# CANOPEN CONNECTED POWER SUPPLY CONTROL SYSTEMS FOR THE ELECTRON LINACS

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*Abstract*

Power supplies, which feed magnetic systems of electron linac, together with the control system are very critical parts of any linac. The quality of power supplies and control software defines safety of the accelerator operation, stability and cost of operation. One of the today's tendencies in power supply system architecture is to use distributed CAN-connected power supplies with high level of local intellectual properties. These properties allow to achieve high stability, high safety of operation together with the specific features such as coil temperature check without any temperature sensors. Such programmable power supplies with the intellectual CAN-bus/CANopen controller have been designed for the specific accelerator applications. The control system software was adapted to operate with CANopen protocol. "Marathon IPP-1/100" and "Marathon IPP-4/35" power supplies with CANopen are used now within the control systems of LU-60m and LU-10 linacs. 3200 hours of continues operation were achieved since the year 2008.

## 1 INTRODUCTION

Power supply development was one of the important topic in particle accelerator instrumentation since particle accelerators appeared. Wide spread of different power supplies guarantee stable, safe and long term operation of any accelerator feeding directly magnet elements and feeding other electronic equipment such as vacuum pumps, RF systems and control system. A lot of efforts were made by different groups of accelerator specialists to improve mainly circuit technology in order to achieve the stability of the output values, high degree of efficiency, adjustable limitations of current, voltage and power stability of the output. In the meantime new types of power supplies have been developed – digital programmable power supplies, which could be directly interconnected and integrated into accelerator control system via different fieldbus interfaces such as CANbus.

There are two main approaches which are used today in distributed power supplies systems. The first one is based on modular architecture when control unit is independent and could process few different power modules [1, 2]. The control unit is usually equipped with one (or several different) fieldbus interfaces and realize control logic together with precise measurement and feedback control of power modules. The power modules in such approach are usually just high power (some time very high power) amplifiers of voltage or current, depending on application.

The second approach, that we have chosen, is to develop single channel power supply module as a separate device, based on modern power supply circuits and equipped with individual smart controller and digital interface. The controller provides measurements, stabilizing and locking capabilities. Due to standardized fieldbus interface CANopen, such devices could be combined together into separate power supply control system or with other CANopen compatible sensors and actuators.

To feed beam optic of the LU-60m linac [3,4] control subsystem based on intellectual power supplies "Marathon IPP-1/100" and "Marathon IPP-4/35" have been developed. Control system of the LU-10 linac was significantly improved by replacing existing powers supplies (B5-47/B5-49) with the new ones. All this power supplies systems are based on CANbus fieldbus with CANopen higher-layer protocol and form separate subsystem but naturally integrated in to the whole accelerator control system.

## 2 INTELLECTUAL POWER SUPPLY

There are several features in the accelerator magnet optics control tasks, 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 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 were completed in specially designed smart DC power supplies which Marathon Ltd manufactures. 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 specifications are 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 operates in one of the three modes:

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

The first mode is used for stand alone and lab applications. The second and the third modes are used for computerized control. The second one is used to control a few power supplies simultaneously, while the third mode is used to make distributed multi-channel systems with up to 127 power supplies in one network.

Advanced front panel with LCD indicator and digital encoder gives access to all features of the power supply in manual mode.

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

## *2.1 Power supply software.*

Power supply firmware is distributed between 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-machine interface via front panel and the third is to support CANopen [5] communication protocol over CAN-bus fieldbus.

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

The software of the power supply fulfills 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 source code from Marathon Ltd. to implement CANopen slave functionality[6]. Segmented SDO protocol is used, allowing transfer of ASCII commands of any necessary length via CAN-bus. All mandatory records in the Object Dictionary and NMT functionality are supported. Slave capabilities allow smooth combination of multiple power supplies into the CANopen networks. Standard configuration and analyzer tools are used to configure device behaviour in the CANbus network and trace logical network problems during whole system operation.

It is very important to notice that CANopen profile DS453 for power supplies is under development now within the activity of International organization «CAN in Automation» [7]. It could be downloaded by CiA members or requested by nonmembers from CiA web pages. Marathon Ltd. plans to implement this profile in next versions of their power supplies dedicated for accelerator control systems.

# 3 CAN-BUS BASED DISTRIBUTED POWER SUPPLY SYSTEMS

The power supplies, described above, were used to develop control subsystem for beam optics magnets of the linac LU-60m for NESTOR storage ring. The whole system consists of 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. In addition these power supplies were used to improve control systems of LU-10 which is used for industrial application.

## *3.1 Measurement of the magnet elements state*

The possibility to trace any changes of load parameters and measure current properties is very important especially for high current accelerators. Changes of load resistance due to shortages or breaks, when the average power of the beam is high, could cause vacuum crash and destroying of beam pipes. Presented power supplies realize a function of automatic beam breakdown and alarm signal generation at load resistance variation or at permissible voltage or current value exceeding.

Due to high accuracy of output current and voltage measurements, load resistance could be calculated, which ensures to calculate temperature of magnet elements, taking into consideration that magnet elements are constructed with copper wires The following formula, valid for $0 \angle T_i \angle 200$, was used and gives the temperature of lens or steer in Celsius degrees:

$$T_i = \frac{R_i - R_0}{R_0 * \alpha} + T_0$$
, where

$\alpha$ - temperature to resistance coefficient for copper,

$T_0$ - start temperature,

$R_0$ - load resistance while temperature is $T_0$,

$R_i$ - load resistance while temperature is $T_i$.

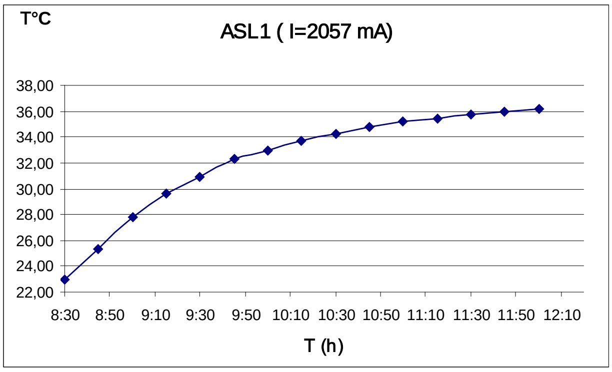


***Fig.2.*** *Magnet lens temperature variation.*

Fig. 2 shows temperature variation of axis symmetric magnet lens, measured with the power supply. The lens resistance is 3.2 Ohm, inductance 0.57 Henry, current range is 0 to 3 Amp.

### *3.2 Power supply system operation results*

Rack crate with installed power supplies is mounted in klystron room at 30 meters distance from operator's control panel. Practice of everyday operation confirmed the correct choice of CANbus for communication because of high reliability and stability of operation in very rush environment with high level of EMI. "Marathon IPP-1/100" and "Marathon IPP-4/35" power supplies operated successfully during 3200 hours within the LU-10 control system.

The commissioning of the linac LU-60m together with NESTOR storage ring is almost finished and run will start soon. The magnet elements of linac LU-60m will be feed by "Marathon IPP-1/100" and "Marathon IPP-4/35" power supplies. There are also plans to replace power supplies of running accelerator "EPOS" with these new power supplies.

## 4 CONCLUSIONS

It is possible to conclude now that circuits for power supplies together with CANopen protocol and architecture of the whole system were selected correctly and can be used in operating accelerators, as well as machines, which are under construction.

The significant advantage of the approach is the possibility to expand the CANopen network with other CANopen devices, such as power supplies or any kind of CANopen-compatible instruments. Application of internationally standardized protocols allows becoming independent on any one vendor of hardware components or configuration and diagnostic tools.

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