INCREASE IN THE PULSE REPETITION RATE OF LIDAR SYSTEMS

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The problem of increase in the sounding pulse repetition rate with reference to the multipulse charger is considered. The multirange systems are shown to provide higher pulse repetition rates as compared to the single–range ones. Relations that enable one to choose the main parameters of the pumping system are presented.

Making use of charging systems with a dosage capacitor when operating with resistive–capasitive load allows the creation of charge–storage capacitor charging systems with wide functioning potentials. Such systems are widely used, even though the efficiency of charging is only about 50%. Such a low efficiency is related to the fact that the total charge of the charge–storage capacitor is transferred via a resistor that limits the current in the circuit. This fact should be taken into account when developing the high–power pumping sources since it worsens operational characteristics of pumping systems of solid lasers.

This paper presents a study of the chargers providing multipulse resonant charging of the charge–storage capacitor. The excess of the voltage across the dosage capacitor over the voltage of power supply is considered to be an appreciable disadvantage of these systems. Such an overvoltage leads to self–triggering of thyristor switches and to unreliable operation of the pumping system as a whole. Dosage capacitor voltage fixing is usually used to eliminate this disadvantage. Block diagram of the charger of such a type is shown in Fig. 1.

The switching capacitor is connected to one of the arms of the thyristor bridge. When thyristors *T1*–*T4* are unlocked, the capacitor C_d, whose lower plate has, for instance, positive potential, is recharged through the following circuit: power supply *E*, thyristor *T1*, dosage capacitor C_d, thyristor *T4*, inductance *L* that limits the current in the circuit, charge–storage capacitor C_s, and power supply. After recharging is finished, the current equals zero, that locks the thyristors *T1* and *T4*. The voltage polarity across the switching capacitor becomes reversed. The next charging cycle begins with unlocking the second arm *T2* – *T3* of the thyristor bridge. A fixing diode *D* is connected in parallel to the charging *LC* circuit.

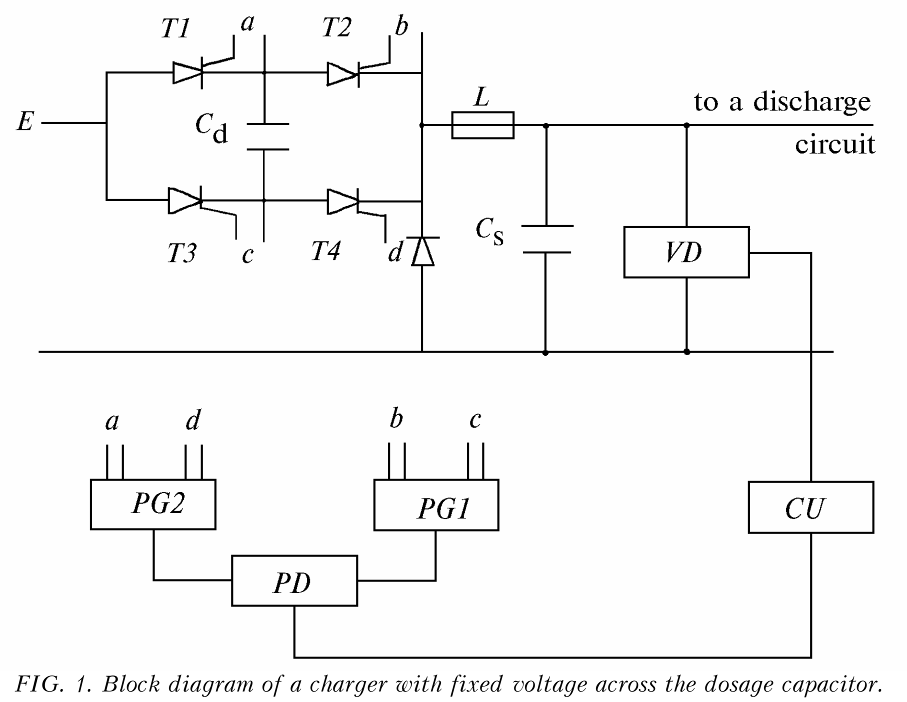

FIG. 1. Block diagram of a charger with fixed voltage across the dosage capacitor.

A voltage divider *VD* is connected in parallel to the charge–storage capacitor C_s for matching of the high–voltage and low–voltage parts of the charger. A signal proportional to the voltage across the charge–storage capacitor C_s comes to the control unit *CU*. Control unit produces triggering pulses if the voltage across charge–storage capacitor C_s is lower than a preset value. After the output voltage reaches a preset value, formation of triggering pulses is stopped. Clock pulses formed by the control unit come to the pulse distributor *PD*. The main

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task of this unit is initiation of the two triggering pulse generators *PG1* and *PG2* in turn. *PG1* triggers the switches *T1* and *T4* whereas *PG2* operates in the same way with thyristors *T2* and *T3*. Thus, both arms of the thyristor bridge are triggered in turn.

