

# ADVANCES IN POWER SUPPLY AND CONTROL SYSTEM FOR ELECTROSTATIC ACCELERATORS

S.N.Chumakov, A.D.Goncharov, A.N.Malygin, V.P.Ostanin, B.N.Sukhina, V.S.Tupikov,  
Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia

## Abstract

Some technical advances and ideas, which allow, the construction of highly reliable, simple and cheap subsystems for electrostatic accelerators and other high voltage devices, are described. The described subsystems were tested during their extensive running for several years on a series of the accelerators ION-1500, ION-300 [1]. They are

- a small sized high efficiency system for power supply via a big isolating gap which is based on a high frequency resonant transformer with a low magnetic couple factor 0.1-0.3 (its characteristics are: 2.2KW, efficiency 90%, 6 cm isolating gap for 500KV);
- a system for a highly efficient medium and low-power regulators based on magnetic amplifiers and working at high frequency power delivered by the above mentioned system;
- an intellectual multifunctional single-board noiseproof controller LOCUS placed under high potential is linked with the central computer by a fiber optic link.

## I. POWER SUPPLY

A power supply system of the DC-operated ion source located under the high potential of the basic accelerator's rectifier consists of an unified series of power supply modules, which differ by the executive part and output characteristics. The blocks of the system use the local network of the increased frequency (20 KHz) and are characterized by the high specific gabarit power and foundation capability of overloading. The electrical power is transmitted to a high voltage terminal via a gas insulating gap by a disjunctive transformer and is absolutely independent of the accelerator energy.

## II. THE FUNCTIONAL STRUCTURE OF HIGH VOLTAGE TERMINAL MODULES

In Fig.1, the functional chart of the terminal is presented. By functions, the terminal structure can be divided into three blocks:

1. The stabilization blocks are intended to stabilize the local network voltage in a crate and restrict the transmitted redundant power:
  - (a) the stabilizer of the parallel type (350V, 1.0KW, 20KHz, 28V, 20KHz, +24V, +6V, +5V.st.) has two feedback loops:
    - i. A hardware loop consists of the magnetic amplifier included in parallel with the load and used as a regulator;
    - ii. A software loop consists of the transmission into the computer of measured value of redundant stabilizer power for the generator's power correction;

- (b) the serial stabilizer (350V, 1.0KW, 20KHz, 28V, 20KHz, +24V, +6V, +5V.st.) is used to vary the second crate placed under bias of ion extractor. The magnetic amplifier included in series with the load in the stabilization circuit is used as a regulator.

The stabilizers consume the power through high voltage disjunctive transformers T1, T2:

T1-unbuckle voltage 1.5MV The power to 2.0KW  
T2-unbuckle voltage 30KV The power to 1.0KW

2. Service units are a receiver-transmitter or a multifunctional single-board LOCUS-controller used to exchange data with the computer, to output the managing voltages and control the parameters in the supply units of the ion source.

3. Controlled power supply units for ion source:

leaker	1300V, 1mA
supressor	5KV, 3mA
extractor, focus	10KV, 5mA
extractor, focus	30KV, 20mA
heater	500W
magnet coil	30V, 3A, 100W
RF-generator's anode	1200V, 0.3A, 400W
cathode's heater	7V, 70A, 500W
discharge	0-150V, 8A, 500W

The dynamic range of the output parameters 20.

The accuracy of the output parameters 0.5%

This set of blocks is suitable for supply the RF ion source, duoplasmatron, or the other similar devices.

## III. THE DESIGN OF HIGH VOLTAGE TERMINAL WITH A POWER TRANSMISSION TRANSFORMER

In the design, the principle of the functional blocks is realized. The electronic blocks are located in a skeleton of the VME-type. A managing part of each supply unit is assembled on identical boards, incorporated with a stabilizer and the receiver-transmitter, or the LOCUS-controller, by a internal trunk.

