An-Najah National University

Faculty of Graduate studies

Management of Electrical Network with PV System and Genset, case study "An-Najah Hospital".

By

Ahmad Nabhan Abdel-Razaq Jallad

Supervisor

Dr. Imad Ibrik

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Clean Energy and Conservation Strategy Engineering, Faculty of Graduate Studies, An-Najah National University, Nablus – Palestine.

2017

Management of Electrical Network with PV System and Genset, case study "An-Najah Hospital".

By

Ahmad Nabhan Abdel-Razaq Jallad

This thesis was defended successfully on 19/7/2017 and approved by:

Defense committee members	**Signature**
- Dr. Imad Ibrik/ Supervisor	…………
- Dr. Basim Alsayed/External Examiner	…………
- Dr. Mohammad Alsayed/Internal Examiner	…………

Dedication

To Palestine

To my parents Nabhan & Lubna

To my sisters Tala, Tina and Anood

To my friends

To my colleagues

To my teachers

To everyone who works in this field

To all of them

I dedicate this work

Acknowledgement

First of all, thanks Allah

I would like to thank my family for their support and love that they have always given me.

I would like to express my special thanks and appreciation to my Dr. Imad Ibrik for his continuous support, guidance and encouragement during this work.

I would like to thank also the Energy Research Center and the staff of the Clean Energy and Conservation Strategies Master Program at An-Najah National University.

الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

إدارة شبكات الكهرباء بوجود مولدات الديزل وأنظمة الخلايا الشمسية / دراسة حالة " مستشفى النجاح الوطني الجامعي "

أقر بأن ما شملت عليه هذه الرسالة إنّما هو نتاج جهدي الخاص، باستثناء ما تمّت الإشارة إليه حيثما ورد، وأنّ هذه الرسالة ككل، أو أيّ جزء منها لم يقدّم من قبل لنيل أيّ درجة أو لقب علميّ لدى أيّ مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

Table of Contents

List of Tables

List of Figures

List of Equations

List of Appendix

Abbreviations

PV	Photovoltaic
Wp	Watt Peak
kWp	Kilo Watt Peak
DSM	Demand Side Management
kWh	Kilo Watt Hour
GHG	Green House Gases
L.F	Load Factor
P.f	Power Factor
EE	Energy Efficiency
DR	Demand Response
DG	Diesel Gensets
GW	Giga Watt
kW	Kilo Watt
PNA	Palestinian National Authority
JDECO	Jerusalem District Electricity Company
NEDCO	Northern Electricity Distribution Company
HEPCO	Hebron Electricity Distribution Company
SELCO	Southern Electric Company
TDECO	Tubas District Electricity Company
IEC	Israel Electric Corporation
kV	Kilo Volt
$	U.S Dollar
WB	West Bank
Div.F	Diversity Factor
KPI	Key Performance Indicators
SAIDI	*System Average Interruption Duration Index*
SAIFI	*System Average Interruption Frequency Index*
LPG	Liquefied Petroleum Gas

CAIDI	*Customer Average Interruption Duration Index*
ASAI	Average Service Availability Index
ETCO	Engineering for Trading and Contracting Company
ATS	Automatic Transfer Switch
AMF	Automatic Mains Failure
kVA	Kilo Volt Ampere
A	Ampere
cm	Centimeter
L	Liter
h	Hour
NIS	New Israeli Shekel
DC	Direct Current
AC	Alternative Current
V	Volt
Ah	Ampere Hour
CC	Capitalized Cost
CC_G	Generators Capitalized Cost
Q	Quarter
BOS	Balance of System
c-Si	Crystalline Silicon
O&M	Operation and Maintenance
PII	Permit, Inspection and Interconnection
Wdc	Watts direct current
Wac	Watts alternating current
G&A	General and Administrative
Vdc	Volts direct current
EPC	Engineering, Procurement and Construction
MW	Mega Watt
R&R	Repair and Replacement
yr.	Year
UPS	Uninterruptable Power Supply

PERC	Palestinian Electricity Regulatory Council
ENS	Energy Not Supplied
ABM	Advanced Battery Management
CC_{PV}	PV Systems Capitalized Cost
m^2	Meter square
VAT	Value Added Tax
L.V	Low Voltage
M.V	Medium Voltage
COE	Cost of Energy
LCOE	Levelized Cost of Energy
HOMER	Hybrid Optimization Model for Electric Renewables
NPC	Net Present Cost
SB	Storage Battery
TOU	Time Of Use
COE_W	Average Cost Of Energy of Winter season
COE_S	Average Cost Of Energy of Summer season
$COE_{Sp/A}$	Average COE of Autumn and Spring seasons

Management of Electrical Network with PV System and Genset, case study "An-Najah Hospital".

By

Eng. Ahmad Nabhan Abdel-Razaq Jallad

Supervisor

Dr. Imad Ibrik

Abstract

This thesis is based on searching for solutions and alternatives, which in turn may help overcome, solve and reduce the impact of all the obstacles and challenges that face, or may face the electricity networks in Palestine, including challenges such as supply constraints and lack of energy constraints, especially the problem of increasing demand during times of peak demand, and having the electrical current cut off because of that. It is also based on thinking carefully about how to minimize the impact and consequences of these challenges in different ways, whether economic, or non-economic, depending on the available conditions to achieve results that reduce the lack of capacity and help in solving the problems of high demand in the period of the load peak, through analyzing each of the challenges which encounter the electricity networks in Palestine, specifying all the methods of energy management and development, also through using and showing all the methodologies which may help in reducing the electrical capacity and the electrical consumption; by taking samples and places as case studies to help in analyzing, and reaching results. As in the case of An-Najah National University Hospital in Nablus, whose daily load

was studied, and it was thought about applying all possible and available conservation methods, all possible energy management methodologies and

the application of different tariff systems, such as the TOU tariff . That would happen just if applying the peak management steps, which are suggested in this thesis, and try to cover the load peak period by using generators and solar cells connected to the grid or unconnected, to get the best option and the lowest cost of energy production, which was estimated with 75% of the solar cells in the presence of the network, without the need to use energy storing batteries, and so the same result through 25% load feeding by using electric diesel generators and 75% of solar cell systems for independent systems not connected to the network.

Introduction

Most of countries nowadays seek to find an optimal solution to conserve the electrical consumption according to each case and its nature. Some studies were held in foreign countries on both off-grid and on-grid systems as a way to utilize the renewable energy systems in solving their problems and to make electrical conservation as much as possible, as a study from multiple aspects including economic, environmental and technical.

Firstly, for most of off-grid systems as it is in some rural and/or undeveloped regions where there is no grid power and more water is needed, the residents of these areas are looking for another way to get electricity, the choices for powering are usually solar systems or a fuel driven engine, usually diesel generators. Diesel generators are typically characterized by a lower initial cost but a very high operation and maintenance costs while the solar system is the opposite, with a higher initial cost but very low on-going operation and maintenance costs, also the initial cost of solar system is often daunting to donors and project implementers who are tempted to stretch their budgets as far as possible to reach the greatest number of beneficiaries by using a low first-cost option without looking at the environmental and economic aspects of the future.

Various studies were conducted by many competent authorities tried to solve such problems. At first, the outcome showed that PV system is better than fuel driven engines. For instance, in Mexico; a Sandia National Lab study of 3 different sized solar pumping systems (106 Wp, 848 Wp, 1530

Wp) showed that all had lower life-cycle costs than diesel-powered pumps. The PV systems vs. diesel had paybacks of 2, 2.5 and 15 years respectively when replacing fuelled pumps (gas or diesel). [1] In.

comparison between fuelled pumps vs. PV, a German study showed PV-powered pumps has the lowest life-cycle costs for PV array sizes of 1kWp and 2kWp and the same cost as fuel pumps for power ratings of 4kWp. (The largest PV pump SELF has installed to date for village water supply is 1.9kWp). [2] Secondly; they showed that PV/Diesel/battery hybrid power system is feasible in terms of economics as well as technically. It has also less greenhouse gas emission, such as in technical and Economic Assessment of solar PV/diesel Hybrid Power System for Rural School Electrification in Ethiopia. [3]

Secondly, for on-grid systems; Most of the electrical generation and distribution companies in Palestine would benefit from having no electrical overload especially at peak demand during the day, so the electrical companies in Palestine impose different tariffs during the day to maintain the system stable and to reduce the peak demand all times as much as possible, so we can notice some changes in tariff value also the electrical bills during the day.

Jerusalem District Electricity Company (JDECO) is one of the companies that tracking time of use tariff system, it changes the tariff during the day and always the highest tariffs are in the maximum demand period of the city or the company's customers, so that will lead the consumers to try to conserve their electrical consumption, as well as the distribution of their use of electricity to reduce the peak demand during the day, helping them to reduce their electricity bills. As a result; the company doesn't need to purchase large ratings of power to meet the consumers need and the outages of power because of the maximum demand and the occurrence of other problems. The lack of knowledge and experiences in the methods of energy conservation cause a problems in the high value bills and multiple problems. Some studies have resolved these problems through the use of a hybrid system at the peak time or at all times, such as the article studied in Malaysia for optimal sizing of building integrated hybrid PV/diesel generator system for zero load rejection in 2011[4,5] shown that the optimized system exhibits a minimum system cost.

In our research we will study the Optimum configuration between Network (grid), PV system and Gensets (generators) at different tariff structure for An-Najah National University Hospital – Nablus, from multiple aspects, whether economic, environmental or technical to identify any of these systems can be the best system at peak time, or at other times, whether individually or in a hybrid.

Objectives

The main objective of this thesis is to analyse the loads - special case An-Najah Hospital; to make a peak demand management and demand side management (DSM), from technical and financial point of view. The specific objectives:

1. Improving the network efficiency through the optimal use of energy in the hospital, especially during the peak time and choosing the perfect choice as between each of the three network systems, solar cells and diesel generator.

2. Reducing the electricity bill for the hospital as much as possible through the optimal use of electricity during the day and especially at the peak time by studying of the three cases available.

3. A comprehensive study of the hospital to get the best results from the economic, environmental and technical aspects.

Thesis Structure

The thesis work has been summarized in seven chapters.

Chapter One: Management of Electrical Network, Literature Review.

This chapter illustrates the management of peak demands for the loads also it shows the demand side management and the managements by using other sources.

Chapter Two: Demand Problems in the Palestinian Electrical Networks.

This chapter illustrates and describes the energy management problems in Palestine such as supply constraints and the lack of electricity also the suggested solutions for solving the peak demand problems.

Chapter Three: Using Renewable Energy and Genset for Covering the Peak Demand.

This chapter illustrates and describes the effects of using solar PV and diesel generators for the peak demand management also describes how to select the elements of these systems and comparison between these two sources for solving the peak problems.

Chapter Four: Economical Evaluation of using PV and Diesel Genset for Solving Peak Problems.

This chapter illustrates the modeling of the Genset, the modeling of the PV, the modeling of the hybrid (PV and Genset) and their fixed and running costs.

Chapter Five: Peak Demand Management by Using Different Tariff Structures.

This chapter illustrates the managements of the network under the flat rate tariffs and the time of use tariffs and describes several alternatives and options to implement the managements.

Chapter Six: An-Najah Hospital (Case Study), for Solving Peak Demand by using PV and Genset.

This chapter illustrates the managements of the load with PV, diesel genset or hybrid systems with the electrical network under the flat rate tariffs and the time of use tariffs and without it and describes several alternatives and options to implement the managements.

Chapter Seven: Conclusion and Recommendation

This chapter describes the research conclusion, recommendations and the future scope of the work.

Chapter One

Management of Electrical Network, Literature Review

1.1 Peak Demand Management

Electrical energy management mainly aims at efficient use of electricity in any electrical system, so increasing the efficiency means increasing the production for the safe consumption of the electrical energy or reducing the energy consumption for the same output. And also, energy management is an important issue especially for energy generation, transmission and distribution companies.

Demand management has several activities in order to maintain the network reliability in the short term and defer or avoid the need for network augmentation over the longer term, so peak demand management is employed and imposed by energy supply companies in order to reduce the need for infrastructure upgrades by encouraging consumers to use less energy as much as possible during peak hours, to move energy use to off-peak or to decrease the overall energy consumed, Thus increasing the reliability of the system and the continuity of electrical energy, which reflects positively on the electrical tariffs and on the consumers by reducing the electrical tariffs, which the high cost of electrical tariff is derived from and depend on several factors: [6]

1. **Types of load** i.e., domestic, commercial, or industrial.

2. Maximum demand.

3. **The time at which load is required**.

4. **The low power factor** and increasing the losses in the systems.

5. **The amount of energy used.**

As mentioned; electricity bill contains a charge based on maximum demand which provides the consumer with the incentive to reduce the level of maximum demand or eliminate it completely outside the peak period

where possible. Most of the electrical generation and distribution companies in Palestine would benefit from having no electrical overload especially at peak demand during the day , so the electrical companies in Palestine applying an imposed systems of different tariffs during the day and different tariffs for each type of load to maintain the system stable and to reduce the peak demand all times as much as possible , so we can notice some changes in tariff values also the electrical bills during the day varies from one company to another as well as from load to load so the reduction of maximum demand during peak periods can be achieved in three ways:

1- Turning loads on and off at specific times.

2- Disconnecting loads automatically.

3- Operating other electrical sources to supply the electrical load at peak hours.

As mentioned in the last factors; electricity consumption is expressed in (kWh), so the cost of buying every kWh or the electrical tariff, even if fixed, changes according to the circumstances mentioned in the previous five points, which The tariff of the electric energy varies according to their requirement, so the increased in maximum capacity means increased in the installed capacity of the generating station. If that coincides at peak periods ; then additional plant is required, and if occurs during off-peak hours; the load factor is improved, and no extra plant capacity is needed and costs.

The details of all charges currently used in Palestine for billing purposes are available to consumers, for example:

1. Flat Rate tariff.
2. Time of use tariff.
3. Power factor penalty.

1.1.1 Benefits of Peak Demand Management

Peak demands management supplies wide ranges of benefits to the energy supply companies or the electricity sector, such as [6]:

1. Reduces the need for costly infrastructure upgrades.
2. Provides better insight into customer requirements and practices.
3. Improves customer satisfaction by decreasing electricity bills.

As mentioned; Peak demand management also provides a wide range of benefits to the customers and community value, such as [6]:

1. Reduces GHG emissions.
2. Improves network utilisation and reliability.
3. Reduces energy costs for customers.

4. Increases ‘value adds’ for customers through incentives, rebates and in-home consultation.

5. Increases community awareness of benefits of energy conservation.

1.1.2 Load Factor and Power Factor Improvement and Management

Load management basically aims at improving system load factor (L .F) in which it is the ratio of the average load over a designated period to peak demand load occurring in the period , say a day, a month , or a year. [7]

$$L.F = \frac{\text{Average demand}}{\text{Peak demand}} \tag{1.1}$$

$$L.F = \frac{\text{Total kWh}}{\text{Peak kW demand x Total hours}} \tag{1.2}$$

Load Factor (LF) describes how erratically electricity is used by measuring the average use of electricity over a time period and then comparing that average load to the peak load during the same time period as well as an important indicator used in the evaluation of the electric network and energy management. Notice table (1.1). [7]

Table (1.1): Load factor ranges for several loads [8].

	Domestic	**Agricultural**	**Commercial**	**Industrial**
Load Factor Range	10-15%	15-25%	25-30%	60-65%

Most of electrical companies and municipalities in Palestine impose a penalty on the low power factor less than 0.92 as a method of making a demand management; that will let the customer pays an additional cost over the tariff on his bill. The penalty as shown in table (1.2).

Table (1.2): Low P.f penalties in Palestine [9]

Customer P.f	**Penalty add to electric bill**
Above 0.92	No penalty
0.7-0.92	0.77% * electric bill for each 0.01 of the P.f less than 0.92
0.6-0.7	0.95% * electric bill for each 0.01 of the P.f less than 0.92
0.5-0.6	1.20% * electric bill for each 0.01 of the P.f less than 0.92
Below0.5	1.50% * electric bill for each 0.01 of the P.f less than 0.92

1.2 Demand Side Management

Energy supply or distribution companies are trying to orient their users or customers to change their demand profile, in which it is generally can be done by the optimum tariff incentives to let the consumer to schedule their peak or demand activities in order to reduce the energy costs or to save money. Demand side management (DSM) has been traditionally seen as a methodology used for the reduction of peak electricity demand. In fact that can be done by reducing the overall load on the electricity network.

1.2.1 Benefits of Demand Side Management

DSM has several positive beneficial effects including the following [10]:

1. Mitigating electrical system emergencies.
2. Reducing the number of blackouts.
3. Increasing system reliability.
4. Reducing dependency on expensive imports of fuel.
5. Reducing energy prices.
6. Reducing harmful emissions to the environment.
7. Deferring high investments in generation, transmission and distribution networks.

As mentioned; when DSM applied to the electricity systems provides significant economic, reliability and environmental benefits, so it is very important method to enhance the quality of power supply in spite of lack in supply situation, so this may reduce the shortage cases at peak demand periods especially in some areas in Palestine.

Nowadays; customer may have several reasons and necessities for selecting and using a certain DSM activities. In general these activities would be economic, environmental, marketing or regulatory. The above points are expressed in a slightly different way, where it is argued that the benefits of DSM to consumers, enterprises, utilities and society can be realized through the following [10]:

1. Reductions in customer energy bills.
2. Reductions in the need for new power plant, transmission and distribution networks.
3. Stimulation of economic development.
4. Creation of long-term jobs due to new innovations and technologies.
5. Increases in the competitiveness of local enterprises.
6. Reduction in air pollution; reduced dependency on foreign energy sources.
7. Reductions in peak power prices for electricity.[10]

1.2.2 Demand Side Management Categories

DSM has different types of measures and activities that can be used to reduce the energy demand for the end-user, that can be used to manage and to control the loads from the utility side, and that can be used to convert unsustainable energy sources and practices into more efficient and sustainable energy use. [10] The main types of DSM activities classified into two main categories: [11]

A. Energy Efficiency.

B. Demand Response.

The EE category is designed and used to reduce electricity consumption throughout the year by focusing on reduction of electrical energy consumption and overall demand for energy, also DR category is an automatic method with a processing unit having the right to moderate or turn-off certain appliances (e.g. air-conditioners, pool pumps, washing machines, etc.) for a short period of time at customer sites.

1.2.3 Load Shaping Methodologies

DSM is used to reduce the consumption of the electrical domestic, commercial and residential loads such as homes, offices, hospitals and factories especially the peak demand by using the pervious mentioned methods and categories through a continuous monitoring and actively managing how appliances consume energy. [11] The most common techniques used for load shaping classified in figure (1.1).

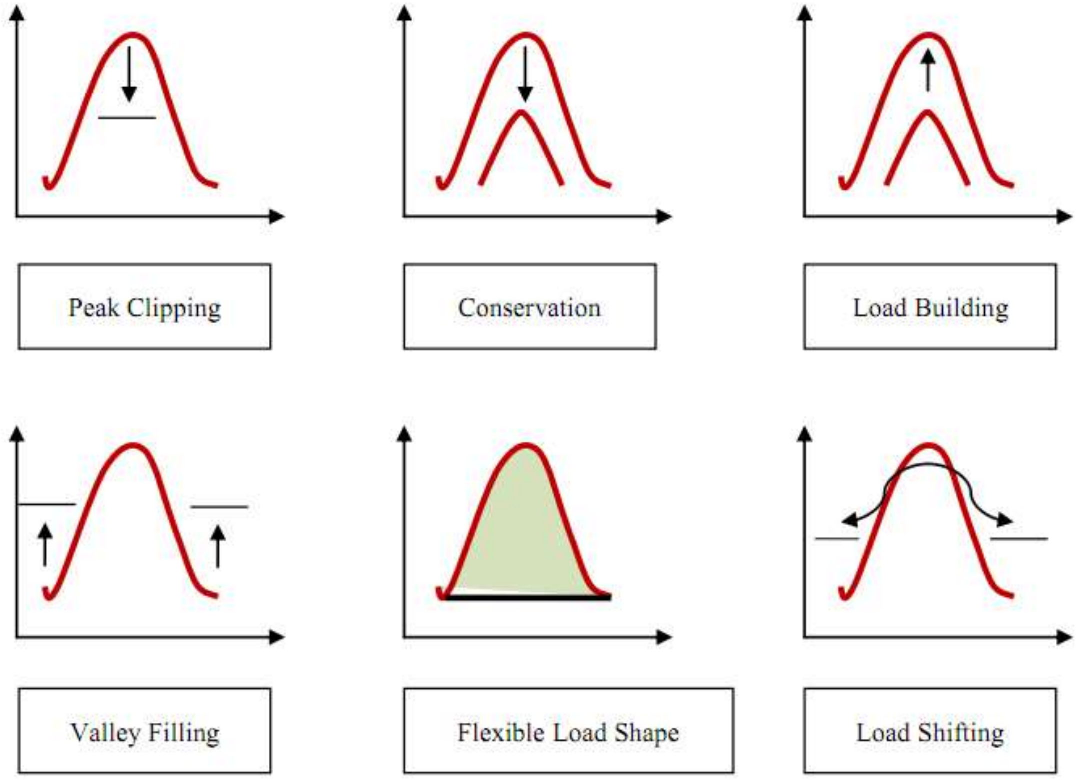


Figure (1.1): Load shaping techniques.[11]

Each of these techniques uses a certain principle explained as following: [11]

A. Peak clipping; clipping the peak demand and then the load reduced mainly during peak demand periods.

B. Valley filling; a form of load management that involves building off-peak loads. This may be desirable where the long-run incremental cost is less than the average price of electricity, since adding off peak load decreases the average price.

C. Load shifting; reduction of grid load during peak demand and simultaneously the load shifted to the valley or off-peak periods by using clipping and filling.

D. Conservation; using high efficient loads instead of the low efficient and old loads by reducing the load throughout the day by utilizing more energy efficient appliances or by reducing overall consumption.

E. Load building; increasing the load throughout the day by increasing the overall consumption.

F. Flexible load shape; specific contracts and tariffs with the possibility of flexibly aims for controlling consumers load time and periods.

1.2.4 Demand Side Management Disadvantages

Despite all the advantages of DSM implementation, several disadvantages can be noticed through the process of implementing the DSM. These disadvantages can be summarized in two points: [12]

1. Large investments for installing and using the DSM equipment and controls may minimize the chance of expanding the fixed assets of the utility itself and slow or no repayment for their investments.

2. May gain less marketing power income or profits because of carrying out DSM so as to affect their profits.

1.3 Load Managements by using other sources.

Many times; DSM enhances the use of several alternative sources especially at peak demand periods to be a solution to reduce the peak demand costs which also enhance the use of the on-grid PV systems or other on-grid hybrid systems, in which these methodologies came depending on the increasing of the demand and electricity tariff at peak period. These alternatives in our study focused on the use of alternatives available in our country, such as PV and Genset Systems with the following methodology:

1. Studying the load and make a determination of the peak demand period.
2. A qualitative study of the loads as much as possible and look at how to make energy conservation.
3. Finding the possibility of the application and the preference of other hybrid and standalone alternatives as following:

A. Standalone PV systems.

B. Standalone Diesel Gensets (DG).

C. On- grid system and provides the load by the amount of 75%, 50% or 25% from PV system with or without storage batteries.

D. On- grid system and provides the load by the amount of 75%, 50% or 25% from DG system.

E. On- grid system and provides the load by the amount of 20% from PV system and 60% from DG system,40% from PV system and 40% from DG system, 60% from PV system and 20% from DG system with or without storage batteries.

F. Off- grid system and provides the load by the amount of 25% from PV system and 75% from DG system, 50% from PV system and 50% from DG system, 75% from PV system and 25% from DG system with or without storage batteries.

4. Considering alternatives results especially the cost of energy COE

5. Considering the possibility of implementing these applications.

1.4 Summary

It is clear that there are many ways and methodologies to improve the efficiency and the reliability of any electrical network as can be seen from the previous sections in this chapter. This leads to make a peak demand management and demand side management due to the demand problems in the Palestinian electrical networks which discussed in chapter 2.

Chapter Two
Demand Problems in the Palestinian Electrical Networks

2.1 Overview of the Palestinian Electrical Networks

The Palestinian electrical networks faced and are facing nowadays a lot of challenges. This section discusses the challenges that encounters the Palestinian energy sector and evaluates the renewable energy potential in meeting part of the energy demand. Firstly, the energy sector depends on several external sources for supplying and feeding these electrical networks; in which 86% of the consumed electricity comes from Israel energy sector because of the political situations and the occupation. Secondly, the costs of importing these energies are too much, in which the yearly electricity import bill is evaluated and estimated at about 400-500 million dollars. Finally, several environmental hazards arise due to the usage of the traditional resources of energy such as fossil fuels. These facts are very serious and important challenges to the Palestinian decision maker in terms of advancing, crafting and utilizing a strategy for finding reliable, usable energy alternatives. [13]

The power consumption in the Palestinian Territory in the year of 2009 was at about 4.413 GW/hour. The needed power covered and imported from three supplier sources: Israel (86%), Egypt and Jordan (4.5%) and Palestine Electric Company in Gaza (10%) as shown in figure (2.1). [13]

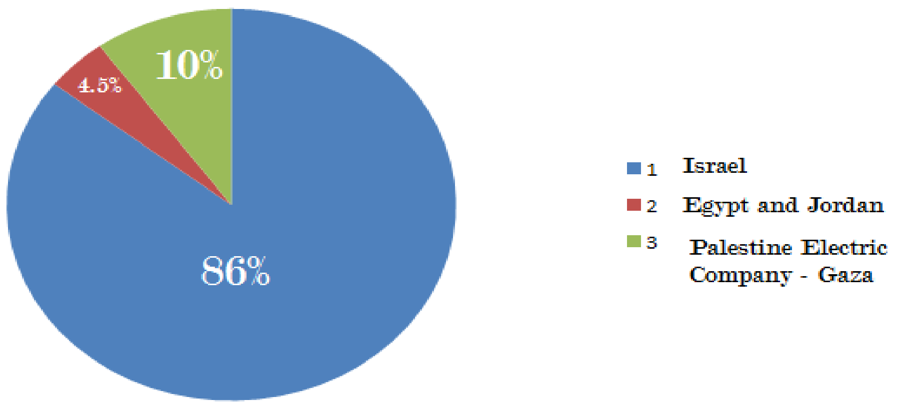


Figure (2.1): Primary energy sources in Palestine.[13]

The main characteristics of Power sector in Palestine are as the following: [13]

1. Household and services consume about 75% of total consumption, while 25 percent is consumed by economic and productivity activities.

2. In 2020 the expected annual consumption may reach 8.400 GW / hour-assuming an annual growth rate of 6%.

3. The wastage of electricity is about 26% of imported energy, while the electricity prices are relatively high as a result of importing most of the needs from Israel.

