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MULTI-CHANNEL SWITCHING MAGAMP POWER CONVERTER FOR RADIO RECIEVING DEVICES

Volodymyr Yaskiv[1], Anna Yaskiv[2]

[1] Ternopil Ivan Puluj National Technical University, [2]West Ukrainian National University, Ternopil, Ukraine

yaskiv@yahoo.com, annyaskiv@gmail.com

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Abstract: Development of high-quality energy supply of radio receiving devices is an urgent task. The article discusses the methods of designing high-frequency multi-channel power converters based on high-frequency magnetic amplifiers, the magnetic cores of which are made of an amorphous alloy with a rectangular hysteresis loop. Their significant advantages when powering radio receiving devices are the high quality of the output voltages and the low level of electromagnetic interference, both radiated and conductive. At the same time, they have a higher level of dynamic characteristics, reliability and efficiency while reducing their topological complexity and cost. In addition, it allows the implementation of multi-channel power converters with equivalent and independent output channels in a wide range of output powers. The paper presents the implementation of such a converter for powering radio receiving devices.

Key words: power supply, power converter, high-frequency magnetic amplifier, amorphous alloy, rectangular hysteresis loop, radio receiving devices.

1. Introduction

Radio receiving devices are one of the most responsible units of modern communication systems. The specificity of its operation requires high-quality energy supply. The main requirements for the power supply of radio receiving devices are as follows:

– high quality of the output voltages of the converter in all range of the load current changes: low level of the high-frequency pulsations, absence of high-frequency peaks, high stabilization coefficient;

– low level of the electromagnetic interference (EMI);

– high level of the dynamic characteristics.

Therefore, linear power converters are usually used to power radio receivers in communication systems currently in use. They are characterized by high quality of the output voltages. The disadvantages of linear power converters are well-known: low level of efficiency and low level of mass-dimensional characteristics. Therefore, the use of modern pulse converters with high quality of their output voltages is a priority. In the current paper we propose a new method of design of multi-channel DC power supply based on high frequency magnetic amplifiers (MagAmps).

2. State of Art

The strict requirements of radio receiving devices for the quality of the switching power converter output voltage create prerequisites for the development of alternative topologies of converters. The use of semiconductor elements in the role of power switches in converters leads to the appearance of high-frequency electromagnetic interference. They propagate both by radiation and conduction by the supply buses, and are present in the output voltage of the converter.

So-called soft-switch resonant converters can be a partial solution to the problem. In such converters, the power part is supplemented by a resonant circuit, and the switching of the power switches is carried out at the time moment when the current or voltage crosses zero. This solution allows you to minimize switching losses in converter and thereby reduce the level of EMI generated, as well as slightly increase its efficiency [1-3].

High quality of output voltages can be achieved with design of multi-channel power converters based on high-frequency magnetic amplifiers [4-15].

3. Principles of MagAmp operation

A multi-channel converter with equivalent and independent output channels based on high-frequency magnetic amplifiers is proposed for powering radio receivers.

In this case, the output channels are equivalent in output power level and equivalent in their topology. The functional diagram of the MagAmp converter is shows on the Fig. 1.

MagAmp regulator requires an input high-frequency power inverter 1 operating at a given frequency. MagAmp regulators are connected to the secondary windings of the high-frequency power transformer of the inverter.

The principle of operation MagAmp regulator, its advantages are shown in the literature [4,5,7, 13-15].

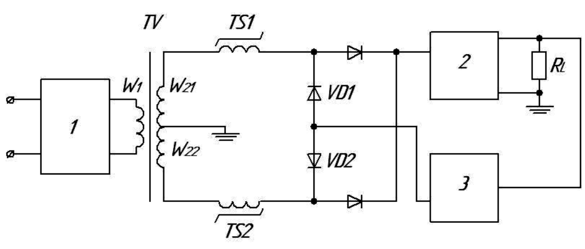

Fig. 1. Functional diagram of the MagAmp converter.

