RESULTS OF DEVELOPMENT AND RESEARCH OF THE CHARGE DEVICE FOR EMERGENCY AUTOMATICS OF POWER COMPLEXES

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Abstracts – **Results of development and research of the charge device with microprocessor control for an operative feed of circuits of d.c. power complexes are described. The device is executed with an opportunity of modules parallel inclusion of different power. High accuracy of output energy parameters stabilization is achieved: voltage 0,33 % at a level of pulsations no more than 0,24 % in voltage stabilization mode; current 1,67 % at pulsations level no more than 1,66 % in current stabilization mode that guarantees the increased service life of the battery. Devices efficiency 0.9 with power 24 kW.**

Necessity for high reliability of power supply for devices of emergency automatics of power complexes predetermines application of a direct current network with rated voltage 220 volt with use of storage battery (SB). SB constant readiness is provided with charge device (CD). For achievement of maximal service life SB stability of the CD output voltage or current should not exceed then 0.5%.

Marketing researches of the Russian market of the similar devices, carried out by SLL "Oldham-techno" (RUS), decrease in the nomenclature of used accessories, their availability and the minimal cost have defined a modular principle of construction of the device. CD block diagram in the maximal complete set is shown in Fig.1.

The device consists of CD basic channel (CDBC) with a nominal output voltage 220V (UOUT1) and additional channel (CDAC) with a range of rating value of the output voltage 12 – 65V (UOUT2). The module 1 of CDAC and modules 1…3 of CDBC are same power circuits of transformation of common power variable voltage UIN in constant. The developed device series allows to receive necessary CD capacity by parallel inclusion up to three modules with a nominal output current of the module from 10 up to 30A (i.e. the range of CDBC output current makes 10 – 90A with step in 10A). CDBC and CDAC contain each power supply of a control system (SPS), a microprocessor part of a control system (MPC), the block of indication and control of operating modes (BI), the sensor of an ambient temperature of the storage battery (t^oC) and the relay (R) of the remote signal system. Control principles of parallel included converting modules are like those described in [1].

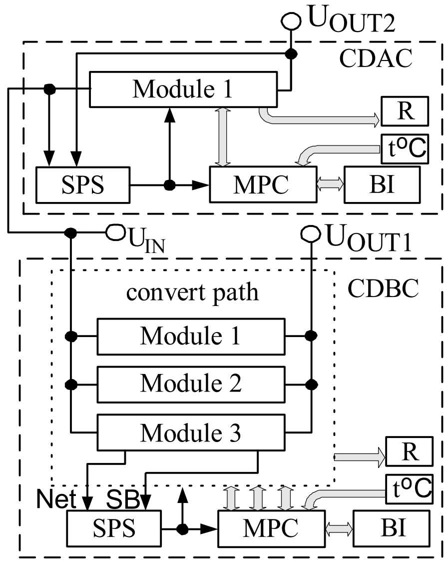

Fig.1 Charge device block circuit (full complete)

In Fig. 2 the structure of a power path of CDBC converting module is in detail opened. The three-phase voltage of industrial network U_{IN} acts through automatic device A1, fuses FU, contactor C1, through the transformer T, the uncontrolled rectifier R, the circuit of a preliminary charge (PCC) of the capacitance of low-frequency LC-filter F1 on DC/DC converter (HF) of step-down type with pulse-width control. The received voltage acts in loading through LC-filter F2, contactor K2 and automatic device A2.

Distinctive feature of construction of CD control system is presence of two processors.

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BG is a block of sensors, protection and restrictions of parameters of instant output energy, control of the contactors and the relay of the signal system. Besides actually circuits of sensors of currents and voltage BG contains Motorola MC68HC908MR32 microcontroller. Its functions consists in check in a mode of self-checking of circuits of sensorss, protection and restrictions before submission of network voltage in the power circuit and connection CD to load, in control of the contactor equipment (input: K1; output: K2; PCC: K3), and as in control of the relay (R) of remote signal system.

