



## Solar Photovoltaic Direct-Driven Air Conditioning System Performance in Iraq

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### KEY WORDS

Photovoltaic, Direct Driven, Dc Air Conditioner, Test

### ABSTRACT

*The present research paper is on photovoltaic air conditioning system using the direct drive method. The experimental system setup arranged in Iraq at Al-taje site at longitude 44.34 and latitude 33.432 during the summer season inside a room. The proposed off-grid system consists of an array of photovoltaic, battery used to store power, PWM (pulse width modulation) charge controller, and DC air cooler. During the examination of the system, proven success of this new type (dc air conditioner) of client urges Iraq warm conditions as an alternative type used instead of the prevailing types of air conditioners (AC air conditioner) in Iraq which consume large amounts of electrical energy and gets a cooling system for the room full working on solar energy.*

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## 1. Introduction

Air conditioner system is one of the largest appliances that consume power for a household. It is the mean of transferring energy from space-air to defined space, to achieve a lower temperature of that defined space compared to the natural surrounding environment. Air conditioning is intended to enhance air quality; temperature as well as humidity for a defined space, to offer a healthy and suitable environment. This makes it the reason for high energy consumption in buildings. Furthermore, in the past years, the outdoor temperature during the summer season is highly elevated due to global warming. The cooling systems' ability ordinarily is not designed to handle these changes which leads to utilizing the peak capacity for cooling systems output to meet the harsh environmental challenges. This would create a deficiency in cooling capacity, a sharp increase in electrical consumption, as well as high system maintenance cost. The scarcity of conventional electrical energy sources and costs encouraged researchers to examine the air conditioner general functional design and applications and acquiring new methods and processes to achieve suitable conditions in buildings by ordinary means. During the summer season in Iraq, the weather condition

is very hot and dry, while the outdoor temperature sometimes surpasses 50 °C [1, 2]. Iraq experiences insufficiency in production in electrical power and several other challenges to meet the increasing demand for electrical power. In Iraq, air conditioners are popularly utilized in commercial and as well as residential buildings. Thus, electrical power consumption decreasing is believed as an imperative factor while designing air conditioner systems, which can be accomplished by enhancing the system's efficiency. Air conditioner system performance that operates at high ambient temperatures can be enhanced by decreasing the air conditioner compressor power consumption [3]. By utilizing solar energy, which has the advantages of inexhaustible, pollution free, along with small regional limitation. Solar energy becomes the most significant replacement of nonrenewable energy sources. Since 1990, the technology of solar photovoltaic started to evolve fast, by the continuous development of photovoltaic performance and the continuous prices drop of solar modules, the technology of solar photovoltaic is growing to be more widespread [4-5]. Air conditioners with PV direct driven method is a collection of solar power generation technology and new cooling technologies that can effectively transform solar power to air conditioner compressor during operation. Furthermore, the excess power is used to charge the battery for night time or during cloudy days, therefore contribute considerably by saving energy cost used from the grid. Thus, for power cost saving also emission reduction, solar powered air conditioners have incomparable benefits when compared to traditional air conditioners, Y. Li et al. This study shows the experimental outcomes of air conditioner system utilizing solar photovoltaic, which investigated the system performance for cooling and heating in hot summer season and cold winter season for Shanghai, China. The study investigated four modes which are; heating in winter and cooling in summer for both night time and day time. The experimental system includes PV modules, charge controller, power inverter, lead acid battery bank, and a commercial split type variable frequency air conditioner. The system could be switched to the power grid if the electricity from the PV module and battery bank is not sufficient to run the air conditioner. The study deduced that the solar air conditioner system could steadily work to meet the load for cooling and heating in various peak times in the hot summer season or cold winter season in China or for other areas around the world with alike weather conditions. The PV/AC system is vulnerable to local weather conditions, the system can accomplish higher COP solar. The selection of variable frequency air conditioner is proper for the standalone systems. It can attain a steady room temperature [6]. Bin-Juine Huang et al studied the design of directly driven solar air conditioning systems with standalone solar modules, completely off grid system. Six solar air conditioners prototypes with various sizes of PV panels and air conditioners built and examined outdoor to experimentally study the working possibilities of air conditioning at different solar radiance. The system made of PV modules, air conditioner, battery bank, capacitor, PWM charge controller, and power inverter along with battery voltage recorder and radiance data recording. The battery bank is used to balance the load between the solar panels and air conditioner. Consequently, concluded that the air conditioner may experience power loss which could be described via two variables; instantaneous operation probability(OPB) along with daily total runtime fraction (RF), No obvious association between RF and OPB with t<sub>bp</sub> (time to completely charge the battery at peak PV power production) and T.B.L(the battery maximum service time) is determined[7]. Farkad et al made air conditioning adsorption chiller combined with a residential solar collector which was examined under Baghdad, Iraq weather conditions. The system consists of two residential solar evacuated tube collectors and two water tanks used for storage under Iraq climatic conditions. To reach the optimal system performance, it is clear that the COP reduced with the increase of hot water flow velocity [8]. We can notice that PV air conditioner can play an important role in saving energy cost and decrease room power consumption, as well as environment friendly. This research designed a full PV solar system for room and record the power generated by photovoltaic, current, voltage and indoor temperature throughout the day in the summer season. which evaluated by analyzing the energy conversion in the system and air conditioner cooling influence on the run time of PV air conditioning performance.

