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Research paper

Investigation of solar radiation distribution over three zones north, middle and south of Jordan

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Abstract

Solar energy considers as the best alternative energy source in Jordan as the solar radiation average is high in Jordan which is between 4 and 8 kWh/m^2. The average solar radiation is connected with an energy potential of 1400 to 2300 GWh per year. Electricity is the main source of energy used in Jordan as all daily applications rely on it such as heating, cooling, lighting, etc. For that studying solar radiation carefully is an essential issue to ensure the availability of the power when it needed. In this study, a solar radiation distribution is provided of three main zones in Jordan north, middle and south.

Keywords: *Energy; Electrical Demand; Solar Radiation Distribution; Solar Energy.*

1. Introduction

Jordan has more than 300 days as sunny days over the year that makes the solar energy is a suitable candidate to cove a big portion of the energy needs in Jordan and to reduce the needs for importing traditional fuel for electricity generation [1-23]. As the prices of conventional fuel increased sharply the cost of installing the solar energy application in dramatically decreased. Thus, investigation in solar energy become worth. Comparing to other countries over the world Jordan consider one of the highest in the solar radiation as the range of the radiation in Jordan comes in between 4 and 8 Kwh/m^2[24-27].

In order to get the maximum benefit of the solar energy application a measurement of solar radiation is essential for that a several measurement devices are implemented for this issue, parallel to that a well study of the weather and geographical information for the different sites planned to have PV application is important [28-30].

For the purpose of studying the solar radiation at several position i.e. horizontal, vertical and with a tilt angle several models are implemented. As the sun is the main operator of the other energy sources, the solar intensity is very important as it is an explanation of the energy transfer to the planet. Thus, studying and quantify the magnitude and the distribution of the solar radiation is an essential issue for the solar energy applications. Unfortunately, there is a lake in the investigation and collection of the solar radiation data. Solar radiation data is very important tool to make a decision were the investment in solar application is possible in a selected region or not. For that archiving the data of solar radiation is a strategical goal for all countries over the world [7], [27], [31].

2. Geographical and meteorological data

The divided zones of Jordan lie within a 32º north as latitude and 36º East as longitude. With about 300 sunny days Jordan consider a country of sun and that makes the investment of the solar energy is very worth. Figure.1 shows the zone panted on the map of Jordan.

Fig. 1: The Divided Zones of Jordan.

3. Solar radiation theory

The sun considers the main operator of the rest of the renewable energy as it is the biggest source of the energy ever. In this work a solar map of three main zones of Jordan is provided in order to make the decision of the solar investment is easier for the decision makers. For that a mathematical model is studied based on the following equations [32-35].

Declination is calculated by using:

$$\delta = 23.45\sin\left(2\pi\frac{284+n}{365}\right)$$

The sunset hour angle ωs can be calculated by using:

$$\omega s = cos^{-1}(-tan\emptyset tan\delta)$$

The daily extraterrestrial radiation on a horizontal surface, H_o, can be calculated by using:

$$H_0 = \frac{24 \times 3600 G_{sc}}{\pi}\left(1 + 0.033 cos\frac{360n}{365}\right) \times \left(cos\emptyset cos\delta sin\omega + \frac{\omega\pi}{180} sin\emptyset sin\delta\right)$$

Where Gsc=1367 W/m2

The monthly average clearness index, KT, can be calculated by using:

$$K_T = H/H_0$$

Where H=9864000 J/m^2.

Monthly average daily diffuse radiation Hd can be calculated by using:

Since ωs≤81.4˚ and 0.3≤KT≤0.8

$$H_d = 1.391 - 3.560K_T + 4.189\, K_T^2 - 2.137K_T^3$$

Geographical position, time (day of year as well as time of day) and plane orientation are the main parameters that the incidence angle depends on. Where Tilt angle is β and an azimuth angle is γ of the plane. Taking a note that the time will be in the standard time. For that, the solar time needed to be calculated and secondly the hour angle ω as well the declination δ. All of this calculations lead to calculate the incidence angle θ based on the following function:

$$cos\theta = sin\delta\, sin\emptyset\, cos\beta - sin\delta\, cos\emptyset\, sin\beta\, cos\gamma + cos\delta\, cos\emptyset\, cos\beta\, cos\omega + cos\delta\, sin\emptyset\, sin\beta\, cos\gamma\, cos\omega + cos\delta\, sin\beta\, sin\gamma\, sin\omega$$

