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Maan Jenan Basheer Buni
University of Technology,
Baghdad, Iraq

Correspondence:
Maan Jenan Basheer Buni
University of Technology,
Baghdad, Iraq

The Impact of Solar Photovoltaic Cell Tilt Angle on Its Performance

Maan Jenan Basheer Buni

Abstract
The solar radiation falling on the solar cell changes during the day and from month to month. In this study, the effect of the angle of the cell's solar cell on the resulting capacity in external environment conditions was discussed in the city of Baghdad, the capital of Iraq. During daily experiments, the solar cell angle of 0 ° -90 ° was changed and the effect of sunny, cloudy and dusty weather conditions on tilt angle changed. The results of the study showed that the best angle for a fixed cell varies from time to time. The best value in the early morning and near the sunset is 60 degrees. At noon, the best value is 40 degrees. The angle of solar radiation falls from day to day and from month to month. The performance of solar cells under the influence of dust was very large, which is greater than the effect of clouds.

Keywords: PV cell, tilt angle, time variation, dust, clouds, outcomes.

1. Introduction
Most of the global energy comes from fossil fuels. These sources are limited and going to deplete in 50 to 75 years as most studies indicated. The high dependence on oil in generating electricity and operating vehicles, trucks and construction equipment in the last century caused a great damage to environment and human health [1, 2]. In the last decade the oil prices were fluctuating between 150 to 22 US dollars, which caused economic disasters for both the importers and the exporters [3]. In the same time, burning this fuel is the primary reason for climate change. This phenomenon becomes a reason for many complications in human life. The authorities in most countries are now considering this phenomenon as a serious problem that needs monitoring and solutions [4, 5]

The shift towards new energies that are renewable and environment friend becomes an important issue. This description fits to renewable energies such as biofuels, wind, solar, and geothermal energies. Biofuels gives great expectations and many biofuels are used today in cars and trucks [6, 7]. Wind energy also takes a significant share of generating electricity in many countries that have good wind speeds [8]. Studies and investigations proved that he use of fuel cell gives high power with no or small rate of pollutants [9]. In the same time, solar energy studies started since seventeenth of the last century, and today, it has a share from power generation market. Solar energy can be used directly in heating water for domestic purposes in water heaters [9]. Also, it can be used for air heating and Trombe walls [10-15]. Solar energy can be stored in solar ponds to be used in many heating applications and in water desalination [16-20]. Of course, solar radiation can be used directly for water desalination and treatment [21, 22]. On the other side, solar radiation can be used to generate electricity from concentrated solar power stations and from solar chimneys [22-27]. Photovoltaic solar cells are used for generation electrical power that can be used in rural and remote areas where the grid lines are far away [28-30]. These cells are used to light streets [31], powering telecommunications towers [32], and operating water pumps for irrigation [33, 34], supplying electricity for buildings and factories [35] and lighting car parking [36].

The solar PV cells are affected by environmental variables such as solar radiation [37], ambient temperature [38], relative humidity [39], and wind speed [40]. It is also affected by the intensity of solar waves [41], shadow [42, 43] and dust [44, 45]

The researchers studied the causes and results of every single parameter and the effect of other environment parameters on it. Two main parameters have the most significant impact on PV cell efficiency. The dust and pollutants accumulation on the PV module with bad cleaning causes remarkable reduction in the cell performance [46-48]. Also, the high solar radiation that heat up the cell and reduces its outcomes is an obstacle that hinder the wide speared of PV technology in hot climates countries. The dust accumulation effects can be eliminated or reduced by good maintenance and cleaning the PV module with proper cleaning detergents. To get rid of the high PV cells' temperature, the researchers today are studying the use of hybrid PVT system [49, 50]. In these systems, the high temperature of the solar cell is utilized in applications such as air heating or water heating for domestic purposes [51]. The studies in this field reached advanced stages, as the researchers investigated the use of nanofluid in cooling the PV cells [52, 53], as well as using PCM and nano-PCM for this reason [54, 55].

