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Analytical Study and Design of Thermal Power Plant

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Abstract: Effective energy utilization and its management for minimizing irreversibility has made human to look for energy consumption & conversion. Traditionally, our demand for energy has always come from non-renewable sources such as coal and oil. But due to the rapid depletion of these resources in the past few years is increased, our focus is slowly changing towards the renewable sources such as solar energy. Our projects aims in harnessing this energy in an efficient manner. The average irradiation receive in India is 2100 Kwh/m^2/yr. Project aims at designing a 10MW solar power plant which can generate electricity continuously for 8 hrs during daytime. It also consists of all the major parts of the power plant system i.e., energy sources and power conversion systems.

Keywords: solar Declination angle, Azimuth angle, Reynolds number, etc.

1. Introduction

The term green energy can be described as the energy that is considered environmentally friendly and pollution free such as wind energy, solar energy, hydroelectric energy, ocean thermal energy etc. Green energy are named 'green' because they perceive low carbon emission and thus less pollution. It is commonly thought that green energy is mostly used in electricity generation. With the advancement of green energy now it is commonly used in electricity generation at small as well as large scale. Consumers and organization purchase green energy too support further development and help to reduce environmental impact of conventional power generation.

Most of the developing countries like Asia, Africa and Latin America where half the population is without electricity and solar energy is usually abundant. A number of projects have been developed in India, Egypt and Morocco. According to international energy agency investment needed for electricity generation will be increased to trillion euro. Exceed of co_2 emission in atmosphere has already been reached. We must take the advantage of using renewable energy resources that are easily available today. Today, questions of energy infrastructure must be thought of in Indian terms. So it's the need of hour to work on these renewable technologies before it's too late and this project is a first step taken by us towards a sustainable development in the energy sector.

2. Literature Review

Availability of cheap power is an index of technological advancement and standard of living of a country. Conversion of solar energy into mechanical or electrical energy has been the subject of research for nearly last four decades. Most of research was conducted on solar electrical generation for power generation and was abandoned not due to technological reasons but more due to economically more viable and cost effective power options. It is hoped that solar generated power will play a significant role by the beginning of the next century. One of the most promising methods of collecting and converting solar energy into electricity is the CSP (concentrating solar power), systems use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electrical power is produced when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermo chemical reaction.

In 1866**, Auguste Mouchout [1]** used a parabolic trough to produce steam for the first solar steam engine. The first patent for a solar collector was obtained by the Italian **Alessandro Battaglia [2]** in Genoa, Italy, in 1886. Over the following years, inventors such as John Ericsson and Frank Shuman developed concentrating solar-powered devices for irrigation, refrigeration, and locomotion. In 1913 Shuman finished a 55 HP parabolic solar thermal energy station in Maadi, Egypt for irrigation. The first solar-power system using a mirror dish was built by **Dr. R.H. Goddard[3]**, who was already well known for his research on liquid-fueled rockets and wrote an article in 1929 in which he asserted that all the previous obstacles had been addressed.

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Professor Giovanni Francia (1911–1980)[4] designed and built the first concentrated-solar plant, which entered into operation in Sant'Ilario, near Genoa, Italy in 1968. This plant had the architecture of today's concentrated-solar plants with a solar receiver in the center of a field of solar collectors. The plant was able to produce 1 MW with superheated steam at 100 bar and 500 °C. The 10 MW Solar One power tower was developed in Southern California in 1981, but the parabolic-trough technology of the nearby Solar Energy Generating Systems (SEGS), begun in 1984, was more workable. In India the first Solar Thermal Power Plant of 50kW capacity has been installed by MNES following the parabolic trough collector technology (line focussing) at Gwalpahari, Gurgaon, which was commissioned in 1989 and operated till 1990, after which the plant was shut down due to lack of spares. The plant is being revived with development of components such as mirrors, tracking system etc.

