An-Najah National University .

Faculty of Engineering.

Electrical Engineering department.

TECHO _ECONOMIC EVALUATION OF ELECTRIFICATION OF SMALL VILLAGES IN PALESTINE BY CENTRALIZED AND DECENTRALIZED PV SYSTEM

Prepared by:

Linda Ahmad Mansour

Latifa Mahmoud Abu Safya

Supervisor:

Prof .dr.Marwan M.Mahmoud.

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TO

OUR PARENTS,

OUR SISTERS AND BROTHERS,

OUR FRIENDS,

OUR TEACHERS,

AND ALL PALESTINIAN PEPOEL.

ACKNOWLEDGEMENTS

We would like to thank our direct supervisor Prof.Dr.Marwan Mahmoud for his continued support , complete cooperation and Distinguish supervision throughout the course of our study, and who shared with his valuable notes and long experience in the field of pv systems design .

Special thanks also for our university and teachers who participated in the success of our study.

Special thanks goes to our families, friends and who supported us in this study.

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Abstract

This study presents the alternative solution for electrification of small villages far away from the grid by pv-systems designed as centralized or decentralized configuration and the economic evaluation of using such a system .

The purpose of this study is to select the optimum configuration which runs correctly with the least possible cost .

Our economic evaluation for the alternatives is based on the cost of 1 kwh generated by the different types of configurations.

The best configuration is the system which generates energy with minimum cost of 1Kwh.

This study has been evaluated for three small villages in Tubas area (Salhab,Ibziq and Yarza) as a case study.

For the three selected villages ,the cost of 1KWh which is generated by AC decentralized configuration is less than AC centralized configuration ,this indicator shows that AC decentralized pv system is the optimum solution .

Chapter One

DESIGN PHOTOVOLTAIC SYSTEM

1.1 Criteria for a Quality PV System:

A PV system should:

1. Be properly sized and oriented to provide the expected electrical power and energy.

2. Use sunlight and weather resistant materials for all outdoor equipment.

3. Have any roof penetrations properly sealed with roofing-industry approved sealing methods.

4. Be installed with a minimum of shading from objects like foliage, vent pipes, or adjacent structures

5. Be installed in compliance with all applicable building and electrical codes.

6. Be installed with a minimum of electrical losses due to wiring, over current protection, switches, and inverters.

7. Be properly grounded to reduce the threat of shock hazards and induced surges.

8. Properly house and manage the battery system, should batteries be part of the system.

9. Interconnect with the utility company following accepted procedures.

10. Produce utility quality electrical output.

1.2 General Procedural Steps To Specify and Install A Residential PV Power System:

<u>The general steps to design a solar PV system are:</u>

1. **Inspecting the location**
2. **Deciding what type of PV system to install**
3. **Gathering electrical information**
4. **Determining how much electricity you want your PV system to generate**
5. **Sizing the system**

1. Inspecting property:

This step is often referred to as site survey. The purpose of this step is to find out whether a location is suitable for a PV system.

There are tools and computer software available to assist you, like *Solar Pathfinder*, or *SunEye*, Here are some items to look for:

- **Latitude of the location :**

  Latitude, in general, determines how much sunlight the location receives during the day . It also gives you an idea the best tilt angle for the solar panels if you would want to maximize your PV system performance.

  Typically, the tilt angle for the solar panels is left at latitude for spring and autumn. For example, if your latitude is 30 degrees, the tilt angle will be 30 degrees. The tilt angle for the solar panels should be latitude minus 15 degrees in summer;

whereas the tilt angle for the solar panels should be latitude plus 15 degrees in winter.

- **Shade around the property**

Solar PV panels require direct sunlight to be effective. Shade from trees, buildings, utility poles and other objects can hinder the performance of a PV system dramatically. Shade is also affected by the location's latitude and seasons. Shade is longest during winter and shortest during summer.

The equation below shows the minimum distance of pv _arrays should be separated from each others:

$$X= a[\sin \beta \times \tan(23.5+L) + \cos \beta]$$

where : a=length of the pv array (m)

x= the distance between arrays

β=tilt angle

L :latitude

2. Deciding what type of PV system to install:

After you have inspected your property, you can begin to determine what type of solar PV system to install. The three general types to choose from are stand-alone, grid-interactive and grid-interactive with battery backup.

A stand-alone (or off-grid) PV system allows you to run all your electricity from your PV system without using utility power. Generally, stand-alone PV systems are suitable for houses or structures where utility power is not readily available. This type of system normally has other renewable energy sources or a generator as backup.

A grid-interactive system allows you to provide all or part of your electricity need from solar PV system. If the PV system only provides part of your electricity need, the rest is provided by the utility company. This is the most popular PV system type in urban areas. One drawback of a grid-interactive PV system is that when the utility goes out, the PV system also goes out even if the solar panels are working.

A grid-interactive with battery backup PV system is similar to grid-interactive but has a battery bank attached to the system that acts as a backup power source when utility power is not available. Typically, a sub panel connects critical appliances like refrigerator, water pumps and emergency lighting to the battery bank.

3. Gathering electrical information

After you have chosen the type of PV system to design, you need to gather electrical usage information for the location. Different PV systems require different information:

- Stand-alone: List of appliances with power consumption information (used in electrification of small villages far away from the grid)
- Grid-interactive: Annual electrical power usage.
- Grid-interactive with battery backup: list of critical appliances and annual electrical power usage.

For a stand-alone PV system, gather information for all the electrical appliances that will be powered by the PV system. You can find the information on the tag or plate located at the bottom or back of the appliances. Or you can refer to the appliance owner's manual. Keep in mind some owner's manuals cover a group of similar models in one manual. Make sure you locate the correct model. The information to record:

- Appliance name
- Voltage type, i.e. AC or DC (rare)
- Quantity
- Volt (e.g. 120V or 240V for AC and 12V or 24V for DC)
- Amp (e.g. 0.5A, 6A or…)
- Power = volt x amp
- Amount of time used each day
- Number of days used each week
- Usage = Qty x Power x Hrs/day x Days/Wk / 7-days/week

When you finish gathering the information, add up the power usage to get a number in Wh/day (watt-hour per day. This is the amount of power your stand-alone PV system needs to generate each day (assume every day is a sunny day).

The table below shows the appliances taken for atypical house :

name	Quantity	power	Hours /day	Energy /day
CFL	6	16	5	540
TV	1	60	8	480
refrigerator	1	70	16	1120
radio	1	10	1	10
Computer	1	150	3	450
Additional equipment	1	100	3	300
total		486		2900 Wh/day

Table (1-1)

4. Determining how much electricity you want your PV system to generate:

Once you know your average daily power usage, you need to determine how much power (as a percentage) you want your PV system to generate. This step is mainly for grid-interactive and grid-interactive with battery backup PV systems. For a stand-alone PV system, keep in mind that the system will need to generate 100% of electricity you need.

5. Sizing the system:

Once you have the information from Steps 1 through 4, you are ready to size your PV system. Sizing involves determining how many solar PV panels and/or batteries you need, choosing an appropriately-sized controller and/or inverter and experimenting with various combinations to create a final design that fits your need and budget.

1.3 The photovoltaic system:

Components of PV system:

1- PV generator.

2- Controllers(DC/DC converter).

3- batteries.

4-Inverter.

5-wiring.

1.3.1 The photovoltaic generator:

Pv generator: is inter connection of pv array**.**

Pv array: is inter connection of pv module.

pv module: arrangement of series and parallel connection of solar cells.

Pv cells: Thin squares, discs, or films of semi conducting material which generate voltage and current when exposed to sunlight.

At the present time, most commercial photovoltaic cells are manufactured from silicon, the same material from which sand is made. In this case, however, the silicon is extremely pure. Other, more exotic materials such as gallium arsenide are just beginning to make their way into the field.

The three general types of silicon photovoltaic cells are:

1- mono crystalline silicon.

2-poly crystalline silicon.

3-amorphous silicon (abbreviated as "aSi", also known as thin film silicon).

***Mono crystalline silicon*:**

Most photo voltaic cells are mono-crystal types. To make them, silicon is purified, melted, and crystallized into ingots. The ingots are sliced into thin wafers to make individual cells. The cells have a uniform color, usually blue or black.

***Poly crystalline silicon*:**

Polycrystalline cells are manufactured and operate as the same of mono crystalline. The difference is that a lower cost silicon is used. This usually

results in slightly lower efficiency, but polycrystalline cell manufacturers assert that the cost benefits outweigh the efficiency losses.

Amorphous or thin film silicon:

Thin-film technologies reduce the amount of material required in creating a solar cell. Though this reduces material cost, it may also reduce energy conversion efficiency. Thin-film silicon cells have become popular due to cost, flexibility, lighter weight, and ease of integration, compared to wafer silicon cells.

A Photovoltaic panel can be directly wired to a DC Load if the load is needed only when there is sun, and the load is not sensitive to large voltage fluctuations.

Examples include:

- A greenhouse fan - this is a load that will serve to cool down the greenhouse during the day. The more direct sunlight there is, the more the load will be working and compensating for the heat within the greenhouse.

- A water pump - this is a load that does not need to be operational at specific times, and hence, is only operating when there is enough sunlight to power the pump.

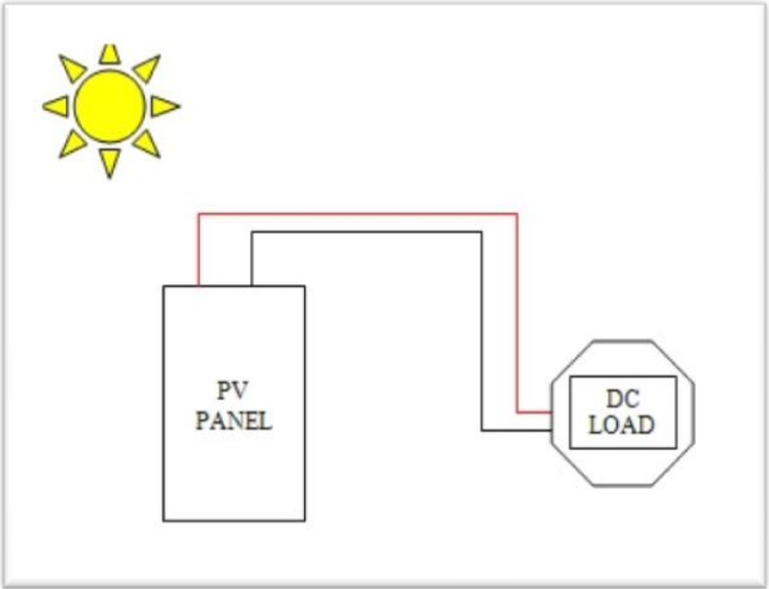


Figure (1)

1.3.2 Batteries:

Batteries are required for any system that needs some sort of storage capacity. If you will be using your system at times when there may not be sunlight available, a battery will store the energy from the pv array in order to power the loads at a later time.

