Modern Starter-generator Electronics Unit Construction

Ismagilov Flur Rashitovich
Department of Electromechanics
Ufa State Aviation Technical University
Ufa, Russia
ifr@ugatu.su

Vavilov Vyacheslav Evgen'evich
Department of Electromechanics
Ufa State Aviation Technical University
Ufa, Russia
vavilovv@ugatu.su

Farrakhov Danis Ramilevich
Department of Electromechanics
Ufa State Aviation Technical University
Ufa, Russia
d.farrakhov@yandex.ru

Yamalov Ilnar Ildarovich
Department of Electromechanics
Ufa State Aviation Technical University
Ufa, Russia
yamalov.i.i@mail.ru

Urazbakhtin Ruslan Rustemovich
Department of Electromechanics
Ufa State Aviation Technical University
Ufa, Russia
urr98@mail.ru

***Abstract*— The paper deals with the aviation starter-generator electronics unit construction. The authors propose an original algorithm for designing an aircraft starter-generator electronics unit, which allows taking into account the peculiarities of its placement on an aircraft and achieving a reduction in weight and dimensions. According to the proposed algorithm, the authors have designed a starter-generator electronics unit with a power of 3.2 kW. The design according to the proposal algorithm showed that a decrease in the electronics unit weight up to 5-7% and a decrease in the electronic units overall dimensions up to 3-5% can be achieved.**

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

I. INTRODUCTION

On modern aircraft, it is perspective to use starter-generators (SGs), which make it possible to start an aircraft engine and generate electricity into the on-board electricity network both on the ground and during the flight. The combination of two devices in one allows to reduce the aircraft weight and aircraft dimensions and save free space inside the aircraft, as well as improve the aircraft sustainability. One of the SG operation features is the need to use a control system that will ensure the SG operation in the motor mode and in the generator mode.

Investigations of electrical machines (EM) for aviation SG are devoted to works [1-10]. Also, in works [1-10] approaches to SG control are mentioned, different variants of SG control schemes are compared. In the works [11-14], methods of increasing the SG reliability and the prospects for the SGs development have been considered. In general, the literature analysis has showed that the EM development and design for the SG topic and electronics for the SG design topic is widely discussed in modern scientific literature. At the same time, the existing works do not consider the construction of SG electronic units (EU). Nevertheless, the SG EUs construction is an important task since the SG EU is located inside the aircraft and its reliable operation affects the flight safety.

When designing the SG EU, two important tasks are posed: (1) minimization of the SG EU weight and dimensions; (2) consideration of external factors affecting the SG EU operation. The first task is due to the need to create a new generation aircraft with increased fuel efficiency and meeting the increasingly stringent environmental requirements. The second task is due to the fact that the aircraft may experience special effects on the SG EU, for example, vibration and shock loads. Therefore, when constructing SG EU, measures should be taken to increase the SG EU resistance to external influences.

Obviously, to create SG EU, which will have minimized weight and dimensions and which will be resistant to external influences, it is necessary to form a generalized approach to their construction. Therefore, in this paper, the authors propose an original approach to the SG EU construction. To verify the proposed SG EU construction approach, the authors construct an SG EU with a power of 3.2 kW and compare its characteristics with existing analogues.

II. SG EU CONSTRUCTION SEQUENCE

The main tasks in the SG EU construction are to minimize its weight and dimensions and make it reliable, resistant to external influences (for example, to vibration and shock loads), due to the EU SG placement area on the aircraft. Further, the authors propose a step-by-step sequence for EU SG construction.

The first stage in the SG EU constructing is the initial data analysis. Initial data can be presented as technical requirements. Often, for aircraft EMs and EUs, the technical requirements specify the requirements for resistance to external influences, the placement area on the aircraft, etc., which must be considered during further constructing. In the absence of technical requirements or insufficient amount of data in technical requirements, it is necessary to refer to the previously accumulated experience or to carry out the quality functions deployment (QFD). As a result of the initial data analysis, the functions of the SG EU are formulated, and the requirements are imposed on the SG EU functions.

The second step is to analyze the SG EU electrical circuit. As a result of this design stage, the SG EU electronic components and their number are selected. For example, the brand of transistors in the inverter circuit is selected and the number of transistors installed in parallel in one arm is determined. It is important to note, that N-channel MOSFETs have been used as the SG EU transistors. The EU SG electrical schematic diagram, designed by the authors, is shown in Fig. 1.

