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THE APPLYING OF AN AUTOMATIC CONFIGURATION TOOL FOR THE INVESTIGATION OF THE UAV ELECTRICAL NETWORK

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Abstract: *These researches were a part of a project which lasted more than a year and were done in collaboration with LMS International from Leuven, Belgium and Katholieke Hogeschool Brugge – Oostende that help us with the technical support.*
The main purpose of these researches was to determine the optimum configuration that can offer the best results in a real flight. This was possible by applying the Model – Based System Engineering (MBSE) in the developing and the investigation of an UAV electrical network. Based on the "black box" principle from System Modeling, it was created different models for the main components of the aircraft.
Using specific mathematical formulas and taking account of the basic forces and the moments developed on the surface of the aircraft structure during the real flight, it was computed the functional parameters for the main components (propeller, motor, servo, battery).
It were developed two different models for the UAV electrical network (electrical and thermal model). Also, using the automatic configuration tool, it was created, for the both models, different configurations.
Keywords: *UAV, configured architecture, Model-Based System Engineering, System Simulation.*

1. INTRODUCTION

The aim of these researches was to determine the optimum configuration of an UAV electrical network by using an automated configuration tool. According with this goal it established a set of main objectives, as: the designing of two reference architecture for the UAV electrical network (electrical and thermal model), the creation, for each of these, of a set of configurations and the investigation of every configuration. Using Model – Based System Engineering (MBSE), it was possible to obtain the specific results.
Starting with the 90's interest in UAVs grew significantly within military and civil areas as well with a large number of producers and covered missions. According to [1], in 2012, it is estimated 76 countries have some sort of UAV.
UAV (unmanned aerial vehicle) is an aircraft without a human pilot on board. Its flight is controlled either autonomously by computers in the vehicle, or under the remote control of a pilot on the ground or in another vehicle.
The use of drones has grown quickly in recent years because unlike manned aircraft they can fly for many hours (*Zephyr* a British drone under development has just broken the world record by continuous flying for over 82 hours); they are much cheaper than military aircraft and they are flown remotely so there is no danger to the flight crew [2].
UAVs are well suited for emergency situations. Some typical applications are the following: disaster operations management, transport, search and rescue, firefighting, flood watch, volcano monitoring, hurricane watching, nuclear radiation monitoring etc. Most of these missions require extended time in the air and also real-time video to the ground control situation.
It is expected to see increasing automation built into UAVs. In the near future UAVs will be able to take off, navigate to a destination, return and land without operator intervention [1]. This should improve reliability by reducing the impact of a disruption to radio signals between the UAV and control center.

2. THE MATHEMATICS FUNDAMENTALS IN UAV COMPONENTS MODELING

The strategy of the components modelling is based on an observation and theoretical analyses of the component individually and after that an iterative process is started with first reviewing the AMESim library to find the best matching model available and second, characterizing the component by essential output, input and internal parameters.
The basic principle of the AMESim modelling was taken from the System modelling theory, namely "Black Box" principle that is represented in Figure 1.

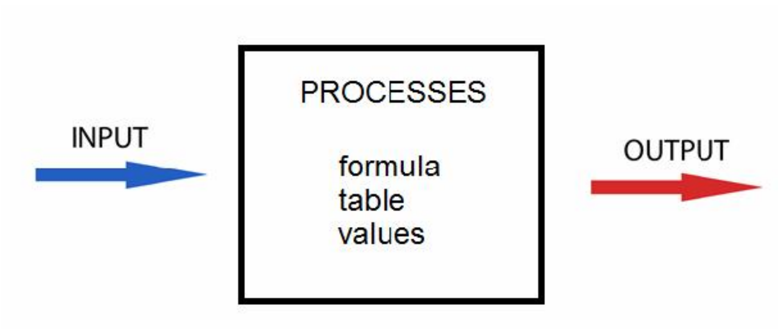

Fig. 1 The scheme of Black Box principle

In science and engineering, a black box consists in a device, system or object which can be viewed in terms of its input, output and transfer characteristics without any knowledge of its internal workings.
The "black box" principle is considered a mathematical model that consists in a series of mathematical relations between the process variables. These relations link, one with other, the state process variables or more commanded variables of this system.
In the systems modeling theory it specifies that the mathematical models offer high possibilities of study regarding the optimization of a modeled process, because by solving the equations from within the "box" it determines the optimum values of the commanded variables [3].
Based on this concept it created submodels for the main components of the UAV (propeller, motor, battery, servo, ESC …).
Data available from the manufacturer, other documentation and/or measurements is used and put into the submodel as parameters, functions or tables [4].
The parameters used for the submodels were computed using the specific formulas and taking account of the forces and environment parameters that are involved in the real flight conditions.
Basing on this principle, it created the models for main components involved in the UAV electrical network that are presented in Figure 2.

