Power Components for the Space Station
20-kHz Power Distribution System

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ABSTRACT
Since 1984, NASA Lewis Research Center has been developing high power, high
frequency space power components as part of The Space Station Advanced Develop-
ment program. The purpose of The Advanced Development program was to accelerate
existing component programs to ensure their availability for use on the Space Sta-
tion. These components include a rotary power transfer device, remote power
controllers, remote bus isolators, high power semiconductor, a high power semi-
conductor package, high frequency-high power cable, high frequency-high power
connectors, and high frequency-high power transformers. All the components
have been developed to the prototype level and will be installed in the NASA Lewis Space Station power
system test bed.

INTRODUCTION
In the late sixties and early seventies it became
apparent that the power requirements of future space-
craft would rise from the present kilowatt level to
the hundreds of kilowatt level by the year 2000. The
initial space station which is planned for the middle
nineties has a projected power level of 75 kW
with a
growth potential of 300 kW. A low voltage
dc distribution system will not be
suitable due to the large conductor weight required to
carry the currents. An obvious solution to reducing
conductor weight is to raise the operating voltage.
Another way to reduce weight is to use a high fre-
quence ac system which decreases both weight and size
of magnetic devices such as transformers.
At the beginning of the Space Station Program,
NASA performed an extensive power system trade study
comparing 150 V dc, 440 V-400 Hz, and 440 V-20 kHz.
The conclusion of this trade study was that the
440 V-20 kHz power system was the most efficient,
lightest, and lowest in-cost. The study also showed
that the 440 V-20 kHz power system had no technical
show stoppers but that the 20 kHz component technology
was not as fully developed as that of the other power
systems.

NASA Lewis has been developing power components
for some time that take advantage of both high volt-
age and high frequency (1). The Space Station
Advanced Development program augmented these existing
programs and started new ones on an accelerated sched-
ule to ensure that the components would be available
for use in the Space Station Power System. The objec-
tive of this paper is to summarize the Space Station
Advanced Development Program for space power compo-
nents and provide a comprehensive report.

ROTARY POWER TRANSFER DEVICE
In the early eighties, Sperry Flight Systems deve-
loped for NASA Lewis a multihundred kilowatt Roll Ring
assembly (2). The Roll Ring is a device that trans-
fers electrical power across a rotating joint through
rotating flexures compressed between concentric con-
ductors (Fig. 1). The advantages of the Roll Ring
over the slip ring are the elimination of sliding
friction and the low torque needed to rotate the
device. The Roll Ring can transfer both ac and dc
power and has a measured efficiency of 0.9998 (3).
There are eight circuits in the assembly (Fig. 2)
each capable of conducting 200 A at 500 V dc. This
Roll Ring assembly won a 1985 IR-100 award for one of
the best new products of that year.
A second Roll Ring assembly was built for NASA
Lewis with four circuits (the first assembly had eight
circuits) (Fig. 3). The Space Station Advanced Devel-
opment program redesigned the 4-circuit Roll Ring
assembly after evaluation testing (3) to decrease the
outgassing time of the assembly and to eliminate pos-
sible corona problems. Presently, the Roll Ring is
baselined as the Space Station alpha-joint power
transfer device. The four circuit Roll Ring assembly is
still under going 440 V-20 KHz vacuum testing at
NASA Lewis (Fig. 4). The Roll Ring assembly is corona
checked every few months during the vacuum life test.
Both assemblies have accumulated in excess of 60
Space Station years of rolling time (8-circuit Roll
Ring assembly - 64 years, 4-circuit Roll Ring assembly
- 114 year) at 100 A or greater (3). Thus far the
Roll Ring assemblies have met or exceeded all specifi-
cations of the original contract.
HIGH POWER SEMICONDUCTOR

General Electric Company is presently under contract with NASA Lewis to produce a high voltage MCT (Metal Oxide Semiconductor Thyristor) (4). The MCT under development for NASA Lewis is a 1200 V, 40 A device with a switching time of one microsecond and forward drop of 1 V.

The MCT also requires low gate drive power for turn-off. Figure 5 shows the transistor equivalent, thyristor, and MCT representative schematics (5). The MCT is planned to be used on the Space Station in remote power controllers, main inverters, frequency changers, charge/discharge converters, and motor controllers. The MCT with a 1000 V to 40 A rating will be commercially available in the fall of 1988.

HIGH POWER SEMICONDUCTOR PACKAGE

Power Technology Components developed a high power semiconductor package for NASA Lewis (6). This package has low inductance due to the lead configuration and electrically isolates the power chip from the case. The package is hermetically sealed and has an internal coating of parylene (Union Carbide Corp. Trademark) which provides voltage breakdown protection in case the hermetic seal fails (Figs. 6 and 7).

