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Solar thermal energy: A promising source for Energy Intensive Industries

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Abstract: Sun is the basic source for all the energy. The earth receives in just 1 h, more energy from the sun than what we consume in the whole world for 1 year. It is very important to apply solar energy for a wide variety of applications and provide energy solutions by modifying the energy proportion, improving energy stability, increasing energy sustainability, conversion reduction and hence enhance the system efficiency. The present paper aimed to review the present day solar thermal technologies, to study the solar thermal energy systems utilization in various energy intensive industries.
Keywords: Solar thermal, Energy, Solar, Temperature, Industry

1. INTRODUCTION

From the day 1 of the electricity the world has seen, till today how much electricity we have produced, Sun can produce more than that energy in one second. The earth receives in just 1 h, more energy from the sun than what we consume in the whole world for 1 year. Today, the use of solar energy has reached a remarkable edge. The continuous research for an alternative power source due to the perceived scarcity of fuel fossils is its driving force. Solar energy conversion is widely used to generate heat and produce electricity. A comparative study on the world energy consumption released by International Energy Agency (IEA) shows that in 2050, solar array installations will supply around 45% of energy demand in the world. It was found that solar thermal is getting remarkable popularity in industrial applications. Solar thermal is an alternative to generate electricity, process chemicals or even space heating. It can be used in food, non-metallic, textile, building, chemical or even business related industries. Though many papers are published on the utilization of Solar thermal energy, it is not comprehensive. The present paper aimed to review the present day solar thermal technologies, to study the solar thermal energy systems utilization in various energy intensive industries.

2. SOLAR THERMAL COLLECTORS

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. There are basically two types of solar collectors: non-concentrating or stationary and concentrating. A non-concentrating collector has the same area for intercepting and for absorbing solar radiation, whereas a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux. A large number of solar collectors are available in the market. A comprehensive list is shown in Table 1.[1] In this section a review of the various types of collectors currently available will be presented. This includes flat plate collector (FPC), evacuated tube collector (ETC), and concentrating collectors.

Table 1: Types of solar thermal collectors & their temperature ranges

Motion	Collector type	Absorber type	Indicative temperature range (°C)
Stationary	• Flat plate collector (FPC)	Flat	30 to 80
	• Evacuated tube collector (ETC)	Flat	50 to 200
	• Compound parabolic collector (CPC)	Tubular	60 to 240
Single-axis tracking	• Fresnel lens collector (FLC)	Tubular	60 to 250

	• Parabolic trough collector (PTC) • Cylindrical trough collector (CTC)	Tubular Tubular	60 to 300 60 to 300
Two-axes tracking	• Parabolic dish reflector (PDR) • Heliostat field collector (HFC)	Point Point	100 to 500 150 to 2000

3. SOLAR THERMAL ENERGY FOR INDUSTRIES

Nearly all the industrial energy networks and systems are partially or fully dependent on burning fossil fuels to generate essential thermal energy. Distribution of energy consumption indicated that about 13% of thermal industrial applications require low temperatures thermal energy up to 100^0C, 27% up to 200^0Cand the remaining applications need high temperature in steel, glass and ceramic industry. Table-2 [2]shows few of potential industrial processes and the required temperatures for their operations.

Many industrial processes are involved in heat utilization with temperature between 80^0C and 240^0C. Industrial energy analysis shows that solar thermal energy has enormous applications in low (i.e. 20–200^0C), medium and medium-high (i.e. 80–240^0C) temperature levels. Almost all industrial processes require heat in some parts of their processes. In southern European countries, almost 15% of the final energy demand in industrial sector is used for heating applications. Most common applications for solar thermal energy used in industry are the SWHs, solar dryers, space heating and cooling systems and water desalination. Solar as an input power is widely used for heat engines in many industrial applications. Stirling engines use any kind of external heat source for their operation. They are highly reliable, simple in design and construction, easy to operate and cost effective. Nevertheless, the efficiencies of such mechanical devices are quite low. Compared to external combustion engines, they perform more efficiently with less exhaust emissions. Using solar irradiation to generate heat for Stirling engines can reduce the cost and complexity of the system while increasing their efficiency. Mass production of solar powered Stirling engines would make them cost effective. Generating solar electricity using Stirling engines in the range of 1–100kW for industrial applications is the cheapest alternative. Stirling engines use compressed fluids like air, hydrogen, helium, nitrogen or steam on a Stirling cycle. Stirling engines are applicable in numerous applications where quite operation is required or in systems with multi-fueled characteristics, very good cooling source, low speed, constant power output and low pace of changing output power. Using solar energy to generate thermal energy for industrial processes not only reduces dependency on fossil fuel resources but also minimizes greenhouse emissions such as CO2, SO2, NOx. Nevertheless, there are some challenges for merging solar heat into a wide variety of industrial processes like periodic, dilute and variable nature of solar radiation.[3]

