Medicon Engineering Themes
Volume 2 Issue 5 May 2022
Research Article

Power Quality Improvement Using Modified ANFIS in Hybrid Miniature Solar Power Generation Units through Reduction of Total Harmonic Distortion

J Samuel Manoharan*

Professor/Dept. of ECE, Sir Isaac Newton College of Engineering and Technology, Nagapattinam, South India

***Corresponding Author:** J Samuel Manoharan, Professor/Dept. of ECE, Sir Isaac Newton College of Engineering and Technology, Nagapattinam, South India.

Received: April 01, 2022; **Published:** April 21, 2022

DOI: 10.55162/MCET.02.038

Abstract

Research in solar ponds have been on an increasing trend in recent times as an alternative for fast depleting non-renewable source of energy. Solar ponds are artificial saline water holding structures which are capable of retaining heat in the saline molecules. A suitable thermo electric generator is capable of extracting power from these ponds. A miniature solar pond has been taken up for experimentation and output power quality improvement has been achieved by reducing the total harmonic distortion using an adaptive neuro fuzzy inference system. Experimental results justify power quality improvement using the proposed learning based approach.

Keywords: Solar Pond; thermo electric generator; Total harmonic distortion; Power quality improvement

Introduction

Nonrenewable energy sources have seen a rapid rate of depletion due to excessive consumption and hence necessitating for alternate sources of energy. As per the statistics of 2016 [1], the energy consumption per capita for China is seen to have a growth of 1.4% compared to the previous year with its coal consumption reaching up to 4.5 billion tons followed by USA nearing 3 billion tons closely followed by India, Russia and Japan. Many of the Middle East countries including some western countries have already begun small scale implementations using renewable sources of energy with solar power being the major contributor. Typical global solar power installations could be seen in USA, China, Japan, Cochin, Tibet, Chile etc. [2-3] contributing to nearly 20000MW of energy to China followed by 13000MW to USA, 9000MW to Japan and 4000MW of power to India.

Solar energy is an abundant form of energy available in nature. Widespread increase in installation of solar panels for harvesting this abundant energy is on the growing trend especially Middle Eastern and Asian countries due to the nature of its tropical climate. While the installation is costly, significant amount of quality power could be harvested using these solar panels. The efficiency of power generated is dictated by the optimal number of solar arrays used which in turn depends on the load requirement on the output side. Certain signal conditioning and tuning models are used to reduce the harmonics in order to provide quality power. In recent, times, another growing means of collecting this solar energy is through artificially constructed ponds known as solar ponds which collects heat and generates an electrical output equivalent based on the working of Peltier effect. There has been growing interest in the domain of solar ponds in recent times especially due to its cost-effective approach. However, the amount of power collected in comparison to the solar panel is quite low. In spite of their low power generation, they are excellent sources of energy storage due to the nature of the brine solution which is the content of the pond, and they find wide utility in hybrid energy conversion systems involving solar panel themselves or the wind energy conversion systems. Solar ponds act as excellent compensators in a hybrid system by generating power when the source of power in the other renewable energy system is down due to failure of components or weather conditions.

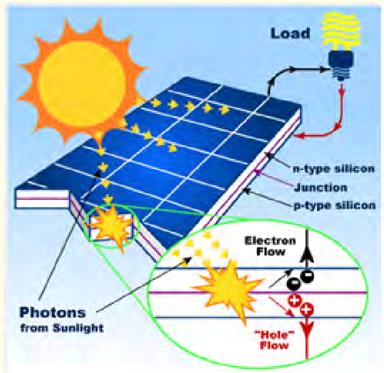

Figure 1: Working Principle of solar panel.

A typical solar panel operation is depicted in figure 1. The output power from this renewable energy source is given to a grid or micro grid depending on the load requirement. Before generating and giving the raw power to the grid for consumption, inverter circuits are employed to convert and condition the output power to reduce the effect of harmonics which when left unattended may tend to degrade the signal quality. The advantages of solar power and solar panels include that once the system's installation costs are paid, then the electricity is produced for the rest of the system's lifetime, i.e, 15-20 years is free for electricity production based on the system quality. For grid-tie solar power design owners, the advantage obtained from the online system, which is used to eliminate the monthly electricity bills, and this will help the system's owner to earn additional revenue from the electric organization. When the power use is less than what the solar electric system generates, then the extra electricity is used to sell to the electric utility provider, often at a premium.

