PRECISION THERMOSTATIC CONTROL FOR LUE-200 ACCELERATOR SECTION

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Abstract

A two-loop thermostating system for the accelerating section of the S-band electron linac has been developed. To provide the required heatsink path and an opportunity of re-changing the section while altering the acceleration mode, the temperature in the system of the thermostat and the cooling water channel in the external contour are regulated. To achieve the required precision and stabilization time of the temperature of the thermostat having extended waterways (~70 m), the method of proportional-integral-derivative (PID) control has been applied. The programmed controller allows one to adapt the system for several operating modes: the fast warming up, operated establishment of temperature and thermostabilization, change of the preset temperature of the thermostat. It provides the reduction of setting time of the thermostatting regime, and also of minimization of errors and power consumption of the thermostat.

INTRODUCTION

The LUE-200 linac based on the traveling wave (2856 MHz) is used in IREN installation as the driver of a pulse photoneutron source [1]. For the LUE-200 thermal energy losses on RF-warming up of walls of the accelerating structure are about 30% of RF-power reached from the klystron, and in dependence on the repetition rate of cycles the losses can reach 10÷12 kW. The change of a of the accelerating structure temperature mode leads to displacement of its resonant frequency that results in the following: decreasing the mean energy of the accelerated electron beam, increasing the beam energy spread out and, eventually, decreasing the intensity of the neutron flux of the source. Influence of fluctuations of the temperature on the electron beam and, as a result, on the intensity of neutron flux is illustrated in Figs. 1 and 2, that was observed while adjustment of the accelerating section. Fluctuations of intensity of the neutron flux (Fig. 2) correlate on time with temperature deviations ±0.3°C (Fig. 1), repeating with a period of time of ~10 minutes.

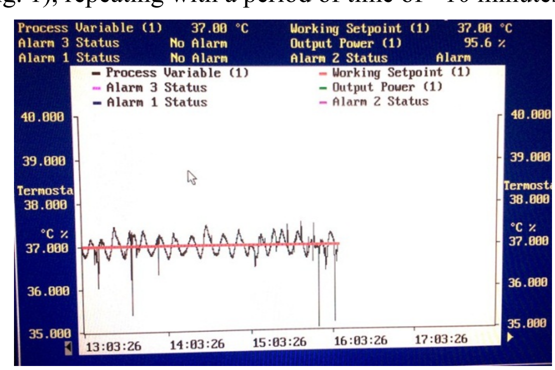

Figure 1: Fluctuation of the thermostat temperature.

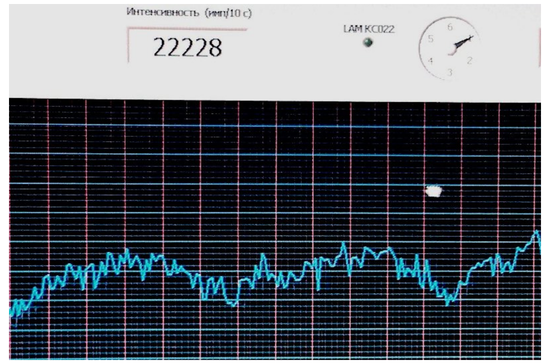

Figure 2: Fluctuations of neutron intensity.

THERMOSTATIC CONTROL SYSTEM

The Structure Chart of the Thermostatic Control

The structure of system of the thermostabilized cooling for the accelerating section is presented in Fig. 3.

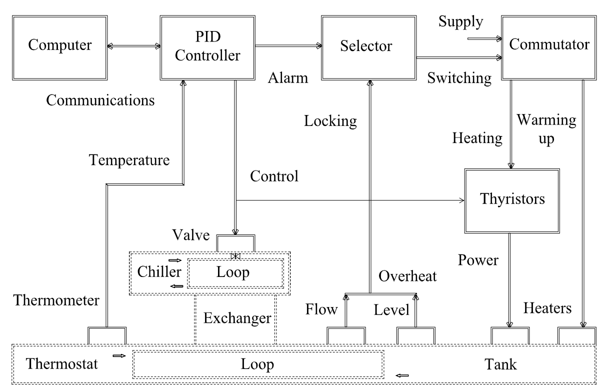

Figure 3: The system of thermostatic control.

The thermostat loop connects a tank of water heating, the thermostat, the heat exchanger, and also the built-in detector showing the lack of the water flow. The thermometer is installed at the exit of the pumped water from the thermostat. In the tank there are heaters and sensor controls of emergency overheating and the water level. The cooling loop joins a linac chiller and the heat exchanger, and, also, the built-in valve and the electric drive. Besides, the equipment for water mains has casual valves, pumps, etc.

The PID-controller (type 906S Eurotherm Controls) has measurement lines with the Pt-resistance thermometer and a control line. At the length of lines (~ 70 m) under the conditions of high-intensity noises the raised interference protection of the control unit is provided. The

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relays of the alarm system supervising the temperature conditions manage the mode choice.

Thyristor units (type 425A Eurotherm Automation) and the electric driven valve motor (type VBA-90 Clorius Controls) control the output power and the water flow.

The mode selector has been developed for diagnostics of the alarm state and also of the possible interlocks from thermostat warning devices. The unit provides turning on, checking out, heating interlock, and also mode switching. The commutator was built for switching the three-phase supply for thyristor units and heaters. The solid-state relays commutate the heating supply and warming up.

