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Solar Ponds as Source of Non-Conventional Energy Case Study in Fayoum, Egypt

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Abstract**—** *Egypt prioritized the implementation of non-conventional energy storage. Accordingly, this research was imitated taking into consideration impacts of solar pond "SP" salinity profile on non-conventional energy productivity, where Fayoum Governorate was taken as a case study. Primarily, literature was reviewed in the field of non-conventional energy storage systems, where salinity profile was the predominate parameter that dominates the energy production. Site visits were carried out, where the study area was selected and solar ponds were constructed in Shakshouk Research Station in Fayoum. An experimental test program was designed and tests were achieved. Temperature and salts concentration gradients were developing energy by heating the bottom pond. Measurements were executed and a salinity profile was obtained. The results were analyzed and discussed. The results indicated that the SP temperature reached 70^o C, which denoted that a proper salinity profile was established. This indicated that the SP could provide reasonable energy as a non-conventional source.*

Keywords**—** *Solar Energy, Salt-gradient, solar ponds, Non-Conventional Energy, Fayoum.*

I. INTRODUCTION

In 1900, 10 million barrels of oil was consumed worldwide. It is expected to increase to 400 million barrels by 2030. Consequently, a non-conventional source such as solar pond should be sought, where its salinity gradient is apparent was responsible for the obtained amount of Energy. Accordingly, this research was commenced with the objective of investigating the impact of the solar pond "SP" salinity profile on the non-conventional energy productivity, where Fayoum was taken as a case study.

Many researchers investigated non-conventional energy sources, as follows:

[1] Stated that an increase in energy demand amplified the requisite of renewable energy, which plays an important role in driving the world towards the direction of implementing secure sustainable energy source.

[2] Documented that solar energy is the cleanest friendly solution to the environment compared to pollution resulting from fossil fuel.

[3] Advocated that solar energy is progressing rapidly.

[4] Designated that the foremost challenge is how to storage solar energy. He further reported that there are many systems for harvesting solar energy, the most important of which is SPs. Described

[5] Termed SPs as huge shallow dark bed water body heated by solar radiation.

[6] Described the types of ponds, which is divided into 2 categories (i.e., convective and non-convective).

[7] Advocated that salt-gradient of a SP is a particular parameter, which relies on the salt solution increment by depth.

[8] Designated that SPs are economic captors of solar energy

[9] Reported that the stored energy could be implemented in many applications

[10] Stated that LCZ "lower convecting zone" is the highest salinity zone and UCZ "upper convecting zone" is the least salinity zone. These layers are separated by a non-convective zone with escalating concentration, figure (1).

[11] Documented that heat is accumulated in the storage zone for seasons. Moreover, the proposed idea of power chimney is an addition to produce distilled water.

[12] Stated that UCZ protects NCZ from external perturbations as wind and to balanced system.

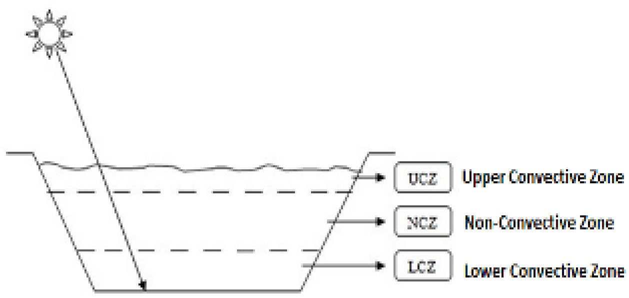

Figure 1: SP layers modeling

II. SITE VISITS AND SITE DESCRIPTION

Several site visits (i.e. 2018 - 2020) were realized to amass data; shoot photos; capture measurements and sample water in order to visualize a comprehensive picture to the study area. Based on these visits, apparent was the extracted information describing it:

- Fayoum is an oasis. It is 6068 km^2. It is gifted by a moderate climate.
- The site is liable to produce 70 ^{o}C, if a solar pond was constructed.
- The site is exposed to high solar radiation. It has a low wind speed with minimum vegetation, which facilitates the construction of solar pond with minimum excavation.

