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STUDY MODE VOLTAGE BOOSTER TRANSFORMER WITH THYRISTOR CONTROL

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Abstract: *Calculated-experimental research work VDT thyristor controlled in different modes. Installed module change phase and the harmonic components of the EMF and current in the windings of the transformer, given their quantitative assessment and management advice regimes VDT work.*

Keywords: voltage booster transformer, thyristor control.

INTRODUCTION

One of the main tasks of the service of electrical networks - supply consumers with the electricity and voltage, does not go beyond the established norms. To do this, along with centralized control are widely used local voltage regulators. The static devices contactless switching devices and voltage booster transformers (VBT) are used increasingly as the latter [1,5]. Their development - an important area of research in the field of improving the quality of electricity. In making such devices must take into account several features of booster transformers at different switching modes, in particular, the nature of the EMF changes at the terminals of the windings VBT in the following modes [2,3]: |

1) idling, at VBTs deep saturation of the magnetic system, the caused by magnetomotive force the load current;

2) in the operating mode, in oncoming operation or concordant inclusion of the primary windings of VBT;

3) at transients caused by commutations in the circuit the primary windings.

EXPOSITION

To study the processes in VBT experimental studies were carried out on full-scale sample VBT. The value of parameters of mode and the nature of their changes were recorded using an oscilloscope.

The schematic diagram of the research facility of the work of VBT in these modes is shown in fig. 1. In Fig. 2 shows the magnetization curve of the magnetic circuit of the VBT and the instantaneous value $i_2\omega_2$ magnetomotive force generated by the load current flowing through the secondary winding of the VBT.

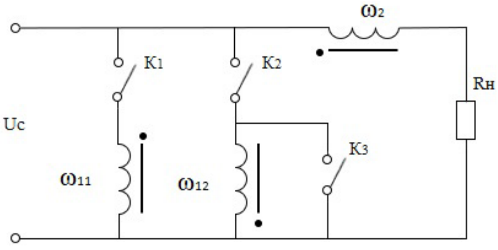


Fig. 1. *Schematic of the experimental setup for studying modes VBT*

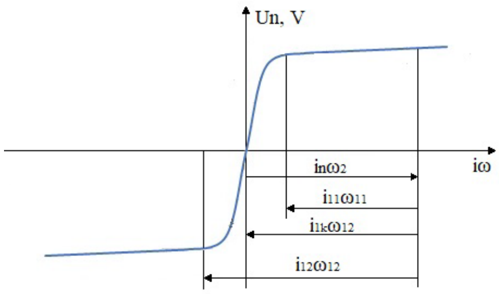
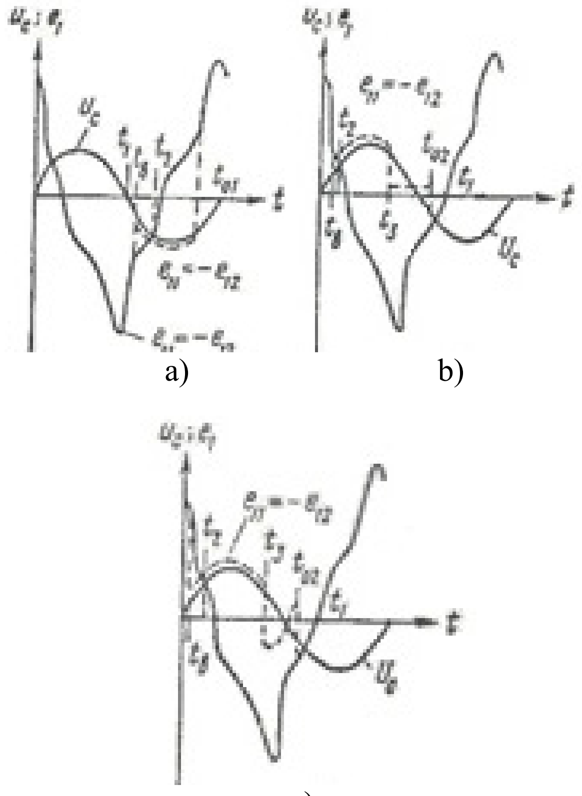


Fig. 2. *The magnetization curve of the magnetic circuit of the VBT*

In idle, the both of primary windings are disconnected from the network and magnetic deeply saturated.

EMF e_{11} and e_{12} at the terminals of the primary windings non-sinusoidal and their amplitude, as seen from the curves in fig. 3, 3-4 times higher than the amplitude of the mains voltage.



a) b)

c)

Fig. 3. *Change EMF VBT winding in idle mode and in modes: a – oncoming inclusion; b – oncoming inclusion and short-circuit; c – oncoming inclusion and concordant inclusion*

With resistive load EMF e_{11} and e_{12} are shifted in opposite directions with respect to the mains voltage by an angle slightly different from the values π/2, due to the fact that the transformer operates as a choke, introducing an inductance in the load circuit. The instantaneous value of the voltage across the switching keys K_1 and K_2 that. Determined, respectively, as sum of the voltages Uc and the EMF network e_{11} and e_{12}, in this mode may exceed 1000 V. Thus, the idling mode is undesirable and VBT operation of the regulator should be deleted.

