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Performance Evaluation of Solar Parabolic Trough for Cloths Laundry application

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Abstract- Solar thermal technology installation has enabled to use a completely free and clean form of energy. Because of this diesel consumption in many industries can be saved and hence can positively affect the environment. In this paper particularly laundry of cloths application is evaluated as this process conventionally used diesel in large quantities and hence makes suitable for the use of solar thermal technology.

Key Words: Solar Thermal, Parabolic Trough, Collector, Laundry, Steam, Renewable energy, Solar Energy

Introduction

Thermal or heat energy from the sun can be utilized or converted in one form or another to meet the suitable requirement or application such as cooking, electricity generation, etc. there are two types of radiation that we deal in Solar Thermal Designing: DNI (Direct Normal Incidence) & GHI (Global Horizontal Incidence). Water Heating Parabolic-trough is a proficient technology of renewable energy for heating applications. In India Direct Normal Incidence is also high which makes this technology much more suitable. Hot water applications can be used at various places such as temples (Meal preparation), Hotels, Cloths laundry, etc. This technology has a good payback as compared to Solar PV technology. There are various types of Solar concentrating thermal technologies which includes Linear Fresnel, compound parabolic, paraboloid dish, solar tower, flat plate collector.

Solar Concentrator Parabolic Trough

Solar thermal collectors can be considered as a heat exchanger which transforms solar direct irradiation to enthalpy of the fluid medium in the tube. Following are the main components of Solar Thermal Collector

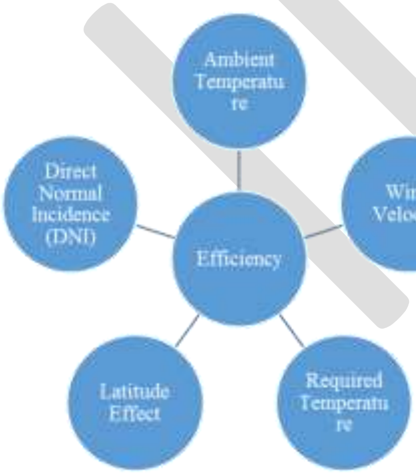


Fig 1: Factors effecting Efficiency of Solar Thermal Technology

- **Collector:** Receives or collects the sun radiation convert it to heat and directs or concentrates it to the receiver
- **Receiver**: It is a glass tube in working fluid which circulates and gains the heat from the collectors and transfers it to the desired equipment or heat storage tank
- **Fluid:** It can be organic fluids, water, heating oil, etc.
- **Tracking:** E-W tracking or N-S tracking or both can be done to increase the efficiency of parabolic trough
- **Storage tank**: In case of cloudy, rainy & non-sunshine conditions heat can be stored in a storage tank.

Literature Review

A. Valan Arsau et.al (2007) [1] designed the parabolic trough with rim angle 90^o with the use of reinforced fibreglass and provide the manufacture techniques. This modal has very low drag coefficient in the acceptable range. Standard deviations of the of the parabolic surface error distribution was in the limit range of accuracy. Kalogirou et.al (2004) [2] Explains the importance of renewable energy considering environmental factors as a major issue. Author also discussed various solar thermal technologies such as flat plate collector, parabolic troughs, etc. and their applications. Krishnamurthy et.al (2012) [3] Focuses on economic evaluation of the solar thermal parabolic trough technology considering various factors such as rate of equity, discount rate, capital cost, generation cost, solar insolation and various models are compared. Omid karimi sadaghiyani et.al (2014) [4] Designed two solar collectors and evaluate and compared performance characteristics by using CFD and MATLAB. S. D.Odeh (1998) [5] Evaluate the performance characteristics of parabolic trough by considering absorber wall temperature instead of fluid bulk temperature to provide flexibility of use of any working fluid. Author used Syltherm 800 as a working fluid for experimental work. Vinay V Gadikar et.al (2016) [6] Assesses the Solar concentrator technology use in laundry purposes at Goa by detail specification discussion and also discussed about the problems and challenges faced and performance evaluation is also done. Richter et.al (1996) [7] provides the methods to improve the optical efficiency of parabolic trough which plays a great role in overall efficiency of the solar thermal technology. Price.H et.al (2002) [8] stated at low working temperature difference Concentrating solar thermal technology works with high efficiency. Many design considerations can also be improved to improve the efficiency.

Case study undertaken

Gandhinagar city is considered for the case study. It has good DNI. An industry of approximately load of 2000 cloths per day for dry cleaning is considered for the case study in this paper.

