Fuel cell power system options for Mars rovers

Executive Summary

Preparations for upcoming missions to the surface of Mars include the development of a wide range of different power systems designed to provide electrical energy to stationary, mobile, and portable mission elements. Finding suitable approaches in onboard power system design is a particularly challenging task with mobile applications, where the restrictions in solar array size have to be considered with the power system design procedure. The availability of innovative power system technologies provides scientists and engineers with the ability to consider and to investigate new approaches in power system design. One of the main goals of this research project was therefore to develop a software utility, which enables quick and flexible analysis of power system configurations with an eye on these innovative technologies. In addition, a special emphasis was put on providing a software platform for investigating the possibilities of operating different power system technologies in a hybrid power system. The Power System Simulation Tool (PSST) software version 1.0 was developed as technology demonstrator for a new approach in power system design.

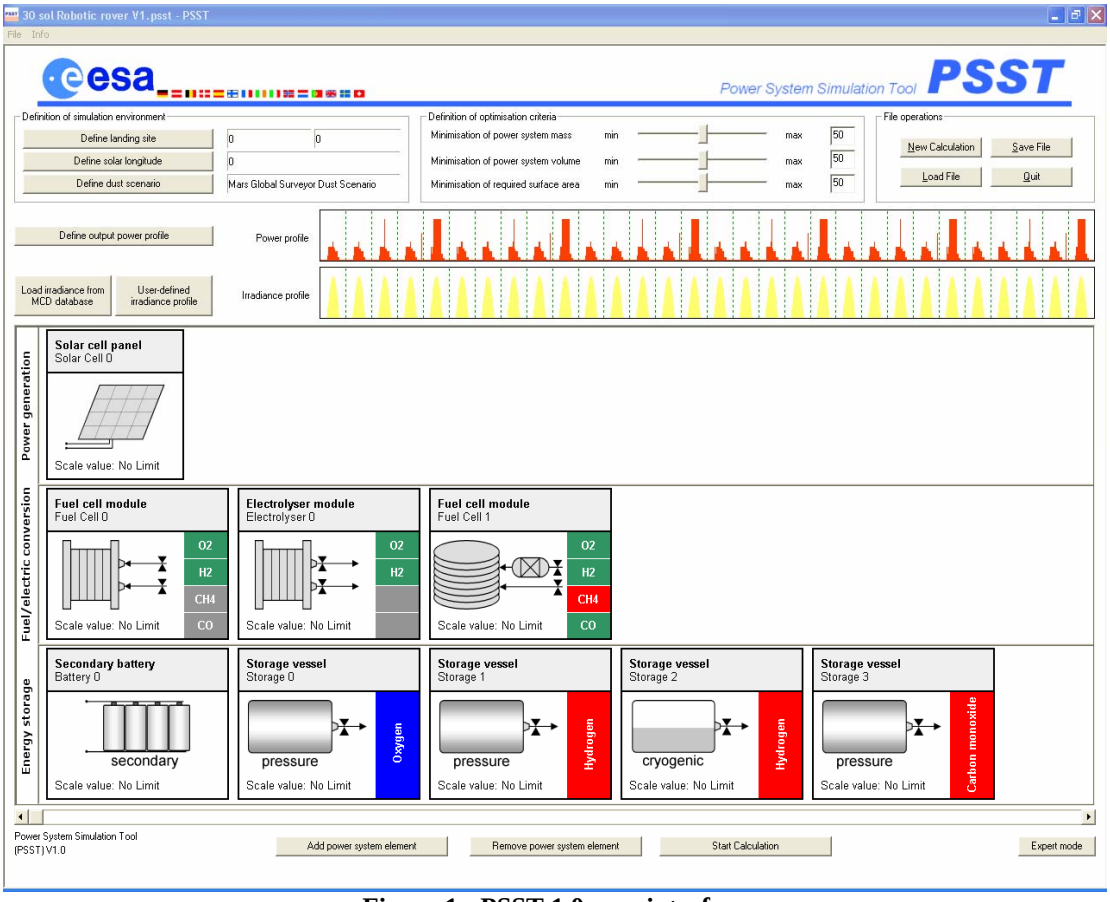

Figure 1 - PSST 1.0 user interface

The fundamental approach pursued with the development of this software is to combine established power system design procedures with an integrated configuration optimisation algorithm. Thus, the software can be utilised to scan through a pool of different power system elements that have been manually suggested for consideration by the user. Power system technologies that seem particularly promising with the investigated application are automatically identified by custom-developed software algorithms. Operation of individual elements in a hybrid power system configuration is implicitly considered with the power system configuration search procedure.

