PAPER • OPEN ACCESS

Investigation of a DC voltage boost converter based on a multifunctional integrated electromagnetic component

To cite this article: R R Aflyatunov *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **990** 012039

Investigation of a DC voltage boost converter based on a multifunctional integrated electromagnetic component

R R Aflyatunov, P I Vasilyev and R T Khazieva

Ufa State Petroleum Technological University, 1, Kosmonavtov ave., Ufa, 450064, Russia

E-mail: radmir.afl@yandex.ru

Abstract. The methods of functional integration of discrete electrical and electromagnetic components allow to increase the reliability and efficiency of electrical energy conversion systems, to reduce their weight and dimensions. The authors proposed a solution based on replacing some individual discrete components of a DC voltage boost converter with a multifunctional integrated electromagnetic component (MIEC). The component acts as an inductor and filter capacitor. A computer model of a DC voltage boost converter based on MIEC in the MatLab software package has been developed. The graphs of the output voltage are obtained. The circuits of step-up converters of constant voltage are analyzed. The optimal for the implementation of the replacement of the inductor and the filter capacitor with a multifunctional integrated electromagnetic component has been chosen. A circuit of a DC voltage boost converter based on MIEC is assembled. Oscillograms of the output voltage were taken. The analysis of the computer model and laboratory test sample was carried out.

1. Introduction

The operation of a DC voltage boost converter is based on the phenomenon of self-induction. The semiconductor switch commutes the current through the inductor. When the current is interrupted, the energy stored in the magnetic field of the inductor is fed through the semiconductor diode and the filter capacitor to the load. By controlling the switching time of the semiconductor switch and the current through it, you can adjust the output voltage [1-3]. The use of functional integration methods makes it possible to replace the inductor and filter capacitor with a single hybrid element. Thus, the replacement of individual discrete components with a multifunctional integrated electromagnetic component (MIEC) makes it possible to increase the reliability and energy efficiency of a DC voltage step-up converter, to reduce its weight and dimensions. MIEC consists of two conductive copper plates, separated by a polyimide dielectric and rolled up (figure 1). The equivalent circuit of a multifunctional integrated electromagnetic component is shown in figure 2 [4-8].

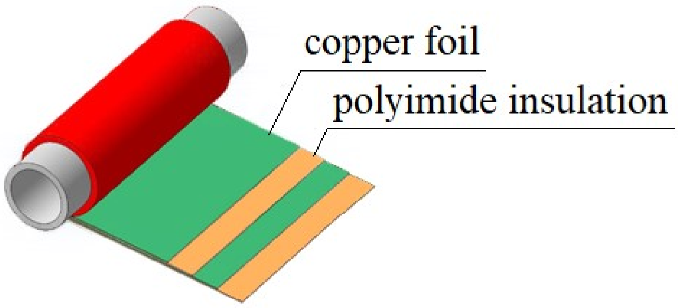

Figure 1. MIEC.

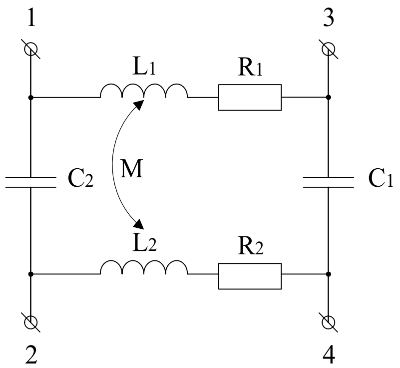

Figure 2. MIEC equivalent circuit.

2. Computer modelling

In order to obtain high-quality results of laboratory research, it was decided to create a computer model of the proposed technical solution. So, in the MatLab software package, a computer model of a simplified circuit of a DC voltage boost converter based on MIEC was created (figure 3) [6-11].

