Journal of Green Engineering (JGE)

Volume-10, Issue-2, February 2020

Study of Photovoltaic System's Parameters that Influence on the Efficiency of Inverter

[1]Muhammed Salah Sadiq Alkafaji, [2]Ahmed Daud Mosheer, [3]Sara Al-Waisawy

[1]Lecturer, Department of Electrical Power Engineering Technique, Al-Mussaib Technical College, Al-Furat Al-Awsat Technical University, Najaf, Iraq.
E-mail: com.muh7@atu.edu.iq
[2]Assistant Lecturer, Department of Electrical Power Engineering Technique, Al-Mussaib Technical College, Al-Furat Al-Awsat Technical University, Najaf, Iraq.
E-mail: com.md.ahmad@atu.edu.iq
[3]Assistant Lecturer, Department of Electrical Power Engineering Technique, Al-Mussaib Technical College, Al-Furat Al-Awsat Technical University, Najaf, Iraq.
E-mail: com.ks.sara@atu.edu.iq

Abstract

This work is an investigation of influences of PV solar system `s parameters on the performance of inverter, The PV system which was utilized in this study is a stand –alone system. It is considered more compatible technique to circumstances in Iraq, Karbala province was selected as an appropriate location has large amount of solar radiation. Parameters of PV system which were studied variations of solar exposure angle as well as input power of inverter , an experiment was conducted on residential unit in the above mentioned region , power input of the inverter was varied from 5% to 30% and five angles of solar exposure have been determined, these angles corresponded to five values of efficiency. The obtained results have proved that a significant influence of these parameters on the inverter efficiency.

Keywords: Gird Connected System, Tracking System, Static System, Dust, Power Density

Journal of Green Engineering, Vol. 10_2, 447–462. Alpha Publishers

1 Introduction

Tremendous developments in requirements of lifeworld ideas well as speedy industrial growth have been rising incredibly, hence it is normally sector of energy production has experienced a noticeable shortage. Providing an adequate matching level between energy production and energy demand represents an obvious challenge faces investor in electrical energy sector. Based on mentioned previously, scientific researches have granted a wide area associated with sustainable energy resources such as wind and solar energies [1-3]. Sun can be considered one of the most natural resource of essential energy for maintaining life; continuously our planet obtains sufficient energy generated by sun. [4,5]. In order to utilize emitted energy from sun properly, that`s required advanced system responsible for transforming energy from pattern (light) to another (electricity).This process has been implemented by a photovoltaic system which is considered optimal solution to supply electricity to far areas and be separated from public power system, in this case PV system is considered a stand-alone (Fig1) [6-8]. Also, it is can be integrated with generation level in electrical power system and under this condition PV system will called a grid system (Fig2) [9-11].

A number of constraints should be taken into consideration involve sun or solar energy in spite of its tremendous contribution in providing necessary electrical power in diverse field as well as reduction of serious pollution caused by using coal or oil as fuel in electrical power generation. For instance, global electricity market especially with existence of numerous competitors in this sector [12,13]. Generally for Inhabited areas a small number of kilowatts is required for each housing unit ,thus when available electrical power generated by photovoltaic system covers demand of a particular region ,remaining power can be sold via common grid with others whereas customers have to purchase their needed power when there is a shortage or mismatching between consumption and production[14,15].

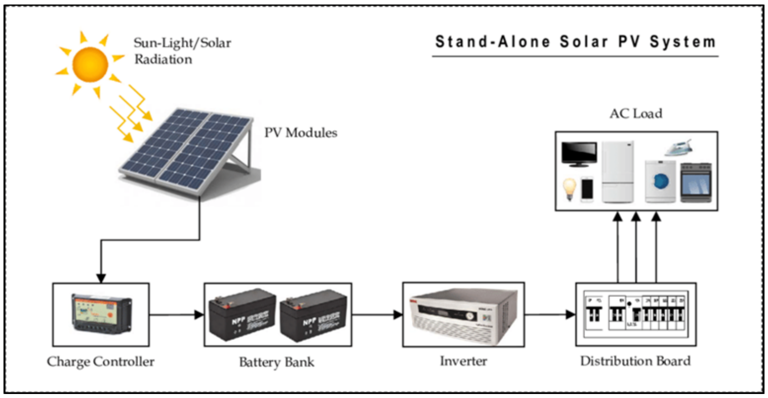

Figure 1. Stand-alone PV system [8]