MPC is the microprocessor part of a control system formed Motorola DSP DSP56F801FA80. In this part control of a course of complex CD self-testing; system of automatic control in parameters of output energy with distribution of power between in parallel included modules, output voltage temperature compensation and voltage drop compensation in the output cable; work with the block of indication and control of CD operating modes (BI) are realized.

Presence of the second processor located in BG allows to realize independent work of CD modules on load in case of MPC failure, that substantially raises reliability of power supplies.

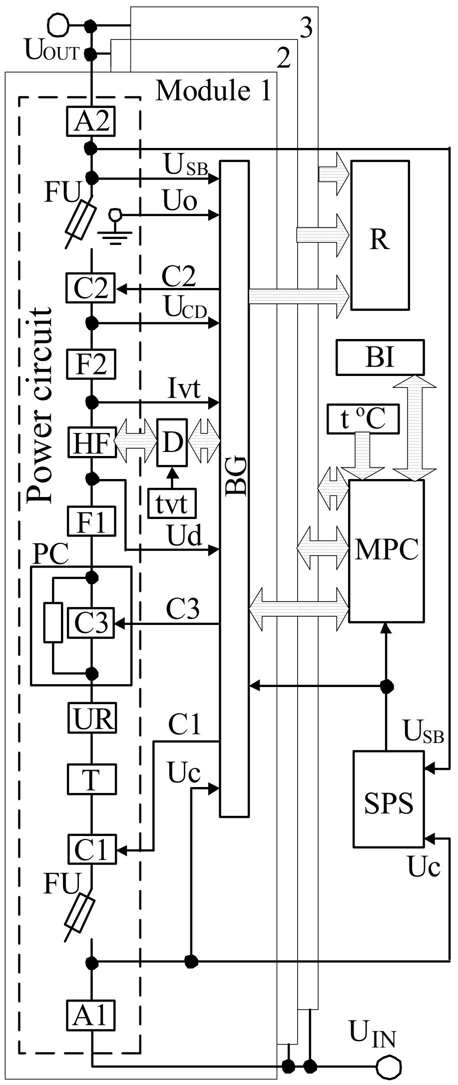


Fig.2 Block circuit of the CDBC

CD carries out at inclusion self-testing of the force circuit and sensors of a control system and works in modes: a voltage source with restriction of maximal current value or a current source with restriction of maximal voltage value. At loss of the network voltage over 3 minutes CD automatically passes to 15 hours mode of SB accelerated charge. Levels restriction of corresponding values are established from the control panel and can change depending on the type of accumulators used. With BI it is possible to choose one of three operating modes CB on SB: constant charge mode, constant voltage leveling charge mode and mode of the stabilized direct current charge. One of the important functions of CD protection system is the control of the isolation resistance within the range 20 kOhm – 100 kOhm with the step set by means of BI in 20 kOhm.

The analysis of quality of the accumulator charge current is made without the decision of the differential equations by the direct method of their algebraization [2]. The equivalent circuit of a charge network is shown in Fig.3, where DC/DC converter with PWM is submitted by the source of a pulse voltage u, filter - LC by the circuit and accumulator - source emf EC with internal resistance R.

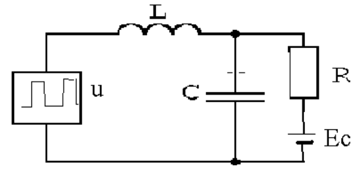


Fig.3 The equivalent circuit of a charge network

The differential equation for the accumulator charge current has the form

$$LCR\frac{d^2 i}{dt^2} + L\frac{di}{dt} + Ri = u - E_C \qquad (1)$$

Algebraization of this equation is made by means of transformation its in the integrated equation with the subsequent squaring and averaging for the period of PWM frequency .