A derivative solar power generation in the form of solar pond could be seen in Bhuj in the state of Gujarat spread over an area of 6000 sq. m which caters to power needs of nearby dairy production in Kutch. A solar pond is a manmade artificial lake or pond filled with a saline solution of suitable concentration. The solar pond gets divided into three distinct regions namely the upper convection zone (UCZ), the middle non-convective zone (NCZ) and the lower mixed zone. The salt molecules in the saline solution trap the incident solar irradiation during the daytime thus heating up the lower zone. As one progresses from the bottom of the pond, the heat decreases with a cool upper zone observed over the surface. As the UCZ is cooler compared to LCZ, a potential difference is created through Peltier effect which is magnified through appropriate circuity to generate electricity using a thermo electric device. A simple solar pond construction is depicted in figure 1 shown below.

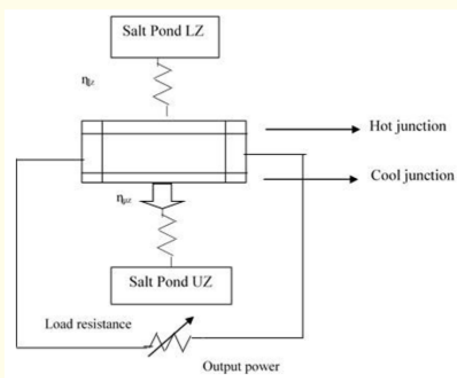

Figure 2: Working Principle of solar pond.

Related Works

Research in solar ponds have been carried out with several variants like mixing of hot and cool waters or mixing of saline and fresh waters resulting in reverse electro dialysis (RED) [4], utilization of nano fluids [5], injection of saline solution [6] with suitable polymer-based materials to retain heat after research experiments establishing relationship between thermal efficiency and gradient layer thickness [7]. A suitable heat transfer system has also been implemented for energy harvesting in the literature [8].

An existing method [9] in the literature proposes a hybrid algorithm called an automatic solar tracker based on a microcontroller which is used for finding the sun's position. The hybrid solar tracking method consists of a mathematical model and sensors. The algorithm is used to find the sun's position precisely, thus optimal solar energy is obtained for different weather conditions. A webpage is also developed, which helps to monitor real-time solar data.

Another method presents a comprehensive study on recent improvements in size optimization methodology [10], and also makes a crucial comparison of hybrid algorithms, and single algorithms. The software equipment is utilized to size stand alone solar and then the wind HRES. Additionally, every possible combination of solar and wind energy is assessed. It also evaluates its metrics of environmental, reliability, and social factors.

An existing method focuses on the feasibility of techno-economic by using a grid-tied hybrid microgrid model for residents of Kallar Kahar, which is Pakistan province nearby Chakwal Punjab city. For a generation of electricity, it makes investigations on the potential through photovoltaic, biomass systems, and hybrid wind [11]. For the integration of the grid, the evaluation of comprehensive resources of biomass, solar energy, and wind is carried out. The software named Homer Pro is applied for a hybrid microgrid model. The entire power generated through photovoltaic, biomass, and wind resources is optimally shared among them. Then, the surplus power obtained is given to the national grid while load demand is obtained.

Another method investigates a hybrid grid model of wind and solar power for an urban region in Khvafcity which is situated in the eastern portion of Iran. Simulation, technical, and economic evaluations of the hybrid method are examined with the help of HOMER software. In this, the variation of investing on PV panels along with the range of the sun radiance and also a variation of investment on wind turbines by considering sun radiance and wind velocity on the model layout are learned and discussed [12].

Another method [13] proposes a converter mesh for a hybrid photovoltaic / wind energy system. Hybridizing sun and wind sources give a sensible kind of intensity age. The method used to manage the domestic application performance by applying GSM. The setup will enable both references for supplying the heap separately or at a similar time contingent on the availability of the vitality resources.