The magnetic amplifiers (one of three nominal types) are installed on the managing boards and used as the regulators: 0.1KW 28V 20KHz; 0.5KW 350V 20KHz; 1.0KW 350V 20KHz. These amplifiers are mounted on ferrite rings as compact monoblocks. The advantage of the magnetic amplifier is its high reliability and ability of restricting the short circuit current. The executive parts of the blocks depending on the output parameters are mounted on the managing boards or serve as separate modules. If the output power (or voltage) more than 100W (or 10KV), the executive part is located outside the power units. The transmission of the electrical power for the terminal power supply is made at a frequency of 20kHz by the resonant transformer T1 of the armoured type, the primary and secondary coils

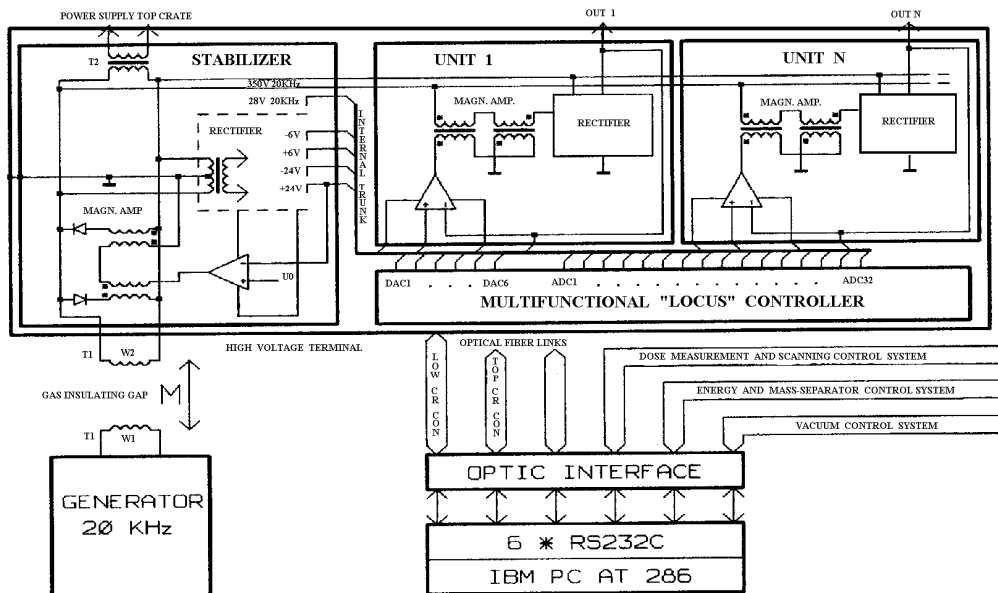


Figure 1. Distributed Control System

of which are inductively connected and separated by the high voltage gas-insulating gap. The core of the transformer is made in the form of two ferrite cups, 200mm in diameter. The material and the form of the cores, the transformer windings are chosen on the basis of the analysis on optimization of the parameters to achieve the maximum values of the Q-factor for the primary and secondary contours, to obtain the necessary factor of the magnetic coupling between the windings, and minimize the power losses.

In Table 1, the main characteristics of the transformers are presented for two accelerators ION-300 and ION-1500 (for 300KV and 1500KV respectively):

type of accelerator	ION-300	ION-1500
high voltage gap	60mm	105mm
transmitted electrical power	2.0KW	0.3KW
factor of magnetic coupling	0.215	0.087
non-loaded Q-factor	66.7	67.0
efficiency	0.90	0.75

#### IV. CONTROL SYSTEM FOR IMPLANTERS

There are two types of control systems for the ion implanters ION-1500 and ION-300. The first one is on a CAMAC base and the second one is a distributed control system designed specially for physical installations and consisting of several universal intellectual multifunctional single-board stations, which are connected to the central computer by means of duplex optical communication (isolation up to 2MV). The systems are adapted to environments with high level of the powerful interference electric pulses. All the subsystems are operated by the central IBM-PC/AT, or compatible computer, under onetasking program (one task manages all the subsystems) in the first case and multitasking one with share time in the second case. To visualize, both systems use a multiwindow graphic interface.

The ION-1500 control is realized by a conventional

COMPUTER-CAMAC model. The process is operated by the central IBM-PC/AT or the compatible computer. It is connected through a CAMAC-adapter (in IBM-PC) to a CAMAC-controller and controls the following modules:

- SAS ( switch of analog signals );
- ADC;
- HVTC ( high voltage terminal controller );
- 2 channels of DAC;
- I/O registers

SAS serves to switch and pass to the ADC one of the signals: energy, ion beam current, profiler current, voltage of the first section, rectifier current, voltage and current of the primary winding of the accelerator, voltage and current of the generator, and current of a separator magnet.