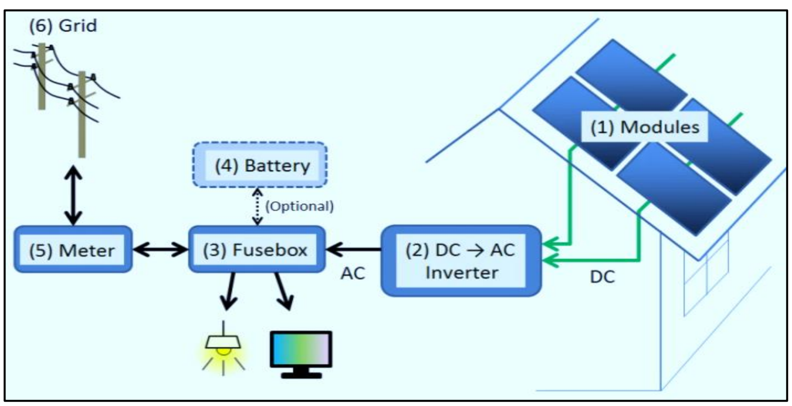

Figure 2 Grid connected PV system[9]

This work was an investigation of photovoltaic system`s parameters which affect inverter performance within power system. The proposed system is a stand-alone which is more compatible for Iraqi(section 3.2).

2 PV System Composition

The elementary constituents of PV system are PV module, battery, Solar charge controller, inverter and required power. In terms of modules, they have been manufactured from semiconductor, they transform light energy into electrical energy, mostly PV modules consist of polycrystalline. The battery is responsible for storing energy while power provided by PV modules surpass user`s load and presents this power to the system to compensate required power under shortage condition. Coordination and regulation unit represents a very vital part in PV system; it is working on maintaining reliable integration of the PV system entirely through avoiding surplus charging of battery thus extending high performance of battery. Globally electrical load for majority of users is operating with alternative current AC so the direct current DC which is generated by PV system should be transformed into AC, inverter has done this mission and it is considered a gateway between generation and users` levels. Users` equipment's and devices in diverse forms such as a ventilation, conditioning and communication systems have significant influences on a quality of PV system. [16-18].

3. Solar Energy in Iraq

3.1 Introduction

Climate of Iraq has a distinct long-lasting sunny time throughout year, the estimated range of solar power density during first half of year starts from about 0.416 KW/m2 to 0.833 KW/m2 per hour [19]. As a compared with numerous countries, Iraq has outstanding intensity of sunlight [20]. Lion share of power density due to sunny radiation comes from deserted regions in Iraq which occupy wide area especially in the west of Iraq .According to some studies , Iraqi deserts have generated power density reaches to 2310 kwh/m2 annually [21,22] Generally Iraqi climate can be divided into summer which is about 60%whereas 40% is a percentage of winter. [23,24] solar power density exceeds 2300kWh/m2 when solar becomes perpendicular on Iraqi plane in summer [25]. The growth of solar photovoltaic power has been increasing significantly, it exceeded 400MW worldwide [26]. Unfortunately, utilization of renewable energies in general and solar energy particularly have been constrained extremely in Iraq. Exception some of public utilities for instance roads lighting systems in limited regions in addition to some of agricultural uses involved watering systems. Table1 shows solar radiation globally included some Iraqi provinces based on three inclination angles (0o, 90o, sloped) according to [25].

Table1 solar radiation globally included some Iraqi provinces based on three inclination angles

Location	Country	Solar Irradiation on Horizontal Plane ($Wh/m^2/year$)	Solar Irradiation on Vertical Plane ($Wh/m^2/year$)	Solar Irradiation on Inclined Plane ($Wh/m^2/year$)	Optimal Inclination (o)
San Bernardino	USA	5294	3637.5	5875.8	56
Phoenix	USA	5280	3685.8	5895.8	57
Seville	Spain	4868.3	3.443.3	5410.8	53
Badajoz	Spain	4705.8	3405	5268.3	51
Newcastle	Australia	4590	3154	5031	57
Abu Dhabi	UAE	5533.3	3186.6	5847.5	66
Cairo, Egypt	Egypt	5290	3227.5	5647.5	60
Mosul	Iraq	4841.6	3319.1	5319.1	54
Mosul		5011.6	3227.5	5402.5	56
Al-Anbar		5000	3136.66	5347.0	57
Karbala		5104.16	3236.6	5492.5	57
An Nasiriya		5129.16	3219.16	5505.8	59
Al Basrah		5035.8	3086.6	5276.66	60