An existing method [14] makes analysis, modeling, and simulation of the energy conversion equations. It explains the behavior of a hybrid wind turbine and photovoltaic system which will supply electrical energy to organic architecture. And a numerical approach depending on the basic equations are coded and developed, and the comparison is made with results and experimental data along with a real-time airplane model situated in a remote place of Ecuador. The technique is utilized as an optimization and then design equipment for hybrid models used in organic constructions.

Another method makes cooling of PV panel via various vegetation and also water tray is performed [15]. The aim is to increase the efficiency of a panel by controlling the temperature of the panel surface and by making cultivation on various vegetation under the panel. The experimentation is carried out for polycrystalline silicon cells. Also, the plants were taken for the experiments have a good effect on evapotranspiration except for aloe vera.

An existing method review about solar power arises from sunlight and their future aspects and trends are discussed [16]. The author also describes types of solar panel types, working and makes emphasizing several methods and applications to promote the solar energy benefits.

Another method makes technico-economic survey depending on integrated simulation, modeling, and optimization technique is applied to design hybrid off-grid solar Fuel/ PV Cell power model. The objective is to improve the design and enlarge the strategy of dispatch control of the hybrid standalone renewable energy model to give the desired electric charge of a residential community situated in a desert area [17]. The temperature effects and accumulation of dust on the PV panels on the system and the hybrid energy system performance in a desert area are also investigated.

An existing method presents [18] a survey of the operation and the dynamics of the hybrid TEG/ PV model in an outer space surrounding where a unified thermodynamic design is presented. Furthermore, the NSGA-II GA is applied to optimize the TEG design based on output power and mass. Particularly, the single and the two-stage design of the TEG are taken.

An existing method study proposed a novel system for renewable power called solar/ photovoltaic pond [19]. The method contains the arrays of the thermal/ photovoltaic collectors, which can be installed near the solar pond along with a heat exchanger that is installed against every solar cell. And an experiment is performed to estimate the mini solar/PVpond thermal performance.

An active method proposes an external magnetic area to repress the convection place and enhance its operating stability [20]. When a solar pond is exerted by a magnetic control, it will reduce the thickness of the non-convective zone. After 35 h of steady illumination, the condition of the solar pond is converted from a thermally unstable to a theoretically stable condition. A Hartmann number which is above 56.67 is used to increase the solar pond stability.

In Benguela, at Caota beach, the thermal efficiency of a 1-hectare solar pond is placed [21]. While in the initial year, there is no extraction of energy from the pond and then the temperature of the water is also lower, approximately 93˚C. After the second year, the extraction of thermal energy is made. Thus, the two conditions are considered, i.e heating of water from 40 to 60°C or 50 to 70°C. The total energy efficiency is obtained in the range of 2 to 5% in solar ponds.

Another method describes [22] in the solar pond brine, the quality and quantity of DOM (dissolved organic matter) will influence the efficiency of brine evaporation rates and mineral extraction. A characterization review of DOM is made by using various models in the solar pond brine oilfield. The result shows that the overall dissolved solids and concentrations of dissolved organic carbon exhibit a 2-3 fold increase along with time exposure in the solar ponds.

An existing method [23] accounts for the temperature drop over the two lower-convective and non-convective zone exchanger surfaces by utilizing a local space and time-dependent heat transfer coefficient. The author makes a useful survey to evaluate extraction of multi-zone under the transient condition from a solar pond more accurate and practical manner.

Another method makes study on [24] salinity gradient solar pond stability by using classical PCA on 3 datasets with a various number of time evolution and variables. In a solar pond, the two operational seasons are taken to establish: (i) For the 2014-2015 operational period, PCA exploratory models are considered, and (ii) during the 2015-2016 operational period, the obtained results are validated. The method shows that for solar pond operation process control and surveillance, PCA modeling is a powerful tool.

A novel method makes investigation on [25] the heat dissipation effects on several thermal aspects from salt gradient solar pond's sidewalls are carried out. Both steady and time-dependent solutions are reported. The method also proposes guidelines of cardinal based on the unsuitability and the suitability of insulations with a suitable choice of solar pond's system.

