Journal of Engineering and Sustainable Development
المجلد 22، العدد2 (الجزء-4)، آذار2018
ISSN 2520-0917
10.31272/jeasd.2018.2.58

LOAD SHARING REGULATION OF A GRID-CONNECTED SOLAR PHOTOVOLTAIC SYSTEM IN KARBALA CITY

*Dr. Kassim Abdulrezak Al-Anbarri[1], Dr. Ali Jafer Mahdi[2], Emad Abdulreza Hameed[3]

1) Assist Prof., Electrical Eng. Dept., College of Eng., Mustansiriyah University, Baghdad, Iraq.
2) Lecturer, Electrical and Electronic Eng. Dept., College of Eng., University of Karbala, Karbala, Iraq.
3) Research Scholar, Electrical Eng. Dept., Faculty of Eng., Mustansiriyah University, Baghdad, Iraq.

Abstract: Microgrid is an effective solution for increasing the reliability of power distribution system using renewable energy sources. In this research, a solar photovoltaic (PV) power system designed for extraction maximum power, i.e. 100kW (at standard conditions, 1000 W/m^2 and 25^{o}C) is simulated for grid utilities. For extraction maximum power, the duty ratio of a DC-DC converter is adjusting based on the specific value of maximum power point (MPP) voltage of the PV array. Thus, the DC voltage of the inverter side is kept constant to meet the grid specifications, e.g. 400V and 50Hz. The PV array is modelled by nonlinear equations which describe the effect of real irradiance levels (for Karbala city) on DC voltage. The PV power system is designed in an actual location in Karbala city for supplying a three-phase load, e.g. about 62 kW. Due to the fluctuations in solar irradiance, a load sharing between the PV power system and the grid is controlled. The load sharing is verified numerically by the Newton-Raphson method for a three-bus ring distribution system. Numerical and simulation results show the capability of the designed PV power system to share the load with grid over the year.

Keywords: *PV system, PV array, Photovoltaic cell, Inverter, Converter, PV panel, Back to back convertor, Irradiance level.*

تنظيم تقاسم الحمل لمنظومة طاقة شمسـية معشـقة بالشـبكة في مدينـة كربلاء

الخلاصة: تعتبر الشبكة المايكرويةحل فعال في زيادة وثوقية منظومة توزيع القدرة وذلك باستخدام مصادر الطاقة المتجددة.تم في هذا البحث تصميم منظومة قدرة شمسية لاستخلاص قدرة قصوى 100 كيلو واط (بالظروف القياسية 1000 واط/م^2 و 25 م^o) لاستخدامات الشبكة الكهربائية. ولاجل استخلاص قدرة قصوى يتم ضبط دورة العمل لمحول DC-DC يالاعتماد على(قيمة الفولتيةالملازمة لنقطة القدرة القصوى وبذلك يتم الحفاظ على فولتية مستمرة DC ثابتة في جهة المحول وذلك لمراعاة معايير الشبكة الكهربائية وهي 400 فولت و 50 هيرتز. تم نمذجة سلوك مصفوفة القدرة الشمسية بواسطة معادلة غير خطية والتي تصف تاثير مستويات الاشعاع الحقيقية (لمدينة كربلاء) على قيمة الفولتية المستمرة. تم تصميم منظومة القدرة الشمسية في موقع مقترح في مدينة كربلاء لتجهيز حمل ثلاثي الطور 62 كيلو واط. تمة السيطرة على تقاسم الحمل بين منظومة القدرة الشمسية والشيكة ويتضح من خلال نتائج برنامج المحاكات. تم التحقق رقميا من تقاسم الحمل باستخدام طريقة نيوتن رافسن لشبكة توزيع حلقية ذات ثلاث عقد. لقد اظهرت نتائج المحاكاة والحسابات الرقمية قابلية منظومة القدرة الشمسية المقترحة في تقاسم الحمل مع الشبكة خلال العام.

1.Introduction

Renewable energy resources technologies are widely used globally to generate electricity. They are considered as economic and environmentally friendly techniques. One of these common resources is the solar energy. Electricity-producing using

* alanbarri@uomustansiriyah.edu.iq

photovoltaic (PV) systems is an important substitute for conventional fossil fuels. It is a reliable technique and plays an important role in CO2 emissions mitigation [1]. Although the initial cost for installing a photovoltaic system is relatively high, the running cost is very low.

There are two main types of PV systems; stand-alone PV system and grid-connected PV system. In general, with photovoltaic grid-connected systems, the inverter transforms the output voltage of the DC from the solar panels into the AC system. The grid-connected PV system produces optimum and maximum capacity for PV arrays. The maximum power point tracker (MPPT) is usually linked to a DC-DC converter. To make the power of the PV panels is maximum; the controller is used to track the maximum power point (MPP) by transforming the variable voltage to the maximum DC voltage and then converting the fixed voltage to alternating by the inverter [2-3].

A control the load sharing between multiple parallel connected inverters have been the subject of several kinds of literature. Parallel connection of inverter module is a solution to increase reliability efficiency and redundancy of inverters in grid-connected type. The suitable load sharing among parallel inverters is a key point. The diffuse current among the inverters can greatly be decreasing the efficiency or even cause instability of the system. One proposed approach is to employs the virtual impedance concept has been given in [4]. Other methods based on adjusting the inverter droop gain to improve the accuracy of the load sharing [5].

Alizadeh et..al[6] use triple-droop-control strategy to share unbalance loads. A control strategy for the power sharing of the distributed generation systems was demonstrated in [7]. In [8] a strategy was developed to control the load sharing task by controlling the modulation index of the inverters.