III. SOLAR POND CONSTRUCTION

A physical model was constructed in the selected location to simulate a real SP. The model was designed with a drainage pattern for heat extraction. The soil was excavated with 3:1

slope. Liners were utilized to prevent leakage of saline into underground water, where it was tested to ensure its tolerance to the maximum pond temperature. The pond was filled and exposed to radiation. An underwater heat exchanger was implemented to circulate water.

IV. Experimental Program

An experimental program was designed to investigate two membrane colors (i.e. black and white) and two thicknesses. Figure 2 presents the experimental scheme.

Figure 2: Experimental Program for the different parameters

V. Measuring Devices

During before and during-construction, the following devices were utilized.

- Surveying devices: A total station, figure (3), was implemented and a benchmark, figure (4) was designated on the site.
- Wireless weather station: A wireless weather station was implemented, Figure (5) to (7).
- During the experiments, the implemented devices were as follows:
- Salinity measuring devices: Conductometer to measure the electrical conductivity, Figure (8).
- Digital thermometer: K-type thermocouples were utilized; figures (9) to (11).

In addition, pipelines quality was controlled, figure (12) and figure (13). Also, Hargreaves-pan-evaporation was utilized, figure (14).

Figure 3: Surveying Devices

Figure 4: Site benchmark

Figure 5: Implemented Wireless Weather Station

Figure 6: Implemented Wireless Weather Station components

Figure 7: Implemented Wireless Weather Station after assembly

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Figure 8: Implemented Salinity measuring device

Figure 9: Thermometer device in the field

Figure 10: Salinity measurement for site samples

Figure 11: Temperature measurement for solar pond

Figure 12: Quality control for pipelines

Figure 13: Quality control for pipelines

Figure 14: Implemented Hargreaves Pan Method

VI. Inspection of Implemented Materials

The implemented materials and tests are as follows:

- Salt: The implemented salt is chemically stable, where sodium chloride properties are brine classification. The implemented salt is the predominate parameter that dominates the salinity profile that provides the required temperature.
- High-density polyethylene (HDPE) geo-membrane: It was tested to determine its properties (i.e., Thermal expansion, Puncture resistance, Ultraviolet resistance and Permeability) [13]. The geo-membrane was welded thermally, figure (15). The surface of the two sheets is melted, Figure (16). Extrusion welding is implemented, Figure (17).

Figure 15: Implemented HDPE wedge welder

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Figure 16: Implemented wedge welder and temperature


Figure 17: Implemented extrusion welding machine

VII. EXPERIMENTAL PROCEDURE AND MEASUREMENTS

The selected site is located at Shakshouk Research Station under the umbrella of the National Water Research Center in Fayoum.

- A 12x12x3 m lined solar pond with a water depth of 2.5 m was constructed, figure (18). The pond was named "Master Pond", In addition to three ponds.
- It was lined by 1.0 mm thick membrane sheets.
- The pond was filled by tap water (1001 kg/m3) at ambient temperature with 0.041% Na and 0.032% CL. This was considered "zero concentration" or "initial conditions" or "control concentration".
- The pond was filled in layers with a salt concentration gradient. A Non-convention-zone (NCZ) of 50 cm was created.
- The pond was exposed to the solar radiation for period between April 2020 to august 2020 and regular measurements were undertaken and recorded for 4 months.
- It is to be noted that 3 unlined ponds were in the site, where measurements to the temperature and salinity profile were measured pond (1) is 56x56 m, pond (2) is 22x68 m , and pond (3) is 24x72 m


Figure 18: Constructed solar pond

VIII. RESULTS ANALYSIS AND DISCUSSION

Results were obtained based on actual field measurements; analyzed and plotted on self-explanatory graphs, where density profiles and temperature variations were perceived. Regarding the Master Pond" results, they are discussed, as follows:

- After 15 days, the salinity gradient turned to be a proper profile (i.e. curved gradient) and no more stepped, as was observed during filling. This proper profile supports a reasonable energy production.
- Salinity difference was 15 % (i.e. Surface and bottom). This emphasized the establishment of a proper profile.
- Density profiles varied by depth for the master solar pond, Figure (19). In addition to the salt analysis for different layers in the solar pond 1,2,3 show in Figure (21), Figure (23), and Figure (25) . The average density was 1.01, 1.07 and 1.16 ton/m^3, for UCZ, NCZ, and LCZ, respectively.
- Variations were designated for UCZ, NCZ and LCZ, all the way through the measurements period for the master solar pond (i.e. 4 months), Figure (20).
- The average values of temperature in UCZ, NCZ, and LCZ were 35, 42, and 70 ºC, respectively.