4. The average per capita consumption of electricity (after deducting wastage) is around 830 kWh per year. This average is low compared with neighboring countries (2093 in Jordan, 1549 in Egypt and 6600 In Israel).

Electricity sector services including both the distribution and the maintenance; are the responsibility of the Palestinian providers. It should be noted that there is no purchase agreements between the PNA and Israel, but the purchase is really done through bilateral contracts between the Israeli Electricity Company and Palestinian providers.[13]These Palestinian providers are JDECO, NEDCO, HEPCO, SELCO and TDECO with several municipalities such as Tulkarm, Qalqeliyah and many other municipalities, where all these providers organized by thoughtful laws come after an approval by the Council of Palestinian Ministers from the Palestinian Power and Natural Recourses Authority and the Palestinian Electricity Regulatory Council. According to the Palestinian Electricity Regulatory

Council (PERC) in Ramallah; the maximum load in 2015 for the last mentioned distribution companies (Discos) was as shown in table (2.1)

Table (2.1): Maximum demand of Discos in different months

	Unit	JDECO	NEDCO	HEPCO	TEDCO	Monitored Companies
Maximum Load	**MVA**	441	109	97	24	671

2.2 Problems of Energy in Palestine

The Palestinian energy sector is suffering from several effects in which the main factor is the Israeli occupation that inhibited the investors from making large scale energy or industrial investments, as well as the lack of energy or peak demand problems which is one of the most important current problems of the energy sector in Palestine. Moreover, the lack of the Palestinian infrastructure for several decades has obstructed any factual progress on the energy sector; also the lack of conventional energy resources and the limited renewable resources has created unrealistic price control, energy shortage and future energy crisis. Under the continuous Israeli occupation; the national and comprehensive energy policy is still not clear, besides the weak and the fragmented institutional framework and the incomplete framework of the Palestinian State. The markets of renewable energy are affected with several factors such as the political stability in the region, economic situation of the people, increasing on the energy demand and availability of resources. [14]Some of these problems summarized by the following:

2.2.1 Supply Constraints

1. Political constraints

The Permanent frustration by the Israeli occupation to generate electricity by using the solar energy or other alternatives, especially in the area "C" which constitutes 62% of the Palestinian territory.[13]

2. Technical and Skill Constraints

Solar cells technology is a recent applied technology in Palestine as a method or alternative way for generating electricity. Despite the initiatives in this connection are considerable, the expansion of applications to broader levels needs technical and human capabilities that is not adequately available in the local market. [13]

3. Financial Constraints

The costs of investments in the alternative electrical sources such as solar energy projects are relatively high, so these projects unaffordable for the majority of people. Moreover, the PNA does not have the financial resources to provide a catalyst fund for these projects. [13]

4. High Costs of Energy Constraints

As mentioned; West Bank depend almost completely on the IEC to supply the electricity in which it imposes a high prices, so the municipalities and distribution companies collect the electricity bills from the final consumers. The final prices or tariffs based on the IEC prices plus a profit depend on the Cost Plus Methodology that necessary to find out the required revenue for the distributers such as O&M cost, developing costs, depreciation and the regulated asset base multiply by the rate of return, so the total approx.

About 10%, which this leads to increase the tariffs of electricity in WB to high levels (0.13-0.5 $/kWh) that including 16% as VAT, so this is three times higher than the average price in Israel (0.07$/kWh). [15, 16]

2.2.2 Lack of Electricity Constraints

1. Lack of Electricity Constrains at Peak Periods

The West bank depends completely on the IEC. It is mainly supplied the electricity by three 161/ 33 kV substations: one in the south in area C close to Hebron, a second in the north in the Ariel settlement (area C) close to Nablus, and a third in Atarot industrial area (area C) near Jerusalem. According to the Palestinian Electricity Regulatory Council in Ramallah (PERC); the indicators about the continuity and the interruptions of supply for distribution sector in 2015 was as mentioned in table (2.2).

Table (2.2): Indicators about the continuity and the interruptions of supply for distribution sector in 2015

KPI	Unit	JDECO	NEDCO	HEPCO	TEDCO	Monitored
SAIDI	Minute	425	832	391	3,048	616
SAIFI	No.	7	10	7	66	10
CAIDI	Minute	58	83	55	46	60
ASAI	%	99.92%	99.84%	99.93%	99.42%	99.88%
IEC Interruptions	Minute	3,154	5,853	848	4,853	14,708

The Previous table shows two types of interruptions, the first four rows related to Discos. which SAIDI describes the amount of electrical interruption periods in 2015 in minutes also SAIFI describes how many times that happened for each of these mentioned distribution companies

$$\textbf{SAIDI} = \frac{\text{Sum of all customer interruption duration}}{\text{Total number of customer served}} \tag{2.1}$$

during the year, furthermore, CAIDI describes approximately the amount of minutes for each interruption process, moreover ASAI gives an indication about the load covering percentages by Discos during the year of 2015, while the last raw related to the interruptions come from the Israeli regulators.

$$\textbf{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customer served}} \tag{2.2}$$

$$\textbf{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}} \tag{2.3}$$

The last numbers trend our thinking to an important term called the Energy not Supplied (ENS). IEC always trend to supply to the normal or stable loads not the over demand loads by upgrading the system capacity so this will always leads to main problems called the peak demand problems. Notice figure (2.2).

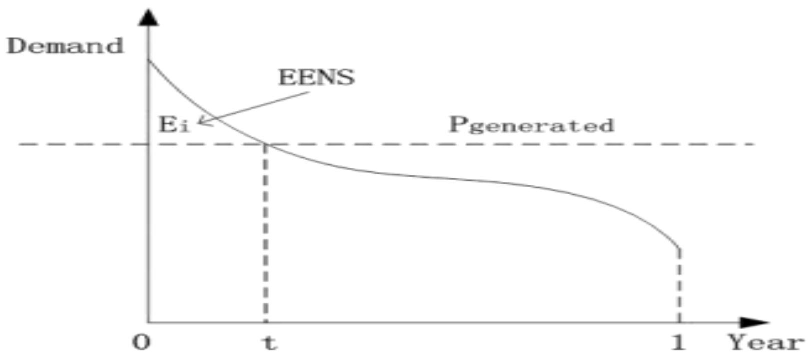


Figure (2.2): Energy not supplied.

These interruptions have several causes such as tree contacts, lightning, adverse weather, defective equipments, etc., but the main important cause is the over demand problem because of the technical and economical

impacts. According to PERC; JDECO it has been taken as an example in 2015; which its interruptions due to over demand = 1,595.2 MWh as ENS also IEC; interruptions due to over demand = 254.723 MWh as ENS

So the first total = 1, 8498.92 MWh as ENS

by regarding 24% losses or others the rest = 1,405.94 MWh as ENS

So If this value multiplied by the average value of tariff (0.54$/kWh); the financial loss will be about 759,208 NIS, so what about consumers?!

2. Distribution Losses Constraints

Because of the lack of financing due to the deteriorating situation in the collection of the electricity bills in utilities, municipalities, and villages has affected the maintenance of the networks, which in turn has increased losses, outages and overloading of feeders in which the average losses are about 20%-30%, this leads the IEC and Israeli government to neglect the growing need of energy, so that affects the quality of supply in the form of electrical shortages especially at peak demand periods. [15, 17]

2.3 Suggested Solutions for Solving Peak Demand Problems

In spite of all these challenges, Palestine has gone forward to utilize its natural resources for rehabilitation and construction.The main objective of this thesis is to discuss the important and optimum way for feeding loads from alternative traditional sources such as the diesel generators or from renewable resources or hybrid systems, especially at peak demand period regardless of economical or financial aspects sometimes in order to keep the continuity of the system and to ensure that no power cuts for long .

periods even though the cost was higher than the purchase price of the distribution companies, or by using the least cost planning methodology(LCP) which it is a process of selecting the mix of generation options, demand side management measures, purchases, and sales that enable a utility to meet society's energy needs at the lowest overall cost subject to variety of constraints, such as minimizing economic and environmental risks also attempt to evaluate the potential available through efficiency improvements, load management and nonutility energy sources on an equal footing with power plants. [18]

As mentioned, using of these types of energy sources may significantly reduce the energy reliance on neighboring countries and improve the Palestinian population's access to energy. As well as, it is estimated that the wind and the solar energy sources have the potential to account for around 36% of electricity demand; the conversion of agricultural wastes into biodiesel fuels which in turn can reduce the diesel imports by 5%; also the conversion of animal waste into biogas has the potential to replace 1.7% of the imported LPG and the use of geothermal energy for heating and cooling can reduce the costs as much as possible. [19]

2.4 Summary

It is clear that there are many constraints facing our Palestinian electrical networks which mentioned in these sections of this chapter such as supply and lack of energy constraints. The available ways to skip these constraints by start thinking about alternative sources as described in chapter 3.

Chapter Three
Using Renewable Energy and Genset for Covering the Peak Demand

3.1 Using Solar PV for Peak Demand Management

Demand for power is increasing daily; especially peak load demand management is becoming crucial, which in developing countries the power is often unable to meet peak load demands, so that may causes a load shedding, voltage drops, power cuts and frequency variations. According to the Discos the term of energy not supplied is a main constraint because of its economic impact as discussed in chapter 2, while according to the consumers; the frequency in a regional grid might vary from a level below the normal level to a level above the normal, that is harmful for the heavy rotating equipment and particular considerable difficulties as well as damage to the end user equipment, moreover, that may stop the production process. Most of solutions must be considered in order to deal with the gap between peak load demand and the availability of power at the regional level, moreover thinking about the solar PV options as renewable source to fill this gap.

Solar PV systems can be classified into two major groups: [20]

1. **Standalone systems**: These systems separated or isolated from the electrical network, which these systems are the most complex; and includes all the elements necessary to serve the AC appliance in a common household or commercial application. Notice figure (3.1).

Standalone PV systems provide power for the critical loads when the power grid is down or to provide power at peak demand times in order to avoid the outage of energy especially for long times, while the downside of these systems that cannot be expected to provide power for all loads since the cost and volume of batteries would be prohibitive.

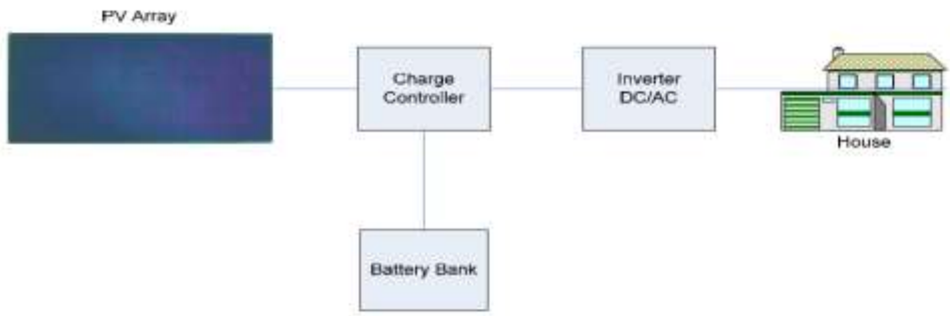


Figure (3.1): Standalone photovoltaic system.

2. **Grid – Tied Systems:** These systems are directly connected to the electrical network and don't require a storage battery, so the electrical energy can be sold or bought from the local electric utility depending on the local energy load types and the solar resource variation during the day. Figure (3.2) illustrates the basic system configuration. Many benefits could be obtained from using these systems instead of the standalone systems. These benefits summarized as following:

A. Smaller PV array can supply the same load reliability.

B. Less balance of system components are needed that will **allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation costs**.

C. Eliminates the need for the storage batteries and their costs. These storage batteries can be used if desired to enhance reliability for the client.

While the downside of these systems that don't provide power to loads during the grid outage.

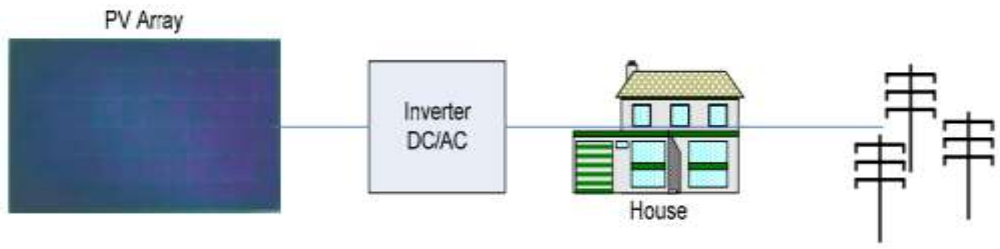


Figure (3.2): Grid-Tied photovoltaic systems.

3.2 Selecting of PV Elements and Technical Impacts [21]

Solar photovoltaic system or **solar power system** is one of **renewable energy system** that uses PV modules to convert sunlight into electricity, so the electricity generated can be used directly or stored, fed back into grid line or combined with one or more other electricity generators or more renewable energy source. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc.

The major components for solar PV system are the PV module, solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances).

1. PV module : converts sunlight into DC electricity.
2. Solar charge controller : regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
3. Inverter : converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
4. Battery: stores energy for supplying to electrical appliances when there is a demand.
5. Loads: Are electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.
6. Auxiliary energy sources: is diesel generator or other renewable energy sources.

The most important steps should be considered to make a PV designing for the Hospital are as following:

Firstly, is to find out the total power and energy consumption of all loads in the Hospital that need to be supplied by the solar PV system by calculating **the total Watt-hours per day for each appliance used, and calculating total Watt-hours per day needed from the PV modules.**

Secondly, is to size the PV module, in which different size of PV modules will produce different amount of power, so the peak watt (Wp) produced depends on the size of the PV module, facility orientation and climate of site location, then **Calculating the number of PV panels for the system**

by dividing the answer obtained in equation (2.6) by the rated output Watt-peak of the available PV modules.

$$PV_{Wp} = \frac{\text{Desired demand (kWh)}}{0.9 \text{ x } 5.45 \text{ kWh/m}^2\text{/day}} \tag{3.1}$$

The number 5.45 kWh /m^2 / day, is the scaled annual average of the daily radiation for the hospital in Nablus city with a latitude equal to 32^o and longitude equal to 35^o.HOMER program can give us the daily radiation curve for these specified orientations as shown in figure (3.3).

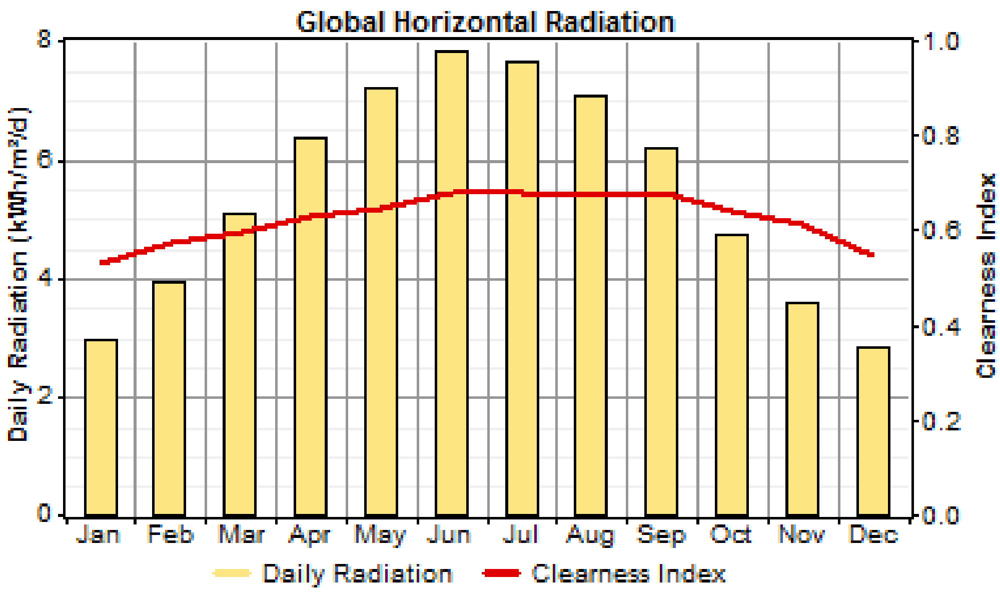


Figure (3.3): Daily radiation curve by HOMER program.

Thirdly, an inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of loads. The inverter must have the same nominal voltage as your battery.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances.

Finally, **is to size the Batteries needed for the system, in which b**atteries used are specifically designed to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years.

The batteries size should be large enough to store sufficient energy to operate the Loads at night and cloudy days. The size of battery can be calculated as following:

$$\text{Battery Capacity (Ah)} = \frac{\text{Total (Wh) per day used x Days of autonomy}}{\text{(0.85 x 0.6 x nominal battery voltage)}} \qquad (3.2)$$

Where, 0.85 for the battery loss and 0.6 for the depth of discharge.

According to JDECO and as mentioned in Chapter 2; the amount of energy not supplied because of the grid down in 2015 was 1,405.9 MWh as annual shortage, so the installed PV system needed for this distribution company to cover this gap may equal to 800 kWp by using equation (3.1).

$$PV_{Wp} = \frac{\text{Annual demand (kWh)}}{0.9 \text{ x } 5.45 \text{ kWh/m}^2\text{/day x } 356 \text{ days}}$$

3.3 Using Diesel Generators for Peak Demand Management [22]

Peak demand or over demand problems, electrical power failures, interruptions, and their duration that covers a range in time from micro seconds to days, a reliable alternate power supply must be provided for facilities and systems that cannot go without power. As a solution for this matter, a wide range of electric energy sources have been developed. This section focuses on the diesel generators as a source of reliable alternate electrical energy. So it can be organized to make a demand reduction (peak shaving) to operate at certain times for short periods as a solution to the problem of over demand or peak demand instead of working for long periods of time due to interruptions as a result of the electrical overload.

The main components of these systems can be symmetrized in figure (3.4) as following:

1. Engine – generator set.
2. Automatic Transfer Switch (ATS).
3. Battery System.
4. Controller.
5. Fuel System – Storage.

6. Exhaust and Inlet/ Outlet Air

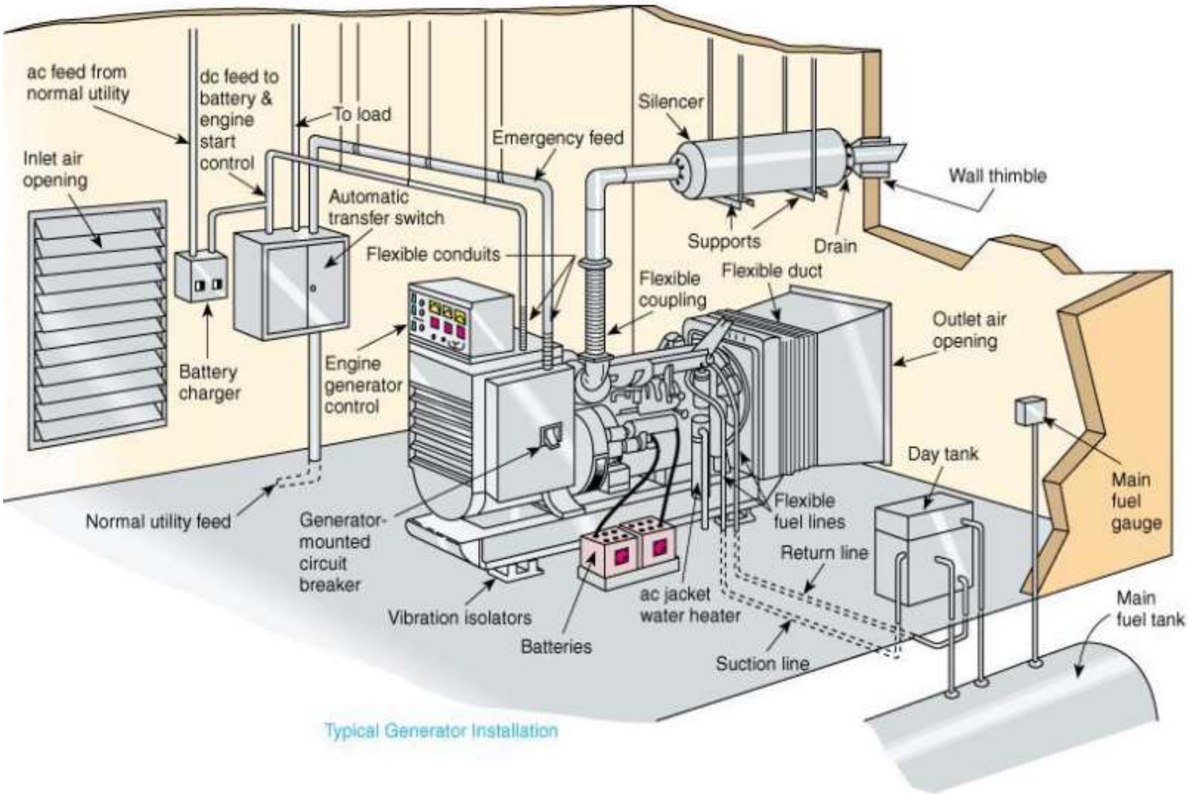


Figure (3.4): Diesel generators components.

The most available electrical sources used in Palestine are the diesel generators, whereas it is easy to design a diesel generator for any load by fast calculation as following:

$$Amps = \frac{KVA \times 1000}{\sqrt{3} \times Volts} \tag{3.3}$$

3.4 Comparison between Solar and Genset for Solving Peak Problems [4]

Diesel generators as mentioned are typically characterized by a lower initial cost but a very high operation and maintenance costs while the solar system is the opposite, with a higher initial costs but a very low on-going operation and maintenance costs, where the initial costs of solar systems are often daunting to donors so the donors trend to use generators in order to reach the greatest number of beneficiaries by using a low first cost option without looking at environmental and economic aspects of the future especially if these generators used to solve the peak demand problems. These costs can be summarized into fixed and running costs that characterized in chapter 4.

3.5 Summary

It is clear that there are many available alternative solutions and sources to solve the problems of electricity demand especially at peak demand periods as discussed in this chapter such as using the solar PV systems or DG to be able for making a peak demand management . After thinking with technical aspects we should really think about the economical aspects of using these alternative sources as discussed in chapter 4.

Chapter Four

Economical Evaluation of using PV and Diesel Genset for Solving Peak Problems

4.1 Introduction

In the last period; the diesel generators were widely used as standby electrical source and sometimes used as a prime electrical source in the remote areas; because of the wide availability of these generators in the markets and the lowest initial costs. Nowadays; the developers and investors are more interested in using the clear or renewable resources as an electrical alternative source, whether it was alone or hybrid to be a solution for several cases such as peak demand cases. This chapter discusses the initial costs and the operational and maintenance costs of these two types of electrical sources.

4.2 Diesel Generators Fixed Costs

According to the sales department at Engineering for Trading and Contracting Company (ETCO) in Ramallah; several kinds of generators have agencies in the Palestinian market and the mainly used types were studied in this section such as:

1. British generators (Engine + Canopy), such as Powerlink brand name.
2. British generators have Turkish agencies (Engine (UK), Canopy (Turkish)), such as Cukurova brand name.
3. Turkish generators (Engine + Canopy), such as EMSA brand name.
4. Small Chinese and Japanese generators, such as Kipor brand name.

The fixed costs of diesel generators include the initial cost, Automatic Transfer Switch (ATS), Automatic Mains Failure (AMF), Battery Charger, Web Interface, Storage Diesel Tank, cables, concrete blocks and rubber bases.

4.2.1 Fixed Initial Costs

These costs mean the initial or purchasing costs of the diesel generators without any other installation or construction costs. Tables (4.1), (4.2) and (4.3) show the initial costs of the first three mentioned generators in section 4.2 with formulas for each type that represents the variation of the cost for each kVA, whereas these costs include the connection of the generators.

Firstly, British generators (Engine + Canopy), while these types of generators have the higher costs in the Palestinian markets. Table (4.1) represents the cost for each available standard sizes of these generators.

Table (4.1): British generators initial prices.

Standby kVA	Max. Current (A)	End user price ($)
14	20.2	11,800
14	20.2	12,100
22	31.7	14,200
23	33.1	14,400
33	47.5	15,100
33	47.5	15,400
50	72	16,800
50	72	17,000
66	95	18,400
66	95	18,800
88	126.7	21,400
110	158.4	24,200
151	217.4	28,300
165	237.6	30,600
198	285.1	33,000

198	285.1	40,000
220	316.8	35,000
220	316.8	41,000
248	357.1	42,100
275	396	44,200
303	436.3	58,300
330	475.2	60,000
385	554.4	61,000
440	633.6	62,800
495	712.8	76,800
550	792	80,000
660	950	108,000
688	950	110,000

According to table (4.1) the variation in the cost for each kVA is not constant. Figure (4.1) shows the formula of the variation for this type of generators.

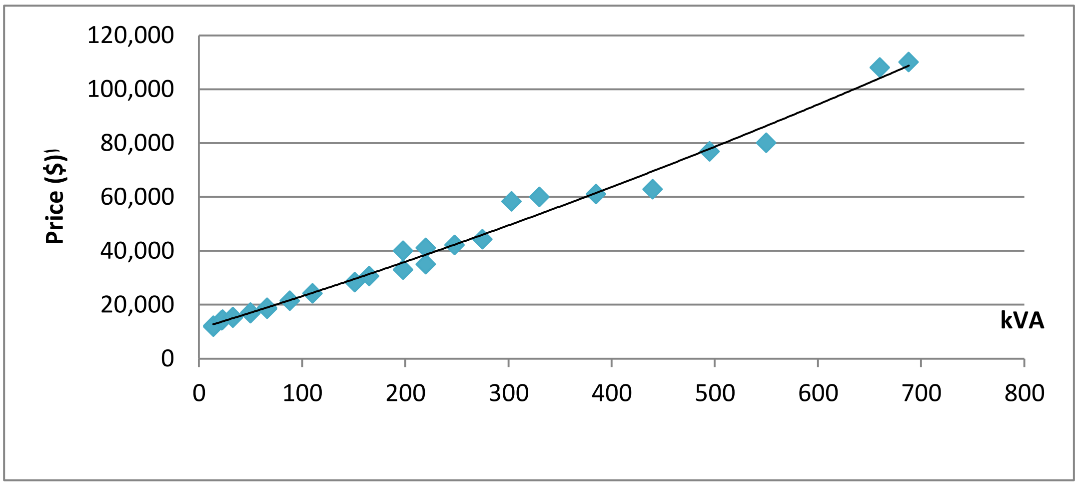


Figure (4.1): British generators prices.

As a result of the price curve for the British generators the price equation:

$$Y = 139.54x+9293.6 \tag{4.1}$$

Where; Y = Generator initial Price ($).

X = Generator Size (kVA).

Secondly, another type of British generators have Turkish agencies. These types are British generators that aggregate in Turkey in addition of Canopy or the Silencer. Table (4.2) illustrates the prices of these standard types of generators.