Evaluation of the different power system combinations and configurations is made with respect to a set of user-defined optimisation criteria. PSST V 1.0 has three optimisation criteria readily installed: minimisation of overall power system mass, minimisation of power system volume, and minimisation of power system surface. Additional optimisation criteria could be easily considered with advanced versions of the software. Linear combinations of the individual evaluation criteria scores are applied to produce the overall configuration score. This score indicates the investigated power system configuration performance. The calculated optimum power system configuration is subsequently presented in the post-processing phase along with a detailed analysis of governing power system properties and a full documentation of the search procedure. This enables a straight-forward analysis of calculation results, and can be subsequently utilised as starting point for a refined power system investigation e.g. with a parametric study.

PSST V1.0 is based on a straight-forward graphical user interface and can be operated as a regular Microsoft Windows application. A limited range of power system technologies is readily implemented with PSST V1.0: low- and high-temperature fuel cells, electrolysers, pressure storage vessels and cryogenic storage vessels for hydrogen, oxygen, methane, and carbon monoxide, primary and secondary batteries, and solar cells. The implemented model parameter structure enables a flexible assignment of power system element properties and performance. Additional power system elements could therefore be easily integrated into the framework of the PSST software. The surface of Mars is furthermore considered as only simulation environment with the current software version 1.0. A link to the Mars Climate Database can be utilised for providing the required environmental parameters.

A future utilisation of advanced versions of the software with applications in terrestrial power system design is envisaged. A set of power system technologies particularly relevant with terrestrial applications could thus be included, along with additional optimisation criteria, identifying e.g. the smallest power system installation costs and/or the smallest electrical energy production costs. The fundamental design concept demonstrated with the Mars-specific software tool could thus be translated into a software utility that is applicable with a wide range of applications in space as well as in terrestrial power system design.

Many power configurations can be implemented. Here below are two samples of simulations:

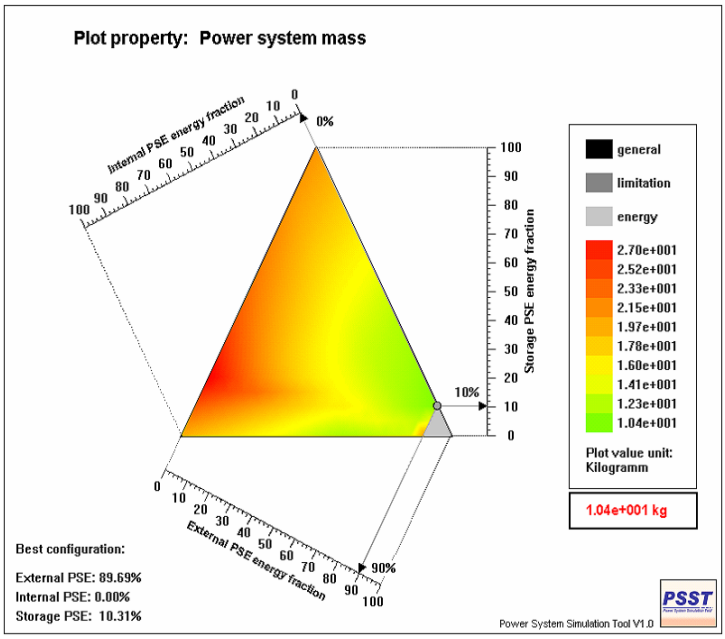

Figure 2 - Overall power system mass as a function of other system composition

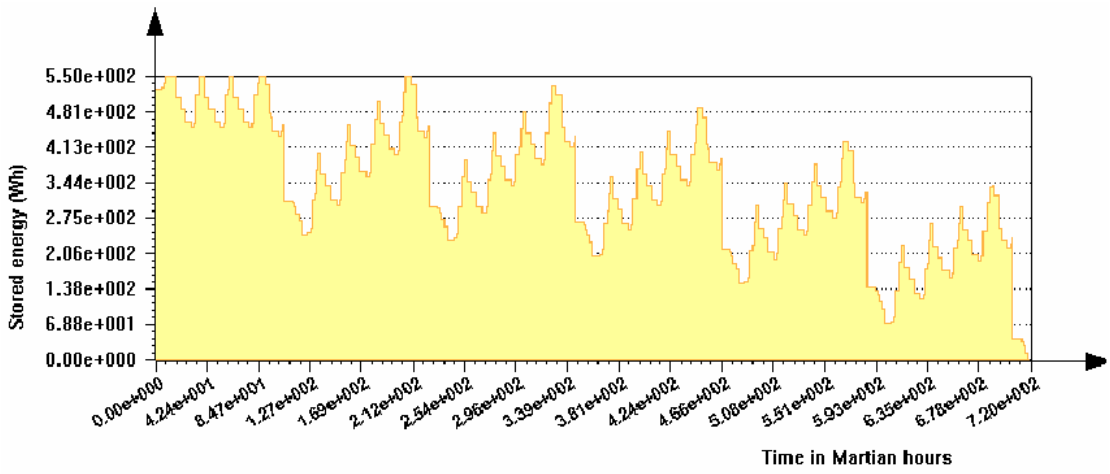

Figure 3 - Energy stored with the fuel/oxygen vessels of a fuel cell system