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High-Voltage Power Supply for Electrophysical Installation

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Abstract: The development of modern expensive electrophysical installations compels to conduct preliminary researches which at this stage are expedient for carrying out on the basis of numerical simulation of the processes proceeding in the main power knots of installation. Application of numerical modeling became especially attractive in connection with emergence of a number of standard programs. Such research significantly accelerates and reduces the price of the process of development, allowing to reveal and eliminate in passing the most strained and emergency operation of work of installation. The problem becomes complicated also by the circumstance that though the development of knots of installation on the basis of commercial products makes it cheaper and accelerates it but at the same time generates a problem of compatibility of parameters of knots. The research presents the modeling of the modes of installation with a problem of coordination of its separate blocks to be executed. The source load is electrophysical installation with consumption current to 7 MA. The research demonstrates numerical modeling of processes being carried out in the most problem parts of the scheme. The model of the converter developing the alternating echeloned voltage has been worked out.

Key words: Electrophysical installation, numerical modeling, source of high-voltage, power, supply

INTRODUCTION

The study presents the results of numerical and subsequent physical modeling regimes in the basic elements of a high-voltage installation, arranged from the industrial blocks, the parameters of which were not initially agreed. Simulation and selection of optimal regimes of installation blocks are performed on the basis of MICRO-CAP program package (Amelina and Amelin, 2007).

MATERIALS AND METHODS

Formulation of the problem: High voltage source to 300 kV consists of a thyristor Frequency Converter (F.C) of “INVERTOR” type with a frequency f = 400 Hz, used in motor-starting devices of electric motor, high-voltage Transformer (Tr) IOM-100 used in testing high constructs, three-fold Voltage Multiplier (VM) and the capacitor filter (C_4) at the output of the voltage multiplier (Fig. 1). The load of high voltage power is electrophysical installation with current consumption of 7 mA. The high-voltage source is configured from the industrial units, the parameters of which were not originally agreed. As a result of this circumstance there appeared a problem of compatibility of modes of operation of such blocks. The need for the frequency converter in the circuit is dictated, first of all, by the desire to reduce the parameters of capacitive elements comprising the Voltage Multiplier (VM) and a capacitive filter (C4). Every half period of the output voltage in the frequency converter is an echelon of pulses following with variable duty factor which allows to regulate effective voltage without cumbersome voltage regulator.

The purpose of the numerical modeling was detection of potential emergency operations in the elements of installation and development of possible ways of their elimination. Numerical modeling of the processes in the source was based on the MICRO-CAP-type program package (Demin *et al*., 2012; Garkusha *et al*., 2011; Demin *et al*., 2011, 2013).

RESULTS AND DISCUSSION

The analysis of possibility of optimization of work of certain installation blocks: With MICRO-CAP software package the processes were computed, the diagrams of which are shown in Fig. 2-7. Figure 2 presents the diagrams of phase voltages (Va, Vb), of displaced by 1/3 period, as it is typical for a three-phase system.

Figure 3 demonstrates the diagram of line voltage (V_{13}) of transformer at the input. As it can be seen from the diagram, there it is reproduced a signal with the envelope of quasi-sinusoidal form.

Figure 4 shows the curve of voltage at the output of multiplying circuit (load). Load voltage reaches 300 kW, which is required according to the project.

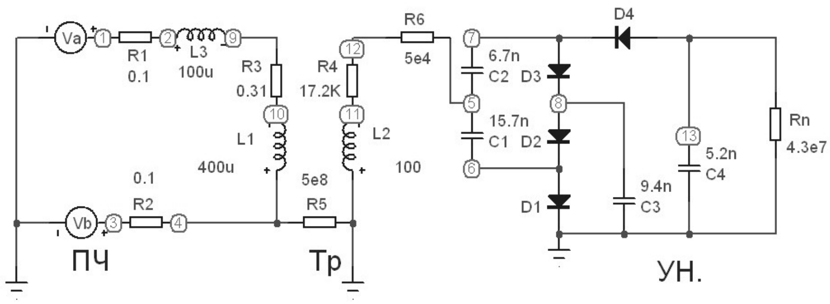

Fig. 1: Schematic diagram (numerical model) of high-voltage power supply of electrophysical installation

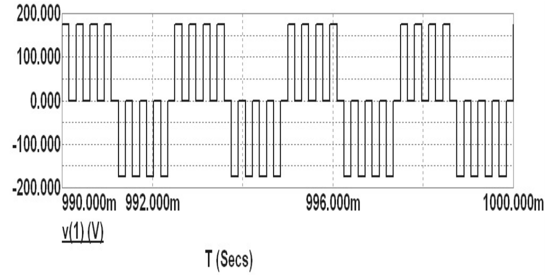

Fig. 2: Phase voltage A (Va) (chart above) and phase voltage B (Vb) (chart below) at the frequency converter output