## 2. Experimental Work

### *1. System Description*

PV direct driven air conditioner system essentially combines; battery bank, PV array, PWM (pulse width modulation) charge controller, and DC air conditioner, which has a DCBL compressor. See Figure 1, PV array firstly generates electricity to meet air conditioning demand, the excess produced

power stored in the battery bank to compensate for short in PV production during its inability of solar photovoltaic panels to produce enough energy to working dc air conditioner.

## II. Photovoltaic System

Cooling load means the volume of heat that requires to be removed from the space per unit time. This is required for engineering air conditioning systems. The purpose of cold load requires to take into account the following four features; space area, number of people, type of activities in the space, and additional cooling devices. Along with local climate parameters and buildings purposes, the primary calculation of the room load indicator is around 80 W/m<sup>2</sup>. Solar panels transform sunlight instantly into electrical power through the photoelectric effect or photochemical effect. The PV array made of interconnected photovoltaic panels in series; PV panels essentially split into monocrystalline and polycrystalline silicon photovoltaic cells. In the presented study monocrystalline silicon cell is utilized. PV modules made in Iraq at Al - Mansour / Al Zawra facility, which have technical parameters as shown in Table 1.

**Table 1: Test results of deep beam specimens**

Table 1:		Table 1: Parameters	
parameters	Value	parameters	Value
pmax	183.92W	pmax	183.92W
voc	45.38v	voc	45.38v
vmp	36.73v	vmp	36.73v

PV power essentially needs to meet air conditioning load, then the excess energy stored in the battery bank to assure the normal operation of the air conditioner even when the weather is cloudy or night time. Battery bank capacity is usually considered based on the maintenance of the system for a specific period needed by power and battery bank itself to define the discharge depth upper limit. Inadequate capacity could not meet the air conditioning load demands, while bigger capacity will raise the investment costs, which will result in resources waste [9]. The battery size can be calculated based on the following formula (1).

$$B = pd / (1 - \text{SOC}_{\min}) \quad (1)$$

B equal designed battery capacity.

P equal daily power consumption of the air conditioning load.

d equal days of max power supply.

SOC<sub>min</sub> equal upper limit of the battery discharge depth.

The equation of the nominal electrical efficiency (n) of a PV panel could be described as [10].

$$N = P_{pv} / G * A_t \quad (2)$$

N is nominal electrical efficiency.

P<sub>pv</sub> is photovoltaic output power.

G is the solar radiation.

## III. System Test

To study PV air conditioning cooling performance during the summer season, based on the above design, PV air conditioning system installed in a room which is 12 m<sup>2</sup> at Altaje site. The proposed system utilizes eight panels, battery bank of capacity 75Ah, as demonstrated in Figure 2 as well as Figure 3. On 23/6/2019, the above system tested from 11:30 am to 17:00 pm, the test time set in this manner to examine the batteries performance when the battery charging before one day with charging before the test at the same day of test, the test parameter; solar radiation intensity, outdoor and indoor

temperatures, PV power production, along with power consumption of the air conditioner, These parameters measured using solar radiation recorder, temperatures recorder, current and voltage Electric current meter (dc) and voltmeter (dc).

### 3. Results and Discussion

#### I. BATTERY

The battery bank charge level for each battery was at full which (13.5- 13.8) volt as mention in the name blat of the four batteries, this was before starting the test before about some minute of (11:30 am). The state of charge for the each battery was taken every 15 minutes to obtain accurate observation of the batteries behavior, which is more precise way than checking the state of charge every 30 minutes. The state of charge of the batteries shows a noticeable drop and high at 11:45 am because the load in start of test is depending fully on the battery so the batteries was loaded with the dc air conditioner without the assistance of solar panel, and the voltage of four batteries continue to drop till 3:00 pm because the power production of the solar array was not sufficient to support the DC air conditioner system, which lead to the depends of the system on the battery bank with the power of solar panel. At 3:15 pm, a noticeable increase in the battery bank charge for the four batteries, this rise in battery voltage that does not indicate batteries charging because the solar panel was not high from the power of air condition, so this strange behavior in batteries indicates a sudden drop in power of air conditioner as it happen in the start of test the voltage of batteries is noticeable drop and high because of the sudden increase of power of air conditioner, from 15:45 until the end of test the amount of voltage of batteries is returned to the normal value because the drop in the power of air conditioner was normal and not high at 17:00 pm the batteries arrive to nearly to 50% so the test is stopped, as show in Figure 4.