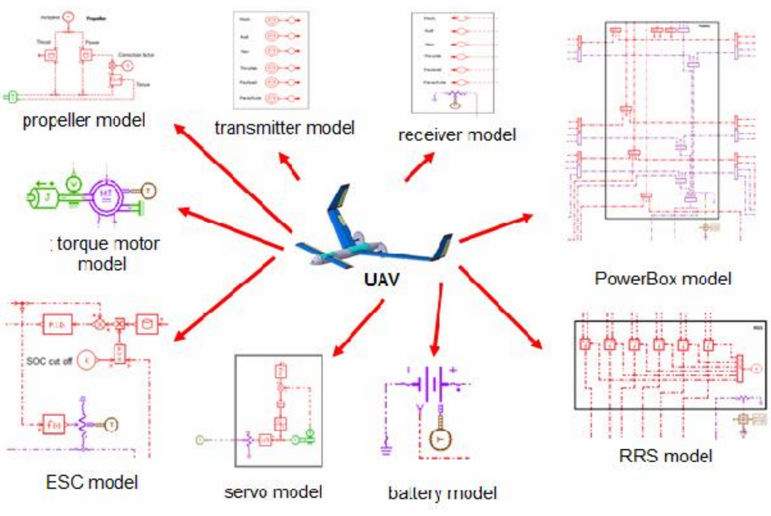

Fig. 2 The main components of UAV electrical network

Starting from these UAV models and using AMESim software it created different supercomponents for all the components of the electrical network of UAV (batteries, servos, motors and propellers).
The supercomponents consist of an icon (image) and ports and are associated with the submodels. After creating each supercomponent, it applied the simulation mode for check if the new supercomponent is functionally.

3. THE APPLYING OF MBSE CONCEPT IN THE INVESTIGATION OF UAV ELECTRICAL NETWORK

Model-based systems engineering (MBSE) is a methodology for designing systems using interconnected computer models. The recent proliferation of MBSE is evidence of its ability to improve the design fidelity and enhance communication among development teams.
One of the main objectives of this research was to investigate of two different electrical models using an automated configuration tool. This could be possible by the system simulation and the evaluation of the output parameters for the both models. For the creating of different simulation scenarios it had to use SysDM and System Synthesis software.
The flow chart from Figure 3 represents the interconnection between the three used software.

