Space Microgrids: A Spin-in Concept for the next generation of Space Power Systems

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Introduction

This work advocates in favor of the application of terrestrial microgrid technology on the electrical power subsystem - EPS of future spacecrafts (S/C) and space bases. Space exploration in Near-Earth Objects, along with the growing power needs of large communication satellites intensify the need for **modular**, **reliable** & **cost-effective** EPS.

State-of-Art in EPS

EPS is a mission critical subsystems, not only because it is responsible for ~25% of all mission failures [1], but also because it comprises ~30% of the total dry mass [2].

Wiring approaches:
a) Centralised
b) Distributed

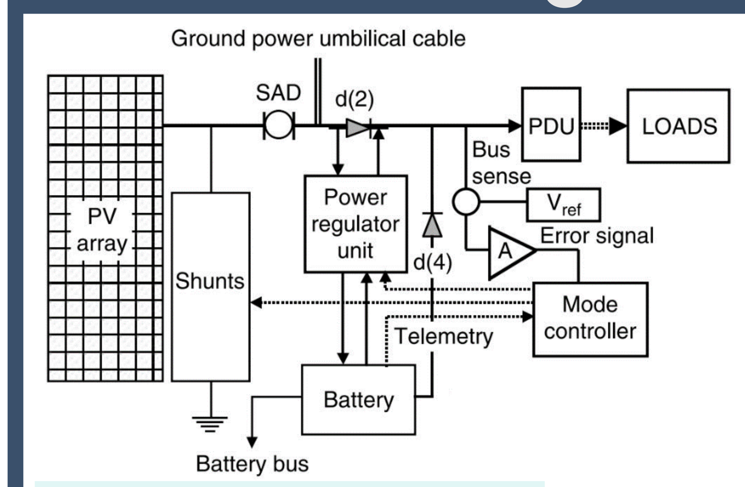
Bus approaches:
a) Unregulated
b) Regulated
c) Hybrids

Common architectures:
a) Direct Energy Transfer - DET
b) Power Point Tracking - PPT
c) Hybrids

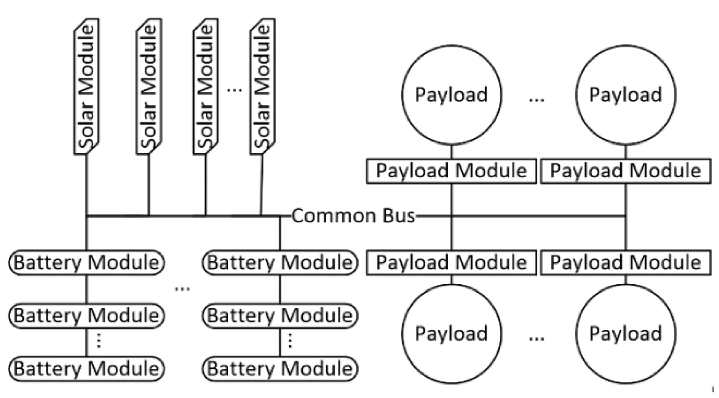
✓**Distributed approaches are more flexible**
✓**PPT is more energy efficient in larger S/C**
✓**Regulated buses are more reliable**

Several combinations of the above has been applied on a mission-by-mission basis. The majority of EPS follows radial schemes, with redundancies, a best practice being *n+1* [3]. Such approaches lead to **increased mass budget** and **pre-set fault tolerance** (max 2 points-of-failures). Also, up until now, power systems are not designed in a scalable manner. Though there are efforts to standardize in a modular way the EPS for CubeSat/ SmallSats, larger missions EPS are still fully customized.

The Challenges & The Vision



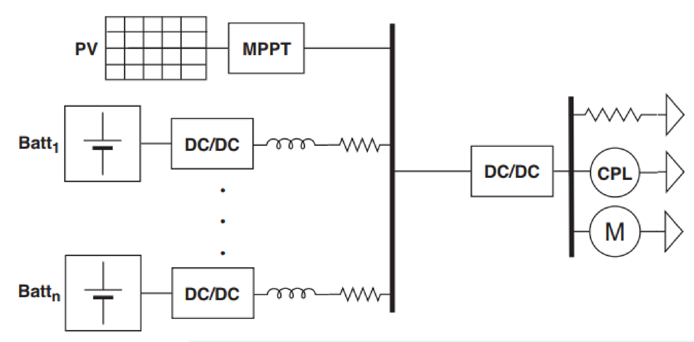
Centralized EPS [2]