Thus the formulas for effective value of higher harmonics of a current Ihh and for average value of a charge current Ic is deduced. Then factor of harmonics of charge current is equal

$$K_{hc} = \frac{I_{hh}}{I_c} = \left(1 + I_c^*\right) \times$$
$$\times \frac{\sqrt{1 + \left(X_L^*\right)^2 - 2\left(\omega^*\right)^2 + \left(\omega^*\right)^4 \left(1 + \frac{2}{\pi^2}\sin^2(\gamma\pi)\right)}}{1 + I_c^* - \gamma} = \qquad (2)$$
$$= f\left(\gamma, I_c, \omega^*, X_L^*\right),$$

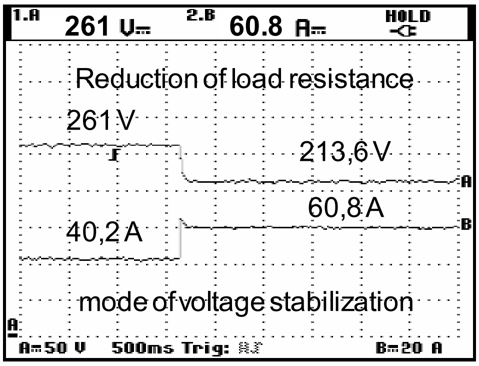
where are teken as base units a charge voltage of the accumulator E_c and its internal resistance R.

Then the relative parameters of filter elements are equal $\omega^* = 1/(\omega LC), X_L^* = \omega L/R$ and γ-relative duration of a pulse on an output of the converter (control parameter), connected with relative voltage on DC/DC converter input by the equation $I_C^* = \gamma E^* - 1$, I_C^* – relative charge current of the accumulator (parameter of the task on control), $\overline{\overline{K}}_{hv} = \sqrt{\sum_{k=2}^{\infty} \left(U_k / \left[k^2 U_1\right]\right)^2}$ – integrated factor of harmonics of the second order of a PWM converter voltage (parameter of quality of a voltage, indicative at load on the LC-filter).

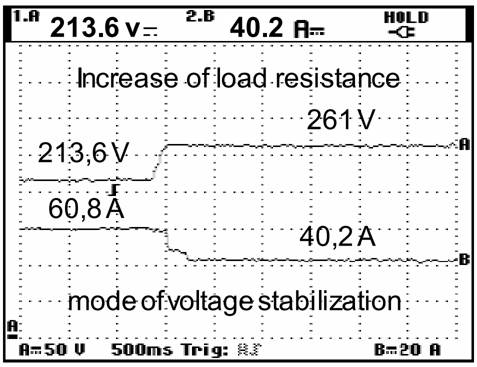
The dependences of factor of harmonics of charge current in function of a task current I_C^* and parameters of the circuit are designed from the expressions received. The results of account are well coordinated with theresults of a simulation and experiment.

Experimental researches of CDBC characteristics, consisting of two operating in parallel 30A modules and CDAC have shown, that accuracy of parameters maintenance of CD output energy with the change of network voltage ±15 % and have made value of load is: ±0,33 % voltage at a level of pulsations no more than 0,24 % in a voltage source mode; ±1,67 % current at a level of pulsations no more than 1,66 % in a current source mode concerning rating values. Non-uniformity of distribution of currents between in parallel working modules made no more than 0,8 A. Device efficiency in the specified modes not less than 0,9, cosφ not less than 0,9.

In Fig.4, 5 oscillograms of the transient caused by switching of active load and illustrating transition of the device from a voltage source mode to a current source one represented.



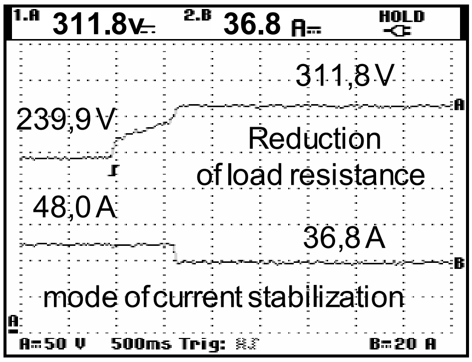
a)