In this paper, the design of a PV system to generate 100 kW using real irradiance levels in Karbala city is presented. A control of the load sharing between the PV system and the grid for various irradiance level is addressed. A PV system is designed to generate 100 kW using real irradiance levels in Karbala city. The structure of the paper is organized as follow: Section 2 explains the structure of grid-connected PV system. The solar irradiance data for Karbala city is analysis in section 3. Section 4 gives the design procedure of the proposed PV system. The simulation of the proposed system and discussion of the results is given in section 5. Section 6 presents the conclusion.

2. Solar Irradiance Levels of Karbala City

Karbala city is situated in the center of Iraq, located about 100 km southwest of Baghdad at 32.37˚ north latitude,44.02˚ east longitude. The solar irradiance of Karbala city strength ranged from (1000 to 400W/m2) and will rest on this special radiation in the Karbala city According to the aerial monitoring station that was installed at the University of Karbala, Faculty of Applied Medical Sciences, which has been monitor the solar irradiance for each day in the year. The data are analyzed and the rates of solar irradiance of each month of the years (2014-2016) are given in Table.1.

Table (1) lists the average Solar Irradiance in Karbala City for each month for the years 2014 ,2015 and 2016.

Month	*Average Solar Irradiance in Karbala City From 8:00 AM to 4:00 PM (W/m^2)*	
1	January	545.92
2	February	627.558
3	March	622.3935
4	April	692.372
5	MAY	666.605
6	June	687.95
7	July	661.5
8	August	672.663
9	September	621.246
10	October	552.226
11	November	412.5
12	December	484.209
	Average	604➔ 0.604

3. Design of the Proposed PV System

In the proposed system, a string topology is selected. The main features of this configuration are Low specific inverter cost, robust, high efficiency, and easy maintenance. In order to meet the load of (100 kW), the proposed configuration has three strings of the subsystem. Each subsystem consists of 7 branches in parallel. Each branch consists of 19 PV panels in series. The characteristic of the used PV panel is given in Table 2.

Table.2 Solar panel specifications used in the proposed design.

Parameters at standard condition(1000W/m^2 and 25 ̊C)	*Unit*	*Specifications*
Nominal power for a PV panel	W	266
Open circuit voltage ($V_{O.C}$)	V	38.6
Short circuit current ($I_{S.C}$)	A	9.03
Voltage at MPP (V_{MPPT})	V	31.6
Current at MPP (I_{MPPT})	A	8.44
Number of panels (for on branch) in series	panel	19
Number of panels (branch) in parallel each branch includes 19 panels	branch	7

3.1. *Derivation the Voltage Equation of the PV Panel*

For the PV cell shown in Fig. 1, The photovoltaic current, the current produced by a PV cell is given by equation 1 and 2, respectively [9]:

$$I_{pv} = N_p I_{ph} - N_p I_{sat}\left\{e^{\frac{q(V_{pv}+I_{pv}R_s)}{N_s AKT_a}}\right\} - 1 \qquad (1)$$

$$I_{ph} = [I_{sc} + K_i(T_{Ref} - T_a)]\,\frac{K}{1000} \qquad (2)$$

$$I_{sat} = [I_{rs}[\frac{T}{T_a}].^3\left\{e^{\frac{q(E_{g0})}{AK}(\frac{1}{T_a}-\frac{1}{T_{Ref}})}\right\} \qquad (3)$$

$$Irs = [\frac{I_{s.c}}{e^{\frac{q(E_{g0})}{AK}\left(\frac{1}{Ta}-\frac{1}{T_{Ref}}\right)}}] \quad (4)$$

$$R_s \leq 0.001\ \frac{V_{o.c}}{I_{s.c}} \quad (5)$$

$$R_p \geq 100\ \frac{V_{o.c}}{I_{s.c}} \quad (6)$$

Where: I_{sat} it's the saturation current; T_{Ref} temperature and T_a actual temperature; N_p no. of cell in parallel; N_S no. of cell series; A constant=1.5; K Boltzmann factor; q
its electron charge; E_{g0} its gap energy (1.1).
R_s it's a resistance in series with the diode cell.
R_p it's a resistance in parallel with the diode cell [12].

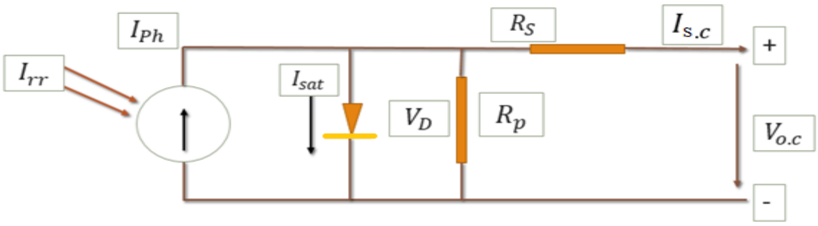

Fig.1 The equivalent circuit of the photovoltaic cell.

After mathematical manipulation of the above equations, the following equation is yielded:

$$V_{Panel} = C_1 l_n [1- C_2 (I_{Panel} I_{RR} – C_3 I_{RR})] – C_4 I_{Panel} I_{RR} \quad (7)$$

Where: V_{pv}, I_{pv}, C_1, C_2, C_3, C_4 are parameters have been derived from the panel coefficient; I_{RR} is the solar Irradiance. For the proposed PV array design in this paper, the values of C_1, C_2, C_3, and C_4 are 2.27, 2210433.245, 0.009027 and 0.04, respectively. Equation (7) is a nonlinear one. It describes the effect of irradiance on the PV array voltage. To find out the voltages generated from the solar panel directly, making the voltage Vdc fixed on the boost converter. Where the derivation of equation (7) is demonstrated in Appendix A.

