Review Paper on Solar Pond and its Classification

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Abstract: *Salt Gradient Solar Ponds (SGSPs) are man-made structures that block the pond's natural fluid convection in order to store solar energy. It uses solar radiation to heat the water, stores sensible heat in saline water that is dense and salty, and generates a density gradient that prevents convective heat transfer, allowing thermal energy to be stored as a clean energy source. This article provides a broad overview of solar ponds, classifies them, and talks about solar ponds with salinity gradients. Furthermore, we will talk about the research that various researchers have done in solar ponds. The majority of research and study on solar ponds has focused on salt gradient solar ponds (SGSP).*

Keywords : Solar ponds, solar gradient solar ponds, convective solar ponds, non-convective solar ponds

I. Introduction

Currently, fossil fuels provide a portion of the world's energy needs. In light of their depletion rates and emission regulations, these fossil fuels should be supplanted by renewable energy sources. Utilizing renewable energy sources can lower the amount of pollutants released into the atmosphere. In both developed and developing nations, research into solar energy in particular can be extremely important [1]. Solar energy is the radiation from the sun that reaches the earth. It is the energy source that is most easily accessible.

The largest source of renewable energy is the sun, which is abundantly present throughout the entire planet. In actuality, it is among the best options to non-renewable energy sources. Solar ponds are one method of utilizing solar energy. Large-scale energy collectors with built-in heat storage, solar ponds provide thermal energy. It has a wide range of uses, including heating purposes, water desalination, refrigeration, drying, and power generation [2].

The solar pond operates on a very straightforward idea. When water or air are warmed, it is a well-known fact that they become lighter and rise upward, like a hot air balloon. Related to this, in a typical pond, the sun's rays heat the water, which then rises to the top before losing its heat to the atmosphere. The overall effect is that the pond water temperature stays constant. The solar pond prevents this tendency by causing the bottom layer of the pond to dissolve salt, which makes it too heavy to rise.

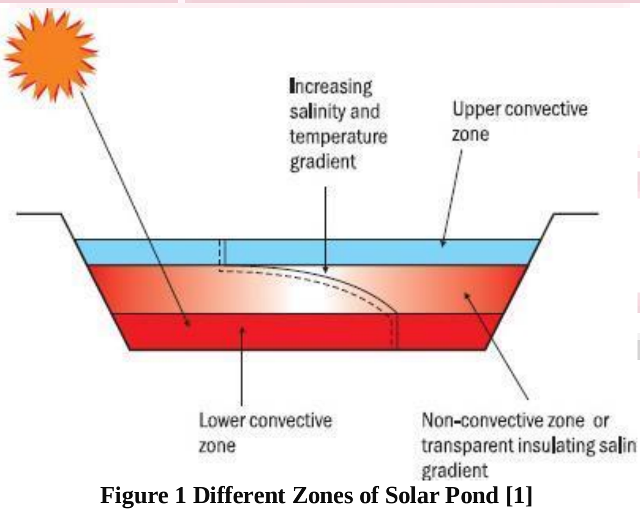

Figure 1 Different Zones of Solar Pond [1]

The 3 zones of a solar pond. The surface zone, also known as the UCZ (Upper Convective Zone), is the top zone. It is at atmospheric temperature as well as contains little salt. The bottom area is extremely hot (between 70 and 85 °C) and salty. This area, also referred to as the storage zone or LCZ, is where solar energy is captured and stored as heat (Lower Convective Zone). The crucial gradient zone, or NCZ, separates these two zones (Non-Convective Zone). In this, the salinity or density gradient is caused by the salt content rising with increasing depth. If we focus on one layer in this zone, the water in that layer cannot rise because the layer of water above it is lighter and has less salt content. The water in this layer also cannot fall because the water underneath it is heavier and has a relatively high salt content. As a transparent insulator, this gradient zone allows sunlight to enter the bottom zone while also trapping it there. The stored (solar) energy is then released from the storage zone as hot brine, which is then removed from the pond.

II. Classification of Solar Pond

Freshwater ponds have rising hot water that is heated by the Sun. As heat is expelled into the atmosphere, the water in the pond cools via evaporation, maintaining the temperature at that of the atmosphere. Contrarily, solar pond technique enables salt, whose concentration rises with depth, to try and stop the loss of heat from the water.