For every location in the earth, the PV cells have an angle of incidence that depends on the optical solar radiation incidence. This angle can be measured theoretically and experimentally, and it is used to improve the array outcomes. The solar angle of incidence varies with the time of the day and with the seasons [56]. It affects the PV module short circuit current (Isc), which is resulted from two causes: first reason is the cosine effect, which is independent of the PV module geometry design. The PV panel's short circuit current (Isc) varies with the cosine of the angle of incidence, because of this cosine effect [57]. Second reason: when the angle of incidence affects directly (Isc) due to the cell design. The optical effect dominant contributor is the radiation reflecting from the front surface [58].

The solar cell's tilt angle can be calculated by (Fig. 1) [59]:

$$AOI = \cos^{-1}([\cos(\beta)\cos(Zs)] + [\sin(\beta)\sin(Zs)\cos(AZs - AZm)]) \quad (1)$$

Where AOI is the solar incidence angle, β is the tilt angle of panel, Zs is the zenith angle of sun, AZ_m is the azimuth angle of panel (0°: South, 90°: East) and AZ_S is the azimuth angle of sun (0°: South, 90°: East).

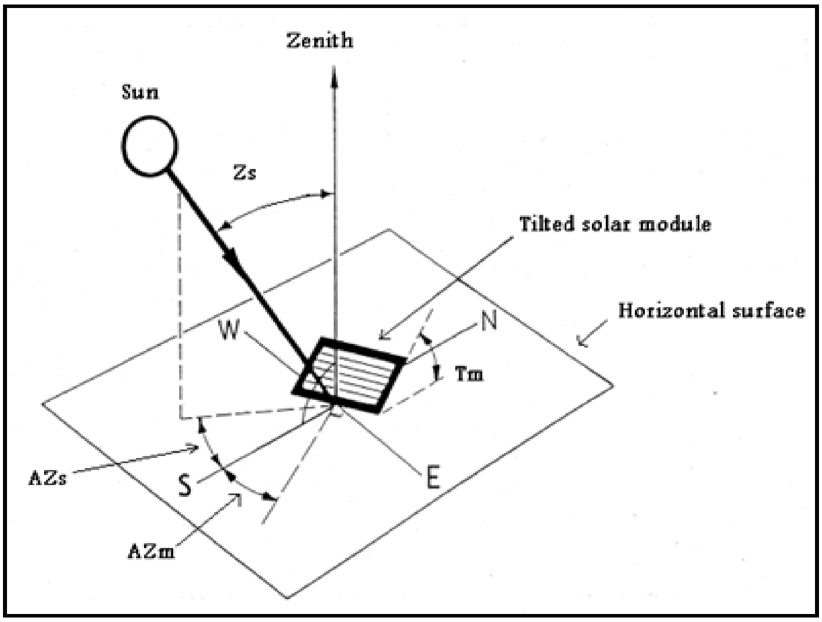

Fig. 1 the angles of a solar system

Estimating the available measured quantities for global radiation on a horizontal surface is important for PV system designers to determine the system specifications of a particular site. They also need to evaluate the direct and diffuse horizontal components of global values. Finally, they need to evaluate these components for a sloping level from the horizontal values. When it comes to solar radiation, there are two specific angles of the solar cell that determine the direction of the unit. The first angle is called the tilt angle and is referred to as (Tm) and defined as the angle between the module surface and the horizontal plane. The second angle is the angle of azimuth known as the angle between the natural projection to the surface of the module and the south referred to by (AZm) [60]. Most of the solar modules are mounted in a fixed position which overlooks the projection of the equator. The direction of the sun changes for unity throughout the day, which means a change in the amount of vertical radiation actually falling on the unit [61]. Thus, sunlight decreases to the active surface of the unit. When the sun shines in the sky, the unit is exposed to more sunlight to the maximum of the opening. When the angle of the sun is large for the unit, the hole is not only small, but the loss of reflection from the surface of the unit increases [62]. The horizontal and vertical dimensions are effective for the opening with the corner pocket of the roses [63].

Iraq characterized by a high solar insolation as it is located near the solar belt area, and the maximum insulation is located in the mid and south of this shiny country. The average annual solar radiation intensity in Baghdad station is between 286 W/m^2 in winter to 864 W/m^2 in summer. This energy can be used in many heating and electricity generation applications. However, the use of solar energy is hindered by many obstacles such as dust accumulation, high PV module temperature, and high level of air pollution. The solar radiation varies monthly or annually affecting installed and fixed solar systems [61].