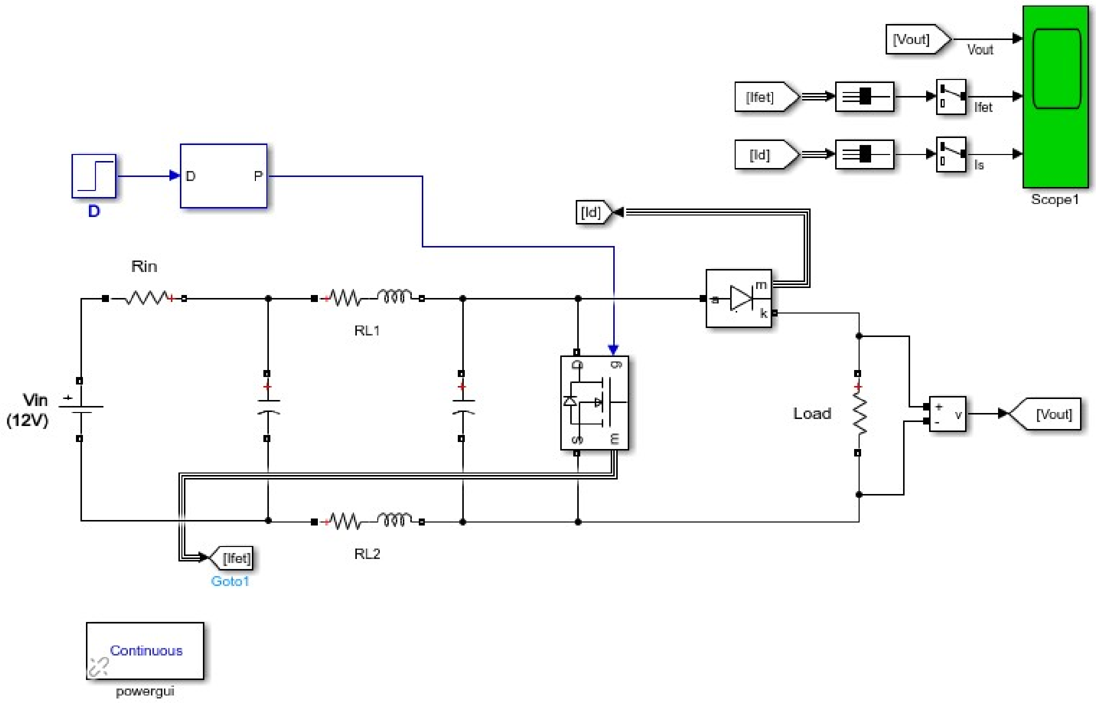

Figure 3. Computer model.

The results of computer simulation are presented in figure 4 in the form of graphs of the output voltage and currents through the rectifier diode and transistor.

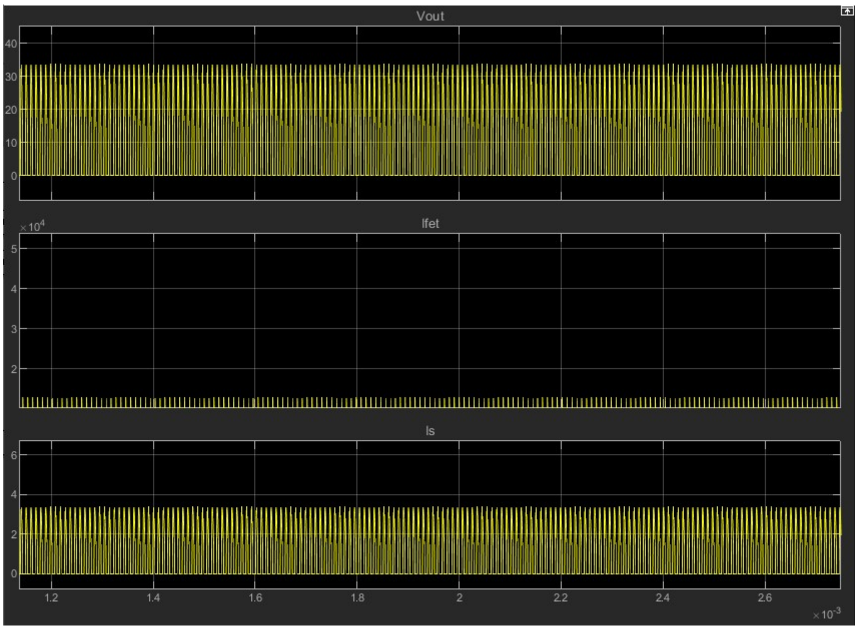

Figure 4. Graphs of the output voltage and currents through the rectifier diode and transistor.

3. Laboratory research

The results obtained in the course of computer simulation showed the feasibility of laboratory studies and the creation of a DC voltage boost converter based on MIEC. The optimal DC voltage converter circuit was chosen (figure 5).

