SPACECRAFTS ELECTRICAL POWER SYSTEMS

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The article is focused on the field of the space vehicle electrical power systems and their electrical power sources. There are described the basic elements of a spacecraft electrical power system and classification of the primary energy sources.

K e y w o r d s: electrical power source, spacecraft, power system,

1 INTRODUCTION

All spacecrafts require sources of electrical power, e.g. for an operation of on-board systems (communication equipment, instrumentation, environment controls, etc.) Satellites and space probes have relatively low electrical power requirements – a few watts. More sophisticated space missions will lead to larger power needs. An important consideration is a voltage required and the peak demand of electrical power. The voltage demand may be low for motors, but high for electronic applications. Furthermore, an alternating current may be required or may be interchangeable with a direct current.

Electrical power sources for satellites and space vehicles must be small, light, rugged, reliable for a long operational life under the severe environment conditions of outer space. The environment generated by the operation of the power source must also be compatible with the operation of instrumentation carried by a space vehicle.

2 ELECTRICAL POWER SYSTEM

The prime power source provide the energy for a conversion into the electricity. The basic elements of spacecraft power systems are (Figure 1):
- primary energy source
- energy conversion
- power control /regulator
- rechargeable energy storage
- power management /distribution / protection
- loads – power utilization by equipment

The primary energy source includes:
- solar radiation
- radioisotopes
- nuclear reactors
- electrochemical / chemical fuel

The energy conversion can be:
- photovoltaic
- thermoelectric
- dynamic alternator
- fuel cell
- thermionic

The energy storage is primarilly electrochemical, but although a flywheel technology.

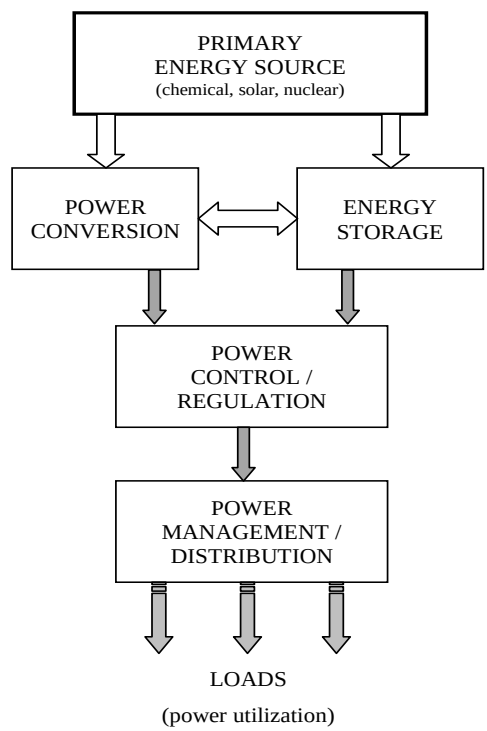

Figure 1 Basic elements of a spacecraft electrical power system

Many factors influence the configuration of a power system. The basic criteria for the electrical power system are:
- low mass / low life-cost (primary criteria)
- continuous and reliable source of peak and average electrical power
- control, regulate, distribute and condition the power provided to the various loads
- protect inself and loads from electrical faults

Very important factor for selection of the prime power source is a duration of the mission:

Mission duration	Energy source	Power level (watts)
days / weeks	Primary battery	10^0 - 10^3
	Fuel cells	10^0 – 10^5
	Chemical dynamic (reactor)	$\geq 10^5$
mounts / years	RTG (Radioisotope thermonuclear generators)	10^0 – 10^2
	Solar array Solar PV battery Solar concentrator – dynamic Solar concentrator – PV battery	10^3 – 10^5
	Nuclear reactor-dynamic	$\geq 10^5$

Chemical batteries, solar energy converters, and nuclear energy devices appear as the most suitable energy systems. Fuel cells have been limited primarily to use in the crewed space program. Radioisotope thermoelectric generators have powered, or augmented solar power on, many planetary missions and probes, and augmented the solar-array battery power system on at least one Earth-orbiting spacecraft.

Solar energy converters with or without storage devices, which also have already practically demonstrated their capabilities in several satellites, will offer a high power for the operation over at least several years.

Nuclear devices under development promise characteristics which may ultimately surpass the capabilities of solar energy converters although sometimes both systems may stay in a close competition.

