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Review of Solar Thermal Energy Storage System

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Abstract—**This Paper attempt to review the solar thermal energy storage system. Solar power is the flow of energy from the sun. The primary forms of solar energy are heat and light. Sunlight and heat are transformed and absorbed by the environment in a multitude of ways. Some of these transformations result in renewable energy flows such as biomass, wind and waves. Effects such as the jet stream, the Gulf Stream and the water cycle are also the result of solar energy's absorption in the environment**

Keywords—Solar Energy, Latent Heat System, Thermal Energy

I. INTRODUCTION

The Earth receives 174 pet watts (PW) of solar radiation at the upper atmosphere. While traveling through the atmosphere 6% of the incoming solar radiation (insolation) is reflected and 16% is absorbed. Average atmospheric conditions (clouds, dust, pollutants) further reduce insolation by 20% through reflection and 3% through absorption. The absorption of solar energy by atmospheric convection (sensible heat transport) and by the evaporation and condensation of water vapor (latent heat transport) drive the winds and the water cycle. Atmospheric conditions not only reduce the quantity of insolation reaching the Earth's surface but also affect the quality of insolation by diffusing approximately 20% of the incoming light and altering its spectrum. After passing through the Earth's atmosphere approximately half the insolation is in the visible electromagnetic spectrum with the other half mostly in the infrared and ultraviolet spectrum.

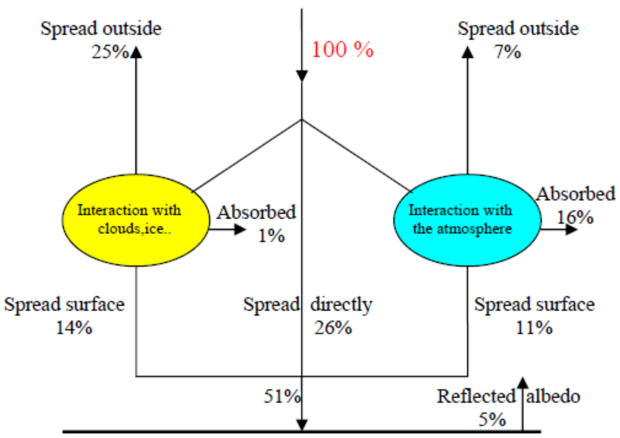

Fig 1 Incident Radiation

Solar energy has an enormous potential like all the different prototypes have shown, and the prediction about this type of technology show that the efficiency of these systems can be increased in a significant way. Different techniques of active solar heating and solar thermal power generation are technically feasible and cost effective, and some commercially available plants can produce up to 350MW these systems are highly dependent on the local climate and energy needs; this is a big limitation because only in certain regions these systems can be efficient enough to be implemented. The main obstacle for the development of these systems is the low price of fossil fuels, and their high availability, like coal and biomass.

The solar systems have a low environmental impact, and one of the most important benefits is that it doesn't have emissions like CO_2 or other toxic gases or radioactive material, like the ones that are produced by the current systems used to produce energy. The costs of these energy systems consist only of the construction and maintenance of the plant, the source of energy is free and in theory unlimited. The environmental impact of these systems is practically zero. Some of the disadvantages are that these systems can only be installed in areas in which the solar radiation is longer during the days and during the year. They are also less efficient than the current energy systems These systems can be a combination of solar energy generators and a conventional fossil fuel generator, this combination has the advantage that energy can be provided even if there is no solar energy available.

II. LITTERARURE REVIEW

[1]. To solve this problem, renewable energy has been introduced to compensate the energy crisis and reduce the harmful emission effects of gases such as CO_2 caused by global warming [2]. The solar energy is considered to be one of the most important sources for renewable energy due to the fact that it is an inexhaustible source. Furthermore, recent studies have confirmed that thirty minute of solar radiation on earth is equal to the world energy request for the whole year [3]. Therefore, solar energy is used in many applications, such as ventilation air preheating, space heating of buildings [4, 5, and 6], drying agricultural crops [7, 8 and 9] and water heaters in homes [10, 11, 12, and 13]. In order to be effective and productive, all the solar energy applications listed above must be integrated with a thermal energy storage unit. The function of a thermal energy storage unit is to absorb and store heat energy. Hence, solar heaters

can be operated for a longer period of time during sunset [14]. Consequently, in recent years, several studies have focused on the development of solar energy systems, particularly the optimal use of solar radiation and the best ways to store solar thermal energy The solar energy collectors can also be grouped into direct or indirect types. A direct type of solar water heating system distributes domestic water during collectors but is inappropriate for frigid atmospheres. The indirect type, on the other hand, is used for heat transfer fluid [15].