3.2 Difficulties Limits Solar Energy Utilization in Iraq

In spite of extensive augmentations in electrical power generation throughout latest years, however Iraq has experienced deficiency of accomplishing the appropriate balance between generation and demand of consumers. The total production of electrical power exceeded 11GWin 2017whereas losses percentage was more than 50%. In order to overcome this challenge, many years ago generators owned by individuals have been in service to compensate huge losses.

However, there is no coordination or schedule to ensure reliable power system between public utility of electricity and owners` generators. Under such conditions grid connected PV system cannot be sufficient solution, thus in the proposed work basic assumption is depending on stand-alone PV system to avoid the above-mentioned problem. On the other hand, renewable energies require vital market to purchase or sell energy, Iraq and its neighbors need long time to form an appropriate economic environment in this field.

4 Operative Parameters of PV System on Inverter Performance

4.1 Inverter Components

Inverter is an electrical equipment responsible for altering direct power from PV system to alternating power in order to provide electrical power to consumers as a part from public power system. The efficiency of power alteration which done by inverter has influenced the performance of entire PV system due to power losses which occurred throughout the alteration process, they have been caused by transformer condition ,copper losses as well as performance of diodes and thyristors. Hence when losses become minimum, the inverter will operate with highest efficiency.

It is imperative to observe efficiency of inverter goes down slightly subsequently climaxing power density starts from 0.4to 0.7 KW/m2because of increasing of temperature throughout the inverter entirely while it deals with high power supplied to consumers .The influence of field conditions associated with transformer has been considered with high efficiencies of operation which exceed 85% , it causes 10% decrease in efficiency`s value. Some of researches proposed non- transformer inverter in order to avoid above mentioned issues as much as possible and to raise efficiency extremely, it exceeds 95%.

4.2 PV Output and Inverter Performance

To ensure reliable performance for entire PV system, balance between PV output and input power of inverter should be considered. There are two operation modes represent abnormal conditions, one of them when PV output less than inverter input due to low solar exposure (irradiation). Inverter output under this condition will not cover entire load, in other words performance of inverter has been influenced significantly. Whereas, in another mode PV system output is greater than inverter input, the alteration from dc to ac power pattern is within allowable capacity of inverter hence unfortunately extra margin of the input power will be useless .Reduction in solar exposure has been come from many reasons ,for instance plants , neighbor buildings as well as animals which prevent sunlight receiving by solar cells. The entire efficiency of PV system has decreased with more than 60% because of 2 percent of area of panel has not received sunlight adequately. Additionally, dust might minimize solar exposure according to some studies received power from solar panel is diminished with 1 percent due to dust but after removing it power becomes within normal condition.

4.3 Influence of Tracking Approach

In most cases output power of PV system has increased significantly when solar panel received sunlight directly (angle between PV panel and sunlight is 90o), hence tracking approach which is used has an obvious contribution to operate PV system with high level of performance .PV system might be static system when the receiving angle of sunlight is a constant or dynamic and under this case PV system will track sunlight to maximize receiving power density .Power generation has raised noticeably by using tracking system with two axes ,there is an increase starts from 25% to reach 45% as a compared with static PV system but performance of tracking system has gone down due to clouds extremely.

5 Study Case

Karbala province locates at 32.6027° N- 44.0197° E geographically, according to table 1 it has a distinct sun radiation makes it qualified to be appropriate case study. This work offers proposed stand-alone PV system to investigate influences of system parameters which considered an essential criterion to evaluate inverter performance. From table.1 solar radiation of Karbala is 5492.5 Wh/m2 with inclination (incidence) angle 57o, in most cases especially with static PV system the installation angle is within (0-90o) thus the proposed investigation depends on this more practical criterion. To facilitate calculations in this study solar radiation was considered 5500Wh/m2, additionally estimation actual essential energy of demand for medium family every day using Equ.1. The entire system efficiency includes all components (panel, battery, and inverter) which was estimated 0.85 to ensure that calculations within allowable margin.