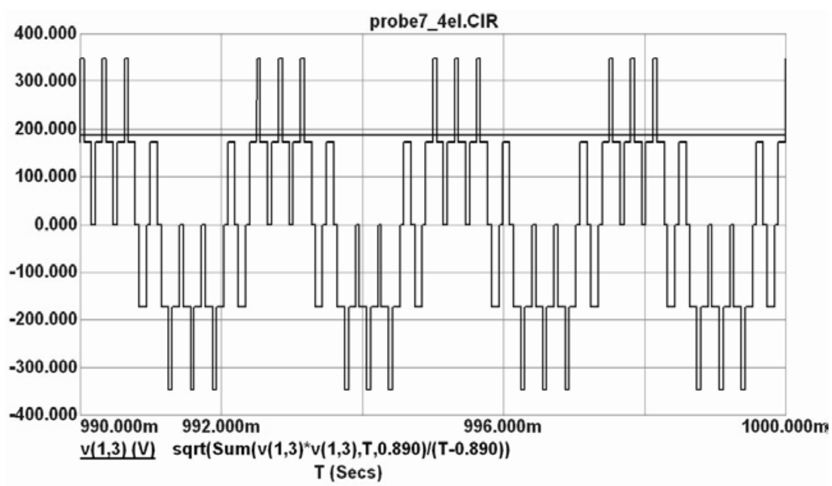

Fig. 3: Line voltage V_{13} at the output of frequency converter. The dotted line shows the current (rms) line voltage of frequency converter

Figure 5 shows the diode voltage (D1) of the multiplying circuit. As follows from the presented graph, reverse voltage is~150 kV, significantly exceeding the permissible 100 kV which requires pairing of the available diodes.

Figure 6 shows a graph of current flowing through the diodes in the process of charging capacitances C_1-C_4. As follows from the graph, current in the diodes is fast, which requires the use of pulse diodes capable of operating in this mode, in order to eliminate the effect of "crowding" the current in the p-n diode.

As the installation uses a high voltage transformer with a low current capacity in the secondary winding, the operating current has been figured out, as indicated by dotted line in Fig. 7.

Computations show that root-mean-square current in high voltage winding of the transformer is 47 mA with allowed value (according to the passport data of the transformer) 36 mA. To eliminate the emergency operation, one should use a more high-powerful transformer or the use iteratively short-time making