Table (4.2): Prices of British generators have Turkish agencies.

Standby kVA	Max. Current (A)	End user price ($)
13.5	19.4	11,600
17	23.8	11,800
22	31.7	12,800
22	31.7	13,000
32	46.1	14,700
51	73.4	16,500
73	105.1	18,800
90	129.6	20,000
115	165.6	23,000
156	224.6	28,000
164	236.2	31,000
196	282.2	39,000
250	360	41,000
275	396	43,000
300	432	58,000
330	475.2	60,000
400	576	61,000
495	712.8	72,300
550	792	80,000
660	950	108,000
670	964.8	108,000
720	1,036.8	110,000

A table (4.2) show the cost of each type of these generators and as previously; the variation in the initial price for each kVA also is not constant; figure (4.2) illustrates the relation between the price and the capacity of each generators.

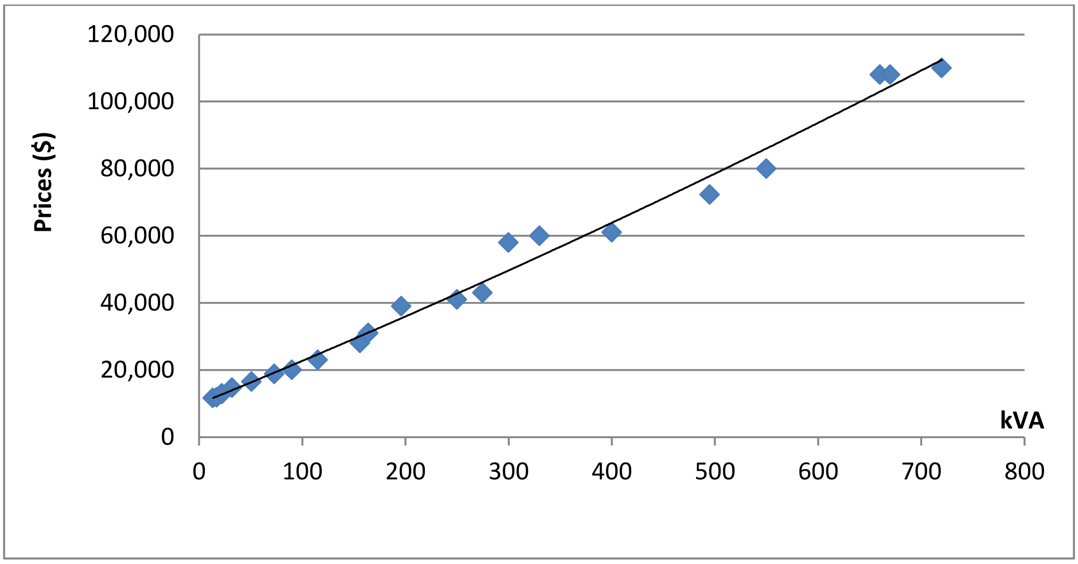


Figure (4.2): The prices of British generators have Turkish agencies.

As a result of the price curve in figure (4.2); the price equation for the British generators that has its agency in Turkey as the following:

$$Y = 141.39x+8614.2 \qquad (4.2)$$

Where; Y = Generator initial Price ($).

X = Generator Size (kVA).

Finally, Turkish generators are another type of generators that are sold in our Palestinian markets. These generators characterized by cheap price somewhat compared to the previous generators. Table (4.3) shows the prices of these generators for each capacity.

Table (4.3): Turkish generators initial prices

Standby kVA	Max. Current (A)	End user price ($)
13	18.7	9,000
17	24.5	9,500
22	31.7	9,500
30	43.2	10,000
50	72	12,000
70	100.8	13,500
82	118.1	15,000
110	158.4	17,000
125	180	18,000
150	216	20,000
165	237.6	22,000

As mentioned above; these generators have lowest initial costs than the previous types, while the variation in the price per kVA illustrated in figure (4.3).

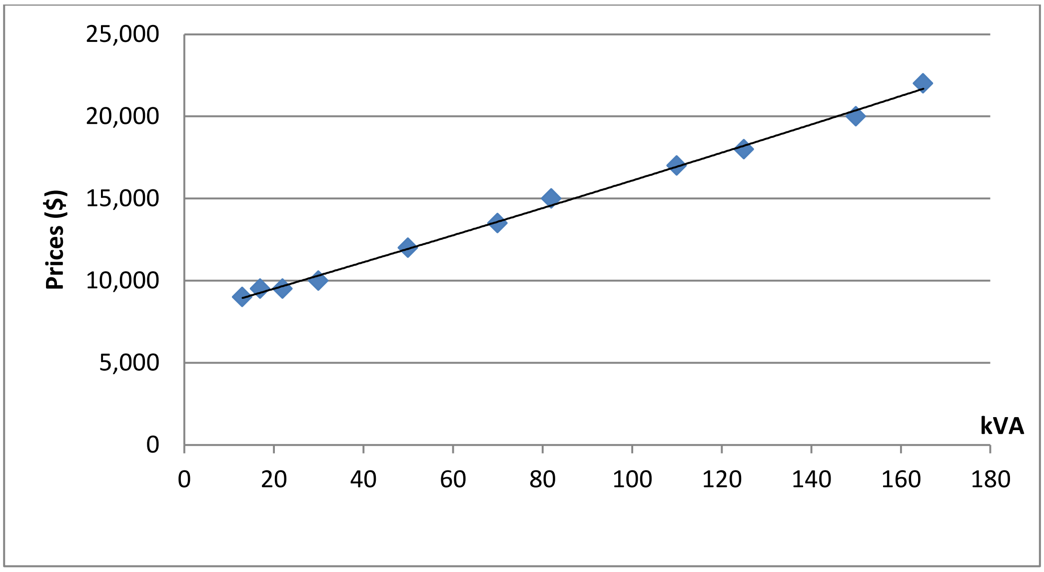


Figure (4.3): Turkish generators prices.

As a result of the price curve for the purely Turkey generators the price equation:

$$Y = 83.581x+7799.4 \qquad (4.3)$$

Where; Y = Generator initial Price ($).

X = Generator Size (kVA).

The difference in the initial costs between these mentioned types of generators depends on several things such as the shape and the durability of the canopy, controller type, internal wiring type … etc. that plays a crucial role in the difference of prices.

4.2.2 Fixed Construction Costs

Installation of generators depends on establishing and equipping the appropriate location for these generators, sometimes the necessity of private rooms and sometimes not, also sometimes although these generators have a built in fuel tank, but may have an external tanks with a larger size than the built in ones in order to let these generators serve for a longer period without interruption or disruption and to provide the continuous re-packing costs, as well as, most of these are provided with rubber bases to play in important role by the absorption of the vibration caused by the operating process, especially start-up and shutdown period. Table (4.4) shows the most important things that play a main role in the construction costs.

Table (4.4): Generators fixed construction costs

Type	Cost ($)
ATS + AMF + Battery Charger	900
Web Interface	1000
1000-2000 liters diesel tank with connections	700-1200
Concrete Blocks 30 x 30 x 15 cm	30
Rubber Bases	100

The net construction costs according to table (4.4) equal to 3230$ if the 2000 liters tank was considered in the designing , So the net fixed cost of diesel generators will be as following :

$$\text{Net Fixed Cost} = \text{Fixed Initial Cost} + \text{Fixed Construction cost} \tag{4.4}$$

4.3 Diesel Generators Operational and Maintenance Costs

Diesel generators characterized by lower initial cost and higher operational and maintenance costs comparing to the other sources, these costs could be fuel, oil, batteries, filters and coolant consumption in which it varies depending on the capacity of generation, and based on the load of which the generator is operating at.

4.3.1 Fuel Consumption

It is well-known that the generators which consume the fuel, most of them use Diesel, while the least uses gasoline. Since the majority of diesel generators have capacities of a range 5-1250 kVA. According to the practical experiments and the catalogues form manufacturer companies, it was found out that a chart in figure (4.4) approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at. Please note that this chart is intended to be used as an estimate of how much fuel a generator uses during operation and is not an exact representation due to various factors that can increase or decrease the amount of fuel consumed. Figure (4.4) illustrates the fuel consumption in litre per hour for each kVA which the full data attached in the appendix (1).

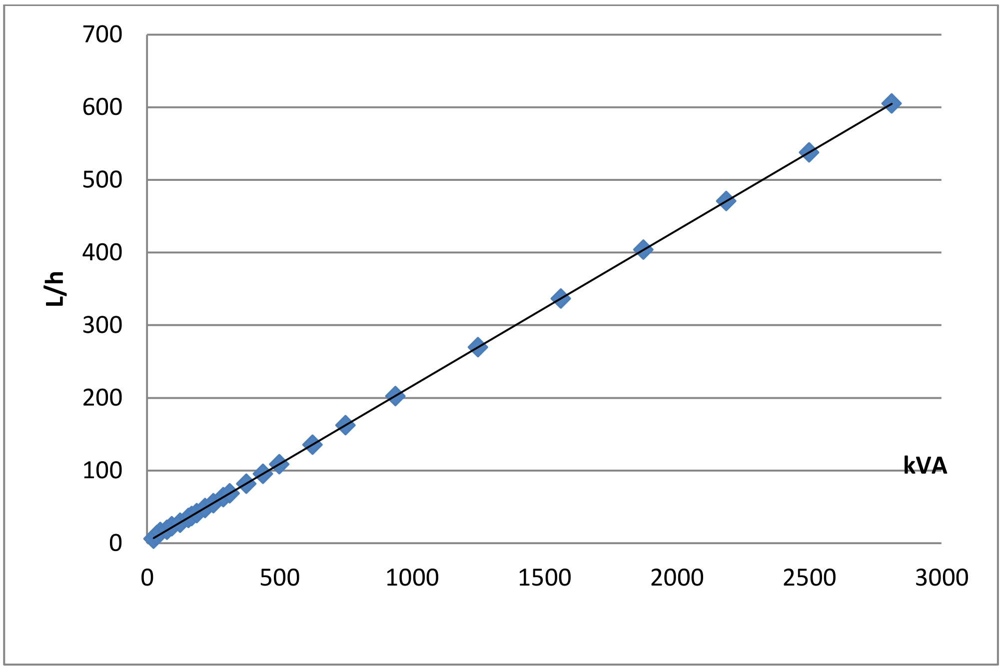


Figure (4.4): Approximate fuel consumption and the cost of it for each kVA.

If we considered the equation (4.5) for the smallest diesel generator 5 kVA, it consumes near 2.68 litres per hour, and when considering a bigger size, 1250kVA, it consumes approximately about 270 litres per hour. Consequently, we relies that it consumes a large amount of fuel within a short period of time, while we are extremely in need for it nowadays, and looking for alternatives to reduce the consumption of the fuel supplies. It is remarkable that the cost of one litre of diesel is approximately 6 NIS, and then we remark that the operating consumption cost of these generators from 5-1250 kVA is between 16-1600 NIS per hour.

As a result of fuel consumption curve in figure (4.4); there is a formula got from this curve at 100 % load as following:

$$Y= 0.2144X + 1.6047 \tag{4.5}$$

Where Y = Fuel Consumption (L/h).

X = Generator Capacity (kVA).

Equation (4.6) represents the consumption of fuel in liter per hour, so the total fuel consumption cost for any period can be calculated by the following formula:

Total fuel consumption cost = Fuel consumption rate (L/h) *x* Rrunning hours *x* Fuel price (1.42 $/L) (4.6)

4.3.2 Lubrication Oil Consumption

It is well known that the generators need oil for the lubrication process; depending on the experiences and the catalogues of the diesel generators; the oil must be changed after every 500 operating hours, where the amount of oil needed depends on the capacity of the generators and the size of the oil sump of each one. As mentioned previously the major capacities of the diesel generators between the range 5-1250KVA; so the oil needed between the range 3-180 litres [23] , also we should change the filters of oil and fuel in each changing process of the oil so this will cause an increasing in the maintenance costs. According to the distribution companies in Palestine such as ETCO, the maintenance contracts for the generators depend also on the size of the diesel generators and on the sump capacity, so the maintenance cost will be within the range of 500-1200 Dollars.

The amount of lubrication oil needed for every generator varies from one to another depending on the capacity of the generator kVA and the size of the sump. Table (4.5) shows the amount of lubrication oil needed.

Table (4.5): Lubrication oil for each kVA [23]

Generator Capacity (kVA)	**Lubrication Oil (liter)**	**Oil Consumption (L/h)**
15	5	0.01
20	5.5	0.011
25	8	0.016
30	8	0.016
40	8.3	0.0166
45	8	0.016
62.5	11	0.022
82.5	10	0.02
100	18	0.036
125	18	0.036
160	18	0.036
180	27	0.054
200	27	0.054
250	27	0.054
320	41	0.082
380	41	0.082
500	45	0.09
600	50	0.1
625	50	0.1

As shown in table (4.5); the amount of lubrication oil needed for each generator’s capacity is not constant in which figure (4.5) describes the curve of oil needed for each capacity in kVA.

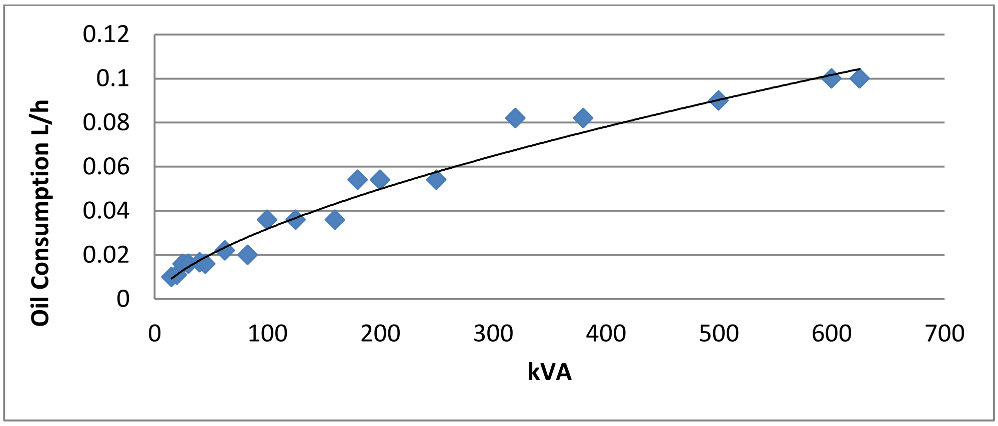


Figure (4.5): Generator Oil Consumption in liter per hour.

Therefore the oil consumption curve varies from size to size with the formula got from this curve at 100 % load as following:

$$Y= 0.0002X + 0.014 \tag{4.7}$$

Where Y = Oil Consumption (L/h).

X = Generator Capacity (kVA).

The Total oil consumption can be represented as following:

Total lube oil cosumption costs = Lube oil consumption rate * Running hours *Oil price (2.61 $/L) (4.8)

Regular maintenance needs not only oil change , but it needs oil filters,fuel filters and air filters replacement .This will add aditional costs : The price of oil filter approx. 9-26$. The price of fuel filter is approx.13-40$ and the price of air filter is approx.80-260$ in which these values vary based on the capacity of generators.

4.3.3 Electrical Consumptions

All fuel generators need DC batteries to start up; these batteries must be always charged , so we need AC to DC chargers to keep charging the batteries all the time .Most of chargers that used in the Gensets between range 45-145watt with output voltage 12v or 24v with output current between 3-5A . The chargers operating 24 hours, so if we suppose that the charger input current is 0.5A and operating all the time for one year (8760 hours) with tariff about 0.172 $ for each kWh; the net electrical cost will be 675 NIS or 175$ each year just from the charger. This means the costs will be about **0.02$/h**. The full data attached in the appendix (2).

Diesel generators could hardly work in cold weather, so always you can see a water jacket heater for heating the engine's water to a suitable temperature about 45 degree. These heaters usually a 230v/15A, so if we calculate the cost for the operating in each year will be approx. about 10000 NIS or 2585$; so it is a high value. If you want to operate it just in the cold weather just about 6 months also it will be a high value. This means the costs will be about **0.6$/h.** Therefor the net electrical consumption cost:

$$\text{Net Electricity Consumption cost} = 0.62\ \$/h \tag{4.9}$$

4.3.4 Batteries consumption

Most of the batteries used today are commercial batteries , so the maximum life with good charging and dischar`ging will reach between 3-4 years , where the costs of replacing the batteries according to the distributers in Palestine will be between 160-360 dollars , also this will increase the operating costs of the generators . Table (4.6) illustrates the size of battery needed for each kVA with their costs.

Table (4.6): Batteries size and costs

Generator Capacity (kVA)	Battery Capacity (Ah)	No. of batt.	Installed Batt. Cost ($)
< 80	65	1	187
80-160	100	1	273
160-300	100	2	395*2 = 790
>300	150	2	395*2 = 790

4.4 Generators Capitalized Cost (CC_G)

The capitalized cost (CC) can be defined as the sum of the total fixed costs and the operational and maintenance costs of the proposed diesel generator at specified period and running hours as a **cash flow**, so the operational costs can be classified as the fuel consumption for every running hour, oil consumption for every running hour and electrical consumption for every hour, while the maintenance costs can be classified as filters replacement and batteries replacement.

$$CC_G = \text{Net Fixed Cost} + \text{O\&M Costs} \tag{4.10}$$

4.5 Photovoltaic Prices and Cost Breakdowns [24]

Solar photovoltaic (PV) prices actually depend on the installed systems. This section covers the fixed and running costs of the residential, commercial, and utility-scale solar photovoltaic (PV) systems built in the first quarter of 2015 (Q1 2015). The methodology used includes bottom to up accounting for all system. The residential and commercial benchmarks represent the rooftop systems, with residential systems modeled as pitched – roof installations and commercial systems modeled as ballasted flat – roof installations, as well as the utility benchmarks represent ground-mounted, fixed-tilt and single –axis tracking systems. The benchmarked prices and price breakdowns include hardware costs (module, inverter, rack, balance of system (BOS)), soft costs- installation labour and soft costs- other. Figure (4.6) represents the Benchmarked system prices and price breakdowns.

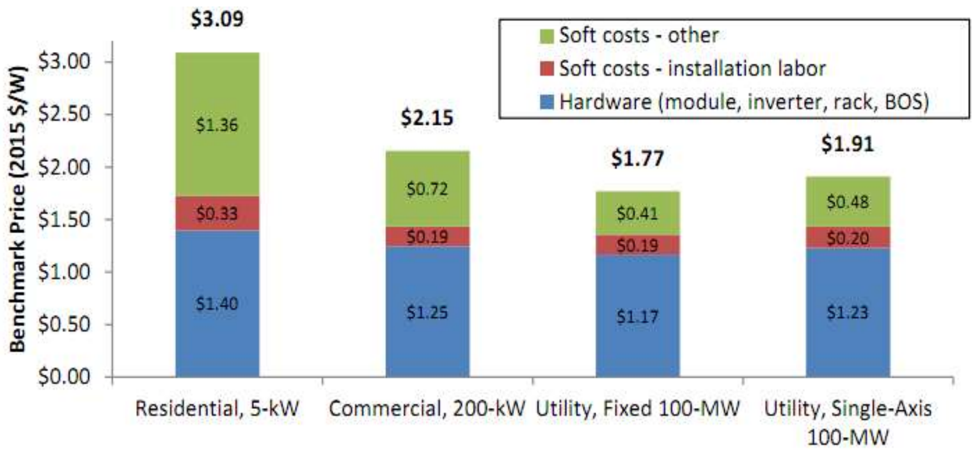


Figure (4.6): Benchmark price summery.

As a result of figure (4.6); figure (4.7) shows the amount or the percentage of contribution of the hardware, soft costs and installation labour from the final value.

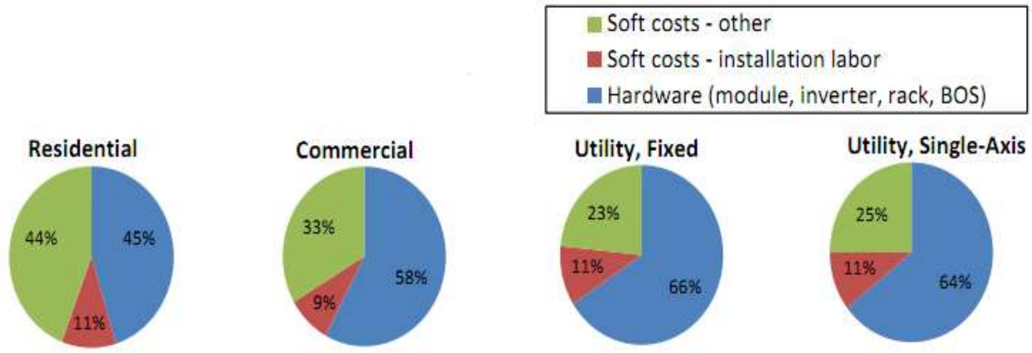


Figure (4.7): Hardware, soft cost and installation contribution percentage.

This section also estimates the cash purchase prices of hardware equipment as well as the cost of the labour associated with typical installation methods, regulatory costs, system size constrains, and all related direct and indirect costs by using crystalline silicon (c-Si) modules.

4.5.1 Residential-Scale System Fixed Costs [24]

The studied system was a residential rooftop system with standard single phase inverters, standard flush-mount and pitched-roof racking system, where the system used 5.2 kW by using 60 cells. Multi-crystalline 250W modules.

Figure (4.8) illustrates the residential benchmark cash purchase price which is modeled at **3.09$/W**, with cost breakdown, that includes capacity-weighted averages between “installer” and “integrator” business structures in which the installer involves in lead generation , sales and installation, also the integrators include all installer functions and further provides financing and system monitoring.

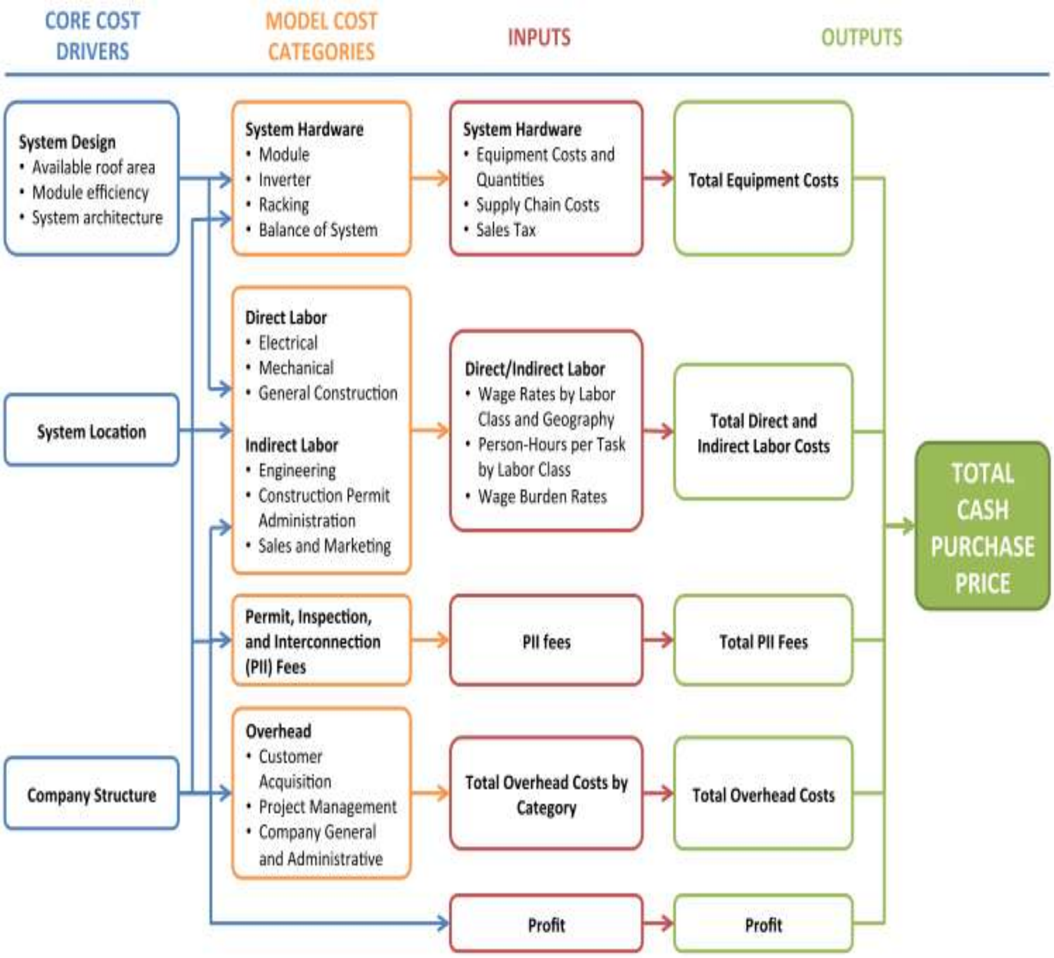


Figure (4.9): Residential PV system model schematic.

According to the schematic model in figure (4.8); there is a difference in the costs between the installer and the integrator, where these costs can be classified in figure (4.9), generally the higher costs that affect the total cost value are the module cost, inverter cost, installation labor and customer acquisition.

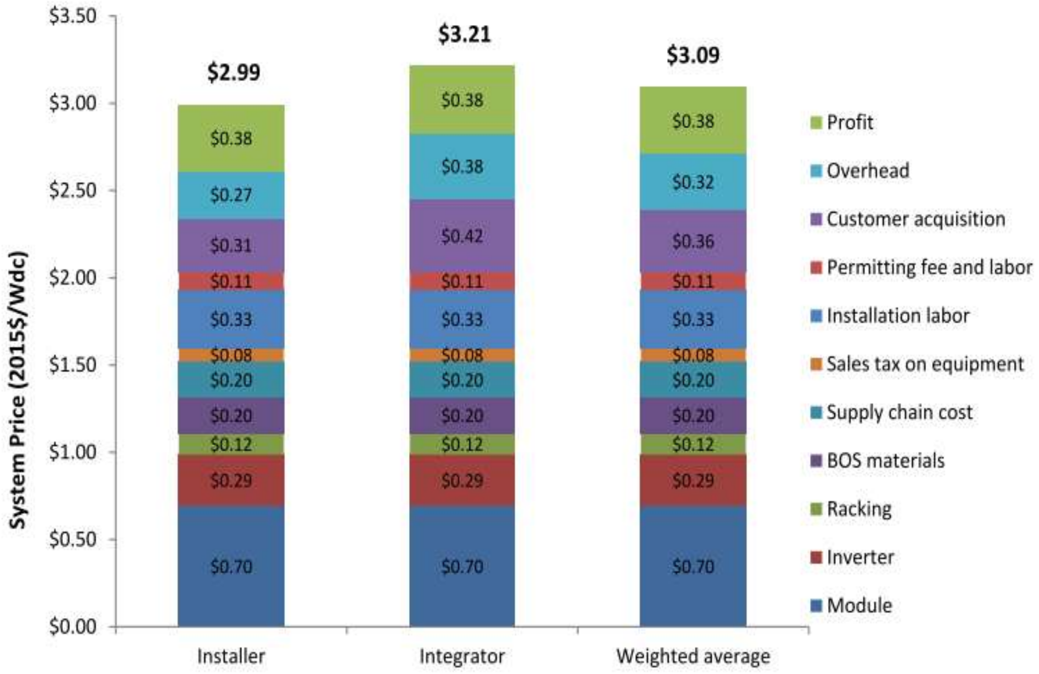


Figure (4.9): Residential roof top PV system prices.

