A Dual Stage Sodium Thermo-Electro-Chemical Converter (Na-TECC)

Alexander Limia
Advisor: Dr. Shannon Yee

The need for reliable and distributable energy is evident, but one prominent obstacle is the lack of an efficient direct heat-to-electricity converter. The sodium thermo-electro-chemical converter (Na-TECC) is a highly efficient thermally regenerative electrochemical system (TRES) that can fill this void. This electrochemical technology uses an ion-selective solid-electrolyte called beta-alumina that is highly conductive to sodium cations. The Na-TECC generates electric power by allowing high pressure sodium cations to expand isothermally through the solid-electrolyte. Theoretically, a device interacting with thermal reservoirs at 1150 K and 550 K should operate above 45% efficiency, but actual devices have not surpassed efficiencies of 20%. To amend this discrepancy, a dual stage conversion process is being explored. Rather than using one isothermal expansion stage, the dual cycle will employ two separate electrolytes to allow for two separate expansion stages. This new cycle is thermodynamically favorable as it allows for regeneration and reheat to complete the expansion in the second stage. Also, the new cycle will allow the device to operate with a lower condenser temperature, will improve the lifetime of the electrochemical components, and it will be amenable to improved thermal management. A dual stage concept for the Na-TECC has never been demonstrated in literature, so it is necessary to properly re-define the thermodynamic parameters such as heat loss, maximum power, and optimal current density. Certain drawbacks from a dual stage concept will also be addressed, such as the need for larger electrochemical area and the increased pressure losses. It will be demonstrated that the dual stage device must have lower thermal losses than a single stage device if it is to have a higher efficiency. The improved operation of the Na-TECC can have a transformational effect on small combined heat and power (CHP) systems at the 1-5 kW range.