#### II. Solar Array

The daily sunlight hours about 12.6 hours in June [1]. At the beginning of the test 11:30 am PV array output 981 watt which is less than the needed power to run the DC air conditioner as show in Fig 5. The output power increases little at 11:45am, the output power increased to reach 985 watt, however it's not sufficient to run the air conditioner without depending on the battery bank, this is due to the impact of heat on solar array power generation efficiency.

At 12:15 pm the output power of PV array reached its maximum which is 996 watt, due to the increase in solar irradiance which is considered the maximum irradiance for Iraq at the testing month. From 12:30 to 1:30 pm, the amount of power of solar panel is convergent and constant with high amount without drop this is because of the temperature of solar panel drop in this time because the wind. After this time, it is gradually lowered to reach 187 watt at 5:00 pm because of reduction in solar irradiance (sunset).

#### III. DC 48V air-conditioned

This type of air conditioner is control on the speed of dc brushless compressor so its power is changing according to the temperature of the room, as show in Fig. 6. The amount of power of air conditioner starts with small amount at 11:30 am and increases to high amount at 11:45am. This increase is continuous nearly linear shape, the maximum value of consume power is measured at 13:30 pm this high level of energy continues until 15:00 pm because the temperature of room was high after 15:00 pm, the amount of dc air conditioner begins to drop and because the decrease in room temperature nearly the time of end the test the temperature of room arrive nearly the temperature so the power consume from the air conditioner arrive at the minimum value of power in the day of test.

#### V. Solar Radiation

Solar radiation depends on the location and weather, in Iraq on 23 June 2019 the solar radiation at 11:30 am was 903 W/m<sup>2</sup>, and it increase to arrive to the maximum recorded reading at 12:00 pm as shown in Table 2, after that the radiation decreased to reach the lowest point at the end of the test which is 119.2 W/m<sup>2</sup>.

**Table 2: Solar irradiation vs. time**

Time	Irradiation	Time	Irradiation
11:30	903	11:30	903
12:00	916.9	12:00	916.9
12:30	906.6	12:30	906.6
13:00	800.3	13:00	800.3

## VI. Temperature reading for indoor, outdoor and panels

### 1-Room temperature

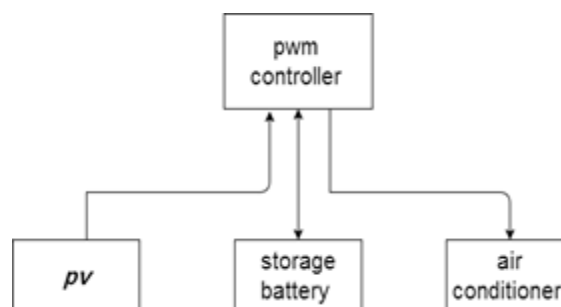
In the start of test, the room temperature start with 30.10 °C as show in the Table 3 and it drop little but continuous until 15:45 pm arrive to 20.9 °C . It is continues to drop until the end of test it is arrive to 20.0 °C . The room temperature on the first test day did not reach to the set temperature of the air conditioner(16.0 °C ), because the test started at 11:30 am, and the room temperature already hot which need more time for the air conditioner to reach the set point because the room is not completely isolated and the temperature is measurement of temperature was in the front side of room that is exposed to the sun and open and close the door due to exit and entry of government department employees of the room have more influence in this part and taking into account the design of the room containing the room on the window of the front part with due to improper insulation of the room. The required temperature was not reached on this day but an acceptable temperature level was reached for the comfort of the persons in the room.

### 2-Solar panel temperature

To get more accurate reading for the PV array temperature, five points have been considered to measure the PV array temperature and the average for these point the solar panel in the begining of test to start with 52.40 °C, as show Table 3. It is continuous to increase because the increase in the environment temperature until arrive to the maximum value at 55.6 °C at 12:15 pm. Although the output temperature was not the maximum at this time this is because the effect of solar radiation was at the maximum value between 12:00 pm to 12:30 pm. After this time, the temperature of solar panel drops because the wind effect on the panel from 12:30 pm to 12:45 pm from 13:00 pm to 13:15 pm, the increase in solar panel because the increase in the environment temperature that arrive to the maximum value of environment temperature from 13:30 pm to the end of test the temperature of the solar panel drop because the drop in environment temperature. The overall temperature of the panels on this day is a high level of heat that leads to losses in solar panels.