By using MATLAB code, the results for PV array voltage for the two extreme values of the irradiance level is shown in Table (3).
Where irradiance equal to 1000W/m^2:
V_{Panel} =31.61Vand I_{Panel}= 8.44A➔P_{Panel} =266W
Where irradiance equals to400W/m^2:
V_{Panel} =29.7374V and I_{Panel}=3.376A➔P_{Panel} =100.394W
The purpose of deriving the formula for the voltage of the PV array is to obtain the value of the voltage (V p v) that acts as an input to the Boost converter. This process makes it easier to calculate the DC-voltage(V_{DC}) after the Boost converter. Also, the DC-Link capacitor can be calculated.

Where irradiance equal to 1000W/m^2 ➔I $_{RR}$= 1 P.U and for one string have 7 branches:
V_{PV}=N_SV $_{Panel}$=19*31.61=600.6V➔ P_{PV} =V_{PV} I_{PV} I_{RR}=600.6*8.44A*7*(1) =35.488kW
Where irradiance equal to400W/m^2 ➔I $_{RR}$=0.4 P. U and for one string have 7 branches:
V_{PV}=N_S V $_{Panel}$=19*29.73=564.88V➔P_{PV}=$V_{PV}I_{PV}I_{RR}$=564.8*(8.44A*0.4) *7=13.352kW
Where: N_S is the number of a panel series, I $_{RR}$ is the solar irradiance. From equation (7) and table 2 above, the number of panels in series 19 panels and number of branches in parallel 7 branches so, the table 3 illustrate PV array results at irradiance (400 and 1000) W/m^2 the effects of solar irradiance on generation have been taken into account, so that the voltages and current generated from the solar panel (PV panel) are affected by solar irradiance. Consequently, the power generated is affected by the change of solar irradiance.

3.2. *Boost Converter Module*

The objective of the maximum power point (MPP) tracking algorithm is to adjust the DC-DC control variable so that the PV array operates at the maximum power point. Achievement of MPP tracking can be realized by one of the following techniques:

Perturb and Observe (P And O), Incremental Conductance Technique (ICT), Constant Reference, Current-Based Maximum Power Point Tracker. In this paper, a Constant Reference method is used. It is common MPPT techniques that compare the PV array voltage (or current) with a constant reference voltage (or current), which corresponds to the PV voltage (or current) at the maximum power point, under specific atmospheric conditions. The resulting difference signal (error signal) is used to drive a power conditioner, which interfaces the PV array to the load. Although the implementation of this method is simple, the method itself is not very accurate because it does not consider the effects of temperature and irradiation variations in addition to the difficulty in choosing the optimum point as shown in fig. (2). [14].

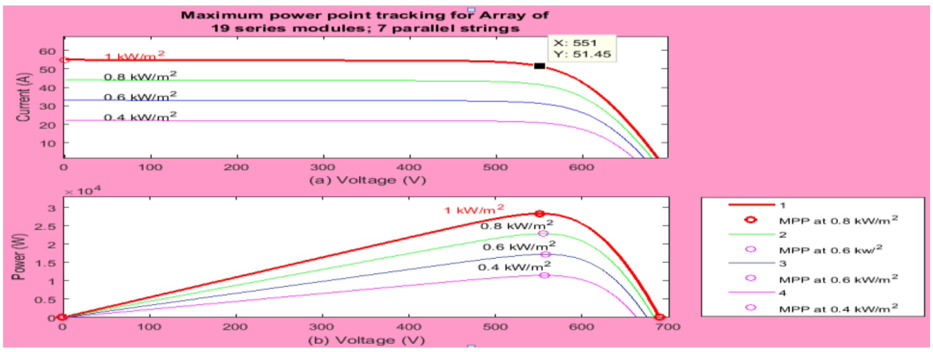

Fig. 2 Maximum power point tracking for Array 19 series and 7 parallel string (branches)at DC-Side.

In order to get an accurate MPP tracking, a boost converter may be used. A boost converter is a dc to dc voltage converter with an output dc voltage greater than input dc voltage. It is containing at least two semiconductors switches, the diode which acts as a freewheeling diode to ensure a path of the current during the off state of other switch and a transistor connecting in series of the source voltage). Filters made of capacitor and inductor is used to reduce the ripple in voltage and current respectively, is used at the output stage of the converter. The basic operating principle of the converter consists of the two distinct states. In on state, a switch is closed, resulting in an increase in the inductor current. In off state, a switch is open, resulting in a decrease in the inductor current The equation which describes the performance of boost converter is given by the following equations: [13]:

$$V_{dc} = \frac{V_{pv}}{1-D} \quad (8)$$

$$I_{dc} = (1-D)\, I_{pv} \quad (9)$$

Equation (8) is then divided by Equation (9) to obtain:

$$R_{in} = (1-D).^2\, R_o \quad (10)$$

Where: D is duty cycle ratio for boost converter and [t_{on}=$D.*T_s$, t_{off}= (1- D) T_s].

By using MATLAB code, the results for PV array and DC voltage for Boost converter voltage is given in Table (3):

Table 3 The results for array and boost converter at irradiance (400&1000) W/m^2. (see Fig. 3).

Parameters		*Unit*	*Specification*	
Irradiance	I_{RR}	W/m^2	400	1000
PV array Voltage	V_{PV}	V	564.88	600.4
PV array Current	I_{PV}	A	23.6	59.08
PV array Power	p_{PV}	kW	13.35	35.5
Duty ratio	D	-	0.273	0.2274
DC-Voltage	V_{DC}	V	777	777
DC-Current	I_{DC}	A	17.18	45.652
DC-Power	V_{DC}	kW	13.352	35.488

The results indicate that the PV array voltages (VPV) before the boost converter are variable due to solar irradiance levels change. To fix it, must be using the maximum power point tracking (MPPT) technique for the boost converter by adjust the duty ratio(D). The DC-voltage is adjusted at (777V). The results show in fig. (3).

