Renewable Solar Power

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Abstract—The primary goal of the project itself is to find a way to convert the energy of the sun into electrical energy. Various methods can be used to achieve this goal. In this project mirrors will be used to focus the sun's energy on one focus line. In the focus line a pipe containing a fluid will be placed. This fluid will be heated up and will be used to make steam. The steam will then be used to make a turbine run and generate electricity. A prototype is already made but incomplete. In order to complete this project, the student need to design the evaporator and condenser, as a result certain recommendations will be made. The companies will use these recommendations to make a final decision.

Keywords—Renewable Energy, Sun, Electricity, Parabolic Trough, Organic Rankine Cycle system, Working Fluids, Evaporator, Condenser, Generator, Pump.

I. INTRODUCTION

A. Companies

The project 'Renewable sun power' is a part of the European Project Semester (EPS) program. The project was supervised by Universitat Politècnica De Catalunya (UPC) and two companies called 'Integral design and development' and 'millennium energy systems'. 'Integral design and development' is a company that is mainly interested in designing of train, but the company is also interested in exploring the market for opportunities to expand the company. 'Millennium Energy Systems' his main occupation is research and development of renewable energy sources.

B. Motivation

Energy has always been a basic necessity for human life. New energy sources have been found, and therefore they have been developed increasingly both socially and economically and increasing their level of effectiveness.

Human is using mainly fossil fuels like oil, coal and gas to provide energy as shown in the chart. The fact is now that these energy sources are not renewable and the energy reserves will be empty in the future. So the world is in need of new energy sources. The sun is a renewable energy source that provides energy every day. [10] [11]
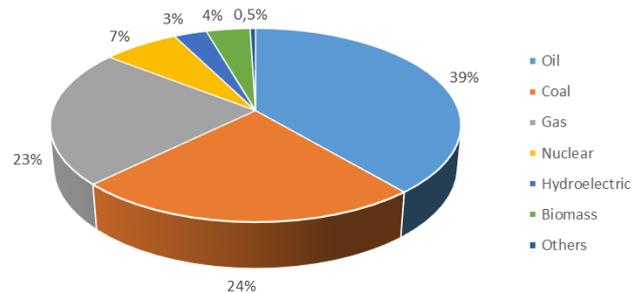
Figure1: Current global energy consumptions

A. Goals

This project aims to cover the following objectives:

- The development of an ORC model in which the behavior of the turbine is simulated to determine the most appropriate configuration from the energy viewpoint. The simulations are performed with Engineering Equation Solver (EES) software.
- Analysis of different organic working fluids, selecting the most suitable for the application. The thermodynamic properties of the fluid, its environmental impact, plant safety and performance benefits that the use itself brings to the cycle will be taken into account.
- Optimization of the ORC cycle from the developed model by simulations with different operating conditions to those in the design. The performances of the turbine and heat exchangers in the cycle are analyzed in these simulations.
- The developed ORC cycle model can be used to:
  - Learn cycle operation.
  - Know how the behavior of the cycle (before the experimental tests are performed).
  - Save costs (time and money) for the actual tests.
  - Assess changes in the experimental cycle before making them.

II. COLLECTORS

### A. *Parabolic dish system*

The parabolic dish system works with a round parabolic mirror that reflects the sun to one focal point as shown in figure 2. The heat in the focal point will be converted to electricity. [10]
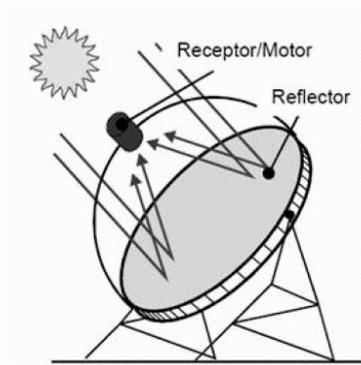
**Figure 2: Parabolic Dish System**

