Development of a Battery-Free Solar Refrigerator

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ABSTRACT

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Recent technology developments and a systems engineering design approach have led to the development of a practical battery-free solar refrigerator as a spin-off of NASA's aerospace refrigeration research. Off-grid refrigeration is a good application of solar photovoltaic (PV) power if thermal storage is incorporated and a direct connection is made between the cooling system and the PV panel. This was accomplished by integrating water as a phase-change material into a well insulated refrigerator cabinet and by developing a microprocessor based control system that allows direct connection of a PV panel to a variable speed compressor. This second innovation also allowed peak power-point tracking from the PV panel and elimination of batteries from the system.

First a laboratory unit was developed to prove the concept and then a commercial unit was produced and deployed in a field test. The laboratory unit was used to test many different configurations including thermoelectric, Stirling and vapor compression cooling systems. The final configuration used a vapor compression cooling cycle, vacuum insulation, a passive condenser, an integral evaporator/ thermal storage tank, two 77 watt PV panels and the novel controller mentioned above. The system's only moving part was the variable speed BD35 compressor made by Danfoss. The 365 liter cabinet stayed cold with as little as 274 watt-hours per day average PV power. Battery-free testing was conducted for several months with very good results. The amount of thermal storage, size of compressor and power of PV panels connected can all be adjusted to optimize the design for a given application and climate.

In the commercial unit, the high cost of the vacuum insulated refrigerator cabinet and the stainless steel thermal storage tank were addressed in an effort to make the technology commercially viable. This unit started with a 142 liter, mass-produced chest freezer cabinet that had the evaporator integrated into its inner walls. Its compressor was replaced with a Danfoss DC compressor slightly larger than the one used in the laboratory unit. The control system was integrated onto a single electronics card and packaged with its starting capacitors. The water for thermal storage was placed behind a liner that was made to fit inside the original factory liner. The original condenser was also augmented with additional surface area to improve performance. PV panels with a total rated power of 180 watts were used. The unit was tested with very successful results in an outside ambient environment, demonstrating its potential for widespread use in many off-grid applications for solar refrigeration.