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On-Comet Power Production: the Case of Rosetta Lander Philae

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Abstract

In this note we discuss issues related to on-comet power production via solar cells. This is a challenging task as the low-intensity, low-temperature environment, together with possible dust deposition and ice condensation, worsen not only the production of power but also make difficult to predict it. To overcome these problems, we have developed solutions in terms of software and hardware tools for power estimation and simulation. These are briefly discussed in this note. Although these issues are reported for the case of Rosetta lander Philae, they apply for possible future missions aimed at performing in-situ operations on comets, asteroids, and distant planets.

1. Introduction

Rosetta is the third of ESA's cornerstone missions within the science programme Horizon 2000. The ambitious goal of this mission is the injection into an orbit around a comet and the delivery of a lander that will perform for the first time a detailed in-situ investigation of the comet nucleus. The prime scientific objective is to study the 67P/Churyumov-Gerasimenko comet to help understand the origin and the evolution of the Solar System. The comet will be reached in 2014 after several close encounters with minor and major bodies. After a phase of close comet investigation, a safe and scientifically important site will be selected for in-situ investigations. The lander delivery is foreseen to occur in November 2014 at a distance of about 3 AU from the Sun.

The Rosetta probe is made up by two spacecraft: an orbiter, Rosetta, with 11 observing instruments on-board, that will orbit the comet 67P/Churyumov-Gerasimenko, and a lander, Philae, with 10 observing instruments on-board, that will land on the comet to perform in-situ analysis. This large array of instruments will perform the most extensive study of a comet to date. Philae can be considered as an independent spacecraft, although it is the main payload of the Rosetta mission. Philae has a mass of 97.9 Kg including 26.7 Kg for scientific payload.

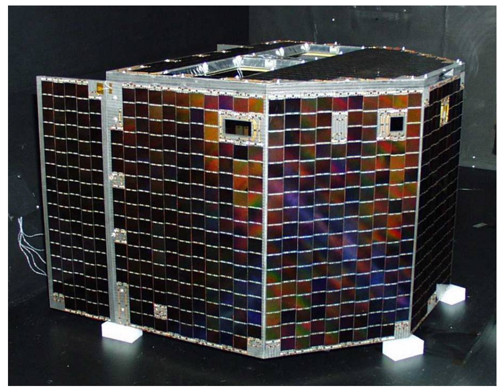

Figure 1: Philae's solar generator.

2. Philae Power Subsystem

The Philae power subsystem manages all the electrical power needed by the lander during its entire lifetime. The main source of power is represented by the primary and secondary batteries, with capacity of 1000 Wh and 130 Wh at comet arrival, respectively (1200 Wh and 150 Wh at launch, respectively). The latter is recharged by the power coming from the solar arrays.

Rosetta is the first deep-space mission that will go beyond the main asteroid belt relying only on solar cells for power generation. During the comet in-situ investigations, the solar generator, made up by 2 m^2 of useful surface, will produce about 8 W (Figure 1). To obtain these results, the solar generator was built using new Low-Intensity Low-Temperature (LILT) solar cells that are able to produce energy in the very tough environment in which Rosetta and Philae will survive and work. The solar generator is made up by six separate electrical section. In total, there are 1224 silicon solar cells with dimension 32.4 mm x 33.7 mm, 200 μm thick.

3. Main Activities

Politecnico di Milano is responsible for the activities of Philae's solar arrays. These are described in the remainder.

3.1 Solar Cells Characterization

It is known that under particular conditions of low insulation and low temperature, solar cells show uncontrollable adverse effects that produce large variations of performances on a statistical basis. This forbids an accurate prediction of power production which, on the other hand, has to be known with high precision to schedule on-comet operations. In order to acquire insights into the behavior of the solar cells at LILT conditions, and therefore derive accurate predictions, several tests at different solar constants and temperature have been performed on a set of sample solar cells of Philae. These cells have been characterized at low intensity, low temperature conditions in a not irradiated environment (0.1 Solar Constants, SC; temperatures ranging from -120 ℃ to +25 ℃). The set of solar cells analyzed is representative of the whole Philae's solar arrays, and the reproduced environment well fits Philae nominal working conditions. The current-voltage (I-V) curves of these cells have been investigated, and their temperature coefficients have been estimated. The models used for predicting the produced power have been updated thanks to the direct measurement of these coefficients, so allowing a more accurate representation of the total power that Philae will produce on the comet 67P/Churyumov-Gerasimenko.

3.2 Solar Array Performances

During its nominal lifetime, Philae will experience large variations of operating conditions, which strongly affects the performances of solar arrays. As an example, the Sun intensity will vary from 0.11 SC (at 3 AU) to 0.69 SC (at 1.2 AU) in case the extended mission will be confirmed. The characteristic temperatures will vary accordingly, and the accumulated radiation dose will increase as the comet approaches the perihelion. In order to correctly simulate the power produced by solar arrays in these conditions, a software simulator has been implemented. This simulator computes the I-V curves of each of the six electrical section once the sun aspect angles (azimuth and elevation), sun distance, solar array temperature, and fluence are specified (Figure 2). Two simulation modes have been implemented: static and dynamic. The former reproduces frozen I-V curves associated to a fixed set of parameters, the latter allows simulating the variation of I-V curves and therefore the produced power profile during one cometary day, which is needed to design operations.

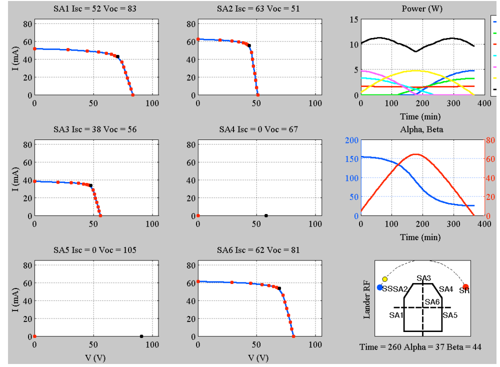

Figure 2: Philae solar array simulator.

3.3 Solar Array Simulator

Testing on-comet operations is not trivial from the power production point of view. In this case, the on-comet I-V curves profile produced by the solar generator has to be mimicked using on-ground equipments. It is known that solar cells currents scale with the cosine of the Sun incidence angles. Thus, the low solar intensity coupled with high values of Sun incidence angles produce very low currents (below 10 mA) that have to be simulated. This is not possible using existing off-the shelf equipments. Moreover, the supplied power has to be refreshed with proper frequency, and this refreshing must not couple with the tracking frequency of the maximum power point trackers (to avoid instabilities). In order to both produce low currents and stabilize the system, a dedicated solar array simulator has been designed and developed. This simulator is made up by two modules: a diode board and an analog regulator. The diode board reproduces the six I-V curves using the software simulator cited above. The analog regulator discretizes the curves and reproduces them as a sequence of line segments. The two systems are complementary and can be used independently.

4. Conclusions

In this short note we have addressed some issues arising when using a solar generator as the main power source to feed comet/asteroid landers. Possible problems are described together with the devised solution. The case of the Rosetta lander Philae is discussed, although the same matters apply in similar context.

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