AC/DC Converter Integrated into the Aircraft Generator

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***Abstract*— In this paper the authors consider the aircraft AC/DC converter weight and dimensions minimization. The authors have designed an AC/DC converter integrated with an aircraft generator. The paper presents the results of its modeling and thermal calculations. The results of the study showed that due to the implementation of the AC/DC converter in a single housing and a common cooling system with an aircraft generator, its weight can be reduced by up to 10%.**

Keywords—AC/DC converter, generator, electric machines, integrated electronics, aircraft.

I. INTRODUCTION

Today, there is a trend towards aircraft electrification with the concepts of a more electric aircraft and an all-electric aircraft. The electric machines (EMs) usage in various aircraft systems makes it possible to increase their reliability, save free space inside the aircraft and, in general, to improve the aircraft environmental friendliness. EMs on board the aircraft can have various applications, for example, as fuel pumps, drives of the wing steering surfaces, etc. In the future, the creation of an aircraft, in which the EM will perform the function of a mid-flight engine, is considered. The growth in the number of electric power consumers on the aircraft requires the generation of more electrical power to provide their operation, therefore, on modern aircraft, it is necessary to use powerful electric generators. It is important to note that most of the electricity consumers on board the aircraft operate on direct current; therefore, it is advisable to build an electric generator together with an AC/DC converter. This work is devoted to the development of an AC/DC converter integrated into the aircraft generator.

II. AC/DC CONVERTER INTEGRATED INTO THE AIRCRAFT GENERATOR

Next existing aircraft AC/DC converters have been considered. In works [1, 2], it is noted that the electricity consumers number on a modern aircraft is increasing, which is due to the aircraft electrification trend. In this regard, it becomes necessary to provide power for various types of consumers. Aircraft generators primarily generate AC power, while many consumers require DC power to operate. This necessitates the AC/DC converters usage, which will convert alternating current into direct current with the required parameters, on aircraft. Work [3] is devoted to the three-phase AC/DC buck converter design. In [3] it is noted that for aircraft AC/DC converters it is important to: (1) provide high quality power; (2) achieve high input power factor; (3) provide maximum power density with minimum weight and dimensions. In work [4], an aircraft AC/DC converter is also designed, which improves the voltage harmonic composition, since it is performed according to the one-way primary inductance converter scheme. To assess the designed AC/DC converter effectiveness, the authors of [4] used the Matlab software. In [5], an AC/DC converter was designed, which allows minimizing the weight and dimensions of an AC/DC converter by performing an AC/DC converter in a two-stage topology with a VIENNA rectifier in the first stage after the DC/DC converter and a high-frequency converter in the second stage. Work [6] compares five topologies of aircraft AC/DC converters. The aim of the research is to identify the AC/DC converter topology with the highest efficiency, low heat generation and minimized weight and dimensions. Works [7, 8] are devoted to the design of aircraft AC/DC converters with high power density. In [7], the weight and dimensions minimization of the aircraft AC/DC converter is achieved by selecting the optimal switching frequency at which the output power is maximum. In [8], the weight and dimensions minimization of the AC/DC converter is achieved by building an AC/DC converter of matrix topology. In [9], a compact aircraft AC/DC converter is designed, which is made according to the scheme of an indirect matrix converter.

Thus, there is a number of modern research projects that are dedicated to the aircraft AC/DC converters development. Their analysis showed that an important task is to minimize the weight and dimensions of aircraft AC/DC converters. Basically, the weight and dimensions minimization of AC/DC converters is achieved by performing them according to a certain topology, or by selecting the optimal parameters of their operation. At the same time, it is possible to minimize the weight and dimensions of aircraft AC/DC converters due to their construction. In this paper, the authors consider the aircraft AC/DC converter weight and size minimization due to its integration into an aircraft generator.

A feature of the AC/DC converter designed by the authors is its usage as part of a more electric aircraft, which imposes several restrictions on it. First, the AC/DC converter is made in a single housing with an aircraft generator. Secondly, the AC/DC converter with the generator is located directly next to the aircraft auxiliary power unit (APU), which imposes certain requirements on its design In the modern works about the

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AC/DC power converters, known from the modern scientific literature analysis, much attention is paid to the AC/DC converters electrical circuit design. At the same time, measures for the AC/DC converters construction and methods for reducing AC/DC converters weight and dimensions are not so well sanctified in the modern scientific literature.

Therefore, the authors consider an approach to reducing the AC/DC converter weight and dimensions due to its integration with an aircraft generator. The aim of the work is to consider the AC / DC converter integrated with the aircraft generator design process and to make a conclusions about the efficiency of AC / DC converter integration with an aircraft generator in terms of reducing "AC / DC converter - aircraft generator" system weight and dimensions.

The AC/DC converter developed by the authors has been made according to the traditional AC/DC converter scheme (Fig. 1). Matlab Simulink software is used to simulate the designed AC/DC converter operation. The simulation model is presented in Fig. 2. The designed AC/DC converter characteristics are shown in Table 1. Fig. 3 - Fig. 5 shows the results of designed AC/DC converter modeling.

