Generator of Powerful Current Pulses for Electrostimulated Metal Processing

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Abstract. The description of the powerful generator of unipolar pulses having the charger connected to power capacitors and the thyristor switch, discharging the capacitors to the low ohm load is presented. In order to reduce the main power, the charge exchange device on the base of thyristor connected antiparallelly in thyristor switch is introduced in the scheme. To realize the possibility of pulse amplitude control and increase in its capacity two irreversible thyristor transformers are used in charger instead of an unregulated direct current source. These thyristor transformers are switched on in series and in unidirectional way. They permit to obtain the regulated voltage at power capacitors. In order to optimize the capacitor charging process a two-circuit system of subordinate regulation of pulse generator parameters with external voltage control circuit and internal control – current capacitor charge. The model of the suggested generator is implemented in the "Matlab, Simulink" medium. The model is adequate to the real pulse generator used in SibSIU for investigation of electrostimulated plastic deformation of metals and alloys. The developed model permitted to improve the technical parameters and device operation regimes. The considerable mains power decreases as well as possibility of capacitor charge voltage control up to 600 V in the range of pulse repetition frequency 400 Hz are the advantages of updated generator in comparison with the analogues. The generator can be used in industry, in particular, rolling production for hard deformed steel wire drawing.

Keywords: pulse generator, charger, recharging device, current pulse, mathematical modeling, transient processes

Introduction

The interest to the investigation of peculiarities of pulse electric current (PEC) effect of high density on the behavior and properties of metallic materials is dictated by the prospects of their application in technology of metal-working [1, 2]. The effect of electric current pulses manifests itself at different structural levels and due to its diversity, versatility and unique possibilities can be used for modification of physico-mechanical properties, stimulation of relaxation processes and reduction of residual stresses in elements of structures.

For the first time the effect of electron action (electroplastic effect – EPE) on the process of metal deformation was experimentally studied and described in the research [3].

Intensive works in this direction have been carried out for more than 50 years, but there is no consensus of opinion among the researchers as to the nature of the discovered EPE [4–8].

In spite of the large number of experimental and theoretical investigations in the given direction, in connection with the deficient definiteness of physical mechanisms of action of PEC on metallic materials as well as the existing disagreement in interpretations of microscopic effects the further investigation of PEC effect on metals and alloys remains the topical and important scientific and practical task.

The solution of the problems of investigation of the developed electrostimulated deformation mechanisms and its practical application in plastic metal working is possible when using the sources of powerful short current pulses [9, 10]. Such sources whose principle of action consists in the discharge of prior charged capacitors to the low ohm load are also used in studying the changes in physical properties of metals under current effect [11]. The disadvantages of the generator preventing it from wide application in industry are:

– low efficiency and substantial energy expenditures of the charging unit in relation to the availability of the charge of capacitors of current-limiting resistance R_z in the circuit;

– impossibility of regulating the amplitude of power pulse.

The purpose of the research is development of circuit elements of generator of powerful current pulses eliminating these disadvantages contributing to the reduction in main power and introduction of generator in industry in plastic metal working.

THE RESULTS OF THE RESEARCH AND DISCUSSION

Figure 1 shows the oscillogram of transient processes of pulse current, the charging current of power capacitors and power capacitors' voltage. After the pulse passage the *C Br1* capacitor voltage takes the negative value ($-U_{z1}$), equal (0.85–0.95) to the initial voltage value U_z. The capacitor charge exchange from ($-U_{z1}$) to U_z occurs from the d.c. source with mains power consumption 3·380 V.

