Kharkiv National Automobile and Highway University

Department of Internal Combustion Engines

ENERGY SYSTEMS AND ALTERNATIVE ENERGY SOURCES‘2025

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SECTION 6.
Electric, hybrid and alternative energy systems, power generation systems and alternative energy sources

Resonant Transformation of Electromagnetic Energy in Serial Contours with Common Capacitive Storage

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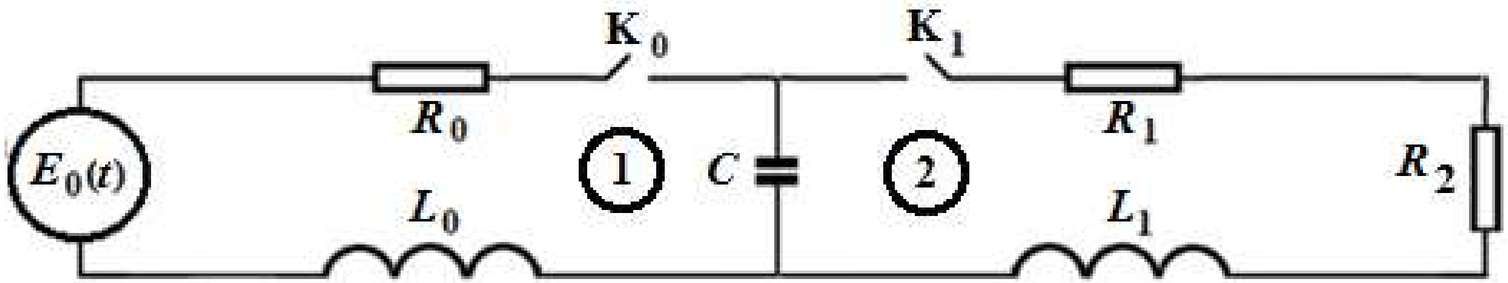
THE AIM OF THE PRESENT WORK

The aim of the paper is to propose and theoretically substantiate the viability of a circuit for resonant transformation of electromagnetic energy in a system of two series active-reactive circuits with a common capacitive storage, excited in the voltage resonance mode and operating as an active power amplifier of an electrical signal in any type of load.

FORMULATION OF THE PROBLEM



The circuit diagram of the amplifier of the active electric power

Action principle.

Switch K_0 is closed, switch K_1 is open. An external energy source excites a voltages resonance in a serial contour – 1, the elements of which are chosen such that its natural frequency coincides with the frequency of the exciting voltage. In the transient mode, the capacitive storage C is charged. Upon reaching a predetermined level of stored energy, the switch K_0 opens, the capacitance charge stops. At the same time switch K_1 closes. The pre-charged capacitance C is discharged through the inductance – L_1 and the active resistance of the elements of the serial contour – 2 to the load R_2, in which active electrical power will be released. At the end of the discharge, switch K_1 opens, switch K_0 closes, the entire system returns to its original state and can operate in the mode of continuous repetition of charge-discharge cycles.

MAIN ANALYTICAL DEPENDENCIES

The state equations describing the transient process in the system:

Charging current

$$J_0(t) \approx \frac{E_0}{R_0} \cdot \left(1 - e^{-\frac{1}{2Q_0}\cdot(\omega_0 \cdot t)}\right) \cdot \sin(\omega_0 \cdot t). \qquad (1)$$

Voltage across capacity,

$$U_C(t) \approx -E_0 \cdot Q_0 \left(1 - e^{-\frac{1}{2Q_0}\cdot(\omega_0 \cdot t)}\right) \cdot \cos(\omega_0 \cdot t). \qquad (2)$$

MAIN ANALYTICAL DEPENDENCIES

The dependence of the increase in energy stored by capacitive storage due to voltage resonance during charging in a series active-reactive contour:

$$\Delta W_0 = \frac{W_C\left(t_0 = \frac{\pi n}{\omega_0}\right)}{W_S\left(t_0 = \frac{\pi n}{\omega_0}\right)} = \frac{Q_0 \cdot \left(1 - e^{-\frac{\pi n}{2Q_0}}\right)^2}{\left(\frac{\pi n}{2Q_0} - \left(1 - e^{-\frac{\pi n}{2Q_0}}\right)\right)}.$$

where Wc – is the energy stored by the capacitive storage;

Ws – is the energy of the exciting power source

Calculating the relationship between the discharge energy to the energy stored in the capacitive storage – $W_C = \frac{C \cdot U_{C0}}{2}$

$$\Delta W_1 = \frac{W_1(\varphi_1)}{W_C} = \left(\frac{1}{1 + \frac{R_1}{R_H}} \right) \cdot \left(1 + \left(\frac{1}{2Q_1} \right)^2 \right) \times$$

$$\times \left(1 - e^{-\frac{\varphi_1}{Q_1}} \left(1 + \left(\left(\frac{1}{2Q_1} \right)^2 \left(1 - cos(2\varphi_1) \right) + \left(\frac{1}{2Q_1} \right) sin(2\varphi_1) \right) \right) \right)$$