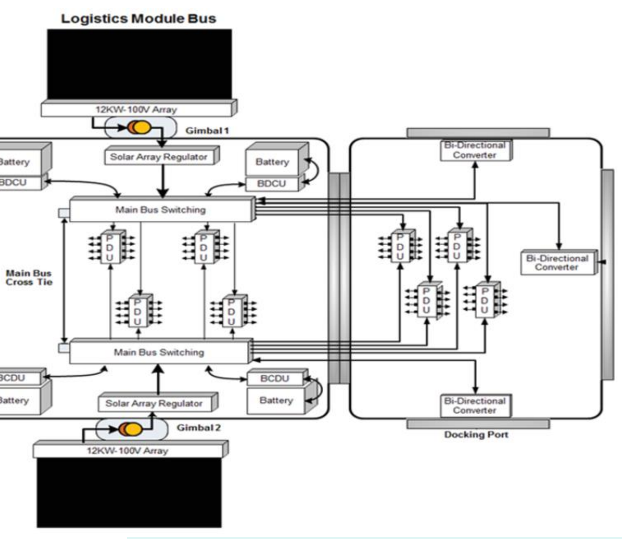
Modern Distributed EPS [6]

By nature, a distributed EPS is an isolated DC microgrid. This claim has been supported by microgrid-related and aerospace academia, and space agencies (e.g. [4],[5]). The same claim can be made for the centralized approaches as well, however, since these are increasingly becoming obsolete, there is little value in analyzing them. Taking also into consideration the global turn towards Electrical Propulsion, it is evident that unregulated (or sun-regulated) bus approaches are posing significant limitations to this trend. Thus, distributed, regulated, modular architectures are expected to prevail. However, these have challenges of their own, the most prominent of which are: a) increased component number and thus, higher complexity and more possible fault points and, b) larger in size and mass compared to simpler centralized DET architectures.

Due to the fast growth in smart grid/ microgrid related technologies that took place in the last two decades, there is great potential to foster proper synergies between the microgrid and the space sectors in order to benefit the development of the next-generation space power systems via the application of well-established terrestrial technologies.



Radial Space Microgrid [4]



Meshed Space Microgrid [7]

The "spin-in" concepts: transferring/ adjusting a technology developed for uses outside of the space sector to meet needs identified inside of it. There are successful spin-in paradigms in Robotics and Automation, Communications and others. However, regarding EPS such spin-in concepts taking advantage of the much prosperous field of microgrids are very scarce. Examples: [7][8].

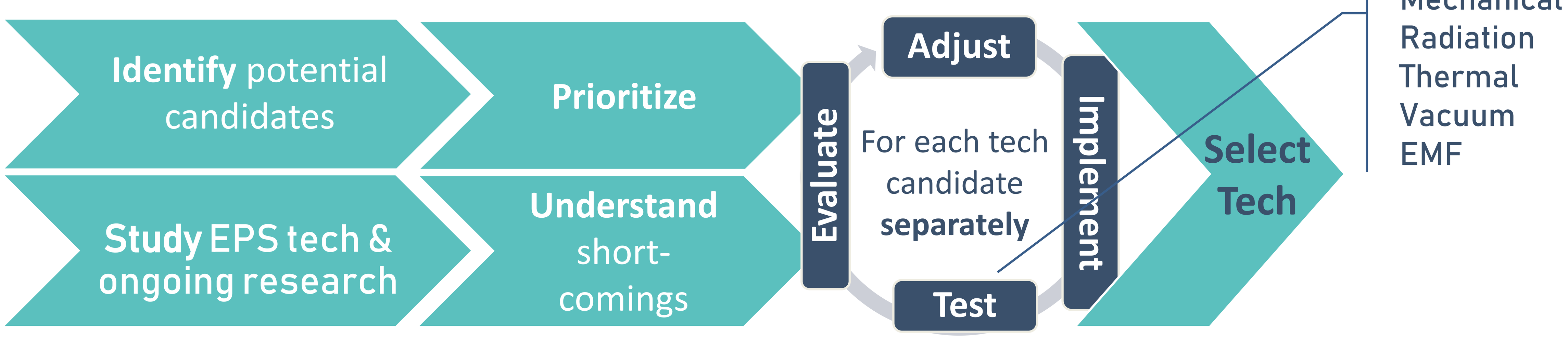
Terrestrial Solutions & Standardization

Microgrids to inspire from: Maritime/ offshore – Automotive – Aviation - Military bases

Objectives: minimize mass, increase reliability, improve power quality , promote modularity

Tech Candidates:
- Grid topologies
- Power/ Energy management Control
- Power Quality improvement
- Fault identification/ Protection schemes

Relevant Standards: ECSS-E-HB-10-02A , ECSS-E-ST-20-20C, ECSS-E-ST-20-08C, ECSS-E-ST-20C31, ECSS-E-10-03A IEEE2030 series, IEEE 1547, IEC 61850, IEC TS 62898-1:2017



Conclusions

In the near-future, space applications and exploration are going to challenge the existing EPS designs, that are currently characterized as big and bulky, fully customized, not expandable/ scalable and expensive. Not surprisingly, developments in EPS-related technologies have been outrun compared to the advancements in smart grid/ microgrids. By adopting well-established terrestrial technology, the design of future EPS has the potential to be transformed drastically and fast (compared to creating a solution from scratch).

Nonetheless, new approaches however need to satisfy the already-standardized reliability because of the criticality of the EPS, thus, concrete spinning-in procedures are necessary.

References

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Further information

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