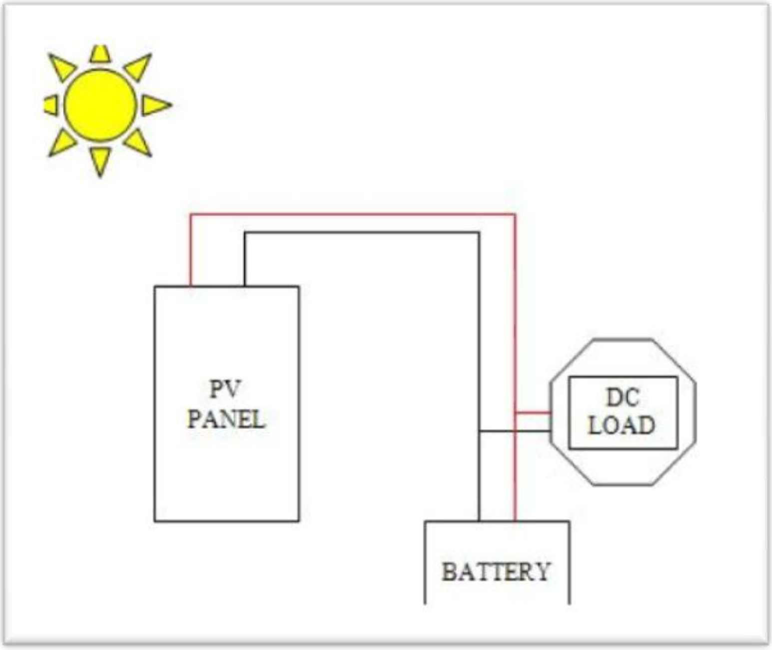


Figure (2)

Importance of batteries in pv systems:

- Batteries allow you to store energy directly from the energy generated by the PV Array.
- Batteries store DC energy and allow you to utilize the energy during the night, when there is not a sufficient amount of sunlight, or when there is a blackout (if you are connected to the grid).
- Batteries are an extremely important power supply for critical electrical loads that consistently require usage. If you are wishing to power a load only during the day, a battery may not be required, i.e. to power a fan on sunny days inside of a greenhouse. Utility

grid-connected pv systems do not require the use of batteries, though they can be used as an emergency backup power supply.

Days of Autonomy :

- Autonomy refers to the number of days a battery system will provide a given load without being recharged by the pv array or another source.
- General weather conditions determine the number of "no sun" days, which is a large variable when determining autonomy.
- The general range of autonomy is as follows:
  - 2 to 3 days for non-essential uses or systems with a back-up power supply.
  - 5 to 7 for critical loads with no other power source.

Battery Capacity (AH) :

- Batteries are rated by amp-hour (AH) capacity. The capacity is referring to how much energy that particular battery is capable of storing. The capacity of the battery needs to be capable of supplying energy to the load. It is necessary to factor in the days of autonomy in order to determine how much storage capacity is required of your battery. The (AH) will tell you how many (amps) you can pull from the battery in one hour.
- If more storage capacity is required for the pv system than one battery is capable of supplying, batteries can be wired in parallel to add additional storage capacity. Higher voltages are obtained through series wiring.
- Initially, the battery capacity should be slightly larger than is required by the load because the batteries will lose capacity as they age. But if you greatly oversize the battery bank, it may remain at a state of partial charge during periods of reduced insulation - ultimately shortening the battery life. Determine the battery based on the size of your load.
- The AH capacity will be listed on the battery.

Rate and Depth of Discharge :

- A battery is charging when energy is being put in and discharging when energy is being taken out. One cycle is considered one charge-discharge sequence, which often occurs over a period of one day.
- The rate at which the battery is discharged directly affects it capacity. The faster the discharge, the lower the capacity. The slower the discharge, the larger the capacity.
- The discharge rate refers to period of time at which the battery discharge was tested. For a battery rated at C/20, the discharge C (in Ah) was reached after 20 hours of discharge. For instance a 220 Ah battery, rated at 220Ah/20 would be discharged for 20 hours at 11 Amps continuously.
- Depth of Discharge (DOD) refers to how much capacity can be withdrawn from a battery. Most PV system batteries are designed for regular discharges of 40 to 80 percent. Battery life is directly related to how deep the battery is cycled; the shallower the cycle, the longer the life span.

Environmental Conditions and Battery Sizing :

- It may be unreasonable to size a battery system that would be capable of providing power during extreme weather conditions, such as three to four weeks without sun. Hence, it may be a better option to size the system according to the average number of cloudy days or to create a design with a hybrid approach adding in a generator or a wind turbine.
- Battery capacity decreases at lower temperatures while battery life increases.
- When sizing a battery, you can compensate for the effects of temperature by using a battery temperature multiplier. Multiply the battery capacity needed by the battery temperature multiplier.

1.3.3 Voltage Regulator:

Importance of voltage regulator in pv systems :

The Voltage Regulator prevents the pv panel from overcharging the battery by regulating the voltage to be always below a certain limit. The battery will specify that it cannot continue to accept current past a certain charge. The voltage regulator lowers the current as it reaches closer to this limit in order to lessen the amount of current charging the battery.

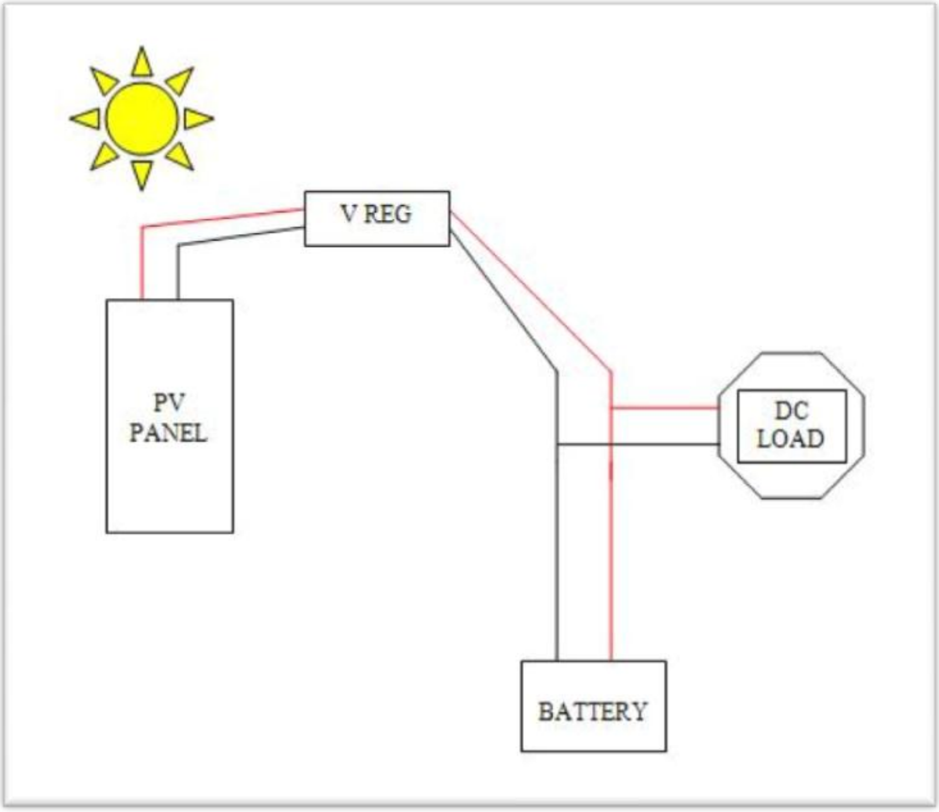


Figure (3) voltage regulator in a pv system

1.3.4 Inverter

Inverters convert DC to AC. To power any AC Loads, the current must be converted via an inverter.

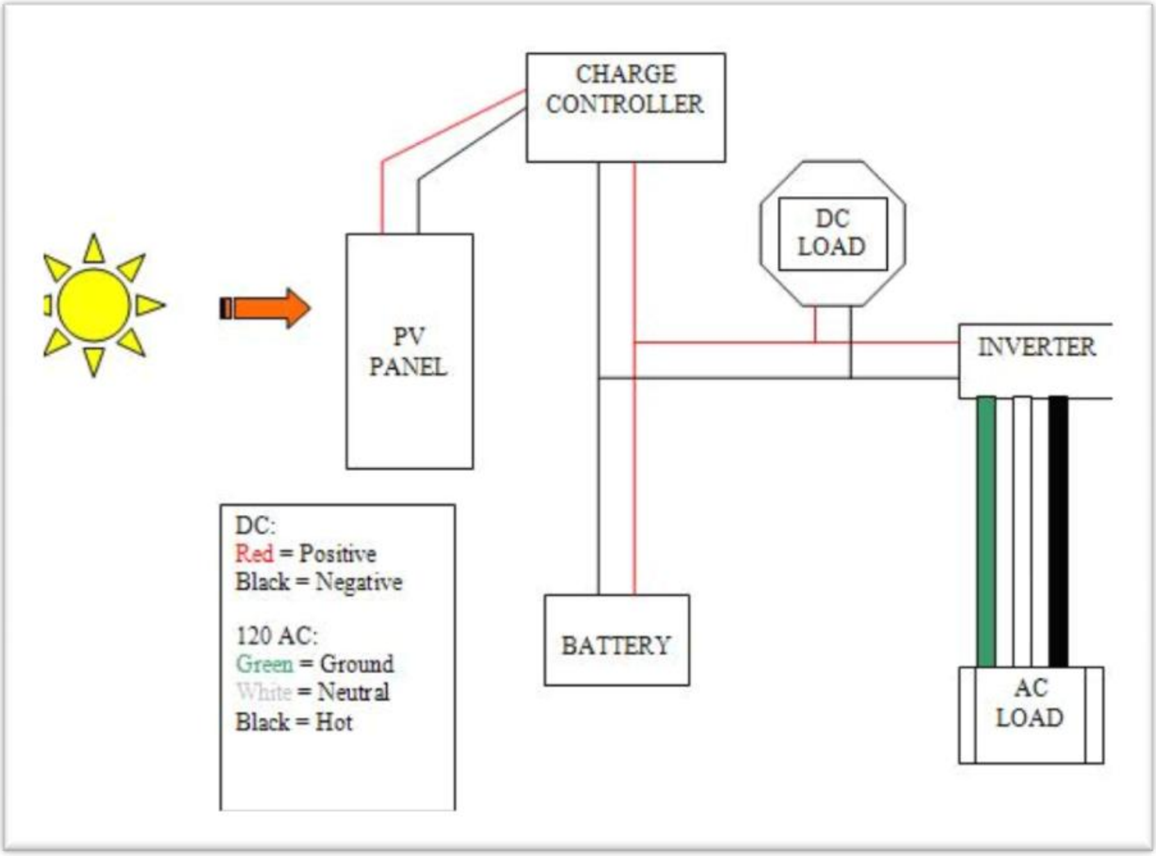


Figure (4)