In order to simplified the function, we assume a horizontal surface, then the incidence angle will be independent of the plane azimuth angle

$$cos\theta = sin\delta\, sin\emptyset + cos\,\delta\, sin\varphi cos\omega$$

Secondly, for a vertical surfaces facing towards south in the northern hemisphere the equation transforms into:

4. Result and discussion

Solar radiation is expressed by a unit of Wh/m^2 and can be calculated based on the daily solar radiation average. Figure. 3 present the horizontal radiation for the zones of Jordan in Wh/m^2. Noted that, the south and the north zones is the highest in the horizontal radiation with a yearly average of 284470 and 336600 Wh/m^2 respectively. The middle zone has the lowest portion of the horizontal radiation with a value of 203530 Wh/m^2. For the three zones, north, middle and south the maximum horizontal radiation was achieved during June with a values of 41860, 25100 and 33390 Wh/m^2. While the lowest horizontal radiation was in December with a values of 14310, 8640 and 13090 Wh/m^2.

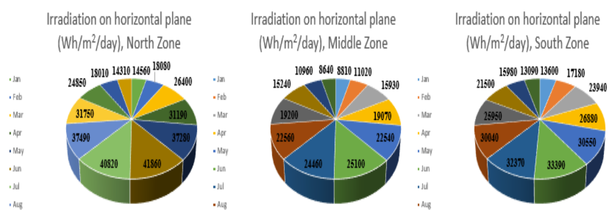

Fig. 3: Horizontal Plane Solar Irradiation in Kwh/M^2/Day.

For increasing the gain from the solar radiation the solar application is designed to be faced the sun as maximum as possible. For that the tilt angle is carefully calculated for the zones in order to get the maximum benefit. Figure. 4 shows the irradiation based on optimally inclined plane in Wh/m^2/day of Jordan zones. It is noted that, the maximum production will be in the north and south zones and the lowest will be in the middle zone. Comparing to the production based on the horizontal radiation it appears that the production with the optimally inclined plane is more than the production with the horizontal radiation.

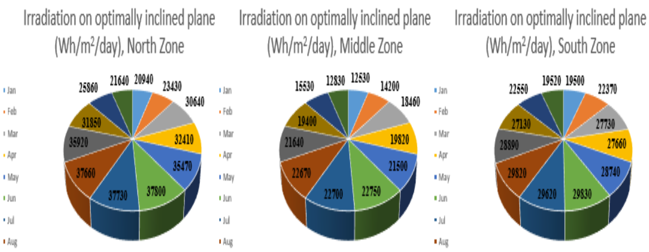

Fig. 4: Solar Irradiation on the Optimally Inclined Plane of Jordan Governorates in Kwh/M^2/Day.

The amount of the solar radiation received on a unit area reflect the direct normal irradiance which is perpendicular to the rays come in a straight line from the direction of the sun with its position in the sky. To increase the benefit from the solar radiation we need to keep the surface of the application normal to the incoming radiation. For that, tracking system is the best solution to make the solar application follow the sun rays. Figure. 5 shows the normal direct radiation in Wh/m^2/day for all zones of Jordan. It can be noted that the north and the south zones have the maximum solar radiation as normal direct radiation with a values of 366060 and 308570 Wh/m^2. While the lowest amount of the normal direct radiation was in the middle zone with a value of 218430 Wh/m^2. The maximum normal direct radiation was during June and the minimum was during January for the three zones of Jordan.

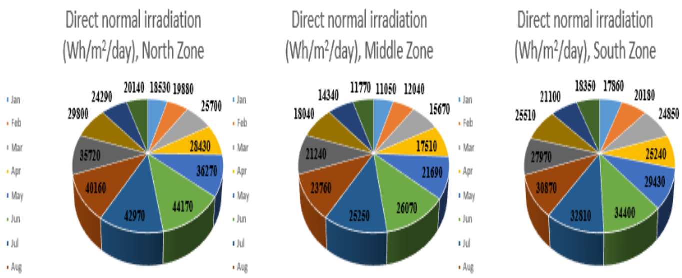

Fig. 5: Solar Normal Direct Radiation of Divided Zones of Jordan in Kwh/M^2/Day.

