Review of Concentrating Solar Energies inMechanical Heat Process Applications

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Abstract:- The Indian hospitality industry is facing a shift from fossil fuel to clean energy technology. This work aims to design a solar paraboloid dish based heat system for cooking, laundry and bathing purposes. The solar paraboloid dish is designed with dual axis tracking for better efficiency. The performance of the system has been compiled with major parameters such as physical dimensions, energy generation potential, total energy requirement, integration within plant, costing of the installation and its economic analysis. The system can be installed at various hospitality industrial plants with high DNI values to make the industry more environ- ment friendly and save them from fluctuating fossil fuel prices.

Keywords:- *Hospitality Industries, SIPH System, Parabo- Loid Dish, Solar Energies, Mechanical Heat Process.*

I. INTRODUCTION

Energy is essential for economic development, and can be classified into primary, secondary, commer- cial, renewable, and non-renewable energy sources. Primary energy sources include coal, oil, petroleum gas, biomass, nuclear energy, warm energy, and po- tential energy. Secondary energy sources can be con- verted into power, coal, and refined oil based goods. Commercial energy is the foundation of mechanical, farming, transport and commercial advancement in the present day world. Non-Commercial Energy is energy sources that are not accessible in the com- mercial advertise at a cost.

Renewable energy is energy acquired from sourc- es that are basically unlimited and can be tackled without the arrival of harmful toxins. Non-renewable energy is petroleum products, which are likely to exhaust with time.

- *World Scenario* -International organizations have published a global energy scenario to help us under- stand the current energy situation and find solutions that are environment-friendly.
- *Indian Scenario* -India's total installed power generation capacity has reached 300-GW, including 57 GW of renewable energy sources. Thermal power is delivered in Coal, Gas and Diesel based power plants, while nuclear power is delivered in nuclear power plants. Inexhaustible power includes wind, biomass, bagasse, waste to-energy and sun based power.

II. LITERATURE REVIEW

The present study is an attempt to analyse solar thermal technology for steam generation to be used for laundry, in kitchen and for bathing purposes. The objectives of the thesis are to develop hospitality industry which is sustainable and environmental friendly by reducing the use of fossil fuels and maxi- mizing the use of solar energy to fulfil thermal needs of the industry. The objectives need to be achieved for successful design of solar concentrator based mechanical process heat applications in hospitality industry: to study the various heating processes in- volved in hospitality industry, to find out the tem- perature range at which thermal energy is required in these processes in what form, to design the feasi- ble concentrated solar heat (CSH) solution to fulfil thermal energy requirement in hospitality industry, to integrate designed solar industrial process heating system with existing steam generation and distribution system based on fossil fuels in hospitality indus- try, to estimate the generation potential of designed SIPH system at selected hospitality, to estimate solar fraction achieved by SIPH system at selected hospi- tality industry, and to calculate economic feasibility and payback period of the designed SIPH system.

III. TECHNOLOGIES USED

A) Paraboloid Dish Solar Collector

Parabolic dish collectors concentrate solar energy at a single focal point, allowing incoming light rays to be reflected towards the focal point. This reduces losses due to imperfections in the parabolic shape and imperfect reflection. Solar energy studies are being conducted to reduce environmental destruction caused by fossil fuel burning. Solar energy is becom-ing increasingly popular due to its clean, abundant, and non-polluting nature. It can be generated through thermal collectors or photovoltaic

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modules, and the demand for energy sources is expected to increase significantly in 2035 due to population growth.

Light collectors are capable of absorbing nearly all of the light that is directed at their opening, focus- ing a huge amount of incident diffuse radiation.

Compound parabolic collectors should be fixed at an acceptance angle of 47 degrees, covering the declination of the sun from the summer to the winter solstices. Solar water heating can be an important approach to promote free energy systems while also operating at a low cost per unit of used energy.