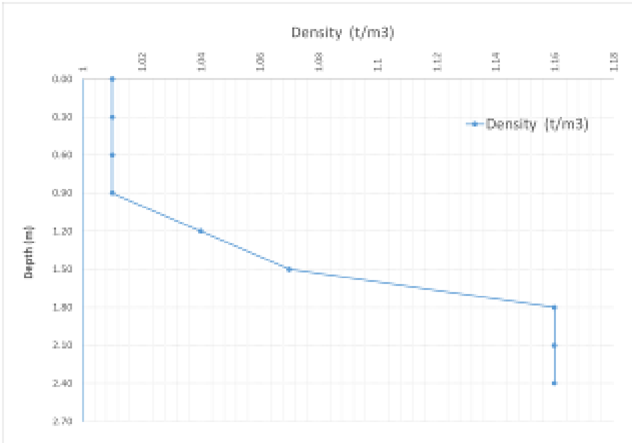

Figure 19: Density profile for the SP

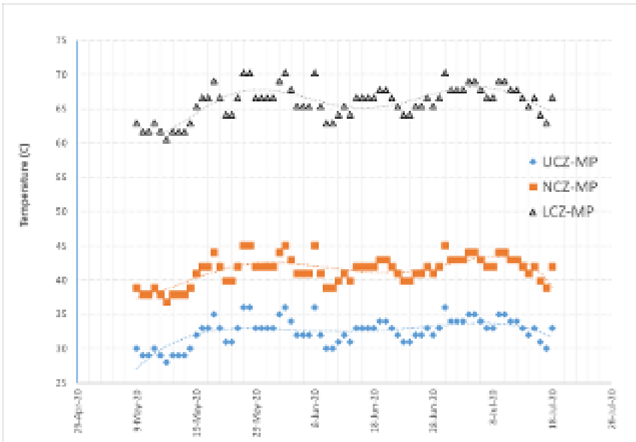

Figure 20: Temperature profile for the SP

Similar results were obtained to ponds 1, 2 and 3, in terms of salinity profiles and temperature variations. These results are discussed, as follows:

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Concerning Pond 1 results, they are scrutinized, as follows:

- The density profile is provided on, Figure (21).
- Variations were designated for UCZ, NCZ and LCZ, all the way through the measurements period (i.e. 4 months), Figure (22).

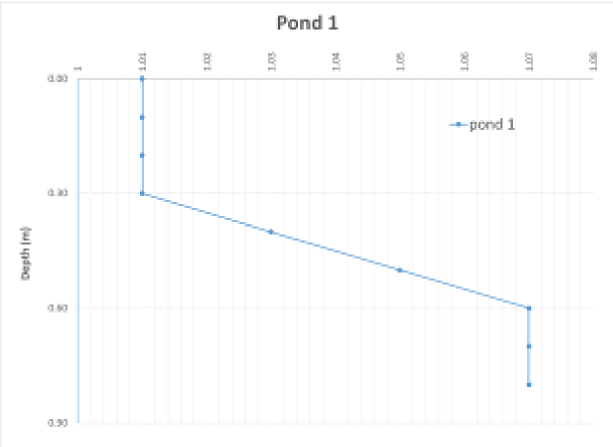

Figure 21: Density profile for Pond 1

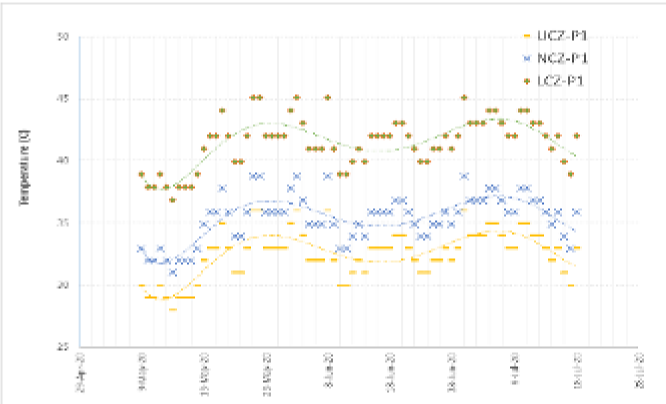

Figure 22: Temperature profile for Pond 1

Figure 23:Density profile for Pond 2

Focusing on Pond 2 results, they are deliberated, as follows:

- The density profile is presented on, Figure (23).
- Disparities were labeled for UCZ, NCZ and LCZ, during the measurements period (i.e. 4 months), Figure (24).