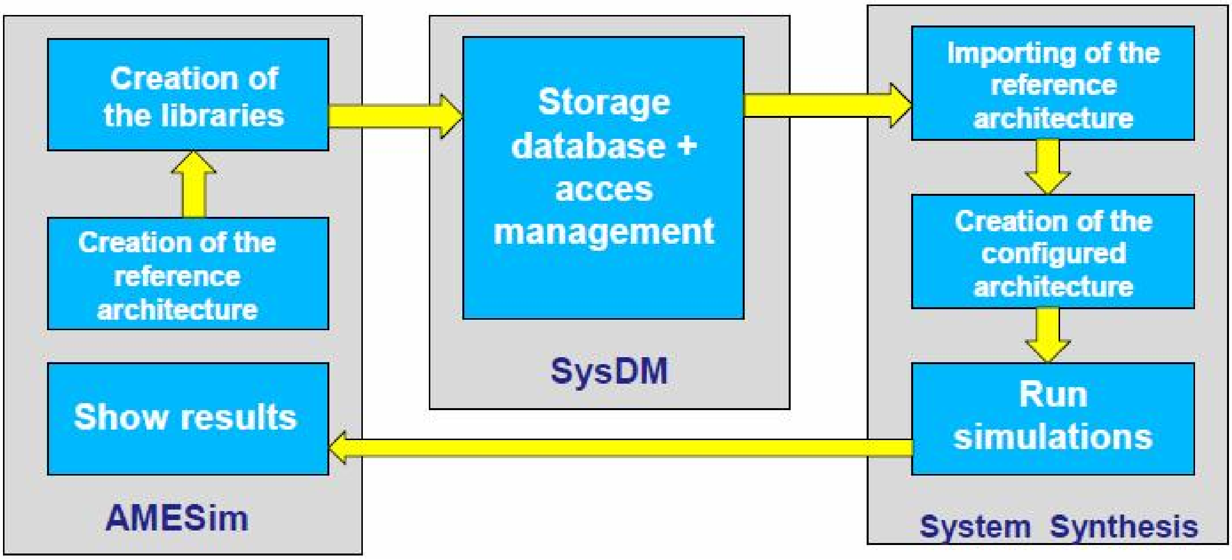

Fig. 3 The interconnection between the three used software

Referred to this scheme, first step is the creation of the reference architecture, using AMESim software, and then it has to create the libraries for the used components.
Next step is to import the libraries of the components, using SysDM software. After that, it needs to import the reference architecture, already created in AMESim software, using System Synthesis software. Base of that it has to create the configured architecture and the following step is to run the simulations.
The final step is to show the results and for that reason it needs to reopen AMESim software.
The original UAV model used in this project was constructed, by KHBO team, in AMESim software, by elements which contain electrical components, which were already presented in Figure 2. The UAV is powered by two electric motors, driving propellers. These motors consume the most electrical energy of all the components installed. This electrical energy is transformed into mechanical energy and transferred via an axle to the load, a propeller.
Starting to this global model, it created two different reference architectures for the UAV electrical network: the electrical model (Fig. 4) and the thermal model (Fig.5).
In the both figures, the lines represent all the connections, red for signals, purple for electrical and green for mechanical connections. The components causing heat production have a thermal port ready for the thermal model.
One of the objectives at the beginning of this research was to investigate to the thermal behavior of the components inside the fuselage. This should indicate if a continuous airstream, whether or not forced, is needed throughout the fuselage. The temperature of the composite structure is limited to 120°C and must be taken into account.

The thermal model makes use of convective heat transfer between components and a medium (air). Their thermal solid properties are characterized in a data file, linked to the solid subcomponent in AMESim and can be copied. Also, the heat flux convection process from the components to a flow of air can easily be copied in the new thermal model.
In the thermal model, subcomponents influencing the surrounding air temperature inside the fuselage were connected to each other.