The difference in the cost between the installer and integrator about 0.22$, where the weighted value estimated in the cost breakdown as the average value between these two values to be about 3.09$/W. Table (4.7) explains the details of each value from the total value.

Table (4.7): Key residential modeling assumption

Category	Model Value (Range)	Description
Module ($/Wdc)	0.7$ (0.64-0.74$)	First buyer, average selling price, Tire 1 module.
Inverter ($/Wdc)	0.29$ (0.23-0.34$)	Single phase string inverter.
Racking ($/Wdc)	0.12$ (0.09-0.14$)	Factory price includes flashing for roof penetrations.

BOS materials ($/Wdc)	0.2$	Wholesale prices for conductors, switches , combiners and /or transition boxes , conduit, grounding equipment, monitoring system/ production meter, fuses and breakers.
Sales tax (%)	0-6% depending on the state	Weighted average.
Supply chain costs (% of equipment costs)	10% (5-10%)	Costs associated with warehousing and logistics.
Direct installation labor ($/h)	Electrician : (15.9-41.6$) Laborer : (9.3-22$)	Assumes a 1-2 days installation, total of approximately 50 person – hours; modeled labor rate assumes non-union labor and depends on state; national benchmark uses weighted average of state rates; benchmark per-watt cost is $0.33/Wdc.
Burden rates (% of direct labor)	Total nationwide average: 31.7%	Workers compensation (state-weighted average), federal and state unemployment insurance, builders risk, public Liability.
PII ($/Wdc)	$0.12	Building permitting fee of $400 and eight labor hours: three hours for building permit preparation, two hours for interconnection application preparation, one hour for building permit.
Customer acquisition ($/Wdc)	$0.31 (installer), $0.42 (integrator) ($0.20–$0.85)	Total cost of sales and marketing activities over the last year—including marketing and advertising, sales calls, site visits, bid Preparation, and contract negotiation; adjusted based on state “cost of doing business” index.
Overhead ($/Wdc)	$0.27 (installer), $0.38(integrator)	General and administrative (G&A) expenses.
Profit (%)	17% (10%–20%)	Applies a fixed percentage margin to all direct costs.

4.5.2 Commercial-Scale System Fixed Costs [24]

The studied system used 200-kW, 1000Vdc commercial-scale flat roof system by using 72 cells. Multi-crystalline 310-W modules (16% efficient), standard three phase string inverters, and ballasted racking solution on a membrane roof. Figure (4.10) shows the schematic of commercial system model.

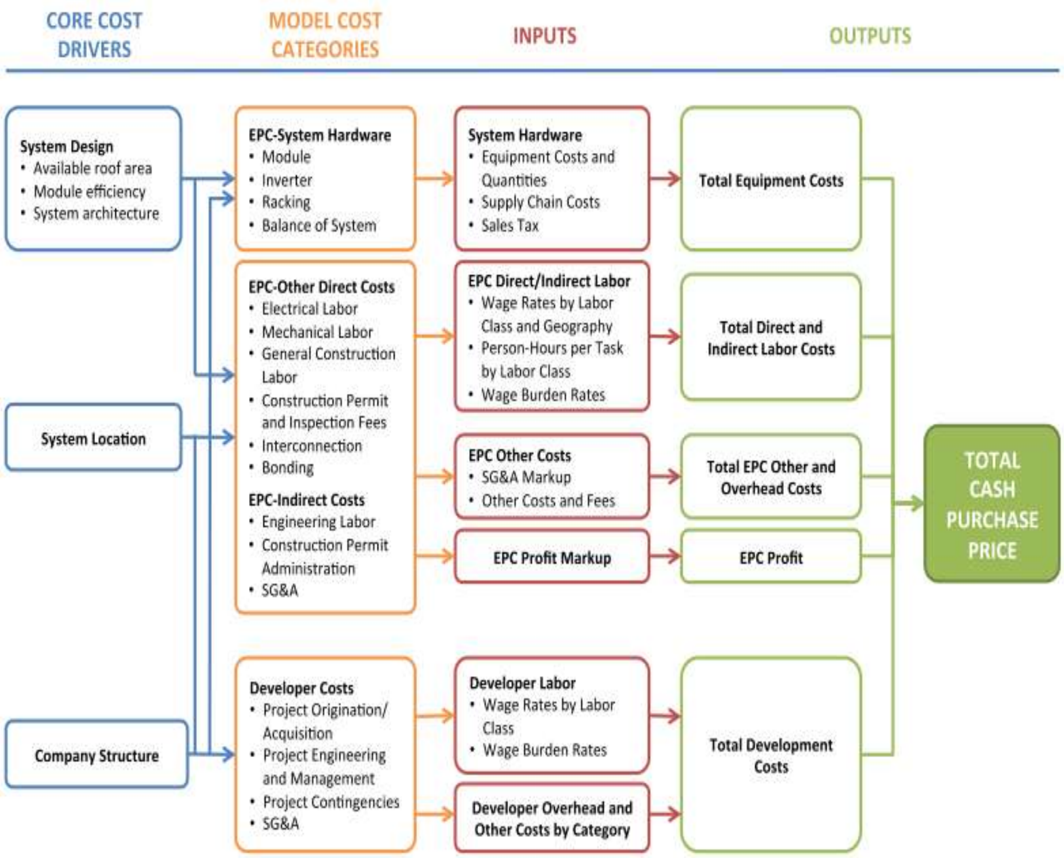


Figure (4.10): Schematic of commercial system model. [24]

There are differences between the commercial-scale system model structure and the residential-scale model by separating the commercial-scale system estimates into distinct engineering, procurement, and construction (EPC) and project-development functions. While some firms engage in both activities in an integrated manner, so that the distinction helps highlight the specific cost trends and cost drivers associated with each function.

According to the figure (4.10); the commercial benchmark cash purchase price is modeled at **2.16$/W**, with cost breakdown,where these costs can be classified in figure (4.11), generally the higher costs that affect the total cost value are actually the module cost or generally the EPC costs and development costs. Table (4.8) explains the details of each value from the total value.

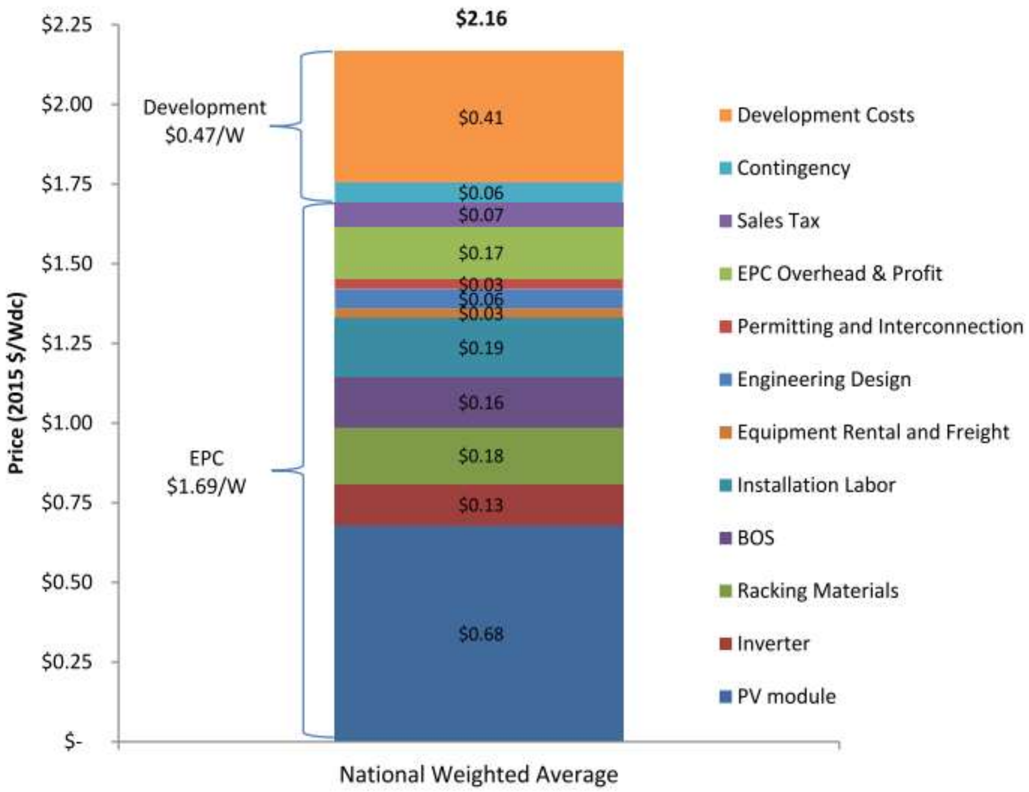


Figure (4.11): Modeled commercial PV system price. [24]

Table (4.8): Key commercial modeling assumptions.

Category	Modeled Price (Price range)	Description
EPC-Module ($/Wdc)	0.68$ (0.65-0.7$)	Ex-factory gate price. 310-W multicrystalline, 72- cell, 6-inch cell, at 16% efficiency.
Inverter ($/W)	0.13$/Wdc (0.15-0.17$/Wac, 0.12-0.13$/Wdc)	Ex-factory gate prices; three-phase string inverter; Per-Wdc pricing assumes a 1.3 inverter-loading ratio.
EPC-Racking, ($/Wdc)	0.21$ (0.16–0.22$)	Ex-factory gate prices; flat-roof ballasted racking system.
EPC-BOS Materials, ($/Wdc)	0.18$	Conductors, conduit and fittings, transition boxes, switchgear, panel boards, etc.
EPC-Sales Tax	(0–6%)	Percent mark-up on equipment only.
EPC Installation Labor, ($/Wdc)	0.19$	All direct installation labor.
EPC-Permitting and Commissioning, ($/Wdc)	0.09$	0.03$/W construction permit fees and inspection costs; $0.06/W for interconnection, testing, and commissioning.
EPC-Overhead and Profit	20% (5–20%)	Markup on all direct costs; covers all overhead items such as back office staff, office space, etc. and profit; We use the upper range of markups because we benchmark a relatively small system size at 200 kW.
Developer-interagency	4%	Estimated as markup on EPC price.
Developer-Overhead, ($/Wdc)	0.41$	fixed overhead expense such as payroll, facilities, travel, etc. across administrative, business development, finance, and other functions; assumes 10MW/year of system sales.

4.5.3 Utility-Scale System Fixed Costs [24]

The studied system used100-MW, 600-Vdc utility system using 72-cell, multi-crystalline 310-W modules from a Tier 1 supplier, three-phase central inverters, and both fixed-tilt, as well as, single-axis tracking ground-mounted racking systems using driven-pile foundations .Figure (4.12) shows the schematic of Utility-Scale System model.

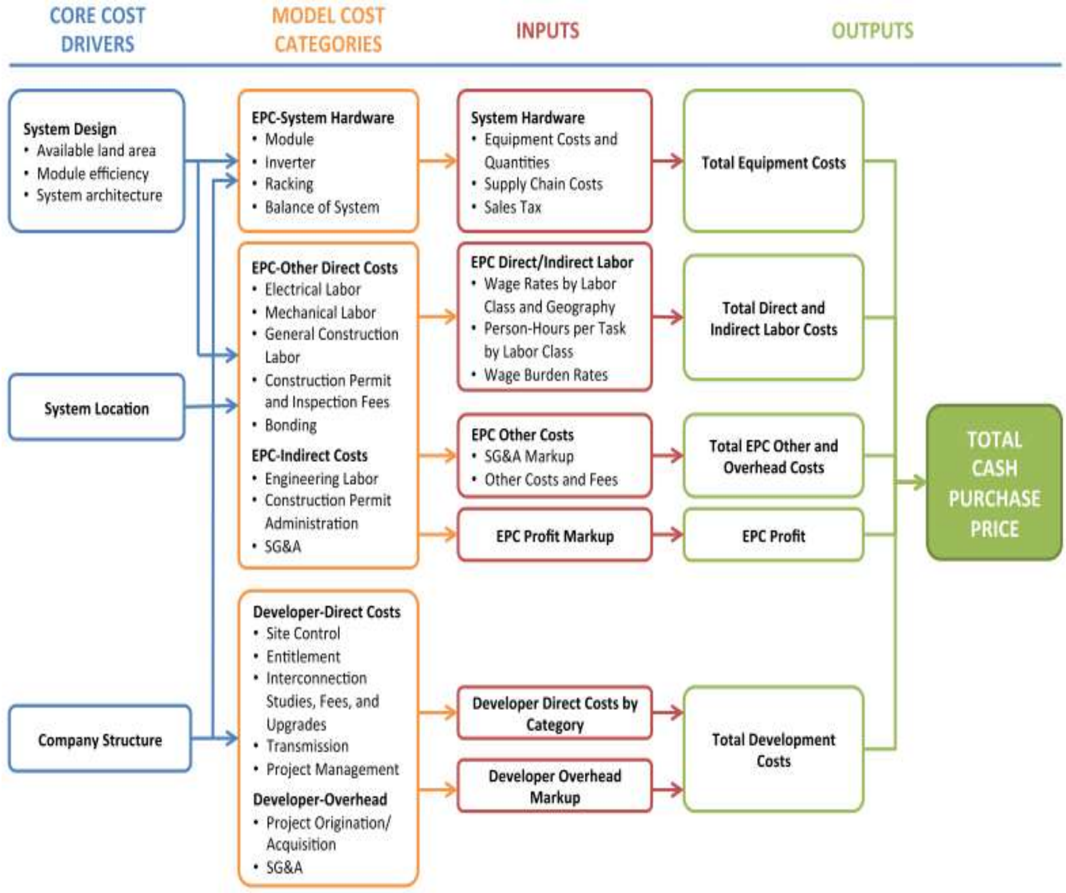


Figure (4.12): Schematic of utility-scale system model. [24]

After analysing figure (4.12); the utility-scale benchmark cash purchase price is modeled at **1.77$/W** for the fixed-tilt systems and at **1.9$/W** for single-axis-tracking systems, with cost breakdown, where these costs can be classified in figure (4.13), generally the higher costs that affect the total cost value are actually the module cost or generally the EPC costs and development costs. Table (4.9) explains the details of each value from the total value.

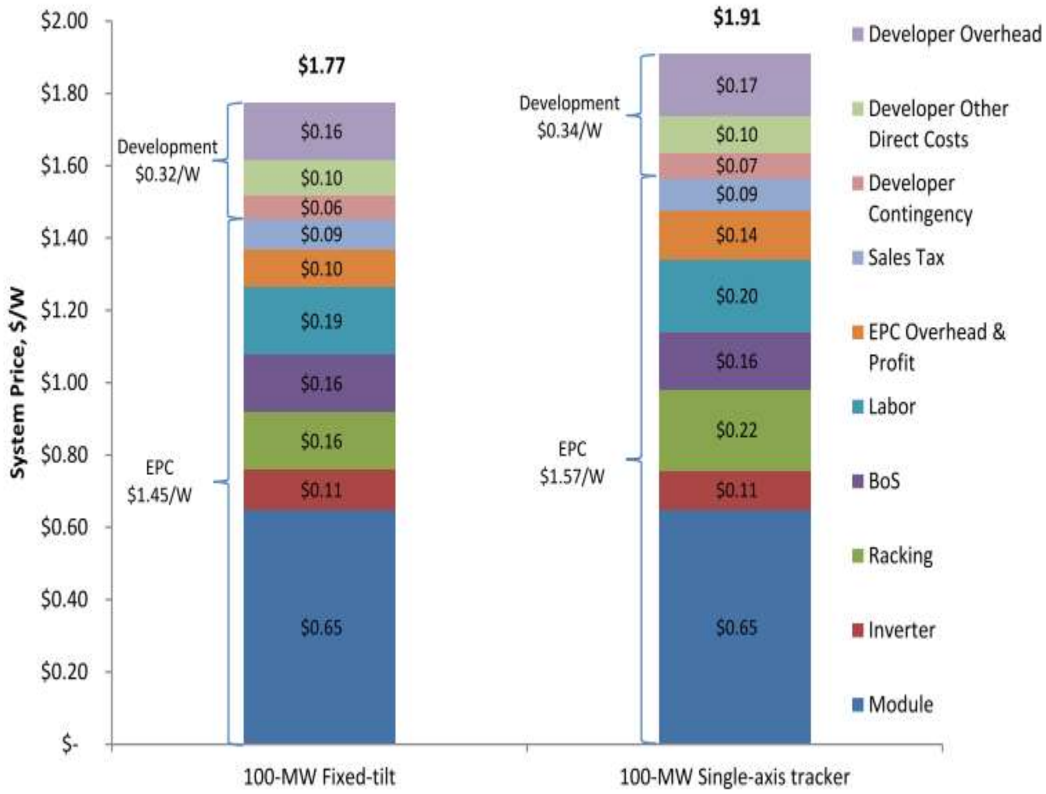


Figure (4.13): Modeled utility- scale PV system prices. [24]

The tracker systems actually cost more than the fixed tilt systems because of the additional cost of tracker machines and sensors, where the difference in the cost in figure (4.13) is about 0.14$/W.

Table (4.9): Key utility modeling assumptions.

Category	Modeled Price	Description
EPC-module ($/Wdc)	0.65$	Ex-factory gate prices.
EPC-inverter ($/Wac and $/Wdc)	0.14$ (AC) 0.11$ (DC)	Ex-factory gate prices; assumes 1.3 inverter loading ratio.
EPC-racking ($/Wdc)	0.16$ (fixed) 0.22$ (tracker)	Ex-factory gate prices
EPC-BOS materials ($/Wdc)	0.16$	Ex-factory gate prices for switchgear, transformers, combiners, fuses, breakers, conductors, conduit, and all other ancillary equipment required to complete a system.
EPC interconnection line costs	<10 MW, 0 miles; >200 MW, 5 miles at 500,000$/mile; 10–200 MW, linear interpolation at 500,000$/mile	All costs associated with construction of AC feeder lines from the main site to the substation at the point of Interconnection to existing transmission lines.
EPC-installation Labor ($/Wdc)	0.19$ (fixed) 0.20$ (tracker)	Uses national capacity-weighted average labor rates.
EPC-G&A	8%	Markup on EPC direct costs.
Development land costs ($/Wdc)	0.03$	Costs associated with obtaining legal control of the site.
Development entitlement And environmental permitting costs	$500,000 in CA; $250,000 in other states	Land entitlement costs, including activities related to obtaining conditional use permits, and any related environmental studies and permitting.
Development overhead (%)	15% for systems <10 MW 10% for systems >100MW Linear interpolation for systems 10–100 MW	Includes overhead expenses covering payroll, facilities, and other expenses across administrative, finance, legal, information technology, and other corporate functions

4.5.4 The Resent PV Prices

Benchmark prices are down in comparison to (Q4 2013), in which these reductions came from the lower equipment prices and the compressed margins, therefore, the reductions in the commercial scale benchmark also reflect changes in our conceptual system design and a change in how we approach modeling profit, so that can now exclude development profit above the total cost coverage, reflecting a project price that results in a developer net income of zero.The cost reduction or the price changes shown in table (4.10).

Table (4.10): Price Changes of Solar systems form (Q4 2013) [24].

Benchmark	Q4 2013 ($/Wdc)	Q1 2015 ($/Wdc)	Change
Residential-scale Benchmark Up to 5-kW	3.31	3.09	-7%
Commercial-scale Benchmark 5-200-kW	2.41	2.16	-10%
Utility-scale Benchmark 200kW-100MW	1.81	1.77	-2%

The modules costs change generally toward the lowest costs, where the change in the costs in dollar per watt can be seen clearly for the U.S modules between the year 2013 and 2015. Today benchmark prices are also down in comparison to Q1 2015and also in comparison to other regions, in which the costs of commercial crystalline modules in the other regions mentioned in table (4.11).

Table (4.11): Commercial crystalline modules prices at Nov. 2016 [25]

Module origin	Module price at Nov. 2016 ($/Wp)	U.S module price at Q1. 2015 ($/Wp)
Germany, Europe	0.53	0.68
Japan, Korea	0.61	
China	0.52	
Southeast Asia, Taiwan	0.44	

4.6 Solar Systems O&M Fixed and Variable Costs

O&M generally represents a small fraction of a solar system project development and operational costs. The estimation of the total established costs and operation and maintenance costs of PV system with different capacities that cover the expected load needed; mentioned in table (4.12) which discusses the costs of the PV generating technology, since these costs include the Conduct or ensure on-going operations and maintenance (O&M), including repair and replacement (R&R) that can be classified as following:

1. O&M agreements.
2. Warranties.
3. Monitoring system.
4. System performance.
5. Production guarantees.
6. Buyout Options.

Table (4.12): Solar systems O&M fixed costs [26]

PV System Capacity	Fixed O&M ($/kW-yr.)	Fixed O&M Std. Dev. (+/- $/kW-yr.)
<10kW	21	20
10-100kW	19	18
100-1000kW	19	15

According to table (4.12); these operational and maintenance costs represented in figure (4.14) in order to get a formula for the other capacities.

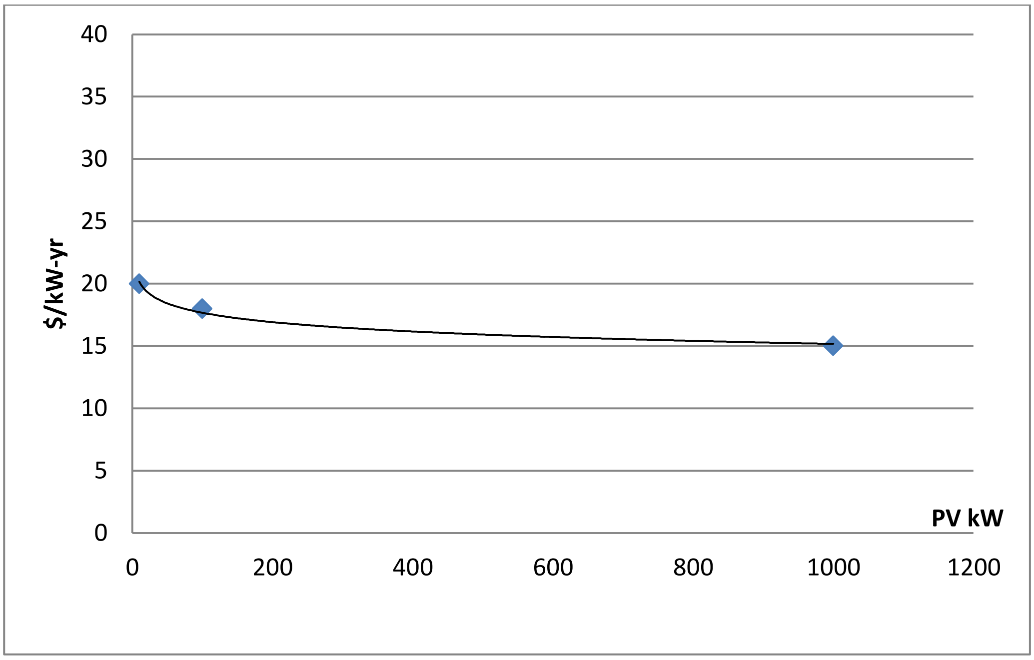


Figure (4.14): Fixed PV systems O&M costs curve.

The fixed PV systems O&M costs curve represents the following formula:

$$Y = -\ 0.00144X + 19.278 \qquad (4.11)$$

Where; Y = Fixed PV systems O&M costs ($/kW-yr.).

X = PV system capacity (kW).

4.7 Inverters Fixed Costs

According to the sales department at Engineering for Trading and Contracting Company (ETCO) in Ramallah; several kinds of inverters mentioned in this section since all of these are made in Turkey.

4.7.1 Hybrid Inverters

These types of inverters characterized with the pure sine wave output, availability to use as solar inverter with connection to solar panels for Photovoltaic off-grid System applications, availability to use as line-interactive UPS with charger wherever utility supply is present, perfect indoor UPS: clean, noise-free and odourless, overload, short circuit and low battery protections. Table (4.13) represents the costs of these types of inverters. The full data attached in the appendix (3).

Table (4.13): Hybrid inverter costs

Hybrid Inverter Capacity (kVA)	**Price ($)**
1.2	720
2.4	990
3.6	1,080
6.6	1,800
10	2,250
13	2,880

After analysing the data that mentioned in table (4.13) and representing these data with a curve of costs; we got the figure (4.15) that shows a formula to enable calculating the costs of any other inverter's capacity.

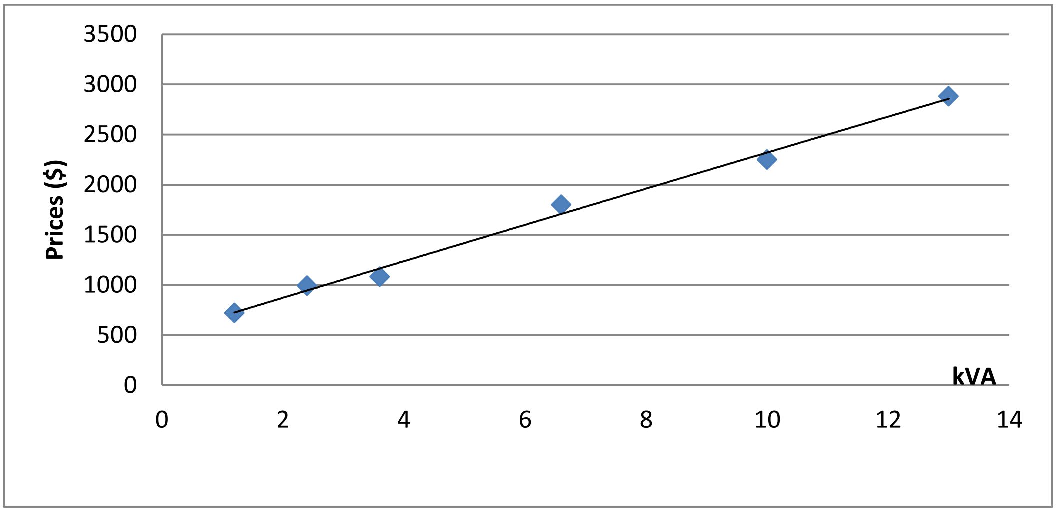


Figure (4.15): Hybrid inverters Prices.