III. Solar Radiation

Interest in solar energy has prompted the accurate measurement and mapping of solar energy resources of the globe. This is normally done using solar meters. Most solar meters measurements are recorded simply as total energy incident on the horizontal surface, other measurements separate the direct and the diffuse radiation.

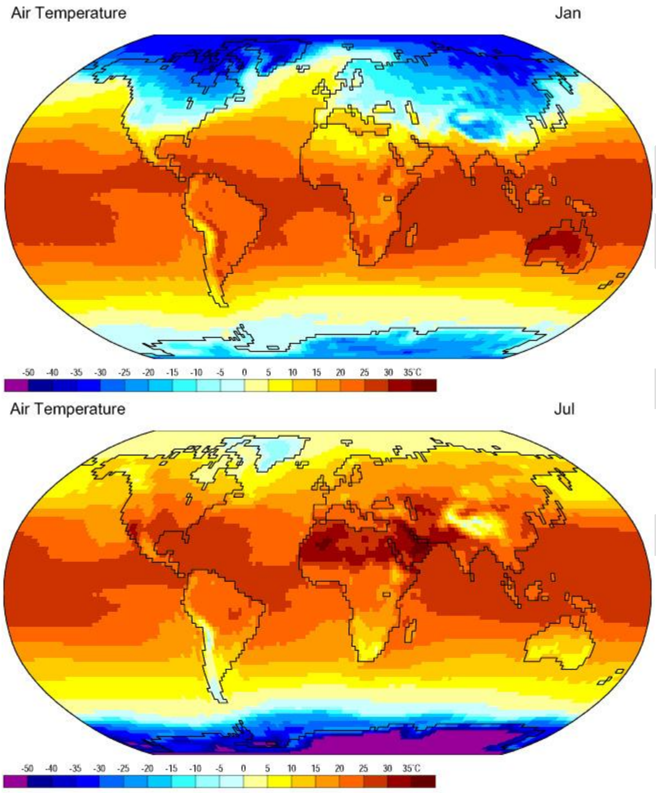

Fig 2 Radiation levels through seasons of the year

IV. Solar Thermal Energy storage Application

A. *Domestic Water Heating*

A solar domestic hot water system uses the sun’s energy collected by a flat-plate solar collector and transfers the heat to water or another liquid flowing through tubes. The system then draws upon this reservoir when you need hot water inside your home. This system usually complements an existing electric or gas hot water system to reduce your utility bill and provide approximately 40-70% of your household’s annual hot water needs.

Two basic solar systems exist to produce hot water: active and passive. An active pumped system can be either an open loop where the water is directly heated by the solar collector, or closed loop where antifreeze or glycol mixture is heated before transferring its heat to the water by a heat exchanger. A popular design of the closed loop system is known as a drain back system. This freeze-proof design drains water back into a small holding tank when freezing temperatures occur.

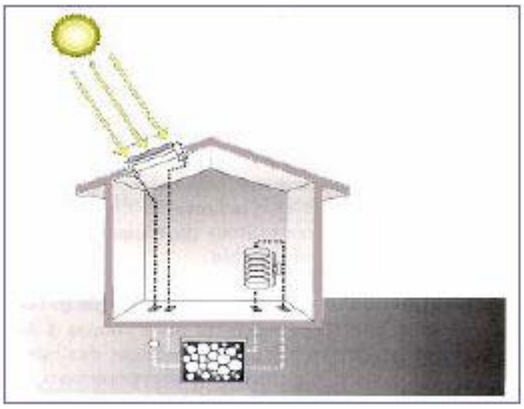

Fig 3 building – equipment – environment

B. *Domestic Space Heating*

A solar space heater collects the sun’s energy by a solar collector and directs the energy into a “thermal mass” for storage later when the space is the coldest. A thermal mass can be a masonry wall, floor or any storage drum used specifically to absorb and store the energy. Many systems involve a distribution system and control devices to circulate the heat throughout the space and to prevent loss from the collector area. These systems may be combined with a solar hot water system and sized to accommodate both uses. Solar space heaters are more economical when it replaces an electrical heating systems.