For a salinity gradient solar pond based on a power generation model [26], the evaluation of thermodynamic feasibility is investigated. The organic Rankine cycle by utilizing the working fluid called zeotropic mixture is employed for energy generation. Then, the effect of walls shading on the solar pond and also heat losses from a solar pond is taken in the simulation.

Another method proposes eigenfunctions expansion to estimate temperature profiles in the solar pond which contains dual-layer extraction of heat [27]. The system net energy output is obtained for a particular period by utilizing the temperature field. Then in the system output, the sensitivity of various designs and operating parameters is also calculated.

An existing method develops a simulation set-up CFD to attain a fully versatile system that applies to any scenario. The results are compared with an existing 1-D MATLAB model and the 2- and 3-D CFD models [28]. It precisely calculates the heat loss, the absorption of irradiance by the solar pond, and also the thermal performance of the solar pond. In this, two geographic areas: Kuwait City and Iran, are calculated.

Proposed Work

The solar panel consists of photovoltaic cells as its backbone. The method photovoltaic power model is used to generate electrical power and semiconductors are used to convert radiation of solar into direct current electricity that shows the effect of photovoltaic. The power generation of PV utilizes solar panels which comprise numerous cells that contain a semiconducting material. Electric power is generated when there is a shining of light on the solar cells. And then there is no electricity when there is no light. In the semiconductor industry, the most commonly utilized element is silicon. It is a semiconductor material in which PV cells are built. The semiconductor material will absorb some portion of light when it strikes the cell. The electrons will lose, and they will move freely when there are energy strikes on the semiconductor. PV cells consist of more electric fields which will force the electron to flow in a certain direction which is freed by the absorption of light. The electron flowing is called a current. The current can be drawn, and it can be utilized externally when the metal is placed on the PV cell's top and bottom. This cell's voltage and current are attained due to electric fields. Thus, a solar cell will produce the power it can be defined in watts.

The PV model is represented and based on the organic construction characteristics it is mainly considered, in such a way it is in circular, rectangular, star, oval, etc. And it is done based on the architectural styles and also combined with the electric power generation model. When there is a shortage of energy production for an hour, it also contains a battery bank to store energy and it will provide the load. Also, it contains a charge controller, in which the input energy enters into its terminal and then makes a connection with the battery. And there is also an availability of an inverter, which will convert direct current (d.c) into alternating current (a.c).If a generation of power is made by renewable resources such as solar, is inadequate based on the voltage and current measurements for the power demand on the side of the load (PL), which will cause a fall in DC link voltage VDC. The positive reference current is produced by a positive mistake (V * DC - VDC). And in a mode of buck, it will transmit power from the power bank battery to charge (discharge) when their SOC (State of Charge) is more than the minimal value. Then, if there is less power supply than demand and also the battery is at lower (SOCmin), to balance the power they require the shedding of load. When the generation of power is exceeded more than the load power, and also increases in DC link voltage VDC, it will produce a reference current in boost mode which is used to manage the battery bank power. In this, from the DC link, the power will flow to the battery with the additional power generation. But, if the SOC battery exceeds its maximum value (SOCmax), the charging mode of the battery will stop, and the PV model will function in MPPT (Maximum Power Point Tracking) off mode to decrease the generation of energy and to keep the energy in a balanced state.

Thus, the proposed method uses the photovoltaic generator with an equivalent circuit namely two diode systems, due to its good capacity of power extraction when compared to the single diode system. And then to balance the photovoltaic (PV) energy fluctuations, it also requires a battery solution. Normally, the P-N junction semiconductor is a building block of the solar cell, i.e. solar array. Because of the effect of photovoltaic, it is capable to generate electricity. In a configuration of series-parallel, the interconnection of photovoltaic cells is made to design a photovoltaic matrix. For the effect, the ideal single diode is modeled as expressed in Figure 3.

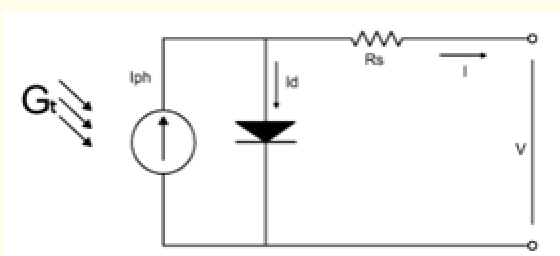

Figure 3: PV model- Single diode.

