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DFH-2A SATELLITE PRIMARY ELECTRICAL POWER SUBSYSTEM

Chen Xiaoni

ABSTRACT

This paper introduces the basic configuration of the DFH-2A primary electrical power subsystem and the basic properties of this subsystem and its components.

KEY TERMS Electrical power source Solar cell Storage battery Current divider China

I. OUTLINE

The East Is Red No.2A (DFH-2A, simply called East 2A) is an improved model of China's first generation of practical communications satellites DFH-2. There have already been 4 satellites launched in this series up to the present time. Besides the 4th satellite, which did not go into predetermined orbit, the previous 3 satellites have already respectively operated in geosynchronous orbits for 4 years, 2.5 years, and 2 years.

The primary electrical power systems associated with DFH-2A series satellites are all solar cell array/storage battery sets connected to single trunk line power supply systems. Solar cell arrays are integral type square matrices. Energy storage systems are Cd-Ni storage battery sets. Solar cell arrays take responsibility for supplying electricity to satellite loads during periods of optical irradiation while operating in orbit. At the same time, they charge storage battery sets. Moreover, Cd-Ni storage battery sets are responsible for supplying satellite electric power during periods of earth shadow. As far as changeovers associated with solar cell arrays and storage battery sets, satellite anti power cut off measures, and storage battery set charging controls are concerned--after passing through earth's shadow--solar cell array charging is controlled and power regulated. In all cases, this is completed by electric power control equipment.

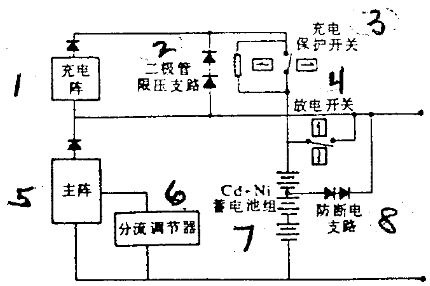

Fig.1 Primary Electrical Power Subsystem Schematic

Key: (1) Charging Array (2) Diode Voltage Limiter Branch Circuit (3) Charging Safety Switch (4) Discharge Switch (5) Main Array (6) Shunt Regulator (7) Cd-Ni Storage Battery Set (8) Anti Power Cut Off Branch Circuit

II. BASIC CONFIGURATION AND KEY PROPERTIES OF PRIMARY ELECTRIC POWER SUBSYSTEM

DFH-2A primary electrical power subsystems are principally composed of solar cell arrays, storage battery sets, power source control equipment and trunk lines. The schematic is seen in Fig.1. The trunk line voltage range is 24.5~ 40.0 volts. The lower limit voltage is designed for when the satellite enters shadow. The upper limit voltage is designed for before charging stops in sections out of shadow. The design life of the subsystem in question is 4.5 years. With regard to satellites during periods of orbital operation, a charging power of 33 watts is necessary to supply the normal 240 watt value of load power for them. Satellite load power is distributed as shown in Fig.2. A Fig. shows peak power consumption and normal power consumption values for various classical satellite flight configurations.

1. Solar Cell Arrays

Due to the fact that DFH-2A satellites are spin stabilized, as a result, solar cell arrays opt for the use of housing installation forms. Solar cell arrays are constructed from two pieces of cylindrically shaped solar cell plate with a diameter of 2.1 meters and a height of 0.72 meters. The area where adhesion is possible is 9.5 square meters. All together, 20592 sheets of solar cell are glued on. Among these, the main array is 19800 sheets. The charging control array is 792 sheets. Solar cell single sheet dimensions are 20mm square. Thickness is 0.3mm. The coefficient used for the solar cell housing area is 86.7%. Solar array initial maximum output powers can reach 365 watts. Area specific powers are 38.4 watts for each square meter.

Solar cell arrays are divided into main arrays and charging control arrays (simply called charging arrays). Each year, divided between spring and autumn, there are around 92 days of earth shadow season. Main arrays supply satellite load power and, in conjunction with that, charge storage batteries. The number of parallel connected sheets associated with charging arrays is used to limit charging currents. Charging array and main array series connection raises voltages to satisfy storage battery set charging terminal voltage requirements. Around the winter and summer solstices respectively there are approximately 136 days of full solar irradiation areas. Main arrays, besides supplying power, are only required to give to storage battery sets small charging power currents (approximately 3 watts).

