Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2019, 6(2):26-33

Research Article ISSN: 2394 - 658X

Optimal sizing of photovoltaic systems using HOMER Software for Al-Amara city south Iraq

Maan Jenan Basheer Buni

University of Technology, Baghdad, Iraq
E. mail: maanjenanbasher@gmail.com

ABSTRACT

In this study, the Homer software was used to determine the optimal system for solar lighting in Al-Amara city-south Iraq. For this purpose, the weather data for the city of Amara was used such as temperature, solar radiation intensity, relative humidity, and wind speed. Homer can be considered the closest global program used in this area.

The results of the study suggested the use of a group of photovoltaic cells producing a total of 8 kW. This system has a basic cost of US $ 2000 considering the cost of electricity is US $ 0.903 /kW and the net cost of the system is US $ 32,015. The results of the study showed that the use of solar cell systems in the city of Amara is economically and practically acceptable, and it is the duty of the state to enact laws and regulations that facilitate the use of solar cell systems on a large scale.

Key words: Photovoltaic Solar System, Design Optimization, HOMER software, Al-Amarah City

---

INTRODUCTION

Solar energy is a renewable energy that is available most of the year for free, so its exploitation to produce electricity will bring great benefits to its users [1-5]. The trend towards the use of renewable energies such as wind energy [6], biofuels [7, 8], hydrogen energy [9-11], fuel cells [12], and solar energy has important justification. Perhaps the most obvious phenomenon of the bad impact of human on environment is global warming and climate change, the main cause of which is burning fossil fuels for energy production [13, 14]. The rise and fall of the catastrophic oil prices have stymied the five-year plans of the oil-exporting countries, including Iraq, and caused a major economic recession [15].

Solar energy can be used in many applications, perhaps the first heating water for domestic and industrial purposes [16, 17], heating the air using multi-shape solar heaters and designs [18, 19]. The use of the Trombe wall has also proved a success for heating homes in cold areas [20, 21]. The use of solar energy in distillation has a great history [22, 23]. Today, solar distillation began to take a small share of the rate of distilled water produced but it increases with days [24, 25]. As for the production of electric power can be produced using solar chimney [26, 27], and can be produced through concentrated solar power stations [28, 29]. Today, many solar photovoltaic plants have proved to be highly efficient in this field [30, 31]. Solar cells have become low prices for the installed power unit and their installation, configuration and use are simple and inexpensive [32]. The advantages of solar cells are their high elasticity, which can be used in remote and desert areas, or the highest mountains or plains [33, 34]. The disadvantages of photovoltaic cells are strongly influenced by climatic conditions such as solar radiation [35], temperature [36, 37], wind [38, 39], relative humidity [40, 41], and dust accumulation as well as the shadow produced from the land topography and buildings [42-47]. Researchers around the world have studied these effects and found important solutions [48]. Perhaps the most important is to switch from photovoltaic systems to photovoltaic/thermal systems (PVT), which have the advantage of extracting the solar cell from the excess heat accumulated in it, thus maintaining the electrical efficiency and high productivity of the system [49-52]. The heat drawn from the cell can be used in other applications [53-55].

Iraq is an oil country rich in its high production of oil and natural gas, yet it has suffered decades of continuous and devastating wars affected the infrastructure of the country and affected completely on the electrical systems [56, 57]. The Iraqi citizen suffers from recurrent national power cuts, which led to the use of medium and heavy-duty generators to work during the power outage [58]. These generators work with gasoline or diesel, which emits large pollutants to the atmosphere, making the environment of Iraqi cities clearly contaminated and negatively affect the health and life of citizens there [59].

The use of Homer Software to reach the optimal design of photovoltaic systems is a good alternative and has been used by many researchers [60-65]. For example, the Ref [66] used this software to reach a design combining the use of photovoltaic cells, a wind turbine, and a diesel engine to produce continuous electrical power to the Masirah Island in the Indian Ocean. The group of researchers chose to use the Homer program to design a hybrid system consisting of photovoltaic cells / wind turbine / diesel generator and battery. During this study, the cost of the hybrid system was assessed with each of these systems individually and the resulting pollution in each case. The systems studied were: PV / wind / diesel / battery, PV / diesel / battery, wind / diesel / battery, and diesel generators only. The results of the study showed that the use of PV / wind / diesel power system can result in a reduction in the cost of energy produced by up to 75%. This system also causes a reduction in the emissions of diesel fuel burned in diesel engines about 25% when using this proposed system. The proposed hybrid system (solar / wind / mixed diesel) is an appropriate option for both the cost-effective processing of Masirah Island and the reduction of emissions to the environment. Ref. [67] used Homer to evaluate the best design of the street lighting organization in Oman. The same software was also used by Ref. [68] to determine the best design for a power generation system for a 10kW communication tower located in Buraimi Oman. In this research work, Homer was used for optimal design and to select a hybrid energy system. An electrical power production system consisting of photovoltaic (PV) cells and diesel generators has been adopted. The results of the HOMER Design program showed that the use of rows of 50 kW photovoltaic cells would be sufficient. The results of the study showed that the proposed system has costs of maintenance of the solar system is about 143.402 USD/year, the total cost of the system 324.569 dollars, while the cost of the electric power unit was 0.29 $/kWh. When comparing these results with the diesel generator, the cost of the power supply by the diesel was 0.584 $/kW. The study concluded that the proposed hybrid system can equip the communications tower in Buraimi with the required electricity. This option is the best among several options proposed during the study. Homer used to design many water and irrigation systems in many parts of the world [69-71].

