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MATHEMATICAL MODEL FOR CALCULATING TRANSIENT AND STEADY MODES OF A VALVE CONVERTER.

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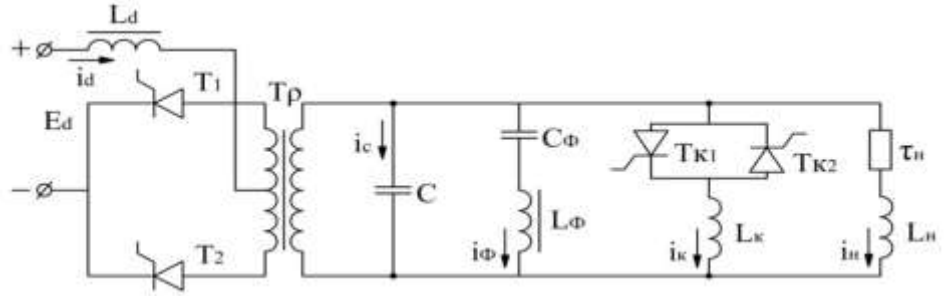
Abstract: The article presents the results of a study of an information-mathematical model for calculating transient and steady-state modes of a valve converter, which will make it possible to effectively use computing systems in solving problems of analysis and optimal selection of elements of a given class of valve converter.

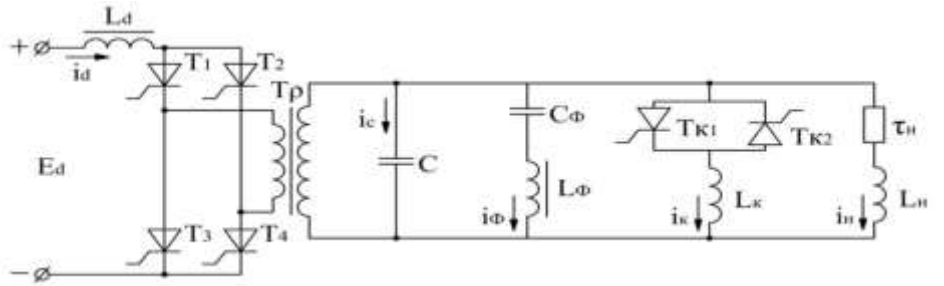
Keywords:

Among the implemented and designed stabilized power supplies (SPS), valve converters built on the basis of single-phase current inverters are widespread. They provide power to various responsible consumers with energy with minimal deviations of parameters in various operating modes. They are characterized by high accuracy in maintaining energy parameters, increased reliability in operation, a long service life, and a high efficiency. Due to good dynamic characteristics, low noise and vibration, they are widely used in various industrial facilities [1].

In order to maintain the stability of amplitude and frequency of output voltage within required limits, the changes in the supply voltage and load, a circuit of parallel autonomous current inverter (ACI) is supplemented by compensating devices (CD), which are connected in parallel to load [2]. A following can be used as a compensating device in ACI: a magnetizable reactor, a reverse uncontrolled or controlled rectifier, and also an inductive thyristor compensator, which is most widely used due to its simplicity and reliability. However, the inclusion of an inductive thyristor compensator in the circuit leads to distortion of the shape of output voltage, therefore, in order to improve the shape of output voltage, it is necessary to add *L, C* filter at the output in parallel with load. Figure 1 below shows the scheme of a valve converter based on a parallel ACI with CD and L, C filter.



a)



b)

Figure 1. Schematic diagrams of SPS based on a parallel ACI with a CD filter:
a) Bridge inverter b) inverter with zero output.

As you know, the solution of various problems of analysis and parametric synthesis of valve converters is associated with implementation of a large volume of calculations. In this regard, it should be noted that a significant part of failures of electronic equipment occurs due to circuit and structural flaws that arise mainly due to the use of manual methods for calculating circuits in engineering practice. This is because the methods of manual calculation are based, as a rule, on a number of simplified assumptions that significantly reduce the quality of design and suggest the need for experimental prototyping - very laborious and expensive process. Therefore, a prerequisite for improving the quality, efficiency and reducing elaboration time of valve converters is widespread use of computer modeling in the design process [2].