In addition a commercial power plant based on Solar Chimney technology was also studied in North-Western part of Rajasthan. The project was to be implemented in five stages. 6In the 1st stage the power output shall be 1.75MW, which shall be enhanced to 35MW, 70MW, 126.3MW and 200MW in subsequent stages. The height of the solar chimney, which would initially be 300m, shall be increased gradually to 1000m. Cost of electricity through this plant is expected to be Rs. 2.25 / kWh. However, due to security and other reasons the project was dropped. A Solar Thermal Power Plant of 140MW at Mathania in Rajasthan, has been proposed and sanctioned by the Government in Rajasthan. The project configuration of 140MW Integrated Solar Combined Cycle Power Plant involves a 35MW solar power generating system and a 105MW conventional power component and the GEF has approved a grant of US$ 40 million for the project. The Government of Germany has agreed to provide a soft loan of DM 116.8 million and a commercial loan of DM 133.2 million for the project

3. Problem Formulation

Traditionally, our demand for energy has always come from non-renewable sources such as coal and oil. But due to the rapid depletion of these resources in the past few years, our focus is slowly changing towards the renewable sources such as solar energy. So our project focuses on harnessing this energy in an efficient manner so that it can be used for generation of electricity. The average irradiation receive in India is 2100 KWh/m2/year. Hence India has tremendous potential to harness solar energy. **The opted project aims at designing a 10 mw solar power plant which can generate electricity continuously for 8 hrs during daytime.** The design also consists of all the major parts of the power plant system i.e. energy sources and power conversion systems. Solar thermal power plants are different from the conventional coal fired or nuclear power plant in the sense that the energy source applied are different.

4. Designing Process

We broke the whole design in two parts

1. Preliminary design
2. Detailed design

We followed reverse design process in which we first calculated energy conversion side calculations and then the solar side calculations

Figure 4.1 Flow chart

4.1 Preliminary Design:

In the preliminary design we followed the reverse design process. It means that we first design the end component of the plant i.e. the generator and then turbine, boilers, absorber tubes, collector. In this design we have assumed suitable data for different components of the power plant like heat exchanger turbines generators reflector efficiency etc. the purpose of this design is to find some of the basic calculations. These calculations will help us in designing the further system. With the help of the suitable data we can know approximate solar irradiation requirements. The assumed data have been taken from some credible sources.

Technical Details

Before doing calculations certain assumptions are necessary to take here.

1) There is no transmission loss in supplying the electricity.
2) No frictional losses in pipes and other parts of the plants.

3) No internal fluid friction.

The calculations for different major components are listed as follows

Generator Calculations: as we have set a target of generating 10 MW power so generator must generated at least a little above 10 MW in the final designing. But as if now we only making a preliminary design using a 10 MW generator we assume we are generating the required capacity and feeding it to the grid.
Now taking generator efficiency as 90%

The required amount of power needed by the generator to rotate at 3000 rpm (to produce electricity at 50 Hz = (10/.9) MW =11.111MW **Turbine**

Calculations:

Assumptions

1) Taking 50% reaction turbine
2) There is no leakage of steam
3) No steam friction losses in nozzles
4) No mechanical losses.

The energy input to the turbine
=(11.111/.35)MW
= 31.7460 MW

Heat Exchanger Calculations

Boilers efficiency about 60%
Energy supplied to boilers = 31.7460/.6 MW
= 52.91 MW

Absorber Calculations

Taking heat transfer properties with, an absorptivity of 0.96 for direct beam solar radiation.
Solar energy incident on absorber tube = 52.91/.96
= 55.1146
Taking transmitivitty as .98 total solar energy incident on outer glass of tube
= 55.1146/.98 MW
= 56.2394 MW
Now taking reflection efficiency of a high mirror quality as 97% (LS-3 collectors by LUZ System)
Irradiation falling on mirror = 56.2394/.97 MW
= 57.9787 MW

Reflector area calculations

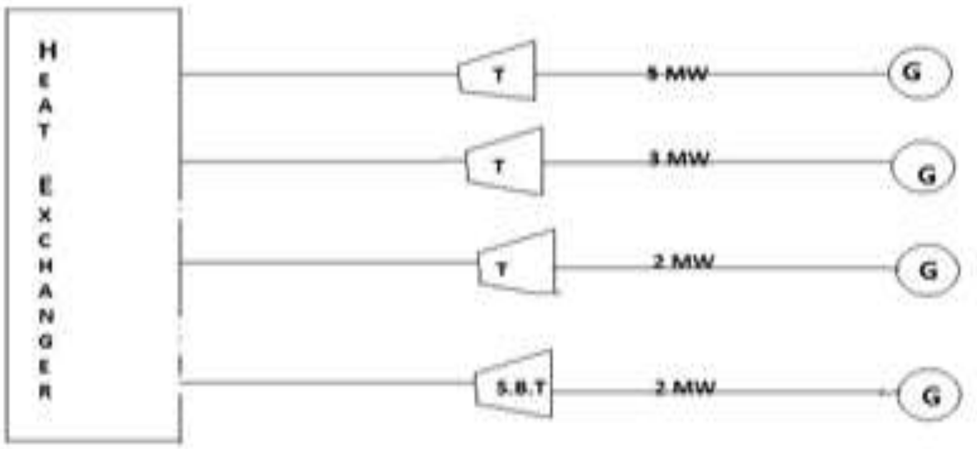
Total reflection surface area required (without considering the curvature of the mirrors)
Considering the plant site at Jodhpur India (site latitude 26° N) annual DNI
= 2200 KWh/m^2