From this humble introduction we find that the use of this software is suitable for the identification of a photovoltaic cell system operating in the city of Amara, south of Baghdad-Iraq. In this paper the author will propose a design planning to use PV system to supply Al-Amara utilizing HOMER programming. The electrical demands for the system used were recorded and the hourly electricity demand data was measured in Al-Amara south Iraq.

Description of the proposed system

Photovoltaic panels produce electricity in the form of a DC current and must be converted to AC current using a reflector for proper load processing. To use this electricity in the evening, you must add a battery that stores electricity to use in such circumstances. The battery storage capacity used in this area should be large. Therefore, the designed system will be consisted of PV panels, inverter, batteries, circuit breakers, electrical wires and cables. This system has been proposed to complete the task of processing the required load.

PV Array

The solar photovoltaic panel consists of a group of semiconductors at the fall of the sun, which absorbs the photons of energy in these rays and converted into an electrical effort resulting in the movement of free electrons. Photovoltaic cells are connected to each other to produce uniform output. Estimated cost of creating and replacing the PV cell system is up to $ 2000 / kW. The estimated life of the solar panel is usually 15 years with the use of a reduction factor of up to 80% for the production of electric power. PV panels are installed facing the south at a tilt angle of about 30 degrees from the horizon.

Batteries

Because the system operates up to seven hours a day, seven days a week, the presence of the battery and the controller are considered to be key parts of the proposed system. Homer Software considers that during battery life, its characteristics remain constant and are not affected by external conditions such as temperature, humidity, and the like. It has been assumed that the battery required to operate operates at a voltage of 12 volts, 200 Ah. The battery value in this specification is up to US $ 300 and its operating life is 917 kWh of each battery.

Inverter is a device that changes the type of current from a constant current to an AC. The efficiency of this type of reflector with a production limit of 85% of all sizes is considered. The estimated cost of the required inverter is $ 300 / kW, with an estimated lifetime of up to 2.5 years. Several reflectors with capacities (1, 2, 3, 4 and 5 kW) were proposed and studied.

Assuming the average daily capacity consumed by the family in the city of Al-Amara, so the system must produce the day after day. Fig. 4 shows the daily load of up to 10 kW/day, with a maximum capacity of 3.6 kW.

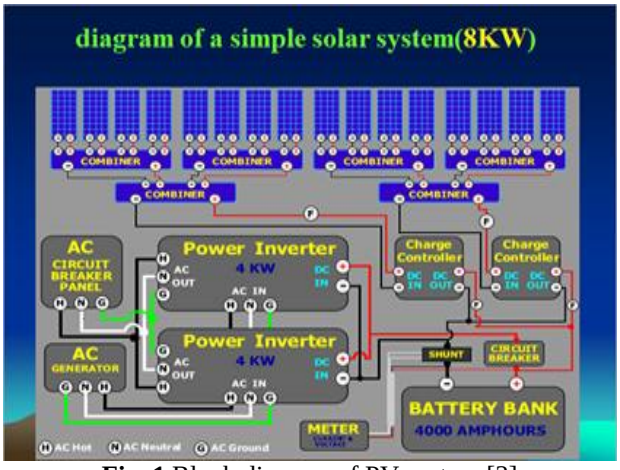

Fig. 1 Block diagram of PV system [3]

Employing HOMER to Design the Optimal Size of the Proposed System

In this study, the possibility of designing an optimal photovoltaic cell system using HOMER programming was investigated. HOMER is a computer program that rearranges and evaluates the process of the expected alternatives to grid or off-grid PV systems for systems operating in remote, rural and outspread areas. This software offers specific products by companies that produce PV modules, batteries, charging control system, reflector, and wire tools.