Purpose/Importance

- Photovoltaic modules generate only DC power. Batteries can store only DC power. An inverter is used as a "bridge" which converts DC electricity into AC electricity.
- AC is easier to transport over long distances, this is an important component for many pv systems.
- AC appliances have become the conventional modern electrical standard, inverters are necessary to power any type of AC load.

1.3.5 Watts Output

- This indicates how many watts the inverter can supply during standard operation.
- Choose an inverter that can handle the system´s peak AC load requirements.

Chapter two

Centralized and Decentralized pv systems

2.1 Stand alone pv systems :

Stand alone pv systems can be designed as :

1)DC_ decentralized pv power system :
Each house has its own pv system and its always dc system so ,it supplies only dc appliances.
This kind of design has a problem because nowadays most of appliances are AC loads and it's hard to find DC appliances

2)AC_ decentralized pv power systems:
Also this kind of systems are designed for each house alone ,
And such a design needs inverter to supply AC loads since most of appliances are AC .

the figure below shows the components of DC_ decentralized pv power system :

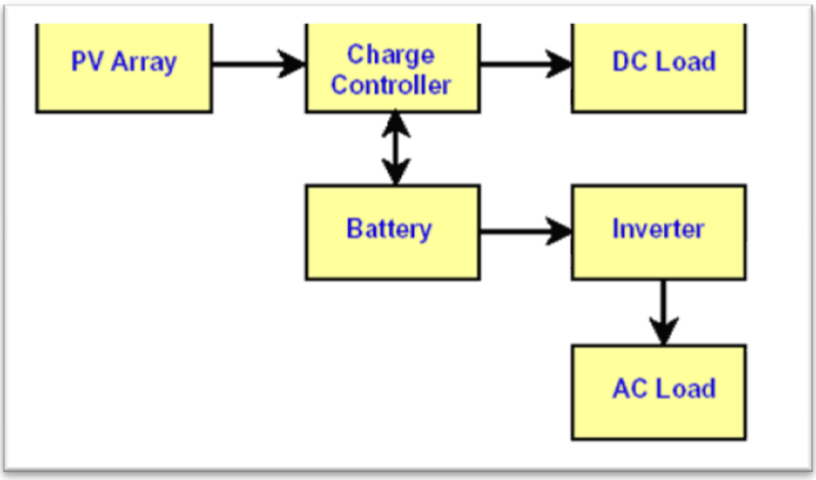


Figure (5)

3)AC_ centralized pv power systems:

this kind of systems usually is used to electrify small villages far away from the grid with small distances between their houses.

These systems need system of transmission components with transmission conductors ,protective devices ,poles and other needed components , also need a large areas to stand the system .

the figure below shows the components of this design :

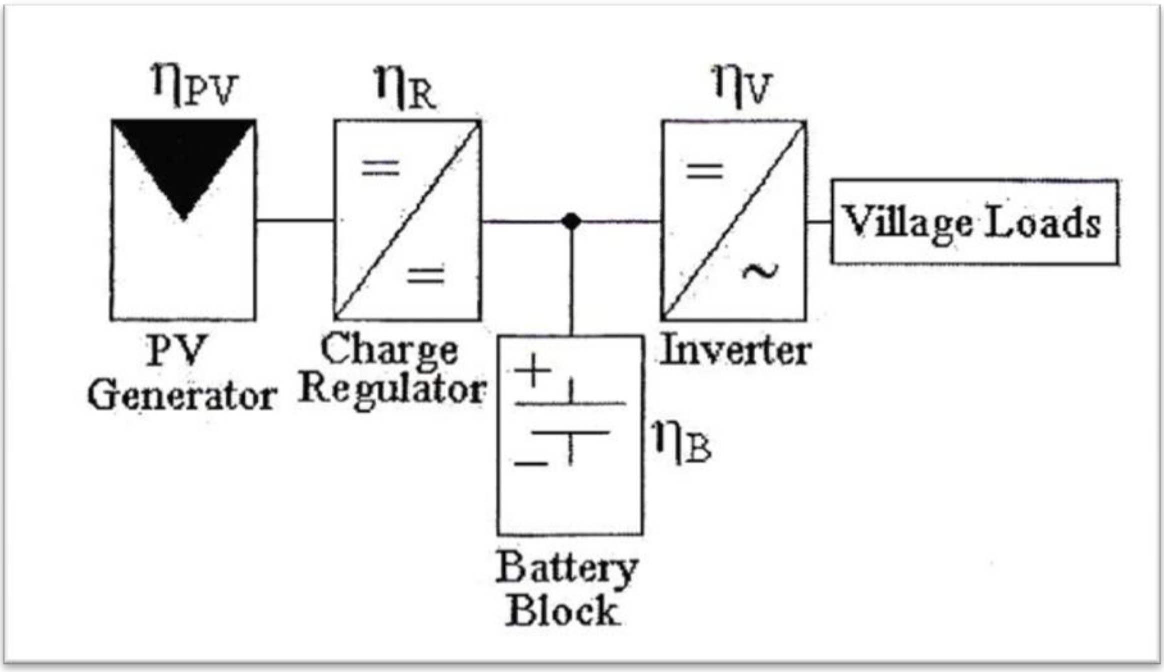


Figure (6)

<u>The main differences between the above two configuration systems are:</u>

1- The centralized PV system is more stable easy to control and to maintain.

2- The overall efficiency of centralized PV system is less than the decentralized (individual) unit, because of the inverters losses and greater wiring losses.

3- The centralized PV system is more expensive than the individual PV systems, because of eliminating the need for big mounting, big installation and big distribution infrastructure.

4- The reliability for all the village interest in decentralized PV system is more greater than the centralized PV system, so if the system stops in any house, the others will continue doing.

5- The use of land in decentralized PV system is nothing comparing to centralized PV system.

6- The decentralized PV system is modular in nature allowing for expansion or reduction based on need and economic means.

7- The decentralized PV system keeps the energy system close to the end user, allowing the end user direct control of acquisition, design, placement and consumption decisions.

8- The decentralized PV systems are holding tremendous potential for an improved quality of life for women, specially , such systems ease the time commitment and human energy required to meet daily needs.

CHAPTER THREE

ELECTRIFICATION OF SMALL VILLAGES IN PALESTINE

3.1 Introduction :

Attention is given to the vital and other justified needs of ruler areas in the Arab world .the required power to satisfy these needs is estimated. accessible energy sources are compared against evaluation parameters and degree of satisfying the needs . these comparisons prove that solar cells are most suitable energy source for development of the rural areas in the Arab world .general specification and recommendations are also provided to ensure proper implementation of such technology .

The least developed areas in the Arab countries are rural and desert communities. therefore a special attention is given to the needs of these communities in order to raise the standard of living ,introduce new means of technical and social development ,and utilize renewable energy sources using existing technology .based on the above the required power is estimated and the proper energy source is identified . in satisfying the requirements certain care is given to the factors ;first the living habits of the consumers , second the fact that solar energy is evenly distributed both in time and space .therefore its suitable utilization in the areas of application should obey the two factors .

Energy dependent basic needs in rural areas in the arab world are mainly water ,food cooking ,lighting ,refrigeration ,and information and educational services .these needs will be classified according to three main categories , namely family needs ,community needs ,and general needs .

Rural areas are remote and scattered with low population .one family or more or a group of people may constitute the solely temporary inhabitants in a given location in the rural areas .another component of rural area is a collection of families forming a community.

-living habits :

The living habits and activities of people in rural areas either inhabitants or travelers differ for different seasons .table below shows type and time of activities during summer and winter seasons:

Possible traveling time	Possible indoor activity	Possible outdoor activity	season
6 pm to 10 Am	12 Am _3 pm 8 pm _10 pm	6 A.m to 12 A.m 5 pm to 8 pm	Summer March to September
Day time	6 pm-10 pm	7 Am to 6 pm	Winter October to February

Table (3-1)

The power requirements of rural areas are classified into three main categories :(1)family needs ,(2)community needs and (3) other requirements .

(1) family needs :

A family in a rural area comprises from 6 to 8 persons on the average .

They live in a house of an area about 100 m^2 . A typical house consists of a living room ,two bed room ,and a kitchen .and the bathroom .

(2) community needs:

(a) Daily water needs:

To estimate the daily water needs of families in rural areas to cover drinking ,washing ,cooking and animals water needs .the following assumptions are made :

m persons	Average family size
1 liters	Daily water consumption per person
d liters	Daily average consumption per animal
a	Number of animals per family
P kw	Power required to pump one m^3 of water at a depth of one meter
H meters	Water head (well_ depth)
M	Number of families per community
Pw	Total power required for water pumping to satisfy daily needs of M families
h	Total sun shine period

Table (3-2)

Accordingly, the total power required for water pumping from awell of H

Meter depth to satisfy the daily needs of M families is given by :

Pw=[((m.1+d.a) M.P.H ×10^-3)/h] kw/hr

Thus the pump power rating is Pw .kw

B_ health care :

Health care center in ruler area is assumed to include two rooms and a path room . one room for service and other is used for storage purposes .basically it requires lighting and refrigeration at a total consumption of 350 w.

