UNIVERSAL COMPENSATORY RECTIFIER

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Thyristor rectifiers (TR) have found a wide use in electric drive, electric technology, electrochemistry, and other sectors of industry. Efficiency rate of powerful TR equal up to 97 %, However, consumption of reactive power *Q* under regulation of output power remains their negative side. A lot of various devices of artificial commutation (DAC), aimed to transit TR into the regime of generating Q into power network have been studied.

Keywords: thyristor rectifier, reactive power, artificial commutation

Analysis of their multiplicity allows one to conclude that only two of the known types of DAC provide for a free circulation of reactive commutation power between network, load, and commutative condensers [1, 2].

A tool that has been introduced in [2] is simpler than [1] and allows one to replace the function of transiting TR into the regime of regenerating Q into the network with the function of artificial commutation in load of current, autonomous inverter, direct frequency transformer, and other loads of active-inductive nature of frequency. Analysis and estimation of DAC elements, and also examples of coupling compensatory thyristor rectifier with the mentioned loads is the objective of this article.

In order to generalize and simplify the analysis, we provide a «classic» example of using compensatory TR for powering a current engine anchor (Fig. 1). Matching transformer (MT) is supplied with low-voltage voltage-adding winding W_3 that is connected according to the secondary winding W_2, therefore, voltage on the commuting condenser *Cc* is higher than the range of linear voltage at the clamps of winding W_2 in the beginning of commutation.

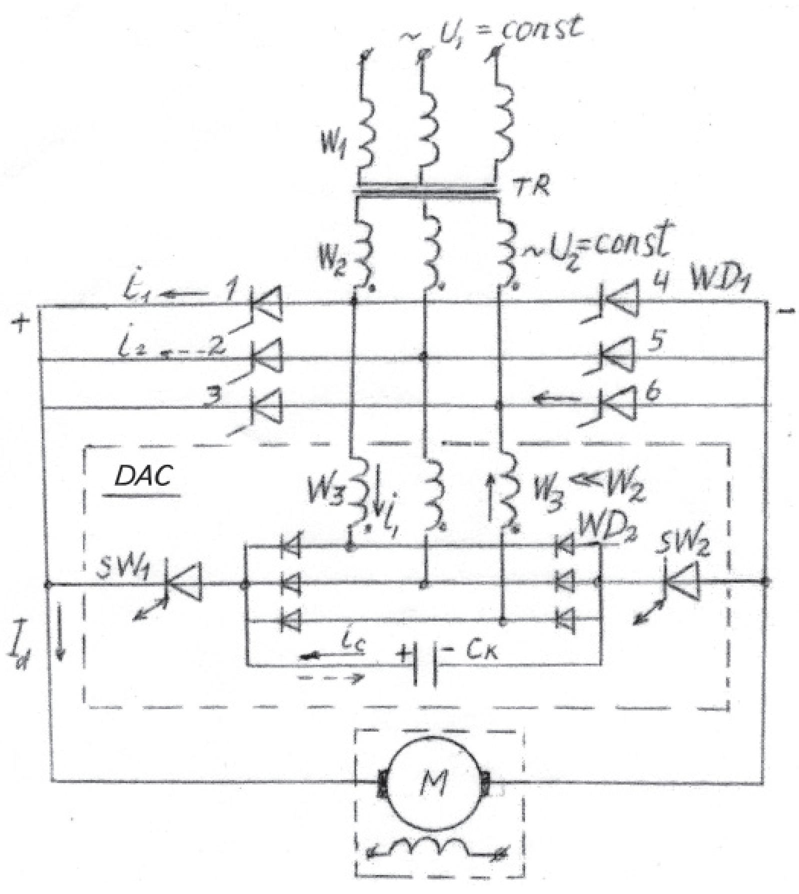

Fig. 1. WD_1 – bridge thyristor rectifier; DAC – device of artificial commutation; WD_2 – diode bridge; SW_1, SW_2 – keys; M – motor

At the moment of commutation start, for example, keys SW_1 and SW_2 close under leading angle β (Fig. 2), and current i_1 from thyristors 1 and 6 (Fig. 1) transits to the corresponding diods of bridge WD_2 and further to the load through SW_1 and SW_2. Current i_1 decreases under the impact of voltage in condenser *Cc*, and all current of load I_d goes through the condenser by the beginning of the first stage. At this moment keys SW_1 and SW_2 close, thyristors 2–6 turn on, and a part of electromagnetic energy of the motor is inverted into the network under the impact of self-induced electromotive load, voltage in the condenser increases, and current in thyristors 2–6 increases up to the load current I_d.