Now assuming sunshine 7 hrs per day. Total amount of energy per unit area per unit sec will be = .8610 KWh
So the total collector area required = (57.9787÷.8610)×10^3 m^2
= 66.3345×10^^{3}m^2
The collector surface area collected above is just an approximation based on some real data obtained from different sources. The actual data considering most of the real world conditions will be taken in the detailed design.

4.1.1 Turbine design/installations

We are using 4 turbines to improve the power factor of the power plant to improve the plant factor.
The specifications of turbines are as follows:

1) 5 MW steam turbine- 1 unit
2) 3 MW steam turbine- 1 unit



3) 2 MW steam turbine- 2 unit

One of the 2 MW turbine unit will be used as standby to take up increased steam production rate.

Turbine calculations

Taking inlet conditions as 40 bar pressure and 350ºC steam temperature
Entropy of steam at 40 bar pressure and 350ºC temperature
S_1= 6.5870 KJ/Kg-K
Enthalpy of steam at inlet condition
$H_1= h_g + c_p(t_{sup} - t_{sat})$
From the steam table directly
H_1= 3095.1 kg/kg

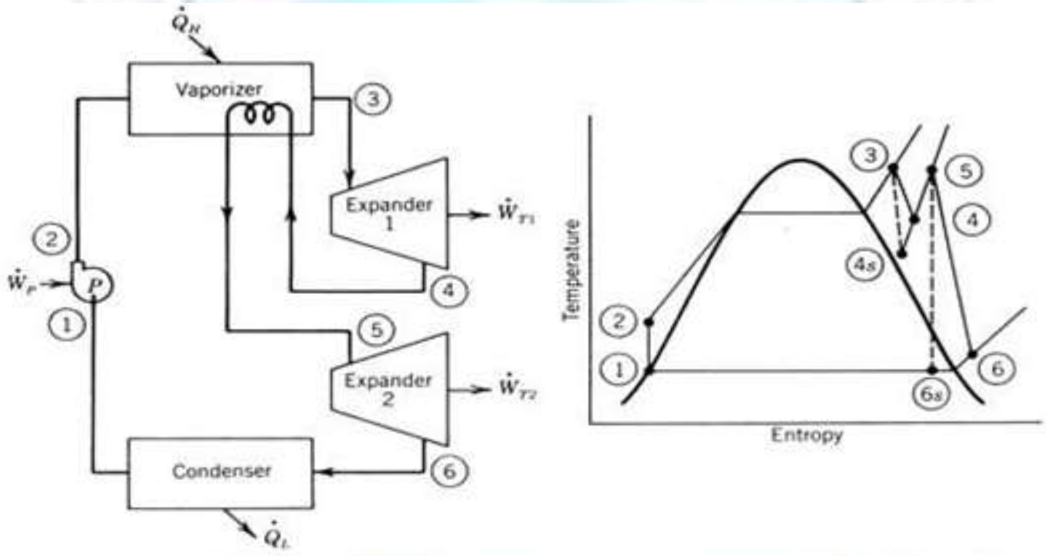


Figure 4.2 Entropy vs Temperature for Turbine

Steam condition at outlet
$S_1=S_2$
$S_2=S_f+xS_{fg}$
6.5870= .6493 + x(7.5018)
x=.79
where S_{f2} is the enthalpy of saturated water at condenser pressure
andS_{fg} is the enthalpy of vaporisation at condenser pressure
and x is the dryness fraction.
Net work done = $h_1 - h_2$
= 3095.1-2082.22
=1012.88kj/kg