C_ information and educational services :

The information and education services include school, a mosque with selected public lighting .

(3)other requirements :

These include Gas stations , rest areas , remote border check points etc..

3.2 potential of solar energy in Palestine:

3.2.1 Introduction:

Solar energy is expected to play a very important role in meeting energy demands in the near future. Since it is a clean type of energy with a diversity of applications, decentralized nature and availability, solar energy will represent a suitable solution for energy requirements especially in rural areas. It is important to state that the use of solar energy in rural regions will protect this area from pollution, since the use of solar home systems avoids large amounts of CO_2 emissions.

In Palestine, there are many remote small villages that lack of electricity, and it is possible to electrify these villages by using solar energy.

3.2.2 Solar Radiation:

Palestine has a high solar energy potential, where average solar energy is between 2.63 kWh/m2 per day in December to 8.5 kWh/m2 per day in June, and the daily average of solar radiation intensity on horizontal surface (5.46 kWh/m2 per day) while the total annual sunshine hours amounts to about 3000, these figures are very encouraging to use Photovoltaic generators for electrification of remote villages as it has been worldwide successfully used The amount of radiation arrives at the WB differs from place to another. The amount of radiation decreases toward the West. This reduction is due to the cloud cover between the hills and the coastal plain. Solar radiation in the West Bank is at a highest in Jericho, solar radiation is reach 8kWh/m2 in June, July and August (summer months).

Table (3-3) Hourly average solar radiation of typical summer day:

Hours	Ambient Temp (C°)	Hours	Ambient Temp (C°)
1:00	22	13:00	32
2:00	22	14:00	32
3:00	22	15:00	31
4:00	21	16:00	31
5:00	21	17:00	29
6:00	22	18:00	28
7:00	23	19:00	26
8:00	24	20:00	24
9:00	25	21:00	24
10:00	27	22:00	23
11:00	28	23:00	22
12:00	31	24:00	22

CHAPTER FOUR

Sizing of decentralized pv power system components for non-electrified small villages in Tubas area

4.1 Introduction:

We will study on three villages lie in the eastern area of Tubas city and in the west of Jordan valley river at coordinates: 32°15' N ; 35°30' E.
These villages are: Salhab ,Ibziq and Yarza .

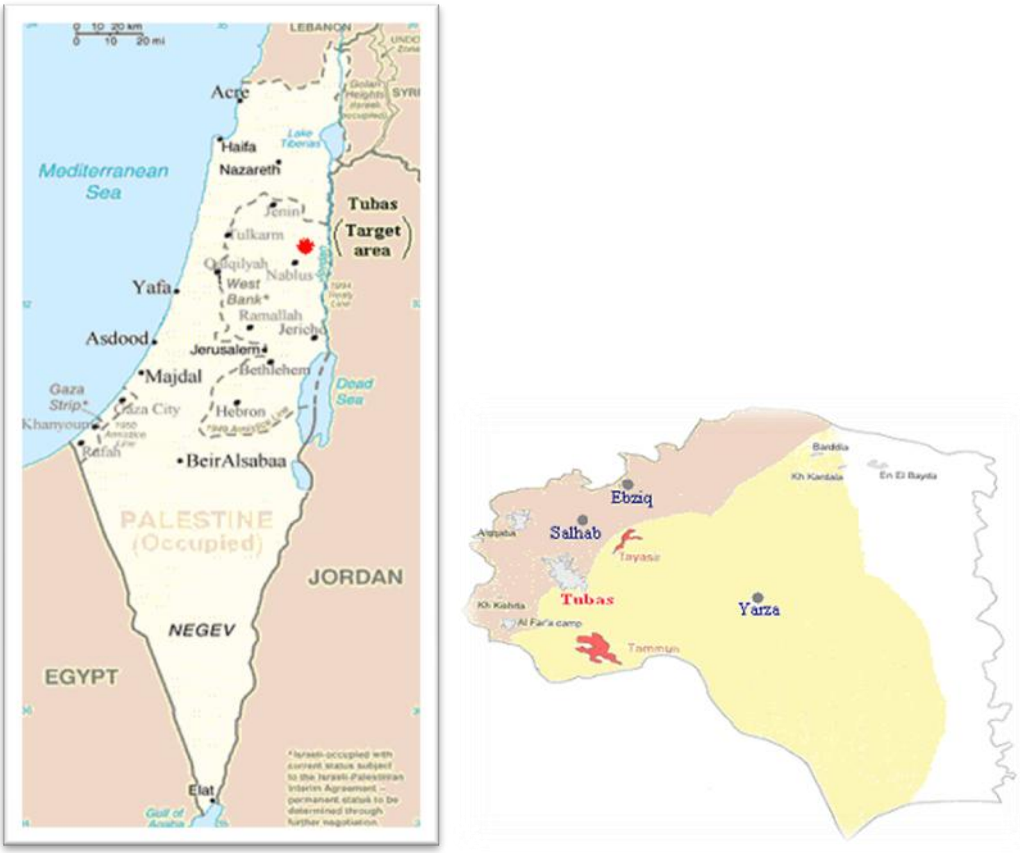


Figure (7): The target area (Tubas villages) non-electrified

Information about the three villages:

- The inhabitants work mainly in farming and cattle breeding.
- The inhabitants number of Salhab village amount to about 65 living in separated simple 10 houses.
- The inhabitants number of Ibziq village amount to be 165 living in separated simple 27 houses.
- The inhabitants number of Yarza village amount to about 85 living in separated simple 12 houses .
- The average daily energy needs in such villages are very low.
- The households use mainly wood and biomass for cooking and baking bread.

- These villages have no gas station and are at least 4 km far from the nearest high voltage grid (33 kV) .

The electrical load for a simple house in these villages is summarized in Table (4-1) :

Propose connected load	Quantity	consumed power	Hours /day	Energy /day
CFL	6	16	5	540
TV	1	60	8	480
refrigerator	1	70	16	1120
radio	1	10	1	10
Computer	1	150	3	450
Additional equipment	1	100	3	300
total		486		2.900 KWh/day

4.2)Design of DC decentralized pv power system components

4.2.1.1)salhab DC decentralized pv power system sizing :

1-Sizing the pv generator :

Since the houses of salhab village are almost similar to each others ,we take one of these houses and according to its electrical load ,we can design its pv power system .

The peak power of the pv generator (Ppv)is obtained as follows:
$Ppv = (El / \eta r \times PSH)$ ………………. equation (1)

Where:

- El (daily energy consumption) =2900Wh/day.
- The peak sun hours (PSH)=5.4
- The efficiency of the charge regulator (ηr)=.95

Substituting these values in equ (1) to obtain the peak power of the pv generator:

$Ppv = 2900/(.95 \times 5.4) = 565.3$ Wp

To install this power , a mono _crystalline pv module type SM55[222]of a gross area A=0.4267m2 ,rated at 12 VDC, And a peak power of P_{mpp} =53 Wp is selected.

The number of necessary pv modules (Npv) is obtained as :

$N_{pv} = Ppv/P_{MPP} = 565.3/53 = 12$ pv modules .

Each 2 modules will be connected in series to build 6 parallel strings

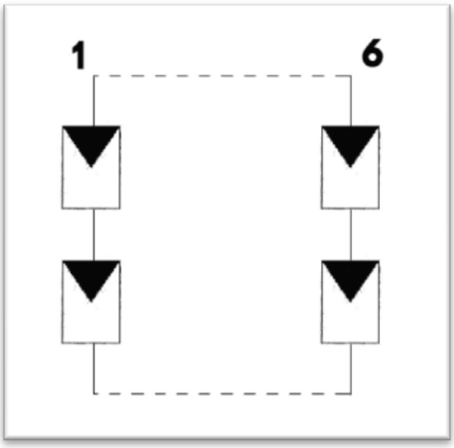


Figure (8)

Considering the open circuit voltage(v_{oc})=21.7v,And the short circuit current (I_{sc})=3.15A of SM55 at standard conditions , we obtain an open circuit voltage and short circuit current for this pv array of :

V_{oc} =21.7×2=43.4 v

I_{sc} =3.15×6=18.9A

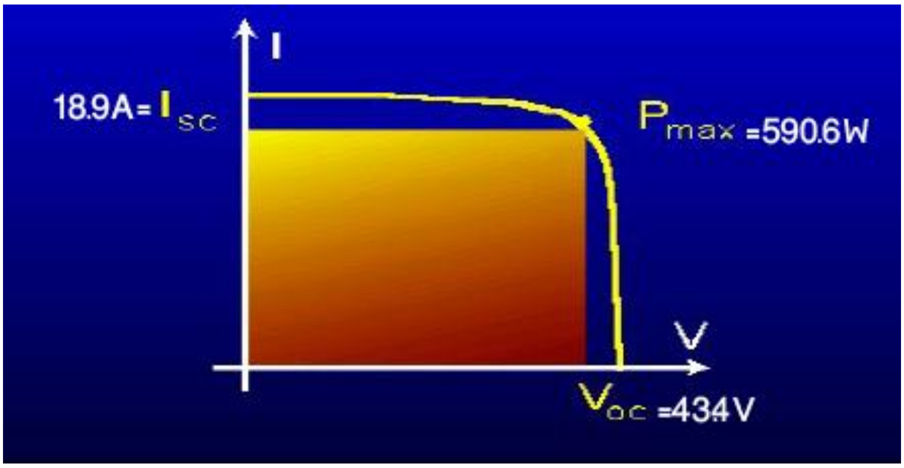
Accordingly ,the maximum power point (m_{pp}) of this array will be in the I-V curve at the coordinates :

V_{mpp} = 0.8× v_{oc} =34.72v

I_{mpp} =0.9× I_{sc} =0.9×18.9 =17.01A

The actual maximum power obtained from this array = 34.72×17.01=590.6 Wp.

