Needs Assessment

Project:
Thermal Storage Solution for Organic Rankine Cycle

Team: # 17

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Submitted to:
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Abstract

In order to meet the needs of a growing population, demands in energy storage have increased dramatically. The search for renewable and less expensive resources has expanded substantially. The company Verdicorp, who specializes in Organic Rankine Cycles, is looking for a thermal storage solution in order to run their machines for longer periods of time at a much less expense. Our goal is to produce a component that allows their organic Rankine Cycle (ORC) to operate even after the initial power supply has been depleted. This unit that is created will be applicable to not only Verdicorp's ORC, but other systems such as solar energy systems and hydro electrical systems. This component if completed successfully will change thermal storage solutions in the future.

Introduction

This report is meant to convey the requirements for our thermal storage device based on the needs of our customer and provide background on existing and cutting edge solutions for similar thermal storage solutions. By establishing a background in the topic and the specific needs of our customer our team will be able to form a more concrete picture of the problem resulting in a more complete solution.

Background

With the human population growing at an exponential rate, energy demands will soon follow. Resources become more and more precious with every human life introduced into the world which is why energy demands cannot rely on fossil fuels forever. The world needs an alternative renewable resource to help provide for the coming generations. In recent years we have seen strides to relieve ourselves from the grips of fossil fuels by building solar power plants, wind farms, using natural gas, bio mass, and even marketing electric cars. However, we are still in the early stages of this transition and have not optimized the technology to be as efficient and profitable as we would like.

In every power generation plant, no matter the fuel source, there is always energy lost during the production process. No system is perfectly efficient. The energy lost often ends up in the atmosphere unused in the form of heat. Some studies suggest that nearly half of the total energy content in the fuel is lost as heat.[1] If that energy could be captured, energy generation could double providing the energy the world needs all while providing it at a lower rate because it won't take as much material to produce the same amount.

The idea of thermal energy storage is simple and has been around for some time. No matter the method of thermal storage, the cycle is the same. The system is charged with thermal energy, the energy is stored for some time, and finally the energy is released. The earliest units may be dated to the 1890s when people used compressed air, flashing high temperature water into steam, and implementing water or steam storage tanks.[2]The problem with water is that it cannot retain the heat for very long, even in an insulated tank. Also, there is only so much heat the water can absorb. Therefore, if more heat needs to be stored more water is needed which means more space is needed. So by using water as a thermal medium the storage device is constrained in almost every way including space, amount of heat absorbed, and duration.

Phase change materials (PCM), is another common thermal storage medium. As heat is added the material approaches its melting temperature. As the material begins to change phase it is able to store more heat without increasing the temperature, given that the pressure doesn't go up in the enclosure due to the volume change. Additional heat also increases the amount of energy stored even after the melting process is complete.[3]What makes the process so unique is the fact that lots of heat may be stored in a material without much change in the material's temperature. This has benefits in areas where temperature control is critical. Many classes of phase change materials exist including inorganic, organic, and bio-based. The organic class stems from petroleum bi-products which are manufactured by major petrochemical companies.[3]For that reason, their availability could be limited and prices could vary. While these materials may be toxic, flammable and expensive they have a potentially infinite number of life cycles. The bio-based class contains organic materials that are naturally existing fatty acids such as vegetable oil. These products are non-toxic, non-corrosive and have infinite life cycles. However, they may be expensive and the risk for flammability increases with high temperature.[3]The inorganic class includes salts which are an engineered hydrated salt solution and deemed to be non-toxic, non-flammable and economical.[3]

Recently, molten salts have become quite popular amongst the solar industry for its ability to be pumped as a liquid when hot enough and retaining heat for extended periods of time. Some estimate that solar thermal plants can keep running for six hours after the sun goes down.[4] The process is simple as stated before. The salts are melted or charged, stored in an insulated container and when energy is needed again, pumped through a heat exchanger to warm the working fluid.[5] These salts must be heated by an incredible amount before they turn to gas so the potential to store heat dwarfs that of water and also surpasses many oils. However, it still faces some of its own challenges, at least in the solar industry. The main challenge is optimization in this technology.

The problem with using molten salts as of now lies in the process for heating and storing the salts. Halotechnics is currently working on developing salts to store energy from any source of electricity.[5] Rather than building long expensive troughs as the only way to heat the salts, electricity may be used as a supplement which cut capital cost down. Terrafore Technologies is also trying to cut the price on molten salts by redefining how the heat is stored and dissipated all together. They plan on combining multiple materials together, all with different melting temperatures to cut the number of tanks needed, essentially leaving one tank for heat storage and one for the cold salts.[4] This would cut the initial capital cost of building a ecofriendly plant such as a solar one, which is always more appealing to investors.

