High-Temperature Superconductive Cabling Investigated for Space Solar Power Satellites

NASA has been directed by Congress to take a fresh look at the Space Solar Power (SSP) concept that was studied by the Department of Energy and NASA about 20 years ago. To summarize, the concept involves (1) collecting solar energy and converting it to electrical energy via photovoltaic arrays on satellites in Earth orbit, (2) conducting the electricity to the microwave transmitting portion of the satellite, and (3) transmitting the power via microwave transmitters (or possibly via lasers) to ground power station antennas located on the surface of the Earth. One Sun Tower SSP satellite concept is illustrated here. This figure shows many photovoltaic arrays attached to a "backbone" that conducts electricity down to a wireless transmitter, which is pointed toward the Earth. Other variations on this concept use multiple backbones to reduce the overall length of the satellite structure. In addition, non-Sun-Tower concepts are being considered.

The objective of the work reported here was to determine the benefits to the SSP concept of using high-temperature superconductors (HTS) to conduct the electricity from the photovoltaic arrays to the wireless power transmitters. Possible benefits are, for example, reduced mass, improved efficiency, and improved reliability. Dr. James Powell of Plus Ultra Technologies, Inc., of Stony Brook, New York, is conducting the study, and it is being managed by the NASA Glenn Research Center at Lewis Field via a task-order contract through Scientific Applications International Corp. (SAIC).

Specific tasks included in the contract were to

1. Review the state of the art of HTS wire and cables, particularly the work that is being done by the Department of Energy and its contractors
2. Compare differences in SSP satellite mass, size, reliability, and efficiency when superconducting and nonsuperconducting cables are used between the solar arrays and wireless power transmitters
3. Consider the benefits of using superconductors to reduce the losses involved in distributing the power over the microwave transmitter surface to the individual transmitters
4. Consider possible applications of HTS for the ground power station
5. Address practicality issues of deployment, maintenance, and vulnerability to space debris and to spacecraft charging due to space plasma.

Space solar power Sun Tower conceptual design.

Thus far, it appears practical to have a massively parallel Sun Tower architecture in which low-voltage (~80 V) direct-current transmission lines run directly from each solar panel to the radiofrequency transmitter without requiring power converters. This architecture would use conventional aluminum conductors for local solar panel power collection and distribution, a high-temperature superconducting (HTS) subtransmission line from the solar panel to the Sun Tower "backbone," and a low-temperature superconductor (LTS) transmission line along the Sun Tower backbone. The 77-K superconductors based on thin yttrium barium copper oxide (YBCO) films have yet not been produced in the length and current capability required. The 35-K superconductors based on bismuth strontium calcium copper oxide (BSCCO) wires appear to be suitable for the Sun Tower. Mutifilament, multikilometer Nb_3Sn conductor wires with 10^6 A/cm^2 capability at 6 K are commercially available. In addition, a new concept, termed magnetically inflated cable, has been developed for a lightweight, highly rigid, automatically deployable backbone structure for the Sun Tower.

Items still to be completed under the current contract are complete reports on (1) the status of HTS and LTS technologies and their applicability to SSP, (2) evaluation of Sun Tower transmission and distribution options including preparation of weight budgets for the various transmission and distribution options, and (3) evaluation of the magnetically inflated cable concept, including weight and refrigeration budgets for systems based on this concept.

Glenn contacts: Roy C. Tew, (216) 433–8471, Roy.C.Tew@grc.nasa.gov; and Albert J. Juhasz, (216) 433–6134, Albert.J.Juhasz@grc.nasa.gov

Authors: Roy C. Tew and Albert J. Juhasz

Headquarters program office: OSS (ATMS)

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