Figure (9) : I-V characteristic



2-Sizing the battery block :

For this system we choose a regular batteries rated at 24v with ampere hour capacity (CAH) and watt hour capacity (CWH) as follow:

$CAH=E_l /(V_B \times DOD \times \eta_B)$ ………equ(2)

$CWH=CAH \times V_B$ ………equ(3)

Where V_B And η_B are the voltage and efficiency of battery block , while DOD is the permissible depth of discharge rate of a cell , assuming realistic values of η_B =0.8 , DOD=0.75,and V_B=24v ,we obtain :

$CAH= 2900/(24 \times .75 \times 0.8)=201.38$ Ah ≈ 240 Ah

$CWH =240 \times 24= 5760$ wh.

To install this capacity, two battery cells (each cell rated at 12v/240Ah) have to be connected in series to build a battery block of an output rated at 24v/240Ah.

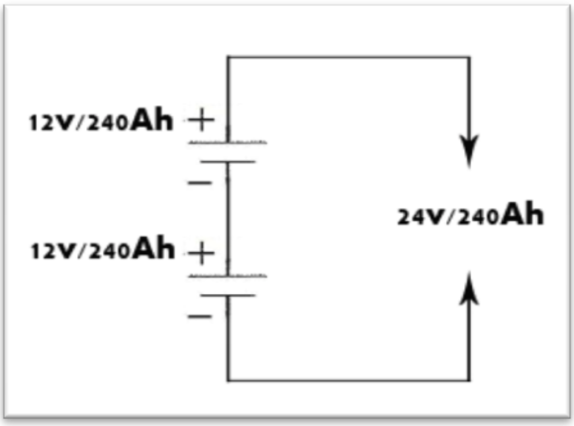


Figure (10)

4-The charge regulator sizing :

Input /output ratings of CR are fixed by the output of the pv array and V_B . In this case the appropriate rated power of CR must be equal to Ppv =565w ≈ 600w.

So,600 w CR have been selected for atypical unit of DC_ decentralized system .

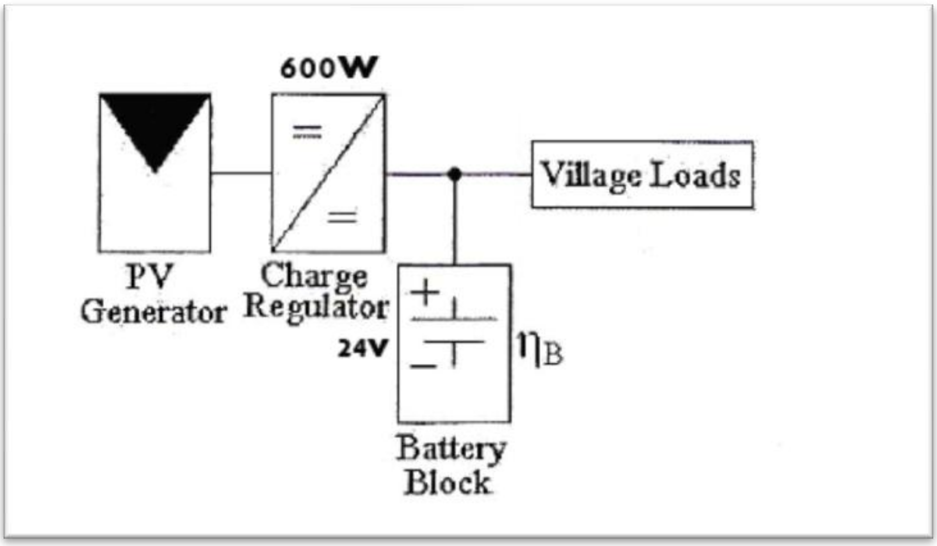


Figure (11)

4.2.1.2)Ibziq DC-decentralized pv power system sizing :

We need 27 units (similar to the calculated units for salhab village)

4.2.1.3) Yarza DC-decentralized pv power system sizing :

We need 12 units (similar to the calculated unit for salhab village)

(Note):

(There is a problem in the DC _decentralized pv power system since the DC loads are not found in the market)

4.2.2)Design of Ac decentralized pv power system :

The Ac _decentralized system is the same as DC_ decentralized system but in the Ac –decentralized we use inverter to convert DC into Ac since there is a lack in the DC equipment's in the markets .

4.2.2.1)Salhab AC-decentralized PV system sizing:

As in DC-decentralized PV system we design the PV system of one house and this applied to all houses in this village (since the loads almost similar).

1-Sizing of the pv _generator:

$Ppv = E_l/(\eta_v \times \eta r \times PSH)$

Where :

- E_l =2900 wh.
- PSH=5.4
- η_v =.9
- ηr=.95

We substitute these values in the above equation to obtain:

Ppv=2900 /(.9×.95×5.4)=628.1 Wp.

The number of necessary pv modules (of type SM55) $=Ppv/P_{mpp}$ =625.1/53=12 pv modules .

So,Each 2 modules will be connected in series to build 6 parallel strings.

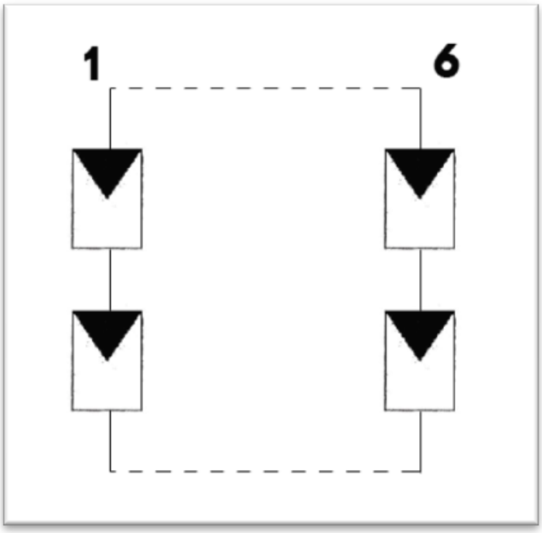


Figure (12)

Considering the open circuit voltage(v_{oc})=21.7v,And the short circuit current (I_{sc})=3.15A of SM55 at standard conditions , we obtain an open circuit voltage and short circuit current for this pv array of :

V_{oc} =21.7×2=43.4 v

I_{sc} =3.15×6=18.9A

Accordingly ,the maximum power point (m_{pp}) of this array will be in the I-V curve at the coordinates :

V_{mpp} = 0.8× v_{oc} =34.72v

I_{mpp} =0.9× I_{sc} =0.9×18.9 =17.01A

The actual maximum power obtained from this array = 34.72×17.01=590.6 Wp.

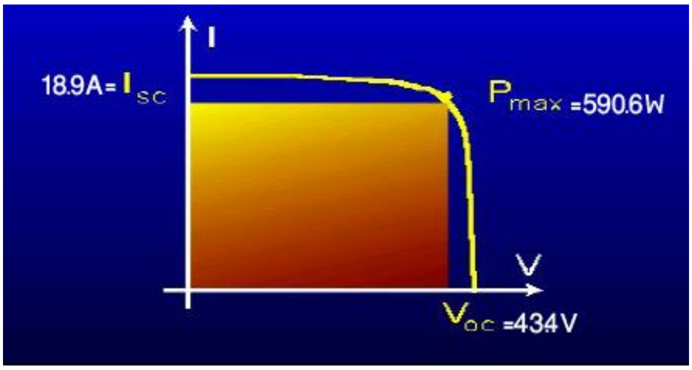


Figure (13)

2-Sizing the battery block :

For this system we choose a regular batteries rated at 24v with ampere hour capacity (CAH) and watt hour capacity (CWH) as follow:

$CAH=E_l /(V_B \times DOD \times \eta_B)$

$CWH=Cah \times V_B$

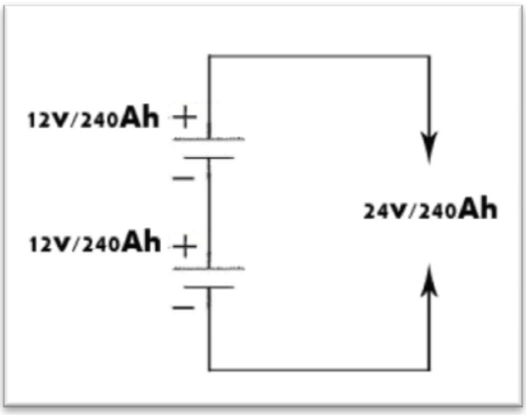
Where V_B And η_B are the voltage and efficiency of battery block , while DOD is the permissible depth of discharge rate of a cell , assuming realistic values of η_B =0.8 , DOD=0.75,and V_B=24v ,we obtain :

Cah=3222.2/(24 ×.75×0.8)=224 Ah≈ 240 Ah

Cwh =240×24= 5760 wh

To install this capacity ,2 battery cells (each cell rated at 12v/240Ah) have to be connected in series to build a battery block of an output rated

at 24v/240Ah as in figure ()



4-The charge regulator sizing :

Input /output ratings of CR are fixed by the output of the pv array and V_B . In this case the appropriate rated power of CR must be equal to

Ppv =600 W .

5-Inverter sizing :

The input of inverter have to be matched with the battery block voltage ,while its output should full fill the specifications of the electric grid of the village specified as 220v ,50 H_z(sinusoidal voltage) and 500 w ,600 VA where the power factor is considered to be .87

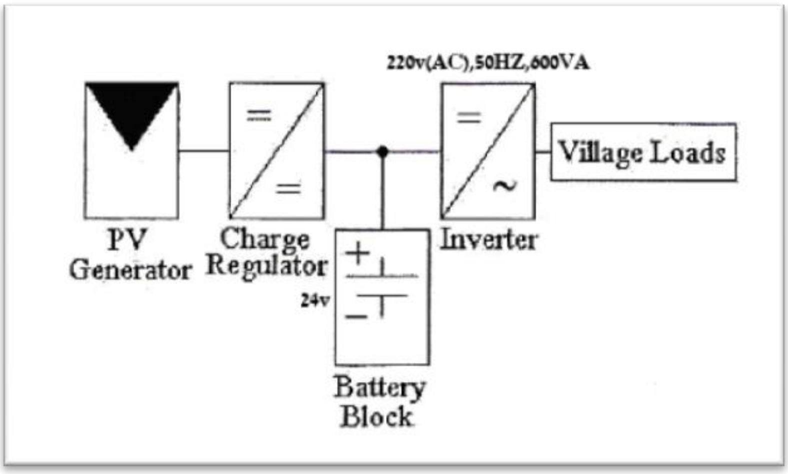


Figure (15)

4.2.2.2)Ibziq AC-decentralized pv power system sizing :

We need 27 units (similar to the calculated unit for salhab village).