The results provided by HOMER allow the designer to assess the extent to which the required financial funding is available to the system and suggests several innovation options, innovation costs and access to manufacturers. The HOMER program is designed to design the physical part of the power generation system, its cost and estimated lifetime. It also provides the designer with options according to the total cost and the life of the system. HOMER Software offers a wide range of options, according to the outline. This is a sophisticated functional and financial advantage provided by this program. This software also helps the designer understand and assess the effects of weakness or changes to be included in the input. Figure 1 illustrates the schematic diagram that was adopted after the requirements of the system were entered.

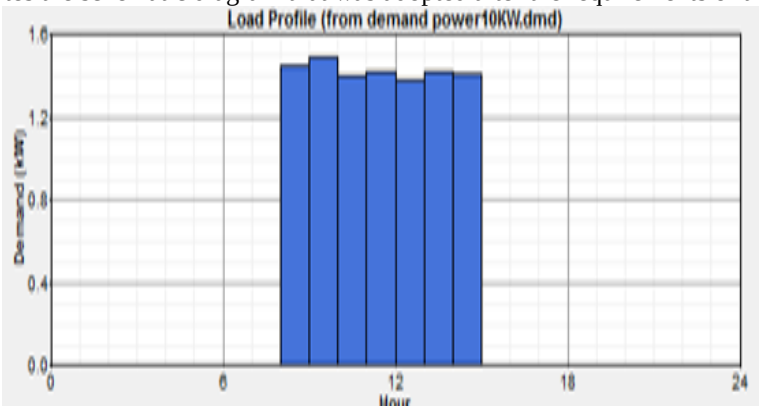

Fig. 2 Hourly load profile

PV Array Data

Figure 3 shows the construction and replacement costs of photovoltaic power systems, which are estimated at US $ 2,000. The results of the program explained that the cost of PV maintenance will not exceed 10 US$. Also, the program considered the estimated life of the PV panels to be 15 years without any decrease in productivity.

Battery Data

Figure 4 shows that the best batteries to be used in the proposed system are 12 volts and the number is 20. These batteries are 6 fm 2000 2000 D. The maximum of these batteries is 200 Ah (2.4 kWh).

Inverter Data

Figure 5 represents the proposed reflector types and their design effectiveness as illustrated by Homer. The program considered that the efficiency of the inverter for each size is about 85%. The proposed volume was 4 kW.