C. *Solar Cooking*

Solar cooking is a technology which has been given a lot of attention in recent years in developing countries. The basic design is that of a box with a glass cover. The box is lined with insulation and a reflective surface is applied to concentrate the heat onto the pots. The pots can be painted black to help with heat absorption. The solar radiation raises the temperature sufficiently to boil the contents in the pots. Cooking time is often a lot slower than conventional cooking stoves but there is no fuel cost. Many variations have been developed on this theme but the main restriction has been one of reducing costs sufficiently to permit widespread dissemination. The cooker also has limitations in terms of only being effective during hours of strong sunlight. Another cooking stove is usually required for the periods when there is cloud or during the morning and evening hours. There have been large, subsidized solar cooking stove dissemination programmers in India, Pakistan and China.

D. Crop Drying

Controlled drying is required for various crops and products, such as grain, coffee, tobacco, fruits vegetables and fish. Their quality can be enhanced if the drying is properly carried out. Solar thermal technology can be used to assist with the drying of such products. The main principle of operation is to raise the heat of the product, which is usually held within a compartment or box, while at the same time passing air through the compartment to remove moisture. The flow of air is often promoted using the 'stack' effect which takes advantage of the fact that hot air rises and can therefore be drawn upwards through a chimney, while drawing in cooler air from below. Alternatively a fan can be used. The size and shape of the compartment varies depending on the product and the scale of the drying system. Large systems can use large barns while smaller systems may have a few trays in a small
wooden housing.

Solar crop drying technologies can help reduce environmental degradation caused by the use of fuel wood or fossil fuels for crop drying and can also help to reduce the costs associated with these fuels and hence the cost of the product. Helping to improve and protect crops also has beneficial effects on health and nutrition.

E. Space Cooling

The majority of the worlds developing countries, however, lie within the tropics and have little need of space heating. There is a demand, however, for space cooling. The majority of the world warm climate cultures have again developed traditional, simple, elegant techniques for cooling their dwellings, often using effects promoted by passive solar phenomenon. There are many methods for minimizing heat gain. These include sitting a building in shade or near water, using vegetation or landscaping to direct wind into the building, good town planning to optimize the prevailing wind and available shade. Buildings can be designed for a given climate - domed roofs and thermally massive structures in hot arid climates, shuttered and shaded windows to prevent heat gain, open structure bamboo housing in warm, humid areas. In some countries dwellings are constructed underground and take advantage of the relatively low and stable temperature of the surrounding ground. There are as many options as there are people.

F. Day-Lighting

A simple and obvious use for solar energy is to provide light for use in buildings. Many modern buildings, office blocks and commercial premises for example, are designed in such a way that electric light has to be provided during the daytime to provide sufficient light for the activities taking place within. An obvious improvement would be to design buildings in such a way that that the light of the sun can be used for this purpose. The energy savings are significant and natural lighting is often preferred to artificial electric lighting.

V. COLLECTION SYSTEMS

There are certain systems to collect the solar thermal energy.
Most systems for low-temperature solar heating depend on the use of glazing, in particular its ability to transmit visible light but to block infrared radiation.High temeprature solar collection is more likely to employ mirrors. In practice, solar systems of both types can take a wide range of forms.

- Low Temperature: T< 100 ºC Domestic Water, Swimming-Pool Heating
- Medium Temperature T< 400 º C Electricity Produce
- High Temperature T> 400 º C Electricity Produce, Blast Furnace...

