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Research Article

Evaluation Method of Average House Demand in Iraq's Middle Territories

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Abstract

Iraqi householders are commonly interesting of hybrid power systems due to the considerable shortage of grid utility to meet there simple daily residential demands. Hybrid power systems that based on combination of multiple power sources (solar panels) and (diesel or gasoline) power generators are most favorable to use there, due to the small sizes and comparatively cheap initial prices of such systems. Renewable energy sources (RES) are intermittent in nature and change seasonally and daily, which make the hourly function evaluation, of electricity demand, is very important in the design of power systems based on these sources. In this work, average house electricity demand of Iraq's middle territories is estimated, by considered Baghdad average house demand as representative for this region, in terms of appliances sizes and annual distribution of daily operation hours. Also, solar system is designed based on the estimated consumption profile. It's found that the estimated profile with and without two tons of refrigeration air-conditioner system provide close results to the real values of Baghdad average house demand. Beside its reliability, independence and environmentally advantages, solar system that designed here show considerably cost effective than the private business diesel generator and discontinuous grid service in this area.

Keywords

Renewable Energy Sources in Iraq, Load Profile, Micropower System, Grid Discontinuous

1. Introduction

Currently, there is growing interesting to develop renewable energy technologies around the world. Renewable Energy Sources (RESs) can contribute to fulfill our ever-increasing energy needs. This concern mainly due to global warming by gas emissions pollutant and rising prices of conventional fossil fuels as well as its limited globally reserves. In Iraq, the main reason of commonly interesting of RES power systems is the considerable shortage of grid utility to meet the simple daily residential demands. Beside the discontinuous grid service, the main reliance of domestic electricity supply in Iraq cities positioned on the private business diesel generators that install near houses and sale electricity by Amber units. Solar energy source is the most RES available widely in Iraq [1] which provides the ability to invest in small size PV power

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systems. PV power systems can install in small or big sizes to serve wide range of electric load demand start from single appliance power supply to big dispatchable power plant. Many studies are conducted to evaluate the potential of this source to boost the energy sector in Iraq [2-5].

Renewable energy sources are intermittent in nature and change daily and seasonally which make the time function or hour by hour evaluation is very important in the design of power systems that based on these sources. Also, the development of RESs power systems requires integration of advanced forecasting and simulation techniques to investigate the operation of RESs in hybrid power systems [6]. The annual daily profile or the annual distribution of load demand during day hours is necessary in any design of micropower systems that determine the exact average daily load and accurate system components size [7].

In this work, average house electricity demand of Iraq's middle territories are estimated by considered Baghdad average house demand as representative for this region in terms of appliances sizes and annual distribution of daily operation hours. Iraq's middle territories have approximately the same weather conditions and renewable energy sources potential of Baghdad capital city of Iraq. Design of any micropower system for specific load demand requires the location that determines the available RESs in that site and load profile of annual distribution of power capacity along daily hours. The importance of this study are represented by providing hourly function of annual load profile for average Iraqi domestic demand to enhance the design efforts of micropower systemsfor this region householders. In addition, its provide a solar system design with its economical evaluation by comparison with other unreliable sources in the region.

2. Baghdad Climate

Baghdad (33° 18′ N - 44° 23′ E) has a hot dry climatein summer and a cool rainy in winter as shown in Table 1. In summer, from June to August, the average maximum temperature is as high as 43℃ accompanied by blazing sunshine. Rainfall is almost unknown at this time of year (Figure 1). Temperatures up to 49℃ in the shade and even at night temperatures in summer are seldom below 20 ℃, because the humidity is very low (usually about 12%) due to Baghdad's distance from the coastline of Arabic Gulf. Dust storms from the deserts in the west are a normal occurrence during the summer. In the winter, from December to February, Baghdad has maximum temperatures averaging 16 to 18℃. The average January low is 4℃ but lows below freezing are not uncommon during this season.