The tracking system is considering the best way in order to increase the performance of the solar applications as the tracking system allow the solar application to receive more solar radiation by make the application follow the sun and faced to it. For that calculating the tilt angle that the tracking system depend on is the key point. Figure. 5 shows the calculated angle of inclination in degree which need to implement for the solar applications in Jordan zones. It is clear that the best monthly inclination angle during January in all Jordan zones is around 55˚ and it is started to decrease until reach 0.0˚ in June where the maximum solar radiation can be achieved. Then it is started to increase to the same value of 55˚ with decreasing in the solar radiation.

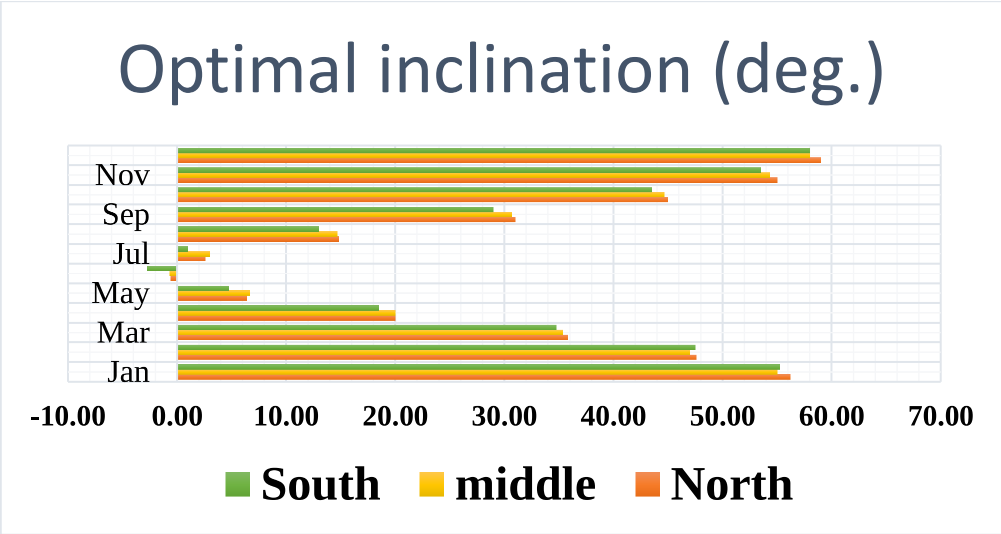

Fig. 6: Optimum Monthly Inclination Angle of Solar Application.

5. Conclusion

This paper presents a solar radiation distribution based on solar irradiation assessment and calculation for Jordan zones. Validation of these models was achieved through a mathematical calculation. Correspondingly, from the result we could summarized several conclusions:

- The north and south zones have the highest irradiation on the horizontal plane among all Jordan zones with a value of 336600 and 284470 Wh/m^2/day. While, the middle zone has the lowest irradiation on the horizontal plane with a value of 203530 Wh/m^2/day.
- The north zone has the highest irradiation on the optimum inclined plane among all other Jordan zones with a value of 371350 Wh/m^2/day. While, the middle zone has the lowest irradiation on the horizontal plane with a value of 224030 Wh/m^2/day.
- The maximum Energy production expected from the solar applications comes in June with an optimum tilt angle of 0° approximately.

The results emphasize that the study presented might be utilized for the calculation of solar irradiation specific to the three zones to select the best applications for using in energy production purpose.

References

[1] Al-Ghandoor, A., *Evaluation of energy use in Jordan using energy and exergy analyses.* Energy and Buildings, 2013. 59: p. 1-10. https://doi.org/10.1016/j.enbuild.2012.12.035.

[2] Al-Ghandoor, A., et al., *Projection of future transport energy demand of Jordan using adaptive neuro-fuzzy technique.* Energy, 2012. 38(1): p. 128-135. https://doi.org/10.1016/j.energy.2011.12.023.

[3] Al-omary, M., M. Kaltschmitt, and C. Becker, *Electricity system in Jordan: Status & prospects.* Renewable and Sustainable Energy Reviews, 2018. 81: p. 2398-2409. https://doi.org/10.1016/j.rser.2017.06.046.