3.3. *Three Phase PWM Inverter*

In this research, a three-phase voltage source pulse width modulation PWM inverter is used. The performance of the inverter is described by the following equation as shown in fig. (4). After three-phase inverters connect LCL-Filter to reducing the harmonics from the inverter current where injected into the grid. We did not study the subject of the filter in this research and will be studding it in other research's [14]:

$$V_{LL,\,RMS} = 0.6124\ m\ V_{dc} \quad (11)$$

Where: m is modulation index,{m=V_{Peek} control $_{Signal}$ /$V_{Peek\ Triangle\ Signal}$}

From above description, the proposed PV system can be configurated as below, also, have been taken into account the efficiency for boost converter and three phase inverters as shown below:

Total power for PV system has three strings at 1000W/m^2.

$P_{PV,\ System}$ =35.488*3=106.464kW

The efficiency of the Boost converter and inverters are= 0.98*0.97=0.9506.

$P_{PV,\ System}$ =106.464kW*0.9506=101.204kW

Total power for PV system has three strings at 400W/m^2

$P_{PV,\ System}$ =13.352*3*0.9506=38.077kW.

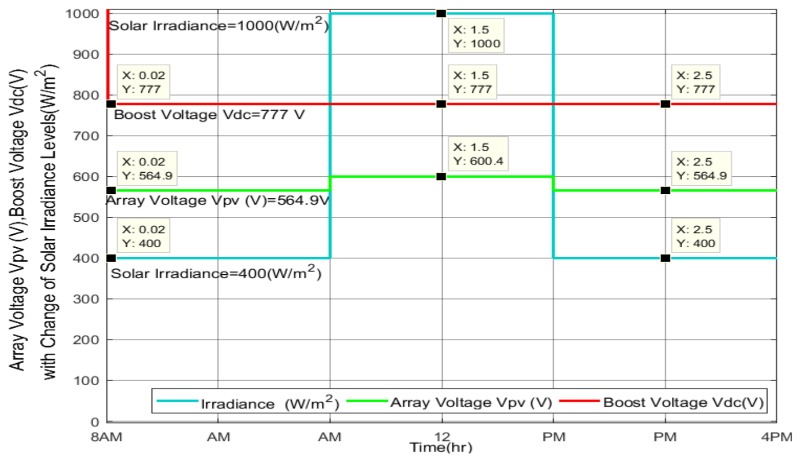

Fig. (3). PV Array voltage(Green), Boost Converter voltage(red)for change irradiance levels(blue) from (1000 to 400) W/m^2.

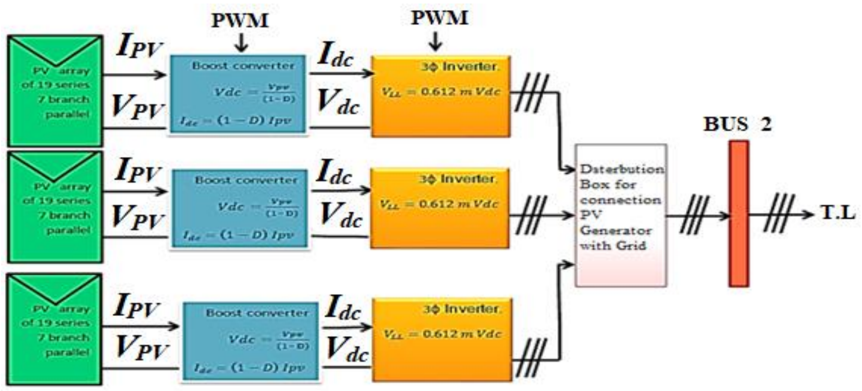

Fig. 4 The proposed PV system.

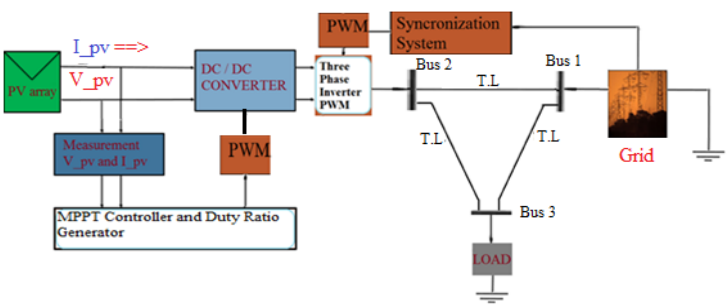

Fig.5 Single line diagram of the studied grid-connected PV System.

4. Simulation of the Designed PV System

The system shown in Fig.5 is represented by three buses in the MATLAB program where the PV system is connected to the Bus 2 and a load connected to Bus 3. The performance of this system as assessed by building an appropriate Simulink model as shown in Fig.6. A typical selected day for each season is considered for detail simulation. The results obtained are shown in Table 5. It is clear from the results obtained that the sharing of the load power between the PV system and the grid is varied according to the irradiance variations for each time of the selected days. The time domain behavior of the daily solar irradiance, the duty ratio D, and the phase current supplied by PV system are given in Figures (7-8-9). Fig.10.Illustrate the results in Table (3) to show PV array, Boost converter and inverter Voltage with MPPT results for the system. Fig.11 shows the time domain behavior of the PV power, grid power, and the load power curve. The importance of the proposed regulator is clear from Fig.11, where the regulator is capable of maintaining a constant level AC voltage from the PV system.

