ARUN Solar Concentrator for Industrial Process Heat Applications

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A group of ex-IITians working as consulting engineers at Clique developments Pvt. Ltd. with research support from IIT-Bombay has achieved a landmark in the field of Solar Energy harnessing and utilization. They have successfully installed and commissioned a large solar concentrator that can generate process heat at about 200°C, store it and supply it at desired process temperature any time of the day or night. A unit has been installed for pasteurization of about 30,000 lit of milk daily by using solar energy at Mahanand Dairy, Latur without firing the conventional Furnace Oil boiler under an MNES sponsored R&D project. It has potential to save about 25 to 100% of process heat in industrial units. The technology when fully exploited in industrial process heat sector holds potential to save up to 6 to 10% of India's oil imports. It also opens up the doors for solar power generation by thermal route at less than half the cost of the Solar Photo-Voltaic (SPV) systems available presently.

Solar Thermal Concentrator for medium temperature up to 200°C

The experience of successful commercial development of solar flat plate water heaters in household sector has already established that the solar energy is economic today in its thermal form. However, for widespread and technically convenient utilization of solar energy in industrial sector, higher temperatures from 100°C to 200°C are needed. Hence, solar concentrators of high efficiency and improved economy is the need of the day. Many efforts have been reported on the development of Parabolic Trough as well as Paraboloid Concentrator with Point Focus. Most of the efforts involve construction of a curved paraboloid support structure fixed with small mirrors or reflecting surfaces to form the paraboloid reflector.

However, a simple, cheaper and more efficient technology 'ARUN™', named after the chariot driver of the Sun, has been developed with a combined synergy of IIT's research capacity and Clique's industrial designing and implementation capability. The 'ARUN™' solar concentrator consists of Fresnel Paraboloid Reflector with Point Focus (or a focus of small area) with reflector facets fixed on to a tracking surface. The reflectors reflect and concentrate the solar beam radiation at its focus. A receiver designed for minimum thermal loss is provided at the focal point. The system fluid outlet temperature can be up to 250°C. An insulated pipeline delivers this heat-energy to user. This system has micro-processor based control system that automatically drives the dish from east to west to continuously face the Sun which helps in operating the system near its peak capacity for about 8 to 10 hours a day. The tracking system also takes care of seasonal shifting of the Earth's axis with reference to the Sun. Process and safety controls are built into the controls along with emergency alarm system and user-friendly display unit. With this design approach, the system can reach efficiencies of about 50 to 80% at the operating temperatures of 200 to 300°C. This efficiency is higher than any other concentrator technology as can be seen from Figure 1. 'ARUN™' Solar Concentrator System is a solar device providing medium range temperatures for industrial thermal applications. The reflectors can be easily cleaned and its reflectivity can be maintained even in the industrial environment. Accessories are provided for daily cleaning of the reflectors with ease. The ARUN™ system, installed at Latur for milk pasteurisation under an MNES sponsored R& D project to IIT Bombay in association with Clique Development Pvt. Ltd. is seen here in Figure 2 with its focus.

Solar Concentrators of 10 and 29 sq.m

Initially a Paraboloid Reflector Concentrator with 10 m^2 collector area was developed, financed and installed by Dr. Shireesh Kedare in 1997-98 with technical support from Avinash Panchal, Vidyanand Deodhar, Manoj Bhataria and Umesh Kamat, all ex-IITians from IIT-Bombay. It had dynamic Fresnel optics and a cavity receiver at the focal point. This system, shown in Figure 3, was tested at Kolhapur, Maharashtra, India in May 1998.

Based on the experience gained, a Fixed Fresnel Paraboloid Reflector Concentrator with 29 m^2 aperture area was developed by Clique Developments Pvt. Ltd., Mumbai. It is an engineering contracting firm, a sister concern of Clique group of companies started in 1987 by Ashok Paranjape and Dhanji Senjalia, both ex-IITians from IIT-Bombay and their senior partner, Shri. T N N Rao. Dr. Shireesh Kedare later joined the group in 2001 along with Shri. Shyam Pathak.