Mass flow rate calculations for 5 mw steam turbine
m=power output/work done
=5x10^6/1012.88x10^3
= 4.936kg/sec
Mass flow rate calculation for 3 MW steam turbines
= 3x10^6/1012.88x10^3
= 2.962 Kg/sec
Mass flow rate calculation for 2 MW steam turbines
= 2x10^6/1012.88x10^3
= 1.974 kg/sec
For generating 10 MW of electricity total mass circulated = $m_1 + m_2 + m_3$
=4.936 + 2.962 + 1.974= 9.872 Kg/sec

Turbine calculations with reheat cycle

Taking previous conditions and taking reheat pressure as 10 bar
So from the steam table enthalpy at 10 bar saturated steam
H_{g2}=2776 KJ/Kg
On reheating the steam at the outlet of high pressure turbine and resupplying it to the low pressure turbine
Entropy at 10 bar and 350ºC
S_3=7.3031 KJ/Kg-K
Enthalpy at 10 bar and 350ºC
h_{sup}= 3158.5 KJ/Kg
Steam conditions at outlet of low pressure turbine
Taking condenser pressure as .1 bar
We know $S_3 = S_4$
7.3031 = .6493 + x(7.5818)
X= .87
Enthalpy at turbine outlet =
H_{g4}= 191.83 + .87(2392.8)
H_{g4}= 2273.5KJ/Kg
Total work done= W_1+W_2
3095.1 – 2276 + 3158.5 – 2273.5
=1204.1 KJ/Kg
From the steam table heat input during reheat
= 3158.5 – 2776
=382.5 KJ/Kg
Taking boiler feed temperature as 25ºC
Enthalpy $\mathbf{h_{f5}}$ = 104.77 KJ/Kg
Heat supplied **Q**= 3092.1 – 104.77
= 2987.3 KJ/Kg
After taking heat from economizer and raising the temperature of feed water to 65ºC
Enthalpy at 65°$_C$ $\mathbf{h_{f5}}$ = 272.02 KJ/Kg
Heat supplied in the boiler **Q'** = 3092.1 – 272.02
=2819.93 KJ/Kg

Comparing efficiency in both cases
η_1 = total work done / total heat input
= 1204.6/(2987.3+ 382.5)
= 35.7%
η_2 = total work done / total heat input
= 1204.6/(2819.9+ 382.5)
=37.59%
So by employing reheat cycle and increasing the feed water temperature the efficiency is increasing.

4.1.3 Design of condenser

Inlet temp to condenser = 81.345 °C
Pressure = .05 bar
Steam to be condensed in condenser/ MW hr= 1.883* 3600
M° c = 6778.8 kg/hr

For 5 MW =M° c *5 = 9.415 kg
For 3 MW =M° c *3 = 5.649 kg
For 2 MW =M° c*2 = 3.766 kg

For condenser

Heat gained by water = Heat lost by steam
Mass of steam flowing = 1.883 kg/s

Heat lost by steam
$Q = M_s(H_2 - H_{f2})$
= 9.415(2695.2 – 340.56)
= 22.169* 10 ^{3} kg/sec

Heat flow is also given by

Q= Uo * A (LMTD)

$$\frac{1}{Uo} = \frac{1}{hi} * \frac{do}{di} + \frac{1}{ho}$$

$$\frac{1}{Uo} = \frac{1}{1000} * \frac{2.9}{2.5} + \frac{1}{5000}$$

$$\frac{1}{Uo} = .00136$$

Uo=735.3 KW/m^2 ^{0}C

$$LMTD = \frac{(\theta_1 - \theta_2)}{\log\left(\frac{\theta_1}{\theta_2}\right)}$$

$$LMTD = \frac{[(81.345 - 25) - (81.345 - 35)]}{(\log e(81.345 - 25)/(81.345 - 35)}$$

LMTD = 51.18 C
Substituting values

Qs = U$_o$* A(LMTD)
22.169* 10^3 =753.3* As * 51.8
As = 566.53 m^2

No. of Tubes (N)
$As = \frac{\pi}{4} * do * L * N$ Eqn.(4.29)
N = 497.7
= 498 tubes

Mass of water required / MW

$\mathbf{M_w * C_{pw} (T_o - T_m) = M_s (H_3 - Hf_3)}$
M_w* 4.187* 10 = 1.883 (2695.2 – 340.56)
= 105.89 kg/s
= 105.89* 3600
= 3.81*10^5 kg/hr

If there is 5°C of under cooling of the condensate then

$Mw * C_{pw}(T_{wo} - T_{wm}) = M_s(H_3 - H'f_3)$
Where $H'f_3 = C_{pw}(T_o - 0)$

