Thermal Storage Solution for Organic Rankine Cycle

Deliverable:
Project Plan & Product specifications

Team: # 17

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Submitted to:
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Abstract

As a customer, Verdicorp, a company that produces and sells Organic Rankine Cycle power systems, has asked us to build a thermal storage unit to extend the running time of their ORC system. The current process of how group 17 will accomplish this task has been laid out in this Project Plan and Product Specification document. Up to this point our team has meet with Verdicorp to better understand what they would need from a thermal storage unit. We were able to learn their ORC operational parameters as well as develop a better understanding of the type of heat sources that will be used in conjunction with their ORC. With a much better grip on what needed to be provided for the customer, we were able to get started on researching the already available thermal storage units in the industry. Most thermal storage units were found to be used for solar energy systems and we were able to compare their specifications to those of our application. Once our group discussed which direction and concept we were leaning toward we were able to research material properties mainly thermal conductivity and diffusivity. This gave us all a more limited range of materials to choose from and further research since the main idea behind the success of this product will be heat transfer and retention capabilities. As a group we completed a Needs Assessment to assure that we were on the right track as well as gain some constructive criticism. Bi-weekly meetings have been arranged with our class instructors to also ensure that we are staying motivated and on top of our project schedule. In the next couple of weeks our group will begin to evaluate and chose a final design including basic material needed for those proposed concepts. Once a design is chosen we will seek approval from our customer and with their approval begin to model it using computer assisted design software.

Introduction

Presented In this report is our current understanding of the Thermal Storage Solution project. The goal of this project is to produce a functional scaled down version of a thermal storage device. Objectives for the final model include that the device display the potential to power Organic Rankine Cycle for up to four hours, ability to respond to energy needs as they're demanded of it, and produces costs at or below the target of 23 cents per kilowatt hour.

The need for thermal storage solutions is currently within a time of growth. As the use of intermittent sources such as solar increases so does this need. When these sources are no longer available power companies need thermal storage devices to continue producing energy. VerdiCorp's ORC is in need of such a device to continue providing the heat needed to produce electricity.

Project Definition

Background Research

With the human population growing at an exponential rate, energy demands will soon follow. As resources become scarcer it becomes apparent that energy demands cannot rely on fossil fuels. The world needs to simultaneously find ways to efficiently use the remaining fossil fuel deposits and develop renewable resources for future generations to rely on. Strides have been made 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, these sources are often intermittent in nature. For example solar plants are unable to produce energy at night. This implies a need for some type of energy storage so that plants can maintain consistent operation. Thermal storage stores excess energy while the renewable source is available and provides energy when the conventional energy source is no longer available.

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.

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 from intermittent sources 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.

Objectives

- To design and construct a functioning thermal energy storage unit prototype by April 2015, under the present day constraints specified below.
- Insure that said prototype is easily serviceable
- Produce power at 23cent per kilowatt hour
- Applicable in developing markets such as China
- Ability to supply extra power during times of peak operation

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:

For Organic Rankine Cycler:

- ORC operation temperature range: 130 – 150°C
- ORC Energy input: 1MW(electrical) or 8.33MW(thermal)
- ORC working fluids: Water, R245a, Mineral oil
- Thermal storage unit should power ORC for a total of 4 hours

For Thermal Storage Unit (actual):

- Stores Heat for a minimum of 4 hours after heat input.
- Robust system-Corrosive resistant
- Resistant high thermal cycle fatigue
- 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 power at or below 23 cents per hour of power.
- Maximum budget for parts and materials: $2000

Critical Time Constraints:

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

Design specifications

Prototype

A prototype of the thermal energy storage unit must be designed and constructed. The prototype must be a scaled working model of the actual storage unit. The prototype must simulate the input state from the heat source and the output state for the ORC system. The prototype must be mobile and able to fit in a classroom environment and deliver a safe demonstration. The alloy 80-20 will be the main construction material for the frame as well as the ground of the prototype, but not actually part of the design. A bullet-proof casing may be mounted on the frame and around the device for further safety. The pressures in the pipes will not exceed 50psi unless it is found necessary.

Sensors and Control

In order to properly deliver the correct temperature and pressure to the ORC system thermal couples and pitot tubes will be applied at the inlet and outlet of each component. These sensors will be connected to a control system which will regulate the compressor, actuators, and flow valves. This control system must be fine-tuned in order to optimize the heat storage and flow properties of the entire system. The ORC must be maintained at an operating temperature range of 130-150°C and run for at least 4 hours after the heat source has been removed.

Energy Storage Configuration

The energy storage material is a key component to the design and must consist of either a phase change material, sensible material, or a combination of both. This material must be contained in an insulated environment and be capable of transferring energy with minimal losses. The heat exchanger configuration and piping must be designed to optimize the energy control to and from the system. The type of material and heat transfer configuration selected will determine the amount of heat that can be stored and the duration. The device must be capable of storing the thermal energy for at least 4 hours and consistently deliver the heat needed to generate power in the ORC system.

Performance specifications

- Must not heat the working fluid, R245, of the ORC to temperatures in excess of 150^0C
- Display estimation of the amount of thermal storage currently stored within the device
- Ability to deliver energy as demand dictates
- Extends the ORC's operation time by 4 hours when standard fuel is no longer available (assuming the device is fully charged)
- Must generate electricity at a cost to the customer of under $0.3 per hour of power
- Composed of materials that are easily obtainable in foreign markets such as China & Brazil

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 on 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.