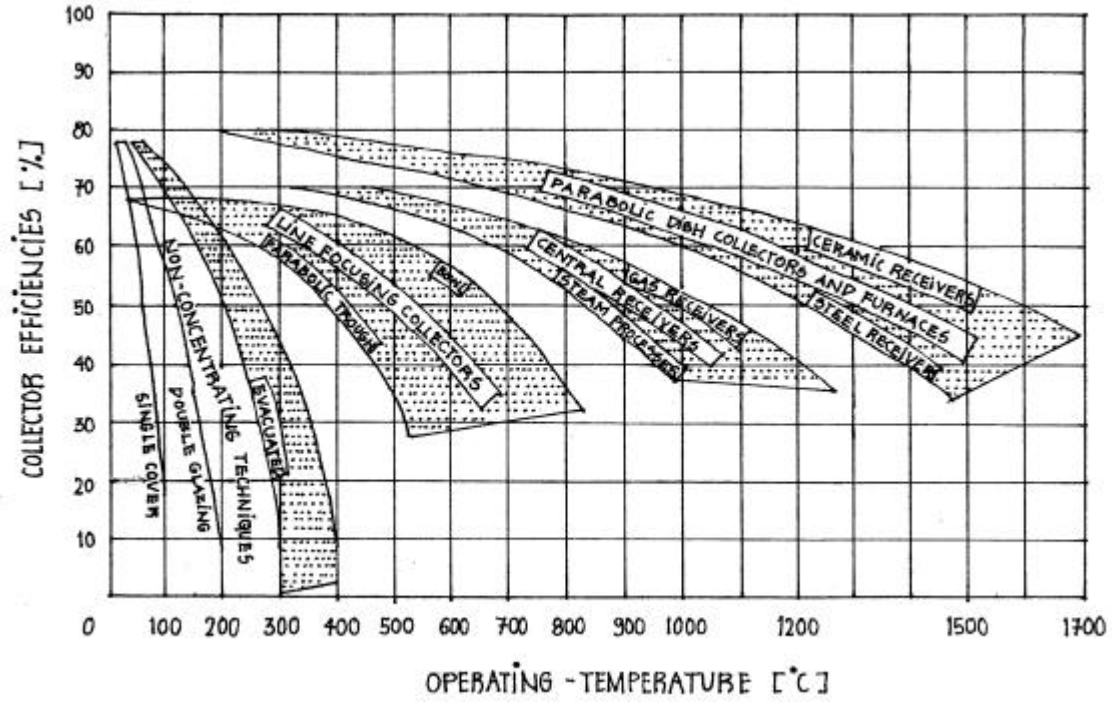

Figure 1 : Comparative efficiencies as function of temperature for different solar thermal technologies

Figure 2 : ARUN160, installed at Latur for milk pasteurisation and its focus on focus plate– June 2005

Figure 3 : The Dynamic Fresnel Paraboloid Concentrator with Point Focus installed and tested at Kolhapur– May 1998

The initial design installed at Pune in December 2001, was tested and improved upon twice. It is shown in Figure 4. The third design of ARUN system at Pune, shown in Figure 5, was tested from March to May 2003 by the Regional Test Centre for solar thermal devices / systems at Pune established by the Ministry of Non-conventional Energy Sources (MNES), New Delhi ('Test Report of Fresnel Reflecting Concentrator', Report No. PU/SES/RTC/OS/2003/004, 'Regional Test and Technical Back-up Centre', School of Energy Studies, University of Pune, 2003). The complete project was financed by Clique Developments Pvt. Ltd. as part of its research and Development (R and D) work.

