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SOLAR POWER SATELLITES – IMPLICATIONS OF ROTARY JOINTS

Abstract

Solar power satellites have recently sparked interest to achieve net-zero greenhouse gas emissions as part of an energy generation portfolio in the wake of COP26. The solar power satellite deploys large-scale solar photovoltaic arrays to generate microwave energy beamed to Earth-based rectenna arrays. It offers a clean source of energy to Earth with superior power densities to terrestrial renewable energy sources. The three distinguishing features of a solar power satellite are: (i) the large solar capture panel area; (ii) the magnetron to convert thermal energy into microwaves transmitted to Earth; (iii) rotary joint to simultaneously point solar panels at the sun and microwave transmitter to Earth. Very large km sized solar power satellites require electrical power transmission over significant distances favouring AC transmission lines. However, most space experience including the International Space Station has been with DC electric power generation but DC power suffers large drops when transmitted over km distances. Recent designs have focussed on horizontal modularity by substituting formation flying of independently controlled solar array concentrators and the energy transduction subsystems to eliminate the rotary joint. We propose vertical modularity in which independent solar power satellite modules retain the rotary joint because they have a venerable legacy in dual spin spacecraft. The use of magnetic bearings eliminate mechanical friction overcoming the major disadvantage of rotary joints. We determine that a minimal solar power satellite module outputs 1 kW microwave power requiring a solar array size of 7 m2 and a minimum microwave transmitter diameter of 1.5 m. However, we focus on the rotary joint by considering the various motor design options for the design of the rotary joint. The most obvious options revolve around the choice of DC or AC motors and their gearing systems. We examine these options in detail. Vertical modularity permits the generation of DC electric power and the use of DC motors. Furthermore, we introduce the prospect of manufacturing complex devices such as electric motors on-orbit as a facility to service such satellites. This will be a crucial capability to ensure the robustness of the solar power satellite fleet.