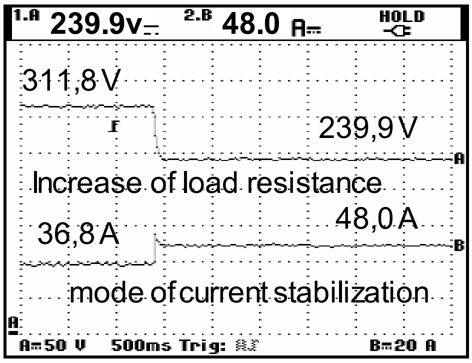
b)

Fig. 4. Voltage source mode. Transient oscillograms.
a) active load resistance reduction; b) active load resistance increase

Research of CD work on the storage battery was carried out for SB such as 12FTR105 at two rating values of voltage ($U_{SB.nom}$). Necessary levels of constant charge voltage (Uccv), accelerated charge (Uac), leveling charge (Ulc) and a current of a charge (Ic) were established from CD control panel (BI) and submitted in TABLE I.



a)



b)

Fig. 5 Current source mode. Transient oscillograms.
a) active load resistance reduction; b) active load resistance increase

TABLE I

$U_{SB.nom}$	Uccv	Uac	Ulc	Ic
V	V	V	V	A
216	245.2	253.8	259.2	12
250	258.8	267.9	273.6	

Figs. 6…8 present time diagrams of SB voltage (U_{SB}) and SB current (I_{SB}) for the modes specified in table 1. Oscillograms illustrates SB constant current charge and CD transition in a voltage source mode of stabilization at achievement of SB voltage value to corresponding chosen mode.