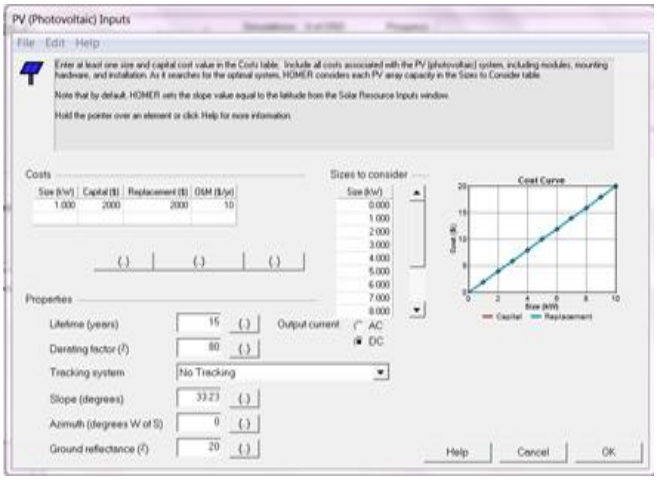

Fig. 3 The PV inputs

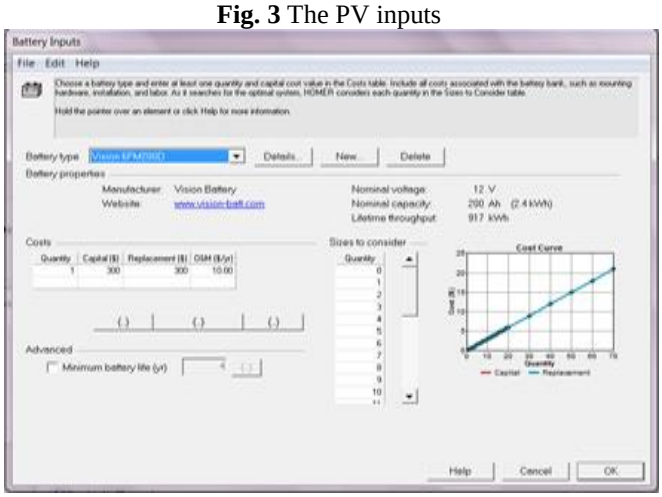

Fig. 4 Batteries input

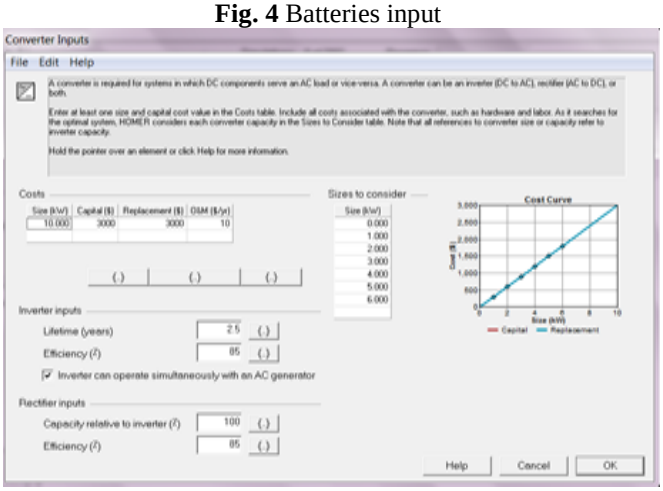

Fig. 5 Converter input

Load Data

In order to build an optimal design, the luminance load was determined to include the use of 10 spherical LED axes as shown in Figure 6. The program has determined the sizes of the different parts of the system as listed in Table 1. As indicated in the table, the program provides the costs of procurement, replacement, operation and maintenance. It should be mentioned here that the default lifetime of system parts must be set as input for Homer.

Figure 7 shows average monthly power output for each month of the proposed system. The results listed in the table can be comfortably processed from the proposed system, making it a suitable choice not only for street lighting but also for different applications in the city of Amara. The use of photovoltaic cells will reduce the emission of all these polluting exhaust gases from internal combustion engines for generators and from power plant burners.

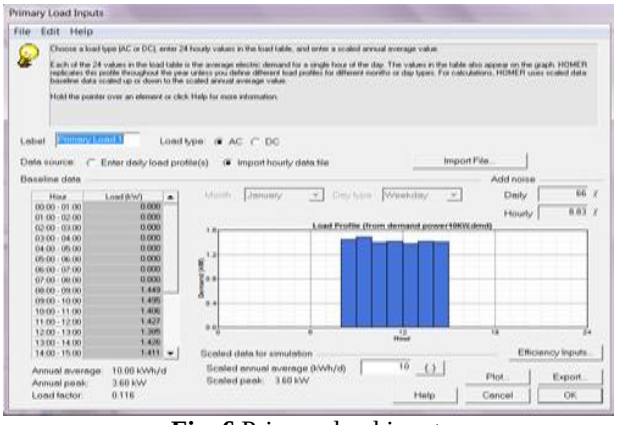

Fig. 6 Primary load input

Table 1: The selected items variable and total costs

Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	16,000	1,647	0	80	0	1,727
Battery	6,000	618	216	200	0	1,034
Converter	1,200	124	408	4	0	535
Totals	23,200	2,389	624	284	0	3,295

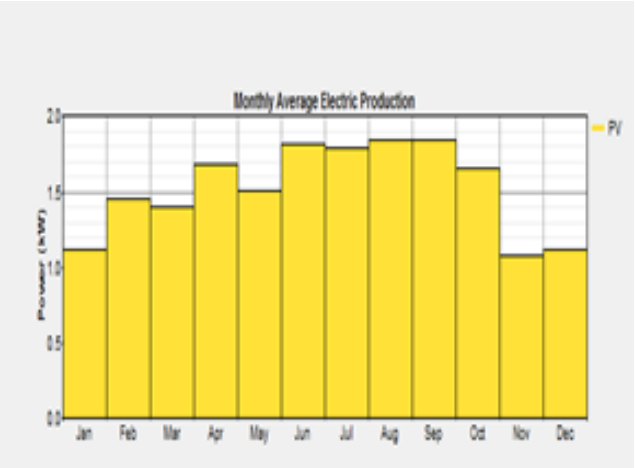

Fig. 7 Monthly average electric production

CONCLUSION

In this study, Homer's program was used to design and define a system consisting of photovoltaic cells and propose the quality of its parts to equip a particular street in the city of Amara in southern Iraq with the electric energy needed to carry the vessel. Homer Software was selected due to the development of improved classifications for all system accessories based on the current net cost. Through this software all the economic results of the parts of the proposed system have been reached for the purpose of saving energy. The cost of a nominal system depends on the size and number of PV panels and the number and size of the batteries used. It also depends on the capacity of the transport as the proposed system is a fixed PV panel. The performance of the PV system depends on a set of daily radiation ($kW/m^2/d$), and clarity for each month during the year.

