POWER SUPPLY CONTROL SYSTEM FOR THE LINAC OF THE "NESTOR" STORAGE RING

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Abstract

To create the X-rays source based on the phenomena of the Compton laser radiation scattering on the relativistic electrons it was a necessity to develop electron storage ring [1] and accelerator-injector with the beam energy 60-100 MeV [2]. The control system of the power supply for the electron linac magnetic system is described in the paper. Programmable current sources equipped with the intellectual CAN-bus (CANopen)[3] controller have been designed for the specific accelerator applications. The control system software was improved to operate with industrial CANopen protocol. The test results of current source are presented.

1 INTRODUCTION

"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.

The modern accelerator should have modern control system for reliable and safe operation and quick and efficient maintenance.

Such a system was developed for the linac control. It allows to control the electron beam current, energy and position, defends the accelerating and scanning systems from the damage caused by beam; blocks the modulator and klystron amplifiers in the case of abnormal operation modes; controls phase and power of HF signals in injecting system and controls power supplies current of magnetic system also [4].

The control system consists of the following logical units performed dedicated functions:

- beam monitor system
- synchronizing system
- thermostatic system
- alarm system
- magnets power supply control system.

To feed electric beam optic magnets the control subsystem based on intellectual power supplies have been developed. It is based on CAN-bus fieldbus with CANopen high level protocol which combine several specially designed intellectual power supplies in to separate subsystem but naturally integrated in to the whole accelerator control system.

2 INTELLECTUAL POWER SUPPLY

There are some features in control of accelerator magnet optics which make impossible to use standard industrial DC power supplies "as is" without extra efforts and use of additional hardware and control software. These features are the following:

- high long term stability and repeatability together with high accuracy;
- bipolar operation with accurate zero crossing and "true zero";
- load check function (detection of shortage, open, impedance changes) and alarm generating;
- load with high inductance;
- operation in a conditions of high level of external EMI
- flexible interface for embedding the power supply in to the existing control
- parallel operation of multiply devices.

It is also important to have a possibility of stand alone operation and operation as lab instrument to check lenses and magnets during commissioning and repairing procedures.

All these features was completed in specially designed smart DC power supplies in cooperation with Marathon Ltd. There are two versions of such a power supply up to now – "Marathon IPP-1/100" and "Marathon IPP-4/35 ". Power supplies are designed to be installed in standard 19" 3U cases in pairs in any combinations, two or one channels in one case (Fig.1). The single box version for lab applications is available also.

General specification is the following:

- two mode of operation – voltage or current tracking in the following ranges :
- "Marathon IPP-1/100" – 0V - ±100 V, current 0A - ±1A
- "Marathon IPP-4/35" – 0V - ±35 V, current 0A - ±4A
- Output voltage increment– 1*m*V
- Output current increment– 1*m*A
- Long term stability – better than 0.05%
- input voltage 220 V AC

The power supply could work in one of the three modes:

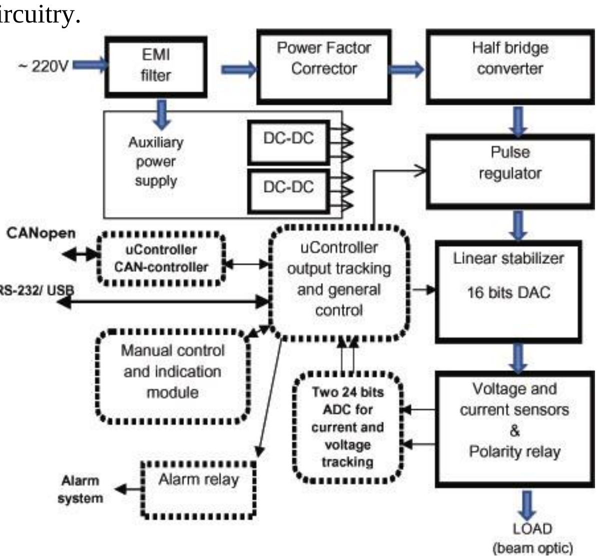
- Manual;
- RS-232/USB control;
- CANopen control.

The first mode is used in stand alone mode and in lab. The second and the third modes are used for computerized control. The second is used to control a few power supplies simultaneously, while the third mode is used to make distributed multi-channel systems with up to 200 power supplies in one network node.
Advanced front panel with LCD indicator and digital encoder gives access to all features of the power supply in manual mode.