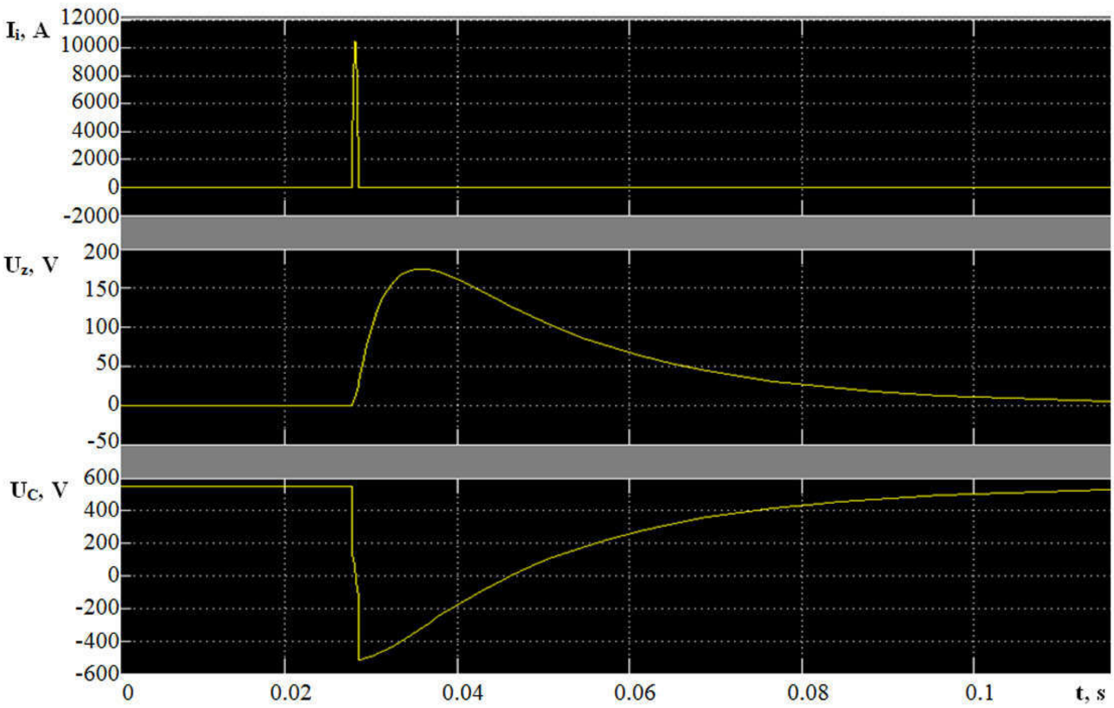

Figure 1. Oscillogram of transient processes of powerful pulse generator
(I_i – pulse current, U_z – charge voltage, U_C – capacitor voltage)

To limit the current rush between the rectifier bridge of the charger and power capacitors the current limiting resistance R_z where the considerable power (30 kW at pulse repetition frequency 100 Hz) dissipates is installed.

In order to decrease the main power the recharging unit *UP* consisting of current limiting inductance *RL Br4* connected in series and thyristor *Th1* connected in antiparallel with thyristor *Th* is introduced in the pulse generator circuit.

At the moment of time when after passage power pulse the current becomes equal to zero, the pulses of different polarity the value of which is proportional to the derivative value of power pulse *dI/dt* are formed in the instrument transformer *Three*. Diode *D* blocks the negative half-wave, and the positive signal is amplified to the required value and is fed to the control electrode of thyristor *Th1*. The latter switches on and capacitors *C Br1* recharge trough the circuit "thyristor *Th1*, inductance *RL Br4*" to the positive voltage value 0.8–0.9 U_z. In this case the charge unit carries out only the milking of capacitors from U_z. Thus, the application of recharge unit decreases the main power considerably.

The transient processes of current pulse and recharge voltage with application of thyristor *Th1* are shown in Fig. 2. For further decrease in charge unit power and possibility of adjusting the charge voltage value (pulse amplitude) the controlled thyristor transformers *Uni Br*, *Uni Br 1* connected in series, in this case one of the transformer is fed from transformer winding *Tr* connected in 'star' circuit and the other – in 'triangle' circuit are introduced in the circuit instead of non-controlled diode rectifier. Such an interconnection circuit firstly, increases the rectified voltage (value of power pulse, respectively) and secondly, decreases the transformer inertia (the pulses number m increase to 12 at the period of feeding voltage, and pulse duration decreases to 1.6 ms). When using the power supply mentioned above the generator is capable of generating the pulse with maximum repetition frequency to 400 Hz. The application of thyristor transformers permitted to remove the current-limiting resistor R_z from the circuit of charge unit and it also increased the efficiency and decreased the a.c. main power.