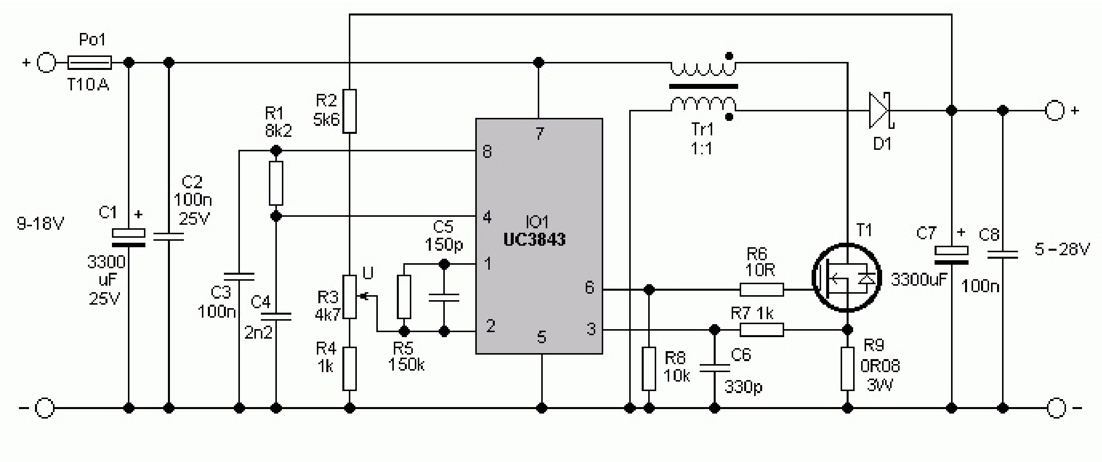

Figure 5. DC voltage converter.

Discrete elements Tr1, C7 and C8 have been replaced with a multifunctional integrated electromagnetic component (figure 6).

IOP Conf. Series: Earth and Environmental Science **990** (2022) 012039 doi:10.1088/1755-1315/990/1/012039

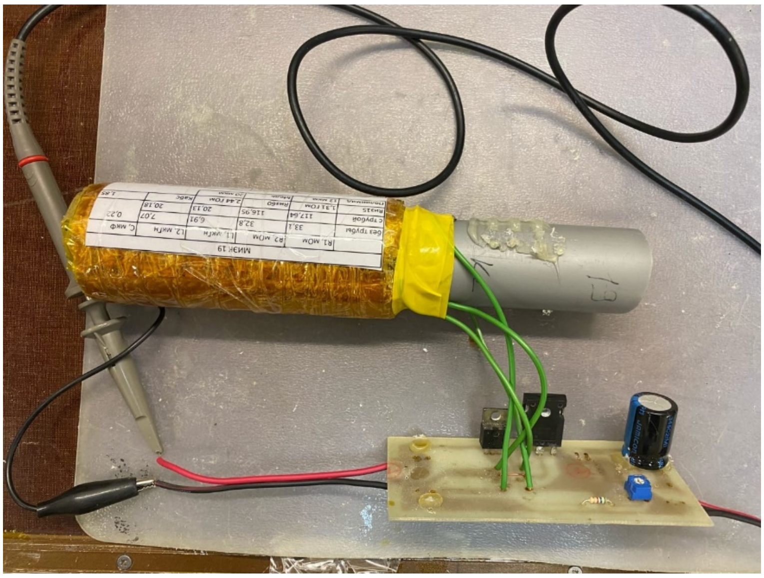

Figure 6. Assembled converter circuit.

When the circuit is powered from 12V, the oscillogram of the output signal has strong ripple, reaching an amplitude value of 27V (figure 7).

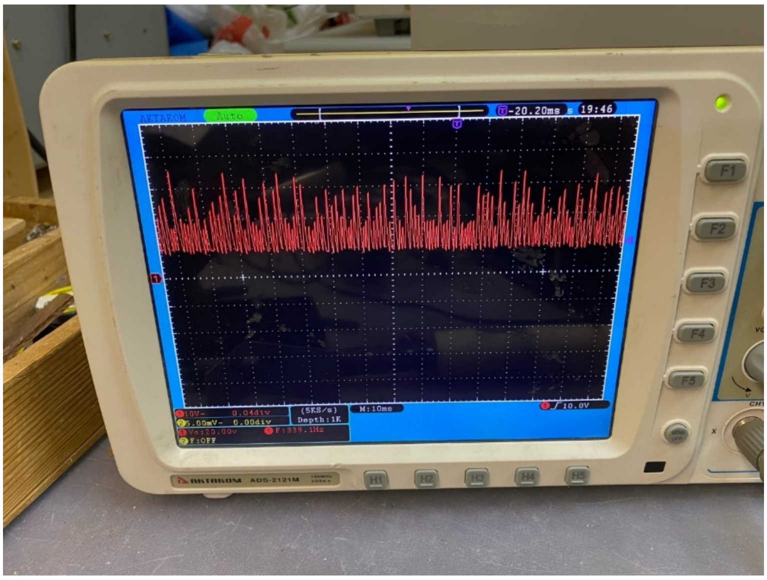

Figure 7. Oscillogram of the output voltage.

