

SHORT-CIRCUIT CHARACTERISTICS OF AIRBORNE DC AND AC GENERATORS

ХАРАКТЕРИСТИКИ КОРОТКОГО ЗАМЫКАНИЯ БОРТОВЫХ ГЕНЕРАТОРОВ ПОСТОЯННОГО И ПЕРЕМЕННОГО ТОКА

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Abstract: This contribution solved the issue of simulation of board DC (AC) generator focused on its short circuit current. The method used by the engineering industry is that of the computer-based mathematical modelling bringing new quality into describing the systems attributes and its components and the educational process as well.

KEYWORDS: SIMULATION, SHORT-CIRCUIT, GENERATOR

1. Introduction

The gradual increase in the level of onboard systems electrification in aviation is adequately reflected in the rising need for a providing reliable, uninterrupted supply of power and energy at standardized parameters. The failures of the individual components of the system ensuring generation and distribution of electrical energy may lead to irregularities in the operation and eventually to breakdowns in the feeding of airborne electrical devices.

The essential feature of next generation aircraft development projects is to achieve maximum level of flight safety and aircraft power efficiency. Increasing the degree of board system electrification is also reflected, by appropriate manner, in needs of providing reliable, uninterrupted power supply by electrical energy and its normalizing parameters.

Mathematical modelling on computer is one of the experimental methods widely used in science and engineering practice [3,4,5,6]. Such a model enables experimenting similarly to real systems thereby obtaining characteristics of required physical magnitudes. It proved beneficial also when describing the properties of systems and its components in the teaching process. The merits of this method are particularly significant in cases when it is necessary to simulate the behaviour of objects in various boundary modes of operation which cannot be induced during laboratory measurement on a physical model as it could be damaging (for example short-circuit or overloading). The method of mathematical experiment is one of the ways how to ensure teaching of onboard electrical power systems and their electrical devices.

To analyse the properties of the onboard electrical generators and perform computer simulation of their short-circuit modes, at first, it is necessary to create their mathematical and simulation models [1].

2. Short-circuit mode of the DC generator

For DC generator excitation and armature circuit in short-circuit mode the following equations are applicable:

$$\begin{aligned} L_a \frac{dI_a}{dt} + R_a I_a + U_n &= c_e \cdot \phi \cdot n \\ L_b \frac{dI_b}{dt} + I_b \cdot R_b &= U_n \\ (T_a p + 1) R_a \cdot I_a + U_n &= c_e \cdot \phi \cdot n \\ (T_b p + 1) \cdot I_b &= \frac{U_n}{R_b} \end{aligned} \quad (1)$$

where $c_e = \frac{pN}{a}$, $T_a = \frac{L_a}{R_a}$, $T_b = \frac{L_b}{R_b}$,

U – the terminal voltage DC-generator, E – induced voltage of machine, p – the number of poles, N – the number of armature winding loops, a – the number of parallel branches, c_e – machine constant, Φ – the magnetic flux, n – the speed in RPM, R_b , L_b – the excitation winding resistance and inductance, R_a , L_a – the armature winding resistance and inductance, N_b – number turns of excitation winding

For short-circuit mode of armature circuit, we can write $U_{n\infty} = 0$ and if $\Phi = \Phi_{or} + bI_b = b(I_{or} + I_b)$ so that:

$$(T_a p + 1) R_a \cdot I_a = c_e \cdot n \cdot b (I_{or} + I_b) = U_{or} + c_e \cdot n \cdot b \cdot I_a$$

The resultant dependance for short-circuit current is gained in form:

$$I_{a_k} = I_z e^{-\frac{t}{T_a}} + \frac{U_{or}}{R_a} \left(1 - e^{-\frac{t}{T_a}} \right) + \frac{c_e b n}{R_b} \frac{T_b}{(T_b - T_a)} \frac{U_n}{R_a} \left(e^{-\frac{t}{T_b}} - e^{-\frac{t}{T_a}} \right) \quad (2)$$

$$I_{a_k} = I_z e^{-\frac{t}{T_a}} + I_{or} \left(1 - e^{-\frac{t}{T_a}} \right) + I_M \left(e^{-\frac{t}{T_b}} - e^{-\frac{t}{T_a}} \right)$$

where I_z – load current of generator before short-circuit, I_{or} – steady short-circuit current determined by remanent magnetism, I_M – maximum amplitude of short-circuit current

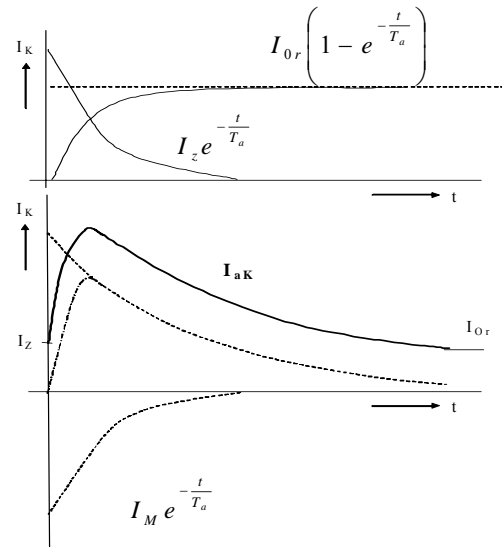


Fig. 1 Short-circuit characteristics in the armature winding

From the equation it follows that the current consists of three components corresponding to the three parts of the right side of the equation. The first component is dependable on the generator load current before short-circuit, the second component on the remanent magnetism and the third one on the value of the current in the excitation circuit. Components behaviour is illustrated in Fig. 1.