The analysis is carried out considering modes of inverter input current and the possible control method. Therefore, while compiling the structures of power circuit involved in development of transition process, the structures, depending on chosen control and regulation method are also taken into account. After identifying the possible structures of the power circuit, they are compiled with equivalent operator schemes (CEO). This procedure is performed taking into account the assumptions made in maintaining the circuit parameters to primary winding of transformer. Moreover, the initial conditions for the capacitance voltages $U_c(0)$ and inductance currents $i_L(0)$ are considered by introducing independent voltage sources into corresponding branches of the circuit - $u_c(0)/p$ and $Li_L(0)$ the positive direction of

which coincides with positive direction of the current in branches at the time of switching. Then, based on the analysis of possible CEO, formulas of images and originals necessary for calculating currents and voltages are derived for universal CEO. The calculation formulas are derived for three SPS options: for a parallel inverter with a CD with representation of active-inductive load in the form of parallel and sequential equivalent circuits; for parallel inverter with CD and filter. The obtained calculated relations can be used to analyze transients in SPS when performing a power circuit of a parallel inverter both in a bridge circuit and in a circuit with zero output.

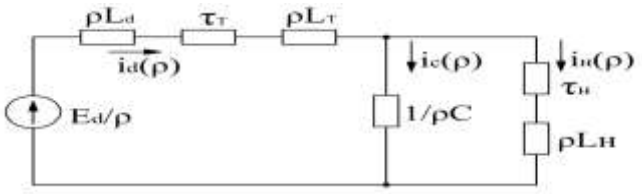
An analysis of electromagnetic processes in ACI with CD from the moment of switching on steady state under controlling the output voltage by changing the α - control angle of CD showed that six CEO can be involved in development of transition process, depending on the operating state of CD, represented by fig. 2 and 3.

Consider possible CEO, when CD is disabled;

a) CEO (Fig. 2, a) corresponds to the start-up of circuit; therefore, the initial conditions uc (0) and ic (0) are equal to zero and there are no sources in the circuit considers independent initial conditions;

б) The CEO (Fig. 2, b) corresponds to the structure at the beginning of clock interval when the control system (CS) pulses are applied to the next pair of power thyristors. Considering that the inverter input current does not change its direction, independent sources $L_d\ i_d\ (0)$ и $L_T\ i_d\ (0)$ are taken with their sign. In contrast, independent sources taking into account the voltage at the capacitance $U_c(0)/p$ and the current at the load inductance $L_H\, i_H\, (0)$ are taken with the opposite sign, since the currents on capacitance and on load at the beginning of each clock interval change direction;

в) The CEO (Fig. 2, c) corresponds to the structure of power circuit when CD is turned off inside the clock interval, since all currents (i_d, $i_н$, i_c) retain their conditionally positive direction.



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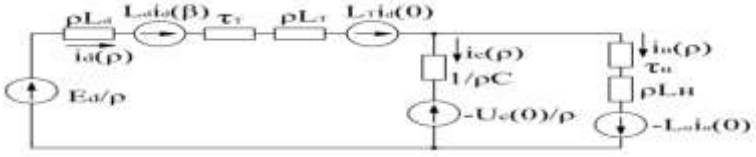

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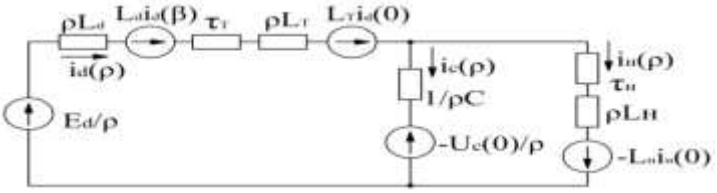


c)

Figure 2. Possible CEO when switchgear is disabled:

a) CEO start-up circuit;

b) CEO at the beginning of clock interval;

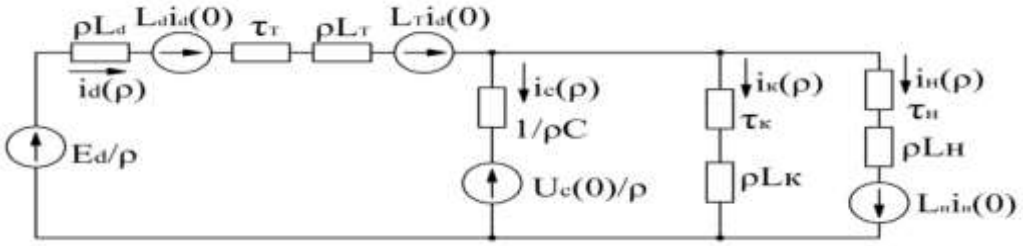
c) CEO when CD is turned off.