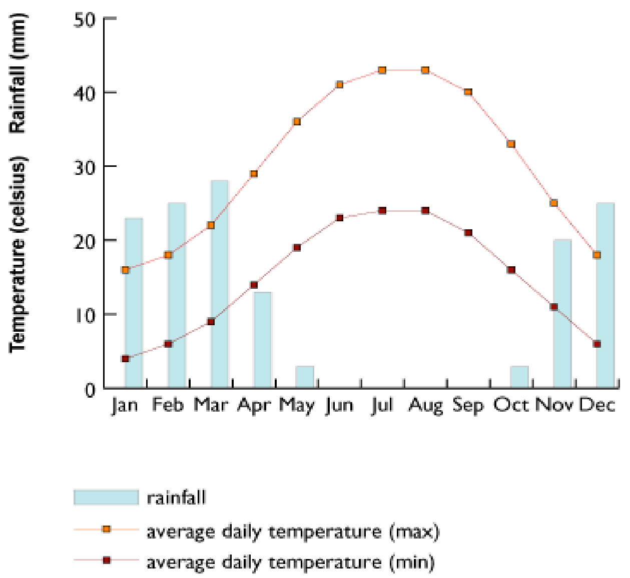

Figure 1. *Bar chart for Baghdad, Iraq shows the years average weather condition readings covering rain, average maximum daily temperature and average minimum temperature [8].*

Table 1. *Year averaged weather condition readings of Baghdad climate [8].*

Month	Average Sunlight (hours)	Temperature ℃				Relative humidity %		Average Precipitation (mm)
		Average		Record				
		Min	Max	Min	Max	am	pm	
Jan	6	4	16	-8	25	84	51	23
Feb	7	6	18	-5	30	78	42	25
Mar	8	9	22	-3	32	73	36	28
Apr	9	14	29	3	40	64	34	13
May	10	19	36	11	44	47	19	3
Jun	12	23	41	14	48	34	13	0

Month	Average Sunlight (hours)	Temperature ℃				Relative humidity %		Average Precipitation (mm)
		Average		Record				
		Min	Max	Min	Max	am	pm	
Jul	11	24	43	17	49	32	12	0
Aug	11	24	43	18	49	33	13	0
Sep	11	21	40	11	47	38	15	0
Oct	9	16	33	4	42	49	22	3
Nov	7	11	25	-2	34	70	39	20
Dec	6	6	18	-7	26	84	52	25

3. Building Style

Iraqis in general prefer to live in private property, rather than complex residential buildings due to the lack in required facilities and infrastructures of such constructions. However, there is a growing needs to residential complexes with vertical construction because of the population increasing and continue needs to more residential units. Also, there are lack of investments in large residential complexes and prefabricated building companies [9] due to the war conditions and political problems beside the weakness of government support for such projects. So most Iraqis builds their own houses or assign small contractors to do so, on owned land of about 250 - 300 m^2area.Building area usually represents one third of the total house area, i.e. about 100 $m^2$and the rest are front or back garden and corridors around the house. Most of the buildings are constructed by concrete, blocks and bricks materials [10]. A brick form the walls, but ceilings, foundations and pillars are usually from steel reinforced cast concrete. Sometimes walls are builds by heavy weight concrete blocks. Roofs generally in Baghdad houses and its suburbs are flat roofs, and seldom is inclined roofs such as it exists in a rainy and snowy countries. Most of Iraqis houses are non-economic designs in terms of thermal insulation and optimal distribution of energy.

Baghdad has extreme weather, in terms of high temperature difference between summer and winter. So it is more worthy to takes into account the thermal insulation in houses designs to be more economic in terms of reducing the cooling power dissipation in summer and heating power in winter. Baghdad usually needs electric power for cooling in summer more than heating in winter. Houses heating systems using kerosene and natural gas heaters are widespread in Baghdad and other Iraq cities, so the electricity consumption occurs in summer more than winter. Moreover, the installing of solar system over houses roofs can form sunshade that significantly reduce blazing sunshine impact and reduce the house electricity demand in summer.

4. Method, Result and Discussion

4.1. Daily Load Profile

There are big houses in Baghdad for wealthy householders and large families, beside small houses for low-income householders. In order to estimate the average electricity consumption of normal Baghdad houses, average house area of 250m^2 are considered with building area of 100 $m^2$and number of residents of about 7 persons.Also this average house size is estimated to be includes 4 rooms, kitchen, bathroom, toilet, patio and garden.

Renewable Energy Center of Iraq Ministry of Electricity replay for our inquiries about average daily load of normal house in Baghdad [11]. They reply that the average daily load of common house in Baghdad is 20 kWh/day without air-conditions load, meanwhile reaches to 50 kWh/day with two tons of refrigeration cycle air-conditioner (about 7 kW operation power).