Actual energy per day = received energy per day(solar radiation) x entire system efficiency (1)

Actual energy per day=5500 x 0.85= 4675 Wh (energy demand for medium family)

Whereas Eq2. is used to evaluate maximum power during day depending on hourly sunny time

maximum power per day=(received energy per day(solar radiation))/(sunny time per day) (2)

At least the sunny time was estimated with 4 hours in order to evaluate maximum power day

received from panels entirely.

maximum power per day=5500Wh/(4h)= 1375 W

PV-MLE255HDsolar panel was used in this study with specification shown below:

Structure: Monocrystalline silicon

Cells: 120 units

Maximum power rating: 185W

Open circuit voltage (Voc): 34.5V

Short circuit current (Isc): 7.19A

Maximum power voltage (Vmp): 28V

Maximum power current (Imp): 6.6 A

Then I_dc will be calculated from Equ.3;

maximum power per day=I_dc×V_dc (3)

I_dc= 1375/28=49.1 Amp

Number of panels as columns was calculated from Equ 4 as below:

columns(panels)ofarray=(entire current of panels)/(current of single panel) (4)

columns (panels)of array=49.1/6.6 =7.43

Columns are integer numbers so above results was approximated to 8, similarly number of panels as rows calculated using Equ 5

rows (panels)of array =(entire voltage of panels)/(voltage of single panel) (5)

rows (panels)of array =(28)/28=1

Consequently, the entire system (array) is 1 x 8 panels. The needed storage of batteries was calculated based on worst condition in other words cloudy or dusty weather completely, at this time it is supposed to maintain reliable operation depending on batteries storage within safety margin. The essential storing energy for proposed load is 4675 W. h , taking into consideration worst condition (supposed 2 days full cloudy or dusty) calculated using Equ 6 , so ;

Needed capacity = 4675x 2 = 9350 Wh,

Actual capacity of batteries = (essential storing)/ (highest tolerable discharge) (6)

Actual capacity of batteries (under worst condition)=9350/0.8 = 11687.5 Wh

According to selected battery (200Ah -12V dc), the batteries number from Equ 7 will be:

Capacity of single battery = (11687.5)/200= 58.43

Batteries number =(entire capacity)/(capacity of single battery) (7)

Batteries number =58.43/12=4.87

Thus, number of needed batteries is 5 for running proposed system properly based on above estimations. The estimated load based on above mentioned is 1375W so the used inverter should be 2000W,220V at least to ensure reliable and efficient operation.

6 Experimental Evaluation of Proposed System

PV output (input power of inverter) was varied manually to investigate inverter efficiency response with manual variation which simulates effect of different factors such clouds, animals and buildings. The proposed PV system consists of 8 panels, each one includes 120 cells. In the first step of experiment, an amount of dust put on some cells to reduce received solar power density and thus power input of the inverter within range starts from 5% and it ends to 30%. Fig3 illustrates variation of inverter efficiency in terms of input power. The efficiencies have been evaluated depending on wattmeter reading (output power of inverter) which is mounted on distribution board of the residential house. It is obviously inverter efficiency has reduced linearly due to manual input power variation; table 2 illustrates the influence of changing input power on output power supplied to the residential unit. The experiment has been conducted at 10:30 A.M to ensure very high solar exposure with in incidence (receiving) angle about 56.73^{o}