The results of the program, based on the proposed inputs, showed that the initial cost of the system is 23,200 US $, while operating costs are 284US $ per year. The results showed that the optimum number of batteries used to store and operate the system in the evening is 20 batteries. The results also showed that the proposed system the best size of the adapter to be used is 4 kW.

REFERENCES

[1] Y Xu, J Ma, D Liu, H Xu, F Cui, W Wang, Origami System for Efficient Solar Driven Distillation in Emergency Water Supply, *Chemical Engineering Journal*, 2019, 356, 869-876.

[2] T Lin, C Yang, Z Wang, H Yin, X Lü, F Huang, J Lin, X Xie, M Jiang, Effective Nonmetal Incorporation in Black Titania with Enhanced Solar Energy Utilization, Energy & Environmental Science, 2014, 7(3), 967-972.

[3] R Norman, P Dauphin, FDS Croix, Systems for Cost-Effective Concentration and Utilization of Solar Energy. *U.S. Patent* 9, 2018, 995,507.

[4] W. Yang, Y Feng, Q Si, Q Yan, P Long, L Dong, L Fu, W Feng, Efficient Cycling Utilization of Solar-Thermal Energy for Thermochromic Displays with Controllable Heat Output, *Journal of Materials Chemistry A*, 2019, 7(1), 97-106.

[5] T He, ZR Chong, J Zheng, Y Ju, P Linga, LNG Cold Energy Utilization: Prospects and Challenges, *Energy*, 2019, 170, 557-568.

[6] HA Kazem, MT Chaichan, AHA Al-Waeli, KH Al-Waeli, Wind Resource Assessment for Nine Locations in Oman, *International Journal of Computation and Applied Sciences IJOCAAS*, 2017, 3(1), 185-191.

[7] MT Chaichan, Performance and Emission Study of Diesel Engine Using Sunflowers Oil-Based Biodiesel Fuels, *International Journal of Scientific and Engineering Research*, 2015, 6(4), 260-269.

[8] MT Chaichan, ST Ahmed, Evaluation of Performance and Emissions Characteristics for Compression Ignition Engine Operated with Disposal Yellow Grease, *International Journal of Engineering and Science*, 2013, 2(2), 111-122.

[9] MT Chaichan, Performance and Emissions Characteristics of CIE Using Hydrogen, Biodiesel, and Massive EGR, *International Journal of Hydrogen Energy*, 2018, 43, 5415-5435.

[10] MT Chaichan, DSM Al-Zubaidi, A Practical Study of Using Hydrogen in Dual–Fuel Compression Ignition Engine, *International Journal of Mechanical Engineering (IIJME)*, 2014, 2(11), 1-10.

[11] MT Chaichan, The Effects of Hydrogen Addition to Diesel Fuel on The Emitted Particulate Matters, *International Journal of Scientific & Engineering Research*, 2015, 6(6), 1081-1087.

[12] MT Chaichan, HA Kazem, Experimental Analysis of the Performance Characteristics of PEM Fuel Cells, *International Journal of Scientific & Engineering Research*, 2016, 7(2), 49-56.

[13] HMS Al-Maamary, HA Kazem, MT Chaichan, Renewable Energy and GCC States Energy Challenges in the 21st Century: A Review, *International Journal of Computation and Applied Sciences IJOCAAS*, 2017, 2(1), 11-18.

[14] HMS Al-Maamary, HA Kazem, MT Chaichan, Climate Change: The Game Changer in the GCC Region, *Renewable and Sustainable Energy Reviews*, 2017, 76, 555-576. *http://dx.doi.org/10.1016/j.rser.2017.03.048*

[15] HMS Al-Maamary, HA Kazem, MT Chaichan, The Impact of the Oil Price Fluctuations on Common Renewable Energies in GCC Countries, *Renewable and Sustainable Energy Reviews*, 2017, 75, 989-1007.

[16] HA Kazem, HS Aljibori, FN Hasoon, MT Chaichan, Design and Testing of Solar Water Heaters with its Calculation of Energy, *Int. J. of Mechanical Computational and Manufacturing Research*, 2012, 1(2), 62-66.

[17] MT Chaichan, KI Abaas, HM Salih, Practical Investigation for Water Solar Thermal Storage System Enhancement Using Sensible and Latent Heats in Baghdad-Iraq Weathers, *Journal of Al-Rafidain University Collage for Science*, 2014, 33, 159-182.

[18] MT Chaichan, KI Abaas, DSM Al-Zubidi, HA Kazem, Practical Investigation of Effectiveness of Direct Solar-Powered Air Heater, *International Journal of Advanced Engineering, Management and Science (IJAEMS)*, 2016, 2(7), 1047-1053.