3 ELECTRICAL POWER SOURCES

A primary battery can economically power a small spacesraft requiring only several watts over several days. It has nonreversible electrochemistry.

The comparison of some types battery performances:

Type	NiCd	NiH2	Li-Ion
Energy/kg (Wh/kg)	30-40	55-65	100-130
Energy/l (Wh/l)	110	80	200-250
Discharge voltage mean (V)	1,25	1,25	3,5
Working temperature (°C)	-5;+15	0;+10	+15;+25
Energy efficiency	75	75	90
Max. voltage (V)	1.55	1.6	4.0
Capacity (Ah)	4 - 50	30 - 350	1,5 - 40
Life duration in Geo	7 years at 50 %	15 years at 80%	15 years at 80%
Life duration in Leo	10 years at 15 %	5 years at 40 %	7 years at 30 %

The fuel cell is a static electrochemical device that generate direct current electricity by the chemical reaction without altering electrodes or electrolyte materials. It was developed as an intermediate-term power source for space applications.

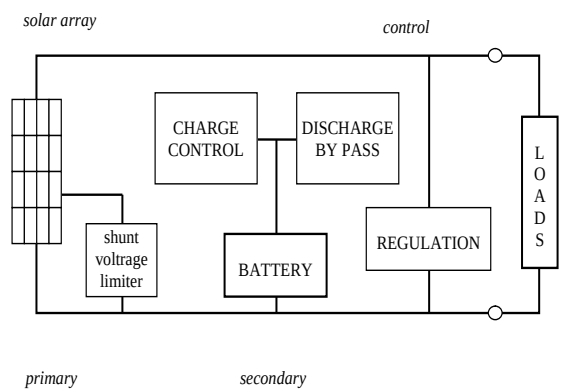

Figure 2 Structure of typical satellites power system

The most widely used primary source of power in Earth orbiting satellites is the photovoltaic cells (PV), convert the solar energy into the electrical energy (Figure 2). Satellites requiring a continuous load power even during an eclipse must use a rechargeable battery. It is charged during sunlight and discharged to power the load during eclipse.

Solar energy is used in systems other than PV-cells. In the solar concentrator-dynamic power system a sun energy is collected from a heat of a concentrator. The heat is used to generate a steam and to drive a rotating turbo-generator (or an alternator). The system structure is shown in Figure 3.

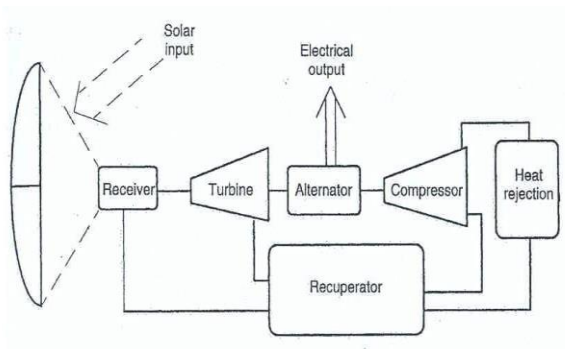

Figure 3 Structure of the typical spacecraft solar dynamic system

The nuclear power - radioisotope thermonuclear generators are using the heat generated from a natural decay of nuclear fuels (plutonium, strontium, curium, uranium) and directly converts this heat to the electrical energy using a thermoelectric couple device.

The electrical architectures of spacecrafts is not standard. They differ in an unregulated or a regulated power bus, voltage values (28 V, 50 V, 70 V, 100 V, 120 V, 160 V …), a conditioning, a protection system (reliablity) and a distribution system (fuse, LCL …). Present-generation spacecraft power systems from 10 of watts to several kilowatts. For example, each of the three fuel cells on the space shuttle delivers 12 kW continuous power and 16 kW peak power. The International Space Station's solar arrays will generate 110 kW total power, with approximately 46 kW available for research activities. The secondary power distribution can be 3-phase 208 V, 400 Hz, or preferred 20-lHz system.

4 CONCLUSION

The development of a space vehicle has confirmed that at every stage of their improvement they belong to the means of the highest technical level together with a space technology, the broadest application of the latest scientific and technical knowledge and the most advanced technologies. The majority of board space technologies has been gradually and successfully used on aircraft boards and spread in ground facilities and equipment. For the purposes of teaching in the aviation field, it is important to constantly monitor and analyze this development.

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