Figure 2 depicts the non-convecting as well as convecting categories of solar ponds. Also with additament of a concentration of 20–30% salt to the bottom level (lower convective zone) of the pond, the more popular non–convecting solar pond lowers heat loss by attempting to prevent convection (the transfer of heat from one position to the other by the circulation of fluids). The temperature of the bottom level increases to around 100 °C (212 °F) when saturated with large quantities of salt in the pattern of concentrated brine because heat from the Sun is trapped there. Compared to the bottom level, the middle level (non-convective zone) receives less salt. Also with additament of a concentration of 20–30% salt to the lower convective zone (bottom level) of the pond, the more popular non–convecting solar pond minimizes heat loss by attempting to prevent convection. The temperature of the bottom level increases to almost 100 °C (212 °F) when saturated with large quantities of salt in the type of concentrated brine because heat from the Sun is trapped there. Compared to the bottom level, the middle level (non-convective zone) receives less salt. The water in the middle level cannot rise or sink considering that it is heavier than the top level but softer than the bottom level. As a result, the middle level acts as an insulator and stops convection currents, trapping sunlight in the bottom level. The upper convective zone, in which there is minimal salt, is the area where water is the coldest. To that level, fresh water is then added while saline water is drained. In the process of extracting thermal energy, heat from the bottom level is eventually transferred to pipes that circulate thru the pond.

Contrary to non-convecting solar ponds, convective solar ponds instead trap heat by preventing evaporation instead of convection. Two layers of plastic or glass glazing are placed on top of a sizable bag of water with a blackened bottom, followed by a layer of foam insulation. This construction allows for convection but restricts evaporation. Throughout the day, the Sun warms the water. Hot water is then injected into heat-storage tanks at night.

Membrane solar Ponds **-** This type of solar pond uses transparent membranes that are closely spaced to transport the majority of the saltwater fluid. The membrane space's primary job is to regulate convection. Water's weight would stabilize the effect of buoyancy, allowing sensible heat to be obtained from solar radiation. The MSPs have three different types of membranes—Horizontal Sheets, Vertical Sheets, and Vertical Tubes—proposed to membrane a stratified solar pond. The membrane stratified solar pond uses thin, transparent membranes placed closely together to prevent convective heat transfer in the top portion of the pond. Membranes can be arranged as vertical tubes, horizontal sheets, or horizontal sheets.

Solar gel ponds **-** In the polymer gel layers solar pond, a thick layer of polymer gel floats on the lower convective zone. The Solar gel ponds are superior to certain other types of solar ponds because they eliminate surface evaporation losses and reduce heat losses. Polymer gels are able to float on a salt solution because of their intermediate density among fresh water as well as saline water.

Salt Gradient Solar PONDS **-** SGSPs are relatively shallow and have a depth of around 1–2 m as well as the bottom surface is generally blackened. In SGSP, the convection currents are usually developed because of hot water's existence in the Bottom with cold water at the top. These convection currents are suppressed by using a density gradient. Some salts such as NaCl, $MgCl_2$, $NaNO_3$ are added into the water with the Bottom concentration of almost 20–30% and a top concentration of almost 0% .