After the voltage across capacitor approaches the value providing by the power supply, the diode *D* becomes unlocking. At this moment, the current through the thyristors becomes equal to zero, that locks the switches. Then the power supply switches off from the charging circuit, and the charge–storage capacitor is extra charged at the cost of the energy accumulated in the inductance. Therefore, two stages of charging can be separated: first, from the beginning of charging till recharging of the dosage capacitor up to the voltage value providing by the power supply and the thyristor bridge switch off and, second, transient processes in the charging circuit concerned with energy transfer from the inductance to the charge–storage capacitor.

The increase in the voltage across the charge–storage capacitor that occurs during the second stage can be calculated from the known current value at the beginning of this stage. The resulting value of the voltage across the charge–storage capacitor is determined by the following expression:

$$U_{C_\mathrm{s}} = U_{C_\mathrm{s}}(0) + 2\,E\,(C_\mathrm{d}/C_\mathrm{s}) + 2\sqrt{C_\mathrm{d}/C_\mathrm{s}}\;\sqrt{E\,(E - U_{C_\mathrm{s}}(0))}\;. \qquad (1)$$

As it follows from Eq. (1), the voltage across the charge–storage capacitor depends on three terms. The first term is the initial value of the voltage at the beginning of the charging cycle. The second term is independent of this value and determined by the recharging process of the dosage capacitor. And the third term characterizes the energy transfer from the inductance to the charge–storage capacitor. When analyzing the third term, one comes to a conclusion that the voltage across the charge–storage capacitor can not be higher than *E*, provided by the power supply, otherwise the radicand becomes negative. In fact, the charging is nearly finished when *E* becomes equal to $U_{C_s}(0)$. Indeed, our examination showed that the voltage U_{C_s} is only 2–7% higher than the *E* value.

Since the voltage across the charge–storage capacitor at the end of *n*th cycle equals to that at the beginning of $n + 1$st cycle, we have the following recurrence expression for $U_{C_s}^{(n+1)}$ value:

$$U_{C_\mathrm{s}}^{(n+1)} = U_{C_\mathrm{s}}^{(n)}(0) + 2\,E\,(C_\mathrm{d}/C_\mathrm{s}) + 2\sqrt{C_\mathrm{d}/C_\mathrm{s}}\sqrt{E\,(2\,E - U_{C_\mathrm{s}}^{(n)}(0))} \qquad (2)$$

for $U_{C_\mathrm{s}}^{(n)} < E$.

Let us dwell on the problem of choice of the ratio between capacities of the charge–storage and dosage capacitors depending on the output voltage required and the relative error of the establishment of output parameter.

Let us introduce the following designations:

$$\gamma = U_{C_\mathrm{s}}^{(n)} / E\,, \quad \alpha = (U_{C_\mathrm{s}}^{(n+1)} - U_{C_\mathrm{s}}^{(n)}) / U_{C_\mathrm{s}}^{(n)}\,. \qquad (3)$$

The ratio *N* between of the capacities of the charge–storage and dosage capacitors at a given value α of the relative error of the establishment of output parameter is defined by the following equation:

$$N = 4 \,/\, \left(\sqrt{1-\gamma} + \sqrt{1-\gamma+2\alpha\,\gamma}\right)^2\,. \qquad (4)$$

One can see from Eq. (4) that *N* depends on both the relative error of the establishment of output parameter and the output voltage required. Figure 2 plots $N = f(\gamma)$ functions at different α values. As it follows from Fig. 2, a decrease in γ value results in increase in *N*. More pronounced increase in *N* is caused by the improvement of the accuracy of the establishment of the output parameter (decrease in α value).

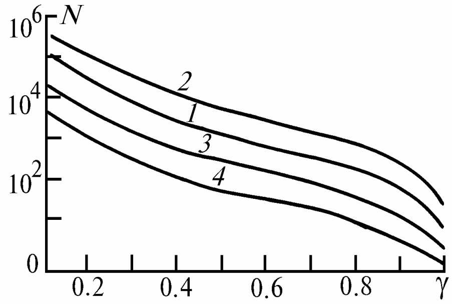

FIG. 2. Dependence $N = f(\gamma)$ at different relative errors of the establishment of the output parameter: $\alpha = 0.01$ *(1),* 0.02 *(2),* 0.05 *(3), and* 0.1 *(4).*

The number of charging cycles is determined by the expression:

$$n = \frac{1}{2}\ln\left(\frac{1+\sqrt{N}\sqrt{1-\gamma}}{1+\sqrt{N}}\right) + \frac{1}{2}\sqrt{N}\,(1-\sqrt{1-\gamma}). \qquad (5)$$

Let us evaluate the feasibility of using this charging circuit for variation of the output voltage over a wide range. For instance, let us consider a source with voltage varying from 0.1 *E* to *E*. The relative error of the establishment of the output voltage should be not higher than 0.01. In this case, *N* equals 3 600 900, and the required number of cycles is 950. Hence, similar to the first case, the maximum attainable pulse repetition rate is 11 Hz when using thyristors with ultimate triggering frequency of 10 kHz.