Converging on Pond 3 results, they are argued, as follows:

- The density profile is presented on, Figure (25).
- Differences were highlighted, during measurements duration, Figure (26).

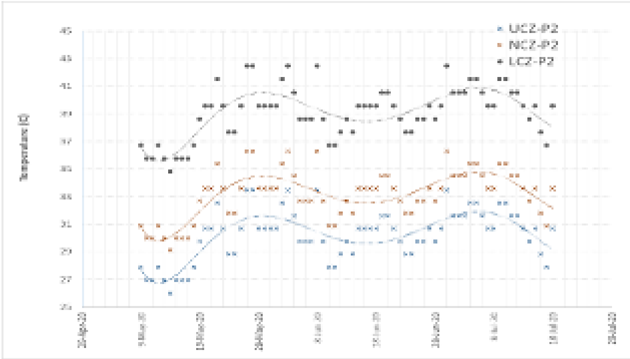

Figure 24: Temperature profile for Pond 2

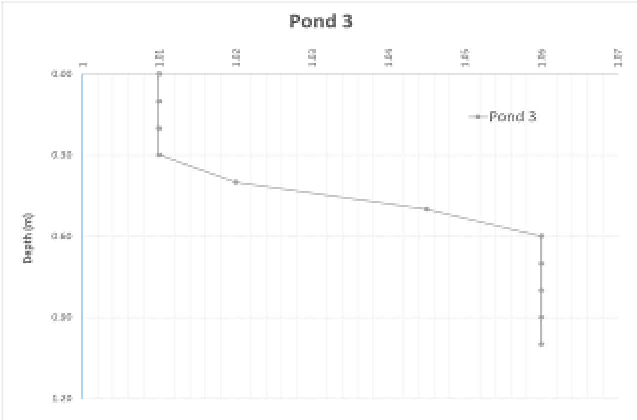

Figure 25: Density profile for Pond 3

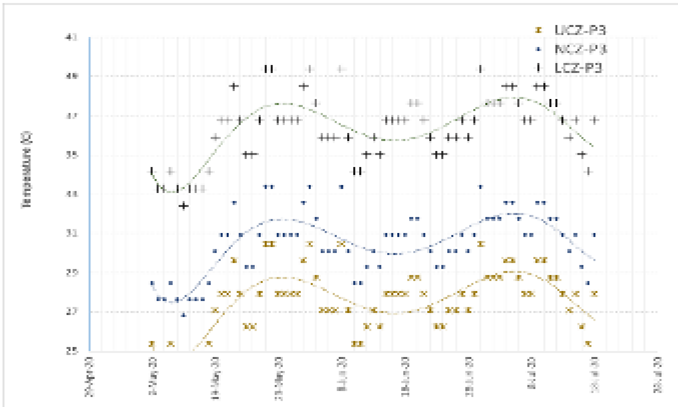

Figure 26: Temperature profile for Pond 3

Figure 27: Implemented master solar pond

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IX. Conclusions and Recommendations

Based on the measurement results, these conclusions were reached:

- Solar ponds provided temperatures between 40 and 70°C. This is attributed to the fact that a proper profile was established that provide reasonable energy.
- Salinity difference was 15 % (i.e., Surface and bottom). This provided an ideal salinity profile. Density was 1.01, 1.07 & 1.16 ton/m^3, UCZ, NCZ and LCZ, respectively.
- Noticeable was that the Master Pond provided relatively higher densities and temperatures, as they are lined.
- Salt analysis to Qaroun lake to know the quantities and percentage of compound of salt types in addition to all solar pond uses in Shakshouk research station, Fayoum governorate, Egypt.

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