The corresponding computer model of DC-generator was assembled in the Simulink environment using standard blocks with the following basic parameters of the DC-generator:

$P_n = 9 \text{ kW}$, $U_n = 28,5 \text{ V}$, $I_a = 400 \text{ A}$, $I_b = 6 \text{ A}$, $n = 4500 \text{ ot/min}$, $R_a = 0,024 \text{ } \Omega$, $R_b = 3,5 \text{ } \Omega$, $L_a = 2,8 \cdot 10^{-5} \text{ H}$, $L_b = 0,1 \text{ H}$, $N = 228z$, $p = 3$, $a = 3$, $c_e = 0,00038$, $U_{rem} = 1,4 \text{ V}$.

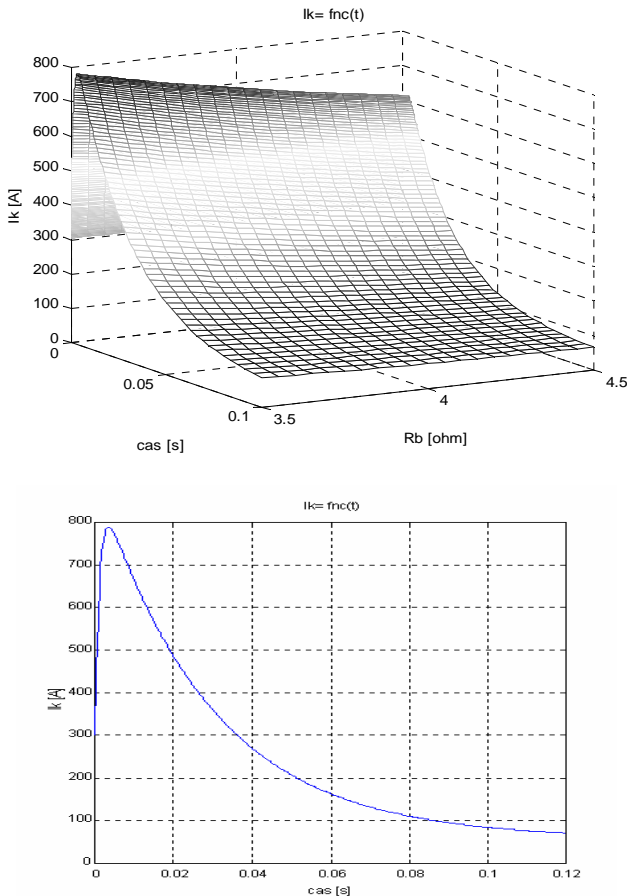


Fig. 2 Resulting simulated behaviour of short-circuit current in the DC-generator armature

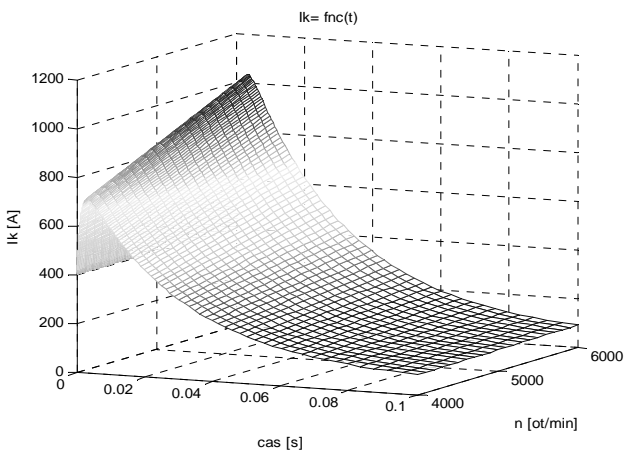


Fig. 3 The influence of changes in the selected parameters of the generator - the excitation winding resistance and RPM - on the behaviour of the short-circuit current of the DC generator

The resulting simulated behaviour of the short-circuit current corresponds to the theoretical assumptions (Fig. 2). The short-circuit current characteristics begins in zero, then rapidly reaches the maximum value of the short-circuit current at 790 A, in a period of 0,002s. The influences of the change in the selected parameters of the generator - the excitation winding resistance and the RPM - exerted on the behaviour of the short-circuit current is illustrated in Fig.3. Changing the resistance in the excitation circuit within the range of 3,5 Ω to 4,5 Ω , changes the maximum value of short-circuit current. When R_b value increases, the maximum value of the short-circuit current decreases. The increase in the RPM value rises the maximum value of the short-circuit current.