Entire solar cell arrays can be divided into a total of 12 fan surfaces. Each fan surface is set up to have a main array circuit and a charging control circuit. No matter whether it is a main array or charging control circuit, the number of parallel connected and series connected sheets is the same in all cases in order to guarantee the uniformity of output power when satellites spin.

Due to the fact that solar cell output powers during initial periods of life have rather large margins, after completing charging, they can reach as large as 35%. Because of this, how to consume the extra power and avoid producing excess voltage and current phenomena which are dangerous to the whole satellite is one of the key problems associated with power source system design. To this end, satellite power source subsystems have installed in them diode voltage limiting branch circuits (as shown in Fig.1), taking trunk line positive terminals and connecting them to storage battery sets. In sections when satellites are out of shadow, a 4 minute delay time is completed. After discharge switches are open, diode voltage limit branch circuits and storage battery sets take main array voltages and clip the potential. Storage battery sets take excess solar cell main array power and shunt it off. The diode voltage limit branch circuit passes large currents to storage battery sets to charge them. Diode limit voltage branch circuits exert control through charging control switches. When storage batteries are adequately charged and charging control switches are opened, diode branch circuits naturally are cut off from trunk lines.

After charging is completed, diode branch circuits and trunk lines are cut off. If solar cell array output voltages are still on the high side, through trunk line sampling, circuit output error signals control shunt regulator operations, taking main array excess power and short circuiting it to ground and guaranteeing trunk line voltages not higher than 40 volts. In solar radiation areas associated with solar cell array constant surface operating temperatures, main array operating points--on the basis of load power magnitudes and differences in output powers--shift on volt-amp characteristic curves. They are automatically adjusted, and excess power from solar cell arrays themselves is converted to become amounts of heat which are dissipated away, causing solar cell array tempeatures to rise approximately 1°C.

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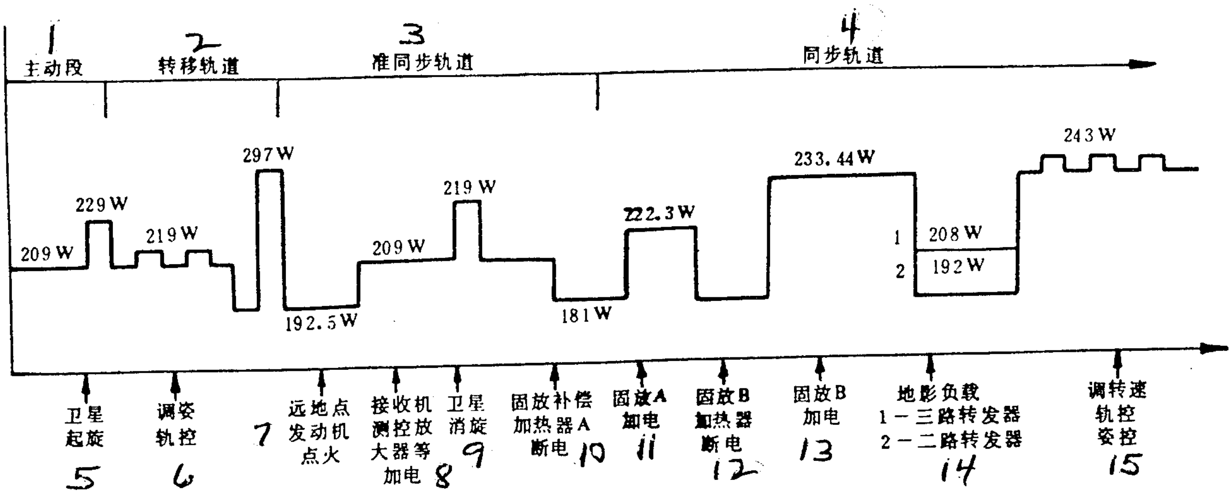