The formula got from figure (4.15) as following:

$$Y= 180.65X + 512.01 \quad (4.12)$$

Where, Y = Hybrid inverter price ($).

X = Hybrid inverter capacity (kVA).

4.7.2 On-grid Inverters

These types of inverters characterized with the accurate power conversion from Solar panel to local grid, compact size, light weight, ease of installation to save time and money, increased efficiency (up to 98%) minimum power loss, maximum reliability and enclosure for both indoor

and outdoor application. Table (4.14) represents the costs of these types of inverters. The full data attached in the appendix (4).

Table (4.14): On-grid inverter costs

On-grid Inverter Capacity (kW)	Price ($)
2	2,000
3	2,500
5	3,250
10	6,250

These data are analysed to get the figure (4.16) and to get the formula of the costs from the cost curve of On-grid inverters.

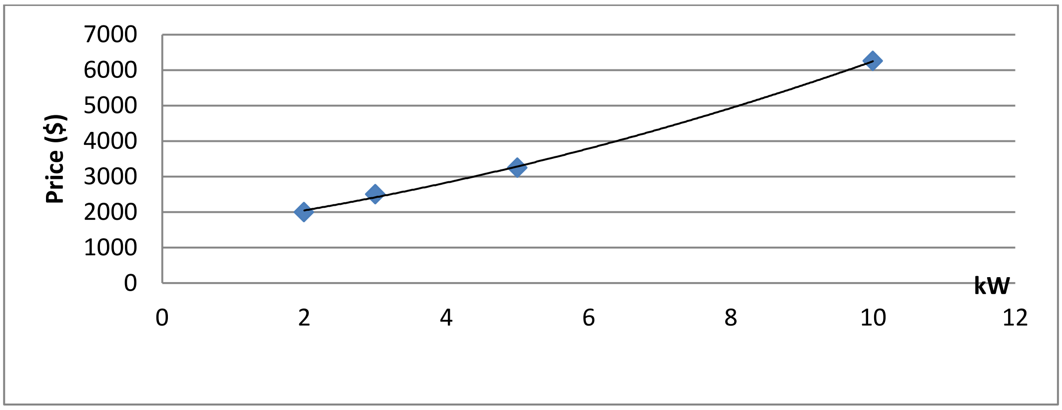


Figure (4.16): On-grid inverters Prices.

The formula got from figure (4.16) as following:

$$Y= 532.89X + 835.53 \tag{4.13}$$

Where, Y = On-grid inverter price ($).

X = On-grid inverter capacity (kW).

4.7.3 Home Inverters Costs

These types of inverters characterized with the advanced battery management (ABM), Auto restart after mains recovery, charging during switched off mode, short circuit and overload protection. Table (4.15) represents the costs of these types of inverters. The full data attached in the appendix (5).

Table (4.15): Home inverter costs

Home Inverter Capacity (VA)	Price ($)
600	250
800	270
1000	350
1500	400

4.8 Batteries fixed Costs

According to the sales department at Engineering for Trading and Contracting Company (ETCO) in Ramallah; several kinds of batteries mentioned in this section in which all of these made in Turkey. Table (4.16) shows the costs of batteries per Ah.

Table (4.16): Batteries fixed costs

Battery Capacity(Ah)	Price ($)	Installed Price ($)
12v/5Ah Standard	13	18
12v/5Ah Long Life	14	19
12v/7Ah Standard	18	27
12v/7Ah Long Life	20	29
12v/9Ah Standard	21	30
12v/9Ah Long Life	25	34
12v/12Ah Standard	28	37
12v/12Ah Long Life	33	40
12v/20Ah Standard	46	53
12v/20Ah Long Life	53	60
12v/26Ah Standard	63	72
12v/26Ah Long Life	66	76
12v/40Ah Standard	100	115
12v/40Ah Long Life	115	132
12v/65Ah GEL	163	187
12v/100Ah GEL	238	273
12v/150Ah GEL	344	395
12v/200Ah GEL	466	536

The batteries costs are analysed in order to get the following formula as shown in figure (4.17):

$$Y = 2.6407X + 6.2528 \tag{4.14}$$

Where, Y =Standard installed battery Price ($).

X = Standard Battery Capacity (Ah).

As well as:

$$Y = 2.6135X + 11.277 \tag{4.15}$$

Where, Y = Long life installed battery Price ($).

X = Long life Battery Capacity (Ah).

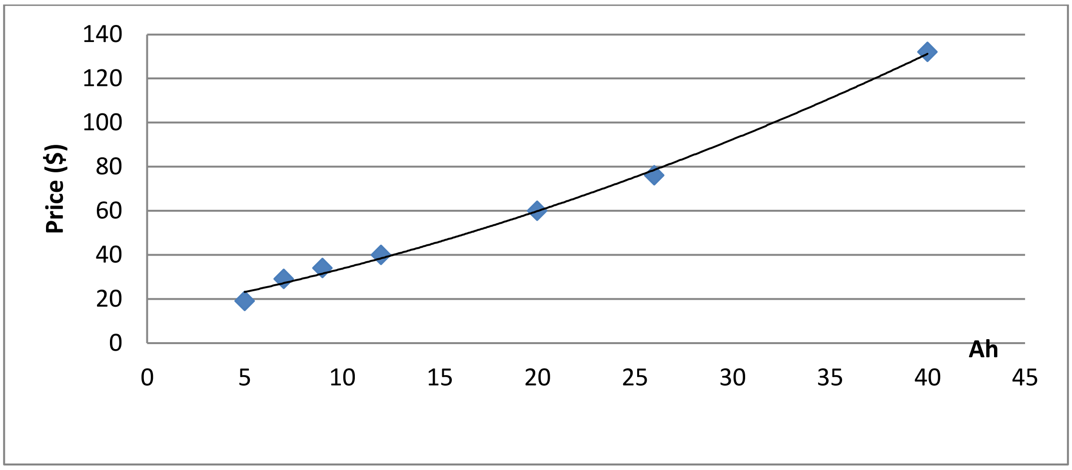


Figure (4.17): Batteries fixed costs curve.

4.9 PV Systems Capitalized Cost (CC_{PV})

The PV capitalized cost (CC) can be defined as the sum of the total fixed costs and the operational and maintenance costs of the proposed PV system at specified period and running hours.

$$CC_{PV} = \text{Net Fixed Cost} + \text{O\&M Costs} + \text{Land cost} \tag{4.16}$$

The above equation represents approximately the capitalized cost of PV system, they supposed the useful life cycle of the PV system to be **25-40 yr.** [26] and without discussing the cost of the land used. The approximate area which is needed for each system shown in table (4.17).

Table (4.17): Costs of the PV system land used [26]

PV System Capacities	**Size (m^2/MW)**	**Size Std. Dev. (m^2/MW)**
PV<10 kW	12949.93	8903.03
PV 10-100kW	22257.7	2832.2
PV 100 – 1,000 kW	22257.7	2832.2

According to table (4.17), the area mentioned for PV sizes was based on installed projects, but vary from project to project according to its elements, components and requirements. Therefore, the average area and the standard deviation of this average were taken into account, either by increasing or decreasing under the title Size Standard Deviation.

4.10 Summary

It is clear that there are many types of alternative and available solutions such as diesel generators and PV systems which their costs vary due to the different types, different sizes and consumption of these systems, and also vary according to their differences in the fixed costs and O&M costs as mentioned in this chapter to be able to choose the most economical alternative solution with less cost of energy. To get the less cost of energy system from these alternative sources we should study the tariff systems in Palestine as discussed in chapter 5.

Chapter Five

Peak Demand Management by Using Different Tariff Structures

5.1 Introduction

Tariffs are the most common kind of barriers to trade; that can be defined as a tax imposed on an imported or exported things, so the electricity tariff is the amount or the costs that the consumer has to pay for making the power available for them at their homes. Electrical tariff value varies widely from one country to another, and may vary significantly from a locality to another within a particular country, as well as, there are many reasons that account for these differences in price. The price of power generation depends largely on the type and market price of the fuel used, government subsidies, government and industry regulation, distributers regulations and even local weather patterns.Tariffs used in Palestine are divided into two parts: Flat Rate Tariff and Time of Use Tariff.

5.2 Flat Rate Tariff in Palestine [9]

This section highlights the flat rate tariffs, where these tariffs are fixed values per time during the day that the consumer must pay to the electricity distributers depending on the nature and the classification of the load, which can be categorized as following:

1. Residential Tariff

This tariff is applied in all areas of WB except the areas of Jericho and the Jordan Valley, residential houses within the housing projects, places of worship and the elevators used by the consumers, for post-paid single phase and three phases meters. Table (5.1) illustrates these categories excluding VAT.

Table (5.1): Residential tariff categories.

Category	Tariff (NIS/kWh)
1-160kWh per month	0.4366
161-250 kWh per month	0.4707
251-400 kWh per month	0.5429
401-600 kWh per month	0.5805
More than 600kWh per month	0.6417

Other tariffs can be applied for the areas of Jericho and the Jordan Valley, residential houses within the housing projects, places of worship and the elevators used by the consumers, for post-paid single phase and three phases meters. Table (5.2) illustrates these categories excluding VAT.

Table (5.2): Tariff categories for Jericho and the Jordan Valley.

Category	Tariff (NIS/kWh)
1-500kWh per month	0.4275
More than 600kWh per month	0.4655
For prepaid meters	0.4513

2. Commercial Tariff

Applied to hotels, public buildings, hospitals, sport, social and cultural clubs, shops, private and public companies, banks, restaurants, nightclubs, amusement parks, cinemas, regular bakeries, shops for selling sweets, photography studios, doctors' offices, pharmacies, X-ray clinics, laboratory clinics, weavers, shops for selling shoes, elevators in commercial buildings, shops that are using the technology of water purification for trading, Water pumps for the purpose of selling water, refrigerators used to save the plant and animal products, automobile laundries, stores for punctures , shops for upholstery and the power of cars, refrigerators repair shops, offices and engineering firms, educational facilities and the institutions of civil society and internationally, for post-paid single phase and three phases meters. Table (5.3) illustrates these categories excluding VAT.

Table (5.3): Commercial tariff categories.

Category	Tariff (NIS/kWh)
Post-paid meters	0.5956
Pre-paid meters	0.5684

3. Industrial Tariff

Applied on the industrial loads supplied from the low voltage (L.V) networks and who have monthly consumption less than 60,000kWh. Table (5.4) illustrates this category excluding VAT.

Table (5.4): L.V networks Industrial tariff categories.

Category	Tariff (NIS/kWh)
Fixed tariff	0.4850

Applied on the industrial loads supplied from the medium voltage (M.V) networks 33, 11, 6.6kV and there is no possibility to apply the Time of use tariff system. Table (5.5) illustrates this category excluding VAT.

Table (5.5): M.V networks Industrial tariff categories.

Category	Tariff (NIS/kWh)
Fixed tariff	0.4136

For the industrial loads supplied from the low voltage (L.V) networks and who have monthly consumption more than 60,000kWh, where there is no possibility to apply the Time of use tariff system; new tariff taken into account. Table (5.6) illustrates this category excluding VAT.

Table (5.6): L.V networks Industrial tariff categories.

Category	Tariff (NIS/kWh)
Fixed tariff	0.5238

4. Agricultural Tariff

Applied to all kinds of farms, refrigerators to store the Palestinian agricultural fresh products between the seasons and refrigerators to store the seeds as shown in table (5.7).

Table (5.7): Agricultural tariff categories.

Category	Tariff (NIS/kWh)
Fixed tariff	0.4400

5.3 Time of Use Tariff in Palestine [9]

Time of use tariff (TOU) is a tariff applies different prices for electricity at different times of the day. Time is divided into Peak, Shoulder and Off-Peak periods which reflect the level of demand on the electricity network,

which during Off-Peak periods the electricity prices will be cheaper than at other times. Nowadays most of companies in Palestine trend to apply these tariffs to be a main solution of the peak demand problem such as JEDCO Company.

The important advantages of the time of use tariff for the energy company are that they can then avoid building very costly power plants by suppressing peak demand, as well as peak supply can also be lower without power shortage because of the over peak demand and then savings can be passed on to consumers.

This type of tariffs Applied to the industrial consumer supplied from the L.V networks a tariff according to the time of consumption, in the case if the consumption exceeded 60,000 kWh per year, if technical possibility allowed only. While the tariff according to the time of consumption optionally applied to the rest of the not industrial consumers supplied from the L.V systems, in the case if the consumption exceeded 60,000 kWh per year, if technical possibility allowed only. Table (5.8) illustrates the sliding scale tariff for the L.V networks excluding VAT.

Table (5.8): Sliding scale tariff for the L.V networks.

	Summer	**Autumn and spring**	**Winter**
Time interval A (NIS/kWh)	0.3767	0.3602	0.4010
Time interval B (NIS/kWh)	0.5408	0.44	0.6263
Time interval C (NIS/kWh)	1.1894	0.5303	1.0283

While there are other tariffs applied as time of use tariffs for the consumers connected on the M.V networks such as 33,11,6.6 KV, if technical possibility allowed only. Table (5.9) illustrates the sliding scale tariff for the MV networks excluding VAT.

Table (5.9): Sliding scale tariff for the M.V networks.

	Summer	Autumn and spring	Winter
Time interval A (NIS/kWh)	0.2886	0.2780	0.3149
Time interval B (NIS/kWh)	0.4349	0.3491	0.5285
Time interval C (NIS/kWh)	1.0305	0.4336	0.8939

As shown in the last two tables, the tariff's value varies from season to season but also varies from hour to hour during the day depending on the intervals shown in these tables. According to JDECO Company; the time of use tariff for low voltage systems has been applied with determining the periods for each of these intervals as shown in figure (5.1), figure (5.2) and figure (5.3).

1. Winter Season Tariff

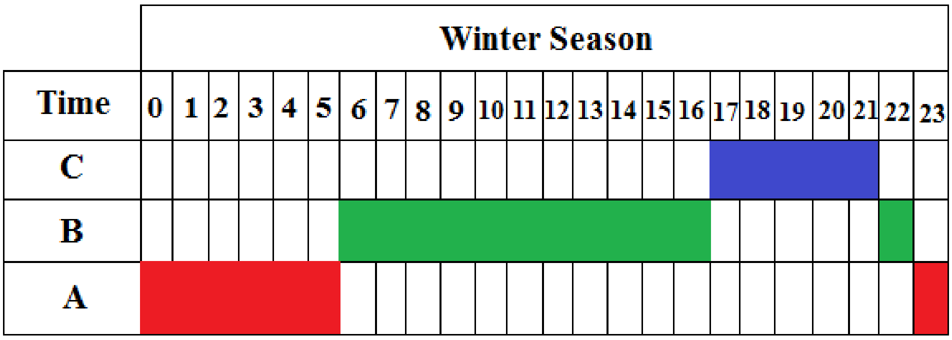


Figure (5.1): Winter season tariff.

2. Spring and Autumn Tariff

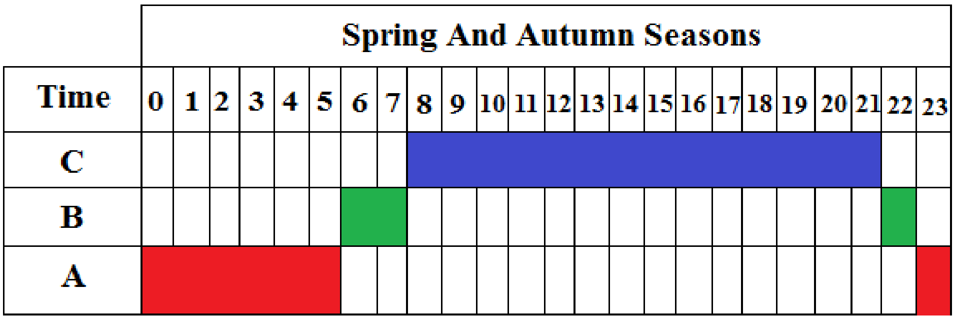


Figure (5.2): Spring and autumn season’s tariff.

3. Summer Season Tariff

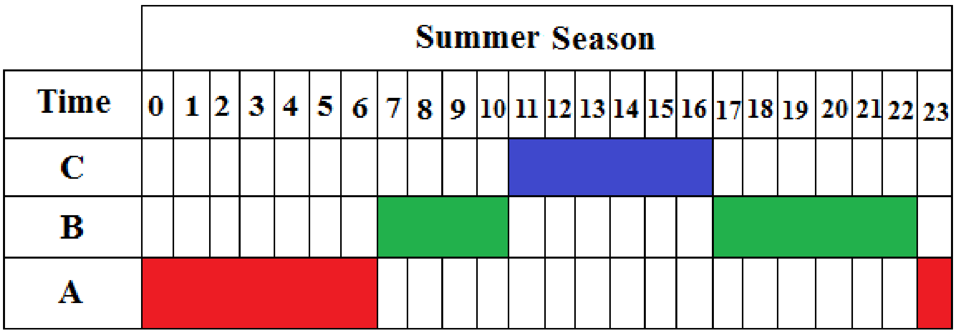


Figure (5.3): Summer season tariff.

5.4 Demand Management by using Different Tariff Structures

The most important issue to study is the peak demand management, so according to the last mentioned types of tariffs; the highest tariff was the Commercial Tariff. This section made a comparison between the commercial flat rate tariff and time of use tariffs by using load as sample that connected to the L.V network shown in figure (5.4), with a scaled annual average equal to 2,054kWh/day in summer season, while the scaled annual average equal to 1,578kWh/day in winter season in order to find the difference in the costs.

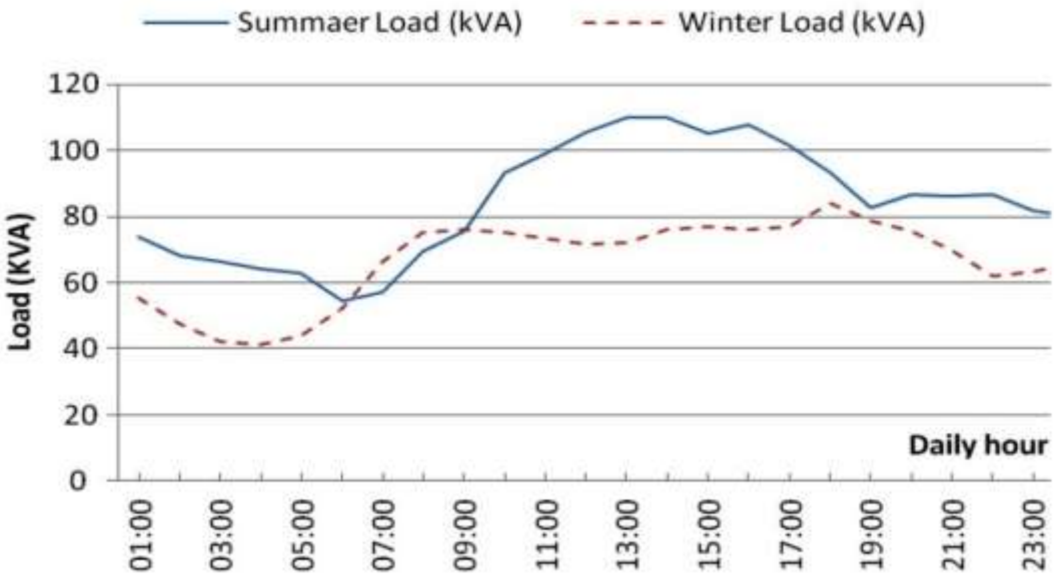


Figure (5.4): Supposed daily load curve.

The commercial flat rate tariff is constant during the day, while TOU tariff varies with time, so by analysing the load in figure (5.4) the cost of consumption in summer and winter season summarized in table (5.10).

Table (5.10): Consumption's costs during summer and winter seasons.

	Flat rate Tariff	**TOU Tariff**
Summer consumption ($/day)	353.3	410.4
Winter consumption ($/day)	271.4	238.1

According to the results in table (5.10); in summer seasons using the flat rate system is less expensive than the TOU system; but using TOU system in winter is better than the flat rate system, so to achieve the less cost of energy if the technical aspect allows to apply the TOU system, we must focus on alternative sources to feed the loads at peak demand periods with cost of energy less than the tariff from the network as discussed in chapter 6 focused on this issue or by making a peak demand management such as peak shifting .

5.5 Summary

It is clear in this chapter that the tariffs varies form facility to another due to the classification and the demand of theses facilities which the commercial tariff is the highest tariff among these tariffs so the TOU system came to help these facilities to reduces their consumption and to save more money through using the methodologies of management that mentioned in the previous chapters which in turn leads to solve the problems of peak demand. Using alternative sources can also help for getting less cost of energy as discussed in chapter 6.

Chapter Six

An-Najah Hospital (Case Study), for Solving Peak Demand by using PV and Genset

6.1 An-Najah National University Hospital Load Analysis

Load curve is a graphical representation showing the variation in the demand for the energy of consumers on a source of supply with respect to time, in which these loads are never constant; it varies from time to time. These load variation during the whole day for example 24 hours are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as daily load curve as it reflects the activity of a population quite accurately with respect to electrical power consumption over a given period of time. [27] According to the hospital case; Table (6.1) shows measurements of power consumed taken by the Energy Research Center during a day in January by using the digital energy analyzer.

Table (6.1): Daily consumed energies of An-Najah Hospital.

Time	Power (W)	Time	Power (W)
0-1	254,685	12-13	461,515
1-2	248,610	13-14	448,470
2-3	242,670	14-15	455,110
3-4	250,250	15-16	405,695
4-5	258,000	16-17	342,435
5-6	274,115	17-18	344,415
6-7	282,360	18-19	386,935
7-8	382,505	19-20	389,015
8-9	419,120	20-21	388,080
9-10	436,145	21-22	372,015
10-11	460,400	22-23	322,025
11-12	458,185	23-24	303,120

According to table (6.1); the daily load curve was created and illustrated in figure (6.1); that describes the variation of the load during the day.

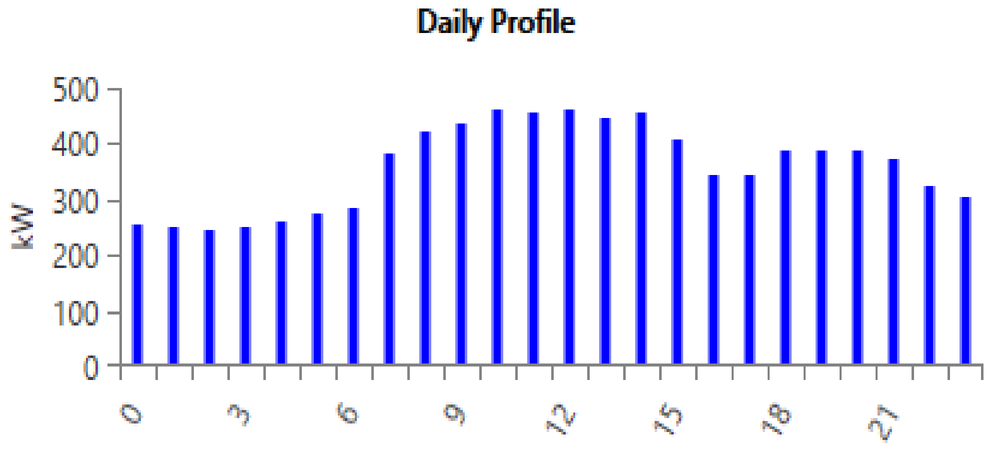


Figure (6.1): An-Najah Hospital daily load curve.

The daily load curve illustrated in figure (6.1) has a great importance in generation and supplying as the curve supplies the following information readily:

1. The daily load curve illustrates the shape of the variation of the load during different hours of the day.

2. The highest point of the curve represents the maximum demand which is equal to 461.515kW.

3. The area under the curve divided by the total number of hours illustrates the average load.

$$\text{Average Load} = \frac{\text{Area (in kWh) under the daily load curve}}{\text{24 hours}} \tag{6.1}$$

Average Load = 357.74 kW.

4. The daily load curve helps in selecting the size and the number of generation units.

6.1.1 Economical Factors

As mentioned in chapter one; energy management is very important in the energy sector , especially for the companies of energy generation, transmission and distribution, in which these companies always aim to optimize the system , so the most important economical factor used as the following:

1. Demand Factor.
2. Load Factor.
3. Diversity Factor.

Firstly, the demand factor is the ratio of the maximum demand of a system to the total connected load, in which the maximum demand is the greatest demand of the load on the power station during a given period, while the connected load is the sum of the continuous ratings of all the equipment connected to supply system. The maximum demand is generally less than the connected load so the values of the demand factor are usually less than 1. [28]

$$\text{Demand Factor} = \frac{\text{Maximum demand}}{\text{Connected load}} < 1 \tag{6.2}$$

The demand factor is constantly changing from time to time or hour to hour of use and it will not be constant and the connected load for large facilities not easily to be measured. Table (6.2) shows several demand factors for several facilities. [28]

Table (6.2): Demand factor for several utilities [28].

Utility	Demand Factor
Residential	0.6
Commercial	0.7
Flats	0.7
Hotel	0.75
Mall	0.7
Restaurant	0.7
Office	0.7
School	0.8
Common area in building	0.8
Public Facility	0.75
Street Light	0.9
Indoor Parking	0.8
Outdoor Parking	0.9
Park/Garden	0.8
Hospital	0.8
Workshops	0.6
Ware House	0.7
Farms	0.9
Fuel station	0.7
Factories	0.9

The demand factor for buildings always between 0.5-0.8 of the connected load, while for the industrial installation this factor may be on an average equal to 0.75, but for the incandescent- lighting equal to 1. [28]

Secondly, as mentioned in chapter one; the load factor is the ratio of the average demand to the maximum demand in a specified period it may be a day, a month or a year. If the factor measured for a day then it is called a daily load factor and the same for the others. [28]

$$\text{Load Factor} = \frac{\text{Actual load}}{\text{Full load}} < 1 \tag{6.3}$$

$$\text{Load Factor (Hospital)} = \frac{357.74}{461.515}$$

$$= 0.78 < 1$$

The load factor is always less than 1 because the maximum demand is always more than the average demand, in which it is used for determining the overall cost per unit generated, as well as, load factor is the other terms of efficiency. The higher load factor is GOOD so the power plant may be highly efficient at high load factors. [28]

Finally, the diversity factor is ratio of the sum of the individual maximum demands of the various sub circuit of a system to the maximum demand of the whole system. [28]

$$\text{Div. F} = \frac{\text{Sum of the idividual maximum demand}}{\text{Maximum demand of the system}} \geqslant 1 \tag{6.4}$$

Div. F (Hospital) = 1.84 >1

Diversity Factor is always more than or equal to 1 because sum of individual maximum demands more or equal to the maximum Demand. [28]

6.2 Feeding Loads under Flat Rate Tariff by Alternative Sources

It should be noted that the commercial's flat rate tariff represents the highest tariff among these tariffs approximately about 0.172$/kWh depending on the VAT values, where it is necessary to find other solutions to feed these loads in order to get the lowest cost of energy (COE), which can be defined as the average cost per kWh of useful electrical energy produced by the proposed system. In other words, there is a term called the Levelized Cost of Energy (LCOE), which is known as the price at which electricity must be generated from a specific source to break even over the lifetime of the project. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel and cost of capital. It can be calculated in a single formula as: [29]

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \tag{6.5}$$

Where, It = Investment expenditures in year t.