Table.5. simulation results for 4 seasons in the year, one day for each season.

Seasons	*Day*	*Time*		*PV Generation kW*	*Grid Generation kW*	*Grid Bus Control*
Spring	24/3/2016	8:00am	3:30pm	96.89	0	Off
		3:30pm	4:00pm	58.71	8.448	On
Summer	1/7/2016	8:30am	9:00am	58.71	4.346	On
		9:00am	3:30pm	96.89	0	Off
		3:30pm	4:00pm	56.18	5.821	On
Autumn	3/10/2016	8:00am	9:00am	54.08	7.923	On
		9:30am	2:00pm	96.89	0	Off
		2:00pm	4:00pm	50.93	11.07	On
Winter	31/12/2016	8 am	9am	23.92	38.08	On
		9	10	38.46	27.03	On
		10	11	45.71	16.29	On
		11	1pm	52.82	9.6	On
		1pm	2pm	47.69	14.31	On
		2pm	3pm	34.25	27.75	On
		3pm	4pm	20.23	41.77	On

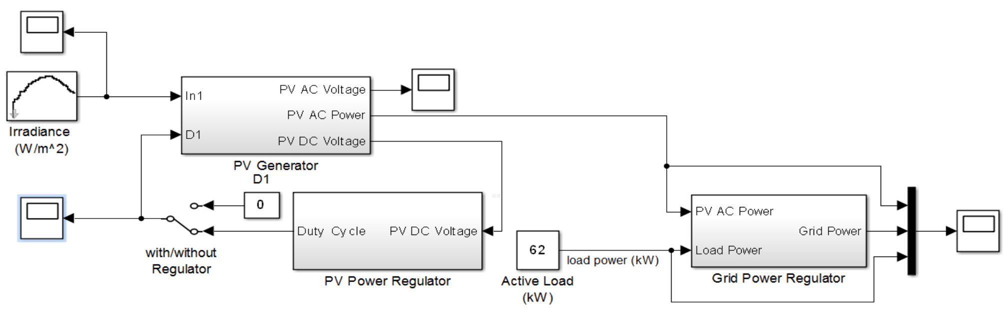

Fig .6. Simulink model of a grid-connected PV power plant under real irradiance in Karbala city. based on Embedded MATLAB func. F

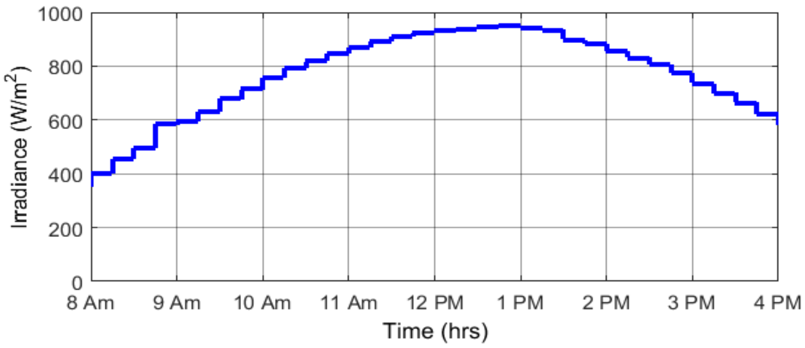

Fig. 7. Daily solar irradiance levels for Karbala city at 01/07/2016.

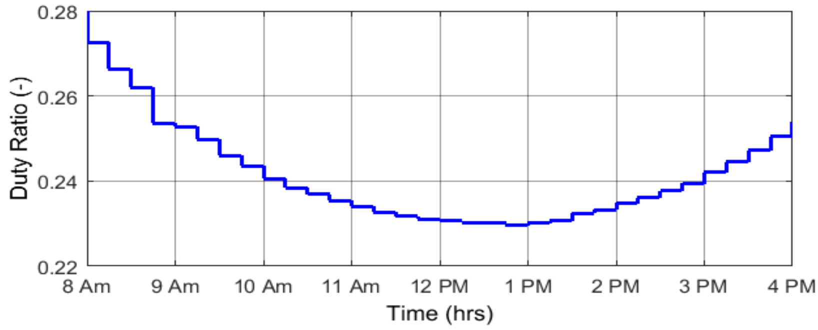

Fig. 8. Controlling of duty ratio of the boost converter using a MPPT algorithm.

According to the equation (8):
At irradiance 1000w/m^2 V_{PV} = 600.4Vand V_{DC} =777V ➔D= 0.22728≈0.2273.
At irradiance 400w/m^2 V_{PV} = 564.88Vand V_{DC} =777V ➔D= 0.27299≈0.273.

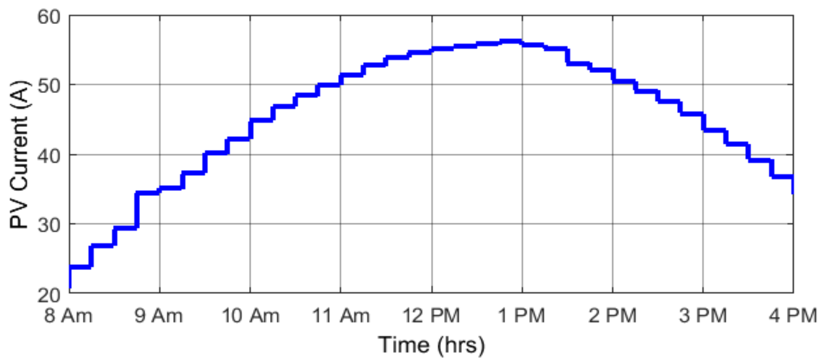

Fig. (9-a). The current supplied by the PV power plant.