The current I_{pv} is calculated in Eqn(1):

$$I_{pv}(s) = I_{ph}(s) - I_{rs}(s)\left[\exp\left(\frac{e\left(V_{pv}(s)+I_{pv}(s)I_{rs}\right)}{D_c KT(s)}\right)-1\right] \qquad (1)$$

In given insolation, Cph is the generation of current. The Crs is the saturation current, and in given insolation, Cph is a generation of current on the panel surface. The Crs reflects the reverse current in the cell. V_{pv} is the PV panel voltage. E is the electric charge. Rs is an intrinsic resistance cell. From the characteristic of P-N binding, Dc is the deviation of a cell. Then, T is the temperature of the cell and K is the Boltzmann constant. Equivalent modeling of a single solar cell is depicted in figure 4 shown below. For an ideal shunt diode system, an extra shunt resistance is connected in parallel, and it is used by a single diode system. By applying a single diode system, the PV cell's I-V characteristics are derived.

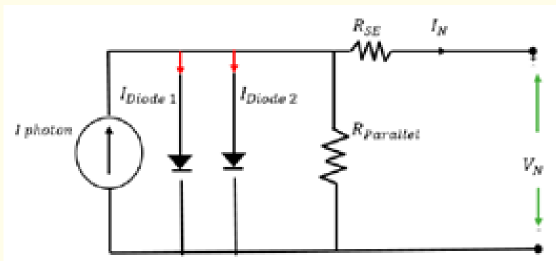

Figure 4: PV model - Double diode.

The output current of PV cell is shown in (2) mathematically as:

$$I_N = I_{Photon} - I_{Diode1} - I_{Diode2} - \left(\frac{V_N + I_N R_{SE}}{R_{Parallel}}\right) \qquad (2)$$

Then, the PV solar collector which absorbs thermal energy is given in Eqn (3)

$$P_{pv} = \rho_{pvg} S_{pvg} Y_t \qquad (3)$$

Where ρ_{pvg} is an efficiency of PV generation, S_{pvg} is an area of PV generator (m^2), and Y_t is irradiation of solar in module plane. Further ρ_{pvg} is defined as in (4):

$$\rho_{pvg} = \rho_r \rho_{pc} [1 - \alpha(T_a - T_{aref})] \quad (4)$$

When MPPT is utilized, then it is equal to the efficiency of power conditioning (ρ_{pc}), α is the coefficient of temperature [[.004–.006] per 0°C], ρ_r is the efficiency of reference module, T_{aref} is the temperature of reference cell in °C, and T_{aref} is the temperature of collector reference. In a solar panel, the area S_{pvg} is determined based on their shape w.r. to the plane reference, whether it is circular, rectangular, star, oval type, etc. The photovoltaic matrix is categorized into various photovoltaic modules and its connection is made in series-parallel. Then the connection is permitted to possess the PV matrix's voltage and current value and hence its power is obtained.

Results and Conclusion

The proposed solar pond is implemented in an open terrace with an artificial well designed with dimensions of 2m x 2m with a depth of 2m. The well is sealed with low density polyethylene membrane (LDPE) with an average thick ness of 15 microns over which a layer of clay is spread out. A saline solution is prepared by mixing water with salt with density of 1700gms/m^3 and allowed to settle for five hours. The pond was installed on 28.02.2020 with a network of thermoelectric generators and thermocouples along the poly vinyl chloride piping system. The solar irradiation measured at the experimental site in Tranquebar in Southern India with coordinates 11.0290°N and 79.8507°E on a house rooftop. The solar irradiation measured during the peak summertime of March 2020 and October 2020 is tabulated in table 1 shown below.