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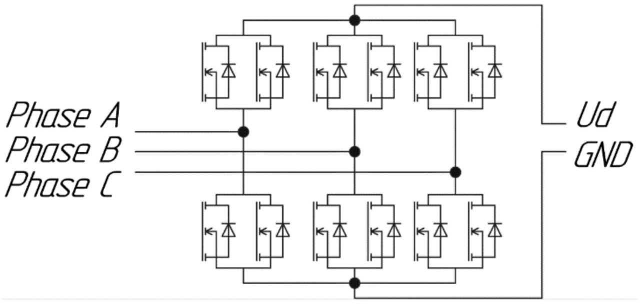

Fig. 1. The EU SG electrical schematic diagram

It is convenient to use the Matlab Simulink software package to analyze the SG EU electrical circuit. Here, currents and voltages on transistors, currents and voltages on transistors internal diodes, etc. can be obtained. According to currents and voltages, a preliminary transistors selection and other electrical circuit components is made. The SG EU electrical circuit analysis in the starter mode is of particular interest, since the starter mode is the most difficult for the SG EU. A model for analyzing the SG EU electrical circuit in the starter mode is shown in Fig. 2.

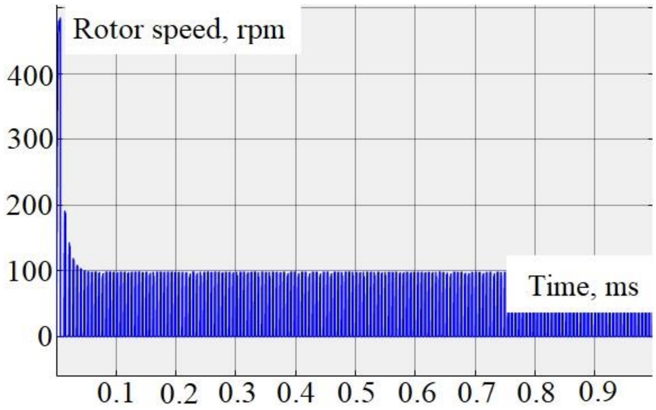

Fig. 3. Drain to source current in the SG EU invertor

The authors propose to calculate the SG EU inverter transistors losses by the analytical method presented in [15].

Knowing the SG EU power elements losses, it is possible to calculate the EU SG cooling system. It is preferable for SG EU to design the cooling of power switches by convection or by air cooling. Liquid cooling allows more heat to be

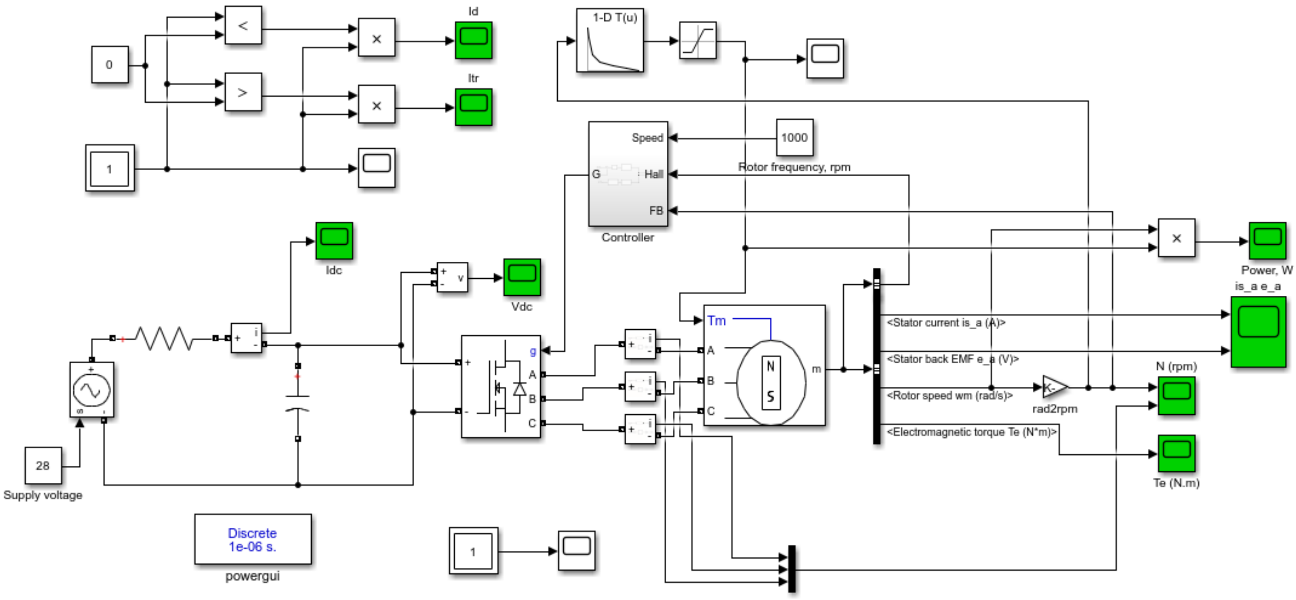

Fig. 2. A model for analyzing the SG EU electrical circuit in the starter mode

After components preliminary selection, it is necessary to calculate the SG EU cooling system, the power of which will be sufficient to remove heat from the SG EU inverter power switches. The first step in SG EU cooling system calculating is to determine the losses on the SG EU inverter transistors. For this, the results of the SG EU electrical circuit analysis are used. For example, you need to know the drain to source transistor current (see Fig. 3). Also, to determine the losses on a transistor, it is necessary to use this transistor documentation, which indicates its certain parameters.

removed from the SG EU, but significantly increases the SG EU weight and is difficult to perform structurally, can reduce the reliability of the SG system. The main task of EU SG cooling system calculating is to select a radiator topology sufficient to dissipate the power released on transistors in the form of heat, and to determine the required airflow. The results of the SG EU radiator thermal modeling are shown in Fig. 4.