As a high-frequency unregulated transistor inverter was used the pulse power inverter on autogeneration scheme, designed by authors [18]. It features saturable choke with rectangular hysteresis loop in its positive feedback loop tied to inverter's output voltage. The moment of the choke saturation defines the change of the commutation state of power switches. Besides, the choke is a time-setting component, as the time of its complete remagnetization defines the half-period of inverter's working frequency. Moreover, the symmetry of the choke's hysteresis loop eliminates the submagnetization of inverter's high-frequency power transformer [19]. The use of the common saturable choke for a few autogenerators provides their parallel operation with synchronous and synphase commutation within the whole range of change of the load current. Such topology is used for power converters with high level of load current.

4. Proposed topology of the MagAmp power converter for radio receiving devices

The designed 10-channel MagAmp power converter for radio receiving devices is shown in Fig. 2.

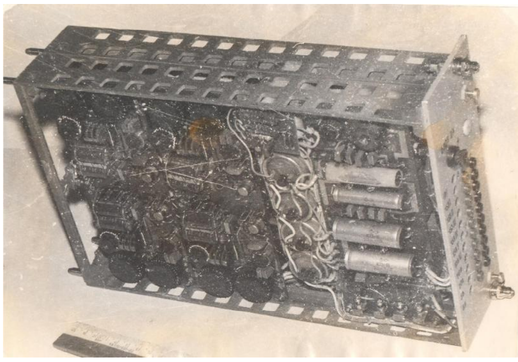

Fig. 2. 10-channel MagAnp power converter for radio receiving devices.

The waveform of the output voltage of one of the channels at an output power of 70 W is shown in Fig. 3. The main technical data of this 10-channel power converter are as follows:

Channels	Output voltage, V	Output current, A
1-6	15	1
7	20	1
8	5	3
9	6	1,5
10	110	1

– input voltage 220 V, 50 Hz;
– operating frequency 50 kHz;
– output power 244 W;
– total instability of the output voltage < 0.2 %;
– high-frequency pulsations of the output voltage < 10 mV;
– double the range of high-frequency peaks in the output voltage < 40 mV;

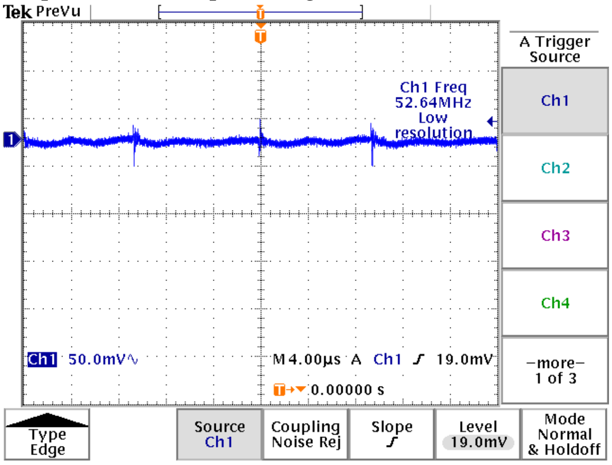

Fig. 3. Waveform of the output voltage of MagAmp regulator.

The external electromagnetic radiation test of the MagAmp power converter (24 V, 8 A) and its transistor counterpart (USA) at the same output power was conducted within the framework of a joint NATO grant with the Power Electronics Laboratory (Prof. K. Smedley) of the University of California (Irvine, USA). (COLLABORATIVE LINKAGE GRANT "High-Reliability Switching Power Converters for Security of Informat ion Technology" on "Nato Programme Security Through Science" – IC S.NUKR.CLG 982639).

The level of electromagnetic interference emitted by the MagAmp power converter in the frequency range from 42 MHz to 400 MHz is significantly lower than that of the transistor analog (so in the frequency range of 130-200 MHz – by 4-5 times). Radiation interference levels are approximately equal at 400-1000 MHz (except for a slight excess for the analog at 500 MHz and 810-850 MHz) [20,21].

The lower EMI level of the MagAmp power converter is explained primarily by the specifics of its circuit design:

– the use of high-frequency magnetic amplifiers in the role of power regulating elements, the operation of which in the key mode is not accompanied by the appearance of high-frequency interference of a high level. In addition, the magnetic amplifier itself serves as a conductive EMI filter in both saturated and unsaturated states;

– the opening of the power transistor of the high-frequency unregulated transistor inverter occurs at zero load current due to the fact that at the beginning of each half-cycle, the regulating power element (high-frequency magnetic amplifier) of the constant voltage pulse stabilizer is in an unsaturated state;

– the developed method of controlling the power transistor is used to form the trajectory of its closure, which ensures its closure at almost zero collector current (the mode is similar to the mode of the switch in the "quasi-resonant" converter, only with rectangular forms of voltage and current, which ensures higher efficiency of the switch) and prevents leakage through currents in a half-bridge circuit.