The aim of this study is to evaluate practically the optimum tilt angle for a PV panel installed in Baghdad City. The tilt angle variation will be followed by changes in the PV panel's voltage and current outcomes. The optimum efficiency resulted indicates the optimum tilt angle for the specified day, month, and season.

2. Experimental Procedure

In this experimental work, a PV cell, which its specifications are listed in Table (1) was used. A hybrid ammeter-voltammeter was used to measure the panel's voltage and current. The solar cell tilt angle was changed by using ruler (Fig. 2). The used panel's tilt angle can be varied from 0°-90°. At the peak hours (from 11 AM to 3 PM), the panel tilt angle was varied to evaluate the best tilt angle for the tested days each one with its specific condition. The tilt angle was tested in three variable conditions: sunny day, cloudy, and dusty day. This procedure was used to compare and evaluate the reduction in the PV panel's outcome for each case. The question that needs an answer: can we gain some of the losses in the panels' outcome by changing the tilt angle in cloudy and dusty days?

As the clouds affecting the productivity of solar cells are available only in the winter season, so the practical experiences was done during specific days of the months of November and December 2017 and January 2018.

Table 1: The used PV panel electrical performance under standard test conditions (S. T. C.)

Model		**STF-120P6**
Rated power	Pmax	120±2%
Open circuit voltage	Voc	21.5 V
Short circuit current	Isc	7.63 A
Voltage at Pmax	Vmp	17.4 V
Current at Pmax	Imp	6.89 A
Electrical efficiency	(%)	14%

3. Results & Discussions

The effect of solar radiation falling on a solar cell is greater when the radiation is exactly orthogonal on the cell face and this depends on the tilt angle. The variation of the tilt angle from the optimal value decreases the cell performance due to visual and engineering impact. Figure (2) shows the relationship between peak time where the intensity of solar radiation at the maximum value with the resulting power of four tilt angles. The highest value of the power generated was between 12 AM and 1 PM, since the intensity of solar radiation at that time at its peak. The difference in the angle of the cell's slope causes the difference of the resulting capacity over time. Results show that the best value of the generated power was at a 40 degree angle, which is near the value indicated by Refs. [60, 61] while the best productivity of the cell in the early morning and near the sunset was at a greater angle of inclination (60 degrees) The productivity of the cell depends heavily on the intensity and angle of the solar radiation

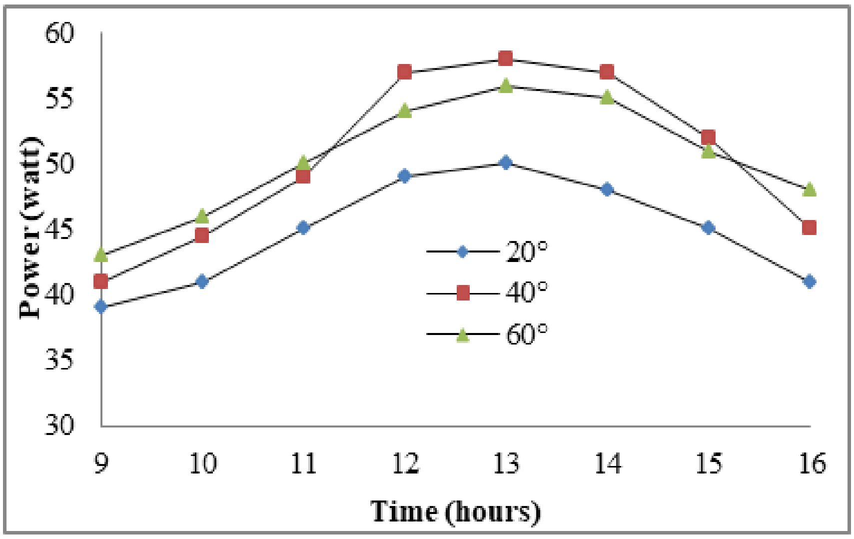

Fig. 2: Effect of local time on the output power from solar cell.