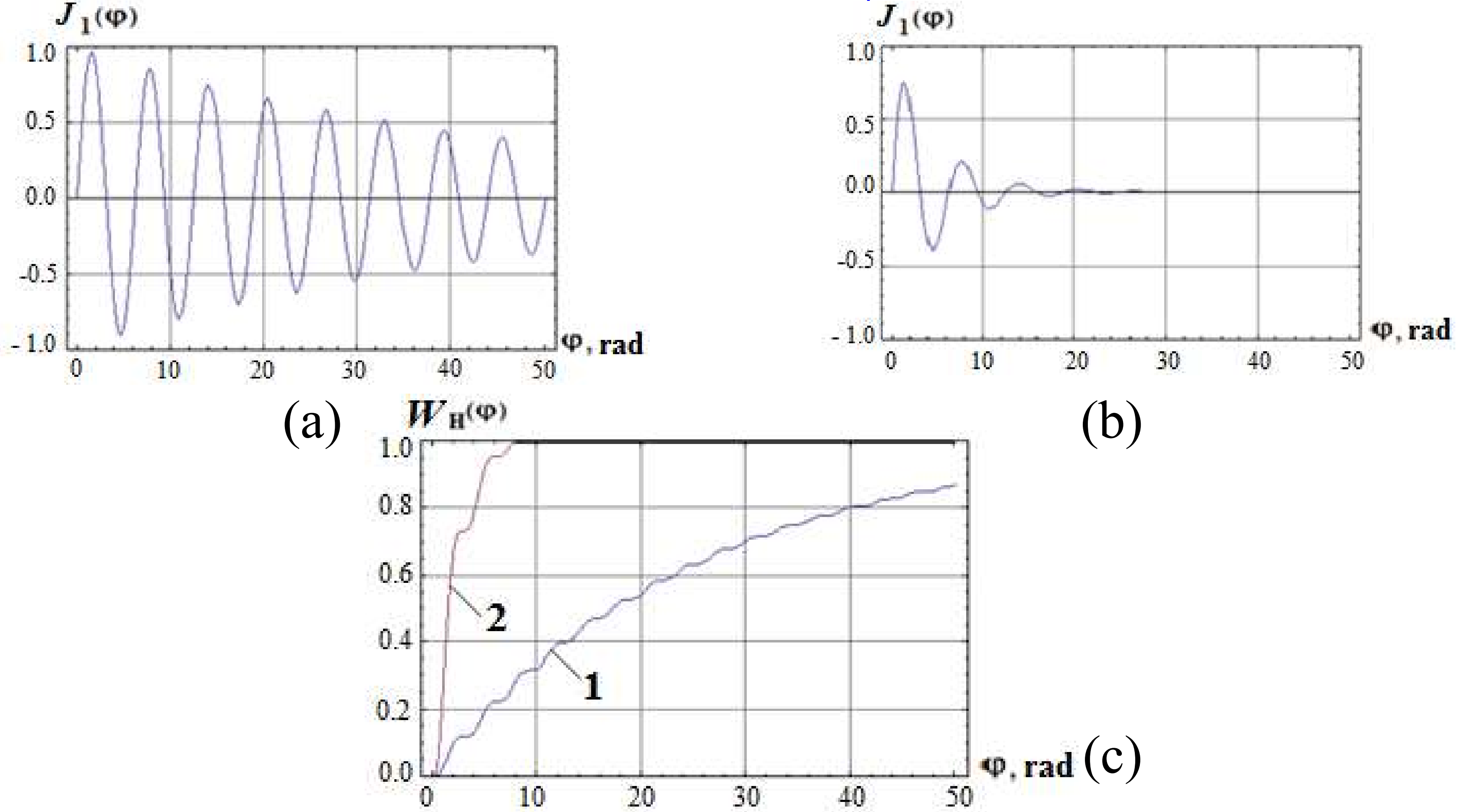
The obtained dependence determines what part of the capacitive storage energy is transformed into the active energy of the discharge current during the discharge time – t_1.

NUMERICAL ESTIMATES, MAIN RESULTS

The main result of the performed numerical estimates is the conclusion about the significant dependence of the characteristics of the ongoing process on the quality factor of the discharge circuit. Thus, the duration of the current pulse in the load, as well as the development time of the discharge process, increase significantly with an increase in the quality factor and decrease with a decrease in this parameter. Also, the output of active energy in the load is determined by the quality factor.

Naturally, the development time of the discharge process decreases at a low quality factor and increases at its sufficiently large value (Fig. 1).

NUMERICAL ESTIMATES, MAIN RESULTS



Typical characteristics of the discharge process of a capacitive energy storage;

(a), (b) – normalized to the maximum discharge current with a variation in the quality factor of the circuit: a) $Q_0 = 25.0$, b) $Q_0 = 2.5$;

(c) the ratio of active energy in the load to the energy stored in a pre-charged capacitive storage: $1 - Q_0 = 25.0$, $2 - Q_0 = 2.5$.

CONCLUSIONS

The workability of the scheme of resonant transformation of electromagnetic energy in a system from two active-reactive contours with a common capacitive storage, excited in the voltages resonance mode and operating as an active power amplifier of an electric signal in a load of any kind, is proposed and theoretically substantiated.

It was found that the charging current and voltage on the capacitance grow in time according to an exponential law to their stationary values.

It is shown that the use of the phenomenon of voltages resonance provides a high level of efficiency of charging a capacitive storage in series active-reactive circuits.

It was found that the output of active energy in the load is determined by the quality factor. So, the development time of the discharge process decreases at a low quality factor and increases at a high value, but for a sufficiently long discharge pulse duration and a high quality factor, the ratio between the output energy and the input energy into the discharge circuit is determined solely by the ratio between the active resistance of the elements of the discharge circuit and the active resistance of the load.

THE REPORT IS OVER,

THANK YOU FOR YOUR

ATTENTION!