency spectrums with opened and closed feedback loops are presented on the Fig.2 and Fig.3. Two spectrums on each figure accord with operating of thyristor thermoheaters (TH), which stabilise temperature of coolant water [4]. One can see that TH operation raises disturbances approximately in two times.

Disturbances with upper frequencies (200-300 kHz) have been observed as a result of non-optimal operational regime of the klystron that caused the appearance of amplitude pulses with 10 mks fronts Fig. 4.

The trends (low frequency 0.01-5 Hz disturbances) appear as a result of thermo process after start up procedure from the "cold" state, regardless of the feedback loops are closed or opened.

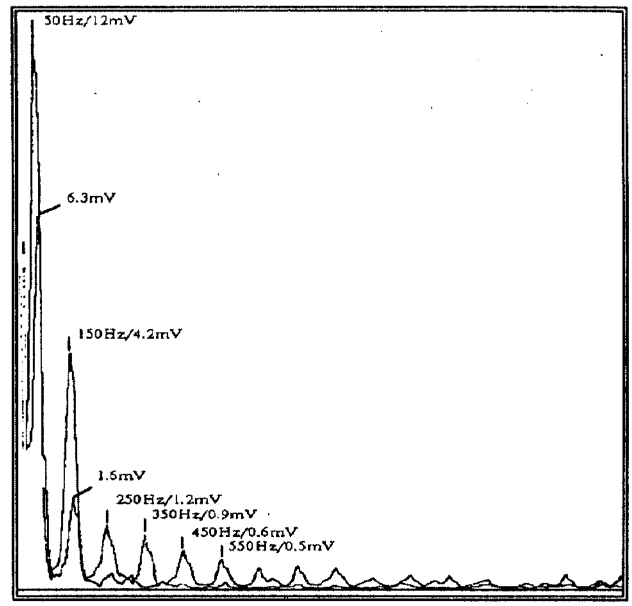

Figure 2. An example of RF amplitude disturbances spectrum. Amplitude feedback is opened. The spectrum with more high amplitude of harmonics corresponds to the operation of a thyristor thermoheater.

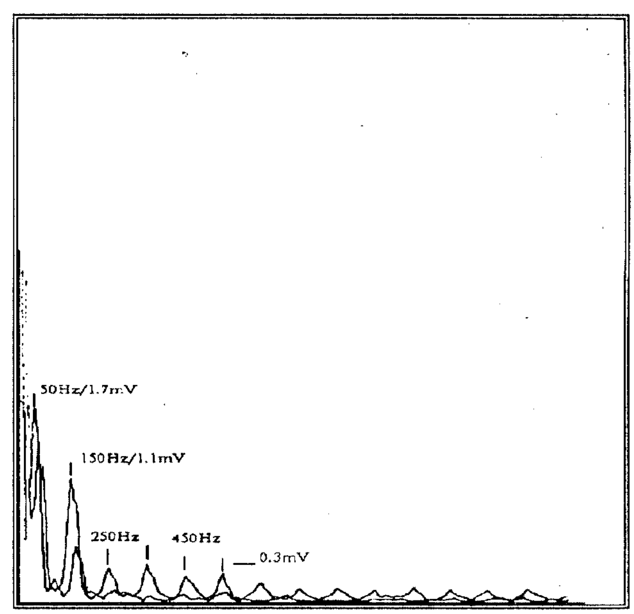

Figure 2. The same signal as in Fig.2, but amplitude feedback is closed.

The bandwidth of closed feedback loop equal to 50 kHz allows to achieve reasonable quality of the beam under normal RTM operation.

Now operating phase and amplitude analogue systems have the bandwidth equal to 2.0 MHz and proportional - integral control algorithm. The integral part of controller influences the bandwidth up to 20 kHz and suppresses low frequency disturbances. The proportional part suppresses the high frequency disturbances. The quality of the integrator ensures acceptable relative error of the average value of parameters. It has become possible after optimising of signal to noise ratio (S/N) in the closed loop. The S/N ratio should be less that acceptable relative error.

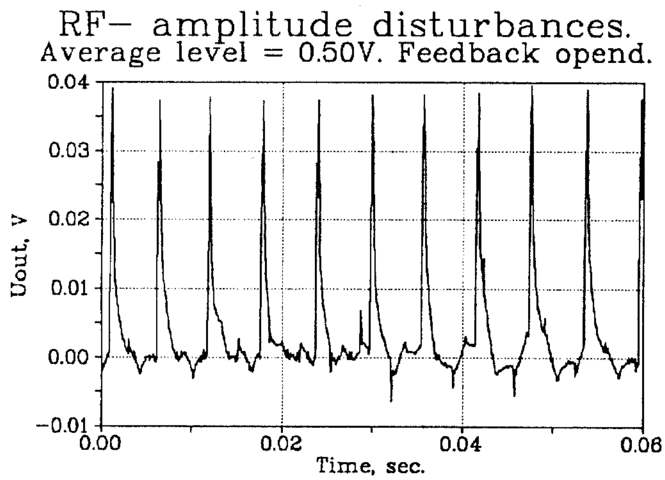

Fig 4. RF amplitude pulse disturbances as a result of non-normal regime of klystron operation.

UPGRADING OF FEEDBACK SYSTEMS.

Optimal parameters of the systems could be achieved in local area around a point of operation due to nonlinear character of object static characteristics. Furthermore, degradation processes in RF-devices change internal transmittance constants of the object.. Therefore it is very difficult to ensure long time (a few months) operation without repeating two or three times during the month procedure of feedback system adjustment. To solve this problem intellectual devices with direct digital feedback loops could be used. We are developing these devices on the base of digital signal processors (DSP). Performance of available DSP and achievements in the field of direct digital control algorithms admit to suggest that it is a fruitful way of local control system improvement [6].

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