ANALYSIS OF WORK OF INFRA-LOW FREQUENCY HARMONIC OSCILLATOR

Uvaysov S. U.,*Diagilev V. I.,*Kokovin V. A.
MIEM HSE,

*The International University “Dubna” of Nature, Society and Man, Branch “Protvino”

The results of mathematical modeling of the equivalent circuit of a powerful generator of sinusoidal oscillations infra-low frequency. Shows the time dependence of the stresses and parametric currents and powers, allowing to perform the calculation scheme and selection of its elements.

Modern technologies are widely used infra-low frequency vibrations. These technologies are used in metallurgy (metal mixing crucibles), geophysics (exploration) [1,2], energy (diagnostics of electrical cables), medicine (diagnosis, physiotherapy). Frequency range of these fluctuations - from a few hertz to a fraction. For example, when testing high-voltage cables and degauss need 1-0.05 Hz frequency. For transmission infra-low frequency oscillations cannot be applied to the load conventional transformers. For this purpose, various ways of converting these vibrations largest stresses.

This article describes the formation of low-frequency oscillations necessary infrastructure through the use of piezoelectric amplitude (PEP) and magnetostrictive electromechanical converters (SMEs) in solving a wide range of applications in engineering, geophysics and oil production. [3] Control panel power and high-frequency ICPs sinusoidal voltage, which is obtained by using a bipolar transistor voltage generator with oscillating circuit.

To improve performance and process quality and supply voltage PEP and SMEs modulate low-frequency sinusoid. Among the existing methods of obtaining such strains become widespread method of amplitude modulation [4]. He carried out very simply: two sinusoidal voltage generator with frequencies $F_1$ and $F_2$ are connected in series and are working on a common load. Then the output voltage to obtain two frequencies - one of them, $- F_3 = F_1 + F_2$ and, as a rule, it is not used, and the other $F_4 = F_1 - F_2$ is equal to their difference. It is used for the desired purposes.

Technical realization of such a device is very difficult, because for voltages with a frequency of 1 Hz requires two oscillator frequency, for example, 50 Hz and 49 Hz. Known method - application of digital generators infra bass is quite complicated. Fig. 1 is a schematic diagram of the transistor current generator of high frequency (TCGHF) [5]. By the DC power source V1 is connected transistor bridge (M1-M4). Each half-bridge transistor M1, M3 and M2, M4 is controlled by the control unit V2, V5 and V3, V4, providing key mode transistors. Efficiency such a generator is quite high (95%).
Fig.1. Equivalent scheme LFPG

When both control units operate at the same frequency, the output voltage generated by the high-frequency rectangular. If the frequencies are different, the output formed by the width-modulated rectangular voltage pulses with amplitude equal to the supply. Then this voltage is applied to filter the first harmonic oscillator circuit formed by $L_1$, $C_1$. A capacitor $C_1$ connected in parallel load $R_{11}$ ($R_L$) flowing through it and a low frequency sine wave form current with a superimposed high-frequency pulses. For "pure" sine wave demodulator used. In most cases this is not necessary. Thus, at high powers can be used very small high-power transformers in a wide frequency range of the output sine wave. This is a very significant advantage of the proposed scheme.

Also encouraged to include in series oscillating circuit capacitor $C_4$. Through this, you can either stabilize the output voltage, or adjust it at constant values of the supply voltage and load resistance. To determine the parameters of the oscillatory circuit at a given frequency $F_1$ and the load resistance $R_L$ use the known relations [6]:

$$(\omega_0)^2 L_1 C_1 = 1, \quad \omega_0 = 2\pi F_1$$ — the resonant frequency of the oscillation circuit $L_1, C_1$,  

$$Z_1 = \sqrt{L_1 / C_1}$$ — impedance of the circuit,  

$$Z_2 = \sqrt{L_1 / C_4}$$ — serial impedance circuit $L_1, C_4$,  

$$K_n = R_n / Z_1$$ — load factor  

With an input voltage of a rectangular (1) can be written  

$$\pi^2 L C = (t_p)^2, \quad t_u = T/2 = \pi/F$$  

For the parallel part of the circuit $C_1$, $R_L$ must specify their value.

Let $R_L = 1/\omega C$, then, since (1) and (4) we find  

$$C = t_p / \pi \quad R \quad L = (t_p R) / \pi$$  

A study of low-frequency oscillator circuit voltage infrastructure (LFPG) on a mathematical model. The following experiments were conducted:
1) Change the load resistance at fixed values of the remaining elements of the equivalent circuit.
2) Changing the voltage of the transistor bridge ($M_1$-$M_4$).
3) Change the duration of the control pulses at the gates of the power transistors ($M_1$-$M_4$).

Table 1 shows the simulation parameters.