The computer and the adapted program [2] supplement the controller while adjustment of the system configuration and parameters. The program supports data accumulation and graphic representation [3] of thermostatic control processes (Fig. 4).

Figure 4: The monitor of the thermostatic control.

The process variable is shown while warming up, temperature settling and stabilising on the working setpoint. Change of the status of the alarm leads to switching off the warming up. Then the temperature goes to the preset level.

Basic Control Modes and Processes

The system controls not only heating of the distilled water, submitted to the thermostat, but also water flowing in the cooling system. To reduce the time of temperature setting in addition to PID-control, the fast warming up is carried out. The checking of temperature conditions and the choice of modes of the preliminary warming up, operated heating and thermostabilization, are performed for this purpose (see Table 1).

Table 1: Basic Control Modes and Processes

Mode	Temperature	Process
Warming up	Below Threshold	Sped Growth
Operated Heating	Up to a Setpoint	Settling
Thermostabilization	Near the Setpoint	Maintenance
Warming up Selection	Threshold 1	Mode Choice
Heating Selection	Threshold 2	Mode Choice
Heating Protection	Alarm	Locking

An impotent condition of mode selection is the predetermined level of temperature, a temperature threshold or an alarming state. Warming up or heating switch-off happens at the excess of the threshold temperature. Their reclosure is possible when the temperature is below the threshold on a hysteresis specified value. The programmed switch-off of heating protects the microwave section against excessive heating. Protection of turning on of the heating is possible at the diagnostic of conditions of emergency signalling and interlocking. At the chosen process conditions there is a speeded up rising of the temperature, warming up switch-off, smooth settling and temperature maintenance at the preset level, or interlocking of the thermostat heating.

Operating Sequence

The water temperature at the thermostat exit is measured with a sampling rate of 10 Hz. The controller analyzes the temperature change (concerning the predetermined level) and appoints the necessary PID regulation. By a warming up mode (at the beginning) all electric heaters of the thermostat are completely powered up, and the cooling valve is closed, therefore there is the fastest growth of temperature of the thermostat. At the subsequent settling and temperature stabilising the power of controlled heating decreases and the valve of cooling of the heat exchanger (used for the water temperature drop after the thermostat) is slightly opened. The settling time and the errors depending on inertia of the thermostat are minimised by adjustment of parameters of PID regulation. While heat-setting the steady-state level of temperature (and balance of heating power and compensating cooling) is maintained. Increase of RF heating-up level is compensated by the thermostabilized cooling system.

Figure 5 presents processes of establishing the temperature level and thermostabilization of LUE-200 accelerating section.

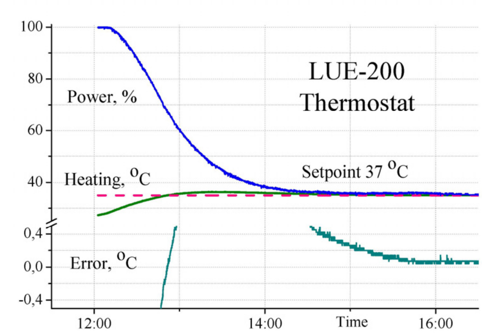

Figure 5: Processes of precise thermostabilization.

Changes of the controlled power and heating temperature (concerning the setpoint of 37°C) provide temperature error reducing up to 0.1°C.

Main Parameters of Thermostatic Control

The main system parameters, their typical values and some predetermined conditions of thermostatic control for

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the first LUE-200 section are given in Table 2. Variations of the temperature settling time and the bound errors depend on the regime variations of the accelerating section and cooling conditions.

Table 2: Parameters of Thermostatic Control

Parameter	**Value**	**Condition**
Thermostat Temperature	37°C	Working setpoint
Warming up Threshold	36.6°C	Below Setpoint
Settling Time	50÷200 min	Related Error
Error of Settling	0.1÷1°C	Time of Settling
Error of Stabilizing	Less 0.1°C	Integral time
Heating Threshold	40°C	Above Setpoint
Power of heating	0÷9 kVA	3 Heaters
Power of Warming up	6÷15 kVA	5 Heaters
Controlled Cooling	0÷3 kG/cm^2	Pressure

PID-regulating allows one to minimize the period of time and errors of temperature settling, and as the Table 2 shows, - to multifold improve the quality of regulating.

THE CONCLUSION

The precision system of a thermostatic control based on methods of PID regulation allows one to reduce errors of temperature setting and stabilization at the level below 0.1%.

The controlled heating and switching of warming up allow one to increase the range of the thermostat power from 0 to 15 kVA and in the result - to reduce the influence of instability factors. The power stock makes it possible to reduce the warming up of the period of time by 1.5÷2 times. Application of warming up and two loops for heating and cooling enable one to reduce the settling time of temperature and also the thermostat power consumption.

The system of thermostatting of the section is used in regular operating modes of the linac, both at short-term setting cycles, and at the long periods of operation.

The further development of the systems for the first and then - second accelerating sections of linac is related with step-by-step escalating of the beam power and frequency of start-up of the accelerator. The growth of the RF warming up accompanying the above mentioned, requires to extend the power regulation range and its adapted algorithms.

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