Table 2:Heat demand industries and range of temperatures

Industry	**Process**	**Temperature (°C)**
Dairy	Pressurization	60–80
	Sterilization	100–120
	Drying	120–180
	Concentrates	60–80
	Boiler feed water	60-90
Tinned food	Sterilization	110–120
	Pasteurization	60–80
	Cooking	60–90
	Bleaching	60–90
Textile	Bleaching, dyeing	60–90
	Drying, degreasing	100–130
	Dyeing	70–90
	Fixing	160–180

	Pressing	80–100
Paper	Cooking, drying	60–80
	Boiler feed water	60–90
	Bleaching	130–150
Chemical	Soaps	200–260
	Synthetic rubber	150–200
	Processing heat	120–180
	Pre-heating water	60–90
Meat	Washing, sterilization	60–90
	Cooking	90–100
Beverages	Washing, sterilization	60–80
	Pasteurization	60–70
Flours and by-products	Sterilization	60–80
Timber by-products	Thermo diffusion beams	80–100
	Drying	60–100
	Pre-heating water	60–90
	Preparation pulp	120–170
Bricks and blocks	Curing	60–140
Plastics	Preparation	120–140
	Distillation	140–150
	Separation	200–220
	Extension	140–160
	Drying	180–200
	Blending	120–140

4. INTEGRATION OF SOLAR THERMAL ENERGY INTO INDUSTRIAL SYSTEMS

A typical industrial energy system is composed of 4main parts; power supply, production plant, energy recovery and cooling systems. Fig. 1 shows a block diagram of a typical industrial energy system. The power supply provides the energy needed for the system to operate mainly from electrical energy, heat, gas, steam or coal. Production plant is the part of the system that executes proceedings of production. Energy is utilized in this part for running subsystems, pressure/vacuum/temperature solenoids, valves and switches. Solar energy systems can either be applied as the power supply sector or directly to a process.

It can be stated that solar thermal is the conversion of solar irradiation into heat. Among renewable energy systems, solar thermal is considered as the most economical alternative. Typically, the systems use solar collectors and concentrators to gather solar radiation, store it and use for heating air or water in domestic, commercial or industrial plants. Fig. 2 presents a schematic diagram of solar irradiation conversion to mechanical energy.