B. Parabolic trough

The parabolic trough system uses a long parabolic mirror. The parabolic mirror reflects the sun beams to a focal line where the heat is used for different purposes. The heat will then be converted to electricity. The heat can also be used to provide houses with hot water. This parabolic trough was used in this project after considering several factors like temperature needed, price for maintenance and installation and efficiency of this system. [10]
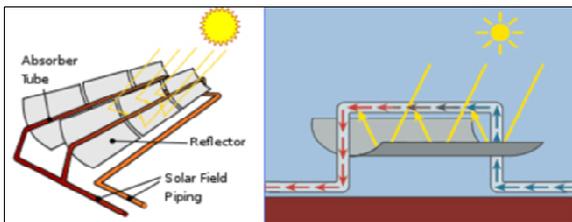
Figure 3: How a Parabolic Trough Works and Its Components

III. ORGANIC RAKINE CYCLE ORC

The Organic Rankine Cycle was used in this project consists of an evaporator, a turbine, a condenser and a pump. The evaporator transforms the working fluid in to vapor. The vapor will then go passed the turbine to convert it to electricity. After the fluid passes the turbine it goes through a condenser to transform the vapor again to a liquid. [3] [6]
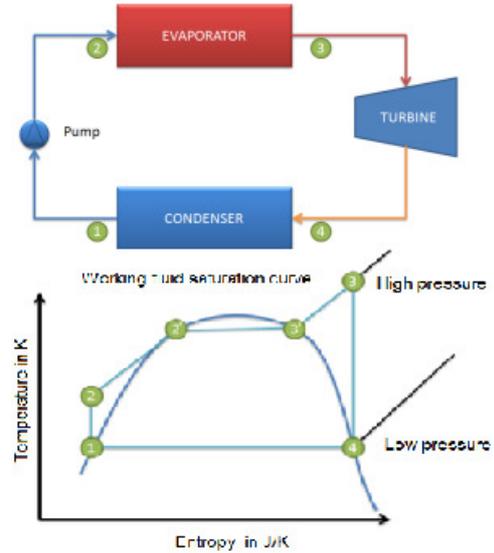
Figure 4: Components and Graph Entropy against Temperature of ORC

IV. WORKING FLUIDS

The first important choice is individuating the working fluid in the Organic Rankine Cycle (ORC) system. The working fluids that are suitable for low temperature ORC's are well known in the literature. The choice of the fluid depends on the following main factors [4] [5]:

- The critical point of the working fluid (in this case of small solar power plant the maximum temperature can be within 100 and 200◦C);
- The specific volume ratio over the expander must be low in order to reduce the size, and, thus, the cost (in general the higher the critical temperature, the higher the specific volume ratio over the expander);
- The working fluid should have a null Ozone Depleting Potential (Montreal Protocol and, for EC, regulation 2037/2000);
- The fluid must fulfill other conditions such a toxicity, cost, and flammability;
- If a scroll compressor is used for the expander the temperature must be below 150◦C because refrigeration compressors are not designed for temperatures higher than 150◦C.

For these reasons, the use of water is strongly recommended for the exploitation of high temperature heat sources and large thermal power plant. However, when the temperature of the heat source is lower, the use of water as working fluids may be unfeasible, through the specific trend of its saturation curve. In such case, an organic fluid shows a significantly better performance than water. The high molecular weight, the low

evaporation heat, the positive slope of the saturated vapor curve in the T-s diagram and the low critic and boiling temperatures allow the organic fluids to:

- Reduce the heat per unit mass required during the evaporation process;
- Reduce the temperature and pressure inside the evaporator;
- Increase the pressure in the condenser;
- Reduce the pressure ratio;
- Reduce the stage number of turbine (the use of single stage turbines is allowed);
- Reduce the vapor density at turbine inlet;
- Reduce the volume flow rate;
- Eliminate the superheating process.

Other refrigerant also used instead of only water. This refrigerant is used in ORC system. Here is the table of the several possible working fluids that can be used for the ORC system in this project.

|	P1 (Bar)	P2 (Bar)	Tc (ºC)	VAPOR QUALITY (%)	EFFICIENCY (%)
R134a	32.47	10.170	101.0	0.9615	4.57
R245fa	28.15	2.496	154.0	1.0000	9.19
R227ea	25.56	7.003	102.8	1.0000	4.50
R423a	29.47	9.306	99.52	1.0000	2.64

Table 1: Comparison of Working Fluids

From the comparison that have been made, the refrigerant R245 fa has been chosen as it need low pressure for condensation (P2) and evaporation (P1). In term of critical temperature, this refrigerant has high temperature to withstand a high temperature from sun. For the vapor quality properties, a high vapor quality fluid was chosen as low vapor quality would contain a high percentage of moisture therefore would damage easily the component. Lastly, the R245 fa has high efficiency compared to others.