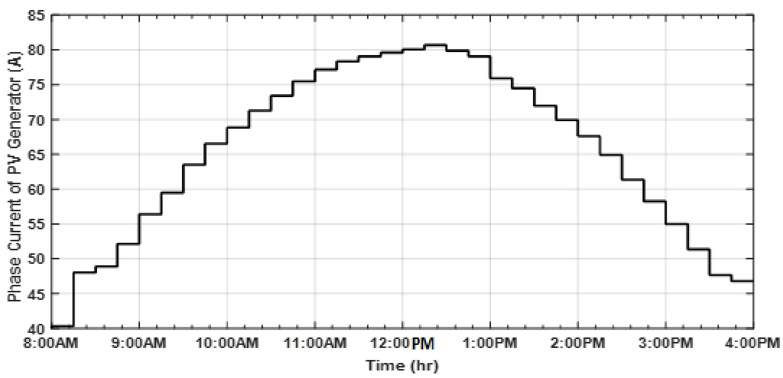

Fig. (9-b). phase current supplied by PV power plant.

From the calculations below, note the effect of solar irradiance on solar generator (PV Generator).

For one string P_{AC} (at 1000 W/m^2)

$P_{AC} = I_{PV}\ V_{L\text{-}L}$ p. f = (80A) *(1.0166P. U*400V)*(0.99) = 32.205kW. For three strings ➔P_{AC} = 3* 32.205= 96.617kW.

For one string P_{AC} (at 400 W/m^2):

$P_{AC}= I_{PV}\ V_{L\text{-}L}$ p. f = (46.52A) *(1.0166 P. U*400V) *(0.99) =18.727kW. For three strings ➔P_{AC} =3*18.727kW=56.183kW.

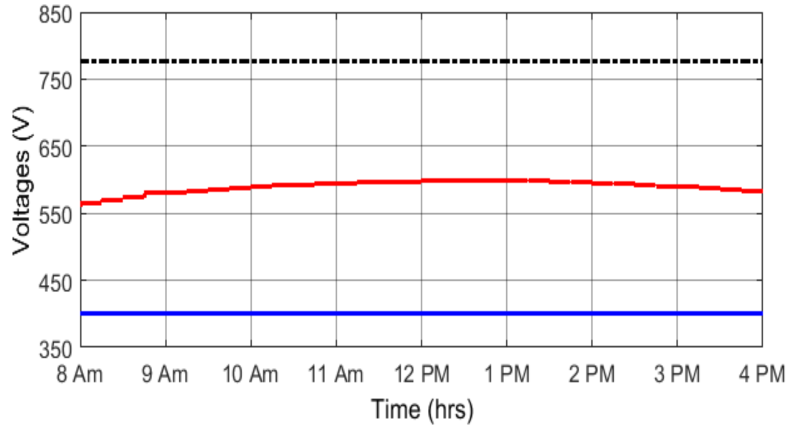

Fig.(10-a). Voltage values at PV(red), boost converter(black) and Inverter(blue).

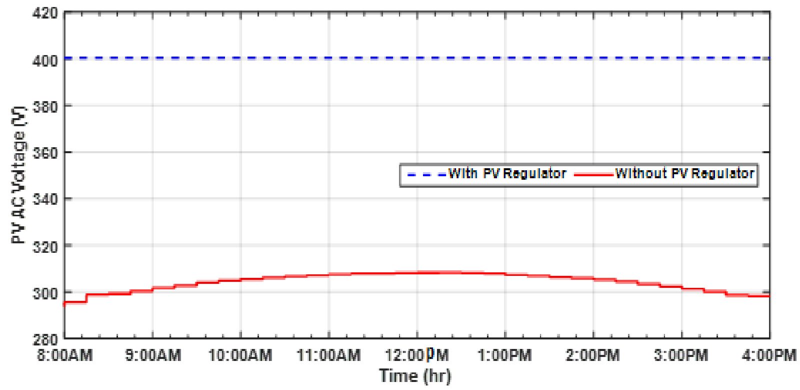

Fig. (10-b). AC voltage of plant with (blue)and without(red) regulator.

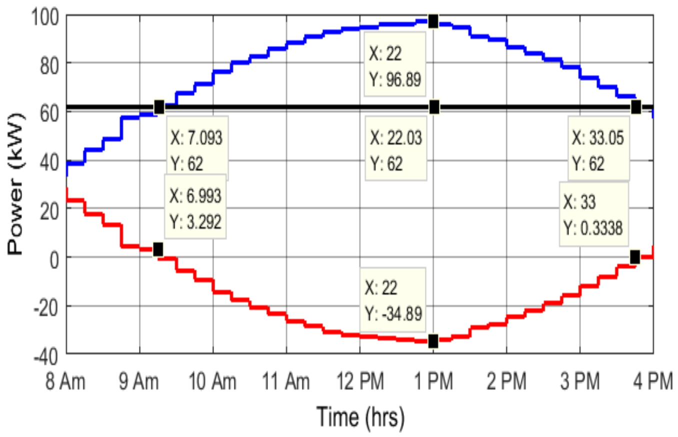

Fig. 11. Scheme of power generation, PV (blue), load (black) and grid (red).

That's mean, the load didn't take its power from the grid from 9:00 hr. to the 3:30 hr.

4.1. *Verification of the Load Sharing*

The results obtained by the simulation is verified by making a load flow calculation using Newton-Raphson method [15]. For the three-bus system shown in Fig. (12), the bus connected to the grid is considered as a slack bus. The parameters of the feeders connected the buses are shown in the same figure. Note that most of the research focused on a force of load in transmission lines accounts and the presence of stationary generators، but at the present we discussed the turbulent solar power plant on grid distribution because continuous change in solar Irradiance and changing load so we need to keep track of the greatest generation of electric power points and a force of load every 15 minutes account.