[4] Al-Ghandoor, A., et al., *Energy and exergy utilizations of the Jordanian SMEs industries.* Energy Conversion and Management, 2013. 65: p. 682-687. https://doi.org/10.1016/j.enconman.2011.11.036.

[5] Al-Najideen, M.I. and S.S. Alrwashdeh, *Design of a solar photovoltaic system to cover the electricity demand for the faculty of Engineering- Mu'tah University in Jordan.* Resource-Efficient Technologies, 2017. 3(4): p. 440-445. https://doi.org/10.1016/j.reffit.2017.04.005.

[6] Alrwashdeh, S.S., *Modelling of Operating Conditions of Conduction Heat Transfer Mode Using Energy 2D Simulation.* International Journal of Online Engineering (iJOE). 14(9).

[7] Alrwashdeh, S.S., *Map of Jordan governorates wind distribution and mean power density.* International Journal of Engineering & Technology, 2018. 7(3): p. 1495-1500. https://doi.org/10.14419/ijet.v7i3.14326.

[8] Alrwashdeh, S.S., *Assessment of Photovoltaic Energy Production at Different Locations in Jordan.* INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH 2018. 8(2).

[9] Alrwashdeh, S.S., *Comparison among Solar Panel Arrays Production with a Different Operating Temperatures in Amman-Jordan.* International Journal of Mechanical Engineering and Technology, 2018. 9(6): p. 420–429.

[10] Alrwashdeh, S.S., et al., *Improved Performance of Polymer Electrolyte Membrane Fuel Cells with Modified Microporous Layer Structures.* Energy Technology, 2017. 5(9): p. 1612-1618. https://doi.org/10.1002/ente.201700005.

[11] Alrwashdeh, S.S., et al., *Neutron radiographic in operando investigation of water transport in polymer electrolyte membrane fuel cells with channel barriers.* Energy Conversion and Management, 2017. 148: p. 604-610. https://doi.org/10.1016/j.enconman.2017.06.032.

[12] Alrwashdeh, S.S., et al., *In Operando Quantification of Three-Dimensional Water Distribution in Nanoporous Carbon-Based Layers in Polymer Electrolyte Membrane Fuel Cells.* ACS Nano, 2017. 11(6): p. 5944-5949. https://doi.org/10.1021/acsnano.7b01720.

[13] Alrwashdeh, S.S., et al., *Investigation of water transport dynamics in polymer electrolyte membrane fuel cells based on high porous micro porous layers.* Energy, 2016. 102: p. 161-165. https://doi.org/10.1016/j.energy.2016.02.075.

[14] Ammari, H.D., S.S. Al-Rwashdeh, and M.I. Al-Najideen, *Evaluation of wind energy potential and electricity generation at five locations in Jordan.* Sustainable Cities and Society, 2015. 15: p. 135-143. https://doi.org/10.1016/j.scs.2014.11.005.

[15] Ince, U.U., et al., *Effects of compression on water distribution in gas diffusion layer materials of PEMFC in a point injection device by means of synchrotron X-ray imaging.* International Journal of Hydrogen Energy, 2018. 43(1): p. 391-406. https://doi.org/10.1016/j.ijhydene.2017.11.047.

[16] Mohammad A. Saraireh, F.M.A., and Saad S. Alrwashdeh, *Investigation of Heat Transfer for Staggered and in-Line Tubes.* International Journal of Mechanical Engineering and Technology 2017. 8(11): p. 476–483.

[17] Saad S. Alrwashdeh, F.M.A., Mohammad A. Saraireh, *Solar radiation map of Jordan governorates.* International Journal of Engineering & Technology, 2018. 7(3).

[18] Saad S. Alrwashdeh, F.M.A., Mohammad A. Saraireh, Henning Markötter,Nikolay Kardjilov, Merle Klages, Joachim Scholta and Ingo Manke, *In-situ investigation of water distribution in polymer electrolyte membrane fuel cells using high-resolution neutron tomography with 6.5 µm pixel size.* AIMS Energy, 2018. 6(4): p. 607–614. https://doi.org/10.3934/energy.2018.4.607.

[19] Sun, F., et al., *Complementary X-ray and neutron radiography study of the initial lithiation process in lithium-ion batteries containing silicon electrodes.* Applied Surface Science, 2017. 399: p. 359-366. https://doi.org/10.1016/j.apsusc.2016.12.093.