However, this circuit does not use traditional snubber circuits, which also has a positive effect on the final value of the converter's efficiency. If you use the method of synchronous rectification proposed by the authors in the MagAmp power converter [22], you can significantly increase the efficiency of modern converters. For example, the efficiency of the MagAmp power converter for the output parameters of 24 V, 15 A with an input voltage 220 V reached 96% with minimal financial costs [23]

5. Conclusion

A new method of designing energy supply based on high-frequency MagAmps for radio receiving devices is proposed. This makes it possible to achieve high quality of output voltages, low level of electromagnetic interference, high quality of dynamic characteristics while significantly reducing the complexity of the topology. It also provides operation over a wide range of input AC voltage, high efficiency, high level of specific power and of reliability.

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БАГАТОКАНАЛЬНИЙ ІМПУЛЬСНИЙ БЛОК ЖИВЛЕННЯ РАДІОПРИЙМАЛЬНИХ ПРИСТРОЇВ НА ОСНОВІ ВИСОКОЧАСТОТНИХ МАГНІТНИХ ПІДСИЛЮВАЧІВ

Володимир Яськів, Анна Яськів

Створення якісного енергетичного забезпечення радіоприймальних пристроїв є актуальною задачею. У статті запропоновано нові методи проектування високочастотних багатоканальних перетворювачів потужності з високою якістю вихідних напруг при зниженні його топологічної складності та вартості. Описано принцип дії магнітного ключа на основі високочастотних магнітних підсилювачів, магнітопровід якого виготовлений з аморфного сплаву з прямокутною петлею гістерезису. Запропонована топологія дозволяє отримати більш високу якість вихідної напруги, більш високий рівень динамічних характеристик, надійності і ефективності перетворювача електроенергії. Він також забезпечує низькі рівні як випромінюваних, так і кондуктивних електромагнітних завад. Крім того, це дозволяє реалізувати багатоканальні перетворювачі електроенергії з рівноцінними і незалежними вихідними каналами в широкому діапазоні вихідних потужностей. У роботі наведено приклад реалізації такого перетворювача для живлення радіоприймальних пристроїв.

Volodymyr Yaskiv received his MS degree in Electrical Engineering at Lviv Politechnical Institute, Lviv, Ukraine in 1986. Specialization: Electric Drive and Automation of Industrial Installations. Since 1986 worked in Lviv Scientific Research Radiotechnical Institute as engineer-designer of power supplies. Received Ph.D. degree in Electrical Engineering in MPEI in 1993. Specialization: Semiconductor electric power converters. From 1993 Associate Professor in Ternopil Ivan Puluj National Technical University (TNTU), Ternopil, Ukraine. Received Doctor of Science Degree in Electrical Engineering in National Technical University "Kharkiv Polytechnic Institute" in 2021. Now he is Professor of Radiotechnical Department, Head of the TNTU Power Electronics Laboratory. He is the author of about 120 scientific papers. Current research interests are switch mode AC/DC and DC/DC power converters with high-frequency magnetic amplifiers, parallel operation, high level of the load current, resonant converters, power inverters.

Anna Yaskiv BS and MS in Biotechnical and Medical Systems and Apparatus awarded by Ternopil Ivan Puluj National Technical University in 2011 and 2012, respectively. In 2012 within a framework of the MS programme she studied at University of California, Irvine, USA. Working at Power Electronics Laboratory, she prepared her MS thesis on Mathematical Modeling for Design of High-Frequency Power Converters for Electromedical Apparatus. In 2021 she defended her Ph.D. thesis at Ternopil Ivan Puluj National Technical University, specialty – Mathematical Modeling and Numerical Methods, topic Mathematical Modeling of High-Frequency Magnetic Switches for Secondary Power Supplies. Her scientific interests include mathematical modeling and computer-aided design for power electronics.

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