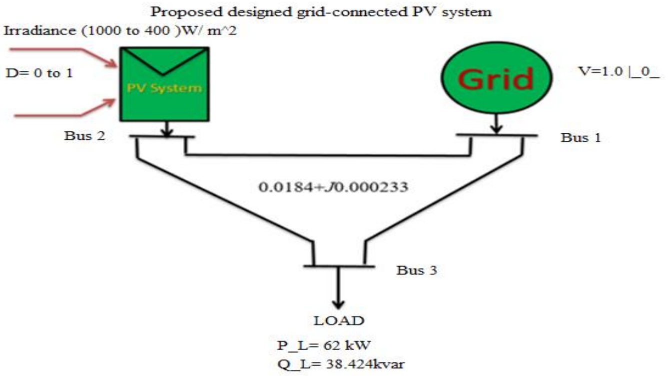

Fig. (12) Proposed designed grid-connected PV system.

After applying equations to Newton Raphson method were obtained the following results: Chose $\boldsymbol{S}_{Base}$=100 KVA, $\boldsymbol{V}_{Base}$ = 400V.

Table (6) Analysis of the Newton Raphson Method for PV System connected with grid according to the Solar Radiation of the Holy Karbala City by One Day of the Month for each season.

Season	*Day*	*TIME*	*Active Power of PV (P.U)* P_{PV}	*Reactive Power of PV (P.U)* Q_{PV}	*Voltage on BUS 2 (P.U)* $V_2 \angle \delta_2$	*Voltage on BUS 3 (P.U)* $V_3 \angle \delta_3$	*Active Power of Grid (P.U)* P_{Grid}	*Reactive Power of Grid (P.U)* Q_{Grid}
summer	1/7/2016	8:00am-3:30	0.9689	0.13802	$1.0166\angle +0.45264$	$0.988\angle -0.6417$	+ 0.3489	- 0.2462
		3:30 pm_4 pm	0.5618	0.0801	$1.0189\angle +1.129$	$0.9969\angle +0.4698$	- 0.0582	- 0.3042
winter	31/12/2016	8am_9 am	0.2392	0.0341	$1.0196\angle +1.66$	$0.997\angle +1.352$	- 0.3808	- 0.3502
		9am_10 am	0.3846	0.0548	$1.0197\angle +1.42$	$0.9993\angle +0.95$	- 0.2354	- 0.3294

Autumn	3/10/2016	11am _12 pm	0.5282	0.0753	1.019∟ +1.18	0.997∟ +0.56	- 0.0918	- 0.309
		3pm_ 4 pm	0.2023	0.0288	1.0197∟ +1.719	0.99∟ +1.45	- 0.4177	- 0.3554
		8am – 9am	0.5408	0.0883	1.019∟ +1.163	0.9973∟ +0.527	- 0.792	- 0.3072
		9am _2 pm	0.9689	0.1381	1.0169∟ +0.452	0.989∟ - 0.642	+ 0.3489	- 0.2462
		2pm _4 pm	0.5093	0.0726	1.019∟ +1.214	0.998∟ + 0.613	+0.1107	- 0.3117
spring	24/3/2016	8am_ 3.30 pm	0.9689	0.2850599	1.017∟ +0.452	0.98882∟ - 0.642	+0.3489	- 0.2462
		3:30p m_4 pm	0.5871	0.0837	1.0187∟ +1.237	0.9964∟ +0.401	+ 0.0329	- 0.3006

5. Discussion

In order to achieve the validity of the ideal power flow it must be in the following for:

1. $V_1 > V_2 > V_3$
2. $\delta_3 > \delta_3$ and δ_0=0 due to it reference.

From the above solution of the N.R. method note the following points:

1- If the generation of the PV array (S_{PV}) was greater than the required power of load(S_L), the angle of the bus2(δ_2) was positive and greater than the negative angle of bus3(δ_3). That's mean the load flow from bus2 to bus3 indirectly as shown in fig. (13) below:

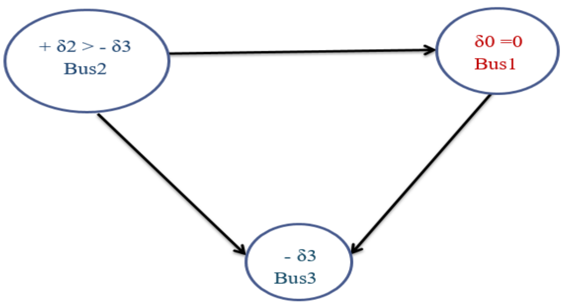

Fig. (13) Load flow when the power generated from PV sys. greater than the power of load.

2- If the generation of the PV system is less than the load power, the angles of the first and second bus (1&2) are negative, but the angle of the second bus2 is greater, and the flow of the power of the PV sys to the load is not direct from the second bus2 to the third bus3. but from the second bus2 to the first bus1, then to the third bus3, as shown in fig. (14).

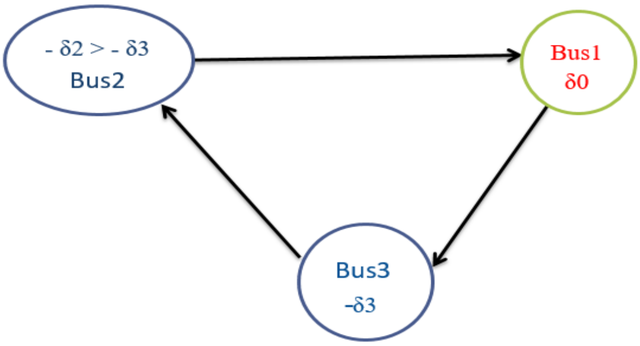

Fig. (14) Load flow when the power generated from PV sys. less than the power of load

6. Conclusions

After taking the solar irradiance data of the holy Karbala city through the air monitoring station designed in the University of Karbala college of Applied Medical Sciences. The tables are recorded using Excel program, and the annual rate for solar irradiance was 604W/m^2.