[20] Alrwashdeh, S.S., *Investigation of Wind Energy Productionat Different Sites in Jordan Using the SiteEffectiveness Method.*

Energy Engineering, 2019. 116(1): p. 47-59. https://doi.org/10.1080/01998595.2019.12043338.
[21] Alrwashdeh, S.S., *Energy ProductionEvaluationfrom a Linear Fresnel Reflectors Arrays with Different Array Orientation.* International Journal of Engineering Research and Technology, 2018. 11(11): p. 1827-1835.
[22] Alrwashdeh, S.S., *Assessment ofthe energy productionfrom PVracks based on usingdifferent Solar canopy form factorsin Amman-Jordan.* International Journal of Engineering Research and Technology, 2018. 11(10): p. 1595-1603.
[23] Alrwashdeh, S.S., *Predicting of energy production of solar tower based on the study of the Cosine efficiency and the field layout of heliostats.* International Journal of Mechanical Engineering and Technology (IJMET), 2018. 9(11): p. 250–257.
[24] Hammad, M., M.S.Y. Ebaid, and L. Al-Hyari, *Green building design solution for a kindergarten in Amman.* Energy and Buildings, 2014. 76: p. 524-537. https://doi.org/10.1016/j.enbuild.2014.02.045.
[25] Hrayshat, E.S., *Status and outlook of geothermal energy in Jordan.* Energy for Sustainable Development, 2009. 13(2): p. 124-128. https://doi.org/10.1016/j.esd.2009.05.004.
[26] Handri D.Ammari, S.S.A.-R.a.M.I.A.-N., *Evaluation of wind energy potential and electricity generation at five locations in Jordan.* Sustainable Cities and Society, 2015. 15: p. 135-143. https://doi.org/10.1016/j.scs.2014.11.005.
[27] Jaber, J.O., et al., *Renewable energy education in faculties of engineering in Jordan: Relationship between demographics and level of knowledge of senior students'.* Renewable and Sustainable Energy Reviews, 2017. 73: p. 452-459. https://doi.org/10.1016/j.rser.2017.01.141.
[28] Bertrand, C., et al., *Solar irradiation from the energy production of residential PV systems.* Renewable Energy, 2018. 125: p. 306-318. https://doi.org/10.1016/j.renene.2018.02.036.
[29] Jaber, J.O., et al., *Employment of renewable energy in Jordan: Current status, SWOT and problem analysis.* Renewable and Sustainable Energy Reviews, 2015. 49: p. 490-499. https://doi.org/10.1016/j.rser.2015.04.050.
[30] Kandemir, E., N.S. Cetin, and S. Borekci, *A comprehensive overview of maximum power extraction methods for PV systems.* Renewable and Sustainable Energy Reviews, 2017. 78: p. 93-112. https://doi.org/10.1016/j.rser.2017.04.090.
[31] Bahrami, A. and C.O. Okoye, *The performance and ranking pattern of PV systems incorporated with solar trackers in the northern hemisphere.* Renewable and Sustainable Energy Reviews, 2018. 97: p. 138-151. https://doi.org/10.1016/j.rser.2018.08.035.
[32] El-Kassaby, M.M., *Monthly and daily optimum tilt angle for south facing solar collectors; theoretical model, experimental and empirical correlations.* Solar & Wind Technology, 1988. 5(6): p. 589-596. https://doi.org/10.1016/0741-983X(88)90054-9.
[33] El-Sebaii, A.A., et al., *Global, direct and diffuse solar radiation on horizontal and tilted surfaces in Jeddah, Saudi Arabia.* Applied Energy, 2010. 87(2): p. 568-576. https://doi.org/10.1016/j.apenergy.2009.06.032.
[34] Le Roux, W.G., *Optimum tilt and azimuth angles for fixed solar collectors in South Africa using measured data.* Renewable Energy, 2016. 96, Part A: p. 603-612.
[35] Moghadam, H. and S.M. Deymeh, *Determination of optimum location and tilt angle of solar collector on the roof of buildings with regard to shadow of adjacent neighbors.* Sustainable Cities and Society, 2015. 14: p. 215-222. https://doi.org/10.1016/j.scs.2014.09.009.