Daily load profile is divided in this study into two parts, fixed part and seasonally variable part. Also, daily load profile is selected to be at minimum capacity and minimum number of appliances to reduce energy consumption as much as possible to be economically feasible for reliable power system design.

1) Fixed part (table 2) includes the appliances that used constantly throughout the year such as lighting, television, washing machine, computer... etc.
2) Seasonally variable part (table 3) includes the appliances that used in specific times throughout year seasons, which is heating and cooling devices.

Table 2 show the fixed load appliance unites with its operating capacities, total operation wattage, operating hours per day, total energy consumed per day, average wattage per hour and energy consumed per year. The average daily load of this part is resulted as 10.17 kWh/d while the annual energy consumption is 3712 kWh/yr. Washing machine considered to operate for about 3 hours, two times per week, which account about 1 hour per day as an averagein normal house consumption profile estimated in this study. Table 3 shows the variable load appliances with its operating capacities and total operation wattage. One refrigerator and one freezer are considered as minimum in this normal house. One unit of desert cooler is considered with 600 Watt power capacity for a moderate size as minimum number of air conditioner units in this normal house profile.

Table 2. Fixed load appliances.

Device	Unites	Operating capacity (watt)	Total (watt)	Operating hours/day	kWh/day
Fluorescent lamp	7	40	280	8	2.24
Tungsten light bulb	2	60	120	12	1.44
TV	1	80	80	8	0.64
Washing machine	1	250	250	1	0.25
Radio, computer, satellite receiver, kitchen appliances, …etc		700	700	8	5.6
Totalannual energy consumption (kWh/yr)	3712				
Average of daily energy consumption (kWh/day)	10.17				
Average Wattageper hour (W)	424				

Table 3. Seasonally variable load appliances.

Device	Unites	Operating capacity (watt)	Total (watt)
Water heater	1	1500	1500
freezer	1	500	500
refrigerator	1	350	350
fans	3	100	300
Desert cooler air conditioner	1	600	600
Two Ton air conditioner	1	7000	7000

4.2. Seasonally Variable Load Distribution

Table 4, show seasonally variable load appliances operation periods divided as "hours per day" throughout year months for each appliance, annual energy consumption for each appliance, daily energy consumption for each month, average wattage per hour and the total annual and average daily energy consumption for all appliances in the house. Two tons of refrigeration-cycle air-conditioner annual operation distribution is showed in Table 5.

Annual energy consumption for each appliance is calculated by using this equation:

$$\text{Annual energy consumption (kWh/year)} = [(\text{appliance wattage}) \times (\text{operating hours per day}) \times (\text{operating days per year})] \quad (1)$$

Average daily energy consumption is calculated as:

$$\text{Average daily energy consumption} = [\text{Total annual energy consumption}] / [365 \text{ day/year}] \quad (2)$$

Table 4*. Variable Load appliances operation periods in hours per day sorted by year months.*

Appliances	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual consumed energy (kWh/yr)
Water heater	6	6	3	3	1				1	3	3	6	1440
Freezer andRefrigerator	2	2	3	3	4	5	5	5	4	3	3	2	1045.5
Fans				6	12	20	20	20	12	6			864
Desert cooler air conditioner					6	12	12	12	6				864
Daily Load (kWh/day)	10.7	10.7	7	8.8	12.1	17.5	17.5	17.5	12.1	8.8	7	10.7	
Total annual energyconsumption (kWh/yr)	4213.5												
Average daily energyconsumption (kWh/d)	11.5												

Table 5*. Two Ton air conditionerannual operationdistribution.*

Appliances	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual consumed energy (kWh/yr)
2 ton Air condition					6	12	12	12	6				10080
Daily Load (kWh/day)					42	84	84	84	42				
Total annual energyconsumption (kWh/yr)	10080												
Average daily load (kWh/d)	27.6												