To decrease the charging time and thereby to increase the sounding pulse repetition rate, it is necessary to use multirange systems or systems with coarse and fine charging cycles. Below, we discuss the possibilities of increasing the sounding pulse repetition rate basing on multirange chargers.

Let us evaluate the potentials of the above–mentioned pumping system when the range of the output voltage variation is divided into two or three subregions. The general tendency is the same if larger number of subregions is used.

Let us consider the operation of two–range system. Let the initial range be from γ_low to γ_up, and the voltage across the charge–storage capacitor does not exceed the value provided by the power supply. The problem is to divide this range into two subregions in such a way that the obtained two–range system would exhibit the best dynamical characteristics, i.e., it would ensure the highest discharge pulse repetition rate. This can be achieved in sole case: when the number of cycles, required for charging the charge–storage capacitor up to a maximum, will be the same in both subregions.

The ratio between charge–storage and dosage capacities for the first subregion N_1 is determined by the lowest level of the output voltage. The value of N_2 depends on γ_m that is determined by the charge–storage capacitor voltage, at which the switching from the first subregion to the second one occurs.

According to aforesaid and basing on Eq. (4) we have

$$N_1 = 4 \Big/ \left(\sqrt{1-\gamma_{low}+2\alpha\,\gamma_{low}} - \sqrt{1-\gamma_{low}}\right)^2 . \qquad (6)$$

$$N_2 = 4 \Big/ \left(\sqrt{1-\gamma_m+2\alpha\,\gamma_m} - \sqrt{1-\gamma_m}\right)^2 . \qquad (7)$$

The maximum numbers of charging cycles for subregions are equal to each other, and they can be calculated by the following equation:

$$n_{max} = \frac{1}{2}\ln\left(\frac{1+\sqrt{N_1}\sqrt{1-\gamma_m}}{1+\sqrt{N_1}}\right) + \frac{1}{2}\sqrt{N_1}\left(1-\sqrt{1-\gamma_m}\right) =$$

$$= \frac{1}{2}\ln\left(\frac{1+\sqrt{N_2}\sqrt{1-\gamma_{up}}}{1+\sqrt{N_2}}\right) + \frac{1}{2}\sqrt{N_2}\left(1-\sqrt{1-\gamma_{up}}\right). \qquad (8)$$

The value of γ_m can be obtained from Eqs. (6), (7) and (8). We have solved this system of equations using the numerical method. Depicted in Fig. 3 is γ_m versus γ_{up} at fixed $\gamma_{low} = 0.1$ and different α values ($\alpha = 0.1$ (*1*) and $\alpha = 0.01$ (*2*)).

As follows from the Fig. 3, γ_m is independent of the relative error of the establishment of output parameter and determined only by the given limits of the output voltage variation. The relations obtained enable one to evaluate the benefit in the rate of operation of the two–range pumping system as compared to the single–range charger. Plotted in Fig. 4 is the ratio of the maximum number of charging cycles for a single–range system to the same number for a two–range system, K, as a function of γ_{up} at fixed $\gamma_{low} = 0.1$.

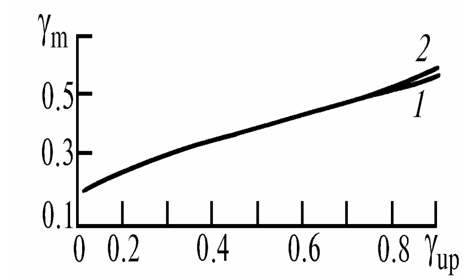

FIG. 3. Dependence $\gamma_m = f(\gamma_{up})$ *at* $\alpha = 0.1$ *(1) and* $\alpha = 0.01$ *(2)*

Figure 4 demonstrates that K factor increases if the range of output voltage variation is widened. For $\gamma_{up} = 1$ and $\alpha = 0.1$, K equals 4.5.

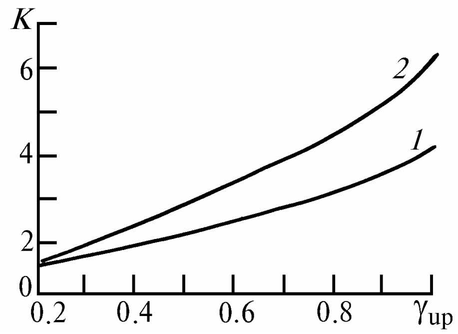

FIG. 4. Dependence $K = f(\gamma_{up})$ *for the two–range (1) and three–range (2) systems at* $\alpha = 0.1$.

Three–range systems have the operation rate higher by a factor of seven or even more as compared to single–range systems.

Thus, to develop the pumping systems with higher operation rate, it is necessary to use the multirange systems.