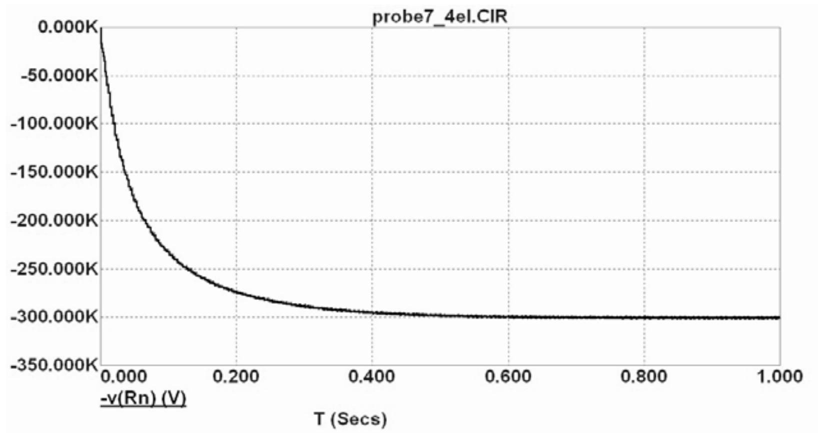

Fig. 4: The output voltage of the triple voltage multiplier

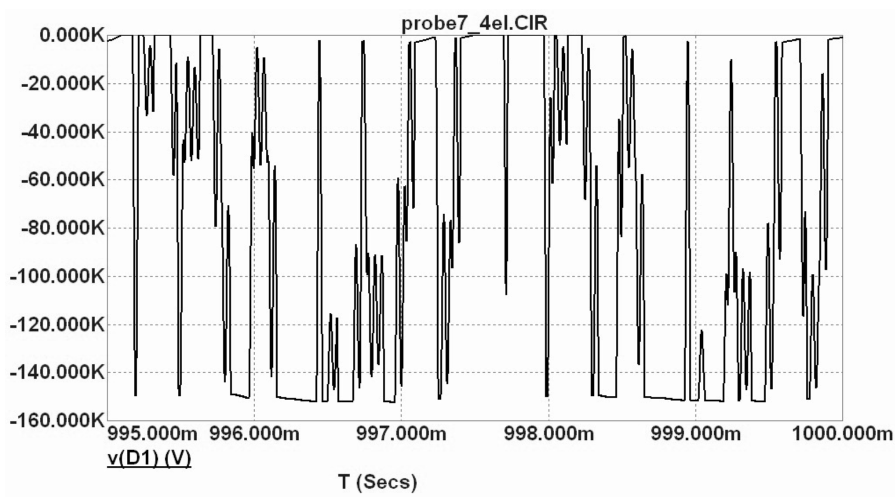

Fig. 5: The diode D1 voltage

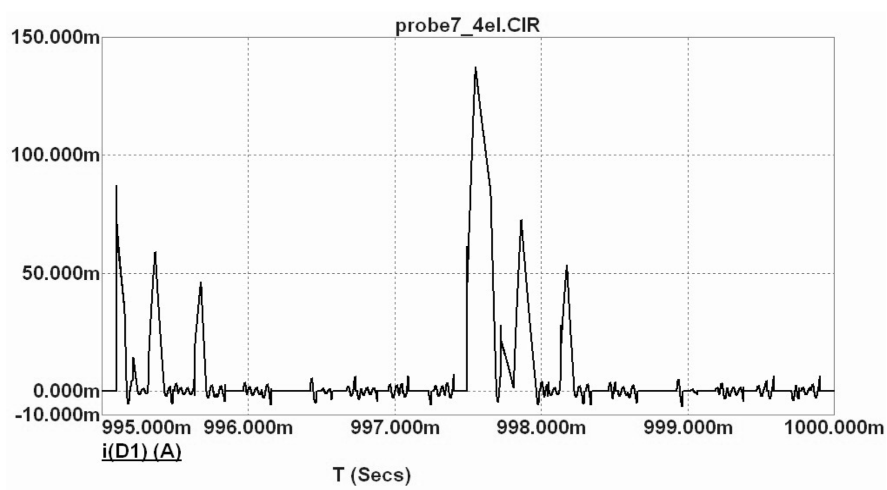

Fig. 6: Current in diode D1

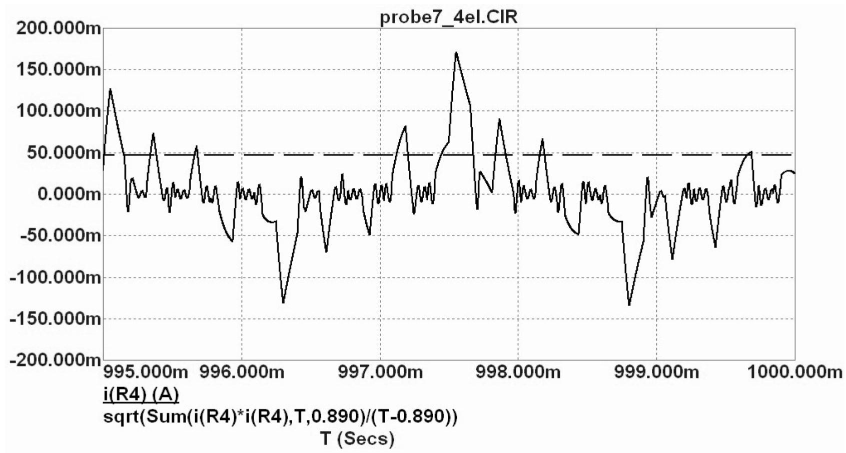

Fig. 7: The current on the secondary side of the step-up transformer (dashed line indicates root-mean-square current)

Table 1: The coefficient voltage pulsation in load

Ñ$_{4(i)}$/C_4	Cp %
1	0.32
0.5	0.63
0.25	1.24
0.1	3

conditions of the installation so, that at the interval of switching time of 15 minutes, the current (according to the technical data of the transformer) does not exceed 60 mA.

Since, the installation contains a large number of high-voltage capacitive elements which makes it structurally bulky, it is interesting to tie up the dependence of the parameters of capacitive elements of the allowed coefficient of the output voltage pulsation. The most difficult is to realize constructively the capacitive filter at the output of voltage multiplier (C_4) which is across total output voltage of 300 kV.

Calculation of pulsation coefficient Cp by multiplicity of reducing parameter C_4 is given in Table 1. The calculation shows that filter capacity can be reduced 10 times, if one assumes the value of the coefficient of pulsation Cp = 3%.

Summary: The results of numerical modeling of the processes in installation allow to make reasonable use of the circuitry of installation and necessary adjustments for its reliable operation.

CONCLUSION

Modeling the circuit with voltage multiplier allowed to reveal potential emergency operation in the units of installation and block them before its physical implementation. As shown by numerical analysis of operations of installation when creating electrical systems comprising series-produced units by industry, preliminary numerical modeling is necessary to elicit opportunities and constraints in their co-work.

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