C_{pw} is the specific heat of condensate and T_c is the temp of the condensate and of the condenser
T_c = T_5 – 5 = 81.345- 5= 76.345
Hf_3 = C_p*T = 4.2* 76.345
= 320.649 KJ/KG

Now substituting the above values in the equation
M_w* 4.2* 10 =1.883* 3600(2695.2 – 320.649)
M_w = 3.83 *10^5 Kg/Hr

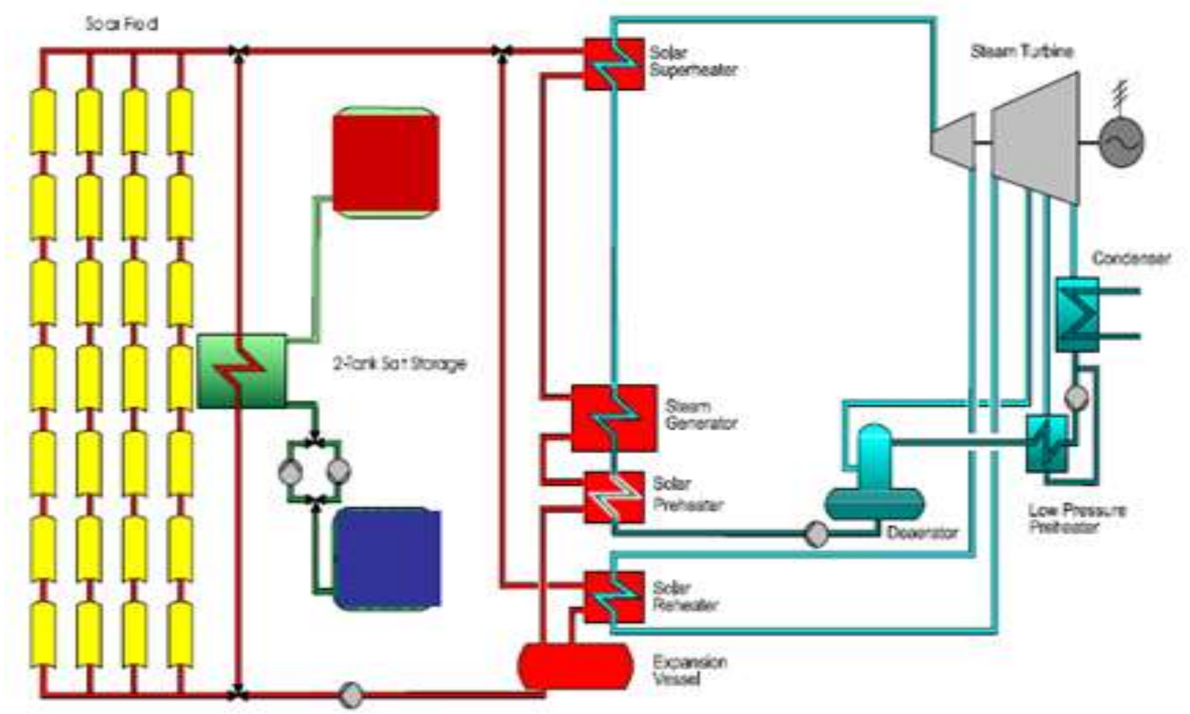


Figure 4.4 Plant Layout

4.2 Detailed Design:

4.2.1 Specification of Generator

Table 4.1: Generator Specification

Type of Generator Used	**3-Phase Synchronous**
No. of Poles	4
Speed	1500 RPM
Frequency of Generated EMF	50 Hz
Diameter of Rotor	1.2 m
Rating of the Generator	1000 MVA
Nature of the Field	Revolving field
Rotor	Smooth Cylindrical
Field System Exciter (Small DC Shunt gen.) Rating	0.3 -1% of Syn. Generator
Rated Voltage of Exciter	125 to 250 V

Redesigned Final System Calculations

After searching through reference books and on performing a brief economic analysis we found that the reheat cycle is not viable in plants less than 30- 40 MW so we omitted that option. Again on selecting a new heat transfer fluid which is more economical, we had to change our inlet conditions to suit the fluid properties. The final design calculations are as follows.

Inlet condition:

Pressure =25 bar, temp. =275°c.

Entropy (S) $= S_v + S_{pv}*\ln(T_{sup}/T_s)$
$= 6.2536 + 2.3*\ln(275/223.94)$
$= 6.2536+2.3*.2053$
$= 6.7258$ Kj/kg K.