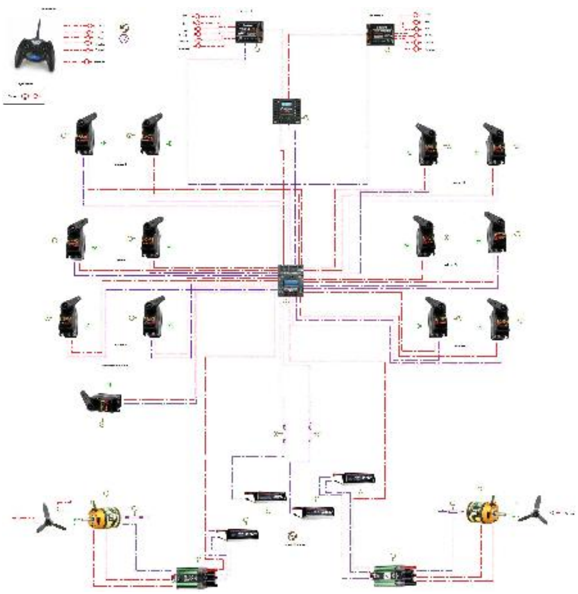

Fig. 4 Energy management only reference architecture

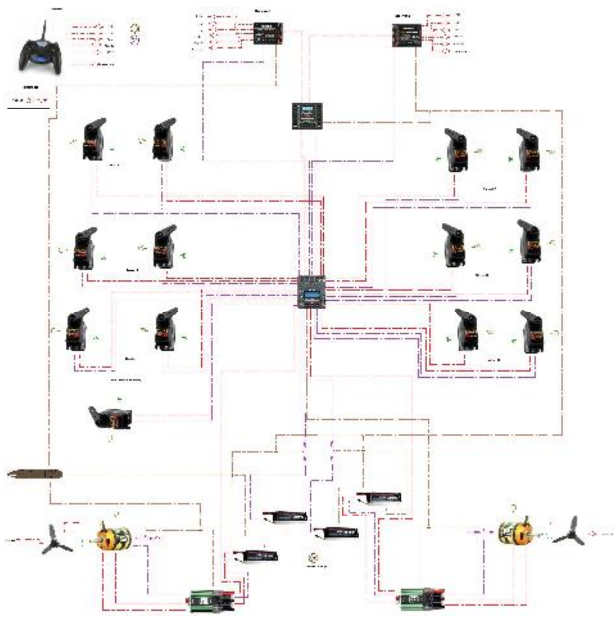

Fig. 5 Thermal and Energy management reference architecture

Starting from the reference architecture of UAV electrical model and using System Synthesis software it created 9 configurations with different parameters of some components (motor, propeller). Because it were created 3 models of these components it was easy to choose the configuration that it wanted.
Finally, after that it created all the possible configurations, it started to run simulations in System Synthesis software.
In the same way, for the UAV thermal model, 8 configured architectures were created. Using the 2 models of ESC and 4 models of fuselage it was possible to create the configured architectures, helping by System Synthesis software.

4. SIMULATIONS AND RESULTS

Also, it made simulations on the configurations of UAV electrical model, realized helping by System Synthesis software. It used for these simulations normal flight mission (the maximum time at the value of 3400 s).
The results obtained after simulations were around of the value of 10 % for the state of charge output of the main batteries, but not for all the tested configurations was possible a simulation at 3400 s. It observed that the maximum time of simulation flight was different in function of the motor and the simulations were executed using three sets of parameters for the propellers (AmeProp 17x10, AmeProp 18x10 and AmeProp 19x10). The best results were obtained at the using of the propellers with smaller parameters (the diameter).
So, if these parameters (torque motor and the diameter of the propeller) are too big, then, the time of flight simulation decrease because the state of charge for the main batteries reaches more quickly at the value of 10 %.
In the table 1 can be observed the values of output SOC of the main batteries for the 9 configurations of UAV electrical model.

Table 1 The numerical results of the simulation for the configurations of UAV electrical model propeller parameters.

Configuration no.	Value of State of charge output for the main batteries, [%]
1	**10.577**
2	**Failed (the simulation stops after 2100 s)**
3	**Failed (the simulation stops after 2600 s)**
4	**Failed (the simulation stops after 2600 s)**
5	**Failed (the simulation stops after 1600 s)**
6	**10.5264**
7	**Failed (the simulation stops after 2400 s)**
8	**Failed (the simulation stops after 1900 s)**
9	**37.3146**

For the UAV thermal model, the simulations were done at normal flight, which means 3400 s. As output variables were followed the temperature developed in fuselage and in Electronic speed controller. The graphical results for the 8 configurations were plotted.
In the table 2 can be noticed the numerical results for the output temperature for fuselage and ESC at normal flight mission.

Table 2 The numerical results for the output temperature for fuselage and ESC

Configuration no.	Temperature fuselage [°C]	Temperature ESC [°C]
1	**98.5151**	**529.15**
2	**137.221**	**536.887**
3	**137.221**	**536.887**
4	**98.5151**	**529.15**
5	**72.5153**	**189.35**
6	**97.8255**	**191.214**
7	**97.8255**	**191.214**
8	**72.5153**	**189.35**

The fuselage has a temperature of 98.5151 °C while the electronic speed controllers, mounted onto the fuselage have a staggering of 529.15 °C. This output temperature for the electronic speed controller has obtained because the UAV thermal model has not been calibrated yet and it were not used the realistic parameters of simulations.
In real flight conditions it should be impossible that a controller to resist at this big output temperature; after a temperature of 200 °C this type of controller should be decomposed.
For avoiding a very big increase of the output temperature for the electronic speed controller it used for the last configurations an additional sink of cooling air and the values of the temperature were significantly decreased till the value of 189.35 °C.

5. CONCLUSIONS

After the simulations developed on the two models it can identify some conclusions, as:

- the use of the automated configuration tools in system designing significantly decreases the work time for the process of components change;
- the simulation process can be applied of a set of configuration that exists in a list;
- by using the automated configuration tool, it obtained many configurations of the same reference architecture without its modify;
- when a system is investigated, it is always necessary to create a set of configurations. In this way, it can determine, after the simulations were done, the optimum configuration for a specific mission profile. Related to this work the optimum configuration for the electrical model was No. 9 from the Table 1

beacuse after the 3400 s of flight simulation, the level of charge of the main batteries reached at the value of 37,3146. It has to be clear that this imposes an adjustement of the imput parameters for the motor and for the propeller. For the thermal model, it is identified two optimum configurations (No. 5 and No. 8 from Table 2).

As a final conclusion, it can asserts that the cosimulation process between the software tools is, in the current days, a good option for saving time and money.

6. ACKNOWLEDGEMENTS

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