4.2.2.3) Yarza DC-decentralized pv power system sizing :

We need 12 units (similar to the calculated unit for salhab village)

4.3) sizing of centralized pv system components for non-electrified small villages in Tubas area :

4.3.1) design of single phase centralized pv power system for salhab village :

1-Sizing of the pv _generator:

The peak power of the pv generator (Ppv) is obtained as follows :

$Ppv = E_l/(\eta_v \eta r\ PSH)$

Where:

E_l (daily energy consumption)=2900 Wh,

The peak sun hours (PSH)=5.4 ,

The efficiencies of the system components ((η_v =.9, ηr=.95)

Substituting these values in the above equation :

Ppv =29000/(.95× .9× 5.4) =6281.1 Wp

Using a mono _crystalline Pv module type SM55[222]of agross area of A pv=0.4267 m^2 ,rated at 12 V_{DC} and apeak power of p_{mpp} =53 Pw .

The number of necessary pv modules (Npv) is obtained as

: $Npv = Ppv/p_{mpp}$=6281.1/53=120 module.

Each 4 modules will be connected in series to build 30 parallel strings

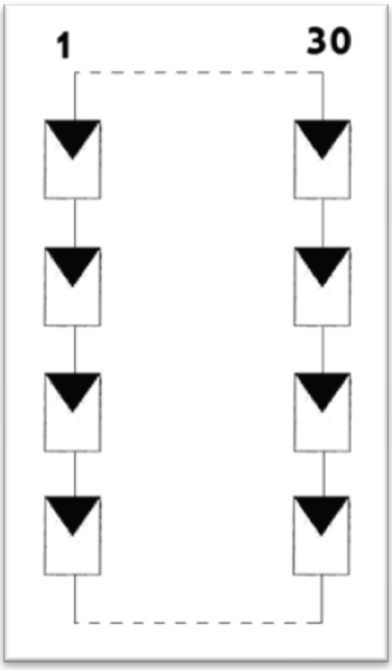


Figure (16)

Considering the open circuit voltage(v_{oc})=21.7v,And the short circuit current (I_{sc})=3.15A of SM55 at standard conditions , we obtain an open circuit voltage and short circuit current for this pv array of :

V_{oc} =21.7×4=86.8 v

I_{sc} =3.15×30=94.5A

Accordingly ,the maximum power point (m_{pp}) of this array will be in the I-V curve at the coordinates :

V_{mpp} = 69.44v

I_{mpp} = 85A

The actual maximum power obtained from this array = 96.44×85=5902.4 Wp.

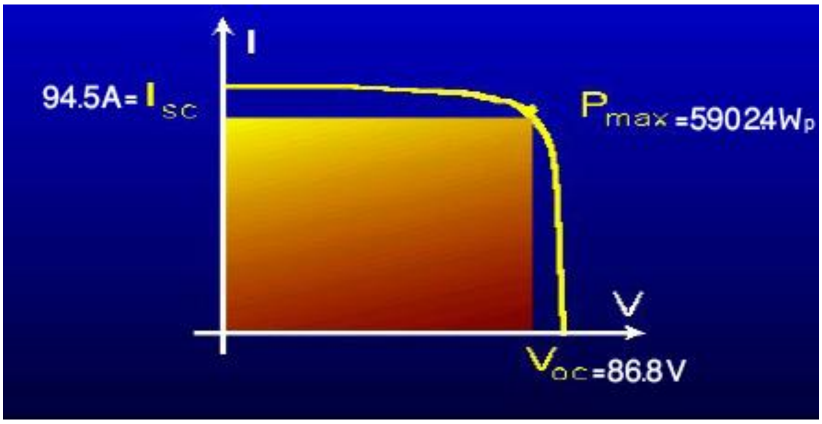


Figure (17)

2-Sizing the battery block :

For this system we choose block batteries rated at 48v with ampere hour capacity (CAH) and watt hour capacity (cwh) as follow:

$CAH=E_l /(V_B \times DOD\times \eta_B)$

$CWH=Cah \times V_B$

Where V_B And η_B are the voltage and efficiency of battery block , while DOD is the permissible depth of discharge rate of a cell , assuming realistic values of η_B =0.8 , DOD=0.75,and V_B=48v and for a period of 1.5 days without sun ,we obtain :

Cah=1.5× 32222.2/(48 ×.75×0.8)=1678 Ah

Cwh =1678×48= 80544 wh

To install this capacity ,24 battery cells (each cell rated at 2v/1678Ah) have to be connected in series to build a battery block of an output rated at 48/1678Ah.

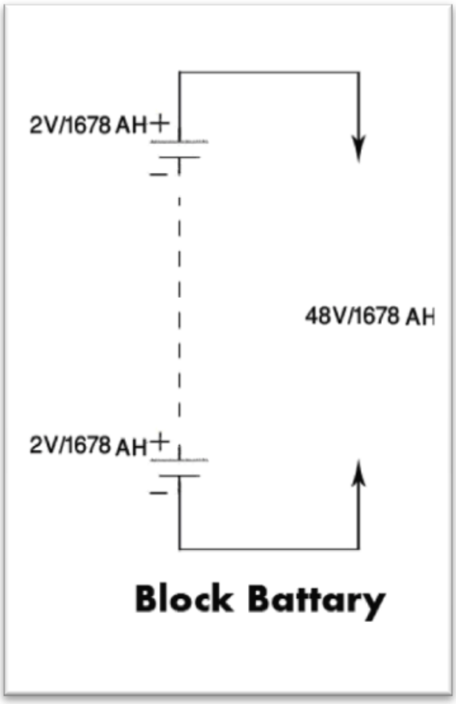


Figure (18)

3-The charge regulator and inverter sizing :

Input /output ratings of CR are fixed by the output of the pv array and V_B .

In this case the appropriate rated power of CR is 6kw .

The output of inverter have to be matched with the battery block voltage ,while its output should full fill the specifications of the electric grid of the village specified as :

220v,50Hz (sinusoidal voltage) and 5 Kw

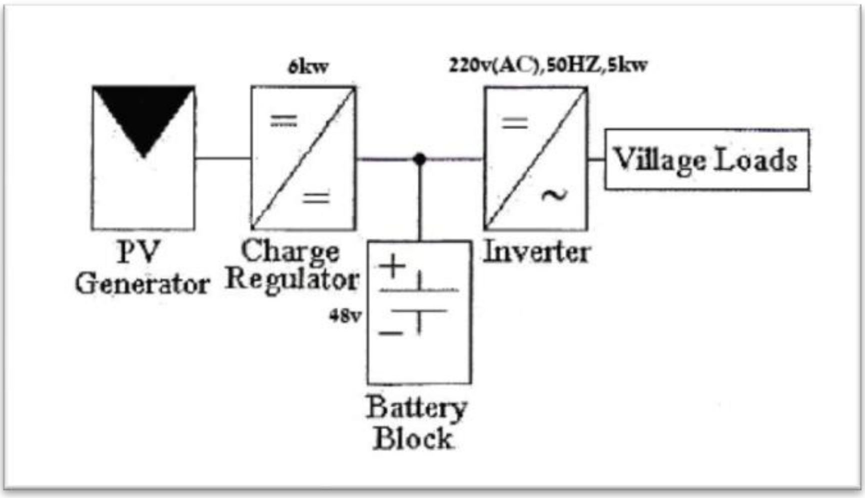


Figure (19)

4.3.2) design of single phase centralized pv power system of Yarza village:

1-Sizing of the pv _generator:

The peak power of the pv generator (Ppv) is obtained as follows :

$Ppv = E_l/(\eta_v \, \eta r \; PSH)$

Where:

E_l (daily energy consumption)=2900 wh,

The peak sun hours (PSH)=5.4 ,

The efficiencies of the system components ((η_v =.9, ηr=.95)

Substituting these values in the above equation :

Ppv =2900×12 /(.95× .9× 5.4) =7537 Wp

Using a mono _crystalline Pv module type SM55[222]of agross area of A pv=0.4267 m^2 ,rated at 12 V_{DC} and a peak power of p_{mpp} =53 Pw .

The number of necessary pv modules (Npv) is obtained as :

Npv =Ppv/p_{mpp}=7537/53=142 module. (144 is taken as a number of modules)

Each 8 modules will be connected in series to build 18 parallel strings .

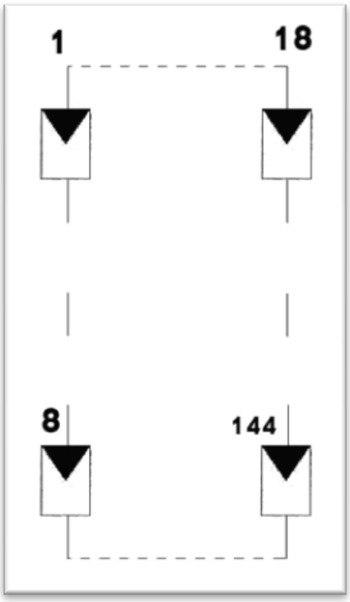


Figure (20)

Considering the open circuit voltage(v_{oc})=21.7v,And the short circuit current (I_{sc})=3.15A of SM55 at standard conditions , we obtain an open circuit voltage and short circuit current for this pv array of :

V_{oc} =173.6v

I_{sc} =56.7A

Accordingly ,the maximum power point (m_{pp}) of this array will be in the I-V curve at the coordinates :

V_{mpp} = 139v

I_{mpp} = 51A

The actual maximum power obtained from this array = 139×51=7098Wp.