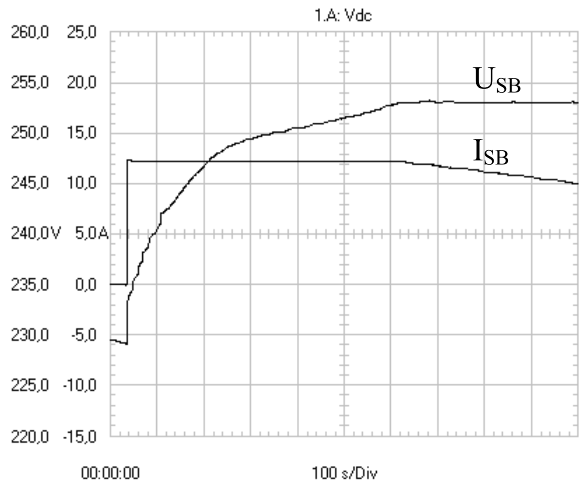


Fig. 6 Accelerated charge of the SB

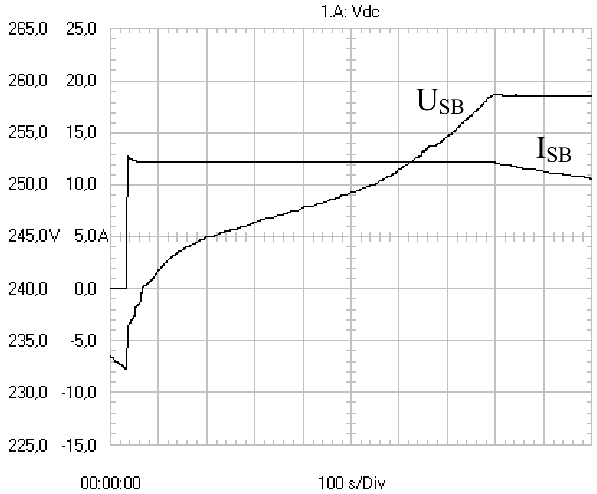


Fig. 7 Leveling charge of the SB

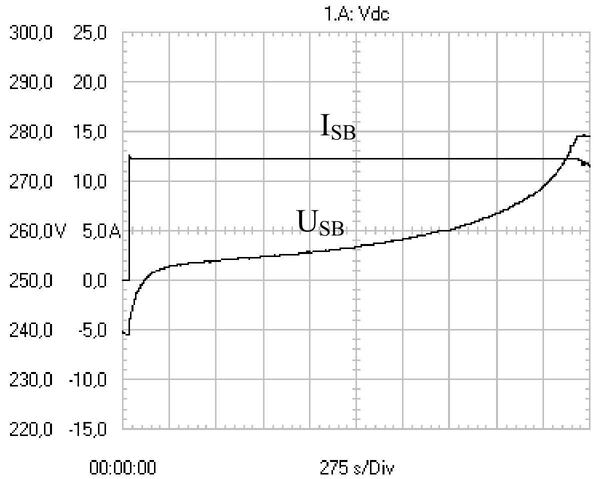


Fig. 8 Constant current charge of the SB

More over, fig. 9 presents the 15 hour accelerated charge. Such CD mode is occurred when power network voltage is disappears for over 3 minutes. In this figure, as well as fig. 6…8, I_{SB} = 30 (A). When U_{AC} achieved the level according to TABLE I I_{SB} decreases.

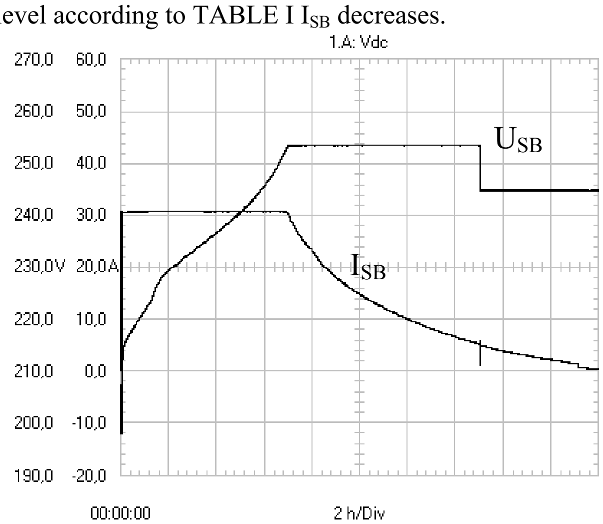


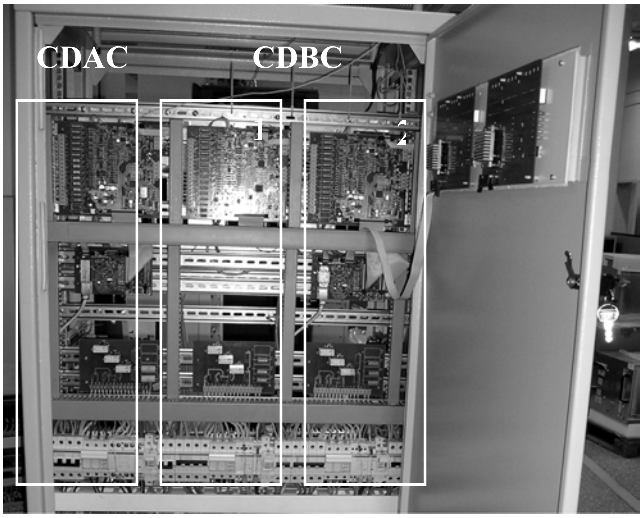
Fig. 9 15 hour accelerated charge

CD (CDBC and CDAC) output power characteristics, input power characteristics, working mode, protection type and indication type are reduced in TABLE II.