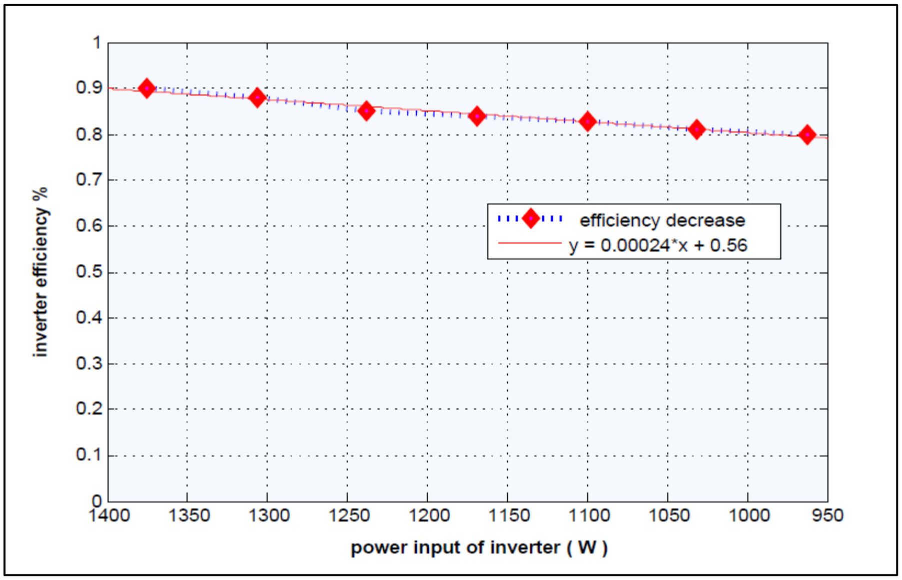

Figure 3 Inverter efficiency in terms of variation power input

Table 2 Obtained Efficiencies and Output Power Due To Variation Of Input Power

Percentage of manual variation in input power %	Input power (w)	Output power (wattmeter) (w)	Inverter efficiency %
0	1375	1237.48	0.91
5	1306.25	1144.22	0.88
10	1237.5	1051.874	0.85
15	1168.75	981.75	0.841
20	1100	913	0.829
25	1031.25	835.31	0.81
30	962.5	770	0.8

In the proposed work PV system is a static mounted with above mentioned incidence angle, the solar exposure angle was changed manually to investigate tracking or angle influence on the performance of inverter. Five angles have been determined for this purpose; these angles corresponded to five values of efficiency. This experiment was conducted between (10 -11 AM), Fig4 illustrates a significant change in the inverter efficiency in terms of solar exposure angle.

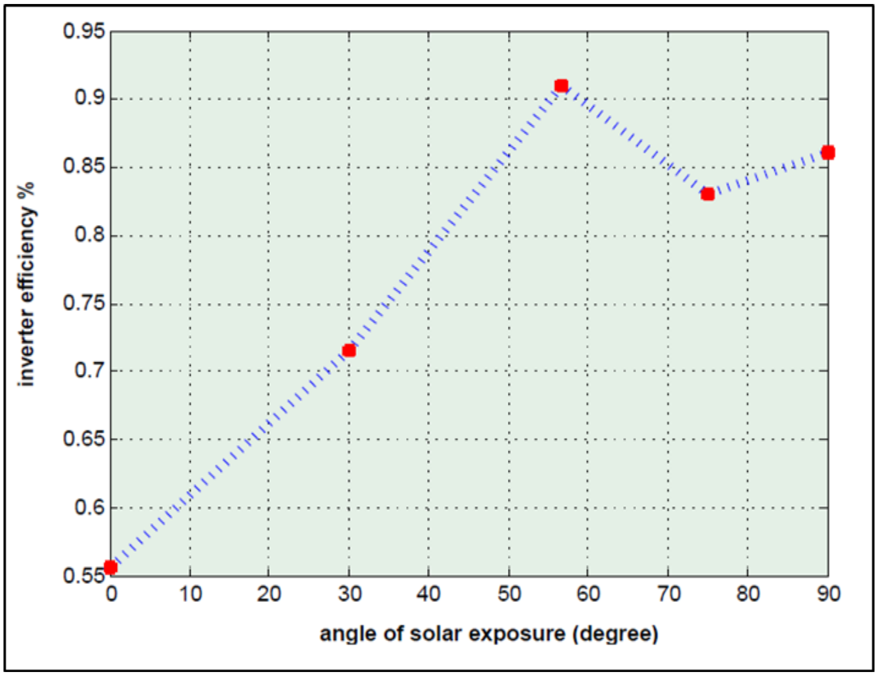

Figure 4 effect of solar exposure angle on inverter efficiency

Other effective factors on inverter performance involved design of inverter such as transformer,copper losses cannot investigated experimentally during limited duration such as in the proposed study or other similar researches .Because of their influences become more noticeable throughout long operation time which might take many years, hence the proposed investigation included effect of input power variation because of diverse reason as well as tracking or angle of solar exposure. Because integrated market of electricity is not existing in Iraq and its neighbors, therefore; the cost effect cannot be studied sufficiently in order to evaluate cost effect as an important constraint in the proposed study.

