THE COMPUTER ANALYSIS OF THE SERIES-PARALLEL INVERTERS WITH CONTINUS REGULATION OF AMPLITUDE AND FREQUENCY

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Abstract:

Computer-aided analysis of the inverter with series-parallel resonance circuit and continuous frequency and magnitude control is presented.

The method for output voltage and frequency control for thyristor and transistor inverters is given together with computer-aided analysis of voltages and currents waveforms.

Three-phase series-parallel inverter for high-speed drives is an example of dynamic properties of closed-loop drive system.

Key words:

Simulation and Analyses Series-Parallel inverters

Introduction:

In many branches of industry there is a problem of continuous regulation of amplitude and frequency or the voltage with sinusoidal waveform or other shapes to feed different types of electric drives.

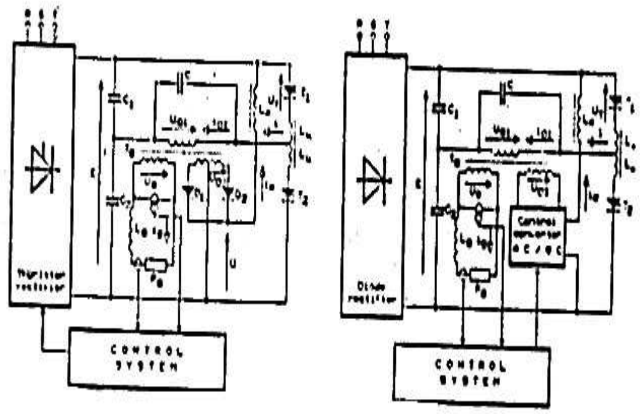
A good example may be drives with regulated rotation speed of electric motors.

Continuous regulation of output voltage magnitude and frequency may be obtained using the thyristor inverter with commutation circuits or using the transistor inverter with phase and frequency modulation. In the first case the control properties of voltage and frequency regulation are restricted (mainly by the disposable time for thyristor switch off). The other disadvantages of this solution are great dimensions of commutative elements. In the second case one may obtain big augmentation of frequency changes range and better properties of power continuous regulation. Because of much higher frequencies of cooperating inverters we obtain much smaller dimensions of resonance circuit's elements.

Simulation results were obtained using the electronic circuits analysis program package which was run on an IBM PC/AT compatible micro-computer.

2/-Continuous regulation of voltage and frequency of the Thyristor series-parallel inverter

The continuous regulation of output voltage of series-parallel inverter with feedback (fig.2.1) may be obtained by changing the switching on angle of thyristors of the rectifier supplying the inverter in closed regulation system [1, 2, 3] with negative voltage coupling fig.2.1a) or by changing the values of current (I_z) in feedback using the controlled converter AC/DC which makes it possible to return the energy to the source supplying inverter (fig.2.1b).



A B

Fig.(2.1): Series- parallel inverter with feedback
A: magnitude regulation of thyristor rectifier
B: magnitude regulation of AC/DC converter

The continuous regulation of output voltage frequency (U_0) of the inverter is obtained by changing the frequency of switching ON of the thyristor (F_1).

In dependence on the ratio frequency of impulsing the thyristor (F_1) to the resonance circuit frequency (F_0) [$k= F_0 / F_1$] the output voltage frequency (U_0) and the current form in the inverter main branch change. Such an inverter can work within natural or forced commutation [4, 5].

When the resonance circuit frequency equals the frequency of impulsing the thyristors a sinusoidal waveform of current (I) in the main branch is obtained.

When coefficient K changes are wide ranged, there is an increase of higher harminics of the output voltage. Because of this range of continuous frequency regulation is limited and the max ratio is 1:2. The feedback (D_1-D_2) ensures the correctness of inverter work without load and stabilizes output voltage.

Three type of commutation (natural, critical and forced), are considered in the results of computer analysis of forms of voltage and current waveforms for series-parallel inverter fig.(2.2) .

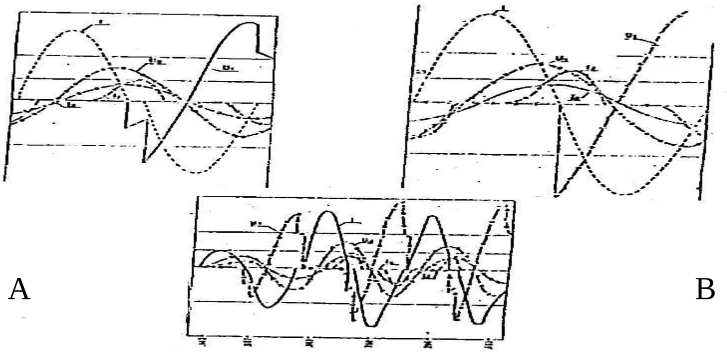


Fig .(2.2): time runs of voltages and currents
A/ forced commutation
B/ critical commutation
C/ natural commutation

3/-Dynamic features of A three-phase series-parallel inverter working in the system of closed voltage and output current regulation:

The inverter dynamic features are presented using the energy-electronic high-speed drive.
The inverter shown in (fig.3.1) was used as a three-phase voltage source of higher frequency for group feeding of motors used in technological lines for rolling bearing grinding [6,7] .