B) Construction of Model

The reflector is used to collect and amplify radia- tions, and the dish has a diameter of 1200 MM and a height of 150 MM when viewed from above. Adhe- sivebonded 100*100 MM square mirrors are mount- ed on the concave surface, and 25*3 mm MS strips are banded into circular arc shape. Two members of 30 MM round MS pipe are welded in a shaft mount- ed on two bearings, and a movable joint is welded at one end of the dish to provide angular moment to a 600 MM long pipe. The angle needs to be adjusted and fixed every month according to the tilt angle calculator. This work demonstrates the performance of parabolic solar collectors, which are designed and fabricated to make a commercial water heating sys- tem for house hold purposes. Experiments were done in three sets of events, with the receiver open in air and inlet water at mass flow rate 600 ML per Minute,the receiver covered with black box at mass flow rate 600 ML per Minute, and the receiver covered with a pump provided system for 20L water at average 46 degree centigrade rise in temperature in an hour.

C) Design of Dish Concentrator And Receiver

The function of the concentrator is to intercept solar radiation with a large opening i.e.aperture and reflect it on to a smaller area. The pa-rameters associated with the design of the concentrator are as follows: -

- Concentrator aperture area, Aapp Receiver aperture area, Arec
- Un shaded concentrator aperture area fraction, EAngle of incidence, Oi
- Surface reflectance, p
- Capture fraction

D) Design Calculation And Performance Analysis

Design calculations are done for solar paraboloid dish to be used for industrial process heating system by using the basic heat gain equation and equations used for Concentrator and receiver design as stated above. Basic input variable are selected and con- stants necessary for calculations are assumed from appropriate reference to calculate the daily perfor- mance of solar dish. Design performance parameters are calculated like useful heat gain rate (Quseful), geometric concentration ratio (CRg), concentrator optical efficiency (qrec) and overall system efficien-cy (noverall).

Design Parameters	Design Value
Rim Angle (0)	45
ratio	0.58
Reflectivity of solar grade mirrors P	0.92
Un shaded aperture areafraction E	0.92
Capture/ Intercept frac-tion	0.9
Transmittance t	0.9
Absorptance a	0.9
Overall heat transfer coefficient of air currentsU (W/m K) at 8.3 m/sec maximum wind velocity at Delhi	31
Receiver operating tem-perature / Temperature for steam production Trec (c)	175
Receiver cavity openingdiameter (m)	1
Equivalent radiative conductance F for selec-tive coating on receiver surface	0.3
Beam solar radiation for rated design value (w/m)	1000
Ambient temperatureTamb (oc)	30
Stefan Boltzmann con-stant 6 (W/m)	5.67 * 10

Table 1: - Design Calculation and PerformanceAnalysis

Following design parameters are now used for cal- culation for various performance parameters of 14 m diameter solar paraboloid dish. Overall heat transfer coefficient U for the selected Delhi site is calculated for the air current flowing through cavity receiver are calculated by given formula as follows :-

U = 10.45 -v + 10

Where

V = wind velocity in m/sec

Different values of U are calculated for different V values for plant at Delhi with corresponding value for maximum wind velocity of 8.3 m/sec is calcu- lated as 31 W/m K. This value is chosen for maxi-mum heat loss that is possible from cavity receiver
i.e. solar paraboloid dish is designed for worst case.

Following figure gives the values for U for different wind speeds:-

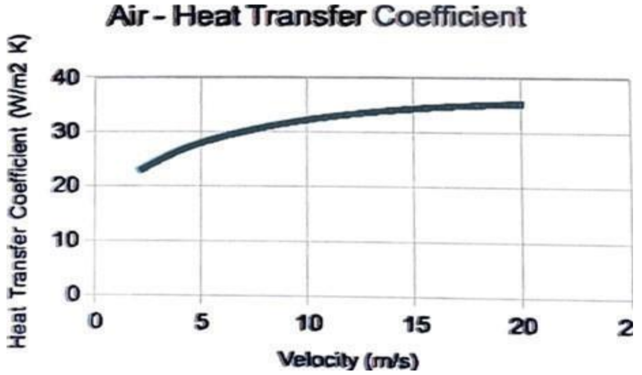

Fig 1: - overall heat transfer coefficient VS wind speed curve

E) Pattern of Energy Consumption HospitalityIndustry

The hospitality industry has a high energy demand,with 65% of it being for heating and the rest for electricity. Natural gas is the main energy source, followed by electricity with 39% and other sources with 2%. Most of the energy consumed is in the kitchen, followed by 25% in laundry and 9% in bath-ing. To reduce energy consumption, businesses mustrespond with energy productive hotels and methods. Solar energy innovations are becoming increasingly popular in the hospitality industry due to government sponsorships, devaluation benefits, and rising costs.