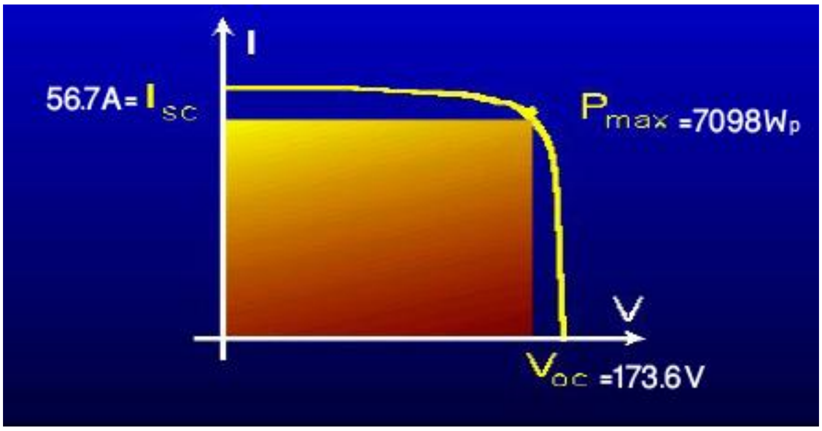


Figure (21)

2-Sizing the battery block :

Lead _Acid battery cells (block type)will be used in this system .

capacity (CAH) and watt hour capacity (cwh) as follows:

$CAH=E_l /(V_B \times DOD\times \eta_B)$

$CWH=Cah \times V_B$

Where V_B And η_B are the voltage and efficiency of battery block , while DOD is the permissible depth of discharge rate of a cell , assuming realistic values of η_B =0.85 , DOD=0.85,and V_B=100v and for a period of 1.5 without sun ,we obtain :

Cah= 1.5× 38666.7/(100 ×.85×0.85)=802 Ah

Cwh =802×100= 80.2 kwh

To install this capacity ,50 battery cells (each cell rated at 2v/802Ah) have to be connected in series to build a battery block of an output rated at 100VDC/802Ah.

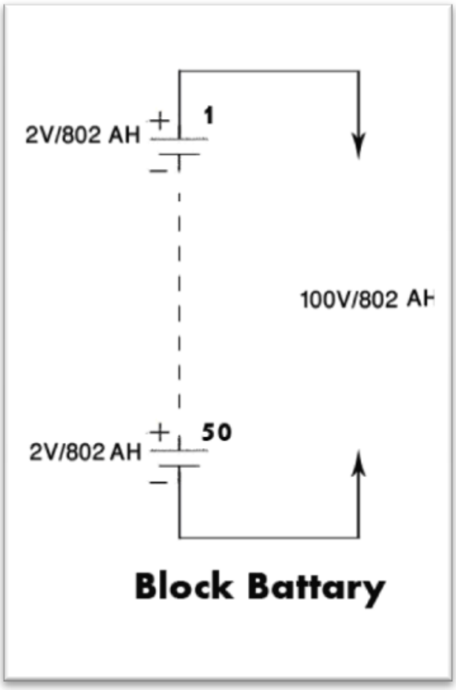


Figure (22)

3-The charge regulator and inverter sizing :

Input /output ratings of CR are fixed by the output of the pv array and

V_B .

In this case the appropriate rated power of CR is 8kw .

4-sizing of inverter:

The output of inverter have to be matched with the battery block voltage ,while its output should full fill the specifications of the electric grid of the village specified as :

220v,50Hz (sinusoidal voltage) and 6 Kw ,7 kvA

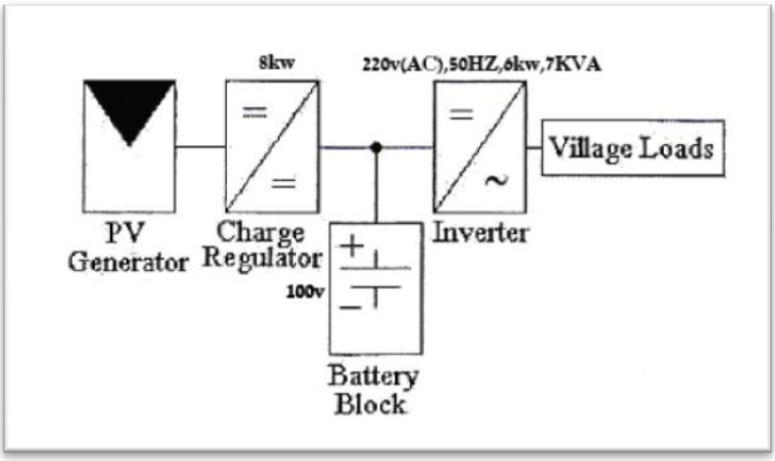


Figure (23)

4.3.3)Design of three phase centralized pv power system of Ibziq village :

1-Sizing of the pv _generator:

The peak power of the pv generator (Ppv) is obtained as follows :

$Ppv = E_l/(\eta_v \, \eta r \; PSH)$

Where:

E_l (daily energy consumption)=2900 Wh,

The peak sun hours (PSH)=5.4 ,

The efficiencies of the system components ((η_v =.95, ηr=.95)

Substituting these values in the above equation :

Ppv =2900×27 /(.95× .95× 5.4) =16066 Wp

Using a mono _crystalline Pv module type SM55[222]of agross area of A pv=0.4267 m^2 ,rated at 12 V_{DC} and apeak power of p_{mpp} =53 Pw .

The number of necessary pv modules (Npv) is obtained as

: Npv =Ppv/p_{mpp}=16066/53=304 module.

Each 16 modules will be connected in series to build 19 parallel strings :

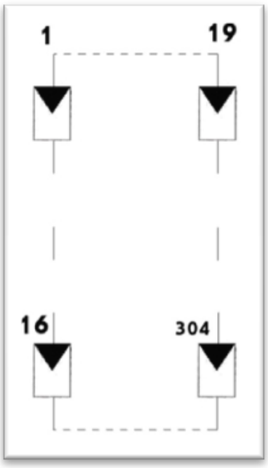


Figure (24)

Considering the open circuit voltage(v_{oc})=21.7v,And the short circuit current (I_{sc})=3.15A of SM55 at standard conditions , we obtain an open circuit voltage and short circuit current for this pv array of :

V_{oc} =347.2v

I_{sc} =59.58A

Accordingly ,the maximum power point (m_{pp}) of this array will be in the I-V curve at the coordinates :

V_{mpp} = 277.76v

I_{mpp} = 53.9A

The actual maximum power obtained from this array = 277.76×53.9=14971.3Wp.

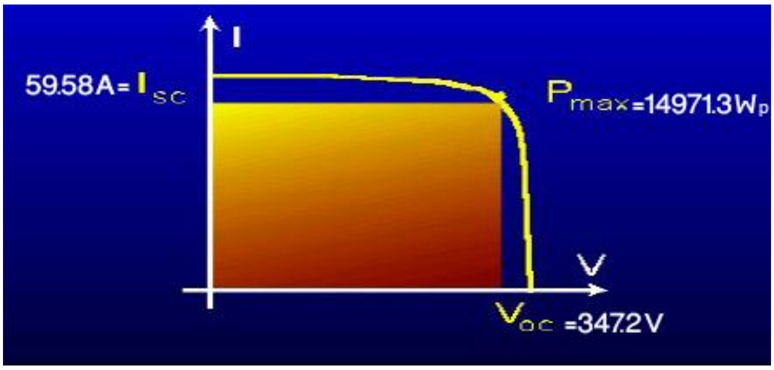


Figure (25)

2-Sizing the battery block :

Lead _Acid battery cells (block type)will be used in this system .

capacity (CAH) and watt hour capacity (cwh) as follows:

$CAH=E_l /(V_B \times DOD \times \eta_B)$

$CWH=Cah \times V_B$

Where V_B And η_B are the voltage and efficiency of battery block , while DOD is the permissible depth of discharge rate of a cell , assuming realistic values of η_B =0.85 , DOD=0.85,and V_B=220v and for a period of 1.5 days without sun ,we obtain :

Cah= 1.5×82421/(220 ×.85×0.85)=777Ah

Cwh =777×220= 171 kwh

To install this capacity ,110 battery cells (each cell rated at 2v/777 Ah) have to be connected in series to build a battery block of an output rated at 220VDC/777Ah.

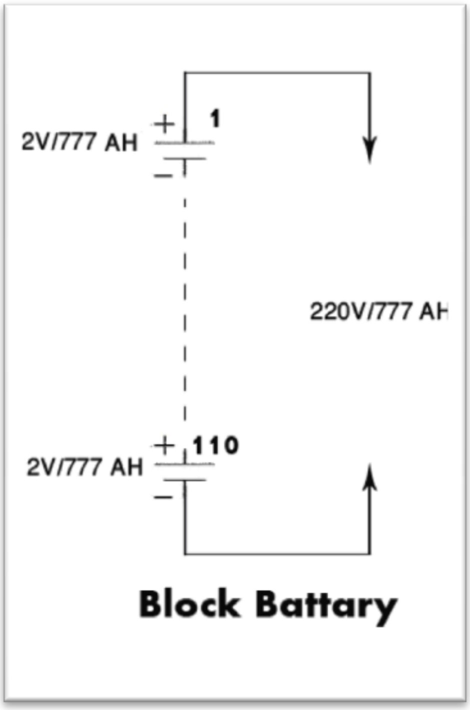


Figure (26)

4-The charge regulator and inverter sizing :

Input /output ratings of CR are fixed by the output of the pv array and V_B .

In this case the appropriate rated power of CR is 16kw .

5-sizing of the inverter:

The output of inverter have to be matched with the battery block voltage ,while its output should full fill the specifications of the electric grid of the village specified as :

220v,50Hz (sinusoidal voltage) and 13 Kw ,15 kvA

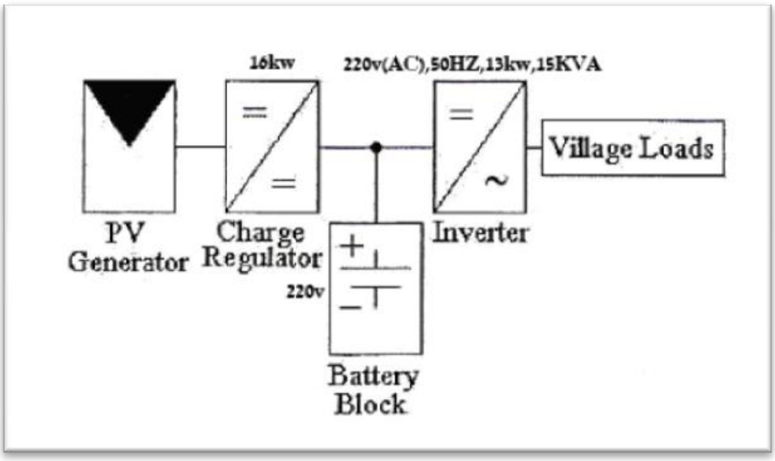

16kw
220v(AC),50HZ,13kw,15KVA
Village Loads
PV
Generator
Charge
Regulator
Inverter
220v
Battery
Block

Figure (27)

CHAPTER FIVE

ECONOMIC MODEL FOR SELECTION OF OPTIMUM CONFIGURAYION OF PV SYSTEMS

5.1 Introduction:

Engineers seek solutions to problems, and the economic viability of each potential solution is normally considered along with the technical aspects.

