Launching system of helicopter aviation transient electromagnetic system

Shen Mingren*
School of information, Beijing University of Technology, Beijing, China
*Corresponding author: shenmingren@emails.bjut.edu.cn

Abstract. Aviation electromagnetic transmitters are used to ascertain the distribution and reserves of underground mineral resources. Among them, the launch subsystem is used as the energy source of helicopter aviation transient electromagnetic exploration equipment, and its performance will have a great impact on the exploration depth and accuracy of mineral resources. The structure and principle of the power conversion circuit of the transmitting subsystem are introduced. Complete the production of the power conversion circuit, and complete the test of several main performance indicators of the circuit. Laboratory test results show that the power conversion circuit has good performance and meets the design requirements.

1. Introduction
Airborne Transient Electromagnetic Method (ATEM) is a transient electromagnetic detection method based on aviation platform[1]. A pulsed electromagnetic field (primary field) is emitted to the ground through the launch loop mounted on the flight platform; under the excitation of the primary field, eddy currents are generated inside the earth; under the action of the ohmic effect, the eddy currents inside the earth are attenuated, thereby exciting New electromagnetic field (secondary field); by observing the secondary field, extracting and analyzing the geoelectric information contained in it, the purpose of detecting underground geological structures can be achieved[1]. The flexible and efficient characteristics of helicopter aviation transient electromagnetic survey system make it more and more used in groundwater survey, large-scale engineering foundation survey, geological mapping, mineral survey, soil salinization survey, and the search for unexploded remnants And other low-quality survey missions[2].

The helicopter aviation transient electromagnetic system includes the helicopter airborne hoisting launcher and the ground data interpretation system. The helicopter hoisting launcher includes two parts: electromagnetic launching system and receiving system. The electromagnetic emission system includes a power conversion circuit and an excitation source pulse modulation circuit. It can be said that the aviation transient electromagnetic system is very complicated. It contains various subsystems. Each subsystem is like every organ of our human body. They cooperate and cooperate with each other. They are connected to each other to form a powerful human body. Only in this way can problems be dealt with in an orderly manner and with ease. The power topology circuit converts the energy output by the helicopter into the shape, frequency and amplitude required by the excitation source pulse current, and then converts it into the excitation source pulse with the corresponding frequency through the transmitting device to radiate the magnetic field into the air for exploration[3]. The power topology
circuit undertakes the role of power conversion and is the core of the helicopter aviation transient electromagnetic launch system[3]. The power topology circuit includes two parts: the power conversion circuit and the excitation source pulse modulation circuit. The power conversion circuit converts the output voltage of the helicopter into the voltage adjustment range required by the excitation source pulse modulation circuit [3]. The excitation source pulse modulation circuit receives the energy of the power conversion circuit to generate the excitation source pulse current waveform, which is finally converted by the transmitter into a pulsed primary magnetic field of the same frequency and radiated into the air [3].

The power conversion circuit of the helicopter aviation transient electromagnetic transmission system converts the output voltage of the helicopter into the voltage level required by the excitation source pulse modulation circuit, which plays an important role in the energy conversion, so the power conversion circuit and its control strategy will be directly affect the performance of the entire helicopter aviation transient electromagnetic launch system [3].

2. Structure

The following shows the structure of the excitation source power topology circuit when the fundamental frequency is 25Hz. When the fundamental frequency is 25Hz, the transmission waveform can adopt the pulse current waveform of multiple excitation sources, and the high-energy momentum of the half-sine wave of large magnetic flux can be used. To explore the deep mineral resources on the earth. Trapezoidal waves with small magnetic moments and low energy are used to improve the resolution of shallow geological exploration on the surface [3]. However, this article will still send out a half sine wave of 25Hz single excitation source pulse current.

During the exploration flight of the helicopter hoisting the launcher, the distance between the cabin and the launcher was 60m, and the peak value of the excitation source pulse current was as high as 800A. Therefore, the high-voltage and low-current transmission method can effectively reduce the loss and weight of the transmission line [3].

The DC boost circuit adopts the traditional full-bridge resonant converter. The full-bridge resonant converter is very suitable for high-voltage and high-power occasions due to the soft switching of switching devices [4], suitable for high-frequency working conditions, and has a small size, advantages such as low power consumption. The transformer's transformation ratio is as high as 1:20, and there are a total of 8 working modes. It boosts the 28V DC output of the helicopter to 450V high-voltage DC. The boost ratio is about 1:16, realizing the conversion from low-voltage DC to high-voltage DC. The intermediate conversion circuit adopts the PSFB-PWM circuit. The PSFB-PWM converter is used in various fields due to its easy realization of soft switching, simple structure and good EMI characteristics. As a practical topology, it is widely used for medium and high power isolation. DC-DC conversion field [5]. The modulation circuit adopts a double resonance circuit. The figure below shows the topology circuit. The full-bridge series resonant converter and the PSFB-PWM circuit form a DC-DC converter. The full-bridge series resonant converter boosts the helicopter's low-voltage power supply from 28V DC to 450V DC high voltage, and the buck bridge steps down the 450V DC high voltage to 60V DC low voltage. 60m high-voltage cable connection between the two. Because the current value in the wire is very small, doing so reduces the transmission loss of the transmission line and reduces the weight of the transmission line. Connect the modulation circuit after the power conversion circuit.
3. Experimental results
The principle prototype experiment platform is built, and the controller uses a digital signal processing chip (TMS320F28335). The key device parameters are shown in Table 1. And get the data when the input voltage is 27V and the emission current is 740A, see Table 2.