The external weather as the shiny atmosphere or the existence of a shadow have a significant impact on the productivity of the cell and also shows a change in the tilt angle as the presence of clouds light or heavy causes the need to change the tilt angle of the cell to obtain the highest productivity. The vapor of the cloud causes the absorption of infrared radiation from the solar spectrum and reduces the heat of the cell, but it also controls the intensity of the radiation falling on the solar cell. Figure (3) shows the relationship between external weather conditions and the change in angle of inclination of the system used. The results show a decrease in the performance of the solar cell due to air dust greater than the presence of a light or heavy cloud. Dust causes significant dispersion in solar radiation and increases the shadow as accumulating on the surface of the cell prevents the arrival of solar radiation. Reducing the tilt angle in light cloudy days has increased relatively the PV output power.

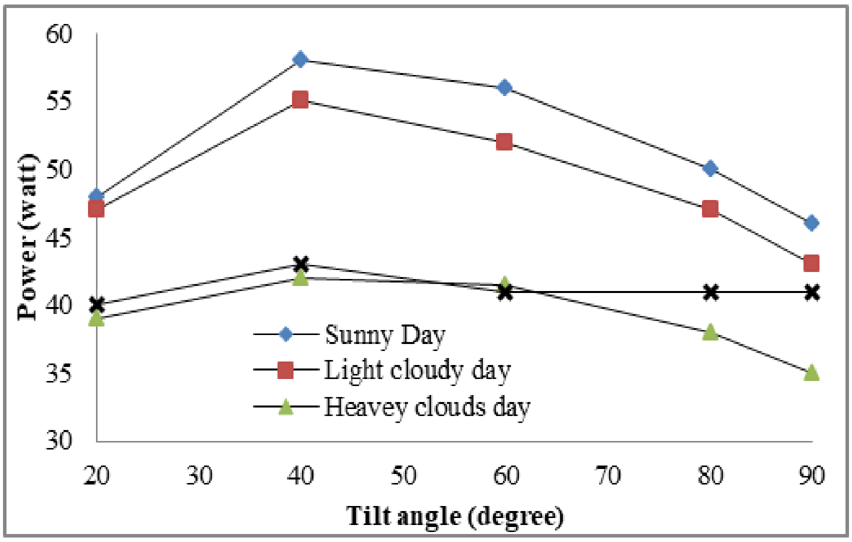

Fig. 3 Effect of atmosphere conditions on the output power from solar cell

Figure (4) shows the maximum cell-generated power variation used for the days of December when using three different tilt angles (20°, 40° and 60°). The atmosphere of Baghdad as is the atmosphere of Iraq in general dusty so the accumulation of dust during the period of study for a month caused a decrease in productive capacity. The use of an angle of inclination far from the ideal angle causes with the accumulation of dust a greater decrease so when working at a tilt angle of 20° decreased the power of the cell by 41% after 30 working days while the use of angles of 40° and 60° caused a decrease of 11% and 21% Respectively. Here, we should point out that the month of December in Baghdad is one of the least dusty months; because of rains sometimes occur during this month. In this case, the impact of dust will be greater in months like April or June where the dust storms are almost daily.