TABLE I. DESIGNED AC/DC CONVERTER PARAMETERS

Parameter	Value
Load voltage, V	821
Load voltage ripple, V	3.5
Load current, A	1025
Diode current, A, rms	548
Diode peak back voltage, V	823
Capacitor peak current, A	98.5

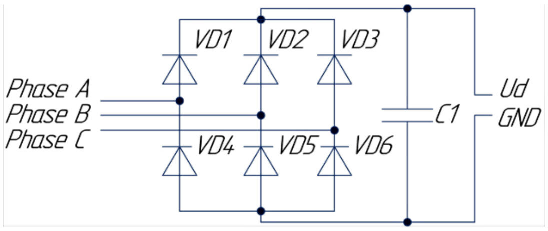

Fig. 1. The AC/DC electrical scheme

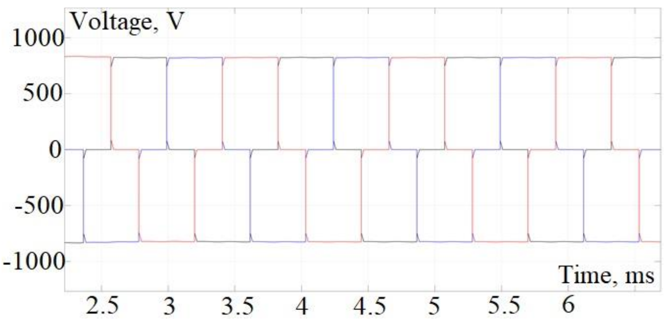

Fig. 3. AC/DC converter input voltage

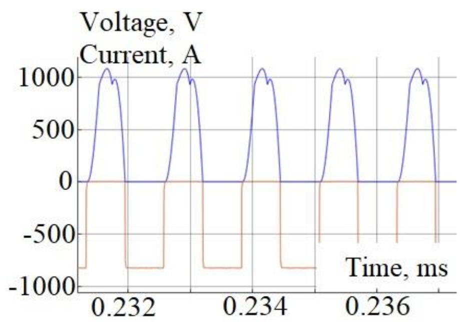

Fig. 4. AC/DC converter diode voltage and current

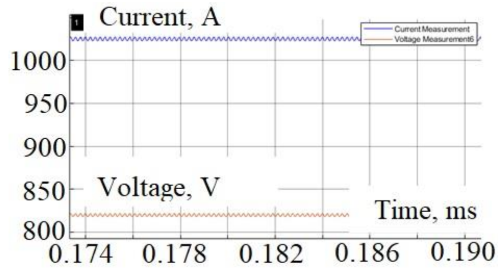

Fig. 5. Load voltage and current after AC/DC converter

The computer simulation results match the AC/DC converter calculated characteristics. Further in the paper, the AC / DC converter design is considered and its key features are described. The designed AC / DC converter appearance is shown in Fig. 6.

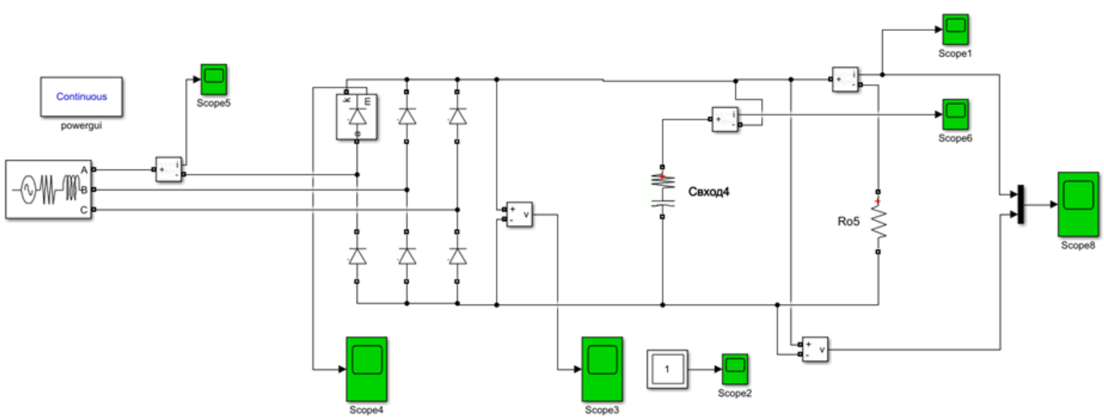

Fig. 2. The AC/DC converter simulation model

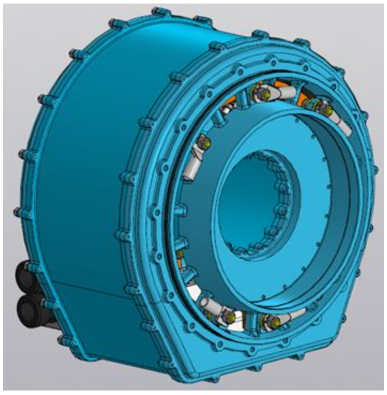

Fig. 6. External view of the AC / DC converter integrated into the aircraft generator