![Figure 1. Power topology circuit.](image)

**Table 1.** Key simulation parameters.

| parameter                      | value  | parameter                      | value  | parameter                      | value  |
|--------------------------------|--------|--------------------------------|--------|--------------------------------|--------|
| resonant capacitor             | 0.15 μF| resonance inductance           | 90 μH  | coil resistance                | 20 mΩ  |
| transformer ratio              | 1:20   | energy storage capacitor bank  | 1 F    | coil inductance                | 500 μH |
| Leakage inductance of transformer high voltage side | 15 μH | resonant capacitor             | 0.01 μF| coil resonance capacitance     | 3 mF   |
| rectifier capacitor           | 3 μF   | resonant capacitor             | 3 nF   | filter inductor                | 120 μF |
Table 2. Test Results.

| Input voltage (V) | Input current (A) | H₁ output voltage (V) | H₁ output current (A) | H₂ put voltage (V) | Bus voltage (V) | Resonance output voltage (V) | Emission current (A) |
|------------------|-------------------|-----------------------|-----------------------|--------------------|-----------------|-------------------------------|---------------------|
| 27               | 98.2              | 432                   | 5.0                   | 46.1               | 39.6            | 932                           | 740                 |

Transmission ratio of H₁ output current to input current:

\[
\frac{V_o}{V_i} = \frac{432}{27} = 16
\]  \hspace{2cm} (1)

Transmission ratio of H₂ output current to input current:

\[
\frac{I_o}{I_i} = \frac{46.1}{5} = 9.22
\]  \hspace{2cm} (2)

H₁ efficiency:

\[
\eta_1 = \frac{432 \times 5}{27 \times 98.2} = 81.5\%
\]  \hspace{2cm} (3)

H₂ efficiency:

\[
\eta_2 = \frac{46.1 \times 39.6}{432 \times 5} = 84.5\%
\]  \hspace{2cm} (4)

Overall efficiency:

\[
\eta = \eta_1 \times \eta_2 = 81.5\% \times 84.5\% = 68.9\%
\]  \hspace{2cm} (5)

Among them, the resonant voltage doubler circuit raises the 27V DC output from the helicopter to a high voltage 432V, the transmission ratio reaches 1:16, and the current drops to 5A. The intermediate conversion circuit reduces the high voltage 432V to an adjustable voltage of 20–40V, and the current transfer ratio is 1:9. The efficiencies of H₁ and H₂ are all above 80\%, and the overall emission efficiency is as high as 68.9\%. The launch waveform is shown in Figure 1. The launched fundamental frequency 25Hz half-sine wave pulse current peak value is 740A, the launch time is 4ms, and the stop time is 16ms. Meet the requirements of the index.
4. Conclusions
This paper presents a design scheme of the core part of the power topology circuit of the helicopter aviation transient electromagnetic system—the power conversion circuit under the 25HZ fundamental frequency. In order to reduce the weight of the cable and reduce the transmission loss of the wire, a DC high voltage and low current transmission strategy is adopted. The resonant boost circuit adopts an improved full-bridge converter, and the intermediate conversion circuit adopts a phase-shifted full-bridge pulse width modulation converter. And the power conversion circuit has been tested, showing that the scheme is basically feasible.

Acknowledgments
This work was financially supported by professor Zhang Yiming of Beijing University of Technology fund.

References
[1] Zhang Wuxin,Xue Guoqiang,Fang Guangyou. Progress in Chinese helicopter transient electromagnetic detection technology[J]. Advances in Geophysics, 2019.
[2] Zhao Yuequn. Research on key technology of series resonant aerial electromagnetic transmitter[D]. Jilin University, 2012.
[3] Zhang Yu. Research on the key technology of helicopter transient electromagnetic launch system[D]. Beijing University of Technology, 2018.
[4] Chen Wu,Wu Xiaogang,Jiang Wei,Hu Renjie. A resonant boost converter suitable for grid connection of new energy sources[J]. Transactions of the China Electrotechnical Society,
2016.

[5] Shi Minkai. Research on Phase Shift Control of High Voltage Output DC-DC Converter[D]. Harbin Institute of Technology, 2018.