Experimental analysis and dynamic simulations of operation of photovoltaic cells installed on the "AGH Solar Plane" unmanned aerial vehicle (UAV)

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Abstract

AGH Solar Plane is a project aimed at constructing an aircraft powered by solar energy. This aircraft is an outstanding example of combination of modern technology advancements with renewable energy sources. One of the project's goals is to allow for continuous flight during the day and night without using any additional energy sources. Developing and introducing aircrafts powered by the renewable energy is important e.g. from the standpoint of environmental protection – aviation and maritime transportation means at use produce 3% of worlds anthropogenic greenhouse gases emission [1].

A prototype developed so far has been designed in a conventional system with center of mass in front of the construction as well as with steering tail arranged in a classical T-system. Steering surfaces of the wings consist of flaperons placed at each of their ends. They combine the functions of both flaps and ailerons in just one moving part. Such construction allows to maximize coverage of available surfaces with photovoltaic cells while reducing moving parts. The visualization of the aircraft's prototype is shown in Figure 1.

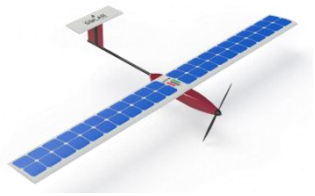


Fig. 1. The visualization of the aircraft's prototype.

This paper shows experimental analysis and dynamic simulations of the operation of photovoltaic cells installed on the unmanned aerial vehicle. The key focus was to develop dedicated PV modules characterized by high efficiency and low weight. The different types of PV cells have been tested using developed for this purpose experimental rig, equipped with light source, cooling base, light, and electrical output sensors. As a result, a current-voltage (I-V) and power-voltage (P-V) characteristics of tested cells were obtained and compared. Based on this comparison, Sunpower's flexible PV cells (characterized by the best power to mass ratio and power per area ratio) were selected. A number of cells that fit on the wing was estimated by dividing the available space by the area of a single cell, accounting for interconnectors. The cells were then divided into two panels (consisted of two segments due to construction restrictions) that matched the nominal system voltage. Finally, PV panels were attached to wing ribs and covered with a transparent modeling film.

Energy generated by the panels was used both directly to power engine and to charge on-board battery. To provide maximum efficiency of the panels under ever-changing conditions, maximum power point tracker (MPPT) was implemented. The system was especially designed to provide its reliability and efficiency [2,3].

The next step was to determine the estimated length of flight in different conditions (depending on the location, season, wind strength etc.). For this purpose, dynamic simulations in TRNSYS (Transient System Simulation Tool) software were conducted. The operation of photovoltaic panels was represented by the Type 94 (component, which uses a four parameter equivalent circuit model to determine the current and power of the PV array [4]). In the model, there were also included: regulator and inverter (Type 48), battery (Type 47), the load (Type 14 – schedule) and weather (Type 15 – Meteonorm database) [5].

Results of the currently conducted study show the high potential of using PV cells to power unmanned aircrafts. The experimental part of the study allowed to select the proper PV cells and the use of dynamic simulations allowed to prepare various flight scenarios, depending e.g. on the expected weather conditions.

Recent Publications

1. McCollum D., Gould G., Greene D., 2010. Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies, UC Davis: Institute of Transportation Studies (UCD)
2. Nordin N.D., Rahman H.A., A novel optimization method for designing stand alone photovoltaic system, Renewable Energy, 2016, 89, 706-715
3. Gibson T.L., Kelly A.N., Solar photovoltaic charging of lithium-ion batteries, Journal of Power Sources, 2010, 195, 3928-3932
4. De Soto W., Klein S.A., Beckman W.A., Improvement and validation of a model for photovoltaic array performance, Solar Energy, 2016, 80, 78-88
5. Kapuścik W., Maraszek J., Borowicz M., Sornek K., AGH Solar Boat – the analysis of energy and ecological parameters of the solar powered boat, IOP Conference Series: Earth and Environmental Science, 2018, 214, 1-9



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Jakub Wiszniewski is a student of the 4th year of Power Engineering on AGH UST. He has been an active member of various scientific circles from different departments since his first year of studies. In the third year, he co-founded and lead AGH Solar Plane project. In addition to being a general project leader, he has been a coordinator of electrical team. The team provides the best power generation and storage solutions for the plane and optimizes them.

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Notes/Comments