Mt = operations and maintenance expenditures in year t.

Ft= fuel expenditures in year t, which is zero for photovoltaic electricity.

Et = electricity generation in the year t.

R= discount rate.

n = investment period considered in years.

To get the lowest COE; An-Najah National Hospital has been taken in consideration as a case study of a commercial load, according to the daily load curve in figure (6.1) and the previous laws and the costs in the previous chapters by using HOMER program, all of the available options should be considered and then making a comparison among them which all figures of cash flow available in appendix (6).

6.2.1 Load Feeding by Grid and Genset

It has been proposed to feed the Hospital' loads from the electrical networks and 25%, 50% and 57% from the DG systems. Table (6.3) shows the results of these assumptions.

Table (6.3): Comparison table of load feeding by Grid and Genset.

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
25% DG	1.56 M	- 163,973	50,000	0.177
50% DG	1.61 M	- 163,463	100,000	0.182
75% DG	1.64 M	- 163,054	140,000	0.186

As a result from table (6.3); the Net Present Cost (NPC) increased by the increasing of the contribution percent from the DG. NPC is the present value of all the costs that the system incurs over its lifetime, minus the present value of all the revenue that it earns over its lifetime .The initial costs also increased as well as the cost of energy, therefore none of the

options is the least COE less than the commercial tariff. This comes from the low initial costs and the high operational and maintenance costs of DG.

6.2.2 Load Feeding by Grid and PV System

In this case, it has been proposed to feed the Hospital' loads from the electrical networks and 25%, 50% and 75% from the PV system with and without storage batteries (SB). Table (6.4) shows the results of these assumptions.

Table (6.4): Comparison table of load feeding by grid and PV system.

Case No.	Option	NPC ($)	Operating cost ($)	Initial Capital ($)	COE ($/kWh)
1	25% PV without SB	1.39 M	-64,574	795,600	0.127
2	25% PV with SB	2.41 M	-101,299	1.48 M	0.22
3	50% PV without SB	1.27 M	+35,335	1.59 M	0.077
4	50% PV with SB	3.24 M	-36,213	2.91 M	0.197
5	75% PV without SB	1.14 M	+135,018	2.39	0.0513
6	75% PV with SB	4.14 M	+26,995	4.39 M	0.186

According to the last results; the COE decreases due to the increase in the size of the PV system, and also the COE for the systems without storage batteries is always less than the COE for the systems with storage batteries that because of the expensive costs of batteries. NPC decreases due to the increase in the size of PV system for the systems without storage batteries, while increases due to the increase in the size of PV system for the systems with storage batteries.

Each of case1, case 3and case 5have COE less than the commercial flat rate tariff, but case 5 has the lowest COE among these cases.

6.2.3 Load Feeding by Grid and hybrid System

In this case, it has been proposed to feed the Hospital' loads from the electrical networks, 20%, 40% and 60% from the PV system and 60%,40% and 20% from diesel genset respectively , with and without storage batteries (SB). Table (6.5) shows the results of this assumption.

Table (6.5): Comparison table of load feeding by Grid, PV system and Genset.

Case No.	Option	NPC ($)	Operating cost ($)	Initial Capital ($)	COE ($/kWh)
1	20% PV,60%Genset without SB	1.86 M	-11,017	777,200	0.186
2	20% PV,60%Genset with SB	2.47 M	-122,948	1.34 M	0.246
3	40% PV,40%Genset without SB	1.57 M	-40,545	1.95 M	0.084
4	40% PV,40%Genset with SB	2.87 M	-48,542	2.43 M	0.203
5	60% PV,20%Genset without SB	1.71 M	+38,889	1.35 M	0.12
6	60% PV,20%Genset with SB	3.31 M	+25,381	3.55 M	0.177

According to the last cases we got table (6.5) as a comparison table; the COE has higher values when we use DGs with high contribution percent more than 40%, while COE has lower values when we use PV systems with high contribution percent more than 40% that is because of the high O&M costs of DGs. Moreover, the COE for the systems without storage batteries is always less than the COE for the systems with storage batteries that because of the expensive costs of batteries. NPC decreases due to the increase in the size of PV system for the systems without storage batteries, while increases for the systems with storage batteries. These results came because of the Homer program tried to use the electricity and PV system instead of DG. Each of case 3 and case 5 have COE less than the commercial flat rate tariff, but case 3 has the lowest COE among these cases.

It is clear that COE by using hybrid systems can be more or less than the commercial flat rate tariff, depending on the demand and desired feeding system. The assumption of feeding the loads from Grid and 75% PV system without storage batteries for all cases has the lowest COE.

6.3 Feeding Loads under TOU Tariff by Alternative Sources

As mentioned in chapter five; the Cost of Energy (COE) is the value of the total cost of installing and operating a project expressed in dollars per kilowatt-hour ($/kWh) of electricity generated by the system over its life, which includes the following: [30]

1. Installation costs.
2. Financing costs.
3. Taxes.
4. Operation and maintenance costs.
5. Salvage value.
6. Incentives.
7. Revenue requirements (for utility financing options only).
8. Quantity of electricity the system generates over its life.

Where the average cost of energy used to find the value of COE for time of use tariff during the day and can be calculated according the following formula:

$$\text{Average COE (\$/kWh)} = \frac{\text{Total energy cost / day}}{\text{Energy / day}} \tag{6.6}$$

Each of figure (6.2), figure (6.3) and figure (6.4); show how the tariff varies according to An-Najah hospital loads during the day for every season with the tariffs in ($/kWh) including VAT approximately about 16% for L.V systems.

1. Average COE of winter season (COE_W)

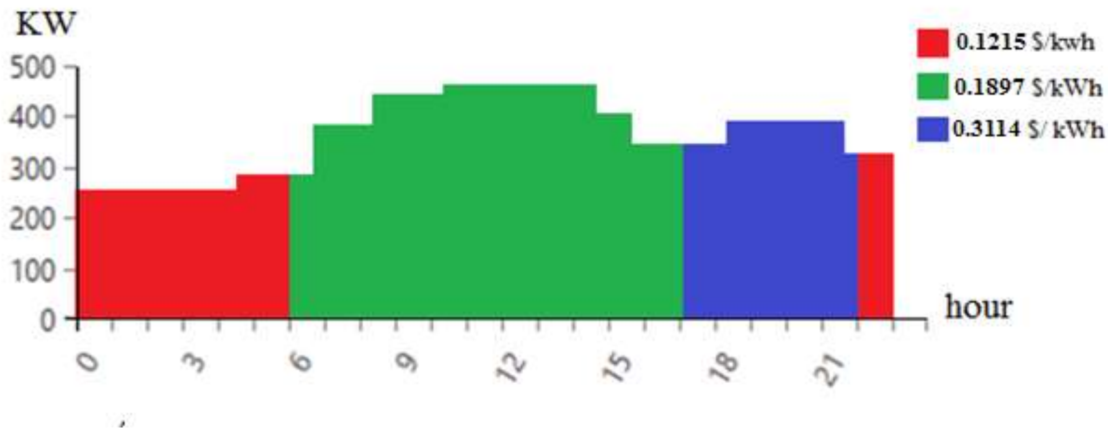


Figure (6.2): Tariff values during winter season.

According to equation (6.6):

$$\text{Average } \mathbf{COE_w} = 0.1992\ \$/kWh = 0.763\ NIS/\ kWh$$

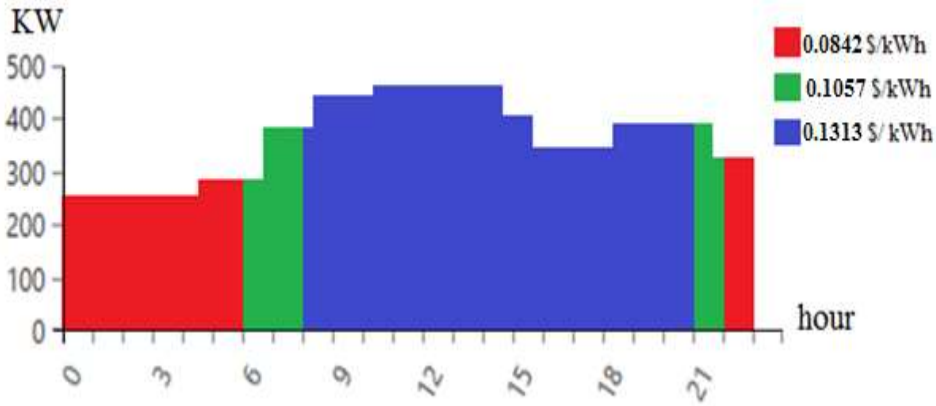


Figure (6.3): Tariff values during autumn and spring seasons.

2. Average COE of Autumn and Spring seasons ($COE_{Sp/A}$)

According to equation (6.6):

$$\text{Average } \mathbf{COE_{Sp/A}} = 0.159\ \$/kWh = 0.608\ NIS/\ kWh.$$

3. Average COE of Summer season (COE_W)

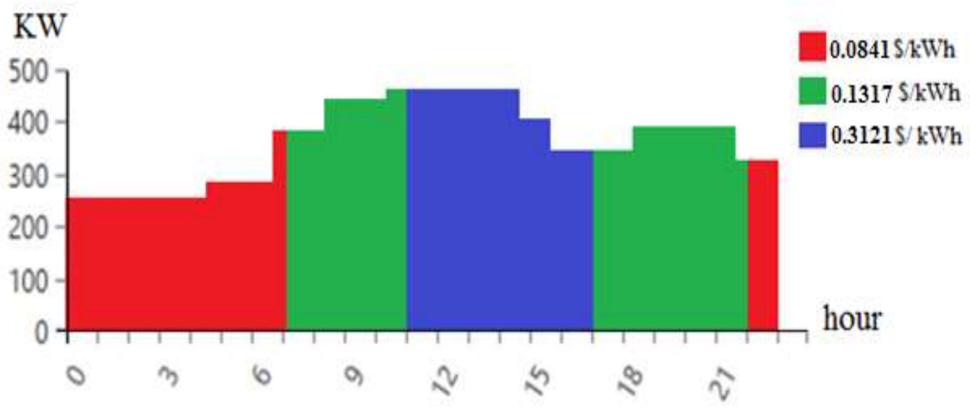


Figure (6.4): Tariff values during summer season.

According to equation (6.6):

Average $\mathbf{COE_S}$ = 0.1535 $/kWh = 0.588 NIS/ kWh.

6.4 Hospital Peak Demand Management

The most important issue to study is the peak demand management, especially for the loads that operating under time of use tariff system because of the highest load values and the highest tariff values. As shown in last figures. The peak demand analysed by using Hybrid Optimization Model for Electric Renewables software program (HOMER) which all figures of cash flow available in appendix (7).

6.4.1 Hospital Peak Management at Winter Season

1. Load Feeding by Grid and PV System

According to figure (6.2); sometimes the peak demand was under tariff equal to 0.1897$/kWh, so the loads analysed as the following to make a peak demand management.

It has been proposed to feed the Hospital' loads from the electrical networks and 25%, 50% and 75% from the PV system with and without storage batteries (SB). Table (6.6) shows the results of these assumptions.

The COE decreases due to the increase in the size of the PV system without storage batteries where always less than the COE_W, while increases for the systems with storage batteries that happens because of the expensive costs of batteries. NPC decreases due to the increase in the size of PV system for the systems without storage batteries, while sometimes increases for the systems with storage batteries that is because of the high initial costs and low O&M costs of PV systems. Each of case1, case 3and case 5 have COE less than the COE_W, but case 5 has the lowest COE among these cases.

Table (6.6): Comparison table of load feeding by grid and PV System.

Case No.	Option	NPC ($)	Operating cost ($)	Initial Capital ($)	COE ($/kWh)	COE_W 0.1897 ($/kWh)
1	25% PV without SB	6.47 M	-456,508	637,500	0.168	COE less than COE_W
2	25% PV with SB	11.26M	-617,706	3.63 M	0.293	COE more than COE_W
3	50% PV without SB	5.69 M	-345,698	1.27 M	0.148	COE less than COE_W
4	50% PV with SB	15.25M	-667,593	6.7 M	0.397	COE more than COE_W
5	75% PV without SB	4.96 M	-238,943	1.91 M	0.129	COE less than COE_W
6	75% PV with SB	11.1 M	-686,873	2.3 M	0.205	COE more than COE_W

2. Load Feeding by grid and Gensets

In this case, it has been proposed to feed the Hospital' loads from the electrical networks and 25%, 50% and 75% from the diesel generator. Table (6.7) shows the results of this assumption.

Table (6.7): Results of load feeding by grid and DG

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
25% DG	7.32 M	- 569,623	28,300	0.19
50%DG	7.33 M	-569,090	58,300	0.191
75%DG	7.34 M	-569,010	62,800	0.192

In these results, the HOMER program tried to use the optimum way to feed the loads, so the program trend to use the electricity from the electrical network instead of diesel generators in order to get the least cost of energy that is because of the high cost of energy of using these generators, therefore all results will have COE more than the $COE_{w.}$

3. Load Feeding by Grid, PV and Genset

In this case, it has been proposed to feed the Hospital' loads 20% from the electrical networks, and the rest from on-grid hybrid system, which 20% from the PV system and 60% from diesel genset, without and with storage batteries (SB). Table (6.8) shows the results of this assumption.

Table (6.8): Load feeding by Grid, 20% from PV and 60% from DG.

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
Without SB	6.66M	-479,885	538,300	0.173
With SB	10,3M	-608,006	2.72M	0.273

As a result of these assumptions, the program tried also to use the optimum feeders, so the program used the PV system and the grid without using the DG. Separating the feeding sources provides the best explanation for it.

4. Load Feeding by Grid, 20% PV and 60% Genset

In this case, it has been proposed to feed the Hospital' loads separately 20% from the electrical networks and the rest from off-grid hybrid system, which 20% from the PV system and 60% from diesel genset, without and with storage batteries (SB). Table (6.9) shows the results of this assumption.

Table (6.9): Load feeding by Grid, 20% from PV and 60% from DG

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
PV +DG Without SB	44.3M	-3.42M	672,812	1.487
PV+DG with SB	39.1M	-2.83M	2.85M	1.302
20% Grid	1.47M	-115,008	0	0.19

5. Load Feeding by Grid, 60% PV and 20% Genset

In this case, it has been proposed to feed the Hospital' loads separately 20% from the electrical networks and the rest from off-grid hybrid system, since 60% from the PV system and 20% from diesel genset, with and without storage batteries (SB). Table (6.10) shows the results of this assumption.

Table (6.10): Load feeding by Grid, 60% from PV and 20% from DG.

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
PV +DG Without SB	36.7M	-2.74M	1.68M	1.224
PV+DG with SB	27.9M	-1.54M	8.23M	0.93
20% Grid	1.47M	-115,008	0	0.19

According to table (6.9) and table (6.10), all cases have COE more than the $COE_{W,}$ because of the high costs of batteries and also the high O&M costs of diesel generators.

6.4.2 Hospital Peak Management at Summer Season

1. Load Feeding by Grid and PV System

According to figure (6.4); sometimes the peak demand was under tariff equal to 0.3121\$/kWh, so the loads are analysed as the following to make a peak demand management.

It has been proposed to feed the Hospital' loads from the electrical networks and 25%, 50% and 75% from the PV system with and without storage batteries (SB). Table (6.11) shows the results of these assumptions.

Table (6.11): Comparison table of load feeding by Grid and PV System.

Case No.	Option	NPC (\$)	Operating cost (\$)	Initial Capital (\$)	COE (\$/kWh)	COE_S 0.1897 (\$/kWh)
1	25% PV without SB	10.5M	-782,391	510,000	0.274	COE less than COE_S
2	25% PV with SB	15.3 M	-943,589	3.24M	0.398	COE more than COE_S
3	50% PV without SB	8.58 M	-571,805	1.27 M	0.223	COE less than COE_S
4	50% PV with SB	13.4M	-732,753	3.99 M	0.348	COE more than COE_S
5	75% PV without SB	6.41 M	-290,696	2.7 M	0.152	COE less than COE_S
6	75% PV with SB	11.2 M	-451,511	5.43M	0.291	COE less than COE_S

The COE decreases due to the increase in the size of the PV system without storage batteries where always less than the COE_S, while increases for the systems with storage batteries that is because of the expensive costs of batteries. NPC decreases due to the increase in the size of PV system for the systems without storage batteries and with storage batteries that is because of the high initial costs and low O&M costs of PV systems. Each of case1, case 3, case 5 and case 6 have COE less than the COE_S, but case 5 has the lowest COE among these cases.

As used in section (6.4.1 case 2) and section (6.4.1 case 3) for winter season we also similarly used for summer season for the rest assumptions and all results of COE was more over than the $COE_{S.}$

It is clear that COE by using hybrid systems can be more or less than the average COE of any season depending on the peak demand, desired feeding system and also on the tariff used at the peak period. The assumption of feeding the loads from Grid and 75% PV system without storage batteries for all cases and seasons has the least COE especially at peak demand.

6.5 Hospital Peak Management for Off-grid Systems

Sometimes the electricity is unavailable or too expensive to bring to homes or cabins, while sometimes it happens to encounter another problem which is the shortage of the electric power needed to feed some of electrical loads. Here it comes the necessity to find alternative energy sources which could be renewable, and the most available solutions are the following: Firstly, Off-grid solar power system that stores the DC electricity in the batteries, so the inverter allows this system to convert DC electrical current coming from the batteries into AC or alternating current. Secondly, Diesel generators as a prime electrical source. Finally, Off-grid Hybrid systems

that use a combination of solar panels and diesel generators according to what is available in the markets. Several assumptions of these solutions considered by using An-Najah Hospital as a special case by using HOMER program which all figures of cash flow available in appendix (8).

1. Load Feeding by Off-grid Solar Power System

In this case, it has been proposed to feed the Hospital' loads totally from the off-grid solar system. Table (6.12) shows the results of this assumption.

Table (6.12): Load feeding by Off-grid solar power system.

NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
7.44M	-176,004	5.82M	0.845

2. Load Feeding by Diesel Generators

In this case, it has been proposed to feed the Hospital' loads totally from the Diesel Gensets. Table (6.13) shows the results of this assumption.

Table (6.13): Load feeding by diesel gensets.

NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
9.43M	-979,911	400,000	1.12

3. Load Feeding by 25% Gensets and 75% PV system

In this case, it has been proposed to feed the Hospital' loads 25% from the diesel generators and the rest from PV system without and with storage batteries (SB). Table (6.14) shows the results of this assumption.

Table (6.14): Load feeding by 25% Gensets and 75% PV system.

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
Without SB	30.2M	-2.12M	3.16M	0.761
With SB	24.2M	-1.33M	7.16M	0.609

4. Load Feeding by 75% Gensets and 25% PV system

In this case, it has been proposed to feed the Hospital' loads 75% from the diesel generators and the rest from PV system without and with storage batteries (SB). Table (6.15) shows the results of this assumption.

Table (6.15): Load feeding by 75% Gensets and 25% PV system

Option	NPC ($)	Operating Cost ($)	Initial Capital ($)	COE ($/kWh)
Without SB	37.8M	-2.9M	839,312	0.952
With SB	32.7M	-2.16M	5.14M	0.824

According to the last cases, the lowest COE for feeding the remote loads was 0.609$/kWh that from 25% from diesel generators and 75% from PV system with storage batteries, because of the lowest operation and maintenance costs of diesel generators.

6.6 Thesis Results in the Management of Peak Demand

Based on all mentioned challenges and constraints in chapter 2 such as supply constraints and lack of energy constraints; several categories and methodologies are proposed in chapter 1 in order to try as much as possible

to find solutions for solving the peak demand and lack of energy capacity problems.

Firstly; by using peak demand management methodologies in order to reduce the need for infrastructure upgrades by encouraging consumers to use less energy as much as possible during peak hours, turning loads on and off at specific times, providing better insight into customer requirements and practices and improving customer satisfaction by decreasing electricity bills . Secondly, by using demand side management categories to implement the mitigating electrical system emergencies, reducing the number of blackouts, increasing system reliability, reducing dependency on expensive imports of fuel, reducing energy prices, reducing harmful emissions to the environment and deferring high investments in generation, transmission and distribution networks.

Another methodology used to reduce the demand especially at peak demand periods was by implementing different tariff structures as mentioned in chapter 5. Tariff varies form facility to another due to the classification and the demand of theses facilities which the commercial tariff is the highest tariff among these tariffs so the TOU system came to solve this issue. In summer seasons using the flat rate system is less expensive than the TOU system; but using TOU system in winter is better than the flat rate system, so to achieve the less cost of energy if the technical aspect allows to apply the TOU system, we must focus on alternative sources to feed the loads at peak demand periods with cost of energy less than the tariff from the network as discussed in chapter 6 focused on this issue or by making a peak demand or demand side management such as peak shifting as discussed in chapter 1.

As mentioned in this chapter; Levelized Cost of Energy (LCOE) is known as the price at which electricity must be generated from a specific source to break even over the lifetime of the project, so DSM enhances the use of several alternative sources especially at peak demand periods to be a solution to reduce the peak demand costs which also enhance the use of the on-grid PV systems or other on-grid hybrid systems in order to get the lowest cost of energy from the optimum alternative sources. An Najah Hospital was used as a special case which the results summarized in the following figures.

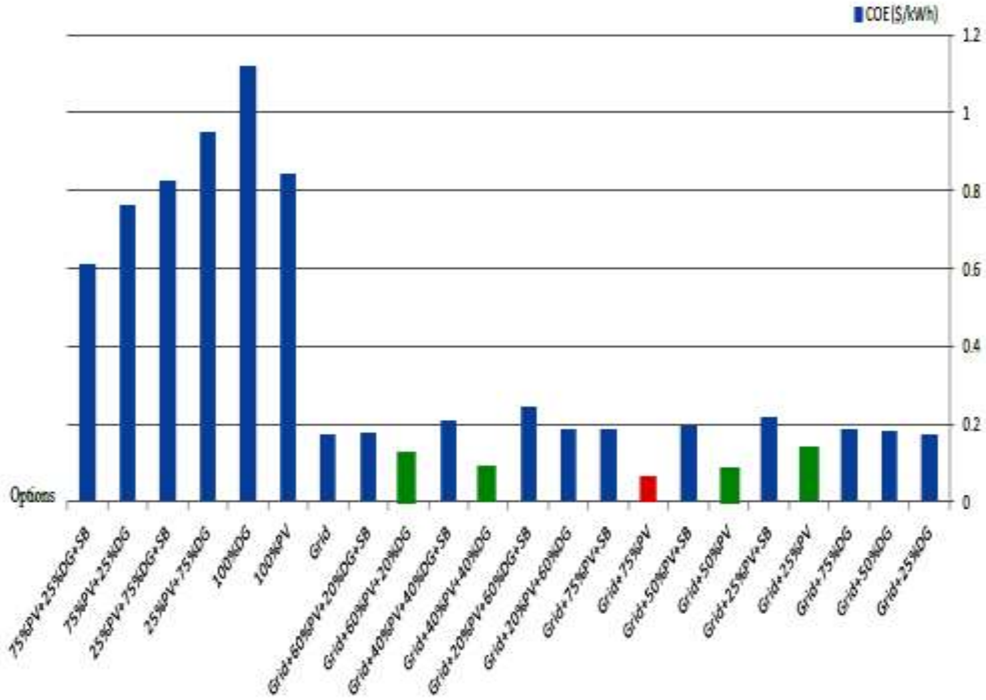


Figure (6.5): COE for several options under flat rate tariff.

As shown in figure (6.5); many options have COE less than the flat rate tariff that can be used as alternative solutions, but the most lowest COE option was " Grid+75%PV".

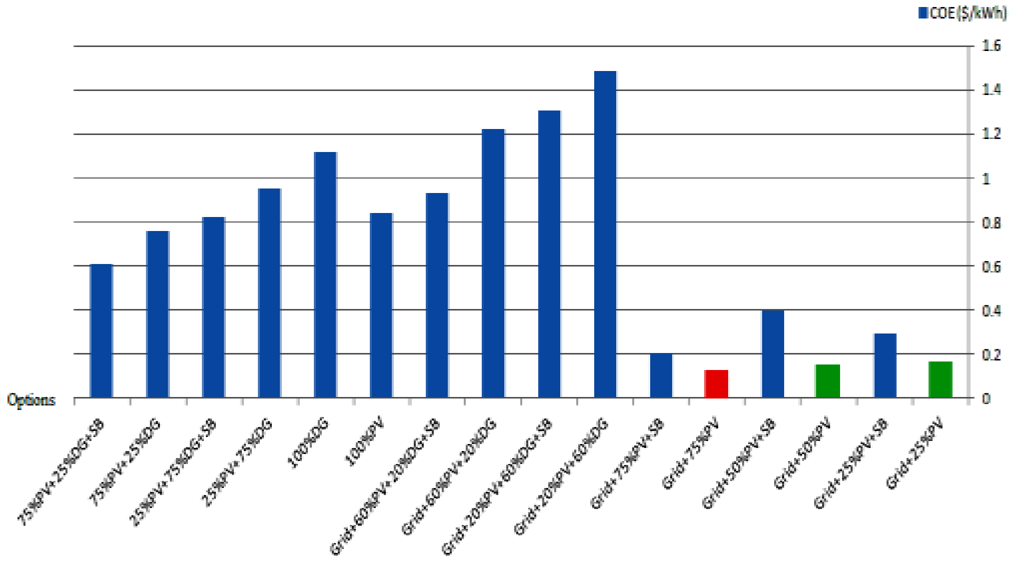


Figure (6.6): COE for several options under winter TOU tariff.

As shown in figure (6.6); many options have COE less than the winter TOU tariff that can be used as alternative solutions, but the most lowest COE option was " Grid+75%PV".