May and October record a peak and average temperature of 42° and 35° respectively. The experimental pond is of a brick and cement construction but well insulated and filled with clay to mimic a real time solar pond. The depth is maintained at 2m with depths of UCZ (0.6m), LCZ (0.8m) and the intermediate zone (0.6m). 140 liters of saline water is filled with an outlet pump for replenishment of the solar pond at regular intervals of time. Coarse sodium chloride of dimensions varying from 0.4 – 0.5mm have been mixed in the fresh water and stirred followed by a two-day settling time. The recordings are given to MATLAB 7.0 platform running a SIMULINK model of a solar pond. Since, power quality influences efficiency, harmonic distortions obtained in the output power has been fine-tuned with the help of a ANFIS controller with back propagation learning. Temperature retained in LCZ varies from 20° to 60°C for solar irradiances of 1500W/sq. m. The proposed model is depicted in figure 5 where a five stage ANFIS model (inputs – solar irradiance (x) and temperature (y)) with a target error fixed at 0.25644 has been used to train the boost converter output to minimize the THD.

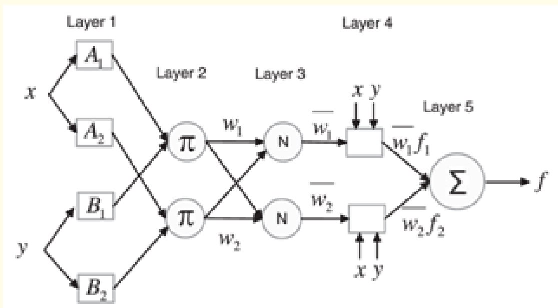

Figure 5: ANFIS model used for proposed miniature solar power generation unit.

Activation function of ANFIS is a Gaussian function modelled as

$$G_{MF} = \exp\left[-\left(\frac{x-b}{2a}\right)^2\right] \quad (5)$$

Where *a* and *b* depict the membership functions which define the shape of the curve. The output of the first layer computes degree of membership followed by second layer defining the firing rule through a 'AND' operator for multiplying the inputs from the previous layer given as

$$G_{1FR} = G_x * G_y \quad (6)$$

The third layer normalizes the firing rules followed by the fourth layer introducing adaptivity. The final layer is the summation layer which computes the output based on inputs coming from all sources form previous layers. 80 iterations (284s) are required to meet the desired target of 0.25644 generating a maximum power output of 15.9W as depicted in figure 6.

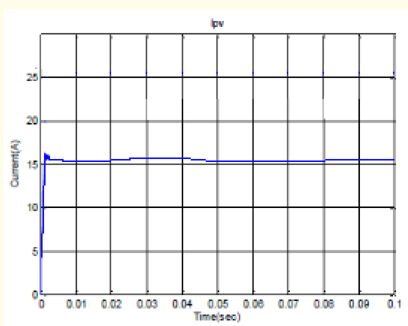

Figure 6: DC output voltage (15.9V).

Table 1 illustrates the observed temperature differences at the TEG plates and the computing power with and without ANFIS control. A significant improvement in the power output as a result of reduced THD amounting to nearly 40% through ANFIS could be observed. Improvement of power quality is estimated at a little over 8.9% which is considerably significant for an experimental solar pond with smaller dimensions. Cost of installation is quite economical with an estimate of over 40$/sq. m excluding the electrical couplers and thermocouple.

Methodology	***Output Voltage (V)***	***THD%***
ANN	14.8V	2.98
ANFIS [Proposed]	15.9V	2.04

Table 1: Performance comparison of proposed ANFIS controller.

A TEC1 – 12706 has been used as the thermoelectric generator based on Peltier effect. As a future scope of research, energy harvesters to store energy during nighttime where the solar pond activity varies from below normal to nearly idle state could be seen as a future scope of this work. Limitations of the solar pond include installation costs on a large scale, continuous replenishment which involves replacing existing saline water with a fresh set of brine on a frequent scale for improved efficiency.