Fig.2 DFH-2A Satellite Power Distribution Chart

Key: (1) Drive Phase (2) Shifting Orbit (3) Semisynchronous Orbit (4) Synchronous Orbit (5) Satellite Starts Turning (6) Attitude Adjustment and Orbit Control (7) Apogee Engine Ignition (8) Powering Up of Receivers, Measurement and Control Amplifiers, And So On (9) Satellite Stops Turning (10) Solid Compensation Heater A Powered Down (11) Solid A Powered Up (12) Solid B Heater Powered Down (13) Solid B Powered Up (14) Earth Shadow Loads 1- Three Circuit Transmitter 2- Two Circuit Transmitter (15) Adjustment of Rotation Speed Orbit Control Attitude Control

The highs and lows of solar cell array operating temperatures have very great influences on output power. Solar cells used by DFH-2A series satellites possess aluminum backed reflector structures. Physical properties are good. Because of this, sunlight absorption coefficients are lowered. Surface test measurement data clearly show that solar absorption coefficient α is approximately 0.73 ± 0.02. Radiation coefficient ε is 0.83 ± 0.02. The ratio α/ε is far smaller than 1. As a result, orbital temperature properties are good--ten to twenty degrees lower than solar cell surface temperatures associated with International Communications Satellite 6, thus increasing solar cell array output powers.

2. Storage Battery Sets

DFH-2A satellites use Cd-Ni storage battery sets to act as energy storage systems. During periods of earth shadow, they supply electric power to satellites.

Cd-Ni storage battery set rated capacities are 15 Amp-hours. Within the period of a 4 year life, even if it is at the end of a maximum earth shadow of 72 minutes, it is still capable of providing 196 watts (26 cells) or 213 watts (28 cells connected in series) of power. Cd-Ni storage battery sets are 26-28 cell sections connected in series divided into 3 sets of combined parts and mounted. Each module of combined parts adopts a frame mounted form in order to save on structural weight. Cd-Ni storage battery set structural weight accounts for approximately 18% of the total cell set weight.

Cd-Ni storage battery set heat design adopts a passive type of temperature control. Due to opting for the use of a frame structure, heat conduction properties are, therefore, good. At the same time, specially designed heat conduction channels make amounts of heat within cells able to be transmitted to the edges of modules. In the middle, there are also 4-5 cell sections sprayed with a layer of white paint, reflecting heat and causing maximum cell temperature differential to be controlled within 2~3°C. The cell set design operating temperature range is −5~25°C.

Protection Against Single Cell Short Circuit and Loss of Efficiency: In order to prevent individual single cell short circuits and loss of efficiency from giving rise to loss of efficiency malfunctions through the whole cell set, a satellite power shut down is made during periods of earth shadow. As a result, each single cell is cross connected to a diode side circuit network, carrying out charging and discharging protection.

Storage Battery Set Charging and Discharging Control: Storage battery set charging and discharging control uniformly opts for the use of designs with automatic controls as primary and remote control as supplementary. Automatic charging control signals are supplied by the third electrode installed inside single cells. Altogether, there are two sections of single cells equipped with third electrodes. When storage batteries begin to overcharge, cell interiors produce hydrogen gas. After third electrodes absorb hydrogen gas, an electrical potential is produced, that is, the third electrode voltage. It is outputed to the power source control device which acts as "information" associated with adequately charged cells, propelling circuit operation. Automatic discharge control information is trunk line voltage. When trunk line voltage reaches 24.5 ± 0.2 volts, the discharge switch is connected.

3. Electrical Power Source Control Equipment

Electrical power source control equipment includes electrical power source control devices and shunt regulators. The primary function is to carry out control of storage battery set charging and discharging and to implement regulation of trunk line voltage in sections out of shadow. /11

(1) Electric Power Source Control Devices Electric power source control devices have primarily the following several types of functions.