The system consist of the following basic blocks:

- Thyristor rectifier ($T_1 \div T_3$).
- Filter L-C.
- Three-phase inverter ($T_4 \div T_9$).
- Output transformer (T_r).
- Three-phase feedback (D1 ÷ D3)

Fig.(3.2) presents a block scheme of a control system.
The control system consist of :

- TR : thyristor rectifier
- F : filtrer LC
- TI : thyristor inverter
- SF : frequency set up
- SV : voltage set up
- G : generator of impulses
- STI : control system of thyristor inveter
- STR : control system of thyristor rectifier
- MSI : measuring system of motor current
- MSV : measiring system of the motor voltage
- RV : voltage regulator
- RI : current regulator
- SI : the system of synchronization of impulses

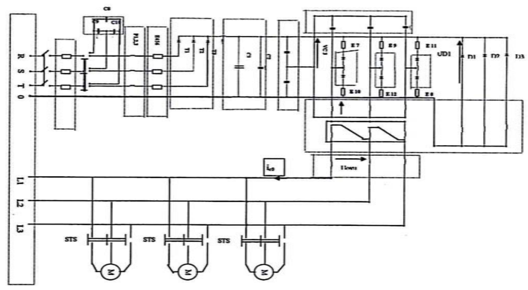


Fig.(3.1): scheme of a three-phases series-parallel thyristor converter of feed high-speed motors

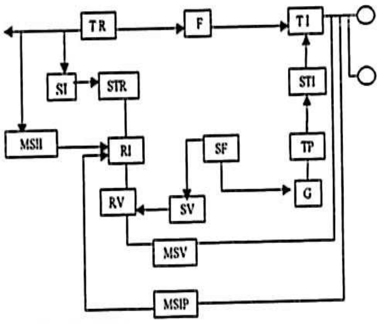
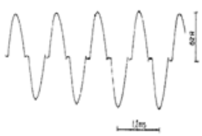


Fig.(3.2) : A block scheme of high-speed control of the voltage

A simplified simulation model of a drive system with a three-phase series-parallel inverter was made. The simulation results were used to make industrial devices of this kind in the factory of rolling bearings, some of the results are presented in (fig.3.3 – 3.8)

Some of the results are presented in (fig.3.3 ÷ 3.8).



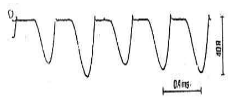


Fig.(3.3): current of the main branch of inverter / I_F / fig.(3.4): current feed / I_Z

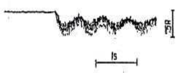


Fig.(3.5): current of feedback / I_Z/ starting

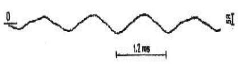


fig.(3.6): current of motor I_0 - idle run

Fig.(3.7): output voltage of converter / U_{OV}
Two electrospindles turned ON +
Starting of the third one

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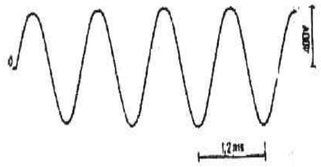

fig.(3.8): output voltage of converter /U_{OVU}/ - three electrospindles turned ON.

4/- continuous regulation of voltage and frequency of The transistor inverter:

Quick development of power engineering electronics elements and especially of

power transistors in the world causes great interest of constructors in new ways of changing energy and of controlling these systems. New configurations of inverters with high frequency output voltages make it possible to obtain much better regulation properties such as for examples continuous change of output voltage amplitude and frequency [8,9] .

One of possible versions of transistor converters with resonance circuits is presented in fig.(4.1) .

turned on.

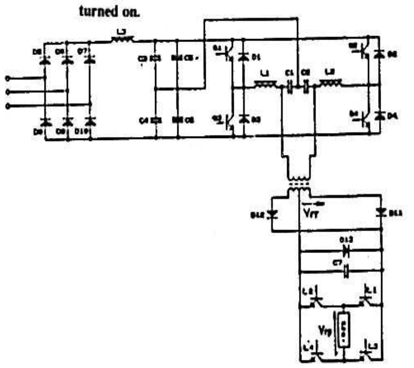

Fig.(4.1): A scheme of one - phase transistor inverter.

