CONTROL SYSTEM OF STORAGE RING NESTOR LINAC

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NESTOR (New-generation Electron STOrage Ring) consisting of electron storage ring, injector and linac with beam energy 60−100 MeV was developed for X-rays source creating based on the use Compton laser radiation scattering on relativistic electrons. Linac control system was developed for linac operating control, which ensures electron beam current, energy and position control, linac systems parameters monitoring, modulator and klystron amplifier in abnormal operation modes blocking, current control in power supplies of magnetic system, phase and power of HF signals in injecting system control. Program and technical complex includes PC equipped with quick 4-channel ADC, synchronizing unit, microprocessor complexes for thermostatic system operating control, alarm system and magnets power supplies.

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1. CONTROL SYSTEM STRUCTURE

The special system (Fig.1) was developed for linac control. It controls the electron beam current, energy and position, defends accelerating and scanning systems from the damage caused by beam, blocks the modulator and klystron amplifier in the case of abnormal operation modes, controls phase and power of HF signals in injecting system and also controls power supplies currents of magnetic system [1]. The program and technical complex consists of PC equipped with quick 4-channel ADC (Fig.1), synchronizing unit, microprocessor complexes (ADAM-5510E) for thermostatic system operating control and magnets power supplies.

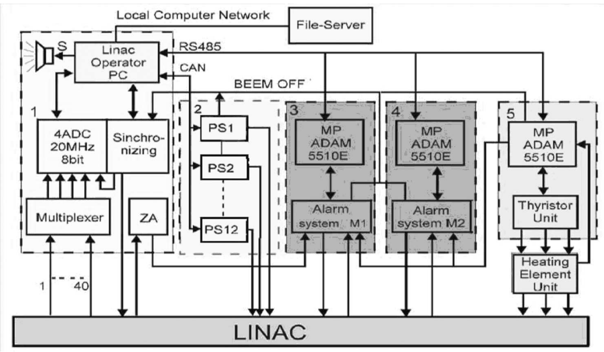

Fig.1. *Control system functional diagram of the "Nestor" linac. 1 - linac(LA) central control panel (synchronizing unit), PC, zone alarm unit (ZA), 4-channel ADC with multiplexer); 2 - magnetic elements power supply (PS); 3,4 -modulators and klystrons alarm system; 5- thermostatic system panel*

The multiplexer (MP) and 8-digits ADC receive signals from analog pulse sensors with 50 nsec period over 4 of 40 switching channels simultaneously. Linac system and beam parameters state data are transmitted to local unit terminals and color graphics display. Operator controls linac operation using PC keyboard and local control panels. Program modules ensure momentary or repeated system parameters check out or issue operating commands if necessary. Parameters of several systems are checked simultaneously and only one of them is controlled. Software operates in Windows environment. It was developed using visual object-oriented programming system C++Builder 5.

2. CURRENT AND POSITION OF ELECTRON BEAM OPERATIVE MONITORING

Linac is equipped with 3 magneto inductance sensors installed on linac input and output sections for value and beam pulse current geometry measurement. Sensors signals are used in control system for rating of amplitude and average current value. Sensors calibration is carried out periodically with help of test pulses trains from a special current generator. Position sensor with 4 windings is also installed on output of each section. This sensor detects beam center position [2].

The system includes:
- magneto inductance sensors;
- current pulse signals and beam center position amplifier;

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- cable signalling links;
- unit for connection unit with information and measuring system;
- amplifiers power supply.

Specifications:
- pulse duration - 1,5 μs;
- repetition frequency - 6−50 Hz;
- dynamic range - 20−100 μA;
- amplifiers power supply - 15V, +27V;
- channel number - 11;
- calibration - 3 channels.

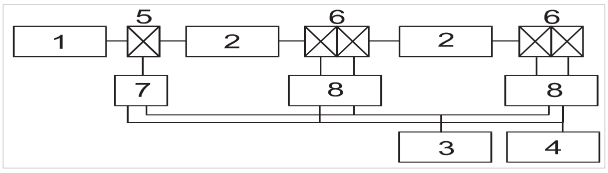

Fig.2. *System structure diagram. 1 - injector; 2 - linac sections; 3 - power supply; 4 -connection unit; 5 - curr ent sensor; 6 - current and beam center position sensors; 7 - current signal amplifier; 8 - 5-channel signal amplifiers*