As mentioned above, the AC/DC converter is made in a single housing with the aircraft generator. Therefore, the shape of the AC/DC converter housing is determined by the generator housing shape. The AC/DC converter has a high power, therefore, the heat dissipation on the semiconductor elements of its circuit is significant. In this regard, the AC/DC converter is liquid-cooled, and the cooling system is the same for the AC/DC converter and the aircraft generator. The refrigerant first flows through the generator stator slots, then inside the AC/DC converter housing and then out of the housing. Since all elements of the AC/DC converter are surrounded by oil, a number of measures must be taken to protect the components from the coolant influence. For example, the filter capacitor housings coating can be destroyed by the cooling oil influence, therefore it is necessary to provide additional capacitors coating with a special oil-resistant compound.

The diodes in a plate form are used in the AC/DC converter construction. The copper buses csn be used as radiarors in this case, so additional weight economy can be achieved.

The main heat sources in the AC/DC converter are the power diodes included in the rectifier. Therefore, to increase the diodes cooling efficiency, the diodes are assembled on two radiators, which are surrounded by oil. The AC/DC converter rectifier unit is shown in Fig. 7.

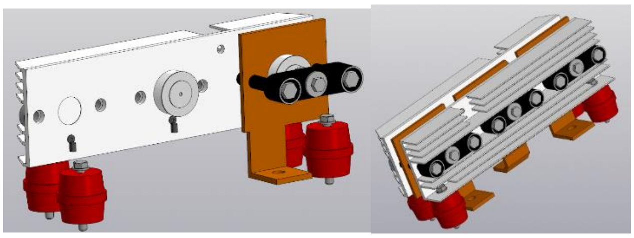

Fig. 7. The AC/DC converter rectifier unit

To evaluate the AC/DC converter rectifier unit cooling efficiency, its thermal simulation was carried out. In this case, the thermal conductivity in a solid is considered, and the purpose of the simulation is to determine the diodes maximum temperature. The AC/DC converter rectifier unit thermal modeling results are shown in Fig. 8.

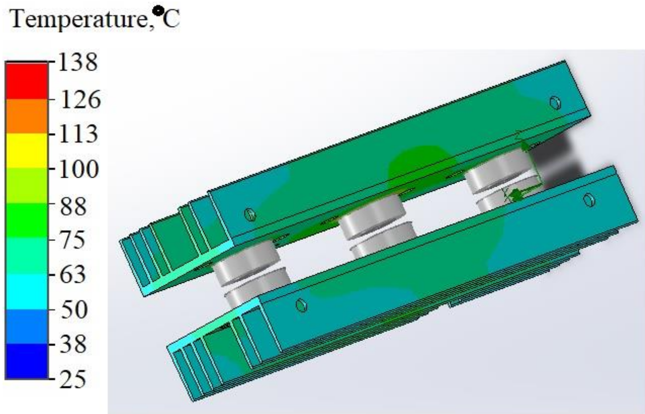

Fig. 8. The AC/DC converter rectifier unit thermal modeling results

The simulation results show that the diodes temperature does not exceed their maximum allowable operating temperature.

As noted earlier, the AC/DC converter integration with the aircraft generator allows AC/DC converter weight reducing by implementation of a cooling system jointly with the aircraft generator, and also to reduce the «AC/DC converter – aircraft generator» system weight due to the common housing implementation. As a design result, the 800 kW AC/DC converter weight is 30.5 kg, and the «AC/DC converter - aircraft generator» system weight is 300 kg. Comparison with the existing AC/DC converters showed that the AC/DC converter integration with the aircraft generator allows achieving its weight reduction up to 10%. At the same time, the «AC/DC converter - aircraft generator» system weight can be reduced by up to 5%. Moreover, the implementation of the AC/DC converter and aircraft generator in a single housing allows saving space on the aircraft and allows simplifying the AC/DC converter and generator placement on the aircraft.

III. Conclusion

This paper discusses the AC/DC converter integrated into the aircraft generator design. The paper presents an AC/DC converter simulation model and the results of its simulation in the Matlab Simulink software package. The AC/DC converter integrated into the aircraft generator design and its features are described. The AC/DC converter rectifier unit thermal simulation results are also presented.

The studies results have showed that the high-power AC/DC converter integrated with the aircraft generator implementation allows its weight reducing by up to 10% compared to AC/DC converters performed by separate units. This is achieved by implementing the AC/DC converter and aircraft generator in a single housing and by implementation of a joint liquid cooling system for the AC/DC converter and aircraft generator. Thus, the work results confirm the effectiveness of the implementation of an AC/DC converter integration with the aircraft generator in terms of reducing its weight and dimensions.

Our future work will focus on further development and experimental research of AC / DC converters integrated into the aircraft generator.

Acknowledgment

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