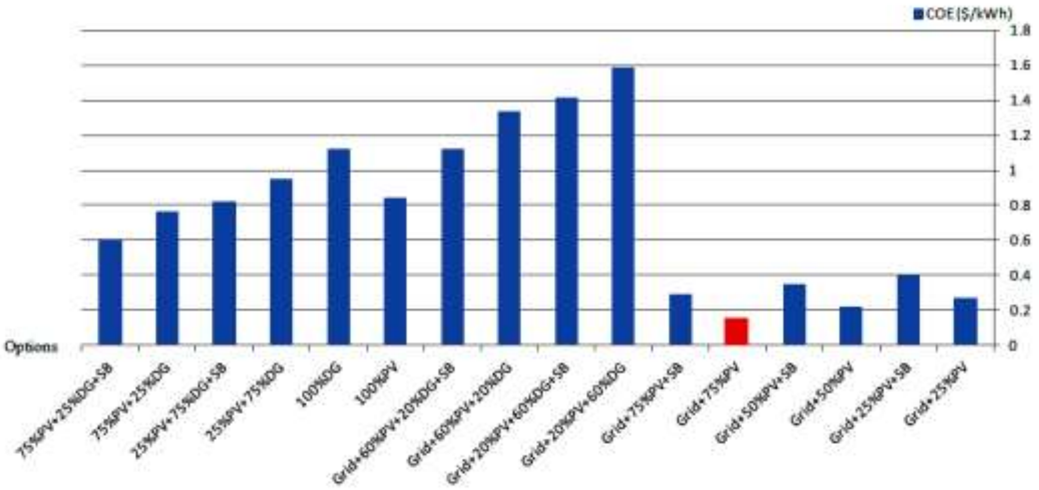


Figure (6.7): COE for several options under summer TOU tariff.

As shown in figure (6.7); many options have COE less than the summer TOU tariff that can be used as alternative solutions, but the most lowest COE option was " Grid+75%PV".

As a result of all these assumptions; some alternative solutions can be used without thinking about the COE especially at peak demand in order to keep the continuity of supply, while other solutions can be used to save more money with less COE.

Chapter Seven

Conclusion and Recommendation

7.1 Conclusion

This study has identified the following:

1. Most of Palestinian electrical networks suffer from several constraints summarized in supply constraints, lack of energy constraints and technical problems such as high losses; high demand that sometimes exceeds the capacity of the incomers.

2. Peak demand management and demand side management are very important methodologies for solving electrical network constraints.

3. Palestine has an excellent solar energy potential that can be used in electricity production.

4. The usage of On-grid PV system can reduce the lack of supply on the electrical network in Palestine.

5. The usage of PV systems with the diesel plants or diesel generators as backup is being disseminated worldwide to reduce diesel fuel consumption and to minimize atmospheric pollution.

6. Diesel engine system has low initial cost, while hybrid PV/generator system is significantly more expensive for the same energy demand at start-up.

7. The PV system uses no fuel and has very low maintenance costs, while the diesel generator requires constant maintenance on a regular basis.

8. Energy management has valuable impacts on the electrical network enhancement especially in peak demand reduction and L.F improvements.

9. The economic analysis of using PV systems and energy management systems for An-Najah Hospital; shows that it is feasible to feed the loads in the On-grid systems from grid and 75% from PV system, while it is feasible to feed the loads in the Off-grid system from the diesel generators and 75% from PV system in terms of the lowest cost of energy for each.

10. The usage of time of use tariffs will motivate the consumers to use the energy management systems.

11. Some times; some of alternative solutions can be used without thinking about the COE especially at peak demand in order to keep the continuity of supply and the reliability of supply, while other solutions can be also used to save more money with less COE.

7.2 Recommendation

Based on this study, the following are recommended:

1. Increase the usage of PV systems with electrical networks especially for commercial facilities.

2. Modify the used tariff structure and to apply the time of use tariff structures for large consumers such as hospitals, factories and universities.

3. Encourage the consumers to use the conservation strategies and energy management systems.

References

1. Foster R. & Cisneros G. (1998). **Life Cycle Cost Analysis for Photovoltaic Water Pumping Systems in Mexico**. The 2nd World Conference on Photovoltaic Solar Energy Conversion. Vienna, Austria: New Mexico State University and Hanley C., Sandia National Laboratory.

2. Bucher W. (2012). **Renewable Energies in Rural Areas**. German Aerospace Research Establishment **:**Cologne, Germany.

3. Zelalem G. (2013). ***Technical and Economic Assessment of solar PV/diesel Hybrid Power System for Rural School Electrification in Ethiopia***. **International Journal of Renewable Energy Research**, Vol. 3, No. 3.

4. Khatib T., Mohamed A., Sopian K. & Mahmoud M. (2011). **Optimal sizing of building integrated hybrid PV/diesel generator system for zero load rejection for Malaysia**. Energy and Buildings, No. 43 p. 3430–3435.

5. Mathias A. (2013, August 14). **Energy Informative: Solar Panels and Home Energy Efficiency**. **Retrieved from Grid-Tied, Off-Grid and Hybrid Solar Systems**: http://energyinformative.org/grid-tied-off-grid-and-hybrid-solar-systems/.

6. Denis, A. (2012). **How to make the most of demand management.** Monash Sustainability Institute Seminar. Monash University: Clayton, Australia.

7. Mehta, V. & Mehta, R. (2004). **Principles of Power System**. **S**. Chand & Co**.**: New-Delhi, India.

8. Divya M. (2015). **Power System Planning and Reliability Module-1: Load Forecasting**. Retrieved from slideplayer: http://slideplayer.com/slide/5291948/.

9. The Council of Palestinian Ministers (2015). **The ratification of the electricity tariff.** Electricity Regulatory Council: Ramallah, Palestinian.

10. United Nations Industrial Development Organization (UNIDO). **Sustainable Energy Regulation and Policymaking for Africa.** Retrieved from Demand-side Management: http://www.unido.org/fileadmin/media/documents/pdf/Module15.pdf

11. Nikhil G. (2010). **A simulation platform to demonstrate active demand-side management by incorporating heuristic optimization for home energy management**. Ohio, United States: The University of Toledo.

12. Krishnappa J. (2008). **Demand side management & voltage control**. Glasgow, Scotland: The University of Strathclyde.

13. Palestine Economic Policy Research Institute. **Renewable energy in the Palestinian territories: Opportunities and Challenges.** Ramallah. 2012.

14. Yaseen B. (2009). **Renewable Energy Applications in Palestine**. 2nd International Conference on the Palestinian Environment. Nablus, Palestine: Palestinian Energy and Environment Research Center (PEC) – Energy Authority.

15. World Bank**.** 2007. **West Bank and Gaza - Energy sector review**. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/731521468137110533/West-Bank-and-Gaza-Energy-sector-review .

16. Yasin A. (2008) **Optimal Operation Strategy and Economic Analysis of Rural Electrification of Atouf Village by Electric Network, Diesel Generator and Photovoltaic System.** Nablus-Palestine. An-Najah National University.

17. Aqel M. (2007). **Power Sector in Palestine**. Ramallah, Palestine: Palestinian Energy Authority.

18. Gellings C. & chamberlin J. (1993). **demand side management planning.** Georgia, USA: Fairmont Press Inc.

19. Abu Hamed T.; Flamm H. & Isma'il L. (2012). **ASSESSING RENEWABLE ENERGY POTENTIAL IN PALESTINE**. Israel: The Arava Institute for Environmental Studies**.**

20.**Solar photovoltaics**. Retrieved from uprm.edu:

http://www.uprm.edu/aret/docs/Ch_5_PV_systems.pdf.

21.**How to Design Solar PV System.** (2013). Retrieved from leonics: http://www.leonics.com/support/article2_12j/articles2_12j_en.php.

22.Gnan, J. W. (2010). **Emergency And Standby Power Systems**. Florida, USA: engineer educators.

23.**Kirloskar oil engines limited**. (2017, January). Retrieved from **Enriching Lives**: http://koel.kirloskar.com/gensets/5%20-%205200%20kVA/320%20-%20625%20KVA.

24.Donald C., Carolyn D., Ran F., Kristen A., and Robert M. (September 2015). ***U.S.* Photovoltaic Prices and Cost Breakdowns**: **Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems**. U.S.: National Renewable Energy Laboratory.

25.**Global Solar Industry Website**. (2016, December). Retrieved from **solar server**: http://www.solarserver.com/service/pvx-spot-market-price-index-solar-pv-modules.html.

26.**Distributed Generation Renewable Energy Estimate of Costs**. (2016, February). Retrieved from National Renewable Energy Laboratory (NREL): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

27.STUDYELECTRICAL.COM**.**(2016).*STUDYELECTRICAL.COM***.** **Retrieved from Load Curve in a Power Plant - Daily and Annual**: http://www.studyelectrical.com/2016/03/load-curve-in-power-plant-daily-annual.html.

28.Parmar J. (2016, December). **How to select MCB / MCCB**. Retrieved from electrical notes and articles: https://electricalnotes.wordpress.com/2011/10/31/demand-factor-diversity-factor-utilization-factor-load-factor/ .

29.Taylor N., Huld T., Jager Waldau A., Ossenbrink H., Szabo S., Dunlop E. (2014). **Cost Maps for Unsubsidised Photovoltaic Electricity**. Ispra, Italy: **European Commission.**

30.System Advisor Model (SAM). (2014). Retrieved from **National Renewable Energy Laboratory** (NREL) : https://www.nrel.gov/analysis/sam/help/html-php/index.html?mtf_lcoe.htm .

Appendix (1)

Approximate Fuel Consumption Chart

Diesel Service & Supply

INDUSTRIAL DIESEL ENGINES & POWER GENERATORS FOR OVER 30 YEARS

Approximate Fuel Consumption Chart

This chart approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at. Please note that this table is intended to be used as an estimate of how much fuel a generator uses during operation and is not an exact representation due to various factors that can increase or decrease the amount of fuel consumed.

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11	18.5	26.4	35.7
600	13.2	22	31.5	42.8
750	16.3	27.4	39.3	53.4
1000	21.6	36.4	52.1	71.1
1250	26.9	45.3	65	88.8
1500	32.2	54.3	77.8	106.5
1750	37.5	63.2	90.7	124.2
2000	42.8	72.2	103.5	141.9
2250	48.1	81.1	116.4	159.6

www.dieselserviceandsupply.com

Appendix (2)

Battery Charger Datasheet

DATAKOM

SMPS-123 / 125 / 243 / 245 BATTERY CHARGERS

DESCRIPTION

DATAKOM SMPS series are fixed output voltage, current limited lead acid battery chargers specially designed for use in gensets. Thanks to their continuous DC outputs they may also be used in a vide range of industrial applications where DC power is required.

The chargers are designed for permanent connection to genset starter batteries. When the battery voltage is below the float charge level, the charger provides constant current, nearly equal to the rated output current allowing a rapid recovery of the missing charge. When the battery voltage reaches the float level, the charger switches to constant voltage charge mode and maintains the battery fully charged, providing the maximum battery life, without overcharging or gassing.

The unit has overload and short circuit protections. This feature makes the units deliver only the rated current during engine cranking or a short circuit condition. They do not need disconnection during cranking. The high temperature protection of the unit reduces the output current in case of overheating. Thanks to their high efficiency, the self-heating of the chargers is kept in minimum levels allowing operation in warm environments.

The wide input voltage range allows the chargers to be used in most countries.

The rectifier fail output is provided as a standard feature. This is a semiconductor output pulling to battery negative when the unit is not operating. Thanks to this output, a rectifier fail signal is provided for the genset control module which will give an alarm in case of failure.

The units provide a "boost charge" input as a standard feature. When this input is pulled to battery negative, the output voltage of the charger will be set to the boost charge voltage. This feature may be used temporarily to improve battery life.

TECHNICAL SPECIFICATIONS

		123	125	243	245
Technology	-	Switchmode (flyback) 100KHz			
Output Voltage	V-DC	13.7		27.4	
Output Current	Amp.	3	5	3	5
Input Voltage Range	V-AC	170-270			
Input Frequency Range	Hz	45-65			
Operating Temp. Range	°C	-20 / +70			
Storage Temp. Range	°C	-40 / +80			
Max. Relative Humidity (non-condensing)	%	95			
Max. Input Power	Watt	45	73	85	145
Efficiency (at full load)	%	85		86	
Output Noise (Vpp)	Volt	0.2			
Rectifier Fail Output	-	Yes			
Rectifier Fail Output Impedance	ohm	270			
Boost Charge Input	-	Yes			
Boost Charge Voltage	Volt	15.0		30.0	
High Temp. Protection	-	Yes			
Short Circuit Protection	-	Yes			
Electrical Connections	-	2 Part plug-in connectors			
Width	mm	108			
Height	mm	112			
Depth	mm	55			
Weight (approx.)	gram	260			

INSTALLATION

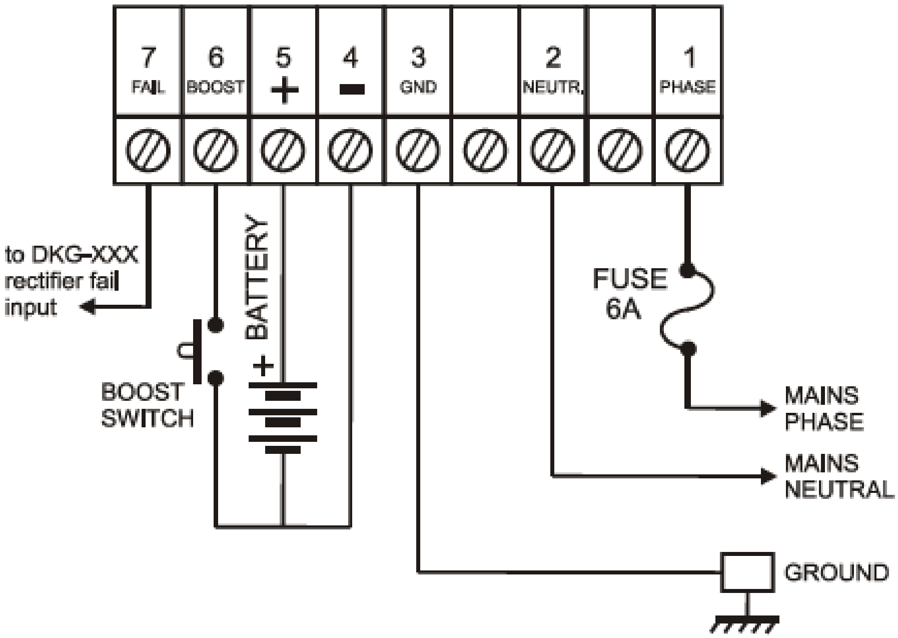
The unit is designed only for installation within other equipment by professional installers. It must not be operated as a stand alone product.

The unit is for enclosed panel mounting. The user should not be able to access the unit. Only authorized service personnel will be allowed to access the unit. Mount the unit on a flat, vertical surface. Allow at least 5cm space on the bottom and top sides to enable cooling by natural ventilation. Blocking the aeration will cause the unit to overheat.

Use 6 Amps external fuse at the phase input.

ALWAYS disconnect the power BEFORE connecting the unit.

CONNECTION DIAGRAM



Appendix (3)

Hybrid Inverter Datasheet

INFO-HI

Inform Hybrid Inverter

- Multi-Functional Hybrid Inverter System with pure sinewave output;
- ✓ Availability to use as Solar Inverter with connection to solar panels for Photovoltaic Off-Grid System applications,
- ✓ Availability to use as Line-Interactive UPS with charger wherever utility supply is present,
- ✓ Availability to use as long back up UPS or Inverter with high capacity Lead Acid or Gel battery group,
- Powerful Charger with 40~60Amp charge current capability,
- Digital Control with Microprocessor controller,
- Advanced LCD Control Panel,
- Power Saving Feature with Highly Efficient Design,
- Low Heat Dissipation for Long Time Operation,
- Practical Design operating with almost all type of high capacity batteries,
- Compatibility with Linear and Non-Linear Loads,
- Pre-settable Parameters,
- Automatic Self-Test Function,
- Perfect Indoor UPS: clean, noise-free and odorless,
- Overload, Short Circuit, Low Battery Protections,
- Wall Mountable Design,

inform

Info - HI Specifications

MODEL			INF-HI-800	INF-HI-1600	INF-HI-2400	INF-HI-4000	INF-HI-6000	INF-HI-8000
CAPACITY (VA/Watt)			1,2kVA/800W	2,4kVA/1.6kW	3,6kVA/2.4kW	6,6kVA/4kW	10kVA/6kW	13kVA/8kW
INPUT	Nominal Voltage		220 / 230 / 240 VAC					
	Acceptable Voltage		120 – 275 Vac					
	Frequency		50 Hz / 60 Hz (45Hz -70Hz)					
	Voltage Range	Line Low Transfer	120 VAC ± 2%					
		Line Low Return	130 VAC ± 2%					
		Line High Transfer	275 VAC ± 2%					
		Line High Return	260 VAC ± 2%					
OUTPUT	Voltage		220 / 230 / 240 VAC (selectable from LCD screen)					
	Voltage Regulation (Batt. Mode)		< %3 rms					
	Frequency		50 Hz / 60 Hz					
	Frequency Regulation (Batt. Mode)		± 0.1 Hz					
	Power Factor		0,67			0,6		0,62
	Waveform		Pure Sinewave					
TRANSFER TIME	Typical		<8msec					
BATTERY	Battery Voltage		12 VDC	24 VDC			48 VDC	
	Battery Charge Voltage		13,8 VDC	27,6 VDC	27,6 VDC	27,6 VDC	55,2 VDC	55,2 VDC
	Max. Input Voltage		25 VDC	50 VDC	50 VDC	50 VDC	100 VDC	100 VDC
	Max. Charge Current (3steps selectable)		40 A	50 A		60 A		
SOLAR	Solar Power Server		50 A					
DISPLAY PANEL	LCD		UPS Status, I/P & O/P Voltage - Frequency, Load%, Battery Voltage & %, Temperature					
	LED		Normal (Green), Warning (Yellow), Fault (Red)					
AUDIBLE ALARM	Battery Mode		Beeping every 4 seconds					
	Low Battery		Beeping every second					
	UPS Fault		Beeping Continously					
	Overload		Beeping twice per second, UPS will shut down automatically in 30sec if overload is between 105-150% and over 150% it will shut down immidiately					
ENVIRONMENT	Operating Temperature		0 – 40 C°					
	Relative Humidity		0-95% (non-condensing)					
	Audible Noise		<55 dBA (from 1m)					
PHYSICAL	Net Weight (kg)		14	21	23	49,2	51,4	53,6
	Dimensions (W*H*D)		298*400*150	298*450*190	298*450*190	415*600*260	415*600*260	415*600*260

Appendix (4)

On-grid Inverter Datasheet

inform

Info - PVI

Inform Photovoltaic Inverter
On Grid Version

- *High Frequency Transformerless Design PhotoVoltaic Inverter*
- *Convectional Cooling System provided to guarantee quiet operation*
- *Compact Size, Light Weight*
- *Accurate Power Conversion from Solar panel to Local Grid*
- *Ease of Installation to Save Time and Money*
- *Real Digital Signal Processor (DSP) Controller*
- *Increased Efficiency (up to 98%)*
- *Minimum Power Loss, Maximum Reliability*
- *LCD Display Panel*
- *IP65 Enclosure for both Indoor and Outdoor Application*
- *Optional Monitoring Software provided to offer operational status and electricity generated data.*

The INFO-PVI-ON series grid-connected Photovoltaic Inverter is delivered in a waterproof IP65 enclosure which can be installed in either a grid connected solar tracker system or a stationary PV system. By taking care of an accurate power conversion from solar panel to local grid, the INFO-PVI-ON series effects conversion process with minimal power loss and maximum reliability.

Info-PVI Technical Specifications

MODEL		INF-PVI-ON2000	INF-PVI-ON3000	INF-PVI-ON5000	INF-PVI-ON10000
Nominal AC Power		2000 W	3000 W	5000 W	10000W
Maximum AC Power Output		2200 W	3300 W	5300 W	10000W
SYSTEM					
Main Circuit		Self Current, Voltage System			
Conversion Mode		High Frequency PWM			
Isolation Method		Transformerless Design			
DC INPUT					
Rated Voltage (DC)		360V			720V
Maximum Voltage (DC)		DC 500V			1000V
Operation Voltage Range (DC)		120V - 500V			300V -1000V
Max.power point tracking range (DC)		150V - 450V			350V -850V
No. Of input connection/max. Current for each connection		1 Input (14.6A max. for each circuit)	1 Input (22A max. for each circuit)	2 Input (17.65A max. for each circuit)	2 Input (18.6A max. for each circuit)
AC OUTPUT					
Phase/Wire(AC)		1-phase/2-wire or 1-phase/3-wire(LNG)			3-Phase / 4Wire
Rated voltage(AC)		230VAC (184-264.5VAC)			400VAC (319-458V)
Rated frequency(AC)		50-60Hz(47.5-50.2Hz or 59.3-60.5Hz)			
Rated Current(AC)		8.7A	13A	21.7A	3x14.5A
Current THD		<5%			<3%
Power factor		>0.99			0.8 - 1.0
Efficiency		up to 96%			up to 98%
Protections		Over Voltage, Under Voltage, Over frequency, Under frequency			
Islanding Operation Detection	Passive method	Voltage phase jump detection			
	Active method	Reactive power control			
Communication interface		RS232, USB, RS485, Dry contact (Optional)			
ENVIRONMENT					
Temperature		-10°C ... +50°C			
Relative Humidity		0-90% RH Maximum, Non-Condensing			
Altitude		2000 m			
Protection Class		IP65			
PHYSICAL SPECIFICATIONS					
Dimension (mm)		455x430x170	455x510x170	455x510x170	445x585x247
Net Weight (kg)		23	28	28	41
STANDARDS					
EMC		EN61000-6-1, EN61000-6-3, EN61000-3-3			
SAFETY		VDE0126-1-1, EN50178, EN60146-1			

CE

Appendix (5)

Home Inverters Datasheet

Guardian & Guardian LCD Series

Line Interactive Technology
600VA to 2000VA

- Microprocessor controlled Line Interactive Technology
- Boost and Buck Automatic Voltage Regulation (AVR)
- LCD or LED Display Panel
- Advanced Battery Management (ABM)
- Input Frequency auto sensing (50/60 Hz)
- Auto restart after mains recovery
- Charging during switched off mode
- Short circuit and overload protection
- Cold Start Function
- USB Communication Interface and Remote Monitoring Software*
- Modem/Phone line protection*
- Compact size and user friendly operation

*Available at AP models only

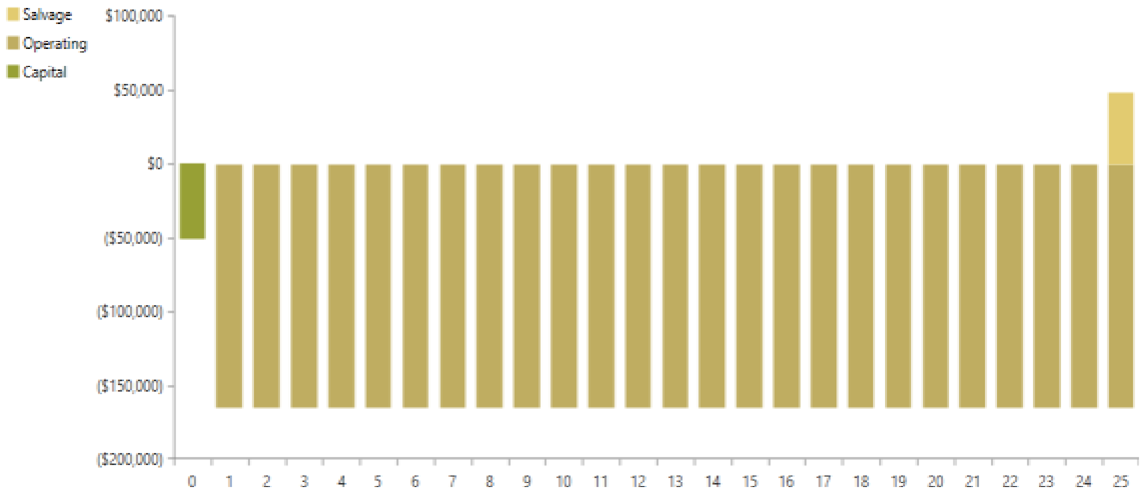
Guardian & Guardian LCD Series Technical Specifications

MODEL	GUARDIAN 600A/ AP GUARDIAN LCD 600AP	GUARDIAN 800A/ AP GUARDIAN LCD 800AP	GUARDIAN 1000A/ AP GUARDIAN LCD 1000AP	GUARDIAN 1500A/ AP GUARDIAN LCD 1500AP	GUARDIAN 2000A/ AP GUARDIAN LCD 2000AP
Capacity (VA)	600	800	1000	1500	2000
INPUT					
Voltage	220V or 230V				
Input Voltage Range	162 to 290VAC				
Frequency	50 or 60 Hz (auto sensing)				
OUTPUT					
Power Factor	0.6				
Voltage (On battery)	220V or 230V ± 10%				
Waveform (On battery)	Simulated Sinewave				
Frequency (On battery)	50 or 60 Hz ± 1Hz				
Voltage Regulation (AVR)	AVR automatically increases output voltage 15% above input voltage if -10% to -26% of nominal AVR automatically decreases output voltage 15% below input voltage if +10% to +22% of nominal				
Transfer Time	2 - 6 ms				
Outlets	1 pc Schuko & 1 pc IEC C13		2 pcs Schuko & 2 pcs IEC C13		
BATTERY					
Type	Maintenance-free lead acid batteries				
Recharge Time	6 hours (to 90% of full capacity)				
Voltage	12VDC		24VDC		
Quantity	1x12V 7Ah	1x12V 9Ah	2x12V 7Ah	2x12V 9Ah	
DISPLAY					
LED Display	Fault, Battery Mode, AC Mode				
LCD Display (optional)	Input & Output Voltage values, AC mode / Load Level / Battery Capacity Indicators				
PROTECTION					
	Short Circuit, Overload, Battery Discharge, Overcharge, Tel / Phoneline (AP Models only)				
COMMUNICATION					
Interface (Communication Ports)	USB Port (only AP models)				
Software	Available with AP models only				
AUDIBLE ALARMS					
	Backup Mode, Low Battery, Overload, Fault				
ENVIRONMENT					
Operating Temperature	0-40 °C				
Humidity	0 to 90% non-condensing				
Audible Noise at 1m	<40dBA				
Protection class	IP20				
PHYSICAL SPECIFICATIONS					
Net Weight (kg)	4,35	4,7	7,8	10,1	10,5
Dimensions (mm) WxDxH	101x298x142		149,3x353x162	158x380x198	
STANDARDS					
Standards	EN 62040-1-1 (safety), EN 62040-2(EMC)				

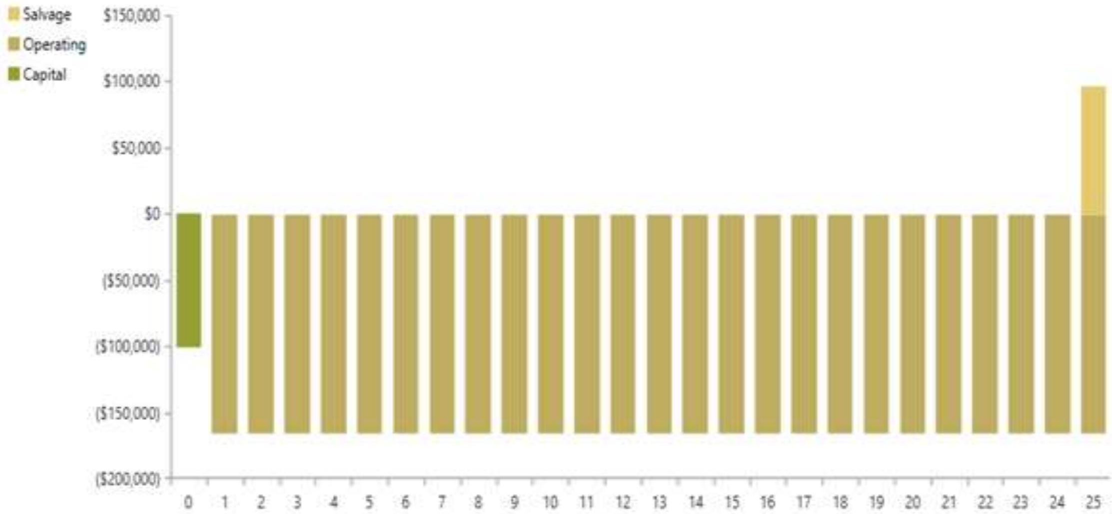
Appendix (6)

Cash Flow of Feeding Loads under Flat Rate Tariff by Alternative Sources

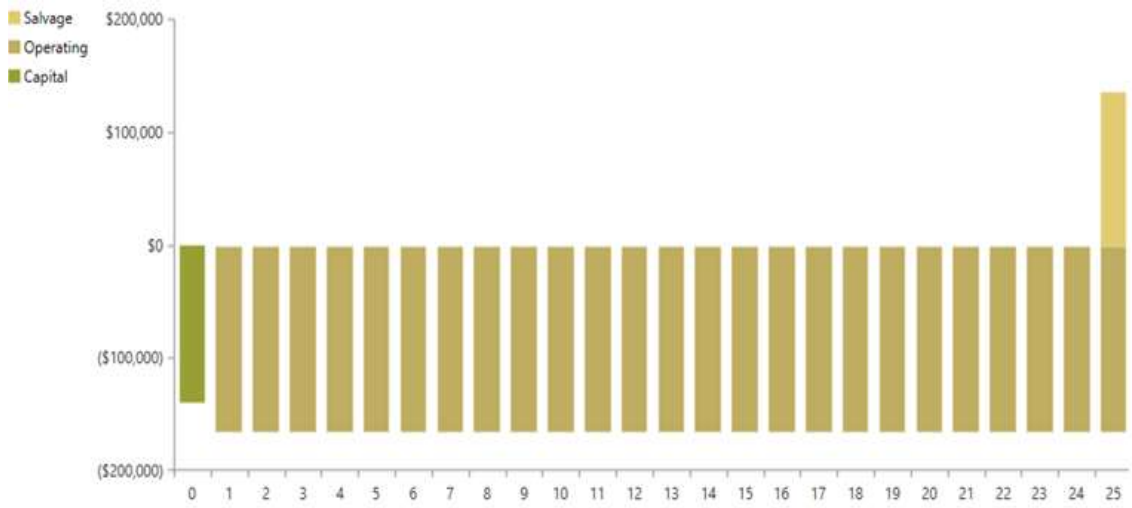
1. Cash flow of Load feeding by Grid and 25% from DG.