It was found that the solar irradiance at good levels at all periods of the year and is considered good level compared with other results of solar irradiance in the world, such as Europe, where the level of solar radiation is up to 400W/m^2 and Can be exploited a solar irradiance energy to produce an efficient electrical energy and environmentally friendly.

A PV grid connected system based on a real irradiance data of Karbala city has been designed. The system is designed to obtain maximum power point tracking by readjusting the duty ratio of the inverter. A fair load sharing between the PV system and the grid is maintained at the point of common coupling. The performance of the proposed system is assessed by simulation and the power flow analyses in the feeders are verified by applying the Newton-Raphson method to evaluate the roots of the active and reactive power (P, Q) to use it as a reference in the controller. The solar energy system should be studied through several aspects in order to be integrated available in order for the system to be integrated into the work under the network. such as power flow analysis and the basic components that transform the irradiance into electrical energy (power electronics devices) and study the control methods (to achieve the synchronization between PV systems and grid).

Acknowledgement

The authors would like to thank Faculty of Engineering Mustansiriayah University (www.uomustansiriyah.edu.iq) Baghdad-Iraq for its support in the present work.

7. References

1. Raza, M.Q., Nadarjah, M. and Ekanayake C (2016). *"Review on recent advances in PV output power forecast"*. Solar Energy, Vol. 136, pp.125-144.
2. Eltawil, M. A. and Zhao, Z. (2010). *"Grid-connected photovoltaic power system: technical and potential problems- A review"*. Renewable and Sustainable Energy, Vol. 14, No.1, pp.112-129.
3. Kouro, S., Leon, J.I., Vinnikov,D. and Franguelo, L.G. (2012). *"Grid- connected photovoltaic systems: An overview of recent research and emerging converter technology"*. IEEE Industrial Electronics Magazine, Vol. 9, Issue1, pp.47-61.

4. Yao, W., Chen, M., Matas,J. (2011). *"Design of the droop control method for parallel inverters considering the impact of the complex impedance on the power sharing*". IEEE Trans. On Indus. Electronics, Vol. 58, Issue2, pp.576-588.
5. Majumder,R. Chandhuri,B., and Ghosh.,A.(2010). *Improvement of stability and load sharing in an autonomus microgrids using supplementary droop control loop*. IEEE Transac. On Power System, Vol. 25, Issue2, pp.796-808.
6. Alizadeh,E. Motie Pirjandi,A., and Hamzeh.,M.(2017). *Decentralized power sharing control strategy in low voltage microgrids under unbalanced load conditions.* IET Proc. On Gen. Transm. & Distr., Vol. 11, Issue7, pp.1617-1623.
7. Marwali.M.N. and Jin-Woo,J.K. (2004). *A control of distributed generation systems. Part II: load sharing control.* IEEE Transac. On Power Electronics, Vol. 19, Issue6, pp.1551-1561.
8. Quamruzzaman,M. and Mujiburrahman,K. (2008). *Development of control strategy for load sharing in grid-connected PV power system.* 5th International conference on Electrical & Computer Enjineering, Dakah, Bengladesh.
9. M. Azzouzi, D. Popescu, and M. Bouchahdane ” Modeling of Electrical Characteristics of Photovoltaic Cell Considering Single-Diode Model” Journal of Clean Energy Technologies, Vol. 4, No. 6, November 2016, PP 414,415 From equation 1 to equation 6.
10. Rajapakse,A. , Muthumuni,D. and Perera,N.(2009). *Grid integration of renewable energy systems, in Renewable Energy*, pp. 109-131.
11. Mahdi,A.J.(2017). D*esign and performance analysis of an on _ grid photovoltaic power system under Iraqi solar circumstances*. journal of engineering and sustainable development, VOL (21), NO. 2, March 2017, page (103-105).
12. Yatimi,H. E., and Aroudam et M. Louzazni,” Modeling and Simulation of photovoltaic Module using MATLAB/SIMULINK”,Université Abdelmalek Essaadi, Faculté des Sciences, Laboratoire de Modulization et Simulation de System Mécaniques Tétouan, Maroc,, DOI: 10.1051/ C Owned by the authors, published by EDP Sciences, 2014 , / 0 2014) 2014110 01 11MATEC Web of Conferences matecconf 01 (3 3 8 8).
13. Turkey K.H. “Application of quasi-Z-source inverter in photovoltaic grid-connected system “, journal of engineering and sustainable development, VOL (21), NO. 2, March 2017, pag (103,104,105).
14. Muhammad H. Rashid,"ELECTRONICS HANDBOOK DEVICES, CIRCUITS, AND APPLICATIONS. Elsevier, Third Edition, 2011.Muhammad H. Rashid, Ph.D., Fellow IET (UK), Fellow IEEE (USA) Professor Electrical and Computer Engineering University of West Florida 11000 University Parkway Pensacola, FL 32514-5754, U.S.A. Phone: 850-474-2976 e-mail: mrashid@uwf.edu.
15. Al-Anbarri, K. and Mageed, W.S. (2012). *A reliable load flow methodfor radial distribution system.* Journal of Engineering and Sustainable Development, Vol. 15, Issue2, pp.13-25.