Active solar heating. This always involves a discrete solar collector, usually mounted on the roof of a building, to gather solar radiation. Mostly, collectors are quite simple and the heat produced will be at low temperature and used for domestic hot water or swimming pool heating. Solar thermal engines. These are an extension of active solar heating, usually using more complex collector to produce temperatures high enough to drive steam turbine to produce electric power. Passive solar heating systems mostly use air to circulate the collected energy, usually without pumps or fans indeed the collector is often an integral part of the building.

VI. ACTIVE SOLAR HEATING

The solar collector plate has four principal elements:

- The transparent covert (1)
- The absorbent layer (2)
- Insulating (3)
- The casting (4)

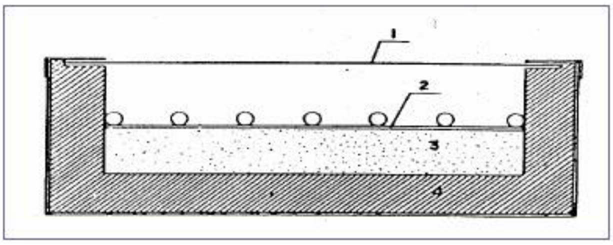

Fig 3 solar collector

The transparent cover should have several characteristics for the appropriate performance of the collector:

- Produce a green house effect and reduce the external losses
- Have a low coefficient of thermal conductivity
- The external surface has to be clean
- The collector must be sealed to prevent water and air to go into the system.

A. Unglazed Panels

These are most suitable for swimming pool heating, where it is only necessary for the water temperature to rise by a few degrees above air ambient air temperature, so heat losses are relatively unimportant.

Fig 4 Unglazed panels

B. Flat plate water collectors

Usually they are only single glazed but may have an additional second glazing layer, sometimes of plastic. The more elaborate the glazing system, the higher the temperature difference that can be sustained between the absorber and the external air.

Fig 5 Flat plate water collectors

C. Flat Plate Air Collectors

These are not so common as water collectors and are mainly used for space heating only. Also can combine this type of collector with a photovoltaic panel

Fig 6 Flat Plate Air Collectors

D. Evacuated Tube Collectors

The absorber plate is a metal strip down the centre of each tube. Convective heat losses are suppressed by virtue of a vacuum in the tube. The absorber plate uses a special heat pipe to carry the collected energy to the water. These focus the sun on to a pipe running down the centre of a trough. The trough can be pivoted to track the sun up and down or east to west. A line focus collector can be oriented with its axis in either a horizontal or a vertical plane.

Fig 7 Evacuated Tube Collectors

E. Solar Towers

Also called central receiver system or heliostat power plants. In this plant the sunlight is focused into a boiler at the top of the central tower by an array of moveable mirrors that track the trajectory of the sun. This boiler heats a synthetic oil or molten rock salt due to their high thermal capacity and conductivity. This heat can be stored by those elements for further use and some new designs have show that this energy can be stored from 3 to 13 hours. A solar tower can produce between 30 to 200MW.

Fig 8 solar tower Manzanares (Spain)

F. Parabolic Through Concentration Systems

This system use large fields of parabolic trough shaped mirrors with a tube running across their length at the focal point. The collectors heat synthetic oil up to 390C that produce high temperature steam via a heat exchanger. This system has an efficiency of solar to electricity conversion between 14 and 22% and the thermal efficiency ranges from 60 to 80%. In absence of sun light these plants use conventional power generators. These hybrid systems need other components like condensers and accumulators. With a normal parabolic trough plant can produce between 14 and 80 MW.

Fig 9 Parabolic Through

G. Parabolic Dish Concentrator Systems

This system puts the engine itself at the focus of a parabolic dish shaped mirror. Some modern systems can reach very high conversion efficiencies, close to 30%. The temperature at the focal point can reach 3000 ºC that can be used to generate electricity, melt steel or to produce hydrogen fuel. This plant can produce between 7 and 25kW.