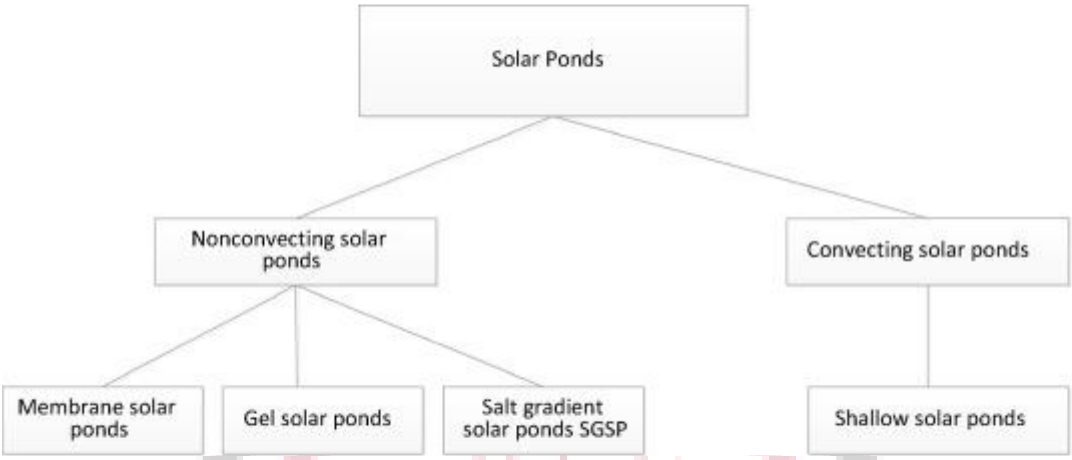

Figure 2 Classification of Solar pond

III. Salinity Gradient solar pond

The energy that can be generated or harvested as a result of changes in the salinity of seawater and freshwater is known as salinity gradient energy. When fresh river water is combined with salty seawater in estuaries, salinity gradient (SG) energy can be derived naturally by taking advantage of the difference in chemical potential. An ever-present renewable energy source is salinity gradient power generation. As a result, it complements sources of energy that are more variable, such as solar, wind, and waves. The most cutting-edge salinity gradient technique currently available is reverse electrodialysis (RED). The difference in salt content between fresh water and seawater can be used to generate energy using RED. Anion and cation exchange membrane stacks are used by RED to produce electricity.

"Salt Gradient Solar Ponds (SGSP)" are man-made structures that capture solar energy by preventing fluid inside the pond from naturally convecting. Utilizing solar radiation to heat the water, dense saline water is used to store sensible heat, a density gradient is created to prevent convective heat transfer, and thermal energy is thus stored as a clean energy source. The system mainly operates using the gradients in saltwater theory. In the saltwater pond, a vertical salinity gradient recognized as a "halocline" is created when low-salinity water floats on top of high-salinity water. The density of the salt solutions in the pond rises with depth because of a rise in concentration. The solution has a uniformly high salt concentration underneath a given depth. A calculated quantity of salt can be added to water to change the density of solar ponds. Solar ponds can store heat that can be retrieved as needed. The low efficiency of solar desalination ponds caused by their high salt concentration is one of their main drawbacks.

In order to gather solar energy and store it as heat for low-temperature implementations like space heating, industrial water heating, as well as crop drying, salinity-gradient solar ponds are of interest. Solar ponds may be significantly less expensive than some other solar collectors when used in such applications, and they also incorporate the capacity for long-term storage. It is conceivable to use solar ponds for solar thermal power generation in advantageous locations where the cost of conventional fuel is unusually high.

There are three distinct zones within a solar pond. The absorption and transmission region, also known as the upper convective zone (UCZ), is the first zone, which is situated at the top of the pond as well as contains the least dense salt/water mixture. Its purpose is to safeguard the salinity gradient layer. Water addition to the solar pond's surface and the avoidance of natural sources wind agitation regulate its stability. The gradient zone, also known as the non-convective zone (NCZ), or salinity gradient layer, is the second zone and includes a range of salt/water densities that increase with depth. The primary function of this zone is to act as an insulator, keeping deeper zones' temperatures higher by preventing the transfer of heat to the UCZ. The lower convective zone (LCZ), also known as the energy storage zone, is the final zone and therefore is composed of saturated brine with essentially uniform salinity as well as density.

IV. LITERATURE REVIEW

(Abdulsalam et al., 2015) A significant source of clean as well as renewable energy is solar energy. Due to solar ponds' ability to simultaneously obtain as well as store heat, that has lowered cost considerably, the technique has recently improved markedly, piqueing the interest of both the industry and researchers. Many salt gradient solar ponds have been built in different parts of the world. In additament to their achievement, enhancement, heat extraction mode, and applications as reported in the literature, the various types of solar pond strategies are reviewed in this paper. Additionally, the solar pond's cost as well as upkeep have been debated.