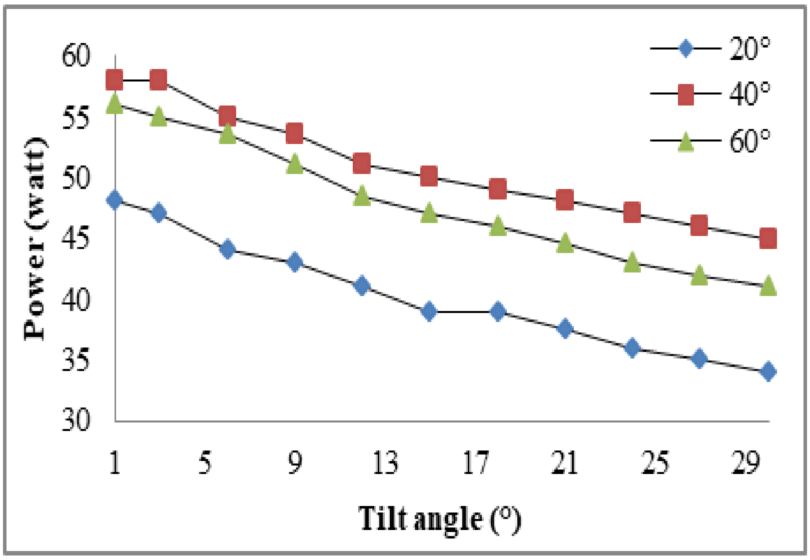

Fig. 4 Effect of accumulated dust on the output power of solar cell

Figure (5) shows the relationship between the tilt angle and the highest output power during the test period, which lasted for three months (November, December, January). The generated power changed as the tilt angle was changed and the maximum value of the produced power varied from month to month. The best output power was at a 40°, followed by those generated at 50° and 60°. Also, the maximum produced power was during the month of November as the intensity of solar radiation was the highest among its counterparts. These differences in the curves result from changing in the falling angle of the solar radiation from one month to another. So, it is best to control the steering of the cell electronically and instantaneously to reach the highest outcomes.

Conclusions

In this study, the produced power and its relation to changing the tilt angle with the change of months were measured and during the weather conditions variation (sunny, cloudy or dusty). Changing the PV panel's tilt angle is better than fixing the cell at specified angle. The slope of the cell must be changed with time. At the morning, the best tilt angle was 60°. During the peak period (from 12 AM to 2 PM), the best inclination was 40°. Before sunset, the best value was 60°. Changing the slope of the solar panel is done in order to reach full compatibility with the falling solar radiation. This dependence varies according to the time of day, month, and year. The results showed a sharp decrease in the power of the solar cell due to dust and this decrease exceeded the effect of clouds. The tilt angle of the cell that gives the highest power varies from month to month as the results show that the best angle of inclination is 40° for the city of Baghdad during the study period

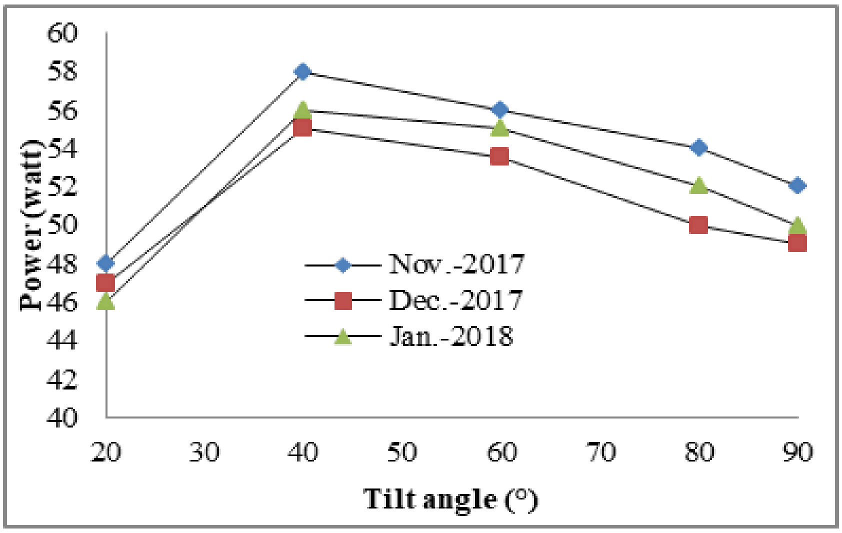

Fig. 5: effect of months on the output power from solar cell.