It is important to note that at this stage it is also important to choose the optimal heatsinks arrangement on the radiator in terms of temperature distribution over its surface. The radiator itself must be selected from the conditions for achieving the minimum weight and dimensions with sufficiently effective cooling. If the temperature of the heatsink exceeds the maximum allowable operating temperature of semiconductor switches, then it is advisable to choose another radiator, or choose transistors with a lower resistance.

The final construction stage is the SG EU construction forming. Here, the location of the printed circuit boards and other SG EU elements is selected (depending on the SG EU placement area on the aircraft), the housing design is developed, materials for the SG EU frame and SG EU housing manufacture, etc. are selected. The SG EU constructed according to the proposed by the authors sequence is shown in Fig. 5.

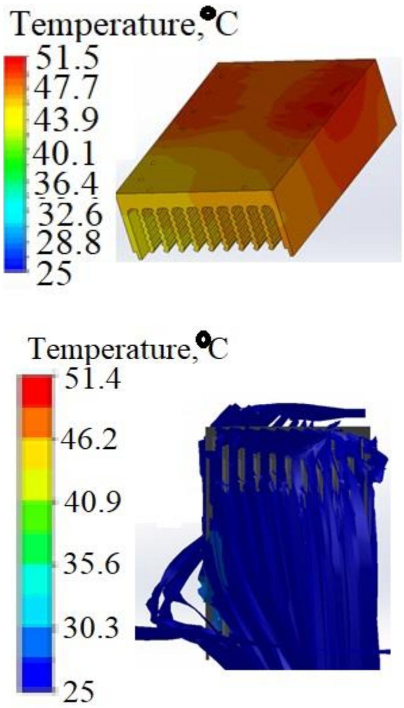

Fig. 4. The results of the SG EU radiator with a dissipated power of 120 W with an airflow of 205.2 m^3/h thermal modeling (top – the temperature distribution over the radiator surface, bottom – the distribution of air flows with a given airflow through the radiator)

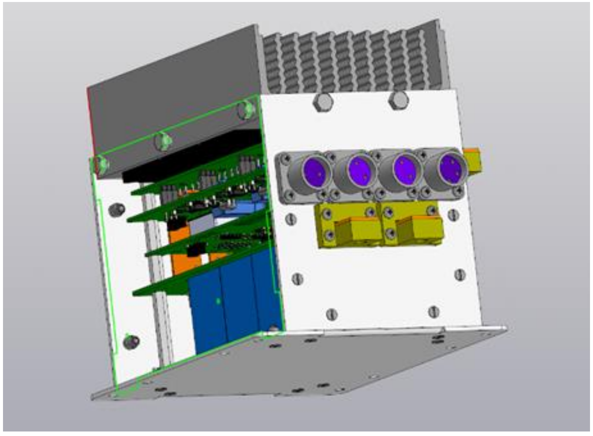

Fig. 5. The constructed SG EU appearance

At this stage, it is necessary to apply some measures that allow SG EU weight and dimensions reducing: (1) composite materials in the housing construction usage; (2) fasteners number reducing in the SG EU construction; (3) the radiator efficiently usage; (4) SG EU execution on basic load-bearing constructions; (5) the frameless electronic micro-assemblies usage; (6) minimization of the free space inside the SG EU housing.

Thus, the authors have outlined an approach to the SG EU construction. To verify the proposed approach, the authors have constructed an SG EU with a power of 3.2 kW. The mass of the constructed SG EU is 2.5 kg with overall dimensions of 150 mm in height, 105 mm in width and 180 mm in length. Comparison of the constructed SG EU with existing analogs with capacities of 3 - 3.5 kW showed that, with comparable electrical parameters, due to the application of an original SG EU construction approach, a decrease in the SG EU weight by 5-7% is achieved, as well as a decrease in dimensions by 3-5%. Moreover, the SG EU constructed according to the approach proposed by the authors is resistant to vibration and shock loads occurring on an aircraft. This proves the relevance of the developed by authors approach for the SG EU construction.

III. Conclusion

In this paper, the authors propose the SG EU construction sequence. The developed sequence makes it possible to systematize the SG EU design process, allows to take into account the peculiarities of the SG EU placement on the aircraft and to design the SG EU with minimized weight and dimensions. The results of applying the proposed SG EU construction approach are verified by comparing the constructed by the authors SG EU with existing analogues. Authors future works will be aimed at experimental studies of the EU in conjunction with the SG.

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