(Simic & George, 2017) Solar ponds with a salinity gradient are sources of renewable energy. By establishing a temperature gradient throughout the pond's depth, energy is captured. The solar radiation that strikes the surface is the source of all energy. Temperature differences of up to sixty degrees are caused by the salinity gradient, which is retained and altered with depth. The heat produced can be used directly for a variety of tasks, or it can be turned into electricity and sent to the grid or used inside the plant. Numerous solar pond parameters, or physical quantities, crucial to the proper operation of these types of energy production facilities are primarily observed locally, at the pond locations. It is more practical to control the solar pond energy production remotely after remote data acquisition (DAQ), and this is the focus of the research we conducted and the findings from which are presented here. A solar pond control center could be situated any part of the globe with the use of wireless, wired, virtual private networks, as well as the Internet, whereas the pond's sites are chosen at the best solar potential places.

(Kasaeian et al., 2018) The accomplishments in solar pond development over the past few decades are the subject of this study. First, new salts and additives are introduced to enhance the thermal properties of the solar pond's solution. Then, the cutting-edge plans for reducing heat losses from the solar ponds' top and bottom are presented. Other problems that could be improved include the ways in which heat is extracted. The systems that might be combined with the solar pond are then discussed. In fact, the progress made in all methods for gathering solar radiation, storing heat, extracting, and using solar ponds is surveyed and examined in this study.

(Panchal et al., 2021) Solar ponds (SP) are a notable development in renewable energy technological advances that have solar energy stored for storage needs and are used in numerous solar thermal implementations. It is also used for a variety of things, including air conditioning, heating, space heating, and many others. The use of an SP to supply hot water using the heat energy it has stored is demonstrated in the current paper as a way to increase the efficiency of solar stills (SS). It also reveals how to use shallow and small SPs in conjunction with SS to increase yield. This paper also includes a number of SS using SPs upcoming relevant research. It was determined from the current review paper that the SP rises the yield of the SS.

(Prajapati et al., 2022) The major amount of research and study on solar ponds has focused on salt gradient solar ponds (SGSP). Since the lower part of these artificially made solar ponds is regularly exposed to solar radiation, the temperature there rises. Convective heat transfer could be used to stop the pond's internal heating by turning it into a brine solution by adding salts like NaCl, $MgCl_2$, $NaNO_3$, etc. The standard attributes of solar desalination ponds are covered in this review. The impacts of temperature, external heat addition, the impact of a reflective surface, the wall profile of the solar pond, and turbidity have all been included in a summary depiction of the factors that affect effectiveness. In addition to the improvement in effectiveness, methodologies used to continue increasing freshwater production, design, as well as economic viability are also briefly covered.

(Nakoa et al., 2015) In order to produce freshwater sustainably and lessen the environmental impact of brine, this exploratory study explores the use of direct contact membrane distillation (DCMD) in conjunction with a salinity-gradient solar pond (SGSP). To assess the viability of freshwater production, a thermal model for the SGSP and a mathematical model for heat and mass flux in the DCMD module are created and coupled. Findings of a study using SGSP and DCMD at RMIT University are introduced. The SGSP warms the 1.3 percent salinity feed stream before circulating it throughout the DCMD module and injecting it into the evaporation pond. The heat from the DCMD's outlet brine stream is also recovered using a thermal energy system, which then pre-heats the inlet feed water stream. Analyzing the actual, it can be seen that if the flow is laminar, the DCMD module linking to the SGSP may cause a significant concentration and temperature polarization occurrence that lowers fluxes.

(AL-Musawi et al., 2020) A solar pond is a body of water with various salt concentrations that is used to collect and store incident solar energy for later use in various thermal energy implementations, including industrialized heating, electricity production, crop drying in agriculture, and home cooling. In order to clearly demonstrate the historical context for solar ponds as well as the most widely used solar ponds, a brief but focused review of the literature that dealt with their implementation is presented in this paper. Along with presenting and discussing the theoretical foundation of heat and mass transfer that guided the operation of the solar pond.

(Tufa et al., 2018) The most important advancements in RED are critically examined in this work, with an emphasis on fouling, stack design, fluid dynamics, process optimization, and promising implementations. The opportunities for using concentrated brine are being considered, driven by advantages in terms of higher power density as well as mitigation of negative environmental effects related to brine disposal, even though RED technology is primarily investigated for energy generation from river water/seawater. The main barriers to market implementation are listed, with a focus on the lack of high performance, reliable, and affordable membrane materials. Essential research directions to speed up the commercial production of RED are also identified through a techno-economic analysis based on the data from the literature that is currently available.