Isentropic expansion to .05 bar:

$S_2 = S_1$
$S_2 = 6.725 = S_f + X*S_{fy}$
$= 0.4763+x*(7.9197)$
$X = 88.9\%$

Now again taking 90% isentropic efficiency

$h_1 = 2800+C_p(T_{sup}+T_s)$
$= 2800+2.3*(275-223.94)$
$= 2917.4$ Kj/kg
$S_2 = S_1$

$$X = \frac{(6.725 - .6493)}{7.5018}$$
$=0.9098$

$\eta = 90\%$
$h_2' = h_1-0.9*(2917.4-2129.6)$
$=2208.38$Kj/kg
$h_2' = h_f + x*2392.9$
X =94.2%

Enthalpy at outlet = 2208.38 kj/kg
Net drop = 2917.4 -2208.38
=709.02 kj/kg
Total mass flow rate$=\frac{power}{(h1-h2)}$ Eqn. (4.33)
$=(10*10^3)/709.02$
= 14.10kg/s.

Taking generator efficiency 96% & mechanical efficiency 99%

Mass flow rate$=\frac{14.1}{0.99*0.96}$
=14.835 kg/s
Mass flow rate in 5 MW turbine = $\frac{5*14.835}{10}$= 7.4175kg/s
Mass flow rate in 3 MW turbine = $\frac{3*14.835}{10}$= 4.45 kg/s
Mass flow rate in 2 MW turbine = $\frac{2*14.835}{10}$= 2.967 kg/s

4.2.2 DESIGN OF CONDENSER:-

Inlet temperature of condenser = 45.833˚c
Pressure = 0.1bar
Steam to be condensed in the condenser/hr. = m_s *3600
= 14.835*3600
= $53.39*10^3$ kg-hr.

Heat lost by steam

$Q = m_s(h_2-hf_2)$
= 14.833*3600*(2208.38-191.83)
= $107.68*10^6$ kj/hr.

Heat flow is also given by:

Q = U*A*(LMTD)

$$\frac{1}{U} = \left(\frac{1}{hi}\right)\left(\frac{d0}{di}\right) + \frac{1}{h0}$$

Taking internal diameter = 2.5cm
Outer diameter = 2.9cm
Length= 5m

$h_i = 1000 w/m^2$
$h_o = 5000 W/m^2$

$$\frac{1}{U} = \left(\frac{1}{1000}\right)\left(\frac{2.9}{2.5}\right) + \frac{1}{5000}$$

= .00136
U = $735.30 W/m^2$

$$= \frac{(45.833-25) - (45.833-35)}{ln\frac{(45.833-25)}{(45.833-35)}}$$

$$= \frac{10}{ln\frac{(45.833-25)}{(45.833-35)}}$$

$$= \frac{10}{.65}$$

= 15.291˚c.

Q = U*A*(LMTD)
29111 = 735.3*A*15.29
A = $2.661*10^3 m^2$
A = $\pi.d_0.L.N$
N = $\frac{2.661*103}{\pi*2.9*10-2*5}$
= 584.4
= **585 Tubes**

4.2.3 HEAT EXCHANGER DESIGN

Reynolds number for tube side flow= $\frac{\rho V d}{\mu}$
= (1000* 2* 14.834)/0.4342
= 68327

Prandtl Number= $\mu\frac{Cp}{K}$
= (0.4342* 4.187)/0 .635
= 2.862

$$Nu = \frac{Hi*Di}{K} = 0.023*(Re^{0.8})*(Pr\ \hat{}0.33)$$

Also $Hi*\frac{di}{k} = 0.023 * 6832^{0.8} * 2.8582\hat{}0.33$

$$Hi = 32.0445\ W/m\hat{}2K$$

$$\frac{1}{U} = \frac{1}{Hi} + \frac{Riln\left(\frac{Ro}{Ri}\right)}{K} + \frac{1}{Ho}(4.42)$$

$$\frac{1}{U} = \frac{1}{32.0445} + \frac{7.417*10\hat{} - 3ln\left(\frac{9.525}{7.417}\right)}{384} + \frac{1}{1100}$$

$$U = 1278.9\ W/m\hat{}2C$$

LMTD $$\theta m = \frac{\theta 1-\theta 2}{ln\left(\frac{\theta 1}{\theta 2}\right)}$$

$$\theta m = \frac{(320-275)-(100-65)}{ln\left(\frac{45}{35}\right)}$$

LMTD = 39.79 ° C
Total Heat Transfer Q = Uo* Ai* θ_m
M* C* ΔT = 12778.4 * Ai* 39.79
Total tube Surface Area Ai = 140.86 m²

No. of Tubes (N),
Ai = π* Do* L* N
N = 393 Tubes

4.2.4 Basic Solar Calculations

We are finding out solar values for only one day and can develop the whole system on the basis of that in future by employing suitable interpolations and extrapolations.