Picture.1. *Power supply "Marathon IPP-1/100" – 2 channels, front and rear view.*

2.1 Power supply hardware.

The power supply was initially designed as a modular device with multiply stages of stabilizing, precise digital measurement and microcontroller control
The structure of the power supply is shown on the Picture 2. The power has input EMI filter and Power Factor Correction (PFC) module which ensures sinusoidal current consumption with 0.98% accuracy which decrease the influence of the device on to the power network. It is very important in the case of multiply devices working simultaneously within one local area.
PFC has the output voltage on the DC 386V level. Schematic of the module ensures to reach output power up to 300W which allows to make the power supply device with output power up to 250 Wt.
Half bridge converter is used as primary converter. It generates necessary secondary DC voltage and has galvanic isolation form the primary grid. This voltage is constant and depends on the input AC voltage only. There is no feedback control to stabilize DC output on this stage.
To extend output range of the power supply and decrease the total power consumption pulse stabilizer is used. It tracks and stabilizes input-to-output difference of the linear stabilizer
Linear stabilizer has standard schematic with negative feedback and could operate either to stabilize current or voltage. Two 16-bits DACs are used to set offset in the feedback to control output voltage or current depends on the mode of operation. If the voltage stabilizing mode is selected but output current exceed the alert level which is settable, than the devices switches itself to the current stabilizing mode. Output circuits of the power supply have precise components for current and voltage measurements and relay for polarity switch. Output voltage set to zero automatically while polarity is switched and restored to the requested value with programmable ramp.
Two 24-bits ADC measure output voltage and current continuously with necessary accuracy. ADC data are used by microcontroller for fine tuning of linear stabilizer.
So, to ensure the most important and critical parameter as output stability two control loops are used connected in parallel. The first loop is the analogue linear stabilizer and the second loop is the microcontroller measurement system which compensate the loop operation according to the measurement of physical output voltage or current. So, the stability of operation depends on the stability of passive components (measurement resistors) in output circuitry.



Picture.2. *Power supply hardware structure.*

Control and stabilizing controller checks all modules of the power supply, ensures stabilizing and sets mode of operation. It sends information to LCD indicator and processes manual commands from the front panel and commands coming from external interfaces. It also checks current and voltage limits and switches on alarm relay to control external safety circuits. External interface RS-232 which is used for external control is galvanically isolated.
The separate communication microcontroller is used to support operation in CAN-bus fieldbus with CANopen high level protocol.
Measuring and control modules of the device are galvanically isolated from each other and from powerful circuits.
Auxiliary internal power supply with isolated multiply outputs is used to feed separate modules of the device. This supplementary power supply is based on Marathons original DC-DC converters using planar transformers with small transit capacity which decrease influence of

different distortions on to the measuring and set-point circuits.

2.2 Power supply software.

Power supply firmware is stored in a flash memory of three microcontrollers dedicated for different purposes. One is for internal operational control and communication via RS-232/USB interface, the second is to support man-mashine interface via front panel and the third is to support CANopen communication protocol over CAN-bus fieldbus.

The software includes measuring module, man-mashine interface module, communication module with RS-232 and CANopen Slave options.

The software has modular structure which increase reusability of the code when new versions and extensions of functionality will be need.

The software of the power supply allows to fulfill the following control commands :

- Status poll
- Set current or voltage stabilization mode
- Set current or voltage value
- Set level of maximum current in voltage stabilization mode or maximum voltage in current stabilization mode
- Store setted values in central computer and restore presetted values from central computer

The software is developed with ANSII C and use CHAI source code and CANopen Slave sorce code from Martahon Ltd. to implement CANopen slave functionality. Segmented SDO protocol is used which aalows to transfer via CAN-bus ACII commands of any necessary length. All mandatory records of Object Dictionary and NMT functions are supported. Slave capabilities allow to combine multiply power supplies in to the CANopen networks very smoothly and use standard configuration and analyser tools to configure device behaviour in the CAN-bus network and trace logical network problems during whole system operation.

3 CAN-BUS BASED DISTRIBUTED POWER SUPPLY SYSTEMS

The control subsystem for beam optics magnets of the linac for Nestor storage ring was designed as distributed networked system based on CANopen high level protocol over CAN-bus fieldbus [5]. CHAI drivers and CANopen Master library from Marathon Ltd are used for control software development.

Power supplies could be used in automatic and manual modes. 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' control panel. The whole system consists of the 10 pieces of "Marathon IPP-1/100" power supplies, 2 pieces of "Marathon IPP-4/35", one Marathon CAN-bus PCI interface board installed in IBM-PC compatible computer together with system and application control software which is integrated into the software of the whole linac control system.

3.1 Power supply test results

Performance testing of power supply in real operational conditions was done in January 2007. The influence of the distortions from working and switching on and off modulator of the high power klystrons KIU-12 of the electron linac KUT-30 was studied on to the accuracy of the power supply operation. Magnet lens with the resistance 8,5 Ohm and inductance 900 mH together with 20 m of connecting cables was used as a load.

The following results of stability measured as the following value 3 * (roof-mean-square deviation)/(mean of sample) have been obtained:

- stability of the output current in the 200-4000 mA range not more than $2,8 \times 10^{-4}$
- stability of the output voltage in the 5-20 V range not more than $1,0 \times 10^{-3}$

4 CONCLUSION

Successful preliminary tests showed that selected hardware architecture and developed software allows to construct control systems for magnet elements of accelerators.

The big advantage of the approach is an ability to expand the CANopen network with another CANopen devices as power supplies as any type of CANopen-compatible instruments. Application of international standardized protocols allows not to be dependent on any one vendor of hardware components or configuration/diagnostic tools.

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