References

1. Chaichan M T and Al-Asadi K A H, Environmental Impact Assessment of traffic in Oman, International Journal of Scientific & Engineering Research, 2015; 6(7): 493-496.
2. Chaichan M T, Kazem H A, Abid T A, Traffic and outdoor air pollution levels near highways in Baghdad, Iraq, Environment, Development and Sustainability, 2018; 20(2): 589-603. DOI: 10.1007/s10668-016-9900-x.
3. Al-Maamary H M S, Kazem H A, Chaichan M T, The impact of the oil price fluctuations on common renewable energies in GCC countries, Renewable and Sustainable Energy Reviews, 2017; 75: 989-1007.
4. Al-Maamary H M S, Kazem H A, Chaichan M T, 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.
5. Al-Maamary H M S, Kazem H A, Chaichan M T, Changing the energy profile of the GCC States: A review, International Journal of Applied Engineering Research (IJAER), 2016; 11(3): 1980-1988.
6. Chaichan M T & Ahmed S T, 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.
7. Chaichan M T, 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. Kazem H A and Chaichan M T, Wind Resource Assessment for nine locations in Oman, International Journal of Computation and Applied Sciences IJOCAAS, 2017, 3(1): 185-191.
9. Kazem H A, Chaichan M T, Experimental analysis of the performance characteristics of PEM Fuel Cells, International Journal of Scientific & Engineering Research, 2016, 7(2): 49-56.
10. Chaichan M T, Abass K I & Salih H M, 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: 158-182.
11. Chaichan M T, Ali A J, Abass K I, Experimental Study on Solar Air Heating, Al-Khawarizmi Eng. Journal, 2018; 14(1): 1-9.
12. Chaichan M T, Abass K I, Al-Zubidi D S M, Kazem H A, Practical investigation of effectiveness of direct solar-powered air heater, International Journal of Advanced Engineering, Management and Science (IJAEMS), 2016; 2(7): 1047-1053.
13. Chaichan M T, Abass K I, Al-Zubidi D S M, 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.
14. Chaichan M T, Al-Hamdani A H, Kasem A M, Enhancing a Trombe wall charging and discharging processes by adding nano-Al2O3 to phase change materials, International Journal of Scientific & Engineering Research, 2016, 7(3): 736-741.
15. Chaichan M T, Abaas K I, 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.
16. Chaichan M T, Abass K I, Jawad R S, Mahdy A M J, Thermal performance enhancement of simple Trombe wall, International Journal of Computation and Applied Sciences IJOCAAS, 2017; 2(1): 33-40.
17. Chaichan M T, Abaas K I, Hatem F F, Experimental study of water heating salt gradient solar pond performance in Iraq, Industrial Applications of Energy Systems (IAES09), Sohar University, Oman, 2009.
18. Chaichan M T & Abaas K I, Productivity amelioration of solar water distillator linked with salt gradient pond, Tikrit Journal of Engineering Sciences, 2012; 19(4): 24-34.
19. Chaichan M T, Abass K I, Kazem H A, Design and assessment of solar concentrator distillating system using phase change materials (PCM) suitable for desertec weathers, Desalination and water treatment, 2016,57(32):14897-14907.
DOI: 10.1080/19443994.2015.1069221