References

1. Tharamuttam JK and Ng AK. "Design and development of an automatic solar tracker". Energy Procedia 143 (2017): 629-634.
2. Al-Falahi MD, Jayasinghe SDG and Enshaei HJEC. "A review on recent size optimization methodologies for standalone solar and wind hybrid renewable energy system". Energy conversion and management 143 (2017): 252-274.
3. Ahmad J, Imran M, Khalid A, Iqbal W, Ashraf SR, Adnan M and Khokhar KS. "Techno economic analysis of a wind-photovoltaic-biomass hybrid renewable energy system for rural electrification: A case study of Kallar Kahar". Energy 148 (2018): 208-234.
4. Akbari Vakilabadi M, Afzalabadi A, KhoeiniPoorfar A, Rahbari A, Bidi M, Ahmadi MH and Ming T. "Technical and economical evaluation of grid-connected renewable power generation system for a residential urban area". International Journal of Low-Carbon Technologies 14.1 (2019): 10-22.
5. Icaza D, Borge-Diez D, Pulla Galindo S and Flores-Vázquez C. "Modeling and Simulation of a Hybrid System of Solar Panels and Wind Turbines for the Supply of Autonomous Electrical Energy to Organic Architectures". Energies 13.18 (2020): 4649.
6. Kande SM, Wagh MM, Ghane SG, Shinde NN and Patil PS. "Experimental Analysis of Effect of Vegetation under PV Solar Panel on Performance of Polycrystalline Solar Panel". Journal of Fundamentals of Renewable Energy and Applications 6.5 (2016).
7. Shaikh MRS. "A review paper on electricity generation from solar energy". International Journal for Research in Applied Science & Engineering Technology (2017).
8. Ghenai C, Salameh T and Merabet A. "Technico-economic analysis of off grid solar PV/Fuel cell energy system for residential community in desert region". International Journal of Hydrogen Energy 45.20 (2020): 11460-11470.
9. Kwan TH and Wu X. "Power and mass optimization of the hybrid solar panel and thermoelectric generators". Applied energy 165 (2016): 297-307.
10. Li W, Shi Y, Chen K, Zhu L and Fan S. "A comprehensive photonic approach for solar cell cooling". Acs Photonics 4.4 (2017): 774-782.
11. Ssenyimba S, Kiggundu N and Banadda N. "Designing a solar and wind hybrid system for small-scale irrigation: a case study for Kalangala district in Uganda". Energy, Sustainability and Society 10.1 (2020): 1-18.
12. Ali MM, Ahmed OK and Abbas EF. "Performance of solar pond integrated with photovoltaic/thermal collectors". Energy Reports 6 (2020): 3200-3211.
13. Tian D, Qu ZG, Zhang JF and Ren QL. "Enhancement of solar pond stability performance using an external magnetic field". Energy Conversion and Management 243 (2021): 114427.
14. Cardoso S, Mourão Z and Pinho C. "Analysis of the thermal performance of an uncovered 1-hectare solar pond in Benguela, Angola". Case Studies in Thermal Engineering (2021): 101254.
15. Yang K, Zhang Y, Dong Y, Peng J, Kaal J, Li W and Nie Z. "Tracking variations in the abundance and composition of dissolved or-

ganic matter in solar ponds of oilfield-produced brine". Applied Geochemistry (2021): 105008.
16. Verma S and Das R. "Transient study of a solar pond under heat extraction from non-convective and lower convective zones considering finite effectiveness of exchangers". Solar Energy 223 (2021): 437-448.
17. Platikanov S, Tauler R, Cortina JL and Valderrama C. "Multivariate analysis of the operational parameters and environmental factors of an industrial solar pond". Solar Energy 223 (2021): 113-124.
18. Kumar A and Das R. "Effect of peripheral heat conduction in salt-gradient solar ponds". Journal of Energy Storage 33 (2021): 102084.
19. Mosaffa AH and Farshi LG. "Thermodynamic feasibility evaluation of an innovative salinity gradient solar ponds-based ORC using a zeotropic mixture as working fluid and LNG cold energy". Applied Thermal Engineering 186 (2021): 116488.
20. Kumar A, Verma S and Das R. "Eigenfunctions and genetic algorithm based improved strategies for performance analysis and geometric optimization of a two-zone solar pond". Solar Energy 211 (2020): 949-961.
21. Anagnostopoulos A, Sebastia-Saez D, Campbell AN and Arellano-Garcia H. "Finite element modelling of the thermal performance of salinity gradient solar ponds". Energy 203 (2020): 117861.

Volume 2 Issue 5 May 2022