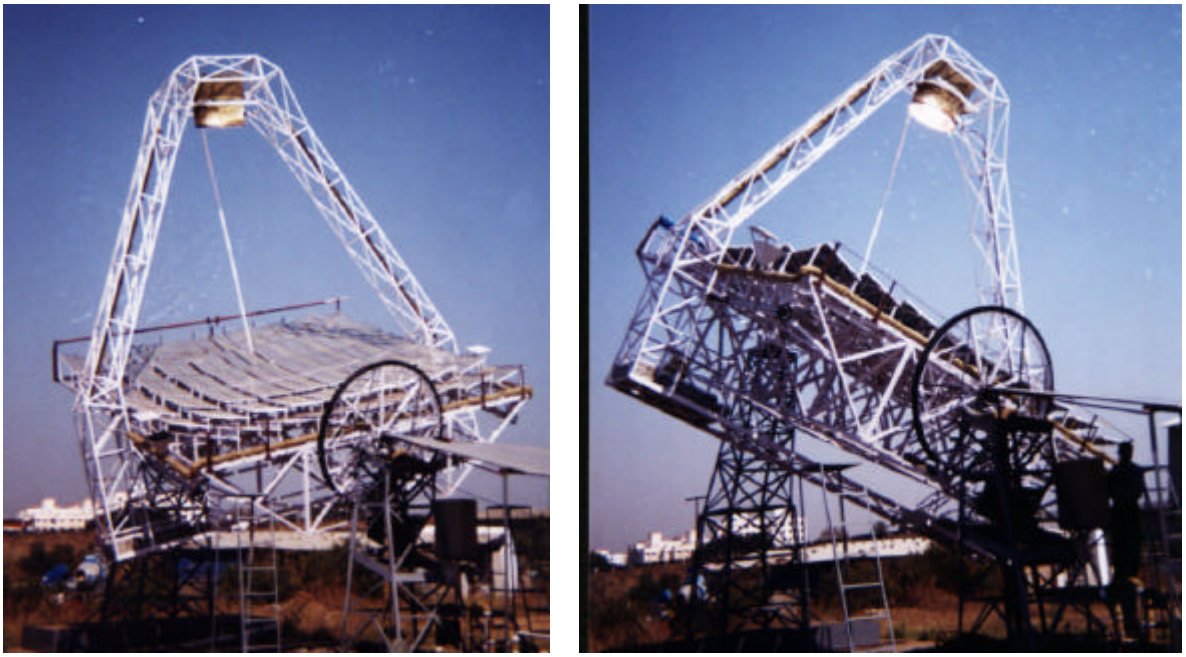

Figure 4 : ARUN30 - The concentrating solar collector of 30 m^2 area tested in December 2001 at Pune

Figure 5 : ARUN™ : The Fresnel Paraboloid Concentrator with Point Focus tested at Pune in 2003

ARUN160 : MNES sponsored IIT-B_Clique_- Mahanand Dairy Project

Based on the experience gained, a project was submitted to Ministry of Non-conventional Energy Sources (MNES), GoI, New Delhi by Energy System Engineering, IIT-Bombay with Clique Developments Pvt. Ltd., Mumbai as collaborating organization with Dr. Kedare as the Principal Investigator of the project. The project aimed at developing, designing, fabricating, installing, commissioning and testing a large solar concentrator that can generate process heat at about 200°C, store it and supply it at desired process temperature. Such a system, if demonstrated, is appropriate for supplying medium temperature industrial thermal process heat. The user for such a system was found at Mahanand Dairy. Shri. Rajkumar Porwal, an ex-IITian from IIT-Kharagpur, and Senior Manager had experience of operating Solar Flat Plate Water Heaters for over 15 years. Shri. Porwal visualized that such a unit would be ideal for milk pasteurization and useful in containing energy costs for Dairy industry. The task of developing testing procedure for this totally new technology was taken up by Prof. J K Nayak of Energy Systems Engineering, IIT-Bombay. The project was sanctioned by the Ministry in March 2004, the concentrator system was developed and installed by June 2005, integration was completed by December 2005 and the system was commissioned in February 2006. Presently, the solar system is processing about 20,000 to 30,000 lit of milk daily. As a result, the user has stopped firing the Furnace Oil fired boiler available with them, thus saving about 80 to 100 lit of Furnace Oil daily. The testing is on-going at the site.

For the FIRST time in INDIA: Solar Concentrator System for Industrial Process Heat with

- Largest aperture area and highest annual heat generation capacity
- Highest operating temperatures and highest stagnation temperatures
- Capacity of Day-long energy storage and integration with a wide range of applications

Salient features of ARUN™

- 100% indigenous technology
- Fresnel Paraboloid Solar Concentrating Reflector with Point Focus
- Two-axes tracking mechanism for automatically tracking the Sun giving maximum daily output
- Specially designed receiver with minimum thermal losses at focus
- Completely automatic operation with minimum maintenance
- Water, thermic fluid, industrial thermal oils or air as working fluid
- Integrable with various industrial thermal processes in add-on mode
- Storage system for heat delivery any time of the day or night
- Built-in safety controls with emergency alarm system and user-friendly operating unit
- Testing procedure developed at IIT-Bombay
- The unit can completely replace boilers on sunny days
- Presently available in two sizes: ARUN™70 and ARUN™160

Technical specifications and performance of ARUN™

Fluids used	Water-steam or thermic fluid or air
Temperature range	Up to 250°C
Operating wind speed	Upto 15 m/s or 54 kmph
Survival wind speed	Upto 39 m/s or 140 kmph
Expected System life	25 years

Performance of a single unit of ARUN™	**ARUN70**	**ARUN160**
Reflector area	55 m^2	123 m^2
Aperture area	70 m^2	160 m^2
Receiver Diameter	800 mm	1000 mm
Optical concentration ratio	100 to 250	150 to 300
Thermal power (annual average)	20 to 35 kW_{th}	50 to 80 kW_{th}
Annual operating hours	3050 to 3125 h/yr	3200 to 3350 h/yr
Annual fuel savings (Furnace Oil or Diesel)	6 to 8 kL/yr	16 to 24 kL/yr
Annual electricity savings	55 to 70 MWh/yr	140 to 180 MWh/yr
Aerial clear space required for a dish	15 x 10 x 12 m ht	25 x 20 x 18 m ht
Foot-print / clear area required on ground / roof	2 x 2 m	3 x 3 m
Tracking power (W)	300 W	500 W
Annual reduction in CO_2 emission	20 to 100 ton	42 to 200 ton