20. Chaichan M T, Kazem H A, Abaas K I, Al- Waeli A A, Homemade Solar Desalination System for Omani families, International Journal of Scientific & Engineering Research, 2016, 7(5): 1499-1504.
21. Chaichan M T, Enhancing productivity of concentrating solar distillating system accompanied with PCM at hot climate, Wulevina, 2016; 23(5): 1-18.
22. Chaichan M T & Kazem H A, Thermal storage comparison for variable basement kinds of a solar chimney prototype in Baghdad - Iraq weathers, International journal of Applied Science (IJAS), 2011; 2(2): 12-20.
23. Chaichan M T & Abaas K I, Practical investigation for improving concentrating solar power stations efficiency in Iraqi weathers, Anbar J for Engineering Science, 2012, 5(1): 76-87.
24. Chaichan M T, Abaas K I & Kazem H A, 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.
25. Ahmed S T & Chaichan M T, A study of free convection in a solar chimney sample, Engineering and Technology J, 2011; 29(14): 2986-2997.
26. Chaichan M T, Abaas K I, Kazem H A, Al Jibori H S & Abdul Hussain U, Novel design of solar receiver in concentrated power system, International J. of Multidispl. Research & Advcs. in Eng. (IJMRAE), 2013; 5(1): 211-226.
27. Chaichan M T & Abass K I, Practical investigation for measurement of concentrating solar power prototype for several target cases at Iraqi summertime weathers, 1st Scientific Conference for Energy & Renewable Energies Applications, UOT, Baghdad, Iraq, 2011.
28. Al-Waeli A H, Kazem H A, Chaichan M T, Review and design of a standalone PV system performance, International Journal of Computation and Applied Sciences IJOCAAS, 2016; 1(1): 1-6.
29. Kazem H A and Chaichan M T, Design and analysis of standalone solar cells in the desert of Oman, Journal of Scientific and Engineering Research, 2016, 3(4): 62-72.
30. Kazem H A, Albadi M H, Al-Waeli A H A, Al-Busaidi A H and Chaichan M T, Techno-economic feasibility analysis of 1 MW photovoltaic grid connected system in Oman, Case Study of Thermal Engineering, 2017, 10: 131-141.
31. Al-Waeli A H A, Al-Mamari A S A, Al-Kabi A H K, Chaichan M T, Kazem H A, Evaluation of the economic and environmental aspects of using photovoltaic water pumping system, 9th International Conference on Robotic, Vision, Signal Processing & Power Applications, Malaysia, 2016.
32. Chaichan M T, Kazem H A, Mahdy A M J & Al-Waeely A A, 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.
33. Chaichan M T, Kazem H A, Mahdy A M J & Al-Waeely A A, Optimization of Hybrid Solar PV/ Diesel System for Powering Telecommunication Tower, IJESET, 2016; 8(6): 1-10.
34. Kazem H A, Al-Waeli A H A, Chaichan M T, Al-Mamari A S, Al-Kabi A H, Design, measurement and evaluation of photovoltaic pumping system for rural areas in Oman, Environment Development and Sustainability, DOI: 10.1007/s10668-016-9773-z, 2016.
35. Al-Waeli A HA, Al-Kabi AHK, Al-Mamari A, Kazem HA and Chaichan MT, Evaluation of the Economic and Environmental Aspects of Using Photovoltaic Water Pumping System, Book ISBN: 978-981-10-1719-3, 2016: 1-9.
36. Chaichan M T, Kazem H A, Energy Conservation and Management for Houses and Building in Oman-Case study, Saudi Journal of Engineering and Technology, 2016; 1(3): 69-76.
37. Kazem H A, Al-Waeli A H A, Al-Mamari A S A, Al-Kabi A H K, Chaichan M T, A photovoltaic application in car parking lights with recycled batteries: A techno-economic study, Australian Journal of Basic and Applied Science, 2015; 9(36): 43-49.
38. Chaichan M T, Kazem H A, Experimental analysis of solar intensity on photovoltaic in hot and humid weather conditions, International Journal of Scientific & Engineering Research, 2016; 7(3): 91-96.
39. Al-Waeli A H, Sopian K, Kazem H A and Chaichan M T, Photovoltaic Solar Thermal (PV/T) Collectors Past, Present and Future: A Review, International Journal of Applied Engineering Research, 2016; 11(22): 1075-10765.
40. Kazem H A and Chaichan M T, Effect of Humidity on Photovoltaic Performance Based on Experimental Study, International Journal of Applied Engineering Research (IJAER), 2015; 10(23): 43572-43577.
41. Kazem H A, Chaichan M T, 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.
42. Kazem H A, Chaichan M T, The impact of using solar colored filters to cover the PV panel on its outcomes, Bulletin Journal, 2016; 2(7): 464-469. DOI: 10.21276/sb.2016.2.7.5.
43. Kazem H A, Chaichan M T, Al-Waeli A H A, Mani K, 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
44. Kazem H A, Chaichan M T, Alwaeli A H, and Kavish Mani, Effect of Shadow on the Performance of Solar Photovoltaic, WREN/WREC World Renewable Energy Congress, Rome, Italy, 2015.
45. Chaichan M T, Kazem H A, Kazem A A, Abaas K I, Al-Asadi K A H, The effect of environmental conditions on concentrated solar system in desertec weathers, International Journal of Scientific and Engineering Research, 2015; 6(5): 850-856.
46. Chaichan M T, Kazem H A, Effect of sand, ash and soil on photovoltaic performance: An experimental study, International Journal of Scientific Engineering and Science, 2017; 1(2): 27-32.
47. Chaichan M T, Abass K I, Kazem H A, 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.
48. Chaichan M T, Abass K I, Kazem H A, Dust and pollution deposition impact on a solar chimney performance, International Research Journal of Advanced Engineering and Science, 2018; 3(1): 127-132.

