An efficient appliance for low voltage DC house

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Background:

This work was offered by CIT (Chalmers IndustriTeknik), CIT is a foundation founded by Chalmers, providing knowledge on commercial terms. CIT has issued this work to find out new solution for normal AC power consuming household appliances which would be compatible with Low Voltage DC.
Kitchen appliances consume large amount of energy in residential houses. By using efficient appliances energy losses can be reduced. Most of the household appliances use DC internally except some appliances such as stove, refrigerator, dishwasher and microwave oven.

The refrigerator and stove is one of the high power consuming kitchen appliances and it consumes large amount of energy.

This work investigated on energy efficient home appliance design to run on low voltage DC and the purpose is to reduce energy consumption and losses. A combined refrigerator stove unit is designed to run on low voltage DC. The system is simulated with Matlab / Simulink and finally a prototype is built to analyze the performance.
Figure shows the combined refrigerator-stove unit. In this work, a refrigerator and stove is designed which run on 48 volt DC. The combined refrigerator-stove unit has three compartments. First one is the refrigerator compartment, middle one is the water tank compartment, and the third one is the stove compartment.

Thermoelectric module (TEM) is used to pump heat energy from one side to another. Two separate TEMs are used for the refrigerator and stove. Water is used as a medium to transfer extracted heat of the refrigerator from refrigerator side TEM to stove side TEM. Stove side TEM extracts partial energy from that heat and remaining energy is stored in the water tank which raises the temperature of water.
Simulated Result

Figure 2 presents the variation of heat pumped by the module with module input current. In the both cases, heat pumped by the module increases with increasing of input current.

Figure 3 presents the variation of heat pumped by the modules with temperature difference. Heat pumped decreases for both modules with increasing temperature difference.

Figure 2 Heat pumped vs. current

Figure 3 Heat pumped vs. Temperature difference
Figure 4 presents the time variation of water temperature. At the time supplying power to the module, the temperature difference is zero, it pumps maximum heat energy. In steady state the temperature difference is almost 60 °C, heat pumped by the module decreased.

Figure 5 presents the time variation of input current. Initially refrigerator side temperature low, it consumes high current to keep the temperature 0 to 4 °C. When it reaches steady state, temperature difference is almost 60 °C, it consumes less current since it pumps less heat energy.
EXPERIMENTAL RESULT

✓ This experiment was performed to evaluate the performance of the appliance. The refrigerator side TEM was supplied by 48 V DC, stove tank was filled with 7 kg of paraffin (Latent heat energy), the temperature of the air inside the refrigerator was 17 °C. Figure shows the experimental result of the system.

✓ The temperature of the air inside the refrigerator decreased from 17 °C to 0 °C within 6 minutes.

✓ The hot side temperature of the stove TEM took 254 minutes to increase the temperature from 30 °C to 100 °C and in the mean time the temperature of the water tank increases from 48 °C to 72 °C.

✓ The input power of each TEM is almost 220W.
CONCLUSION

- Due to the fact that the thermal energy from the refrigerator is stored and later used for heating the stove, the overall efficiency of the system is increased compared to a standard stove and refrigerator.

- To implement the proposed design practically, more research is recommended for improvement of insulation system to improve the efficiency of the whole system.

- More analysis is required to make the TEM more efficient for extracting energy and to make the unit cheaper.

- Design of automatic control system is also recommended for the proposed system.
Thanks for your attention