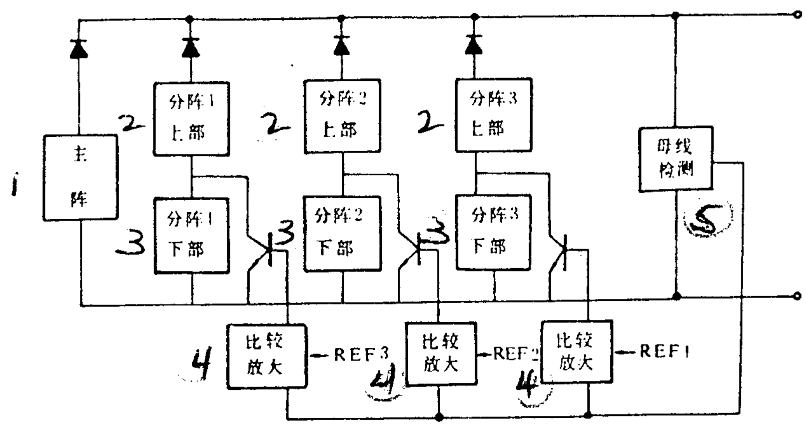

Fig.3 Shunt Regulator Schematic

Key: (1) Main Array (2) Subarray Upper Section (3) Subarray Lower Section (4) Relative Amplification (5) Trunk Line Control Measurements

Charging Control: Charging safety switches in solar cell charging control arrays and electrical power source control devices are used to control the charging of storage battery sets. The function of storage control arrays is to limit charging current. When charging safety switches are closed, a C/15 charging system is used to charge storage batteries (with the exception of times when storage battery set shunts are used in sections out of shadow). After storage battery sets are adequately charged, it is necessary to implement charging safety controls, that is, opening charging safety switches, changing over to small current charging. At this time, storage battery sets give out third electrode signals, opening relays. When satellites enter earth shadows, charging safety switches and discharge switches operate together, automatically closing, in order to complete preparations for charging when leaving the shadow.

Discharging Control: In order to lower storage battery set discharging depths, electrical power source control devices install discharge control switches. When satellites enter periods of earth shadow, trunk line voltages drop to 24.5 volts. Discharge switches automatically close. Storage batteries supply electric energy to trunk lines through discharge switches. After satellites leave shadows, it is necessary to open discharge switches. Otherwise, solar cell main arrays and storage battery sets are placed in a connected power supply configuration. Storage battery sets are not able to charge adequately. Discharge switch opening control signals come from two sheets of silicon photocell which are back ups for each other attached to solar cell plates. Going through large doses of irradiation, constant photoelectric signals are put out. After going through a 4 minute delay time, any optical signal is capable of controlling discharge switch opening.

Electrical power source control devices are also installed to cut out third electrode control circuits. Their function is--when third electrode control signals are not normal and lead to storage battery sets charging inadequately or overcharging--to cut out third electrodes and change to automatically controlled charging safeguards to act as remote control charging protection.

The function of 4 minute delay circuits is to take photoelectric signals which have already arrived and short them to ground. Only after 4 minutes, is it then possible for newly arrived photoelectric signals to initiate control of discharge switches. The purpose is to guarantee that, after satellites leave shadows, main array output powers become able to support loads and only then are discharge switches opened.

(2) Shunt Regulators

Shunt regulators adopt localized linear sequence shunt forms. Their characteristics are high efficiency, light weight, small power consumption, good voltage limiting characteristics, good electromagnetic compatibility, and their initial use was in domestic satellites.

Shunt regulators have installed three shunt sections. Three subarray connections to solar cell main arrays possess tap points. When trunk line voltage sampling circuits installed in electrical power source control devices sense trunk line voltages higher than established values, they go through comparative amplification and produce error signals, causing shunt section high power components to conduct, taking subarray power corresponding to the shunt sections in question and shorting it to ground.

Each subarray short circuit current is approximately 2.1 amps. Moreover, each shunt section shunting capability can reach 2.4 amps, possessing a certain redundancy. If the three shunt sections are all shunting, they are capable of shunting off approximately 40% of main array power thereby playing a regulating role with regard to main array output power.

III. CONCLUDING REMARKS

DFH-2A satellite primary electrical power source subsystems have already undergone 4 years of orbital flight testing. This clearly verifies that subsystem properties are good and operating stability is reliable. There are a number of advanced technologies such as storage battery industrial techniques, solar cell industrial techniques, charging and discharging control principles, shunt regulator partial linear shunt principles, and so on, which will all obtain applications in a new generation of communication satellite electrical power source subsystems.

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