49. Chaichan M T, Mohammed B A and Kazem H A, Effect of pollution and cleaning on photovoltaic performance based on experimental study, International Journal of Scientific and Engineering Research, 2015, 6(4): 594-601.
50. Al-Waeli A H A, Sopian K, Kazem H A and Chaichan M T, Photovoltaic thermal PV/T systems: A review, International Journal of Computation and Applied Sciences IJOCAAS, 2017; 2(2): 62-67.
51. Al-Waeli A H A, Sopian K, Kazem H A and Chaichan M T, PV/T (photovoltaic/thermal): Status and Future Prospects, Renewable and Sustainable Energy Review, 2017; 77: 109-130.
52. Al-Waeli A H A, Sopian K, Chaichan M T and Kazem H A, Hasan H A, Al-Shamani A N, An experimental investigation on using of nano-SiC-water as base-fluid for photovoltaic thermal system, Energy Conservation and Management, 2017; 142: 547-558.
53. Al-Waeli A H A, Chaichan M T, Sopian K and Kazem H A, 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. DOI10.1016/j.energy.2018.03.040
54. Al-Waeli A H A, Chaichan M T, Kazem H A, Sopian K, Comparative study to use nano-(Al2O3, CuO, and SiC) with water to enhance photovoltaic thermal PV/T collectors, Energy Conversion and Management, 2017; 1489(15):963-973. https://doi.org/10.1016/j.enconman.2017.06.072
55. Al-Waeli A H, Sopian K, Chaichan M T, Kazem H A, Ibrahim A, Mat S and Ruslan M H, Evaluation of the nanofluid and nano-PCM based photovoltaic thermal (PVT) system: An experimental study, Energy Conversion and Management, 2017; 151: 693–708.
56. Al-Waeli A H, Chaichan M T, Kazem H A, Sopian K, Ibrahim A, Mat S, Ruslan M H, Numerical study on the effect of operating nanofluids of photovoltaic thermal system (PVT) on the convective heat transfer, Case Study in Thermal Engineering, 2018; 12: 405-413. https://doi.org/10.1016/j.csite.2018.05.011
57. Kazem HA, Yousif J H, Chaichan M T, Modeling of Daily Solar Energy System Prediction using Support Vector Machine for Oman, International Journal of Applied Engineering Research, 2016; 11(20): 10166-10172.
58. Mazin H, Kazem H A, Fadhil H A, Aljunid S A, Abdulmajeed Q M, Chaichan M T, Linear and Nonlinear Modeling for Solar Energy Prediction for Zone, Region and Global Areas, Chapter in Renewable Energy in the Service of Mankind, Vol. II, Springer, 21-34, 2015.
59. Mazin H, Kazem H A, Fadhil H A, Alawi S and Chaichan M T, Global linear, nonlinear and ANN-based modeling of monthly diffuse solar energy, WREC XIV Proceedings, University POLITEHNICA of Bucharest, Romania, June 8 – 12, 2015.
60. Kadhum J A, Design and Construction of a Tracking Device for Solar Electrical Systems, Journal of Scientific and Engineering Research, 2018; 5(7): 225-236.
61. Chaichan M T, Kazem H A, Generating Electricity Using Photovoltaic Solar Plants in Iraq, Springer, ISBN: 978-3-319-75030-9. https://doi.org/10.1007/978-3-319-75031-6
62. Al-Waeli A H A, Sopian K, Kazem H A, Yousif J H, Chaichan M T, Ibrahim A, Mat S and Ruslan M H, 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.
63. Al-Waeli A H A, Kazem H A, Sopian K and Chaichan M T, Techno-economical assessment of grid connected PV/T using nanoparticles and water as base-fluid systems in Malaysia, International Journal of Sustainable Energy, 2018; 37(6): 558-578. DOI: 10.1080/14786451.2017.1323900