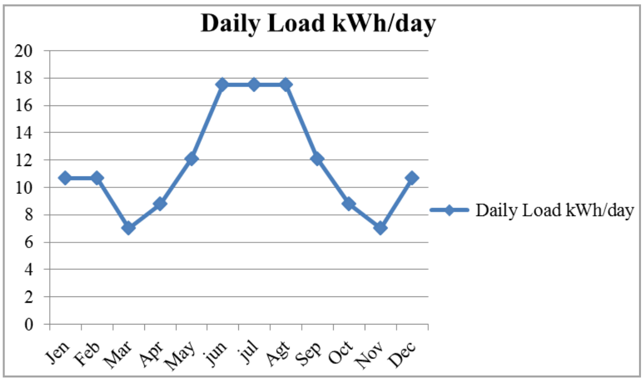

Figure 2*. Daily variable load of normal Baghdad house for each month per year.*

The assumed operation hours (Table 4) of water heater are 6 hours per day at the winter months while it's very cold (mainly used for shower and for washing dishes and clothes), while 3 operation hours in spring and autumn months mostly for shower. The common air heating systems in Baghdad in cold months are kerosene and gas heaters, so, the electric air-heating systems are not considered in this study, for power economy. Freezer and refrigerator are operating gradually from winter to summer, where the little operating hours occur in winter and increase in summer. Freezer used to save food for long terms while refrigerator used to save food for short terms. Both freezer and fridge, although turned on all the time, but it's actually automatically cycles on and off to keep the interior volume at constant low temperatures. The lower environment temperature the less fridge operating hours throughout the day and vice versa.

Air fan is the most commonly appliance used in all Baghdad houses throughout the year, which started operation during spring through summer to autumn, and operation hours reach to 24 hours per day in summer months. Fans operation hours are estimated by 20 hours in summer, 12 hours in May and September and 6 hours in April and October. Evaporate or desert cooler is a dominant cooling appliance in Iraq. It works by simple water evaporation process which is successfully work in Baghdad weather where sufficient water is available and low humidity records in summer. Whether householders use desert cooler or equivalent refrigeration-cycle air conditioner; run-time of 12 hours is considered in the peak of hot climate in summer months and 6 hours in May and September months. Figure 2 show that the daily variable load curve of normal house in Baghdad ripples up and down along year months to take peak value in summer months because of fans and air conditioner loads. Meanwhile, Daily load curve take minimum values in spring and autumn months because of moderate weather in Baghdad region during this time of year and no need for air cooling and heating loads operation.

The annual average daily load of fixed load part are 10.17 kWh/d (table 2) while the annual average daily load of variable load part are 11.5 kWh/d, which results the total average daily load of 21.67 kWh/d. By consider two tonscapacity of refrigeration-cycle air-conditioner (Table 5), which has an operation power of 7kW, and average daily load of 27.6 kWh/day. An additional to the previous variable loads of 11.5 kWh/day, the total average daily load of 39.1 kWh/dresulted for variable load part only. The overall average daily load of normal Baghdad house under this assumption is 21.67 kWh/d without two tons air conditioner and 49.27 kWh/d with two tons air conditioner which close to the real values of (20 and 50) kWh/d respectively, as mentioned in reference [11].

4.3. Design of Solar System

Grid shortage in Iraq are scheduled; usually 2 hours ON by 2 hours OFF, increase to 1-2 hoursON by 3-4 hours OFF in very hot time in June to August, and very cooled time in December to February. So, it's better to take this schedule into account in the design of solar system to reduce the size and cost of solar system components.The schedule of 2 ON 2 OFF will be considerhere as a rate schedule along all year months.

In this part, solar system will be designed according to the previous load profile (Table 4) but without two ton air-conditioner and water heater loads as shown in table 6. These two loads will be consider connected to the grid and operate only during grid schedule ON. Usually, Iraqi house use a water heater that includes a water tank of about 50-80 Liters. This advantage gives a capacity to save a hot water for use during grid shortage time.In addition, solar system will be designed by consider no charging chance from the grid to the battery bank during ON time to prevent grid congestion.

HOMER software is used in this study as simulation tool to configure and calculate the optimized system design. Figure 3 show the global horizontal radiation over Baghdad city (33° 19' N, 44 °25' E). The average monthly solar radiation has a minimum value of (2.62kWh/m^2/day) in December, maximum value of (7.56kWh/m^2/day) in June, and an annual average of (5.02kWh/m^2/day).

Figure 4 show the fixed daily load profile of 424W per hour. As considered in preliminary assumption;the load takes zero value during grid schedule ON, Which means that the solar system doesn't see any load during grid ON (direct the produced energy to charge the battery bank only), meanwhile, recognize the full load during grid OFF only. This led to that the active daily load equals to the half its real value of 10.17kWh/d for fixed load (resulted in table 2) and 7.7kWh/d for variable load (resulted in table 6) by consider grid schedule (2hours by 2hours) configuration. The active daily load is shown in table 7.

