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CONTROLLED REACTANCES IN POWER CONTROL SYSTEMS

For matching of radio receivers output stages and electric drives it is suggested to use the controlled reactance containing two transistors of opposite type of conductance, the resistor between input and control electrodes is connected, the capacitor is connected to control electrode and common electrode. Third and fourth transistors of the opposite type of conductance, four diodes and two throttle valves are introduced.

Key words: *controlled reactances, output stages, power control, matching of driver stage.*

Transition to electronic methods of control of power installations such as electric drive, radiotransmitting devices allowed to increase the efficiency factor of such systems, but put forward the problem of providing optimal conditions for power transmission to load, i. e., matching of output stages of power amplifiers and actuating elements. Such matching is realized in case of compensation of reactive components in output circuits. For realization of the given task it will be expedient to apply controlled inductance and capacitance.

At the same time application of conventional solutions, using varicaps or reactive transistors is limited by the technological possibilities of varicaps application at large reactive powers.

Using of external power source is considerable drawback, limiting the sphere of application of controlled reactances, based on reactive transistors [1, 2, 3].

Setting of needed mode of direct current of controlled reactance transistors requires the usage of additional elements of power supply, blocking and filtration that reduces the reliability of the device. Usage of additional power supply also reduces energy efficiency of the device as a whole and limits the sphere of application of such devices only by low-power units of electronic facilities: frequency modulators, automatic frequency control, etc. In the facilities of power electronics the power of supply unit of controlled reactance must considerably exceed the power of its load, that is not efficient.

Controlled reactance of bridge type is suggested in order to refuse from external power supply, the scheme of such reactance is shown in Fig. 1.

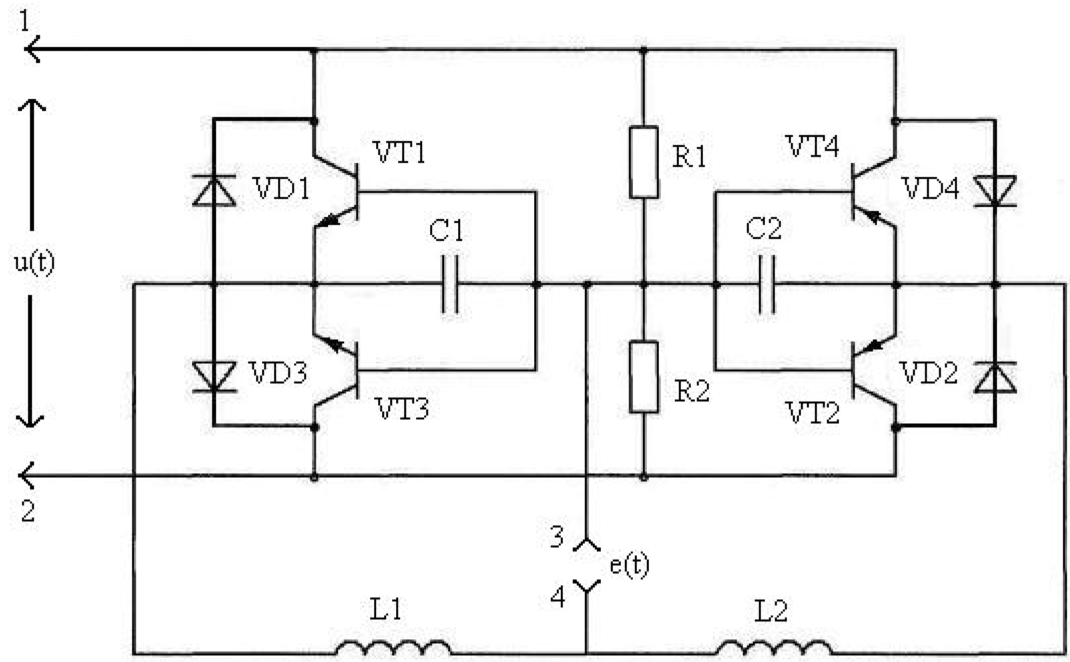

Fig. 1. Circuit diagram of controlled reactance

Controlled reactance contains two transistors of opposite type of conductance VT1 and VT2, resistors R1 and R2 are connected between input and control electrodes, capacitors C1 and C2, third and fourth transistors of the opposite type of conductance VT3 and VT4, four diodes VD1, VD2, VD3 and VD4 and two throttle valves L1 and L2 are connected to control and common electrodes. When control reactance is used on bipolar transistors, collector is an output electrode, base – is control electrode, emitter – is common electrode. When realized on field effect transistors, output electrode is a drain, control electrode is a gate, common electrode is a source.

High frequency harmonic voltage is applied to the outputs 1 and 2 of the device, this voltage can be applied from, for instance, self-excited oscillator:

$$u(t) = U_m \cdot \cos\omega t, \tag{1}$$

where U_m – is the amplitude of high frequency harmonic voltage; ω – is angular frequency of high frequency harmonic voltage.