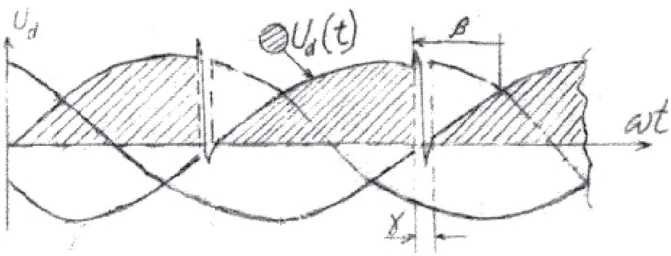

Fig. 2. Diagram of the rectified voltage for anode thyristor group of bridge WD_1, $U_d(t)$ – instant values of rectified voltage

A special feature of the studied FAC is its ability to lock and unlock thyristor rectifier under any angle of activation: $0 < \beta < 180^o{}_{el}$, in other words, work with generation as well as with consumption of reactive power. Besides, presence of unipolar condenser of high capacity provides for a «gentle» commutation with overvoltage limitation at any defined level.

Traditional methods are used to calculate operation regimes and elements of DAC. They are characterized by forming and solving differential equations of commutation contour [4] that is relatively cumbrous and requires graphical constructions. Below we suggest the method of energetic balance that is based upon the equality of energies that flow from the network and return back within a commutation cycle (with no losses).

Commutation energy of the 1st stage:

$$Ecc_1 = U^{2l} m \left(K_1^2 - K_2^2\right) C_c / 2, \qquad (1)$$

where Ecc_1 is energy under condenser discharge; *Ulm* is range of linear voltage considering voltage-adding winding W_3 (Fig. 1); $Ulm \cdot K_1$ is maximum and $Ulm \cdot K_2$ is minimum voltage on condenser, in other words, range of ΔU pulsation.

Suggesting that there are no losses in condenser, network voltage is permanent during the commutation period, and commutation current alter linearly, conditions of energy balance of condenser and network will look as:

$$C \cdot \Delta U^2 = L_S I_d^2 + Ulm \cdot I_d / 2 \cdot t_k, \qquad (2)$$

where from (1) $U^2 = (K_1 - K_2)/2 \cdot U^{2l} m \cdot C$; L_S is inductivity of two phases; $I_d/2$ is an average current during the commutation period, and a $\acute{\omega} t_k = \gamma$ does not exceed 10° el.

L_S can be easily defined through the voltage of short circuit Us:

$$L_S = Us \cdot U_1 / I_d / \acute{\omega} \qquad (3)$$

$0{,}05 < U_c < 0{,}1$ (type value of U_c).

From (2) we can conclude that maximum value of C_c under $\beta = \pi/2$, and, therefore, $U_c = 0{,}1$:

$$Cc_{max} = L_S I_d^2 + Ulm \cdot I_d \cdot t_c / 2. \qquad (4)$$

Calculations according to (1)–(4) show us that under overvoltage below 30 %, pulsation range 20 %, *Ulm*, and $Ul = 380$ V, $C_c \leq 70$ µkF/kWt.

Relation of energy during the period π/m, where π/m = 6 for the bridge scheme, in other words, inter-commutation equals (%): то есть за межкоммутационный период составляет в %

$$Ecc \cdot 100 / P_d \cdot \pi / m\acute{\omega} \approx (6–7)\,\%. \qquad (5)$$

The example of connecting a rectifier (Fig. 1) to autonomous inverter is studied in [3]. In order to connect to reverse loads, for example, reverse electric drive of current or to a direct frequency transformer in parallel to the condenser, devices of artificial commutation are connected through a bridge of four thyristor distributors (Fig. 3).

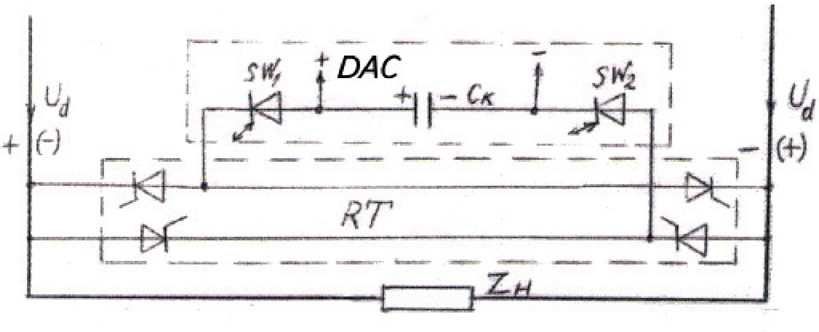

Fig. 3. Connecting compensatory rectifier to reverse load. RT – distributive thyristors

Resume

1. Output of current from all power thyristors of a rectifier can be carried out almost instantly in a compensatory rectifier, equipped with the described device of artificial commutation. It allows one to use the rectifier not only for current loads, but also for powering autonomous thyristor inverters, direct transformers of frequency, and other loads of alternate current with frequency up to 150 H_z. Commutation of the rectifier, as well as loads are carried out by a common commuting device.

2. Estimated efficiency of an artificial commutation device, in other words, relations between reactive commutation power and nominal load power equals no more than 6–7 %. Therefore, elements of an artificial commutation device bear low heat load and small size, compared to the power part, especially if the power of compensatory rectifier is high.

3. Since commuting device can manage commutation of the rectifier and load of autonomous inverter, for example, it takes place not on transistors, but on simple thyristors, it removes limitations in load power.

References

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