Consider the possible CEO when CD is turned on:

a) CEO (Fig. 3, a) corresponds to the structure when CD is turned on inside the clock interval. The length of time from the beginning of clock interval to the supply of pulses of CS to thyristors of CD corresponds to the angle α of control of CD. Since CD switching on occurs inside the clock interval, all independent sources are taken with a positive sign, the source $L_к\, i_к\, (0)$ allows the current at CD inductance equals to zero;

b) The CEO (Fig. 3b) corresponds to the structure when CD is turned on at the beginning of clock interval. In this case, source allows the voltage across the capacitance and the current at the load are taken with the opposite sign, and the source allows the current through the inductance of CD, equals to zero;

c) The CEO (Fig. 3c) corresponds to the structure at the beginning of clock interval, when CD is in working condition, which is possible with combined excitation. Therefore, all independent sources, except for a source that allows the input current of inverter are taken with the opposite sign.



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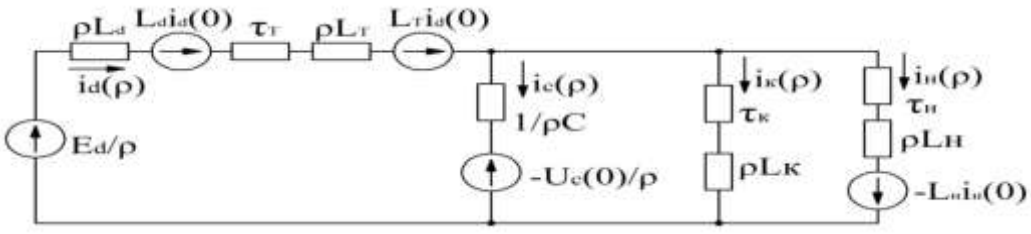

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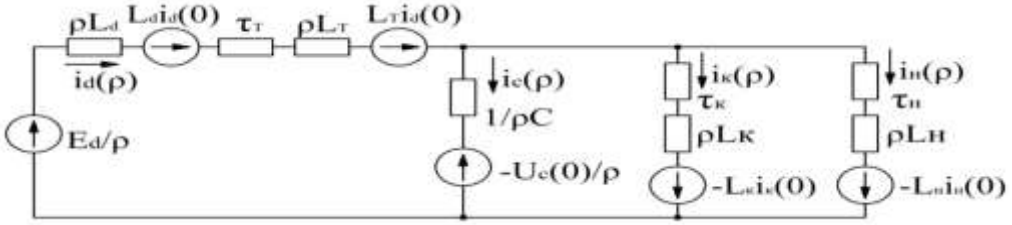


c)

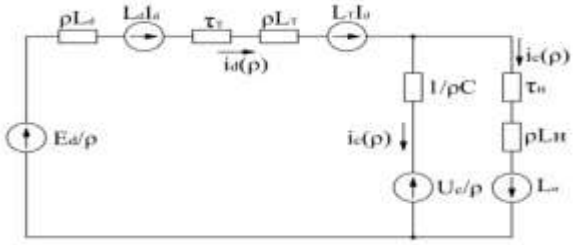
Figure 3. Possible CEO when CD is turned on:

a) CEO when CD is turned on inside the clock interval;

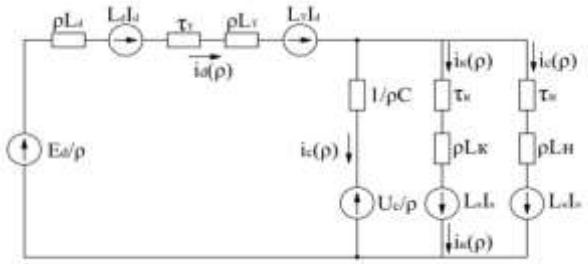
b) When CD is turned on at the beginning of the clock interval;

c) CD is in working condition.

An analysis of possible CEO shows that a complete calculation of CD transient process based on parallel ACI with CD can be carried out on the basis of two universal SPS that differ from each other in operating state of CD. One of them corresponds to the switched-off state of the other, and the switched-on state of CD; their use for analysis of various operational situations is determined by corresponding initial conditions. For each of these universal CEO the calculation formulas for instantaneous values of sought currents and voltages are derived.



a) a) Universal CEO I-I type (CD is disabled)



b) Universal CEO II-I type (CD is turned on)

Figure 4. Universal CEO for serial connection of r_{H} , X_{LH}

a) CEO I-I type (CD is disabled); b) CEO II-I type (CD is turned on).