[19] VS Hans, RP Saini, JS Saini, Performance of Artificially Roughened Solar Air Heaters—A Review, *Renewable and Sustainable Energy Reviews*, 2009, 13(8), 1854-1869.

[20] MT Chaichan, KI Abaas, Performance Amelioration of a Trombe Wall by Using Phase Change Material (PCM), *International Advanced Research Journal in Science, Engineering and Technology*, 2015, 2(4), 1-6.

[21] MT Chaichan, KI Abaas, DSM Al-Zubidi, A Study of a Hybrid Solar Heat Storage Wall (Trombe Wall) Utilizing Paraffin Wax and Water, *Journal of Research in Mechanical Engineering*, 2016, 2(11), 1-7.

[22] MT Chaichan, HA Kazem, KI Abaas, AA Al-Waeli, Homemade Solar Desalination System for Omani Families, *International Journal of Scientific & Engineering Research*, 2016, 7(5), 1499-1504.

[23] MT Chaichan, KI Abaas, Productivity Amelioration of Solar Water Distillator Linked With Salt Gradient Pond, *Tikrit Journal of Engineering Sciences*, 2012, 19(4), 24-34.

[24] MT Chaichan, Enhancing Productivity of Concentrating Solar Distillating System Accompanied with PCM at Hot Climate, *Wulevina*, 2016, 23(5), 1-18.

[25] MT Chaichan, HA Kazem, Using Aluminium Powder With PCM (paraffin wax) to Enhance Single Slope Solar Water Distillation Productivity in Baghdad–Iraq Winter Weathers, *International Journal of Renewable Energy Research (IJRER)*, 2015, 5(1), 251-257.

[26] ST Ahmed, MT Chaichan, A Study of Free Convection in a Solar Chimney Sample, *Engineering and Technology J*, 2011, 29(14), 2986-2997.