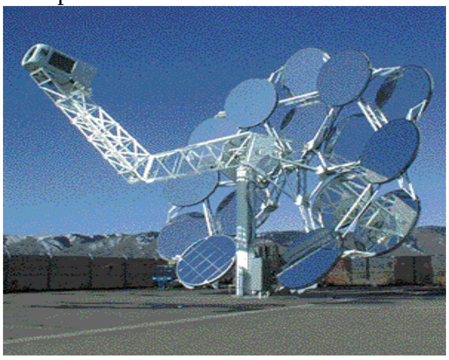

Fig 10 Parabolic Dish

H. Solar Ponds

In this system, a large salty lake is used as a plate collector. With the right salt concentration in the water, the solar energy can be absorbed at the bottom of the lake. The heat is insulated by the different densities of the water and at the bottom the heat can reach 90C, which is high enough to run a vapour cycle engine, at the top of the pond, the temperature can reach 30C. There are three different layers of water in a solar pond, the top layer that has less concentration of salt; the intermediate layer, that acts as a thermal insulator and finally the bottom layer that has a high concentration of salt. These systems have a low solar to electricity conversion efficiency, less than 15% (having an ambient temperature of 20C and a storage heat of 80C). One advantage of this system is that because the heat is stored, it can run day and night if required. Also due to its simplicity, it can be constructed in rural areas in developing countries.

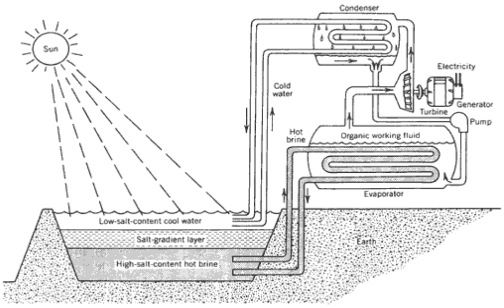

Fig 11 Solar Pond

VII. PASSIVE SOLAR HEATING

Passive solar technologies convert sunlight into usable heat, cause air-movement for ventilation or cooling, or store heat for future use, without the assistance of other energy sources and presents the most cost effective means of providing heat to buildings. Generally, the amount of solar energy that falls on the roof of a house is more than the total energy consumed within the house. Passive solar applications, when included in initial building design, adds little or nothing to the cost of a building, yet has the effect of realizing a reduction in operational costs and reduced equipment demand. It is reliable, mechanically simple, and is a viable asset to a home. Passive solar systems have little to no operating costs, often have low maintenance costs, and emit no greenhouse gases in operation. They do, however, need to be optimized to yield the best performance and economics. Energy conservation reduces the needed size of any renewable or conventional energy system, and greatly enhances the economics, so it must be performed first. Passive solar technologies often yield high solar savings fractions, especially for space heating; when combined with active solar technologies or photovoltaics, even higher conventional energy savings can be achieved.

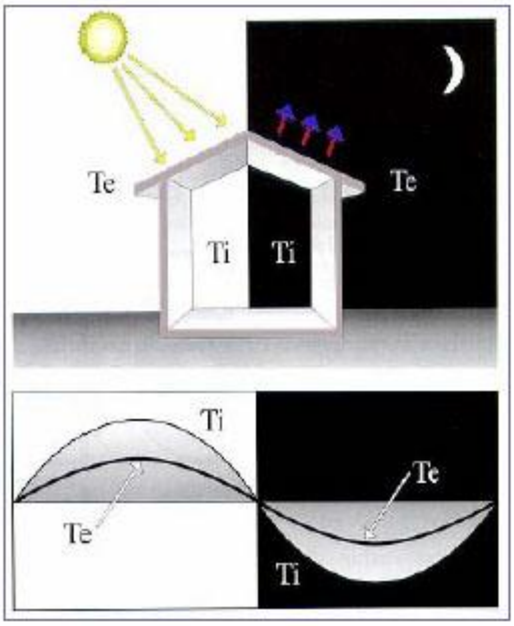

Fig 12 Typical Fluctuation Of The Temperatures Inside Buildings

Instead a dark colored thermal storage wall is placed just behind a south facing glazing (windows). Sunlight enters through the glass and is immediately absorbed at the surface of the storage wall where it is either stored or eventually conducted through the material mass to the inside space. In most cases the masonry thermal storage mass cannot absorb solar energy as fast as it enters the space between the mass and the window area. Temperatures in this space can easily exceed 37.78°C. This build up of heat can be utilized to warm a space by providing heat-distributing vents the top of the wall. Vents at the bottom of the wall allow cool air to be drawn into the heating space thereby replacing the outflowing hot air, and picking up heat itself.