Solar powered thermal system frameworks have become financially appealing due to government sponsorships, devaluation benefits, and rising costs. Dishes take water from the feed water tank to pro- duce steam at 1750C and pressure of 5-8 bars. Steam is then filled to the Common Header and circulated to different applications.

F) Integration of Siph System With Existng Steam Generation And Distribution System

Solar paraboloid based process heating system needsto be integrated in existing steam generation and distribution system to make SIPH system more reliable and easy to incorporate. Existing steam system is based on fossil fuel fired boiler and solar thermal collectors are integrated with it via steam pipelines, solenoid valves and pumps, etc.

IV. CASE STUDY

A. Mahanand Dairy's successful installation of ARUN solar boiler and concentrated solar thermal system for its thermal energy needs.

Mahanand Dairy in India decided to opt for solar en- ergy to satisfy its thermal energy needs in its pasteur-ization process. After a techno-economic analysis, Mahanand decided to give the ARUN technology, Concentrated Solar Thermal technology (CST), a try. The ARUN solar boiler technology was innovative and indigenously developed by Mumbai based Clique Solar, India's first solar boiler company and a company run by an IIT alumni. The installation was completed by Feb 2006. A single ARUN® dish (CST system) delivers energy sufficient for pasteurization of 30,000 liters of milk & CIP of milk storage tanks on a clear sunny day at Latur.

➢ *The Challenges:*

As is the case withpioneers, Mahanand Dairy faced-several hurdles when itdecided touse solar thermal energy to reduce the use of polluting fuels.

There were certain issues since the pasteurization process takes place within 3 hours, while solar ener- gy is available for 8-10 hours. There were more basic questions like the best application of such a solar system in a dairy,keeping in mindthe costvs benefits and the integration requirement; and how to ensure that the system performs as promised, when many solar in spallation's are either dysfunctional or operating at very low efficiencies.

Following were some of the activities identified-which consumed thermal energy:

- Pasteurization Milk Chilling
- Cleaning in Place(CIP) Can and Crate washing Sterilization

➢ *The Details:*

A single ARUN solar boiler is operational for hot water generation for milk pasteurization. The system pressure and temperature is 18 bar and 180°C re- spectively. Duetoa mismatch in the working hours of the plantand avail-ability of sun, an insulated pres-surized water storage tank has been provid-ed for storage of thermal energy. Pressurized water was selected as the medium of heat transfer and storage as it has high specific heat, no fire hazards, no possibility of accelerated oxidization overnight (as in case of tarring of thermic oil), compatibilitywith food products and low operational cost.

ARUN® solar boiler demonstrates excellent techno- logical innovation for dairy industry as the heat is generated by solar & delivered with criti- cal controlled temperature within ±0.5°C at any time during the day or night.

B. Chitale Dairy'ssuccessful installation of ARUN solar boiler systemfor its thermal energy needs

Chitale Dairy has always focused on providing cus- tomers with better value for money by continuously improving the technologies used in their dairy pro- cessing process. Its solar installations at its dairy located at Bhilawadi in Sangli is a fine example of how this corporate philosophy guides its actions.

On average, water heating accounts for more than 30% of the energy con- sumed at dairies in India. By installing two ARUN-160 solar boilers, concen- trated solar thermal systems (CST) dishes on the terrace of its existing dairyat Bhilawadi, Chitale nowsaves an equivalent of almost 40,000-42,000 litresof fossil fuel (furnace oil) per annum, which equates to a reduction in CO_2 emissions by almost 110-130 tons per annum! This is also equivalent to asaving of almost 15-20 paise per litre of milk.