7 Conclusion

This study investigated effect of parameters of PV system on inverter performance, solar exposure angle and input power have affected directly efficiency of used inverter. The study case was a residential unit in Karbala which is considered rich location with solar radiation. The effects of inverter components need long time to evaluate them properly.

References

[1] L Bird et al ,"Wind and solar energy curtailment: A review of international experience", Renewable and Sustainable Energy Reviews, Vol.65, pp. 577-586, 2016.

[2] Braff W. A, Mueller J. M & Trancik J. E,"Value of storage technologies for wind and solar energy", Nature Climate Change, Vol.6, no.10, pp. 964-970, 2016.

[3] Bett P. E & Thornton H. E,"The climatological relationships between wind and solar energy supply in Britain", Renewable Energy, Vol.87, no.3, pp. 96-110.2016.

[4] Armaroli, N., & Balzani, V,"Solar electricity and solar fuels: status and perspectives in the context of the energy transition"Chemistry–A European Journal, Vol.22, no. 1, pp. 32-57, 2016.

[5] Lewis, N. S"Research opportunities to advance solar energy utilization". Science, Vol.12, no.3, pp.456-478, 2016.

[6] Baghaee H. R., Mirsalim M., Gharehpetian G. B., & Talebi H,"A. Reliability/cost-based multi-objective Pareto optimal design of stand-alone wind/PV/FC generation microgrid system", Energy, Vol.115, no.3, pp. 1022-1041, 2016.

[7] R .Hosseinalizadeh, H.Shakouri G,M. S. Amalnick, P.Taghipour, "Economic sizing of a hybrid (PV–WT–FC) renewable energy system (HRES) for stand-alone usages by an optimization-simulation model: case study of Iran", Renewable and Sustainable Energy Reviews, Vol.54, pp. 139-150, 2016.

[8] W.Ali, H.Farooq, A.U.Rehman, Q.Awais, M. Jamil, A.Noman, "Design Considerations of Stand-Alone Solar Photovoltaic Systems", International Conference on Computing, Electronic and Electrical Engineering (ICE Cube) IEEE, Vol.11, no.12, pp.1-6, 2018.

[9] Lewis Fraas, Larry Partain, "Solar Cells and their Applications", Second Edition, Wiley, 2010.

[10]Kouro S., Leon J. I, Vinnikov D, & Franquelo L. G"Grid-connected photovoltaic systems: An overview of recent research and emerging PV converter technology", IEEE Industrial Electronics Magazine, Vol.9, no.1, pp.47-61, 2015.

[11]Kumar, B. S., & Sudhakar, K,"Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India", Energy Reports, Vol.11, no.6, pp.184-192, 2015.

[12]Grandell, L., Lehtilä, A., Kivinen, M., Koljonen, T., Kihlman, S., & Lauri, L. S,"Role of critical metals in the future markets of clean energy technologies",Renewable Energy, Vol.95, no, 4, pp.53-62, 2016.

[13]Ferruzzi, G., Cervone, G., Delle Monache, L., Graditi, G., & Jacobone, F.,"Optimal bidding in a Day-Ahead energy market for Micro Grid under uncertainty in renewable energy production". Energy, Vol. 106, no.4, pp. 194-202, 2016.

[14]Bertolini, M., D'Alpaos, C., & Moretto, M.,"Do Smart Grids boost investments in domestic PV plants? Evidence from the Italian electricity market",Energy, Vol.149, no.5, pp.890-902, 2018.

[15]Mohanty, P., Muneer, T., Gago, E. J., & Kotak, Y,"Solar radiation fundamentals and PV system components",Solar Photovoltaic System Applications, Springer, Vol.23, no.5, pp. 17-47, 2016.

[16]Agarwal, R. K., Hussain, I., & Singh, B. ,"LMF-based control algorithm for single stage three-phase grid integrated solar PV system", IEEE Transactions on Sustainable Energy, Vol.7, no. 4, pp.1379-1387, 2016.