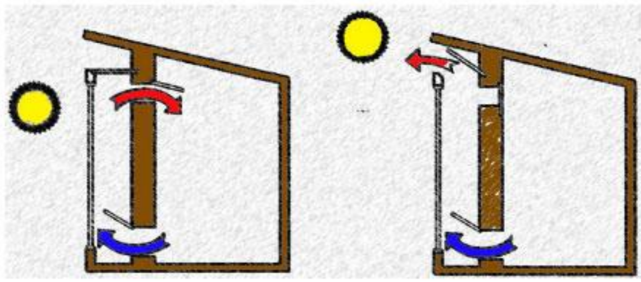

Fig 13 Trombe Wall During The Day

The top and bottom vents continue to circulate air as long as the air entering the bottom vent is cooler than the air leaving the top vent. This is known as a natural convective loop. At night the vents can be closed to keep cold air out and the interior space is then heated by the storage mass, which gives up its heat by radiation as the room cools.

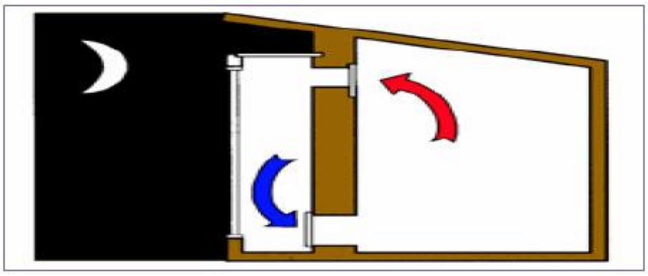

Fig 14 Trombe Wall During The Night

An indirect gain design which provides both heating and cooling is the thermal pond approach, which uses water encased in ultraviolet ray inhibiting plastic beds underlined with a dark color, that are placed on a roof. In warm and temperate climates with low precipitation, the flat roof structure also serves directly as a ceiling for the living spaces below thereby facilitating direct transfer of heating and cooling for the spaces below. In colder climes, where heating is more desirable, attic ponds under pitched roof glazing are effective. Winter heating occurs when sunlight heats the water, which then radiates energy into the living space as well as absorbs heat within the water thermal mass for nighttime distribution. During the summer, a reverse process, described later, occurs. For best effect, roof ponds must be insulated (movable) so that heat will not radiate and be lost to the outside. One of the major advantages of this approach is that it allows all rooms to have their own radiant energy source with little concern about the orientation of the structure or optimal building form.

VIII. Conclusions

Climate change concerns coupled with high oil prices and increasing government support arriving increasing renewable energy legislation, incentives and commercialization. Solar thermal energy accounts for one of the major forms of renewable energy utilization. The mayor aplications of it are heating swiming pools, heating water for domestic use and space heating of building. Current research and developement is focused on improving solar heating technologies to make them even more efficient and afordable, with special emphasis on:

- Tesitng material for durability, much research efforts include glazing and absorbers.
- Conducting thermal analysis of solar water heating technologies that function in different climates.
- Developing advanced applications such as low cost solar water heating and collectors.

Solar savings fraction is very important in dealing about solar energy, which is the amount of energy provided via the solar technology divided by the total energy required. Passive solar technologies often yield high solar saving fractions for space heating, when combined with active solar technologies even higher conventional energy savings can be achieved. The electricity generation from solar energy is also an important feature that is available with different technologies such as solar tower and solar ponds. However solar dish/stearling engine has the highes energy efficiency. The one installed at Sandia National Laboratories produces as much as 25kW of electricity with conversion efficiency of 40.7%. As a solar power plant does not consume any fuel, the cost mainly consists of capital cost and some operational costs. If lifetime of plant and interest are known then cost for kWh can be calculated. Solar technologies have the potential to be mayor contributers to the global energy supply.

The ability to dispatch power allows large scale central solar technologies to provide 50% or more of the energy needs in sunny regions around the world. Large scale solar technologies can provide energy price stability as well as quality jobs to the local comunity. Solar energy has the potential to become mayor a domestic energy resource in the 21st century.

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