### 3-Output temperature

Because of the hot weather of Iraq as show in Table 3, the temperature of environment starts with 38 °C at 11:30 am as show and it is continuous to increase until arrive to the maximum value at 13:00 pm and after this time it drops until the end of test as it arrives to 40 °C .



**Figure 1: Air conditioning system with PV panels direct current drives.**

**Table 3: The measured temperature**

Time	Room°C	Ambient °C	PV array°C
11:30	30.1	38.0	52.4
11:45	28.2	38.5	52.4
12:00	27.4	41	56.2
12:15	27	41	55.6
12:30	26.4	41	50
12:45	25.1	41	50
13:00	25	42.4	51
13:15	24.7	42.1	53.6
13:30	24.2	41	52
13:45	23.8	41	51
14:00	23.5	41	51.2
14:15	22.9	41	50.2
14:30	22.5	40	52.4
14:45	22.0	38	48.5
15:00	21.8	40	48.5
15:15	21.5	39	48.25
15:30	21.1	39	46.5
15:45	20.9	39	43.25
16:00	20.9	38	43.0
16:15	20.7	38	41.25
16:30	20.4	38	42
16:45	20.1	37	40



Figure 2: Storage battery



Figure 3: PV array

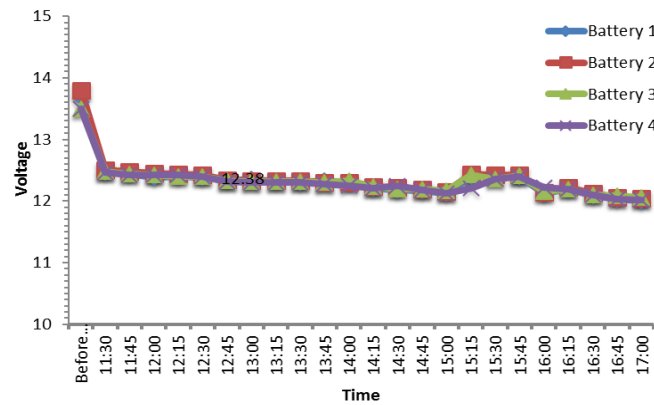


Figure 4: Battery bank voltages

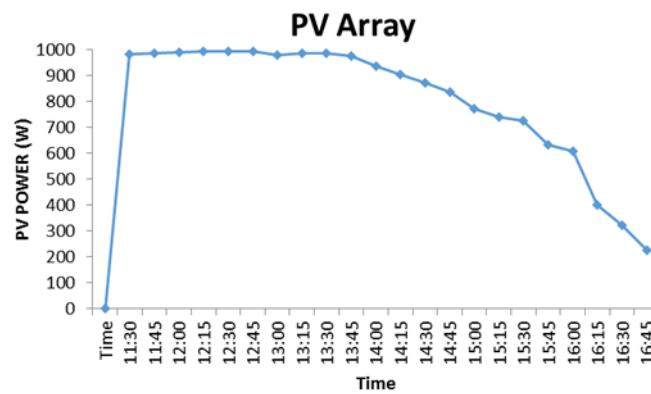


Figure 5: PV power generation during time

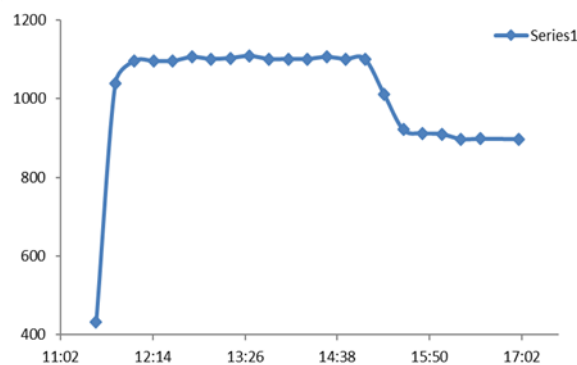


Figure 6: Air conditioner consume power

#### 4. Conclusions

The experimental outcomes of the proposed design of PV direct current drive air conditioner system showed that the system has sound research interest and implementation worthiness with the following conclusions:

- i. Recommended a system design of PV panel's direct driven air conditioner.
- ii. Irradiance intensity during day time change but the proposed solar photovoltaic system with the help of batteries still be able to meet the air conditioner load.
- iii. Despite the drop in PV panel's power production due to high temperature, but the system was able to meet the air conditioner power demand during the entire test time.
- iv. The room was not isolated completely from outdoor environmental factors but the air conditioner drives the temperature comfortable level for person.

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