Two inverters cooperate using one load and are connected by means of transformer (T_r). To the output transformer (T_r) a diode rectifier $D_5 \div D_{10}$ with a filter L_3 ($C_3 \div C_6$) and a bridge with transistor switches are attached. fig.(4.2) presents a simplified block scheme of control system.

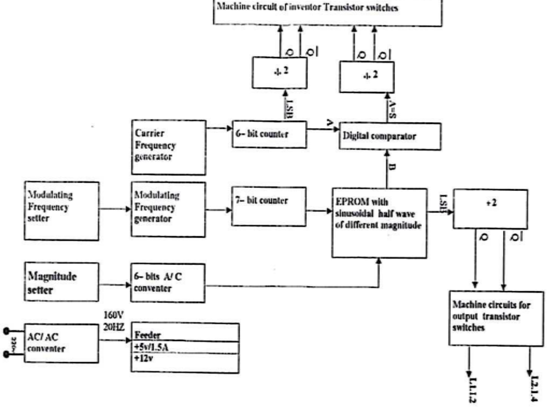

Fig.(4.2): block diagram of control circuits for transistor switches (1 - phase converter).

The system of the inverter control electronics should ensure:

- The generation of impulses controling the inverter transistor switches.
- The impulses generated for one pair of switches Q_1, Q_3 must have the possibility of continuous regulation of phase shift within $0^o \div 180^o$. This enables us to regulate the output power within $0° \div 100\%$.
- The generation of impulses controling the transistor switches on the converter output regulation within, for example from some Hz to some kHz.
- The possibility of modulating the phase shift of the impulses controling the inverter transistor switches pairs, the waveform of sinusoidal halfwave with regulated frequency and amplitude. This will ensure a sinusoidal envelope of the converter output power witch also has its amplitude and frequency regulated [10] .

The results of computer analysis of momentary waveforms of secodary voltage of output transformer Tr and the nverter output voltage one shown in fig (4.3) and fig (4.4).

Fig.(4.3): Momentary waveform of voltage V_{RR}

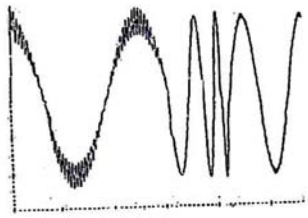

fig.(4.4): Momentary waveform of voltage V_{RP}

Fig (4.4) shows the influence of dynamic change of control frequency into the form of converter output voltage .

The system enables us to obtain very good dynamic properties and that is why a model was made .

On the basis of simulation results [11,12] a three-phase model for the electric drive of 5 KW power squired cage motor was made fig.(4.5) shows a scheme of this three-phase transistor converter .

Simulation and experimental results have been verified .

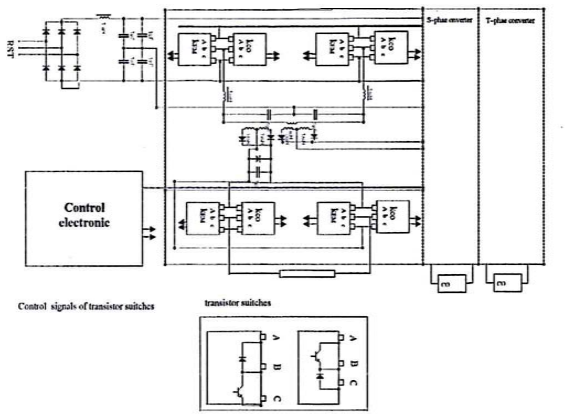

Fig (.4.5): A scheme of three phase transistor converter.

The compatibility of waveforms of momentary voltages and currents is 10%.

Experiments have proved that maximum load power considerably decreases when there is an increase of inverter work frequency in comparison to resonance frequency of the main circuit.

- Because of voltage and load current shapes the work frequency is optimal. it is approx. 10% higher than the resonance frequency.
- The maximal load power for the presented inverter is obtained for the phase shift angle ∅=180°.
- There is great possibility of fitting the inverter to the load by changing its configuration.
- Maximum output power changes nonlinearly when the phase shift angle changes and that is why distortion of load current may occur.
- During the cooperation of inverters when one of them has nonregulated controling impulses and another the controling impulses witch change the phase ∅ in relation to the controlling impulses of the first one when load distribution asymetry occur.
- The powevhr supplied by the first and second inverter for loading are equal for the shift phase angle ∅=180°. Maximum receiver power is obtained then.
- The presented system makes it possible to regulate the power supplied to the receiver continuously.

Conclusions:

- Computer analysis results are consistent with experimental researches results with accuracy of about 10%.
- In the case of transistor inverter we obtain much better control and dynamic properties in comparison with thyristor inverter.
- Because of switch losses of transistor switches in some cases there is reasonable to use sequential inverter, this causes however increase in systems dimensions.

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