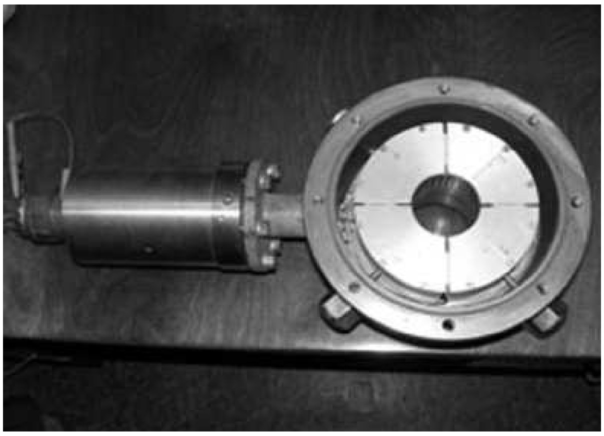

Fig.3. *Sensor appearance*

Main channel characteristics:
- measuring range 15-150 μA/pulse, ±10 mm along coordinates;
- current sensitivity 62.5 V/A;
- beam deviation sensitivity 1.75 mV/mA∗mm;
- sag of a pulse 3%/ μs;
- rise time $\leq 0.15\mu$s;
- noise threshold measurement 5.5 mA∗mm;
- sensor center binding accuracy ±0.35 mm.

3. SYNCHRONIZING SYSTEM

Synchronizing system of NESTOR linac forms frequency scale of pedestal pulses f_0 = 100, 50, 25, 12.5, 6.25, 3.125 or 1Hz. Operation startup frequency of EGM (electron generating modulator) modulator like of KPA modulator is f_0. KPA modulator starts twice at the pulse width 2.5 ± 0.5 μs, delay range from 0 to 10 μs with step 0.1 μs. The first 20 μs earlier pulse ensures KPA modulator preparation, second – operating pulse. Synchronizing unit forms frequency scale over 8 channels. Pulse amplitude is not more than 15 V, pulse width is 2.5 ± 0.5 μs, delay range is from 0 to 10 μs with step 0.1 μs. At synchronizing unit switching off operation delays data is not saved. When “Beam switching off ” alarm signal is received, the beam is to be switched off by additional delay of modulator startup pulse for 15±3 μs by alarm system or PC. At KPA breakdowns, ”0” signal of ignition units startup CI blocking for signal duration time is transmitted to synchronizing unit.

Synchronizing unit operates in continuous mode. F_o-frequency pulses are synchronized with power supply frequency 220V, 50±0,5 Hz. Synchronizing unit was developed using “ALTERA” PLD.

4. THERMOSTATIC SYSTEM

NESTOR linac thermostatic system ensures thermal stabilization of two accelerating sections and accelerating resonator. It consists of 11 temperature sensors (3 sensors – standby), 4 water flow through the object being cooled sensors and 2 water pressure sensors. ADAM5510E microprocessor and POT-63 triac controllers are used for sensors signals analysis and temperature control. Parameters data is transferred to local control panel and also via RS-485 interface to controlling PC, lock signals are transmitted in alarm system.

NESTOR linac thermostatic system is aimed at accelerating sections optimal sizes control. Unlike the previous developments, the described system has automatic control system and acquires data using PC - compatible ADAM-5510E controller. HMI-430 operator’s board is used for data readout and thermostatic system modes change. There are 11 temperature sensors, 3 water flow through the objects been cooled sensors and tank water level sensor in thermostatic system. Proportional-integro-differential (PID) law is used to improve optimal sizes accuracy of accelerated sections during temperature control. This permits to maintain accelerated section temperature accuracy up to ± 0.5 degree when linac operation modes change stepwise and in stationary mode at long-term fluctuations - up to ± 0.2 degree.

For PID algorithm realization next formula is applied [3]:

$$CO = KP \times ((TP - SP) \times (1 + Ts/Ti) +$$

$$+ Sn\_0 + KD \times (TP - PV\_0)/Ts),$$

where:
CO – PID controller output value;
KP – proportional factor;
KD – derivative factor;
Ti – integration time;
TP – measured temperature;
SP – temperature setting;
Ts – sampling time;

Sn_0 – integral component value at preceding step;
PV_0 – temperature value at preceding step. Data acquisition mode at temperature change of object under monitoring is provided for operator PC.

Fig.4. *Thermostatic system support*

5. ALARM SYSTEM

Linac alarm system is aimed at linac systems control and malfunction shutdown in case of equipment failure. It is provided with PC-compatible ADAM-5510E controller based control and automatic data acquisition system and quick blocking unit. Linac local control is conducted from klystron room HMI-430 operator's board and from operator's PC. The developed alarm system tests up to 64 incremental transducers of each linac section and has 16 discrete control signals.

In order to improve linac systems safe protection quick blocking module is used in alarm system,which ensures quick hight voltage switch off by sync pulses blocking. Conventional system de-energizes finally. Alarm system operates in automatic mode without operator interference, except linac parameters control, and in case of failure issues blocking signals. Linac parameters are to be set by operator depending on the task.
Linac operator controls alarm system from klystron room or from operator's PC. System service program operates in DOS 6.22 environment. It starts automatically at power supply switch on. This program checks and carries ADAM-5510E controller peripheral equipment (series modules 5000, serial ports RS232 and RS485 and others) initializing out. At failure detection the program goes to sleep in case of possible failure operational elimination, in others cases the program is aborted.