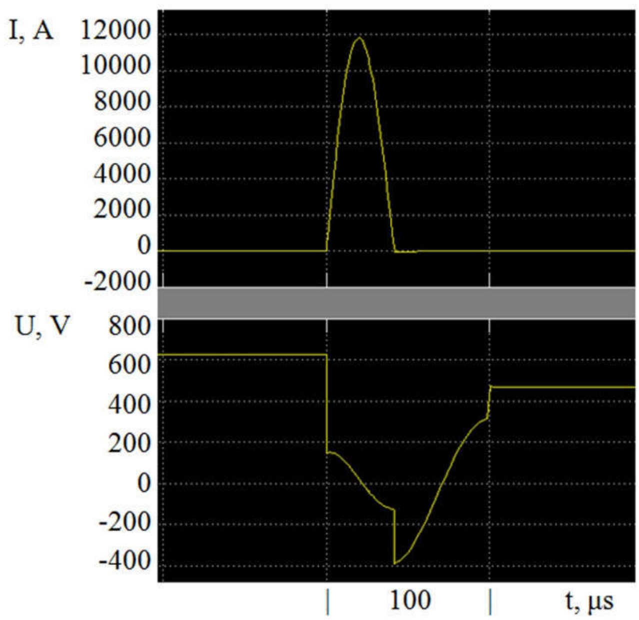

Figure 2. Parameters of capacitors' current pulse and voltage with recharge unit

For controlling the pulse amplitude value a two-circuit system of voltage adjustment is implemented (SVA). The internal circuit of automatic control system is organized like circuit of controlling the current of capacitors' charge and the external circuit – controlling the voltage of capacitors' charge. The circuit of current control consists of current regulator *G1* with block of limitation *S1*, thyristor transformers *Uni Br, Uni Br 1* consisting of inertia links with fast time constant 4 ms and object of control – power capacitors *C Br1*. The additional inductance *LBr3* is introduced into the circuit for stable operation. The active resistors of thyristor transformers and buses as well as power capacitor inductance are taken into account in power capacitor block *C Br1*. The negative current feedback is removed from the shunt *CM1* and is amplified by fast-responding amplifier *Tfcn*. The control circuit of capacitors' charge voltage consists of voltage regulator *G3* and optimized current circuit. The voltage feedback consists of divider and inertialess voltage gauge *Tfcn1*. The limitation of maximum charge current is done at the expense of voltage regulator limitation block *S2*. This block enables to limit the minimum and maximum angular value of thyristor transformer control. The voltage adjustment may be done either by hand or from the signal of technological programmed controller.

If it is necessary to reduce voltage very quickly the control system forms the assignment to the negative value of 'charge' current – discharge current. However, in connection with the fact that thyristor transformers are non-reversible they can reduce current only up to zero value. In this case, the reduction of capacitor voltage occurs strictly at the expense of active losses and has a long character. To increase the speed of system response the device blocking the operation of recharge device by blocking the control pulses to thyristor *Th1* for the time necessary to reduce the capacitor voltage is connected into the circuit. The blocking device contains the amplifier *G2* with block of limitation *S4*. At the negative current assignment the device forms the signal blocking the operation of *G* in the system of formation of control pulses to thyristor *Th1* of recharge.

Figure 3 shows the mathematical model of the updated generator made in medium "MatLab, Simulink" with recharger, controlled thyristor charger and SVA, and Figure 4 – oscillograms of transient processes in operation of the updated generator in the regime of stepwise change of voltage assignment to 600 V. The main power of upgraded generator in static regime at pulse repetition frequency 100 Hz reduced 5-fold (from 30 to 5.5 kW).