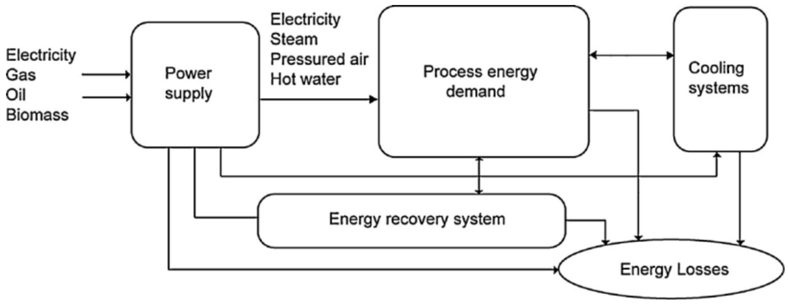

Figure 1: Block diagram of a typical industrial energy system

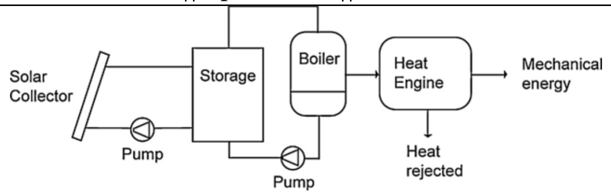

Figure 2: Schematic of a solar-thermal conversion system

The location, type of collector, working fluid to determine required storage volume, size of the system and storage volume to determine the heat exchanger size and the load are the factors that need to be considered for the specific applications [1]. However, it has to be noted for some applications that solar energy is not available continuously for 24 h. In such cases, addition supplementary measures should be provided to accumulate solar irradiation during sunny days, store it in an embedded phase transition and release it in a controlled manner in severe conditions.

To increase the efficiency of solar thermal systems, solar collectors are applied to heat the air or water as the medium of heat transfer. However, each collector is dedicated for a specific application. For example, flat-plate collectors are properly designed to be used in low temperature applications, the concentrating and sun-tracking parabolic trough collectors (PTC) are suitable for high temperature applications in which the system can obtain temperature higher than 250 ◦C with high efficiency, two axes tracking collectors are applied in power generation, stationary (non-tracking) and one axis PTCs are mainly used in industrial heat processes. Among the collectors, movable collectors require higher maintenance cost compared to other collectors. Table 1 illustrates the three main categories and types of solar collectors currently used [1]. A concentration ration, defined as the aperture area divided by the receiver/absorber area of the collector of each type is presented as well.

5. SOLAR THERMAL FOR FOSSIL FUEL FIRED POWER PLANTS

Steam power plant repowering is not a new proposition. It is usually associated with gas turbine addition to the existing plant in order to increase its efficiency and lifetime. In this way, every coal fired plant can be converted into combined cycle plant, where the hot gas turbine exhaust gas delivers heat input to the steam cycle. The same approach can be applied with heat input coming from solar thermal generation field located in the vicinity of plant. Determining how to technically integrate solar heat into the existed conventional steam plant is the first step in the design process.[4]

A very simple introductory option could be the replacement of the plant auxiliary steam system with Direct Solar Steam Generation process. The function of the auxiliary steam system usually is to provide a dependable source of steam to the following plant systems: steam heavy fuel oil heaters, steam air heaters, turbine gland steam, air ejectors, deaerator, burners, soot blowers and thermal seawater desalination system for process water and boiler makeup if applicable. The auxiliary steam system itself can be supplied from several sources depending on the unit status and boiler pressure. The system can receive steam from the unit’s main steam line, the unit’s cold reheat steam line or from the next unit auxiliary steam header. High pressure steams from the main steam line or from the cold reheat line flows in through a pressure control valve. The auxiliary steam header distributes steam with typical parameters: pressure of 10 to 15 bar and temperature up to 230^0C. The auxiliary steam consumption can reach up to 2% to 3% of the actual steam output of the boiler.

The most radical approach in integrating solar heat into the Rankine cycle plant is boiler replacement partially or fully with appropriate solar based steam generation facility. A typical subcritical Rankine cycle power plant has turbine throttle steam conditions of 16 MPa and 540^0C. A steam with such of parameters could be generated by high-temperature solar technology like solar tower or advanced parabolic trough collectors.

6. CONCLUSION

Studies shows that the temperature requirement of different industrial processes can be easily met by the solar thermal systems. Applications & forecasts of solar thermal energy used in industries were presented in this paper. It was discussed how the solar energy utilization can improve the quality and quantity of products while reducing the greenhouse gas emissions. It has been found that solar thermal systems are suitable for various industrial process applications. However, the overall efficiency of the system depends on appropriate integration of systems and proper design of the solar collectors.

Solar energy systems can be considered either as the power supply or applied directly to a process. Large scale solar thermal systems with large collector fields are economically viable due to the usage of stationary collectors. In addition, they need less initial investment cost compared to small plants. Feasibility of integrating solar energy systems into conventional applications depend on industries' energy systems, heating and cooling demand analysis and advantages over existing technologies.

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