Universal circuit I-I type

For CEO (Fig. 4, a) following initial conditions are accepted:

Solving the equations compiled according to the laws of Kirchhoff regarding the sought currents and voltages, we obtain their images in the form:

The polynomials in expressions (1) have the following form:

The polynomial M_1 (p) = 0 has the following roots: Then the originals of currents and voltages will have the following form:

Universal circuit II-I type.

The originals of currents and voltages are expressed as:

Further, a mathematical model of SPS was obtained by programming analytical expressions and compiling an algorithm of ways of development process. Due to which transient processes were calculated, time diagrams of sought currents and voltages were plotted, shown in Fig. 5, 6 and 7.

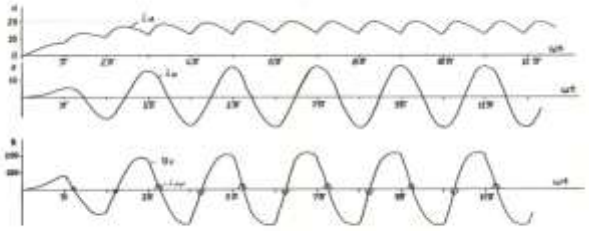


Figure 5. Temporary diagrams of currents and voltages at start-up

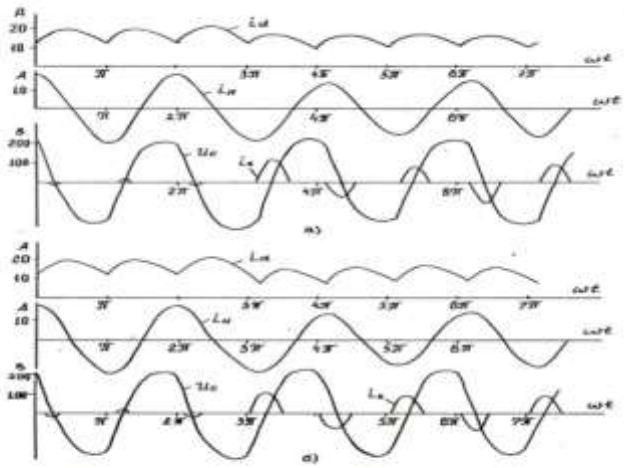


Figure 6. Temporary diagrams of currents and voltages during load shedding: a) Independent excitation; b) combined excitation

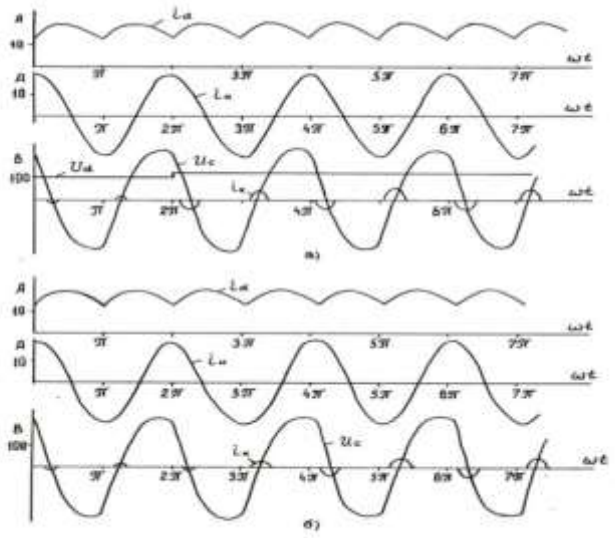


Figure 7. Temporary diagrams of currents and voltages with increasing input voltage:

a) Independent excitation; b) combined excitation

Based on a series of computer research using developed mathematical model (algorithm and program), recommended parameters and typical nominal of SPS circuit elements based on a parallel inverter operating in a continuous mode of input current of the inverter were obtained.

Conclusion

1. An analysis of various dynamic modes of valve converters based on a single-phase parallel to ACI with CD, performed with a ongoing inverter input current considering the control method, showed that six power circuit structures can participate in development of transient processes. In order to reduce the size of mathematical model and, accordingly, efficiently use the machine's DCM, it is shown in the chapter that the complete calculation of transient processes can be performed not on six CEO, but on two universal CEO, which will allow efficient use of digital computers in solving tasks of analysis and gives optimal choice of VP class elements.

2. Unlike existing private BII models based on a single-phase parallel ACI, the mathematical model developed in this work provides research on both inverter power circuits (bridge or zero output circuit) using a single program, since the recurrence relations underlying the model and its software implementation is obtained in the form of a independent power circuit type. This circumstance will allow you to clearly and simply perform a comparative analysis of both power circuits and make an optimal choice of circuit elements.

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