Methodology

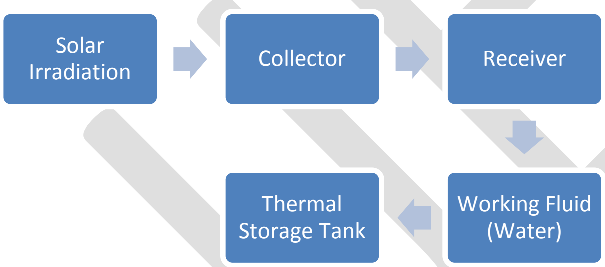


Fig 2: Methodology used in Solar Parabolic Trough

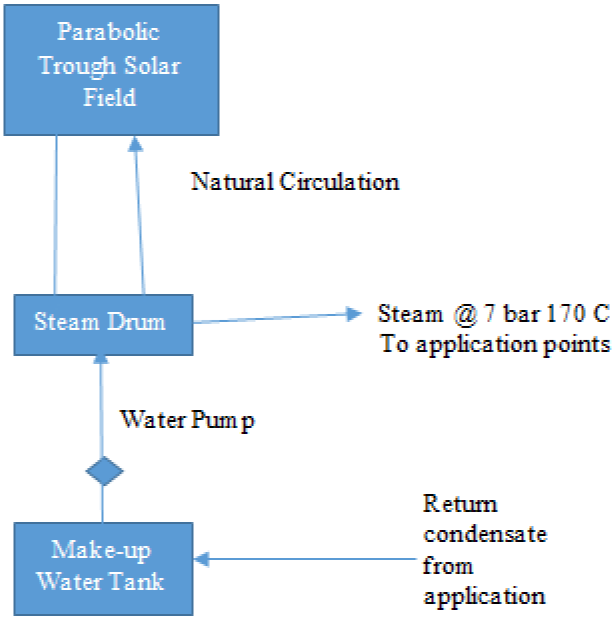


Fig 3: Schematic of Solar Parabolic Trough system

Design Considerations

Longitude: 23.2° N

Latitude: 72.6° E

No. of cloths: 2000-2500

Steam required: 2000 Kg/day

Shade free Area available for Solar Concentrator Technology installation: 80 square meters

No. of operational Hours in a year: 2700

Operating temperature: 170° C

Operating pressure: 7 bar

Table 2: Ambient Conditions Considered

Ambient Conditions		
Parameters	**Units**	
Wind Speed	m/s	3
Irradiation	W/m2	1000
Tilt Factor		1.02

Table 3: Fluid Specifications Considered

Fluid Specifications		
Parameters	**Units**	**Vapour**
Mass Flow Rate	Kg/s	0.25
Density	Kg/m3	5.147
Heat Capacity	KJ/Kg-K	2.5944

Thermal Conductivity	W/m-k	0.0364
Kinematic Viscosity	m2/s	2.91948E-06
Dynamic Viscosity	Kg/m-s	1.50E-05

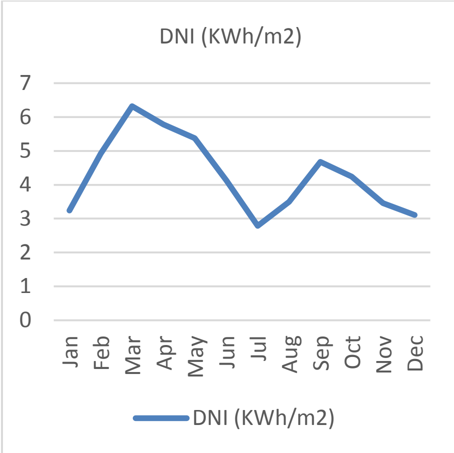
Table 4: Parabolic Trough Specifications Considered

Parabolic Trough Specifications		
Parameters	**Units**	
Outer Diameter	m	0.025
Inner Diameter	m	0.022
Outer Diameter Glass Cover	m	0.055
Inner Diameter Glass Cover	m	0.05
Aperture	m	2
Length	m	4
Aperture Area	m2	7.9
Avg. Value transmissivity-Absorbivity product for beam radiation		0.9
Specular Reflectivity of the concentrator Surface		0.95
Intercept factor (The fraction of the reflected radiation intercepted by the absorber tube)		0.95
Temperature Outlet	Celsius	65
Temperature Inlet	Celsius	30