Assign resources

Table 1. Task Allocation

Person/ Title	Responsibilities	Duration (weeks)
Bruce Orozco/ Communication Officer	Website design Website updates Concept simulation	1.5 N/A 1.5
Cory Nelson/ Financial Adviser	Part procurement submittals Evaluate concept implementation costs Production of Eng. drawings	1 1 2
Belal Nabulsi/ Lead Mechanical Eng.	Production of Eng. Drawings Evaluate concept projected performance	2 1
Jhamal Holliday/ Team Leader	Choose final design Verdicorp correspondence Faculty adviser correspondence Concept simulation Development of critical points of evaluation	2 days N/A N/A 1.5 1.5
Group	Research & brainstorming Choosing materials Concept generation	2 1 2

Project Schedule for October 1, 2014 – November 30, 2014

By setting short term goals our team will be able to assure our client of a product that meets their needs and is finished by the appropriate deadline. The Gantt chart located in the appendix will help us complete these short term goals throughout the semester. It will also help us manage unforeseeable obstacles since our overall timeline for the project will be laid out. Any new tasks that need to be added will be done immediately in order to give our team as much time as possible to adjust to the changes. It is critical to the project to manage our time wisely and the Gantt chart will be our guide

Conclusion

Utilizing all resources available to us, our group will design, create, and present a thermal storage solution to our customer. The materials used in this scaled down model will be chosen with three things in mind, cost, effectiveness, and accessibility. Each group member will be allocated specific tasks and the scheduling of those tasks will be managed using the Gantt chart found in the appendix. In the upcoming weeks materials research will be completed and appropriate materials for the selected thermal storage unit will be chosen. The selection process will on the budget and how well it meets the customer's requirements. This selection process we will be using a "funnel" methodology. Once drawings are created and materials are ordered the creation process can begin.

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Appendix

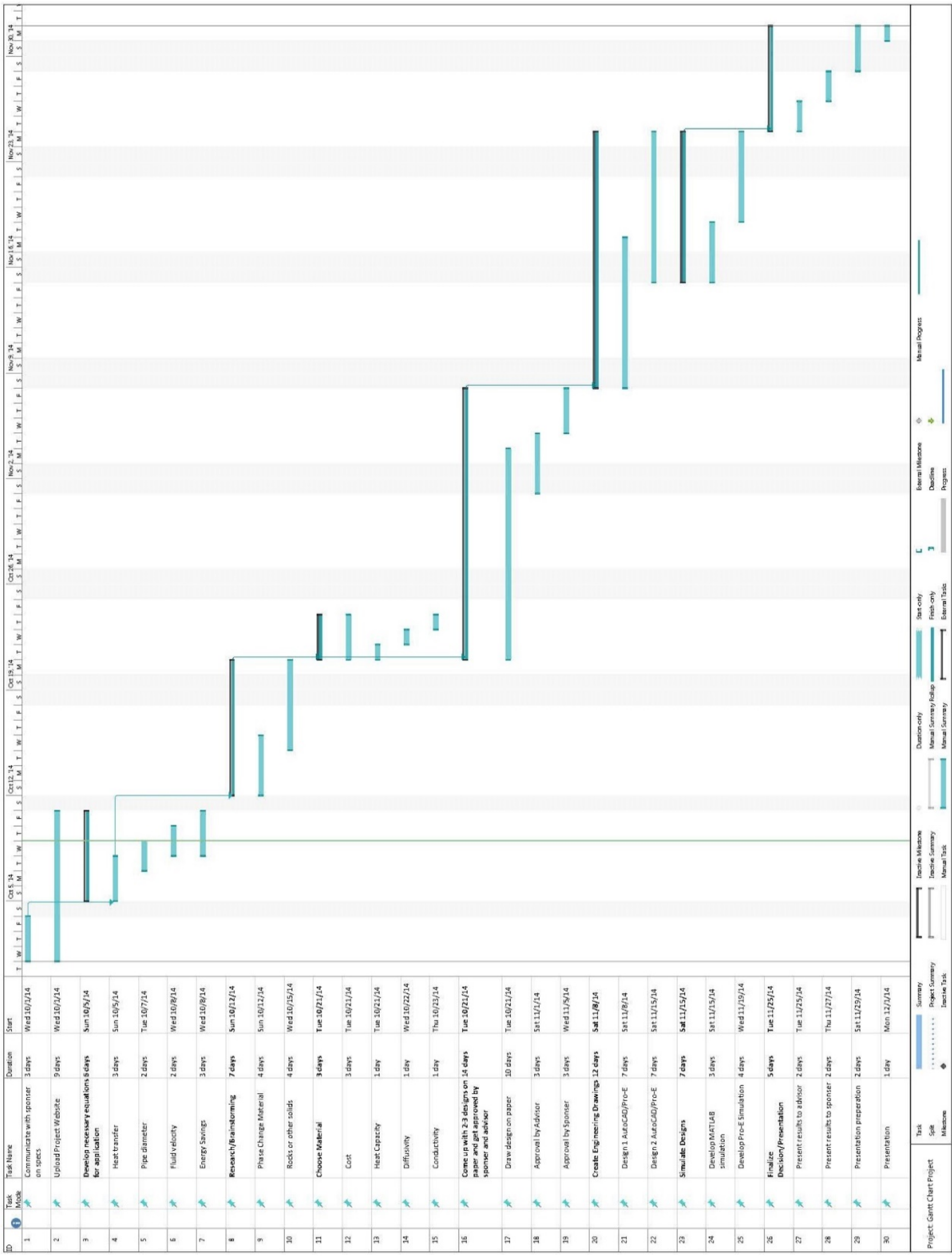

Figure 1 Gantt chart for Project schedule