ZA is a self-contained system, which ensures linac accident-proof operation. It acquires room sensors data, switches linac systems off, switches audible and light signaling.

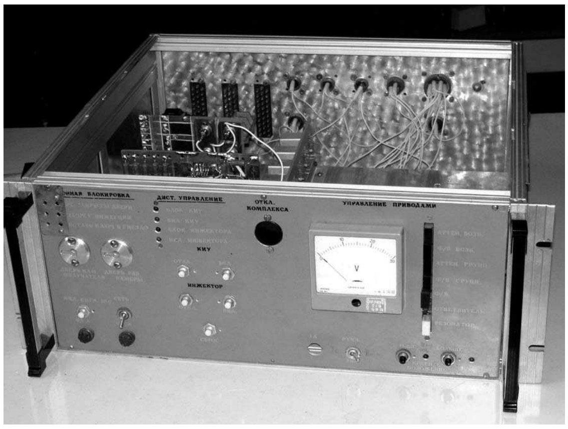

Fig.5. *Zone alarm unit appearance*

6. MAGNETIC POWER SUPPLY CONTROL

Marathon CAN DC power source is used for linac magnetic elements power supply, which are intended for distributed electric power supply system generation, the control is conducted over network with CAN interface, and also for stand-alone use with control over RS232 interface, or in manual mode.
DC power supply is developed in two versions: Marathon CAN-100/1 (voltage from -100V up +100V, current up to 1A) and Marathon CAN-30/5 (voltage from -30V to +30V, current up to 5A).

General performances:
- Output voltage and current for:
i. Marathon CAN-100/1 - from -100V up +100V, current up to 1A,
ii. Marathon CAN-30/5 - from -30V up +30V, current up to 5A
- Output voltage increment– 1μV;
- Output current increment– 1μA;
- Stability – 0.05%;
- Current stabilized mode;
- Output current limiting at voltage regulation;
- Current and voltage digital indication;
- AC power supply 220V;
- Operating temperature range: +5, +40° C.

Power supplies control is carried out in automatic and manual modes.
Control commands:
- Status poll (display monitoring of set voltage or current value, and also resistance of load);
- Set current and voltage stabilized mode;
- Set current or voltage value;
- Change current value for ±1, ±10, ±50 (current value controls in voltage regulation mode or voltage value control in current stabilized mode);
- To restore permitted voltage or current value deviation from the value,which was preset by operator
- Output voltage polarity change.

Automatic breakdown is anticipated at load resistance variation or at permissible voltage or current value exceeding.

Rack panel with power supplies is mounted in klystron room at 30 meters distance from operator's

control panel. Power supplies number :
- Marathon CAN-100/1 (voltage - from -100V to +100V, current - up to 1A) -10,
- Marathon CAN-30/5 (voltage - from -30V to +30V, current - up to 5A) –2.

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СИСТЕМА УПРАВЛЕНИЯ ИНЖЕКТОРА НАКОПИТЕЛЯ НЕСТОР

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Комплекс НЕСТОР, включающий в себя накопитель, инжектор, и ускоритель электронов с энергией пучка 60−100 МэВ был разработан для источника рентгеновского излучения на базе Комптоновского лазера на релятивистских электронах. Для управления работой ускорителя электронов разработана система управления, которая обеспечивает контроль тока, энергии и положения пучка электронов, контроль параметров систем ускорителя, блокировку модулятора и усилителя на клистронах при недопустимых режимах работы, регулирования тока в источниках питания магнитов, регулирования фазы и мощности ВЧ-сигналов в системе инжекции. Программно-технический комплекс состоит из ПК, оснащенного быстродействующим четырехканальным АЦП, блока синхронизации, микропроцессорных комплексов управления работой системы термостабилизации, УБС и источников питания магнитов.

СИСТЕМА КЕРУВАННЯ IНЖЕКТОРА НАКОПИЧУВАЧА НЕСТОР

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Комплекс НЕСТОР, що включає в себе накопичувач, iнжектор, та прискорювач електронiв з енергiєю пучка 60−100 МеВ був розроблений для створення джерела рентгенiвського випромiнювання на базi Комптонiвського лазера на релятивистських електронах. Щоб керувати роботою лiнiйного прискорювача електронiв розроблена система керування, яка забезпечить контроль струму та положення пучка електронiв, контроль параметрiв систем прискорювача, блокування модулятора та пiдсилювача на клiстронах при неприпустимих режимах роботи, регулювання струмiв у джерелах живлення магнiтної системи, регулювання фази та потужностi ВЧ-сигналiв у системi iнжекцiї. Програмно-технiчний комплекс складається з ПК, зi швидким чотирьох-канальним АЦП, блока синхронiзацiї, мiкропроцесорних комплексiв управлiння роботою системи термостабiлiзацiї та джерелами струму магнiтiв.