The Plant Site is at Ahmadabad in Gujarat State, INDIA, for which latitude is 23.07N and longitude 72.63E. Basic calculations are as follows. Standard Values are taken from Reference Solar Data Hand Book. Important calculations and tables are

CO-ORDINATES OF USED STATION

Table 4.2: Coordinates of station

STATION NAME	ABBREVIATION USED	LATITUDE		LONGITUDE		ELEVATION m.a.s.l
		°	'N	°	'E	
AHMEDABAD	AHM	23	04	72	38	55

COMPARISON OF COMPUTED AND OBSERVED VALUES OF DIFFUSE SOLAR RADIATION

Table 4.3: Comparison of Computed and observed values of diffuse solar radiation

STATION		JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV
AHMEDDAB	CALC.	1.10	1.26	1.99	2.15	2.13	2.89	3.32	3.21	2.72	1.6	1.18
	OBS.	1.17	1.43	1.74	2.18	2.33	3.16	3.48	3.24	2.53	1.43	1.12
	% DIFF	6.6	11.7	14.6	1.6	8.5	8.8	4.6	0.8	7.4	11.3	4.9

Solar declination angle (δ)
$\delta = 23.45\, sin\,(360 * (\frac{284+n}{365})$

Taking day as 15 august as it has minimum beam radiation.
N o. of days = 31 + 28 +31 + 30 +31 +30 +31 +15
= 227 days
$\delta = 23.45\, sin(\, 360 * (\frac{284+227}{365})$
= 13.78°

Daylength:
If Collector is tilted at an angle of latitude +15° then angle made by beam radiation or collector at noon:
Hour angle at noon = 0°
δ = 13.78°
$cos\theta = cos(\Phi - s)\, cos\delta cosw + sin(\Phi - s)\, sin\delta$ $= cos\,(23.07 - (23.07 + 15.cos13.78.cos0 + sin13.78.sin\{(23.07-23.07+15\}$
$Cos\theta_t = .876$
θ = 28.83°
At the time of sun rise and sunset the zenith angle Φ_z=90°
Day length $= w_s = cos^{-1}(-tan\Phi . tan\delta)$
$=cos^{-1}(\,-tan23.07.\,tan13.78)$
$cos^{-1}(-.104) = 95.9$
Day length:
$T_d = \frac{2ws}{15}$
$= \frac{2*95.99}{15}$
T_d = 12.79 hrs

For inclined surface at(Lat +15°)

$$W_{st} = \cos^{-1}(-\tan(\Phi - s).\tan\delta)$$
$$= \cos^{-1}(-\tan(23.07 - 15).\tan(13.75))$$
$$= \cos^{-1}(-.141 * .245)$$
$$= 88.01$$
$$T_d = \frac{2*ws}{15} = \frac{2*88.01}{15} = 11.73 \text{ hours}$$

Solar Field Calculations:

Taking into account shading of some part of the collector by the receiver

Aa = (2.5 -0.9)* 10
= 24.1 m²

Calculating Fr:

$$F'' = \frac{Fr}{F'} = \frac{mcp}{ArUlF'}\{L - \exp\left(\frac{ArUlF'}{mcp}\right)\}$$
$$F' = \frac{1}{Ul}/\{\frac{1}{Ul} + \frac{Do}{hfiDi} + \left(\frac{Do}{2K}\ln\frac{Do}{Di}\right)\}$$
$$F' = \frac{\left[\frac{1}{3.82}\right]}{\left[\frac{1}{3.82} + \frac{0.060}{(300 * 0.050)} + \left\{\frac{0.060\ln\left(\frac{0.06}{0.05}\right)}{2 * 16}\right\}\right]}$$
$$= 0.984$$

Then Fr

$$\frac{mCp}{ArUlF'} = \frac{.0537*2674}{1.82*3.82*.982}$$
= 21.22
F" = 21.22*(1- e^(1/21.22)
Fr = F" * F'
= .964

Average Beam Radiation on surface at Ahmadabad.