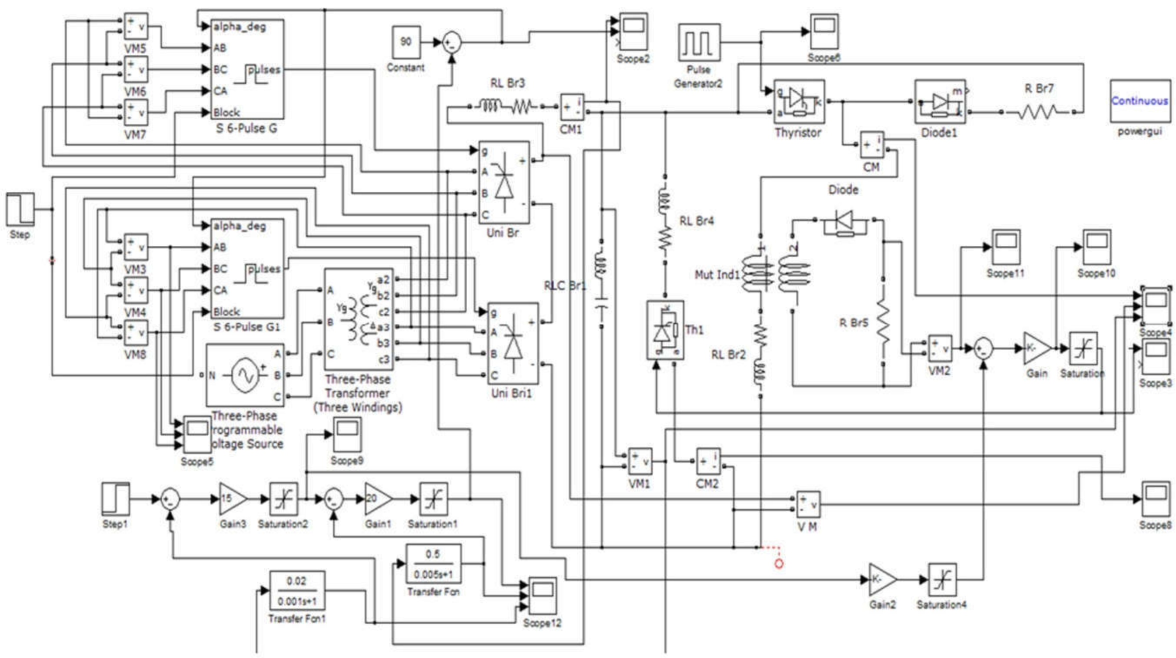

Figure 3. Simulation model of the modernized generator

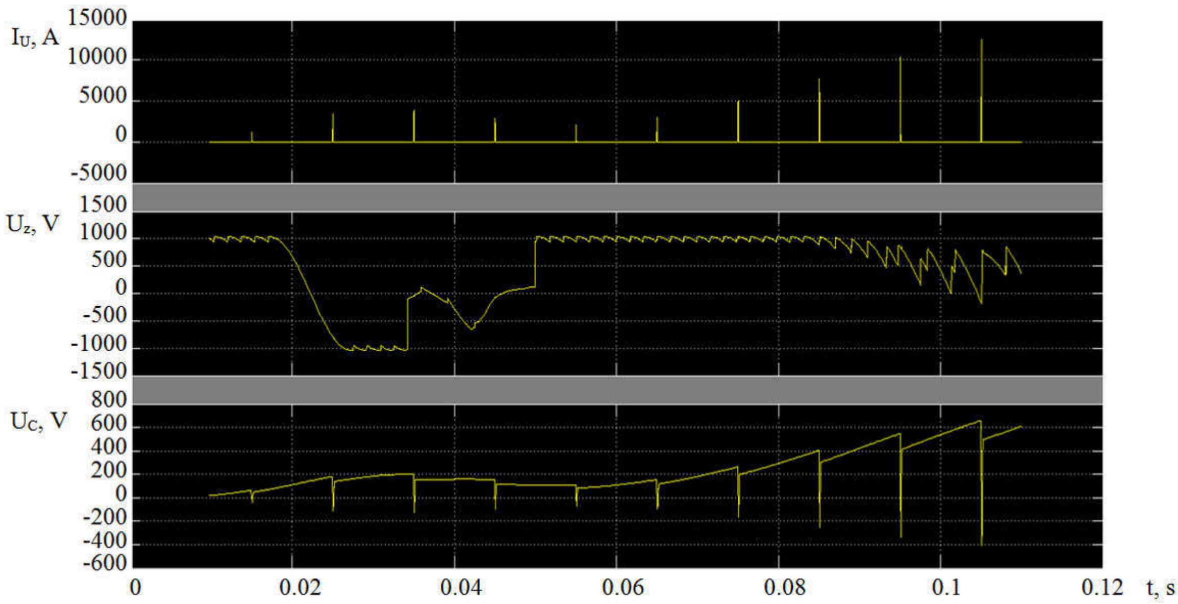

Figure 4. Transient processes in stepwise change of voltage adjustment of capacitors charge (I_u – pulse current, U_z – charge voltage, U_C – capacitor voltage)

Conclusion

1. The introduction of recharger and block of thyristor convertors connected in series in the circuit of pulse generator enabled to reduce the main power as well as to control smoothly the amplitude of power pulse with high speed response (not less than 50 ms) and wide control range (up to 600 V). It widens considerably the possibilities of the device application in industry.

2. The built model is adequate to the real unit which made it possible to use it for parameter refinement of the used elements and the system of obeyed control with the purpose of optimization of operation regimes (transient processes, in particular) and the increase in operational reliability.

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