[17]Halabi, L. M., Mekhilef, S., Olatomiwa, L., & Hazelton, J.," Performance analysis of hybrid PV/diesel/battery system using HOMER: A case study Sabah, Malaysia", Energy Conversion and Management, Vol.144, no. 5, pp. 322-339, 2017.

[18]Kazem, H.; Chaichan, M ,"Status and future prospects of renewable energy in Iraq. Renew. Sustain", Energy Rev., Vol.16, no, 6, pp. 6007–6012, 2016.

[19]Iraqi ministry of electricity.Operating and Control Office https://www.moelc.gov.iq .

[20]Verma, A., & Singhal, S.,"Solar PV performance parameter and recommendation for optimization of performance in large scale grid connected solar PV plant—case study", Journal of Energy Power Sources, Vol. 2, no. 1, pp. 40-53, 2015.
[21]González, R., Lopez, J., Sanchis, P., & Marroyo, L.," Transformerless inverter for single-phase photovoltaic systems", IEEE Transactions on Power Electronics, Vol. 22, no. 2, pp. 693-713. 2007.
[22]Louis, J. R., Shanmugham, S., Gunasekar, K., Atla, N. R., & Murugesan, K.,"Effective utilisation and efficient maximum power extraction in partially shaded photovoltaic systems using minimum-distance-average-based clustering algorithm", IET Renewable Power Generation, Vol.10, no. 3, pp. 319-326, 2016.
[23]Quaschning, V., & Hanitsch, R.,"Numerical simulation of current-voltage characteristics of photovoltaic systems with shaded solar cells",Solar energy, Vol. 56, no. 6, pp. 513-520, 1996.
[24]Costa, S. C., Diniz, A. S. A., & Kazmerski, L. L," Dust and soiling issues and impacts relating to solar energy systems: Literature review update for 2012–2015", Renewable and Sustainable Energy Reviews, Vol.63, no, 1, pp.33-61, 2016.
[25]Loschi, H. J., Iano, Y., León, J., Moretti, A., Conte, F. D., & Braga, H., "A review on photovoltaic systems: mechanisms and methods for irradiation tracking and prediction", Smart Grid and Renewable Energy,Vol. 6, no. 07, pp. 165-187, 2015.
[26]Sungur C,"Multi-axes sun-tracking system with PLC control for photovoltaic panels in Turkey", Renew Energy, Vol. 34, no. 4, pp.111-124, 2005.

Biographies

Muhammed Salah Sadiq Alkafaji was born in Babylon-Iraq. He received his B.Sc. Degree in Electrical and electronic Engineering in 1995 from

Military Engineering Faculty –Iraq, and his M.Sc. Degree in Electronic and Communications Engineering, from University of Technology-Iraq-2003, and he received Ph.D. degree in Electronic/ microwave electronic circuits, from University POLITEHNICA of Bucharest-Romania-2016. His main research interests are in the area of renewable energy and power electronic. He has published many papers in international journals and conferences. Presently he is working as head of department of electrical power engineering technique in Technical College Al-Mussaib, Al-Furat Al-Awsat Technical University, Najaf, Iraq.

Ahmed Daud Mosheer was born in Iraq. He received his B.Sc. degree in Electrical Engineering from Babylon University, Babylon, Iraq, in 2006 and his M.Sc. degree from University Technical Malaysia of Melaka (UTeM), Malaysia in 2016. His main research interests are in the area of Renewable energy and Power Electronics. He has published 2 papers in international journals. Presently he is working as assistant lecturer in Technical College Al-Mussaib, Al-Furat Al-Awsat Technical University, Najaf, Iraq.

Sara Al-Waisawy was born in Babylon, Iraq. She received her Bachelor degree in Electrical Engineering from Babylon University, Iraq, in 2009 and her master degree in Electrical Engineering and computer science from Ohio

University, United States of America, in 2014. Her main research interests are Renewable energy, Electronic, Optoelectronics and Photonics area. She has 4 international publications. She is currently working as assistant Lecturer with Al-Mussaib Technical College, AL-Furat Al-Awsat Technical University, Najaf, Iraq.