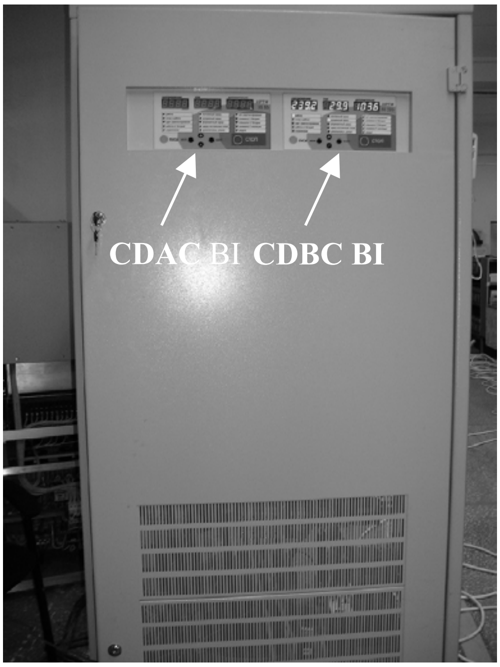
TABLE II

Working mode and characteristics	CD MODE	
	CDBC	CDAC
Complex CD turn on test	+	+
Voltage source mode		
output voltage nominal value of the constant charge, V (installing with control panel BI)	220	12 - 65
	adjustment range +15%	
output voltage value of the accelerated charge, V (automatic mode, it is occurred when power network voltage disappears more than 3 minutes, value is set with control panel BI)	(1 ÷ 1,15)$U_{SB.nom}$	
output voltage value of the leveling charge, V (manual mode, value is set with control panel BI)	(1 ÷ 1.2) $U_{SB.nom}$	
accuracy of the output voltage stabilization	±0.5%	
RMS value of the output voltage ripple, less than	2.5%	
maximum value of the output current, A	90	30
output current peak limiting (automatic mode, value is installing with control panel BI)	(1 ÷ 1.05) $I_{SB.nom}$	
temperature compensation value of the output voltage, V/oC	0 ÷ 0.6	
Current source mode		
output current nominal value, A (installing with control panel BI)	8 ÷ 72	24
output voltage peak limiting (automatic mode, value is installing with control panel BI)	310	80
RMS value of the output current ripple, A, less than	3	
efficiency	more than 90%	
power factor	more than 0.9	
light diode indication: power network voltage disappears, SB voltage is very low, SB voltage is very high, constant charge mode, accelerated charge mode, leveling charge mode, complex CD turn on test is fault, current source mode, isolation resistance is very low, overheat (if radiator is fan cooled)		
Numerical indication of the output power parameters (voltage and current). Accuracy rating is 1.		
Signalization relay: 1 - SB voltage is very low, SB voltage is very high, overheat; 2 - power network voltage is disappeared, leveling charge mode		
CD has high output voltage protection. 235...260 V [14...70 V]. This protection is blocked at the leveling charge mode and current charge mode. If this protection is occurs CD turn off.		
CD realize isolation resistance control steadily. Isolation resistance minimum value is from 20 kOm to 100 kOm with step 20 kOm (installing with control panel BI).		

Figs. 10 (a, b) present photos of appearance of the developed constructive sample having overall dimensions 800x600x2000. In the figure 15,6kW CDBC ($U_{SB.nom}$ = 220V / 198V –min, 310V – max/, $I_{SB.max}$ = 60A, module 1 and 2 in parallel) and 2kW CDAC ($U_{SB.nom}$ = 65V / 12V – min, 80V – max/, $I_{SB.max}$ = 30A) are presented.



a)



b)

Fig.10 CD appearance (a) and construction performance (b)

COMPARISON

Comparison of operation results is made with the most used Russian power complexes of the CI, constructed on the base of semi controlled bridge rectifier with the LC-filter. Such CI provide required quality of the formed electric power in a static mode, but have bad dynamic parameters. Besides such circuits have low the input power factor at regulation with the purpose of stabilization of a output voltage. In comparison with this circuit offered CI with the uncontrolled rectifier and DC-DC the converter has the best power factor (0.9 in dependent on loading) at the same quality of output energy, the same efficiency (0,93) and with higher dynamic parameters

[1] Kharitonov S.A., Berestov V.M., Borodin N.I., Korobkov D.V. About construction of regulation system in parallel work of semi-conductor converters with the sine wave stabilized voltage. The electrotechnology engineering, 2001, №12, p. 14-21.

[2] Zinoviev G. S. Concept of definition of electromagnetic compatibility factors of power converters with supply line and load. Proc. conference PEMC'96. Hungary, Budapest, 1996, p.2.201-2.204.