Applications for Industrial Process Heat

The ARUN™ Solar Concentrator System can be used in 'ADD ON' mode and can be retrofitted to the existing boiler or heater system in the industry. In this mode it delivers thermal energy whenever beam radiation is available and saves fuel used. It needs cleaning of reflectors and no fuel at all. The thermal energy generated can be stored to supply energy requirements during evening and night.

The unit is best suited for the industrial applications using thermal energy from electricity or liquid fossil fuels. The thermal medium can be high or low pressure process steam, water, air, thermic fluid or oil. It can be used for providing process heat for a wide range of industries and chemical processing plants using boilers or heaters, textile mills, sugar mills, paper mills, vegetable oil mills, agro and food processing industries, timber industry, milk processing, drying of horticultural, food and fruits products, drying of chemicals, for Cold Storage Units for perishable food, marine and horticultural products at remote places as well as units using vapour absorption refrigeration for space cooling. It is also suitable for Hotels and Hospitals for providing hot water, steam and cooling.

ARUN™ Solar Concentrator System has opened up immense possibilities of saving significant proportion of Liquid or Gaseous Fossil Fuels or Electricity used in Industrial Process Heat Applications in economically viable manner. It has potential to save 25 to 100% of the energy used for process heat in industrial units depending on temperatures and load cycles of the process. The technology when fully exploited in industrial process heat sector holds potential to save up to 6 to 10% of India's total fuel oil imports.

Economics

The system is 100% indigenous. It is fabricated using indigenously available materials and components. It can save about 20 to 30% of its capital cost every year depending on the place of installation and whether liquid fossil fuels or electricity is saved from heat generation. The system installed at Latur can supply heat for pasteurisation of about 30,000 to 35,000 lit of milk daily. As a result, the existing furnace oil fired boiler need not be fired on sunny days, thus saving 80 to 100 lit of Furnace Oil per day or saving up to about 20,000 to 30,000 lit of Furnace Oil annually. Smaller system with about half the capacity is also available.

The system has 15 to 20% of central subsidy presently and can be depreciated up to 80% in the first year leading to substantial tax benefits. Soft loans @ 5 to 7% pa can be available through Financing Institutes covering 80% of the initial cost for installing ARUN™ Solar Thermal Concentrator System. The system can save more than the EMI of this loan if it is used to replace heating that otherwise uses FO, LDO, Diesel or uses electrical heating. The annual operating and maintenance cost of the system can be as low as 2% of its capital investment. Economic analysis suggests that a payback period of 3 to 5 years is possible when liquid fossil fuels are saved. The system there after provides free energy for 20 more years. The IRR comes to 30 to 40% depending on the fuel saved. The economics improves substantially when electricity is saved.

Electrical Solar Power Generation through Thermal Route

Concentrating solar collectors designed for industrial thermal applications as ARUN™ can be used to generate power through thermal route. 25 kW non-condensing steam turbines can be made available in India. These can be used for power generation as well as for providing process heat. For this purpose, three or more concentrating solar collector dishes can be integrated.

Stirling Energy Systems, Inc, USA has developed a smaller dish of 100 sq.m aperture area having Stirling Engine at its focus. It can generate electrical power through thermal route. The dish has mirror reflectors mounted on paraboloid structure. It tracks the Sun in two-axes arranged vertical and horizontal. Stirling Engine has efficiency of conversion of thermal energy to electrical energy of the order of 22 to 30%. Thus overall efficiency of conversion of solar energy to electrical energy using Paraboloid Dish with Stirling Engine can go up to 20 to 25% in field. This conversion efficiency is about double than that for Solar Photo-Voltaic Panels. It typically requires half the capital cost of Solar Photo-Voltaic Panels and runs for almost double the time. Hence, it can generate electrical energy at the cost comparable with the present day electrical energy costs.

A Solar farm of 1 MW capacity is being installed at Mojave Dessert near Las Vegas, USA with two plants of 300 and 500 MW in offing. A picture of a few of the 6 dishes tested at Sandia Lab is given in Figure 6 with a close up of the Stirling engine at its focus.