**Таблица 1**: Circuit simulation parameters LFPG

<table>
<thead>
<tr>
<th>№</th>
<th>Name</th>
<th>Designation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Supply (SP)</td>
<td>$V_1$</td>
<td>250 V</td>
</tr>
<tr>
<td></td>
<td>Internal resistance SP</td>
<td>$R_4$</td>
<td>0.5 $\Omega$</td>
</tr>
<tr>
<td></td>
<td>Inductance SP</td>
<td>$L_6$</td>
<td>10 $\mu$H</td>
</tr>
<tr>
<td>2</td>
<td>Parallel and serial resonant circuits</td>
<td>$L_1$</td>
<td>165 $\mu$H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_1$</td>
<td>66 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$X_L$</td>
<td>0.5 $\Omega$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_4$</td>
<td>50-500 nF ($\Delta C_4 = 50$ nF)</td>
</tr>
<tr>
<td>3</td>
<td>Impedance</td>
<td>$Z_1$</td>
<td>50 $\Omega$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$Z_2$</td>
<td>55-16 $\Omega$ ($\Delta Z_2 = 3.8$ $\Omega$)</td>
</tr>
<tr>
<td>4</td>
<td>load Resistance</td>
<td>$R_L$</td>
<td>50-500 $\Omega$ ($\Delta R_L = 50$ $\Omega$)</td>
</tr>
<tr>
<td>5</td>
<td>Pulse width control</td>
<td>$t_p$ (PW)</td>
<td>9.9 $\mu$s</td>
</tr>
<tr>
<td>6</td>
<td>Cycle time of control pulse</td>
<td>$T$</td>
<td>20 (21) $\mu$s</td>
</tr>
<tr>
<td>7</td>
<td>MOSFET</td>
<td>$M_1$-$M_4$</td>
<td>IRFP460 (500 V, 20 A)</td>
</tr>
</tbody>
</table>

The simulation results are presented in the form of timing diagrams, parametric curves in the pictures below.

For a given frequency switching transistors $M_1$-$M_4$ (Fig. 1) determine the frequency of the output voltage. It must be equal $F_1 - F_2 = 1220$ Hz. From the diagram (Fig. 2) graphically find frequency sine wave input current, which is equal to 1186 Hz, which practically coincides with the calculation. These charts show that the input current from the power source $V_1$ is sinusoidal, but it is offset with respect to zero the amount of the constant component of the input current. Fig. 3 shows the timing diagram of voltage across the transistor M1 and the current through.
Fig. 2. The timing diagrams of the load current (bottom) and the input current LFPG.

Are important to the design diagram of current and voltage of the power transistor on it shown in Fig. 3.

Fig. 3. Timing diagrams current (upper curve) through M1 and voltage across it.

Parametric dependence of these quantities on the capacitance of the capacitor C4, are presented in Fig. 4. These dependencies are allowed to select the operating mode LFPG.

It was mentioned above that the experiments were conducted on a mathematical model when the voltage V₁. Data from these experiments suggest that when the input voltage to all voltages and currents vary proportionally. Thus, to increase capacity can be increased LFPG voltage. For example, increasing the supply voltage to two times, all the currents and voltages will increase 2 times, and the power factor of 4.

Very indicative capacities depending active P_L and consumed from the power source V_L and reactive power in the oscillatory circuit (Table 2). It can be seen that the reactive power large (compared to the power in the load), because the energy necessary to provide oscillation
processes in the load.

Fig. 4. Parametric dependence of the voltage across the transistor M1 (upper curve), and the load and the current through the transistor M1.

Table 2: The values in the elements of capacity and its efficiency LFPG

<table>
<thead>
<tr>
<th>$C_d$</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{in}$, W</td>
<td>220</td>
<td>800</td>
<td>1300</td>
<td>1500</td>
<td>1500</td>
<td>1450</td>
<td>1380</td>
<td>1240</td>
</tr>
<tr>
<td>$P_{ar}$, W</td>
<td>310</td>
<td>910</td>
<td>1600</td>
<td>1800</td>
<td>1820</td>
<td>1800</td>
<td>1730</td>
<td>1600</td>
</tr>
<tr>
<td>$P_L$, VAR</td>
<td>3750</td>
<td>7800</td>
<td>8700</td>
<td>9000</td>
<td>9100</td>
<td>8900</td>
<td>8500</td>
<td>7900</td>
</tr>
<tr>
<td>$P_C$, VAR</td>
<td>1000</td>
<td>3800</td>
<td>4000</td>
<td>4100</td>
<td>4000</td>
<td>3900</td>
<td>3700</td>
<td>3500</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.72</td>
<td>0.88</td>
<td>0.81</td>
<td>0.83</td>
<td>0.81</td>
<td>0.79</td>
<td>0.78</td>
<td>0.77</td>
</tr>
</tbody>
</table>
Analyzing the data in Table 2 we can conclude that:

1. The values given in Table 2 indicate the possibility of regulating the output capacitor value LFPG only C₄, with the magnitude of the supply voltage and the duration of the control pulses of the power transistors remains unchanged.
2. Power inductor L₁ and the capacitor C₄ constitute the significant value, and this naturally leads to an increase in the currents circulating in the circuit LFPG and degrade its efficiency (about 72%).

CONCLUSION

- The proposed scheme with two oscillating circuit provides a sinusoidal voltage at the output of the infra-low frequency (the output frequency can be higher - up to several hundred Hz).
- The output voltage (and power) can be controlled in three ways: changing the capacitance value series capacitor C₄, change the duration of the control pulses bridge transistors and supply voltage.
- The data obtained allow to design schemes for large capacities. Since modern IGBT transistors produced at currents of hundreds of amperes and voltage up to 2000 volts, and MOSFET transistors connected in parallel and in series.
- It is possible to increase the output power by adjusting the load factor $K_L = R_l/Z_1$.

REFERENCES