In order to reduce ripples for experimental confirmation of a possible lack of capacity of the filtering capacitor, the function of which is performed by MIEC, an external discrete capacitor with a nominal value of 3300 μF is additionally connected. At the same time, the ripple decreased significantly and the output voltage took on a constant waveform (figure 8).

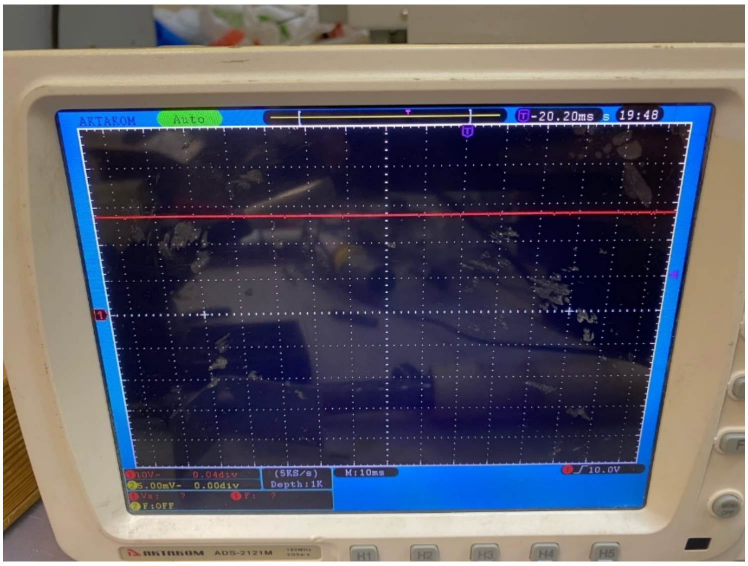

Figure 8. Oscillogram of the output voltage with additional capacitance.

4. Analysis of the received data

In the course of laboratory studies, the performance of the developed computer model of the DC voltage step-up converter was confirmed. The difference between the obtained graph of the output voltage of the computer model and the oscillogram of the output voltage of the laboratory sample was 3V.

The obvious problem is the lack of capacity of the filtering capacitor, the function of which is performed by the MIEC. However, in order to increase the capacity, it is necessary to increase the length or width of the plates, which will lead to an increase in the mass and dimensions of the system. Research is possible aimed at changing the control algorithm of the power part of the system in order to ensure greater pumping of the inductor and, as a consequence, a smoother form of the output voltage.

References

[1] Boujelben N, Masmoudi F, Djemel M, Derbel N 2017 Design and comparison of quadratic boost and double cascade boost converters with boost converter. *14th International Multi-Conference on Systems, Signals & Devices (SSD)* 245-252

[2] Konesev S G, Khazieva R T, Kirillov R V 2019 Inductive-capacitive converters for high-voltage secondary power supplies. *International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)* 1-5

[3] Schefer H, Fauth L, Kopp T H, Mallwitz R, Friebe J, Kurrat M 2020 Discussion on Electric Power Supply Systems for All Electric Aircraft. *IEEE Access* **8** 84188–84216

[4] Liren Z, Yang P, Li Z 2019 Design and simulation of DC current comparator demodulation circuit. *14th IEEE International Conference on Electronic Measurement & Instruments (ICEMI)* 18-23

[5] Martínez-Mares A, Fuerte-Esquivel C R 2011 Integrated energy flow analysis in natural gas and electricity coupled systems. *North American Power Symposium* 1-7

[6] Konesev S G, Khazieva R T, Bochkareva T A 2018 Mathematical modeling of inverter with a hybrid resonant circuit operation modes. *International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)* 1-6

[7] Wang Y, Liu W, Ma H, Chen L 2015 Resonance analysis and soft-switching design of isolated boost converter with coupled inductors for vehicle inverter application". *IEEE Trans. Power Electron* **30(3)** 1383-1392

[8] Zhao Y, Li W, Deng Y, He X 2011 Analysis design and experimentation of an isolated ZVT

boost converter with coupled inductors. *IEEE Trans. Power Electron* **26(2)** 541-550
[9] Mueller J, Bensmann A, Bensmann B, Fischer T, Kadyk T, Narjes G 2018 Design considerations for the electrical power supply of future civil aircraft with active high-lift systems. *Energies* **11(1)** 179
[10] Tariq M, Maswood A I, Gajanayake C J, Gupta A K 2017 Aircraft batteries: Current trend towards more electric aircraft. *IET Electr. Syst. Transp* **7(2)** 93-103
[11] Wang S, Wang S, Qiu H, Feng H, Wang S, Abu-Siuda A 2018 Frequency Response Analysis of the Transformer Subjected to Twice Short-circuit Impulse Tests Under Two Different Connection Schemes. *Condition Monitoring and Diagnosis (CMD)* 1-4