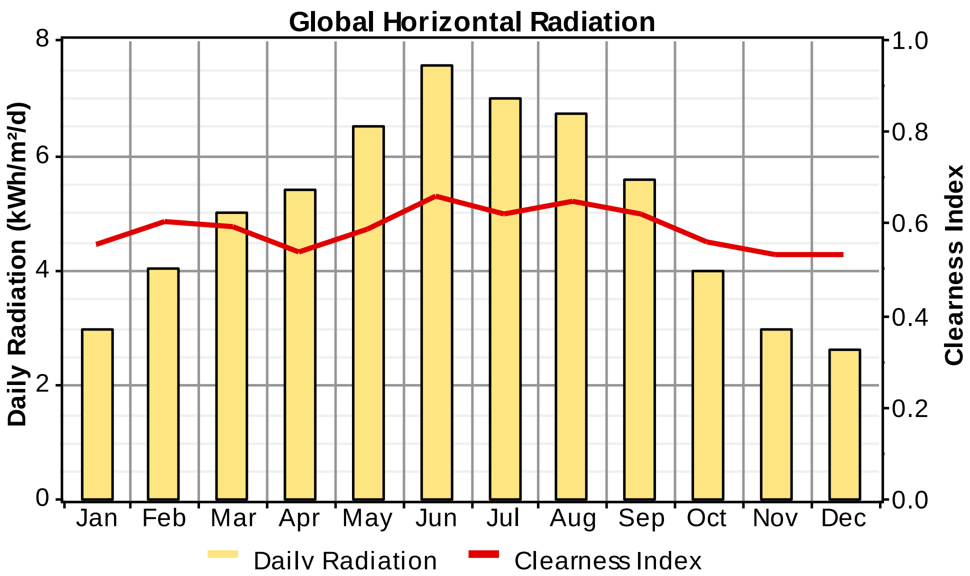

Figure 3. *Global solar radiation over Baghdad city.*

Table 6. *Operation time (by hours/day) of variable load appliances without water heater.*

Appliances	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Freezer andRefrigerator	2	2	3	3	4	5	5	5	4	3	3	2
Fans				6	12	20	20	20	12	6		
Desert cooler air conditioner					6	12	12	12	6			
Daily Load (kWh/day)	1.7	1.7	2.5	4.3	10.6	17.5	17.5	17.5	10.6	4.3	2.5	1.7
Average Wattage per hour without water heater (W)	71	71	106	181	442	729	729	729	442	181	106	71
Average daily load (kWh/d)	7.7											

Table 7. *Real and Active daily load by consider grid schedule (2/2) configuration.*

Daily load	Real daily load(kWh/d)	Active daily load(kWh/d)
Fixed load	10.17	5
Variable load	7.7	3.9
Total daily consumption	17.87	8.9

Fixed daily loadprofile keep a fixed value along all year months as shown inthe seasonal load profile in figure 5.