[27] MT Chaichan, Practical Study of Basement Kind Effect on Solar Chimney Air Temperature in Baghdad-Iraq Weather, *Al Khwarizmi Eng. Journal*, 2011, 7(1), 30-38.
[28] MT Chaichan, KI Abaas, Practical Investigation For Improving Concentrating Solar Power Stations Efficiency In Iraqi Weathers, *Anbar J for Engineering Science*, 2012, 5(1), 76-87.
[29] MT Chaichan, KI Abaas, HA Kazem, The Effect of Variable Designs of The Central Receiver to Improve The Solar Tower Efficiency, *International J of Engineering and Science*, 2012, 1(7), 56-61.
[30] HA Kazem, F Hasson, MT Chaichan, Design and Analysis of Stand-Alone Solar Photovoltaic For Desert In Oman, *3rd Scientific International Conference, Technical Cologe, Najaf, Iraq*, 2012.
[31] AHA Al-Waeli, HA Kazem, MT Chaichan, Review and Design of A Standalone PV System Performance, *International Journal of Computation and Applied Sciences IJOCAAS*, 2016, 1(1), 1-6.
[32] AHA Al-Waeli, MT Chaichan, K Sopian, HA Kazem, Energy Storage: CFD Modeling of Thermal Energy Storage for a Phase Change Materials (PCM) Added to a PV/T Using Nanofluid as a Coolant, *Journal of Scientific and Engineering Research*, 2017, 4(12), 193-202.
[33] HA Kazem, SQ Ali, AHA Al-Waeli, K Mani, MT Chaichan, Life-Cycle Cost Analysis and Optimization of Health Clinic PV System for a Rural Area in Oman, *Proceedings of the World Congress on Engineering 2013, vol. II, WCE 2013, London, U.K., July 3 - 5*, 2013.
[34] HA Kazem, MT Chaichan, Design and Analysis of Standalone Solar Cells in the Desert of Oman, *Journal of Scientific and Engineering Research*, 2016, 3(4), 62-72.
[35] MT Chaichan, HA Kazem, AA Kazem, KI Abaas, KAH Al-Asadi, The Effect of Environmental Conditions on Concentrated Solar System in Desertec Weathers, *International Journal of Scientific and Engineering Research*, 2015, 6(5), 850-856.
[36] HA Kazem, MT Chaichan, Effect of Environmental Variables on Photovoltaic Performance-Based on Experimental Studies, *International Journal of Civil, Mechanical and Energy Science (IJCMES)*, 2016, 2(4), 1-8.
[37] AHA Al-Waeli, K Sopian, MT Chaichan, HA Kazem, HA Hasan, AN Al-Shamani, An Experimental Investigation on Using of Nano-Sic-Water as Base-Fluid for Photovoltaic Thermal System, *Energy Conservation and Management*, 2017, 142, 547-558.
[38] HA Kazem, JH Yousif, MT Chaichan, Modeling of Daily Solar Energy System Prediction using Support Vector Machine for Oman, *International Journal of Applied Engineering Research*, 2016, 11(20), 10166-10172.
[39] S Sinha, SS Chandel, Review of Recent Trends in Optimization Techniques for Solar Photovoltaic–Wind Based Hybrid Energy Systems, *Renewable and Sustainable Energy Reviews*, 2015, 50, 755-769.
[40] HA Kazem, MT Chaichan, IM Al-Shezawi, HS Al-Saidi, HS Al-Rubkhi, JK Al-Sinani, AHA Al-Waeli, Effect of Humidity on the PV Performance in Oman, *Asian Transactions on Engineering*, 2012, 2(4), 29-32.
[41] HA Kazem, MT Chaichan, Effect of Humidity on Photovoltaic Performance Based on Experimental Study, *International Journal of Applied Engineering Research (IJAER)*, 2015, 10(23), 43572-43577.
[42] AA Kazem, MT Chaichan, HA Kazem, Effect of Dust on Photovoltaic Utilization in Iraq: Review Article, *Renewable and Sustainable Energy Reviews*, 2014, 37, 734-749.
[43] HA Kazem, MT Chaichan, SA Saif, AA Dawood, SA Salim, AA Rashid, AA Alwaeli, Experimental Investigation of Dust Type Effect on Photovoltaic Systems in North Region, Oman, *International Journal of Scientific & Engineering Research*, 2015, 6(7), 293-298.
[44] HA Kazem, and MT Chaichan, Experimental Effect of Dust Physical Properties on Photovoltaic Module in Northern Oman, *Solar Energy*, 2016, 139, 68–80.
[45] MT Chaichan, HA Kazem, Effect of Sand, Ash and Soil on Photovoltaic Performance: An Experimental Study, *International Journal of Scientific Engineering and Science*, 2017, 1(2), 27-32.
[46] HA Kazem, MT Chaichan, The Impact of Using Solar Coloured Filters to Cover The PV Panel on its Outcomes, *Bulletin Journal*, 2016, 2(7), 464-469. DOI: 10.21276/sb.2016.2.7.5.
[47] HA Kazem, and MT Chaichan, AHA Al-Waeli, K Mani, Effect of Shadows on the Performance of Solar Photovoltaic, *Mediterranean Green Buildings & Renewable Energy*, 2017, 379-385. DOI: 10.1007/978-3-319-30746-6_27
[48] MT Chaichan, KI Abaas, HA Kazem, Energy Yield Loss Caused by Dust and Pollutants Deposition on Concentrated Solar Power Plants in Iraq Weathers, *International Research Journal of Advanced Engineering and Science*, 2018, 3(1), 160-169.
[49] AHA Al-Waeli, HA Kazem, K Sopian, MT Chaichan, Techno-Economical Assessment of Grid Connected PV/T Using Nanoparticles and Water as Base-Fluid Systems in Malaysia, *International Journal of Sustainable Energy*, 2017. DOI: 10.1080/14786451.2017.1323900
[50] AHA Al-Waeli, MT Chaichan, HA Kazem, K Sopian, Comparative Study to use Nano-(Al_2O_3, CuO, and SiC) with Water to Enhance Photovoltaic Thermal PV/T Collectors, *Energy Conversion and Management*, 2017, 148(15), 963-973. https://doi.org/10.1016/j.enconman.2017.06.072

[51] AHA Al-Waeli, MT Chaichan, K Sopian, HA Kazem, Comparison Study of Indoor/Outdoor Experiments of SiC Nanofluid as a Base-Fluid for a Photovoltaic Thermal PV/T System Enhancement, *Energy*, 2018, 151, 33-44. DOI: 10.1016/j.energy.2018.03.040

[52] AHA Al-Waeli, K Sopian, HA Kazem, JH Yousif, MT Chaichan, A Ibrahim, S Mat, MH Ruslan, Comparison of Prediction Methods of PV/T Nanofluid and Nano-PCM System Using a Measured Dataset and Artificial Neural Network, *Solar Energy*, 2018, 162, 378-396.

[53] AHA Al-Waeli, K Sopian, HA Kazem, MT Chaichan, Photovoltaic Solar Thermal (PV/T) Collectors Past, Present and Future: A Review, *International Journal of Applied Engineering Research*, 2016, 11(22), 1075-10765.