3. Short-circuit mode of the AC generator

Similar approach can be adopted also at identifying the AC generator and its subsequent analysis of its characteristics when in short-circuit mode. The short-circuit current in the stator winding is made up of two components: the alternative i_a and the direct current i_d [2]. The resulting time behaviour of the short-circuit current is illustrated in Fig. 4 and the simulated characteristics of the individual components for the airborne generator GT-40 PČ6 are in Fig. 5.

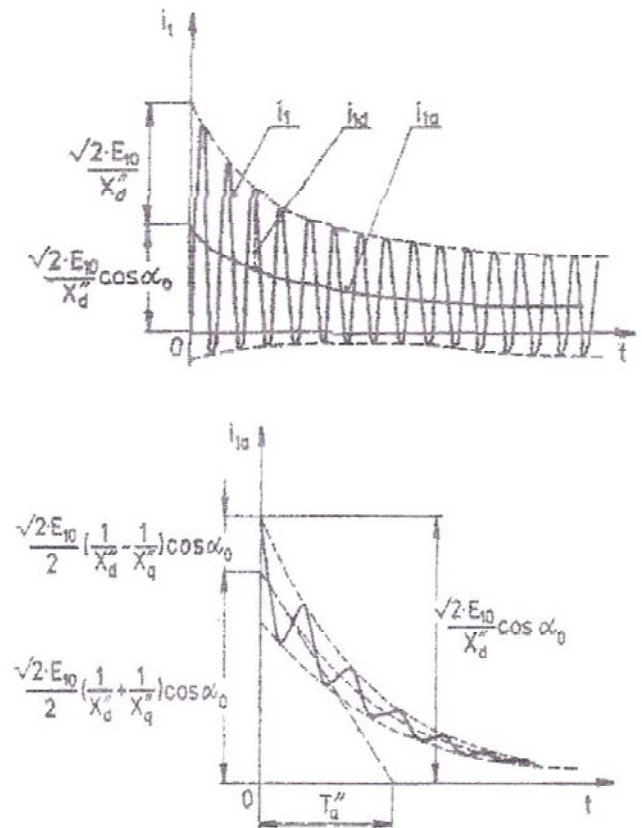


Fig. 4 Behaviour of the AC-generator phasing short-circuit current

4. Conclusion

Time behaviours of individual quantities can be monitored when changing the given input parameters. Simulated behaviours enable description of the basic attributes of the generator and their changes when introducing corresponding changes to input parameters.

The models designed are adjusted to the teaching requirements of the given problem. Higher efficiency in applying the results of simulation experiments in teaching, calls for their finalization in terms of didactics, with the aim to establish an interactive environment enabling optimum presentation of the aquired data acquired as in view of the requirements of the given subject.

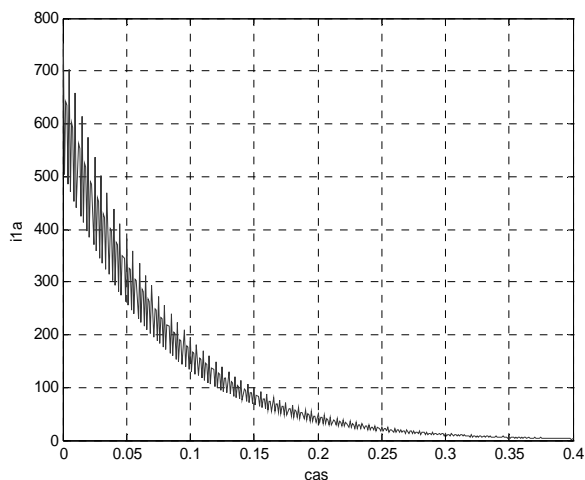
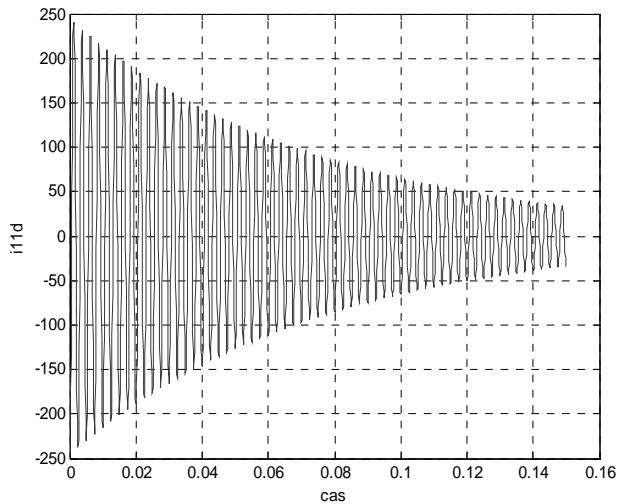


Fig. 5 Simulated behaviours of transient AC and DC components of the stator current

5. References

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