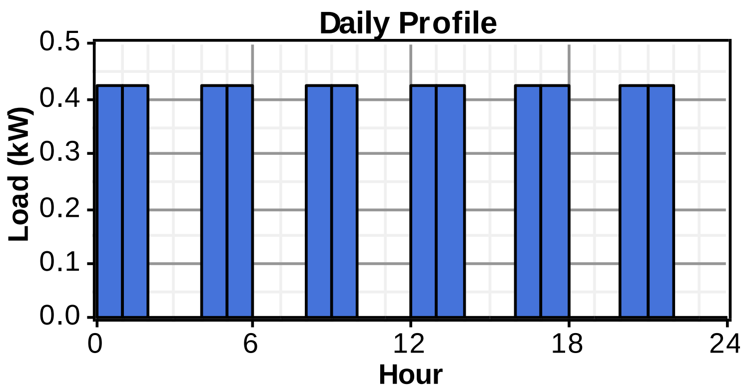

Figure 4. *Daily load profile of fixed load.*

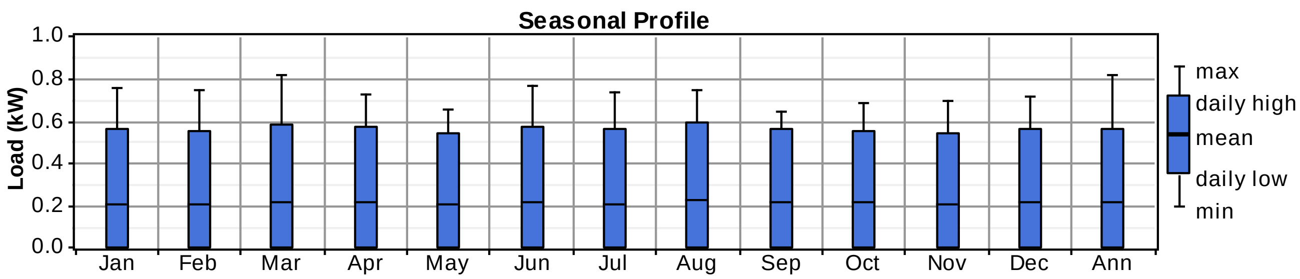

Figure 5. *Seasonal load profile of fixed load.*

Figure 6 show the Seasonal profile of variable load configuration. HOMER allows to add a randomness of 15% day to day and 20% hour to hour to the load data to make it more realistic.

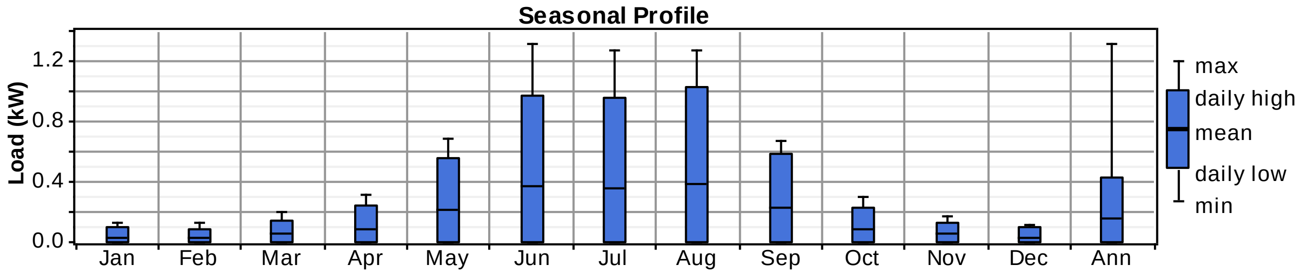

Figure 6. *Seasonal profile of variable load.*

Table 8 show the results of HOMER simulation run, that represent the specifications of the optimized solar system.

Table 8. *Optimized solar system.*

PV	Battery	Converter	Total Capital Cost	Total NPC	Operating Cost	COE	PV Production	Battery Autonomy	Battery Life
kW	unit	kW	$	$	$/yr	$/kWh	kWh/yr	hr	yr
3.6	3	2	3,490	5,293	141	0.127	5,824	15.52	6.4

The total rated power of PV panels is 3.6kW. By consider a normal efficiency of traditional solar panels of (0.18), a total area of panelsA(m) can find by equation:

$$A(m) = \frac{R_p}{1000\left(\frac{W}{m^2}\right) * \mu} \quad (3)$$

Where (Rp) is the total rated power of solar panels and (μ) is the efficiency of the panels. So, the total area covered bysolar panels about 20 m^2. By consider a tilted angle of 33 °in the middle of Iraq, the horizontal area needed for install solar panels take about 17 m^2. This area is available on the roof of normal Iraqi house.

Battery bank of the optimized design includes 3 batteries of 12V-200Ah which account 2400Wh capacity of a single battery or 7200Wh for total battery bank capacity.

4.4. Theoretical Confirmation

The equation that applies to calculate the total energy produced by PV array P_{PV} (kWh/d) is:

$$P_{PV} = f_{PV}\, Y_{PV} \frac{I_T}{I_S} \quad (4)$$

Where f_{PV} is PV derating factor [%], Y_{PV} the rated capacity of the PV array [kW], I_T the global solar radiation (beam plus diffuse) incident on the PV array [kW/m^2/d] in Baghdad, I_S the incident radiation at standard test conditions (1kW/m^2).The derating factor used to account for such factors as soiling of the panels, wiring losses, shading, temperature, aging, and so on. The daily load value used to estimate the suitable PV capacity is that occurs during summer months which records maximum daily load value in Baghdad profile (see table 6). From equation (4), the rated capacity of the PV array Y_{PV} [kW] that required to confront all the day and night load is shown in table 9. The theoretical result of 3.44kW is close to the simulation result of 3.6kW in table 8. If we consider the efficiency of DC-AC converter of 95%, the resulted PV capacity increases to 3.62 which more close to the simulation result.