Arun™ Solar Concentrator can be fitted with 25 kW Stirling engine to generate electrical power through thermal route. With the ARUN solar concentrators already in place, India is not far behind.

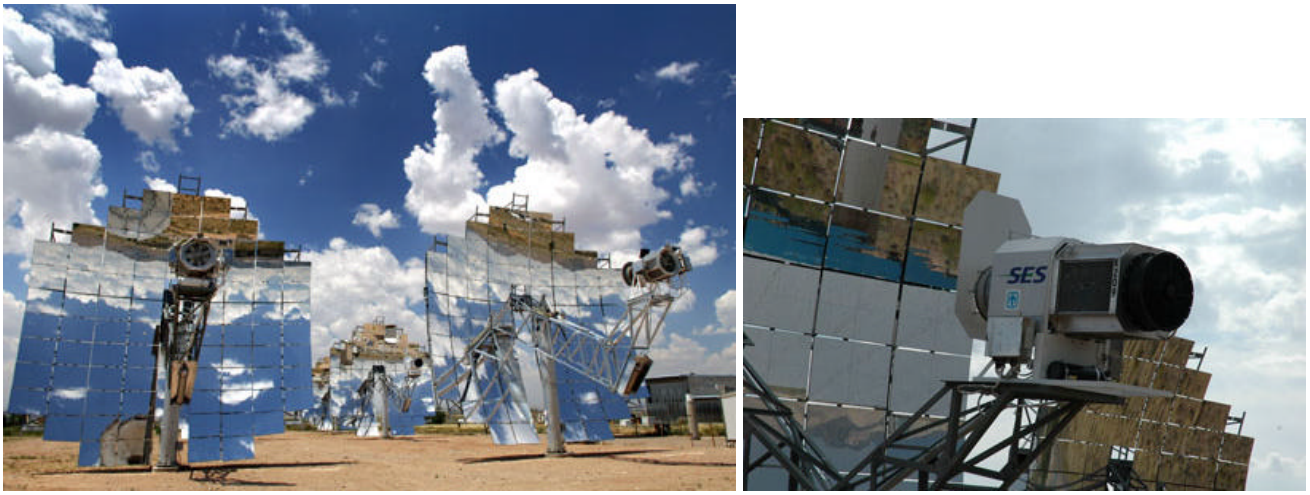

Figure 6 : Picture of a few of the 6 dishes tested at Sandia Lab with a close up of the Stirling engine at its focus

More efficient Solar PV Power Generation through Suryamukhi Tracker

ARUN™ has capacity to track the Sun within 0.1° accuracy. This can be used to install costly Photo-Voltaic panels generating about 30% more energy by same panels at additional installation cost of about 10 to 12%. A schematic of this is shown in Figure 7. Wherever the Solar PV panels are being installed, the same can be installed on 'Suryamukhi' to better utilize the costly national resources invested in PV panels. The mounting structures suitable for 0.5 to 1 kW installations, 10 kW installation and 22 kW installation are available.

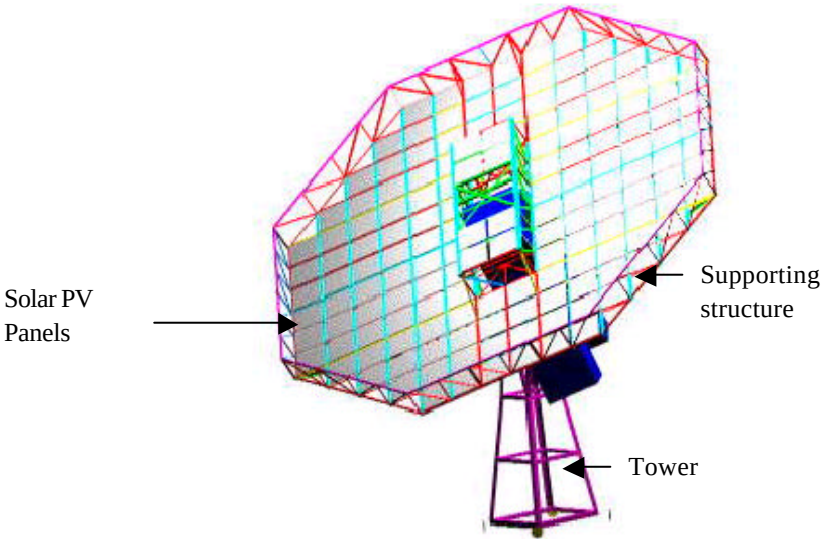

Figure 7 : Solar PV Panels on tracking structure for 30% more generation of energy

ACKNOWLEDGEMENTS

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