The mode switching counter EMF winding ω_2, it is directed towards Vin, decreasing voltage at the regulator output. The mode can be achieved if ω_{1r} winding (fig. 1) connected to the network, a cross key K_1. This incorporation in the case of thyristor keys should be produced at time t_i when $t_1 < t_i < t_2$ (fig. 3a) when EMF counter of the winding e_{11} larger voltage UC and directed to meet him.

i_{11} will meet current voltage Uc, creating magnetomotive force $i_{11}\omega_{11}$. Under the action of the resulting M.D.S. $i_2\omega_2$ and $i_{11}\omega_{11}$ (Fig. 2) EMF the primary coil is reduced, remaining slightly larger Uc. Form EMF under the influence of the nonlinear transformer winding inductance slightly deviates from the sinusoidal. Tension on the key K_1, which in this mode is defined as the voltage difference between Uc and e_{11}, at time t_{0r} becomes zero. The thyristor switch is turned off. This occurs before the voltage is zero. VBT goes into idling mode.

As the results of the experiment, the time t_{01} depends on the moment of switching the oncoming coil t_i. This should be considered when developing thyristor key management schemes.

If at time t_l when the key K_1 is on ($t_i < t_l < t_{01}$), carry out short-circuited winding ω_2 by the key K_3 (fig. 3b), VBT will go into a short circuit mode. I_{1rl} current in the coil ω_{12} creates a magnetomotive force $i_{1kz}\omega_{12}$, total magnetomotive force is reduced to zero and EMF e_1 and e_2 are also reduced to zero. Thyristor switch K_1 is turnning off. The voltage on output of regulator will become equal to Uc.

If, when the key K_1 is open, close K_2, then in winding circuit ω_{12} under influenced concordant directional voltages e_{12} and Uc, current i_{12} will creating magnetomotive force $i_{12}\omega_{12}$, herewith EMF e_1 and e_2 are changing the phase on angle π/2 (fig. 3c). The voltage on output regulator increases.

Inclusion of K_3 or key K_2 at K_1 closed leads to a sharp decrease EMF e_2, whereby the voltage at the key K_1 is reduced to zero, changes polarity and rises rapidly in the first case to the value Uc, in the second - takes the value 2Uc. When using a triac or of thyristor valves are turned on back-to-parallel included operated valve is disabled, and a counter may is turned on under the influence of increasing tension, since the rate of increase du_r/dt voltage in these modes reaches significant values. Turning the key K_1 on at open key K_2 or K_3 leads to accidental emergency short circuit in the circuit of the primary windings VBT. Under the influence of the inductance of windings VBT current through K_3 key in short-circuit mode or K_2 in consonant mode reaches zero with some delay after the passage of the mains voltage through zero (t_{02} point in fig. 3b and c). This leads to delay disabling of keys K_2 or K_3. The delay time, as is evident from the results of experiments that depend on the time the switching key K_2 or K_3 (point t_3 in fig. 3b and c). This phenomenon should be taken into account in the development of thyristor key management schemes, in particular, the node of enable K_1 key and select the points in time t_i.

To quantify the processes in the VBT computational studies using Scilab program conducted.

The differential equations describing the electromagnetic process VBT under normal assumptions can be written as:

$$\left.\begin{aligned} u_1 = r_1 i_1 + L_1\frac{di_1}{dt} + \frac{d\Psi}{dt} + u_{п1(i)};\\ -u_2 = r_2 i_2 + L_2\frac{di_2}{dt} + k\frac{d\Psi}{dt} + u_{b(i)};\\ i_c = i_1 + i_2 k \end{aligned}\right\}, (1)$$

Wherein r_1, r_2 - the active resistance consistent and exciting windings of the transformer;

L_1, L_2 - the leakage inductance of the windings;

k - the coefficient of transformation of the transformer.

In order to simplify the calculation and mainly improve stability of the solution a task on the structural mathematical model to further is consider U_C take into consideration EMF scattering one of a transformer windings. This simplification is not practically affect the accuracy of the calculations, since in the real world, its value is negligible as compared to the nominal load voltage.

Given to a form suitable for mathematical modeling equations are:

$$\left.\begin{aligned} \frac{d\Psi}{dt} = u_1 - r_1 i_1 - u_{n1(i)};\\ \frac{di_2}{dt} = \frac{1}{L_2}\left[-u_2 - r_2 i_2 - k\frac{d\Psi}{dt} - u_{b(i)}\right];\\ u_{b(i)} = -u_2 - k\frac{d\Psi}{dt};\\ i_1 = i_0 - i_2 k \end{aligned}\right\}(2)$$

The third equation in system (2) is the voltage across the valves at a current $i_2 = 0$. It is obtained from the equation of stress equilibrium in the circuit of the exciting coil.