Table 9. *Theoretical result ofPV array total capacity.*

Parameter	Value	Unit
P_{PV}	13835	kWh/d
f_{PV}	80	%
I_T	5.02	kWh/m^2/d
Y_{PV}	3.44	kW

The battery bank autonomy A_{batt} [hours] is the ratio of the battery bank size to the electric load. This value represents the time in hours can the battery bank serve the external load autonomously. The Battery bank autonomy can calculate by using the following equation:

$$A_{batt} = \frac{N_{batt} * C_{batt} * (1 - q_{min}) * 24 \frac{hours}{day}}{L_{prim}} \quad (5)$$

Where C_{batt} is the capacity of single battery in the battery bank [kWh], N_{batt}number of batteriesin the battery bank, q_{min} is the minimum level of state of charge and L_{prim} the primary load [kWh/d]. In this design, HOMER select an autonomy as 15.5 hours that the battery bank mostly serve all the night load without chance of charging from the grid. From equation (5), the number of batteries in the battery bank N_{batt} calculates as shown in table 10:

Table 10. *Theoretical result of battery bank size.*

Parameter	Value	Unit
A_{batt}	15.5	hour
C_{batt}	2400	Wh
q_{min}	20	%
L_{prim}	8.9	kW
N_{batt}	3	unit

The results of equation (5) are showing exact conformity of N_{batt} with the simulation result.

4.5. Optimized System Cost

Because of Grid shortage schedule, Iraqi householders rely commonly on private business diesel generator. They deduct about $15for one Ampere or 230W power (one Ampereby 230VAC is equivalents to 230W power)as rated fees by month. Simple calculations led to that the total daily consumption of active load (table 7) of 8.9kWh/d cost about $580 per month by buying the required power from local diesel generator. Optimized design (table 8) is account total net present cost (NPC) of $5,293 which includes capital, replacement and operating costs along project life time of 25 years.This means that the optimized system cost of about $17 per month. So, the optimized system can settle its total cost (NPC) by the first 9 months and its initial cost of $3,490 by the first 6 months of the project life time.

5. Conclusions

In this work, average electricity demand of Iraqi housein middle territories are estimatedby consider Baghdad average house demand as representative for this region in terms of appliances sizes and annual distribution of daily operation hours.Also, design of a solar system is achieved, based on the estimated daily profile, with its economic evaluation compared to the service provided by private business diesel generator which is currently the popular electricity source in Iraq cities beside discontinuous grid.

It's found that the average daily consumptionwithout two Ton air conditionerequals to 21.67kWh/d by respect the economy distribution of operation hours and appliances sizes. The same annually hours distribution are applied for two tons of refrigeration-cycle air-conditioner provides a close result to real value of Baghdad average house demand. These results give more reality approachfor the estimation of daily and annually electricity consumption in this region. The peak of power load event in summer time, corresponding on peak ofincident solar energy harvesting in this region, which give a considerable chance for use solar system to meet most of daily electricity consumption in this time of year.

In addition, the economic comparison between the total cost of the designed system and the cost of buying electricity from the local diesel generator shows the large saving in the cost as well as the advantages of reliability, independence and environmentally clean energy.

These results indicate the potential of small systemsof solar panels to meet both of the residential electricity demand and provide sun shading over houses roofs for energy saving in these houses.

It is more worthy to takes into account the thermal insulation in houses designs to be more economic in terms of reducing the cooling power dissipation in summer and heating power in winter, which led to more reduce in the cost.

6. Highlights

Providing hourly function of annual load profile for average Iraqi domestic demand.

Average electric demand of normal house in Iraq's middle territories is estimated.

Seasonally demand distribution of daily operation hours is considered.

Solar system is designed based on the estimated consumption profile.

Provide an economical evaluation of new design by comparison with other unreliable sources in the region.

Abbreviations

RES	Renewable Energy System
NPC	Total Net Present Cost
COE	Cost of Energy

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Data Availability Statement

The data that supports the findings of this study are available within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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