The most ideal material would be one that has an incredibly high heat capacity potential, and is able to hold onto that heat indefinitely. Zeolite may be the answer. Its seemingly magical ability to store three to four times the amount of heat as water and retain that heat indefinitely has left a lot of promises for scientists. They are extremely porous, so one gram of the material may have a surface area of 10,764 sq ft.[1] This allows units to be much smaller when compared to water tanks. Water binds with the surface of zeolite in a chemical process which releases heat. When heated, the water filled zeolite pellets produce large amounts of steam. What's strange is that when heated, the zeolite pellets do not get warm. Instead, the energy is stored as potential to absorb water.[1] This ability may help reduce material costs for storage which also makes a good case for its implementation. Scientists in Germany have tested the material on a small scale and are now currently developing and testing a thermal storage system using the zeolite pellets to work under realistic conditions.[1] The small scale tests yield promising results as they were able to successfully charge and discharge the pellets over a profound number of cycles.[7] This stability provides many with relief and much is to be expected from the full scale model.

Need Statement

Thermal storage is needed to increase the operation time and thus the overall feasibility of Verdicorp's existing Rankine Cycle. By using heat, that might otherwise be wasted, to continually power the cycle the ORC is able to take advantage of a greater portion of the heat produced during the combustion process thus requiring less fuel for power production. This produces savings for the customer in fuel costs and reduces the production of any potentially harmful emissions from the system.

Goal Statement

Our aim is to produce a commercially viable thermal storage solution for Verdicorp's Organic Rankine Cycle using environmentally friendly materials.

Objective- To design and construct a functioning thermal energy storage unit prototype by April 2015, under the present day constraints specified below.

Constraints

A key to the success of the project will be the management of the various constraints that are inherent in the design, or that may arise during the design process. In order to optimize the productivity of the team these constraints must be constantly analyzed and reevaluated. The present constraints of the project are categorized by design, finance, and time:

Design Constraints:

For Organic Rankine Cycler:

- ORC operation temperature range: 130 – 150°C
- ORC Energy input: 1MW(electrical) or 8.33MW(thermal)
- ORC working fluids: Water, R43, Mineral oil
- Runs for a total of 8 hours

For Thermal Storage Unit (actual):

- Phase Change or sensible material as medium for the majority of thermal storage
- Use of passive systems for further thermal storage and insulation
- Stores Heat for a minimum of 4 hours after heat input.
- Robust system-Corrosive resistant and high fatigue cycle.
- Serviceable and cost-effective maintenance
- Assume 10MW(thermal) from heat source

For Thermal Storage Unit (prototype):

- Maximum operating pressure: 50 psi
- Construction material: 80-20 alloy
- Must be mobile
- Must be capable of having a safe indoor demonstration

Financial Constraints:

- Design must be marketable
- Design must generate 0.23 cents per hour of power.
- Maximum budget for parts and materials: $2000

Time Constraints:

- Design and Analysis
- Ordering and receiving parts
- Machining parts
- Assembly process

Methodology

Team 17 will approach this problem by using a "funnel" methodology, ensuring that the final resulting product is based on our best ideas, sound engineering techniques, and financial reasoning. Each member will come up with a unique concept for the thermal storage device and present their concept to the group. The group will then brainstorm as a group and use these concepts as a basis for two main concepts. These two concepts will then be evaluated based our financial resources and their mechanical performance. The concept that represents the best solution will then be put into production. Like the way in which a funnel takes a broad cross section of chaotic fluid and produces a steady stream this methodology will take the diverse ideas of each group member and slowly reduce these ideas to a single solution.

Schedule (Gantt chart)

Conclusion

We don’t plan to recreate the wheel, we plan to utilize and combine systems and components that already exist. Using our strategic approach, Team 17 will produce a scaled down working prototype of a thermal storage solution. Through many design matrices and budget breakdowns our team, partnered with Verdicorp, will introduce a commercially feasible thermal storage solution to the industry of energy. This unit will increase operation times of machines as well as their efficiencies on an affordable budget. More efficiency, less cost, and higher sustainability will lead to many enthusiastic and satisfied customers including our partners at Verdicorp.

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