For each design, there are usually many possible alternatives. One option that must be considered in each analysis is often the choice which achieves technical aspects and the opportunity cost of making one choice over another must also be considered.

In this chapter, we will study each possible solution in economic point view to select optimum configuration.

5.2 Economical evaluation of energy supply systems:

5.2.1 The economic evaluation of DC Decentralized pv power system for Tubas villages:

For Salhab village,

Table (5-1) :The associated costs of the pv power system:

NO	Component ,material or work	Quantity	Unit price($)	Total price($)	Life time /years
1	Pv- module (SM55)	600 wp	4	2400	20
2	Support structure			170	20
3	Battery cells	2	150	300	10
4	Charge regulator (with mpp)	1	150	150	20
5	Circuit breakers and switches			35	20
6	Installation material			200	
7	Civil work			250	
8	**Total system cost**			**3805**	

>> The total cost for 10 houses in Salhab village =10 ×3805=**38050 $**.

Evaluation of the cost of 1 KWh :

- Total energy out from the pv system = 1058.5 KWh/year.
- The total fixed cost of this system = 3805 $
- Depreciation factor = 10 % .
- Maintenance cost = 2.5 %* fixed cost .

Annual fixed cost = depreciation factor * total fixed cost
Annual fixed cost = 0.1*3805 = 380.5 $.

Annual running cost = maintenance cost

Annual running cost = 0.025 * 3805 = 95.125 $.

Total annual cost =total Annual fixed cost + total Annual running cost.

Total annual cost = 380.5 + 95.125 = 475.625 $.

The cost of unit generated (1 KWh) = total annual cost / total energy output.

The cost of unit generated (1 KWh)=475.625/1058.5 = 0.449 $/KWh.

For Ibziq village ,

We have 27 similar simple houses ,so we need 27 similar units

>>the total fixed cost will be 27 × 3805=102735 $

>>the cost of 1 KWh =0.449 $/KWh .

For Yarza village ,

We have 12 similar houses ,so we need 12 similar units

>> the total capital cost will 12 ×3805=45660 $.

>> the cost of 1 KWh =0.449 $/KWh.

5.2.2 The economic evaluation of AC Decentralized pv power system for Tubas villages:

For Salhab village,

Table (5-2): The associated costs of the pv power system:

NO	Component ,material or work	Quantity	Unit price($)	Total price($)	Life time /years
1	Pv- module (SM55)	600 wp	4	2400	20
2	Support structure			170	20
3	Battery cells	2	150	300	10
4	Charge regulator (with mpp)	1	150	150	20
5	Inverter	1	500	500	20
6	Circuit breakers and switches			35	20
7	Installation material			200	
8	Civil work			250	
	Total system cost			**4305**	

>> The total cost for 10 houses in Salhab village =10 ×4305=43050$

Evaluation of the cost of 1 KWh :

- Total energy out from the pv system = 1058.5 KWh/year.
- The total fixed cost of this system = 4305 $
- Depreciation factor = 10 % .
- Maintenance cost = 2.5 %* fixed cost .

Annual fixed cost = depreciation factor * total fixed cost
Annual fixed cost = 0.1*4305 = 430.5$.

Annual running cost = maintenance cost

Annual running cost = 0.025 * 4305 = 107.625 $.

Total annual cost =total Annual fixed cost + total Annual running cost.

Total annual cost = 430.5 + 107.625 = 538.125 $.

The cost of unit generated (1 KWh) = total annual cost / total energy output.

The cost of unit generated (1 KWh)=538.125/1058.5 = 0.508 $/kwh.

For Ibziq village ,

We have 27 similar simple houses ,so we need 27 similar units

>>the total capital cost will be 27 $\times$ 4305=116235 $

>> the cost of 1 KWh =0.508 $

For Yarza village ,

We have 12 similar houses ,so we need 12 similar units

>> the total capital cost will 12 $\times$ 4305=51660 $.

>> the cost of 1 KWh =0.508 $.

5.2.3 The cost of centralized pv power system for Tubas villages:

5.2.3.1 Single phase Ac_ centralized PV power system for Salhab village:

Table (5-3): The associated cost of pv power system is:

NO	Component ,material or work	Quantity	Unit price($)	Total price($)	Life time /years
1	Pv- module (SM55)	6360 wp	4	25440	20
2	Support structure			2400	20
3	Battery cells	24	150	20136	10
4	Charge regulator (with mpp)	1	3000	3000	20
5	Inverter	1	4700	4700	20
6	Circuit breakers and switches			220	20
7	Installation material			150	
8	Civil work			2000	

9	Installation work	1000
10	**Total system cost**	**79182**

Evaluation of the cost of 1 KWh :

- Total energy out from the pv system = 10585 KWh/year.
- The total fixed cost of this system = 79182 $
- Depreciation factor = 10 % .
- Maintenance cost = 2.5 %* fixed cost .
- Labor cost = 1200 $/year

Annual fixed cost = depreciation factor * total fixed cost
Annual fixed cost = 0.1*79182 = 7918.2$.

Annual running cost = maintenance cost + labor cost

Annual running cost = 0.025 * 79182+ 1200 = 3179.55 $.

Total annual cost =total Annual fixed cost + total Annual running cost.

Total annual cost = 7918.2 + 3179.55 = 11097.75 $.

The cost of unit generated (1 KWh) = total annual cost / total energy output.

The cost of unit generated (1 KWh)= 11097.75 /10585 = 1.048$/KWh.

5.2.3.2 Single phase Ac_ centralized PV power system for Yarza village:

Table (5-4): The associated cost of pv power system is:

NO	Component ,material or work	Quantity	Unit price($)	Total price($)	Life time /years
1	Pv- module (SM55)	7526wp	4	25440	20
2	Support structure			2400	20
3	Battery cells	50	250	20136	10
4	Charge regulator (with mpp)	1		4500	20
5	Inverter	1		5000	20
6	Circuit breakers and switches			240	20
7	Installation material			180	
8	Civil work			2200	
9	Installation cost			1150	
10	Total system cost			81382	

Evaluation of the cost of 1 KWh :

- Total energy out from the pv system = 12702 KWh/year.
- The total fixed cost of this system =81382 $
- Depreciation factor = 10 % .
- Maintenance cost = 2.5 % *fixed cost .
- Labor cost = 1200 $/year

Annual fixed cost = depreciation factor * total fixed cost
Annual fixed cost = 0.1*81382 = 8138.2$.

Annual running cost = maintenance cost + labor cost

Annual running cost = 0.025 * 81382+ 1200 = 3234.55 $.

Total annual cost =total Annual fixed cost + total Annual running cost.

Total annual cost = 8138.2 + 3234.55 = 11372.75 $.

The cost of unit generated (1 KWh) = total annual cost / total energy output.

The cost of unit generated (1 KWh)= 11372.75 /12702 = 0.895 $/ KWh.

5.2.3.3 Three phase Ac_ centralized PV power system for Ibziq village:

Table (5-5): The associated cost of pv power system is:

NO	Component ,material or work	Quantity	Unit price($)	Total price($)	Life time /years
1	Pv- module (SM55)	16112wp	4	64448	20
2	Support structure			5000	20
3	Battery cells	110	250	42735	10
4	Charge regulator (with mpp)	1	6550	6550	20
5	Inverter	1	8500	8500	20
6	Circuit breakers and switches			550	20
7	Installation material			350	
8	Civil work			4000	
9	Installation cost			4000	
10	poles	8		1830	
11	Total system cost			180,698	

Evaluation of the cost of 1 KWh :

- Total energy out from the pv system = 28579.5 KWh/year.
- The total fixed cost of this system =180,698 $
- Depreciation factor = 10 % .
- Maintenance cost = 2.5 % fixed cost .
- Labor cost = 1200 $/year

Annual fixed cost = depreciation factor * total fixed cost
Annual fixed cost = 0.1*180,698 = 18069.8 $.

Annual running cost = maintenance cost + labor cost

Annual running cost = 0.025 * 180698+ 1200 = 5717.45 $.

Total annual cost =total Annual fixed cost + total Annual running cost.

Total annual cost = 18069.8 + 5717.45 = 23787.25 $.

The cost of unit generated (1 KWh) = total annual cost / total energy output.

The cost of unit generated (1 KWh)= 23787.25 /28579.5 = 0.832 $/ KWh.

5.3 Conclusions:

Table (5-6): The table below shows the associated cost of 1kwh generated from each configuration:

	The cost of 1 KWh in $		
Village / System type	**Salhab village**	**Yarza village**	**Ibziq village**
Dc_decentralized pv power system	**0.449**	**0.449**	**0.449**
Ac_decentralized pv power system	**0.508**	**0.508**	**0.508**
Ac_centralized pv power system	**1.048**	**0.895**	**0.832**

Conclusion :

1- The renewable energy specially solar energy available in Palestine and we can use it in many useful ways .

2-There are many ruler villages in Palestine which make it not efficient to electrify it by the grid and for this reason we turn to solar energy as a solution.

3- As an example of a non electrified villages in Palestine we take Salhab , Yarza, Ibziq villages in Tubas in order to design a pv power system.

4- We apply the centralized and decentralized pv power system in each village and we notice that the DC_decentralized pv power system more cheaper than the other way of design but it is not an applicable system.

5- We notice that the cost of 1 KWh become more cheaper when the number of houses increase in the village in centralized system.

6- The cost of 1 KWh in AC decentralized pv power system cheaper than it in AC centralized pv power system so we can apply it .

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