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Carnot battery based on Brayton supercritical CO2 thermal machines using concentrated solar thermal energy as a low-temperature source

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Abstract-

Carnot batteries store surplus power as heat. They consist of a heat pump, which upgrades a low-temperature thermal energy storage, a high-temperature storage system for the upgraded thermal energy, and a heat engine that converts the stored high-temperature thermal energy into power. A Carnot battery is proposed based on supercritical CO2 Brayton thermodynamic cycles. The low-temperature storage is a two-tank molten salt system at 380 °C/290 °C fed by a field of parabolic trough collectors. The high-temperature storage consists of another two-tank molten salt system at 589 °C/405 °C. Printed circuit heat exchangers would be required to withstand the high pressure of the cycles, but shell and tube heat exchangers are proposed instead to avoid clogging issues with molten salts. The conventional allocation of high-temperature molten salt heat exchangers is then modified. Using solar energy to enhance the low-temperature thermal source allowed a round-trip efficiency of 1.15 (COP of 2.46 and heat engine efficiency of 46.5%), thus increasing the stored power. The basic configuration has a levelised cost of storage of USD 376/MWh while replacing the shell and tube heat exchangers with hybrid printed circuit heat exchangers is expected to lower the cost to USD 188/MWh.

Index Terms- Carnot batteries; Brayton supercritical CO2 thermodynamic cycle; high-temperature heat pump; pumped thermal energy storage; thermal energy storage; renewable energies dispatchability

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