THEORETICAL STUDY OF A MODULAR SOLAR PLANT FOR ELECTRICAL GENERATION WITH A GAS-TURBINE OF 500 kW

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INTRODUCTION

One of the utilization options of solar energy, it is the power generation. Recent studies have treated the electrical generation through solar plants with steam and gas turbine. Have been demonstrated the feasibility of power generation through these systems, but are reported big discrepancies in the results, (e.g. Loebl, 1990) reported that to generate 90MWe is need a solar field surface of 464,000 m^2, while in the other hand (e.g. Valdés et al. 1990) reported that using the same system, to generate 80MWe, is required a solar field surface of 548.3 m^2; There are important differences and they should be fundamentally to the adopted design; therefore, for the adequate application of those plants are made necessary greater studies.

Concerning the solar plants with gas turbine, are reported few results and this work corresponds to the design a plant of 500KWe; to operate in the Mexico city. It is considered that a plant of this type can be of the modular type.

First have the description of the solar plant with gas turbine, subsequently is made a study of the corresponding thermodynamic cycle; below it is tried the design criterion adopted for the solar plant and are indicated the characteristics of the solar field and of the absorber, finish with the development of the solar field.

1. DESCRIPTION OF THE PROPOSED SYSTEM

The system proposed to fulfill the solar power plant functions with cycle of gas turbine, is shown in the figure 1, and have of the following elements: (1) air filter, (2) muffler, (3) turbo-compressor, (4) regenerator, (5) solar absorber, (6) combustion chamber, (7) gas turbine, (8) reducing of speed, (9) alternator and (10) electrical generator.

This is the system correspond to gas turbine with regeneration, the heat supply is made by combustion chamber with solar energy, the results is a hybrid system with respect to heat supply.

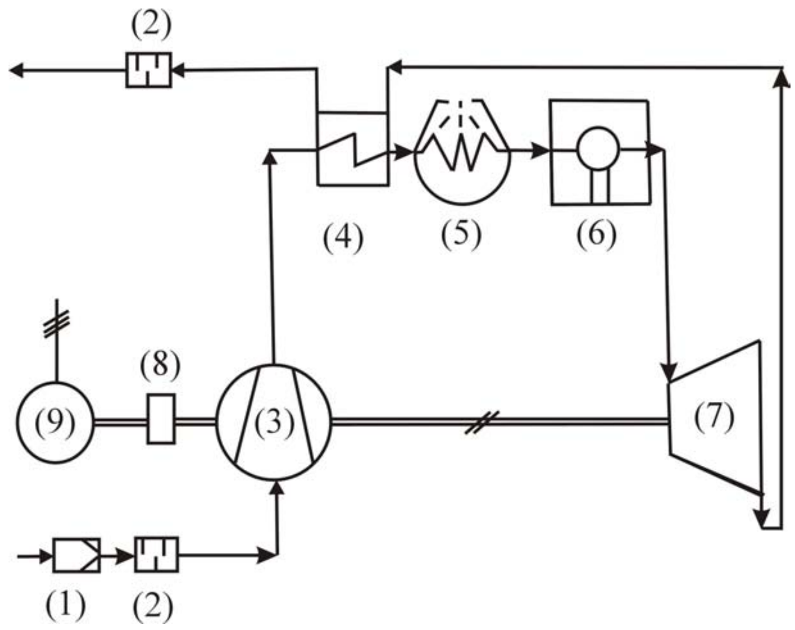

Figure 1. Solar power plant with cycle of gas turbine**.**

2. TERMODYNAMIC CYCLE

For design parameters and of typical efficiencies the equipment, are calculated the thermodynamic characteristics of the corresponding cycle, that is show in the figure 2.

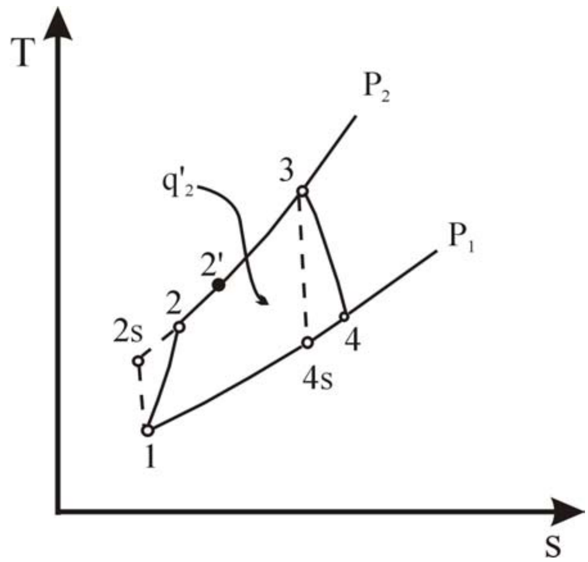

Figure 2.Thermodynamic cycle to the system of the figure 1.