The HVTC executes the control of a leakage valve, beam focusing, anode power supply, transformer temperature, power, and board power supplies of the high voltage terminal.

The first DAC sets the current of the separator magnet and the second one sets the energy of beam acceleration.

The I/O registers control the switching of valves of the vacuum system and start of the profiler gauge.

All the units of the system are operated by a single program written in FORTRAN for IBM-PC running under OS DOS.

As to automation of ION-300, the following rules are accepted: distribution of the control system and multitasking with share time in the managing program. Each separate process in the installation corresponds to a separate intelligent LOCUS-controller which has several measuring and managing functions (ADC, DAC, timers, I/O - registers etc.). This controller is capable of working independently after loading a preliminary program from the central computer under the direct management of the central computer by the standard protocol. The functional difference of the processes on a hardware level and the use of the multitasking program (multitasking OS, or compilers of high level languages like MODULA-2 which enables us to run the procedures with share time) substantially simplify the

programming process. The simplification results in writing the functioning algorithm for the individual installation unit in the form of the procedure similar to our case (MODULA-2) or task (QNX, UNIX etc).

Each procedure of this kind has two forms of communication: downwards to the intelligent controller and upwards to the program manager, which already uses the data of all the units and gives the orders to each procedure. The base of this distributed control system for the installation ION-300 is the LOCUS-controller which includes

1. ADC with continuous dynamic integration of the input signal, a two-wire galvanic isolated input, a programmable integration time ranging from 0.2 to 26 ms (word length ranges from 9 to 16 bit respectively) at an input DC-voltage ranging from + 5.16 to -5.16V;
2. an analog two-wire 32-channel switch;
3. 6 channels of pulse-width digital to analog converters which has a 14 bit resolution and an output voltage ranging from -5.08 to 5.08V;
4. 32 input registers ( TTL );
5. 24 output registers ( TTL );
6. 5 channels of programmable multifunctional timers, which are switched by jumpers and have a possibility of pulse counting, measuring time intervals and forming the pulses of controlled frequency and duration;
7. protection of all I/O signals which pass through plugs (115 lines of diode-resistor chains). The protection is effective against the powerful interference electric pulses with spectra up to approximately 30MHz;
8. a processor i8085, 8KB of ROM and 2KB of non-volatile RAM;
9. a duplex optic connection to the central computer (communication format is compatible to RS232).

The processor has an automatic restart in the following cases: after failure or cycling of the program, or after sudden jump of power supply voltage.

For PC-LOCUS communication, a 6-channel serial interface for IBM-PC and a TTL-to-optic adapter are developed. The serial interface has FIFO-buffers (the depth is 32 bytes) for each input and output. This enables us to increase the rate of the PC-adapter communication and to get rid of the data loss.

To avoid serious accidents in the installation as a result of failure in the apparatus or programming, the hardware arbitrator to block the accidental conditions was developed. In the control system for ION-300, the given arbitrator executes a function of preventing against illegal situations, which are caused by operator failure or break-down in a unit.

In contrast to CAMAC, this single-board intelligent controller can be placed near a particular controlled system. The ION-300 comprises

1. two LOCUS-controllers working under a potential up to 300KV in the ion source system;
2. one LOCUS and an arbitrator module operating by the vacuum-gas system of the implanter;
3. one LOCUS and an arbitrator module controlling the high voltage system of the implanter;
4. two LOCUSes controlling wholly the implantation chamber for semi-conductor plates, including the management

of two step-motors and control of the implantation dose. To measure the charge the block forming with LOCUS the charge-digital converter (accuracy is 97.6C per count) is developed. Such connection considerably reduces the trace of a system that results in the cable saving and failure reduction.

## V. CONCLUSION

More than a two-year experience of operation (about 1000 hours) of the multifunctional LOCUS-controller has shown its good reliability. A series of the experiments were conducted which showed the absence of halts (for example, as a result of short-term short circuits of some wires to the "Ground" through the capacitor 0.01uF). There were no halts under real conditions during a high voltage breakdown to 300KV. A distributed control system turned out to be successful in the sense of the managing program writing process.

## References

- [1] A SERIES OF ION ACCELERATORS FOR INDUSTRY, B.N.Sukhina et al., Proc. of PAC-95 Conference.