Computation of energy potential

Table 5: Monthly Thermal Output Generation

Parameters	**Units**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Incident Beam radiation	W/m2	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
DNI	KWh/day	3.2353	4.9237	6.3184	5.7870	5.3760	4.1276	2.7863	3.4971	4.6744	4.2386	3.4537	3.1160
Overall Loss Coefficient	W/m2-K	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Useful Heat Gain	W	3907	3907	3907	3907	3907	3907	3907	3907	3907	3907	3907	3907
Thermal Units/Day	KWh	12.64	19.24	24.69	22.61	21.01	16.13	10.89	13.66	18.27	16.56	13.50	12.18
No. of Modules		8	8	8	8	8	8	8	8	8	8	8	8
Total Thermal Units	KWh/day	101	154	198	181	168	129	87	109	146	132	108	97



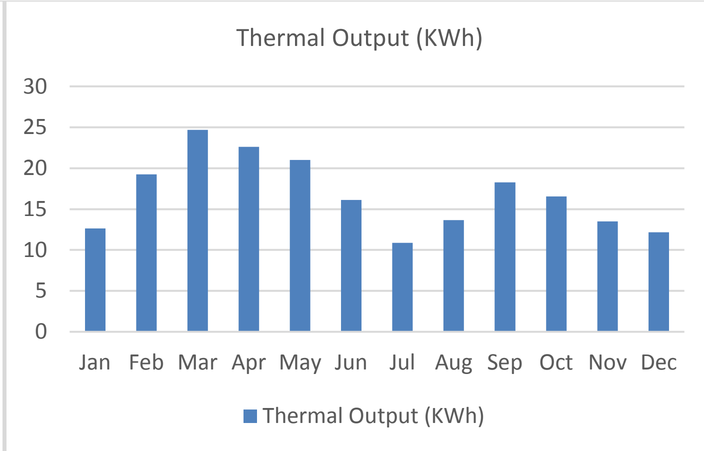


Fig 4: DNI variation with Month

Fig 5: Thermal Output with Month

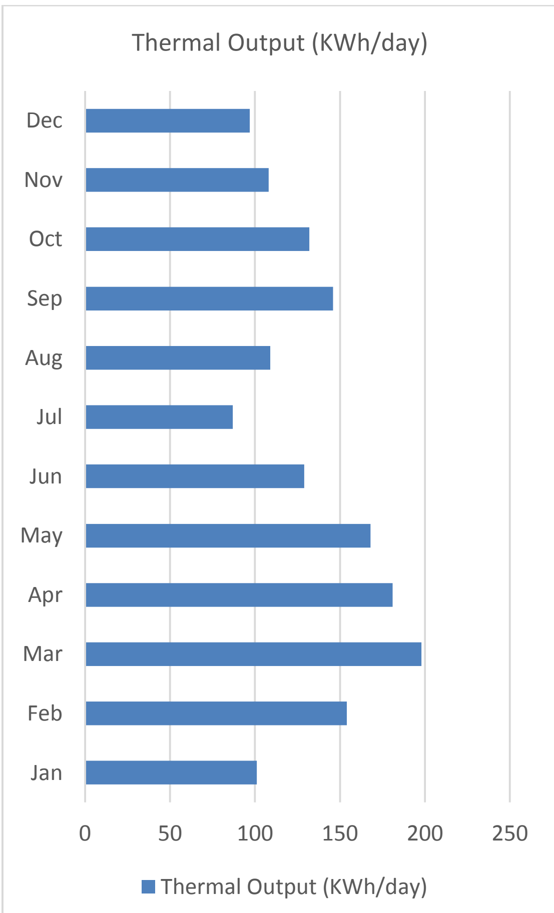


Fig 6: Thermal Output with Month

Results & discussion

15 KWh/day is produced from 8 parabolic troughs with 64 square meters of reflective area. Collector efficiency is 45 %. Concentration ratio is 27. This energy is enough to carry out laundry operation of around 2000 cloths per day. In overall 20 litres/day of Diesel is saved which provides of annual saving of 6000 Kg of LPG gas.

Conclusion

New concept of solar thermal technology has the potential to improve the efficiency of energy (i.e. the thermodynamically efficient use of fuel) supply systems, while at the same time integrate seamlessly with the use of renewable energy sources, for the delivery of the required energy in different forms in industries. Since because of various factors like clouds, dust, etc. Sun's rays reach the earth in a diffuse manner a less Direct rays is received. Solar PV technology works on GHI. While Solar thermal works on DNI. So if we use the Solar thermal output as a heat it will be more useful gain as in converting electricity much more losses occur in concentrating solar thermal technology. A fluid run through a pipe line continuously and gain heat from concentrated sun's rays by parabolic trough. Parabolic trough concentrator is such designed to achieve desire temperature difference. This fluid after gaining heat moves to storage tank where it can be utilized. After utilization again it moves to make up tank then to inlet of Parabolic Trough.

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