Micro-CHP

Combined Heat and Power for Residential Applications

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Project Results and Value to my Educational Program

Fellowship Source: South Carolina Institute for Energy Studies

University Turbine Systems Research Industrial Fellowship Program 2005

Academic Advisor: Dr. Paul Dellenback

Industrial Mentor: Dr. Ulf Jonsson

Industrial Contact: Dr. Tom Rosfjord

Industrial Site: United Technologies Research Center, East Hartford, Connecticut

Introduction

The University Turbine System Research (UTSR) Fellowship Program coordinated my 2005 internship with United Technologies Research Center (UTRC) in East Hartford, Connecticut. At UTRC, I worked alongside Ulf Jonsson on a project to create a proof-of-concept self-powered furnace (SPF).

The intent behind a SPF is to provide a source for a reliable heating load at all times. The characteristic that distinguishes a SPF from a standard furnace is that it is to operate off the electrical grid, only being supplied by natural gas. In the event of a power outage, a SPF could sustain its heat supply to a residential household. Additionally, a SPF can save the user money on their monthly electric bill since the furnace generates its own power supply.

The design for the proof-of-concept SPF was well defined when I arrived at UTRC. The design incorporated an off-the-shelf furnace and a natural gas driven generator with various water-to-air heat exchangers, and numerous other components to fuse the design. A schematic of the SPF can be seen in Figure 1.

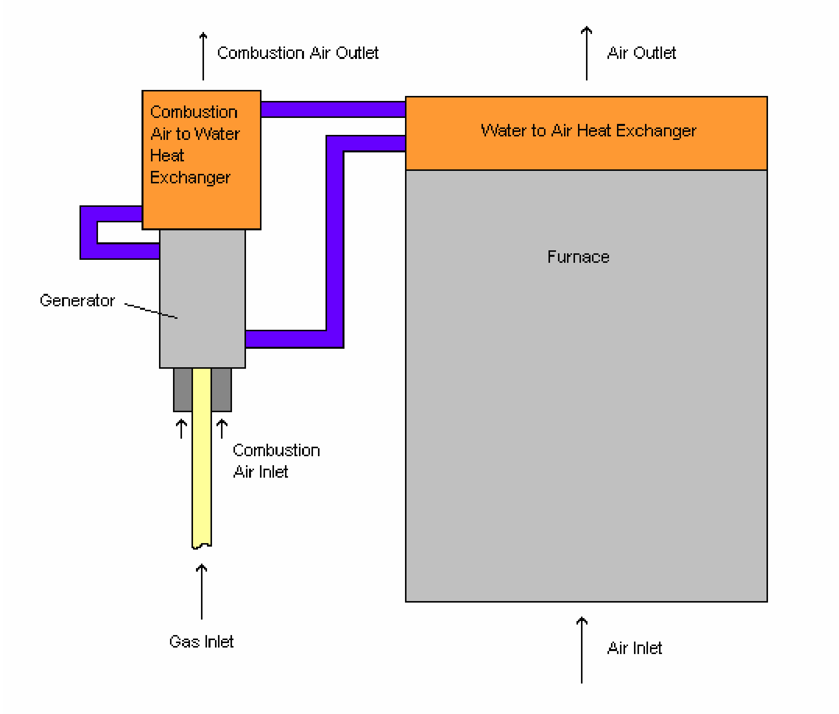

Figure 1. Self Powered Furnace Schematic.

Results

Initial laboratory testing characterized the key elements of the self-powered furnace. Data for the power consumed by the various components of the SPF was essential for sizing the power output of the electric generator. The two devices used to move gases in the system are the blower and inducer. The blower forces air to move through the furnace and into the house. The inducer creates a negative pressure in the combustion chamber to induce combustion gas flow into the chamber. This feature limits potential problems that could occur if a puncture was created in the combustion chamber since it would maintain the flame in the combustion chamber and would not allow the flame to escape into undesirable areas outside of the SPF. The furnace blower and inducer are both variable speed devices and therefore can consume a wide range of power depending on the total airflow desired and the pressure drop, often referred to as head, across the system. Additionally, the SPF design included a water pump to circulate water in a closed loop around the generator and through two heat exchangers. This pump would also consume a substantial amount of power due to the head created by numerous bends in the water ducting and heat exchangers. An igniter was also incorporated and was expected to draw power during startup. Lastly, electronics used to control the many components in the SPF would draw additional power that needed to be accounted.

The electric generator needed to supply enough power for these devices while accounting for a DC to AC conversion that operated around 90% efficiency. Additionally, the generator needed to charge a battery that was used to power the furnace during its long startup period. Startup is defined as the time it takes for the generator to supply enough electricity to run the furnace on its own. Optimized generator combustion and cooling allowed the generator to produce sufficient power to supply the fans and controls and replenish the storage battery as illustrated in Figure 2. During this time, the furnace was providing energy to heat the air at a rate sufficient to provide heat for a single family residence.