[54] AHA Al-Waeli, K Sopian, HA Kazem, MT Chaichan, PV/T (Photovoltaic/Thermal): Status and Future Prospects, *Renewable and Sustainable Energy Review*, 2017, 77, 109-130.

[55] AHA Al-Waeli, MT Chaichan, K Sopian, HA Kazem, HB Mahood, AA Khadom, Modeling and Experimental Validation of a PVT System Using Nanofluid Coolant and Nano-PCM, *Solar Energy*, 2019, 177, 178-191.

[56] MT Chaichan, HA Kazem, Status and Future Prospects of Renewable Energy in Iraq, *Renewable and Sustainable Energy Reviews*, 2012, 16(1), 6007–6012.

[57] MT Chaichan, HA Kazem, Generating Electricity Using Photovoltaic Solar Plants in Iraq, *Springer International Publishing*, 2018.

[58] AA Al-Waeely, SD Salman, WK Abdol-Reza, MT Chaichan, HA Kazem, HSS Al-Jibori, Evaluation of the Spatial Distribution of Shared Electrical Generators and their Environmental Effects at Al-Sader City-Baghdad-Iraq, *International Journal of Engineering & Technology IJET-IJENS*, 2014, 14(2), 16-23.

[59] MT Chaichan, EGR Effects on Hydrogen Engines Performance and Emissions, *International Journal of Scientific & Engineering Research*, 2016, 7(3), 80-90.

[60] M Boussetta, R Elbachtiri, K Elhammoumi, M Khanfara, Optimal Sizing of Grid-Connected PV-Wind System Case Study: Agricultural Farm In Morocco, *Journal of Theoretical & Applied Information Technology*, 2016, 86(2).

[61] A Al-Karaghouli, LL Kazmerski, Optimization and Life-Cycle Cost of Health Clinic PV System for a Rural Area in Southern Iraq Using HOMER Software, *Solar Energy*, 2010, 84(4), 710-714.

[62] KR Ajao, OA Oladosu, OT Popoola, Using HOMER Power Optimization Software for Cost Benefit Analysis of Hybrid-Solar Power Generation Relative to Utility Cost in Nigeria, *International Journal of Research and Reviews in Applied Sciences*, 2011, 7(1), 96-102.

[63] S Sinha, SS Chandel, Review of Software Tools for Hybrid Renewable Energy Systems, *Renewable and Sustainable Energy Reviews*, 2014, 32, 192-205.

[64] R Sen, SC Bhattacharyya, Off-Grid Electricity Generation with Renewable Energy Technologies in India: An Application of HOMER, *Renewable Energy*, *2014*, 62, 388-398.

[65] S Bahramara, MP Moghaddam, MR Haghifam, Optimal Planning of Hybrid Renewable Energy Systems Using HOMER: A Review, *Renewable and Sustainable Energy Reviews*, 2016, 62, 609-620.

[66] HA Kazem, HAS Al-Badi, AS Al Busaidi, MT Chaichan, Optimum Design and Evaluation of Hybrid Solar/Wind/Diesel Power System for Masirah Island, *Environment, Development and Sustainability*, 2017, 19(5), 1761-1778.

[67] MT Chaichan, HA Kazem, AMJ Mahdy, AA Al-Waeely, Optimal Sizing of a Hybrid System of Renewable Energy for Lighting Street in Salalah-Oman Using HOMER Software, *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, 2016, 2(5), 157-164.

[68] MT Chaichan, HA Kazem, AMJ Mahdy, AA Al-Waeely, Optimization of Hybrid Solar PV/Diesel System for Powering Telecommunication Tower, *International Journal of Engineering Sciences & Emerging Technologies (IJESET)*, 2016, 8(6), 1-10.

[69] AHA Al-Waeli, MMK El-Din, AHK Al-Kabi, A Al-Mamari, HA Kazem, MT Chaichan, Optimum Design and Evaluation of Solar Water Pumping System for Rural Areas, International Journal of Renewable Energy Research, 2017, 7(1), 12-20.

[70] AHA Al-Waeli, ASA Al-Mamari, AHK Al-Kabi, MT Chaichan, HA Kazem, Evaluation of the Economic and Environmental Aspects of Using Photovoltaic Water Pumping System, 9th International Conference on Robotic, Vision, Signal Processing & Power Applications, 2016.

[71] HA Kazem, AHA Al-Waeli, MT Chaichan, AS Al-Mamari, AH Al-Kabi, Design, Measurement and Evaluation of Photovoltaic Pumping System for Rural Areas in Oman, Environ Dev Sustain, 2016. DOI 10.1007/s10668-016-9773-z