V. CONDENSER

One of devices or unit that involves in heat transfer is a condenser and it is typically a heat exchanger. The function of this device is to condense by cooling the substance from its gaseous to its liquid state. It operating by removing sufficient heat from the gas or vapor. In the figure 5 shows how a condenser works. [1]

The high temperature and pressure gas refrigerant that come from compressor is condensed into liquid refrigerant when it pass through condenser. This process releasing its heat to the outside air as the working fluid cools. [8]
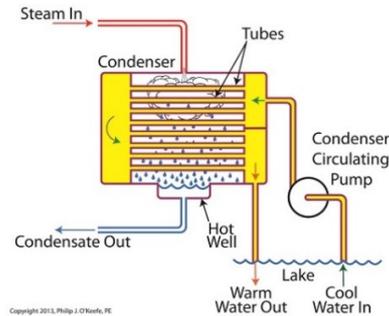
Figure 5: How a Condenser Works

The goal of this project is to design a condenser. Therefore, taking account the working fluid used, temperature and pressure that was applied in condenser, the dimension of the condenser should be precise to adapt in ORC system. In the table below is dimension for the condenser.

	DIMENSION
Total pipe length (m)	129
Pipe length (m)	1.4
Interior diameter pipe (m)	0.019
Exterior diameter pipe (m)	0.025
Number of pipes	92
Distance between pipes (m)	0.034
Thickness of shell (m)	0.007
Diameter of shell (m)	0.4

Table 2: Geometrical Condenser's Parameters

VI. EVAPORATOR

In almost any system that involving heat transfer normally uses evaporator. The principle of evaporator is opposite of the condenser. This device is used to convert the working fluid in liquid into gas form by absorbing the heat from air in the compartment. [1]

As the pressure is reduced and the heat is dissipated as the working fluid or refrigerant (liquid form) reaches in the evaporator, this make the compartment become cooler than the fan air flowing around it. Due to this causes, the heat is absorbed by working fluid from the warm air. The fluid can reach rapidly its low boiling point. Then, the refrigerant vaporizes by absorbing the maximum amount of heat. After that, the refrigerant as a low-pressure gas carries the heat from evaporator to compressor through a hose or pipe. [8]

The goal of this project is to design an evaporator. Therefore, taking account the working fluid used, temperature and pressure that was applied in evaporator, the dimension of the evaporator should be precise to adapt in ORC system. In the table below shows dimension for the evaporator.

	DIMENSION
Total pipe length (m)	274
Pipe length (m)	1.4
Interior diameter pipe (m)	0.019
Exterior diameter pipe (m)	0.025
Number of pipes	196
Distance between pipes (m)	0.034
Thickness of shell (m)	0.007
Diameter of shell (m)	0.44

Table 3: Geometrical evaporator's parameters

VII. PUMP

The power of the pump is calculated in the formula below.

$$Q_{Pump} = \dot{m} \cdot w_{t12} = 0,4 \frac{kg}{s} \cdot 4384 \frac{J}{kg} = 1754 \frac{J}{s} \approx 1,8 kW$$

Equation 1: Power of the pump

VIII. TURBINE

The turbine which is used to actually using the steam to convert it from mechanical energy into electrical energy has a power output of [9]:

$$Q_{Turbine} = \dot{m} \cdot w_{t34} = 0,4 \frac{kg}{s} \cdot \left(-22320 \frac{J}{kg} \right) = -8928 \frac{J}{s} \approx -8,9 kW$$

Equation 2: Power of the Turbine

IX. TOTAL PLANT

The total plant has a power output of:

$$Q_{Plant} = \dot{m} \cdot w_t = 0,4 \frac{kg}{s} \cdot \left(-17936 \frac{J}{kg} \right) = -7174,4 \frac{J}{s} \approx -7,2 kW$$

Equation 3: Power of the plant

X. REFERENCES

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