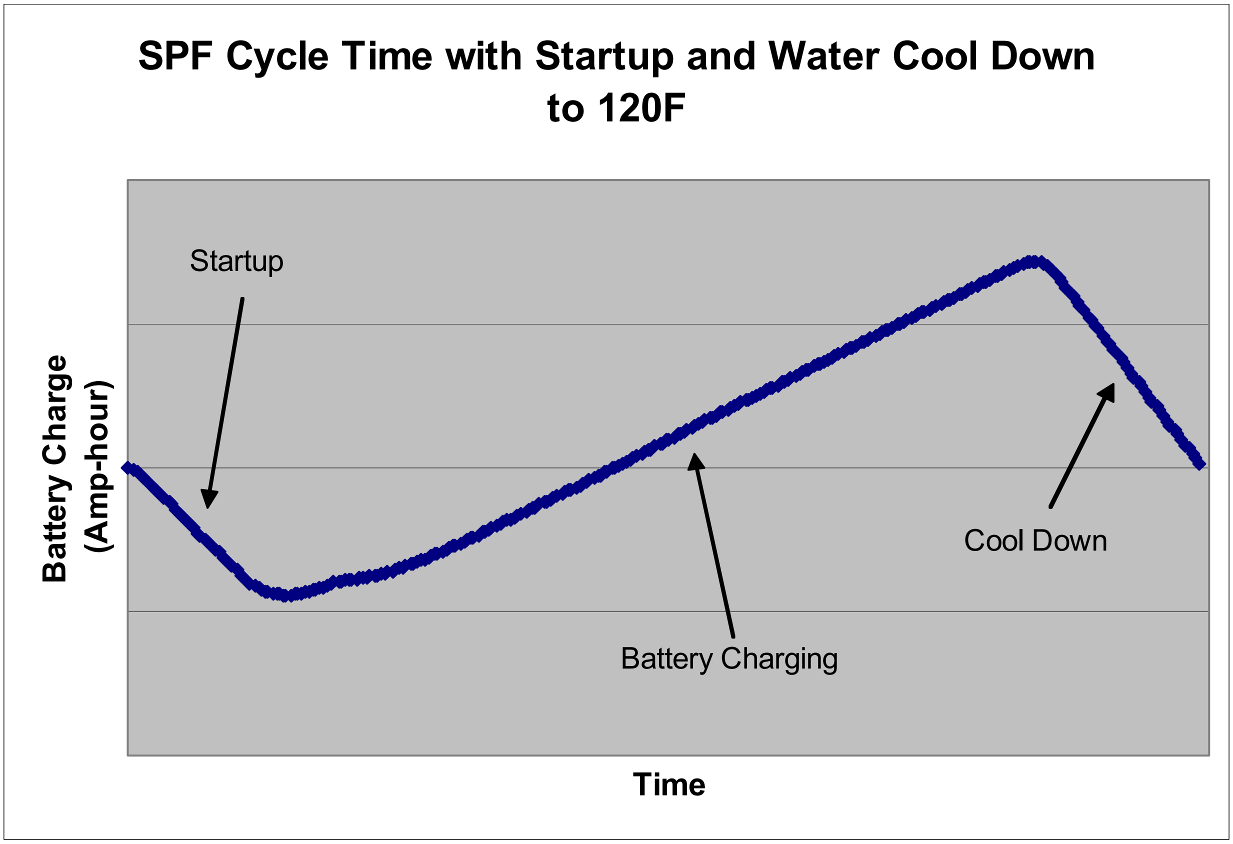

Figure 2. Battery charge for one cycle.

In order to transfer the waste heat from the generator and the hot gas stream to the primary air stream supplied to the house a series of heat exchangers were utilized. First to draw the heating energy from the generator and combustion gas, water was passed around the generator and through an air-to-water heat exchanger. This energy was passed along to the air going through the furnace via a second heat exchanger placed on the outlet of the furnace. At steady state, the energy going into the water through the first stage matched the energy leaving the second stage into the furnace air. The flow of water through the closed loop system was adjusted to allow equilibrium to be reached with the desired heat flux.

Finally, the thermal efficiency of the SPF was very high. Exhaust gasses were found to leave the flue at around 85°F. With a room temperature around 75°F, the energy lost in the exhaust was incredibly small. This resulted in an overall efficiency for the SPF system of around 95% and a thermal efficiency near 97%. Currently, energy star furnaces have efficiencies around 96% in their top-of-the line models with corresponding configurations.

Project Conclusions

A self-powered furnace can provide a reliable heating source for residential usage. Benefits of the device include a heating source during power outages, a reduced utilities bill as long as electricity and natural gas prices remain proportional to their current rates, and high thermal efficiency. Potential downsides of the SPF include increased furnace costs, and potential reliability concerns due to the concept being in its infancy.

Potential hot points of the project could be quenched with further development of the SPF. Different generating devices could be used in the future to provide the heating and power. Use of fuel cells with hydrogen production could be one example. Hydrogen could be produced from natural gas for energy storage in fuel cells while the heat needed for the hydrogen production could be used to heat the residence. Problems arise once again due to the maturity of this technology.

Educational Benefits

As a result of the UTSR Fellowship Program I gained much needed experience in a laboratory environment. Time spent evaluating laboratory facilities, testing components of the project, and debugging sensing devices should prove useful in my research while I pursue a PhD. Additionally, the knowledge gained from working with my industrial mentor, Ulf Jonsson, should be extremely valuable in my understanding of future engineering projects. Ulf's keen insight into fundamental engineering concepts, his resourcefulness, and his vast knowledge of laboratory components continue to amaze me. I hope that being witness to Ulf's laboratory savvy will help me build upon my research ability.

Additionally, experiences gained in the engineering industry will benefit me after my education has been completed. The time spent at UTRC has reinforced my desire to begin my engineering career outside of academia after I have completed graduate school.

A somewhat disappointing aspect of my summer fellowship is that I was placed on a project that had no relationship to gas turbine engines. It seems misleading that a program created to support the turbine industry places one of its fellows in an unrelated field. I hope that future fellows who are placed into non gas turbine fields will be warned as it could potentially influence there likelihood of participating in the program. However, I would like to once again commend my mentor at UTRC for working hard to give me some exposure to gas turbines. On numerous occasions Ulf went out of his way to set up tours of facilities with projects that related to the fellowships vision.

Overall, my summer fellowship at UTRC has been extremely beneficial and I would like to thank everyone involved in the program.