Table 1. Design parameters of the thermodynamic cycle.

Electrical power	500 kWe
Place of installation	Mexico, D.F.
Ambient temperature (T_1)	15 °C
Atmospherical pressure	0.8 bar
Entry temperature to the gas turbine(T_3)	800 °C

Table 2. Equipment efficiencies

Compressor efficiency	77%
Turbine efficiency	86%
Electrical generator efficiency	94%
Reducing efficiency	96%
Regenerator efficiency	80%

Table 3. Thermodynamic characteristics of the cycle.

Relationship of pressures	6.8
Exhaust temperature of the compressor (T_2)	293 °C
Exit temperature of the regenerator (T'_2)	383 °C
Exit temperature of the gas turbine (T_4)	406 °C
Flux mass of air	4.8 kg/s
Flux mass of fuel	0.05 gg/s
Thermal flow of the cycle	2001.6 kW

3. DESIGN CRITERIA OF THE SOLAR PLANT

The propose solar energy system is only a complementary energy, is not used to supply all conventional energy. Therefore, the solar energy is used when the temperature in the absorber is greater to 383° C. however as design criterion, is selected to fill it the total needs by solar energy when the direct solar radiation are maximum, in the month of smaller sunstroke. As value of maximum direct solar radiation for the city of Mexico during month of December, was selected the day 10th, for this day is calculated the radiation level and was obtained 367.64 W/m^2.

4. ABSORBER CHARACTERISTICS

The surface system of receptor-receiver that is proposed is of the parabolic type as the one which is shown in the figure 3, for the one which has been developed its basic equations (e.g. Léon, 1995):

$$\frac{D_A}{D} = \left[\left(1-\frac{2F}{D}\right)\left(1-\left(\frac{D}{4F}\right)^2\right)\mathrm{tg}\left(2\,\mathrm{arctg}\left(\frac{D}{4F}\right)+16\right)\right] \quad (1)$$

$$\gamma = \mathrm{arctg}\left(\frac{D}{4F}\right) \quad (2)$$

Taking that the greater possible concentration efficiency is obtained when F/D is equal to 0.6 (e.g. Almanza, 1980), taking into account to the diameter of the parable is of 7m.

$$\frac{F}{D} = 0.6 \quad \Rightarrow \quad F = 0.6(D) = 0.6(7) = 4.2 \qquad (3)$$

Substituting the value of F in the equation (1), has:

$$D_A = 0.06627\text{m} \approx 6.63\text{cm} \qquad (4)$$

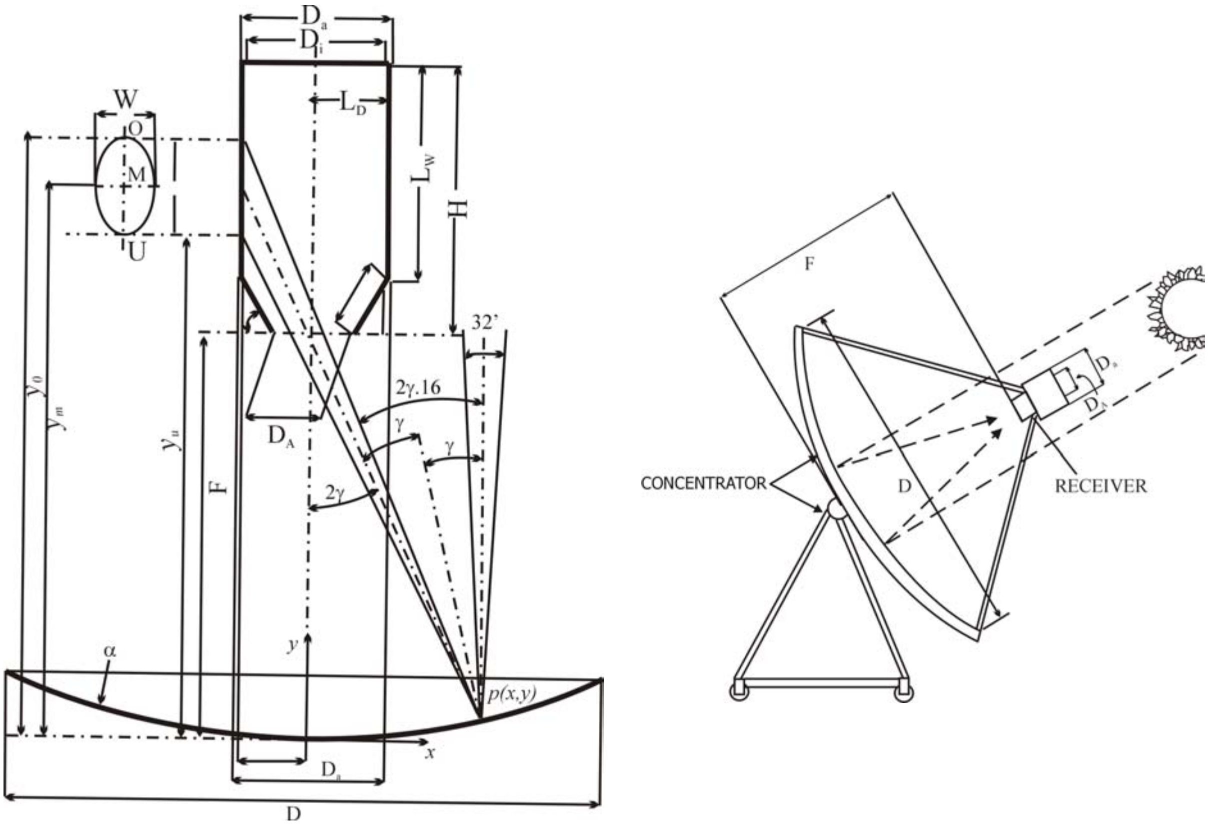

Figure 3. Plan of receiving parable.

Table 4. Efficiencies of the surface system of receptor-receiver.

Receiver surface efficiency:	90%
Absorber efficiency:	86%

5. CAPTATION SURFACE

Considering the following efficiencies, it can be determined the total efficiency of the system of gas turbine with solar generation:

Table 5. Efficiencies to calculate the total efficiency.

Reflection (ρr)	80%
Focal point of the absorber (F)	82%
Approach (E)	90%
Design parameters (η_D)	86%

Parabolic disk (η_{Con})	90%
Electrical generator (η_{EG})	96.6%
Short speed (η_V)	96%

$$\eta = (\rho r)(F)(E)(\eta_D)(\eta_{Con})(\eta_{Com})(\eta_{GT})(\eta_{EG})(\eta_V) \quad (5)$$

$$\eta = 0.280624 = 28.1\% \quad (6)$$

To calculate the necessary area:

$$A = \frac{P_R}{\eta I_b} \Rightarrow A = \frac{500{,}000}{(0.280624)(367.64)} = 4{,}846.43 m^2 \quad (7)$$

To fill the total of the needs of thermal flow to produce 500 kWe by solar energy agreement energy to the criterion selected, and taking the characteristics of the absorber, is needed a solar field with surface of 4,846.43m^2.

6 CONCLUSIONS

In this work was presented the design of a solar plant for power generation as of gas turbine, considering that this can be applied in modular form. The design has been for 500KWe, and it has been made considering the criterion of covering the total of energy by solar energy when the solar radiation is maximum in the month of smaller sunstroke.

NOMENCLATURE

- A Area need for solar field
- D Diameter of the receptor
- D_A Diameter of the receptor aperture
- E Approach
- F Focal point absorber
- I_b Radiation
- P Pressure
- P_R Power electrical
- S Entropy
- T Temperature
- γ Aperture angle
- ρr Reflection
- η Total efficiency
- η_{com} Compressor efficiency
- η_{con} Concentrator efficiency
- η_D Design efficiency
- η_{EG} Electrical generation efficiency
- η_{GT} Gas turbine efficiency
- η_{RE} Regenerator efficiency
- η_{red} Reducing efficiency
- η_V Sort speed efficiency

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