Continuity of current between outputs 1 and 2 is provided in control reactance, at the supply from the source of signal and modulation voltage:

$$e(t) = E_m \cdot \cos\Omega t, \tag{2}$$

where E_m – is an amplitude of modulation voltage; Ω – is an angular frequency of modulation voltage.

Modulation voltage provides potential shift of transistors VT1, VT2, VT3, VT4 bases at any polarity of these voltages. Possible states of transistors VT1, VT2, VT3, VT4 and diodes VD1, VD2, VD3 and VD4 depending on the polarity of input voltages are given in Table 1 (“1” corresponds to the open state of the element, “0” – close state; “+”– corresponds to positive polarity of voltages, “+”– to negative polarity.

Table 1

State of transistors and diodes at different voltage values

N	$u_{1,2}$	$e_{3,4}$	VT1	VT2	VT3	VT4	VD1	VD3	VD4	VD2
1	+	+	1	0	0	0	0	1	0	0
2	-	+	0	0	1	0	1	0	0	0
3	+	-	0	1	0	0	0	0	1	0
4	-	-	0	0	0	1	0	0	0	1

Voltage $u(t)$ is applied to output electrodes of the transistors VT1, VT2, VT3 and VT4.

Nominal values of the resistors R1 and R2 are chosen in such a way, that resistance R of each of them will be greater than reactive resistance X of capacitors C1 and C2 with capacitance C:

$$R > X = \frac{1}{\omega \cdot C}. \tag{3}$$

In this case the current across the divider RC for each transistor VT1, VT2, VT3 and VT4 has the same initial phase with voltage $u(t)$, applied between the outputs of the device 1 and 2. At the expense of reactive resistance of the capacitors C1 and C2 the voltage at them will lag by the angle, close to 90°:

$$U_C(t) = k \cdot U_m \cdot \sin \omega t, \tag{4}$$

where k – is gain factor of RC divider at frequency ω.

Gain factor of RC divider at frequency ω is determined by the formula:

$$k = \frac{X}{\sqrt{X^2 + R^2}}. \tag{5}$$

At the expense of voltage shift $U_C(t)$, that is applied to input electrodes of all the transistors VT1, VT2, VT3 and VT4, currents of output electrodes of each transistor VT1, VT2, VT3 and VT4 in open state will also be shifted by 90° relatively the voltage, applied to output electrodes:

$$i_{out}(t) = S \cdot U_C(t) = S \cdot k \cdot U_m \cdot \sin \omega t, \tag{6}$$

where S – is a slope of transfer characteristic of control reactance, that can be considered as real number while operation of transistors at frequencies below limiting one.

Thus, current $i_{out}(t)$ between outputs of the device 1 and 2 will lag by 90° relatively voltage, applied to the same outputs. That is, at such circuit solution and relations of parameters taken the device is equivalent to inductance L_e. In active mode:

$$L_э = \frac{U_m}{I_m \cdot \omega} = \frac{U_m}{S \cdot k \cdot U_m \cdot \omega} = \frac{1}{S \cdot k \cdot \omega}. \tag{7}$$

Change of inductance L_e value is performed by the supply of modulation voltage at inputs 3 and 4, that change the shift on control electrodes of all the transistors VT1, VT2, VT3 and VT4. Throttle valves L1 and L2 are used to exclude the impact of high frequency input voltage at inputs 3 and 4. Due to the fact that transistors VT1, VT2, VT3 and VT4 have opposite conductance, active modes of each of them will correspond to opposite half-periods of modulation voltage in accordance with the Table 1.

In case of symmetry in branches and identity of parameters of all transistors VT1, VT2, VT3 and VT4, in load, connected to outputs 1 and 2 of the device, constant component of output electrodes currents and even harmonics of modulation frequencies are compensated, that allow to decrease the shift of the central frequency of self-excited oscillator and increase frequency stability. Decrease of the level of even harmonics of modulation frequencies leads to the decrease of non-linear distortions in transmitted signal and correspondingly in the signal, received after demodulation. This allows to perform angular modulation at high levels of power of radioreceivers and provide, synchronization of actuating elements in electric drive systems.

Introduction of the second pair of transistors VT3 and VT4 and four diodes VD1, VD2, VD3 and VD4 allows to provide the supply of transistors from the sources of high frequency signals and modulation signals. This excludes the necessity of using external additional supply sources for the given device, i. e., it is energetically and economically efficient.

In radiotransmitting devices such reactances provide matching of output stage with an aerial, and in the systems of electric drive they optimize operation modes of converter and motor. Besides, in case of emergency modes such device can perform functions of protection of load and output stage when applying corresponding signal at modulation input.

Hence, the suggested reactance can be applied both in high-frequency and in industrial ranges for control of large powers.

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