The MCT chip will be mounted in this package and then tested in the various Space Station test bed circuits. Power Technology Components has a commercial version without the parylene coating marketed as their "power mode" series.

REMOTE POWER CONTROLLERS AND REMOTE BUS ISOLATORS

Leach Corporation is developing for NASA Lewis a family of 208 V rms - 20 kHz remote power controllers (RPC’s) (5, 10, 25 A) and a family of 440 V rms - 20 kHz remote bus isolators (RBI’s) (25, 50, 100 A) (7). The RPC’s are current limiting switches that isolate the power distribution system from load faults (8). If a load fault, the RPC switches in a current limiting reactance within 2 μs, limits the fault to 300 percent of the RPC rating and removes the load at the end of this first half cycle of operation (25 μsec). The RPC’s will accept on and off commands and current trip point commands. The RPC will supply to the data system the status (on or off), load current, load voltage, sign of the volt-ampere product and the last current reading before tripping. This last current reading plus the volt-ampere product will allow for system failure analysis. Figure 10 shows a 100-A RBI without a control card.

POWER CABLE AND CONNECTORS

In 1980, Induction General, Inc. developed for NASA a high power, low inductance, 20 kHz cable (9). The main reason for the low inductance was to reduce the external magnetic field of the cable, it also improved the cable voltage drop and minimized the cross talk between the loads. The cable was constructed as a double sided strip line using strips made of Litz wire (Fig. 11). The Litz wire cable was designed to deliver 25 kW with a 2 percent real loss over 50 m. The Induction General cable parameters were: resistance: 0.83 mQ/m, inductance: 0.035 micro-H/m, capacitance: 0.00137 micro-F/m, and weight: 1 kg/m.

The Induction General cable was developed to demonstrate that a low inductance cable was possible. The Litz wire cable showed some problems, such as: very long outgassing times due to gasses trapped in the Litz wire, high cable configuration constant during the manufacturing process (caused field inductance to increase), not very flexible and fairly heavy. A second generation cable is being made for NASA Lewis by W.L. Gore and Associates, Inc. (10). This cable design uses solid flat foil conductors instead of the Litz wire braid. The foil conductors also were covered with a solid dielectric coating and outgassing will be achieved by using a gas permeable dielectric for a filler and outer jacket material. This cable will have approximately the same electrical parameters as the Litz cable, better uniformity during the manufacturing process, but will weigh less and have greater flexibility (Fig. 11).

G&H Technology, Inc. is developing for NASA a 440 V - 20 kHz - 30 kVA connector for terminating the 20 kHz flat foil cable being developed by GORE (11). The connector being designed for NASA Lewis has a voltage drop of 0.375 V at rated current (68 A) and will weigh approximately 1 lb. It is also being designed for handling with space suit type gloves (Fig. 12).

TRANSFORMERS

TRW is developing for NASA Lewis a 440/220, 20 kHz, 25 kVA transformer (12). The wiring schematic of this transformer is shown in Fig. 13. The measured leakage inductance is 1.6 micro-H, which exceeds the specification limit of 3.0 micro-H. The measured efficiency of 99.36 percent exceeds the design goal of 98 percent and the unit weighs approximately 10 lbs, unpotted (Fig. 14). Figure 14 shows the unpotted transformer along with one seven turn secondary. This transformer will be installed in the NASA Lewis Space Station power system test bed for evaluation and system tests.

REFERENCES


FIGURE 1. - SINGLE ROLL RING CIRCUIT.
FIGURE 2. - CROSS SECTION OF THE 8-CIRCUIT ROLL RING EVALUATION UNIT.

FIGURE 3. - FOUR CIRCUIT ROLL RING ASSEMBLY.

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FIGURE 4. - FOUR CIRCUIT ROLL RING ASSEMBLY IN VACUUM TEST

FIGURE 5. - REPRESENTATIVE SEMICONDUCTOR SCHEMATICS.
FIGURE 6. - POWER SEMICONDUCTOR PACKAGE

FIGURE 7. - HERMETIC, HIGH POWER SEMICONDUCTOR PACKAGE.

FIGURE 8. - FET POWER HYBRID (8 AMP) MODULE.

FIGURE 9. - 25 AMP REMOTE POWER CONTROLLER.
FIGURE 10. - 100 AMP REMOTE BUS ISOLATOR (NO CONTROL CARD).

FIGURE 11. - TWO 20 KHz CABLE CONFIGURATIONS.

FIGURE 12. - 20 KHz BUS CONNECTOR.
FIGURE 13. - 440/220, 25 KVA TRANSFORMER SCHEMATIC.

FIGURE 14. - 25 KVA-20 KILOHURTZ TRANSFORMER.
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