Table 4.4 Average Beam Radiation

Month	Jan	Feb	mar	Apr	May	June	July	Aug	Sept	Oct	Nov	dec
Radiation/m2/day	3.73	4.63	4.94	6.15	5.28	2.91	1.37	1.28	3.02	4.34	3.88	3.98

We are taking only one value which is minimum in previous table. i.e. august month.

Useful Gain

$$\mathbf{Q_u} = F_rA_a\{s - \frac{Ar}{Aa}Ul(Ti - Ta)\}$$

$$\mathbf{Qu} = 24.1 * .964\ 44.1 - \frac{1.88*10.6}{24.1}(100 - 25)$$

= 23.23 * 106.11
= 2465,0

Fluid temperature rise

$$\Delta T = \frac{Qv}{mep}$$
$$= \frac{2465}{.0028*2647} = \mathbf{33.25}°C$$

$$\text{Temperature at exit} = 100 + 33.25 = 133.25°C$$

Average temperature drop outside of receiver to the fluid

$$\mathbf{Tr_o - T_f} = Q_u\{\frac{1}{\pi DroLhfi} + \frac{\ln\left(\frac{\Delta ro}{\Delta ri}\right)}{2\pi krecL}\}$$
$$= 246\ 5\{\frac{1}{\pi*.05*10*300} + \frac{\ln\frac{.06}{.05}}{2\pi*16*10}\}$$
= 5.68°C

Average Receiver temperature

= { $\frac{100+133.25}{2}$ } + 5.68°C

=122.3°C

So rise in temperature in one trough = 22.3°C
Hence no of troughs = $\frac{220.2}{22.3}$ = 10 (approx)

Length of field
= 10*10 = 100m

Width of field
= $\frac{2264.15}{1000}$ = 2.264 km

5. Cost Analysis

System cost summary

Capital investment costs
1. Cost- \$ 0.5497*10^8
2. Unit cost- \$ 5497.24 / KW
3. LEC/kwh – 10.30 cents

Operation & Maintenance costs
1. Cost - \$ 0.1607*10^7
2. Unit cost – \$19.80/ m^2
3. LEC cost/kwh – 3.53 cents

Total levellized energy costs – 13.81 cents

Capital cost breakdown

Concentrator cost

1. Cost -\$ 0 .1120*10^8
2. Unit cost – \$ 138.00 / m^2
3. LEC cost – 2.10 cents
4. Cost - \$ 0.7055 *10^7
5. Unit cost – \$ 86.94/ m^2
6. LEC cost 1.32 cents

Pipe and Auxiliary Equipment cost

1. Cost - \$ 0.1232 *107
2. Unit cost – \$ 15.18 /m^2
3. LEC cost - 1.23 cent
4. Turbine costs
5. Cost - \$ 0.1003* 108
6. Unit cost -\$ 1003.26 /KW
7. LEC cost – 1.87 cents

Cost - \$ 0.5851*107
1. Unit cost -\$ 585.12/KW
2. LEC cost – 1.16 cents

Indirect and contingencies

1. Cost - \$ 0.1424*10^8
2. Unit cost – \$ 1424.16/Kw
3. LEC cost – 2.67 cents

Conclusion

The advantages of solar power include its abundance and little operational maintenance. However, while efficiency rates continue to improve and prices drop, solar energy still does not compare to fossil fuels and, subsequently, remain key limiting factors in expanding its use. The technologies often require a large initial investment, they can take up a large area of land, and material production shortages – including that of precious metals – can raise the costs further.
CSP plants are a fixed-cost generation resource and offer a physical hedge against the fluctuating cost of electricity produced with natural gas. Each CSP plant provides emissions reductions compared to its natural gas counterpart. The economic and employment benefits, together with delivered energy price stability and environmental advantages, suggest that the CSP solar alternative would be a beneficial addition to California's energy supply. While early CSP plants are more costly than their traditional gas counterparts, subsequent plants are estimated to become nearly cost competitive on a levelized cost of energy basis. Despite the many challenges that remain, solar power continues to be heavily researched, and the technologies updated, in order to achieve more cost-effective and reliable solar power systems in the future. The level of direct investment in renewable energy plants worldwide needs to at least quadruple to approximately 500 billion Euros each year to slow down the increasing demand for fossil fuels and stabilize global CO2 emissions.

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