(Sathish & Jegadheeswaran, 2021) This review paper details developments in solar desalination, solar desalination progress, as well as integration of both systems over the last decade. Among the thermal energy storing systems that serves as a sizable solar radiation collector to gather and store solar radiation is the solar pool. The solar pool's built-up heat is counted as low categorization thermal energy. Upgrades are thus required to improve performance. First, the use of unusual salts and different additives is researched.

(Natarajan et al., 2019) A salt gradient solar pond is created and developed in the current research. Additionally, the same model has undergone thermal analysis and performance testing in the Vizag climatic conditions. The generation of sensible and latent heat for implementations such as industrial heating can be done using the same model. Additionally, electricity can be produced by using a suitable heat exchanger and a working medium with a low boiling point, like ammonia.

(Helfer & Lemckert, 2015) The progress made in PRO membrane development, especially over the last ten years, is discussed in this paper, along with the obstacles that still stand in the way of PRO's widespread adoption. By examining various combinations of existing solutions with different salt concentrations, this paper also investigates PRO implementation options. The country of Australia has been chosen to showcase some potential PRO applications. Saline water reserves are abundant in this vast nation and could be combined with less concentrated solutions to produce electricity. A conceptual concept is laid out and an estimated amount of power is produced for each combination of solutions. Additionally, each scheme's benefits and drawbacks are discussed. With a few minor adjustments, the concepts and projections can be easily applied to other nations with comparable conditions. It is hoped that this publication will be helpful to countries with policies like Australia's that provide government incentives for the creation and adoption of new technologies to investigate alternative renewable energy sources..

(Telesh et al., 2013) To demonstrate that eukaryotic and prokaryotic microbes in plankton exhibit a maximum species richness in the difficult zone of the critical salinity 5-8, where the large-bodied bottom dwellers (macrozoobenthos, macroalgae, and aquatic higher plants) experience widespread salinity stress that results in a depleted diversity, we review long-term data on organisms of different size classes and ecological groups. Researchers suggest a novel conceptual framework to demonstrate how the relative vacancy of brackish-water ecological niches and the reduced competitive nature therein favor the diversity of small, quickly evolving, unicellular plankton organisms.
(Goswami, n.d.) Desalination of seawater is a crucial process to meet the growing demand for fresh water, but because the source is so highly salinized, it requires a lot of energy. Studies on the use of solar energy to power seawater desalination are being pursued very actively. This paper first reviews the ongoing research on solar desalination, then discusses solar assisted desalination procedures and various possible combinations. Although solar assisted desalination has been shown to be technically feasible, desalination using low grade waste heat or a combination of solar and fossil fuels may currently be more cost-effective options. Despite the fact that solar assisted desalination processes have not yet been made commercially available, they are still a viable option for future desalination plants thanks to the current ongoing research.

(Velmurugan & Srithar, 2008) A solar pond is a man-made body of water in which the lower regions are made to face major temperature increases by blocking convection. In the pond, salt water is used to prevent convection. They are referred to as "salt gradient solar ponds." Many salt gradient solar ponds with surface areas ranging from a few hundred to a few thousand square meters have been constructed in a number of nations over the past 15 years. Mini solar ponds are now also being built for various thermal purposes. This study reviews various solar pond designs, opportunities for performance improvement, performance-related factors, heat extraction methods, theoretical simulations, parameter measurements, economic analysis, and its applications.

V. CONCLUSION

By preventing the natural convection of fluid inside the pond, Salt Gradient Solar Ponds (SGSP) are man-made systems that store solar energy. Utilizing solar radiation to heat the water, dense saline water is used to store sensible heat, a density gradient is created to prevent convective heat transfer, and thermal energy is thus stored as a clean energy source. In addition to discussing the salinity gradient solar pond, this paper gives a general overview of solar ponds and their categorization. We will also talk about the research that various scientists have done in solar ponds. Researchers and scientists have spent the most time studying Salt Gradient Solar Ponds (SGSP) out of all the different types of solar ponds.

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