Scheme "Structural model VBT" shown on fig. 4.

For playback according $i_0 = f(\Psi)$ functional converter with methodological error applied (piecewise linear approximation). Curve $i_0 = f(\Psi)$ corresponds to the magnetization curve, is removed on the instantaneous values in the successive windings side. Valves characteristics are taken like perfect. In the closed state characteristics controlled valves are modeled by the proposed principle, is accomplished by entering the input of the structural unit of the second equation of system (2) voltage - Ub (i), the corresponding to voltage on the control valves. At the output of the third link of the structural model for modeling the characteristics of valves in a conducting state connected relay RP , by contacts which turn off the voltage - Ub (i), previously reported to the input of the second structural member. In this way, the closed contacts of RP relay correspond to valve closed, open - open. The moment of locking valve, and thus the time of closing the relay contacts must strictly comply with the moment; wherein the current i_2 reaches a value of zero. Changing the duration of the valve is carried RP relay contacts.

The current-voltage characteristic of the load is reproduced using functional converter.

Parameters of the scheme mode are generally non-sinusoidal functions of time, which is caused primarily by non-sinusoidal affecting on exciting winding of the transformer by voltage and the nonlinearity of the transformer and the load parameter [4].

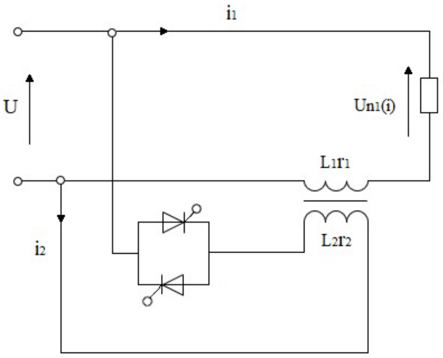


Fig. 4. *Scheme VDT with thyristor controlled*

Obviously, the degree non-sinusoidality will depend on the angle α regulating valves and degree of saturation of the magnetic system. When α = 0 ° non-sinusoidality of parameter of mode is determined only by the nonlinearity of the parameters of the transformer and the load. Calculations characteristic modes circuits at different angles regulating valve made in Scilab program.

To assess the non-sinusoidality held analysis harmonic composition circuit mode parameters.

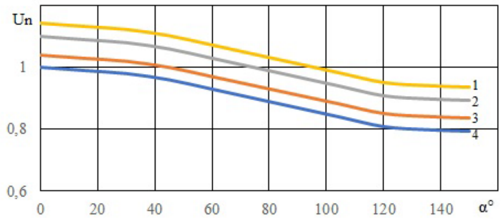


Fig. 5. *Dependence of the relative values of the output voltage from angle adjusting valves: 1,2,3,4 - an input voltage of 1, 0.95, 0.9, 0.85 Unom*

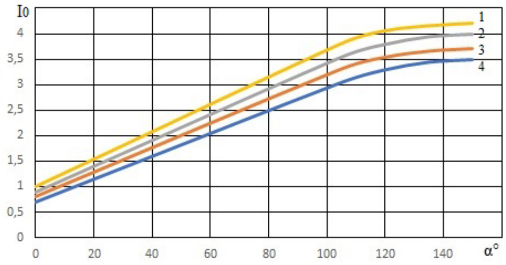


Fig. 6. *Dependence of the relative value of magnetizing current from the angle adjusting valves: 1,2,3,4 - an input voltage of 1, 0.95, 0.9, 0.85 Unom*

The table shows the results of the decomposition of the load current in the harmonic series.

Table 1

The results in decomposition of the load current harmonic series

α° I1/Ik· 100%	0	45	90	135	180
I(1)	100	97,2	90,5	86,9	82
I(3)	0	5,31	7,06	9,7	12,9
I(5)	0	2,1	3,53	4,08	4,4
I(7)	0	0,9	1,23	1,35	1,57

Fig. 5 shows the characteristics of the effective value output voltage when of scheme when it changes the input voltage at 15% of Unom and regulation α from 0 to 180°.

Fig. 6 shows the dependence of the effective value of the magnetization current I * 0 the adjusting the angle valves.

CONCLUSION

According to the study the following conclusions:

1) The study scheme allows to smoothly adjust the effective value of the output voltage when the input voltage and load. Parameters of schemes mode are generally non-sinusoidal functions of time.

2) The magnetization current of the voltage booster transformer increases with the angle adjusting and when valves fully closed valves greatly exceeds the nominal load current of the transformer. Also greatly increases load on the valves and VBT terminals. And when fully closed valve is greater than the nominal voltage of the installation is about 3-4 times. Therefore it is possible to carry out only a limited adjustment range of the adjusting angle.

3) For effective regulation over the entire range of the angle changes to be applied schemes in which, it excludes the possibility of continuous operation without demagnetizing the transformer circuit. This, for example, schemes to the inducing keys or a three-windingVBT.

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