➢ *The Challenges:*

There were issues from economic feasibility to space constraints. There were even basic questions like the best application of such a solar thermal sys-tem in a dairy keeping in mind the cost versus the benefits and the inte-gration requirement; and- how to ensure that the system performs as promised, when many solar installations are either dysfunction-al or operating ativery low efficiencies.

Following are some of the activities which consume large amounts of energy:

- PasteurizationMilk Chilling
- Cleaning in Place(CIP) Can and Crate washing Sterilization

After studying the requirements and constraints of its dairy and under- standing how these factors can be technologically and economically over- come by harnessing solar thermal energy, Chitale concluded that the use ofsolar the rmalconcentratingsystems for their thermal requirements was themost suitable. After a detailed evaluation of multi-ple solar thermal technol- ogies and keeping in mind the space constraints and integration require- ments, Chitaledecided toinstall two of Clique Solar'sARUN solarboilers. Clique Solar is India's first solarboiler company anda- pioneer in solarther-mal concentrating systems in India.

- *The Details:*

Two-dish ARUN concentrated solar thermal (CST) system generates steam which is used for pasteurization, can washing, cleaning in place (CIP) and crate washing. Both these ARUN solar boilers dishes are installed on the terrace of its 3-storey building. The footprint area is less than 3m x 3m per dish. The civil engineering and integra- tion challenges were innovatively handled. The ARUN dish tracks the sun on two axes. Water circu- lates through thereceiver coil which is placed at the focal point of thedishtrans-ferring the thermal energy from the sun to the circulating water and con- verting it to pressurized steam at 152°C at 5 bar

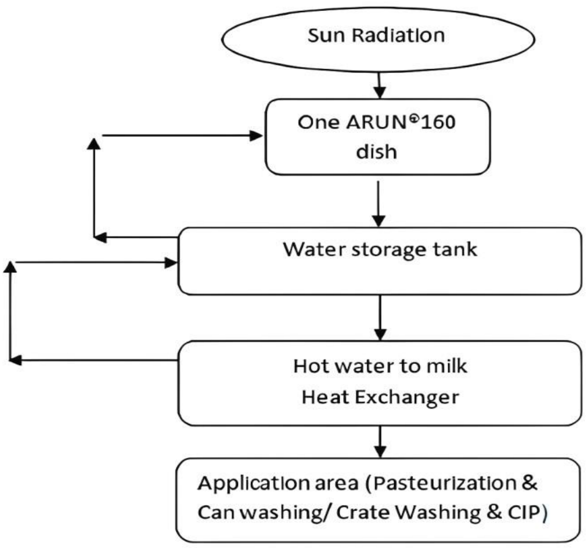

Fig 2: - ARUN DISH process

V. ECONOMIC ANALYSIS

The design of a 14 m diameter solar paraboloid dish system for the hospitality industry has been integrat- ed into existing steam generation system. The eco- nomic feasibility of the SIPH system is discussed in terms of solar fraction achieved and payback period expected. Annual energy estimation for the hospitali- ty industry is estimated by multiplying plant working hour in a day with number of working days in a year and thermal energy required in KWh for each day. The annual thermal energy required in the plant is estimated at 1093500KWh or 1093.5MWh thermal units.

VI. CONCLUSION AND FUTURE RECOMMEN- DATIONS

This text discusses the design of a solar paraboloid dish based industrial process heating system (SIPH) for the hospitality industry. It was integrated into theexisting steam generation and distribution network and economic analysis was done to show its eco- nomic viability. The performance of the 14 m diam- eter solar paraboloid dish at Delhi site was compiled in the form of a table with major parameters such as physical dimensions, energy generation potential, total energy requirement for plant, integration within plant, costing of the installation of SIPH system and its economic analysis in the form of payback period. The technical feasibility of the SIPH system was proved along with its economic feasibility. The SIPH system can be installed at various hospitality indus- trial plants with high DNI values to make hospitality industry more environmentally friendly by reducing greenhouse gas (GHG) emissions and help compa- nies' dependence of quickly depleting fossil fuels for thermal energy requirements. Additionally, the SIPH system will help companies' dependence of quickly depleting fossil fuels for thermal energy require- ments and save them from highly fluctuating fossil fuel prices.

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