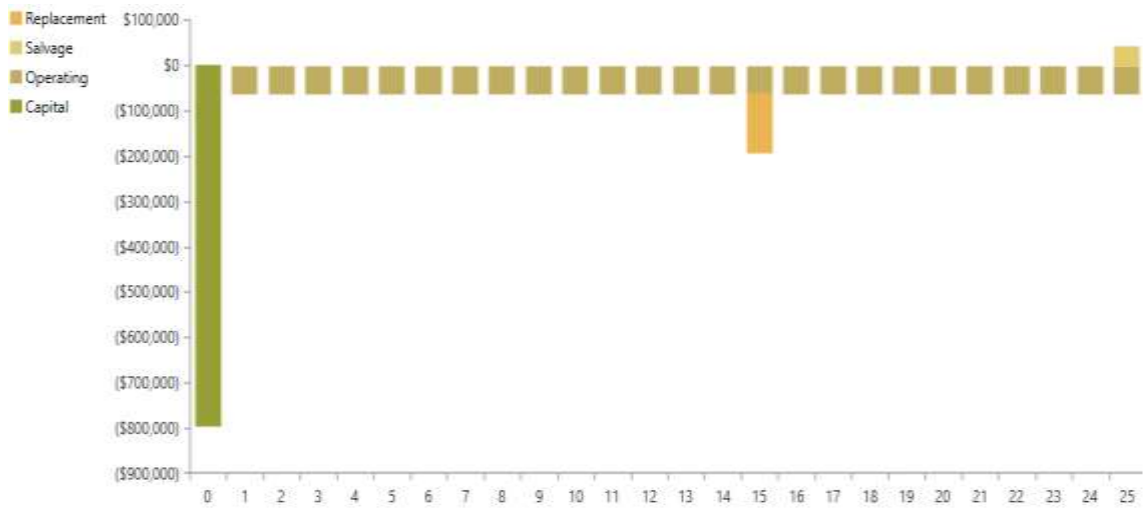
2. Cash flow of Load feeding by Grid and 50% from DG.



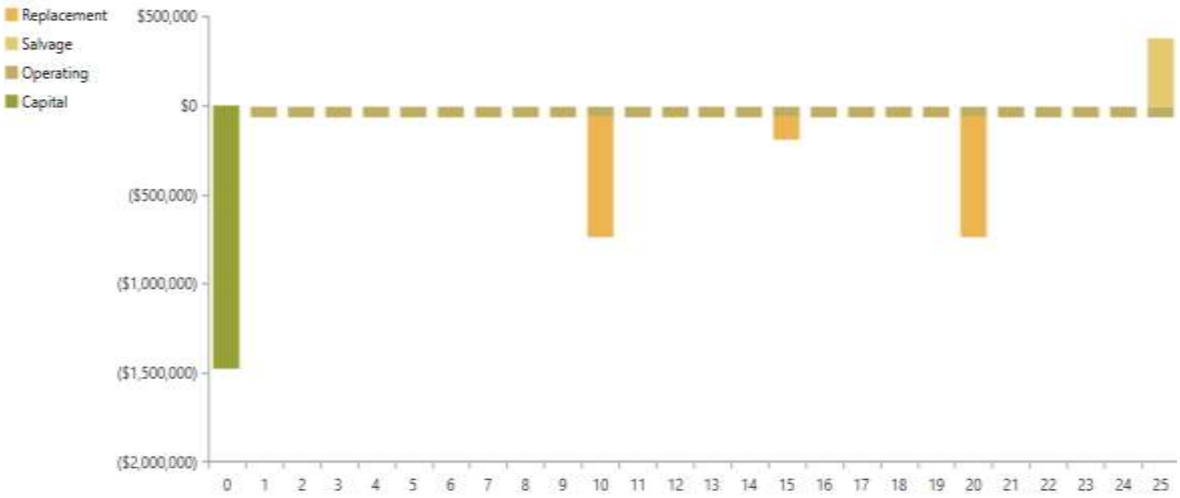
3. Cash flow of Load feeding by Grid and 75% from DG.



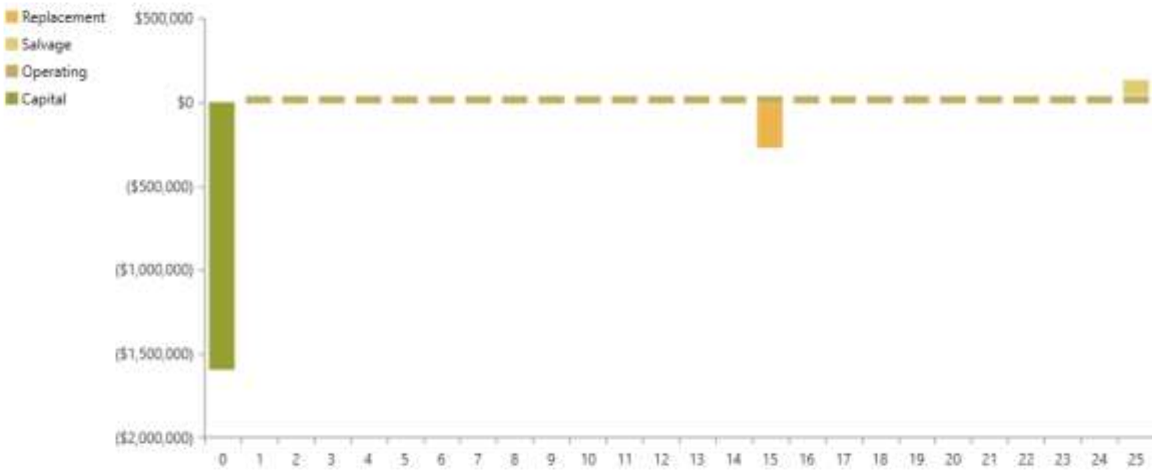
4. Cash flow of Load feeding by Grid and 25% from PV without SB.



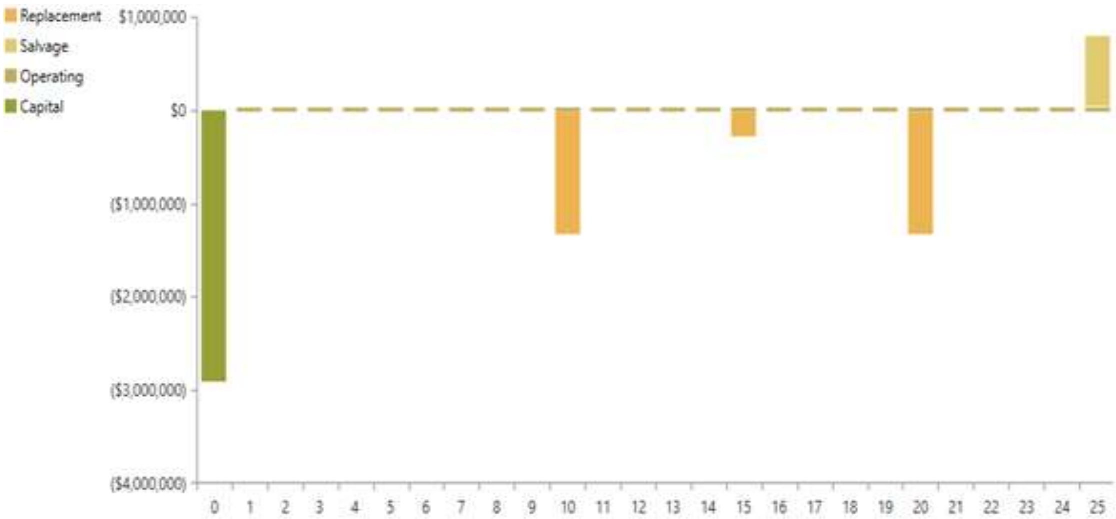
5. Cash flow of Load feeding by Grid and 25% from PV with SB.



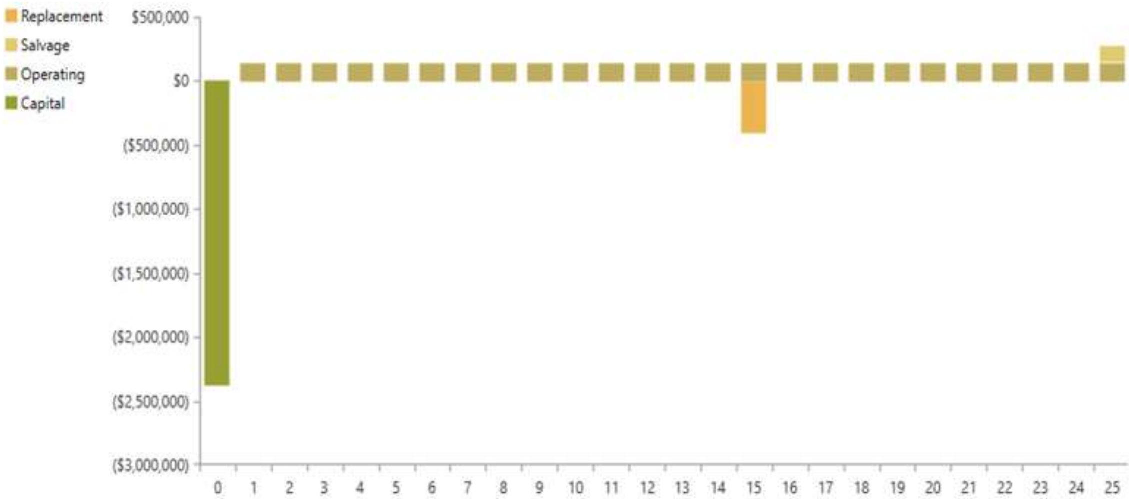
6. Cash flow of Load feeding by Grid and 50% from PV without SB.



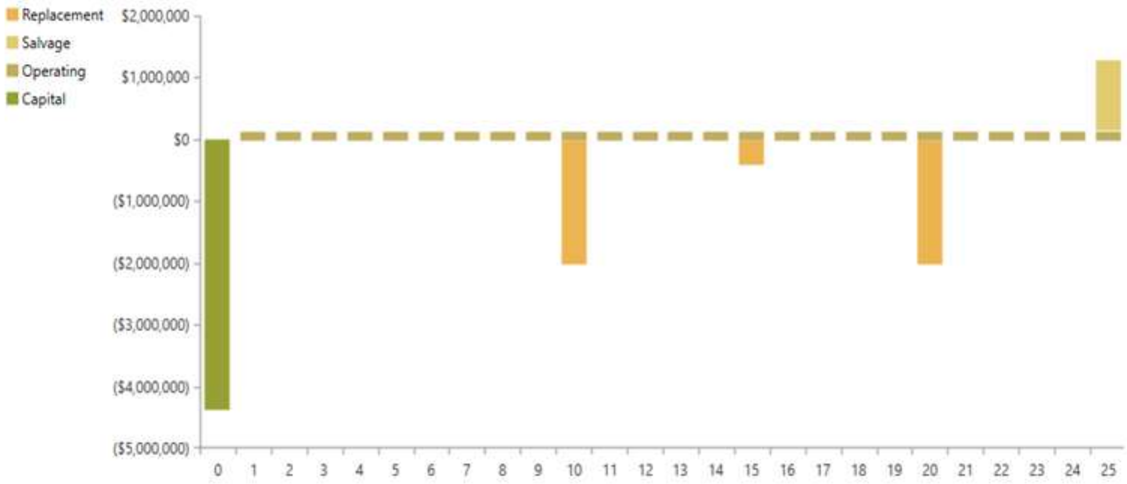
7. Cash flow of Load feeding by Grid and 50% from PV with SB.



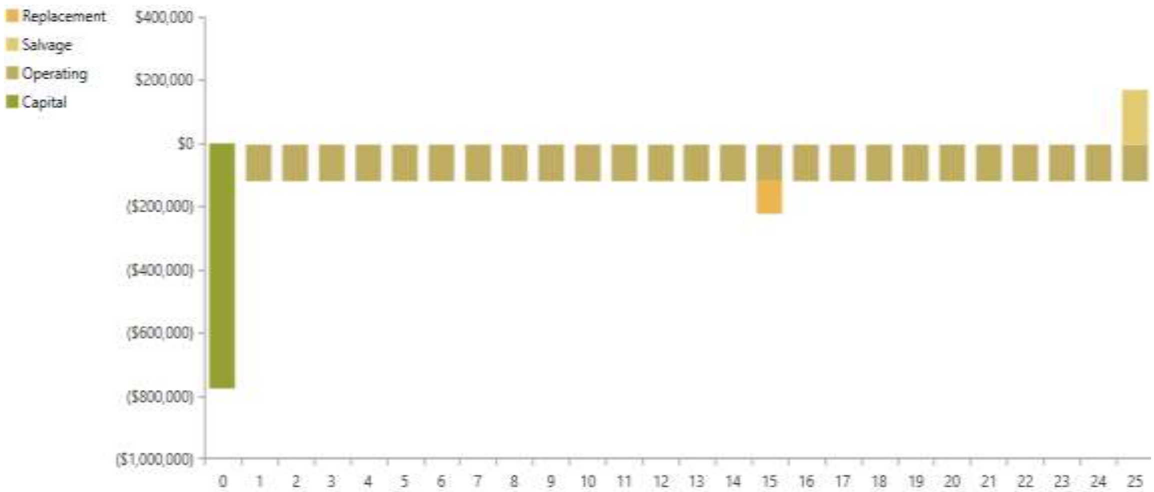
8. Cash flow of Load feeding by Grid and 75% from PV without SB.



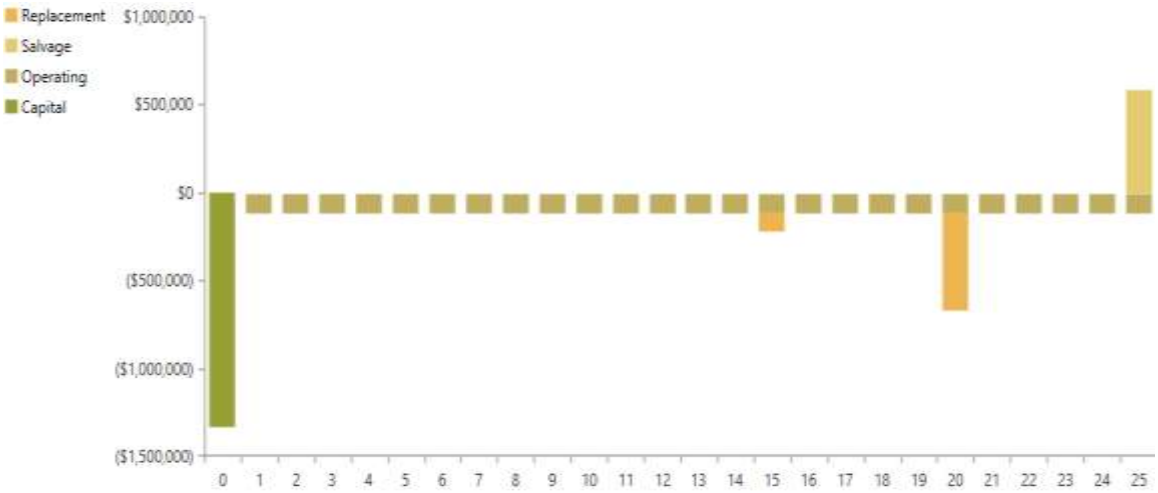
9. Cash flow of Load feeding by Grid and 75% from PV with SB.



10. Cash flow of Load feeding by Grid, 20% from PV and 60% from DG without SB.



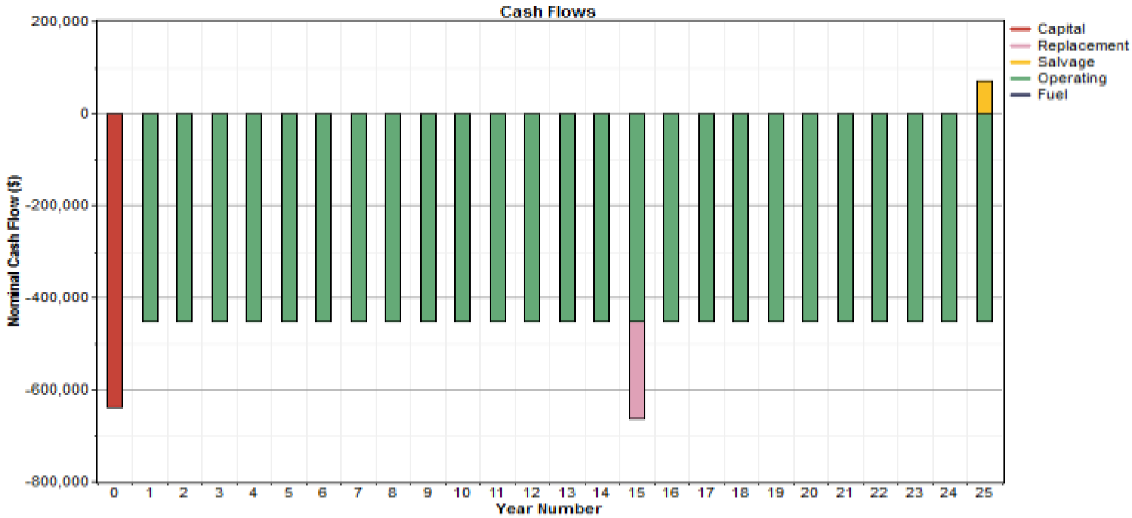
11. Cash flow of Load feeding by Grid, 20% from PV and 60% from DG with SB.



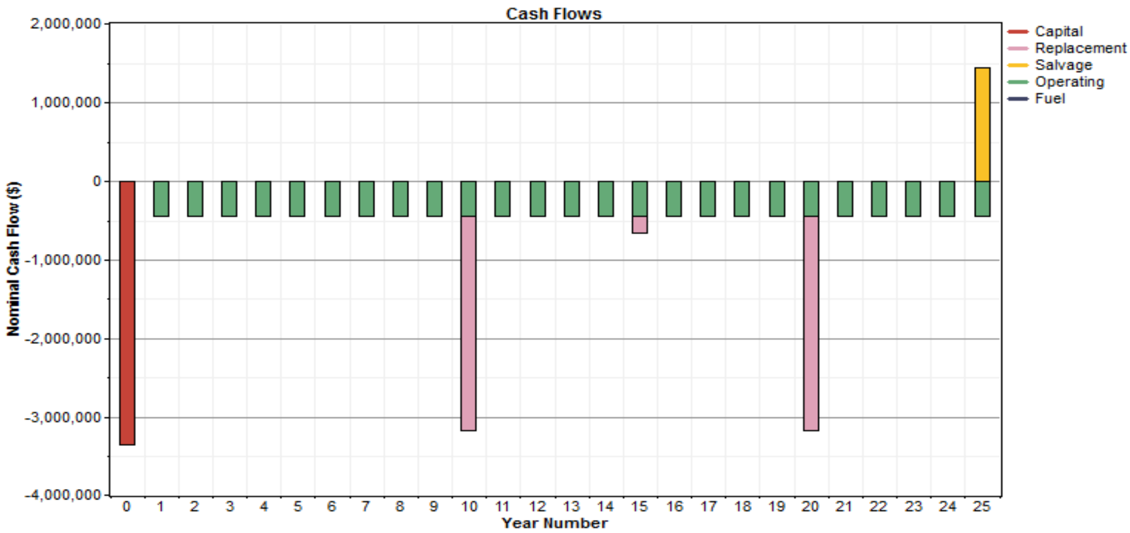
Appendix (7)

Cash Flow of Feeding Loads under TOU Tariff by Alternative Sources

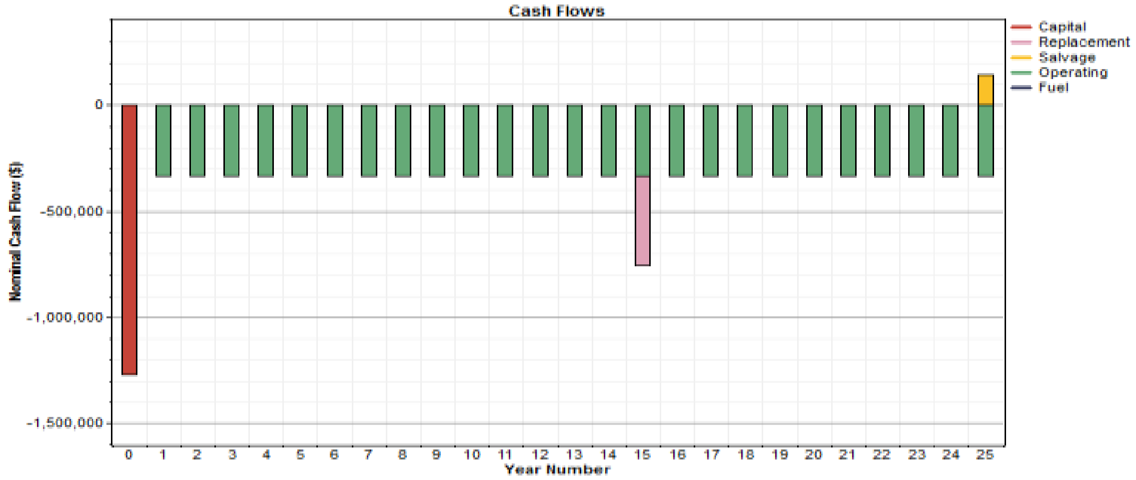
1. Cash flow of Load feeding by Grid and 25% from PV without SB.



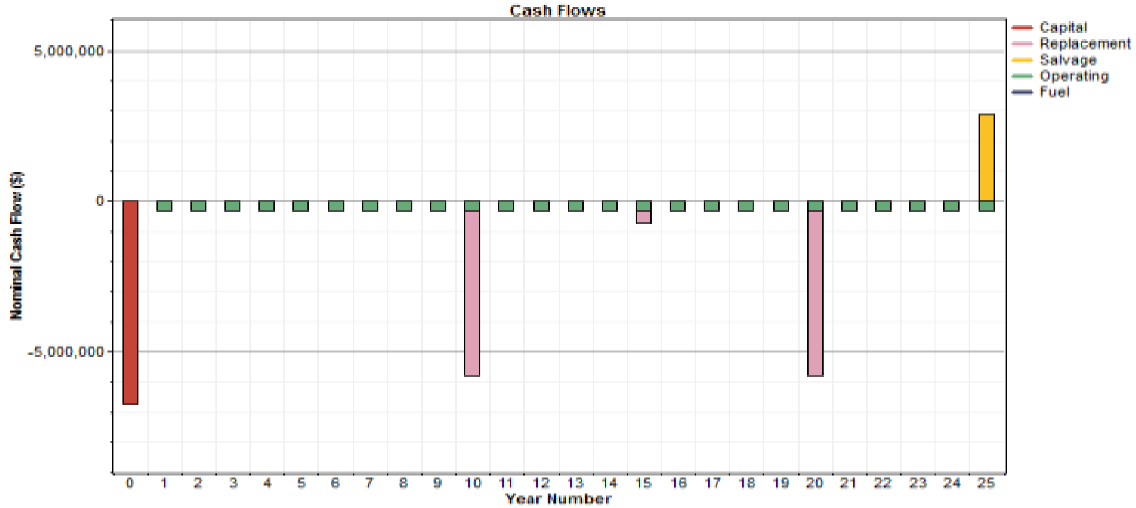
2. Cash flow of Load feeding by Grid and 25% from PV with SB.



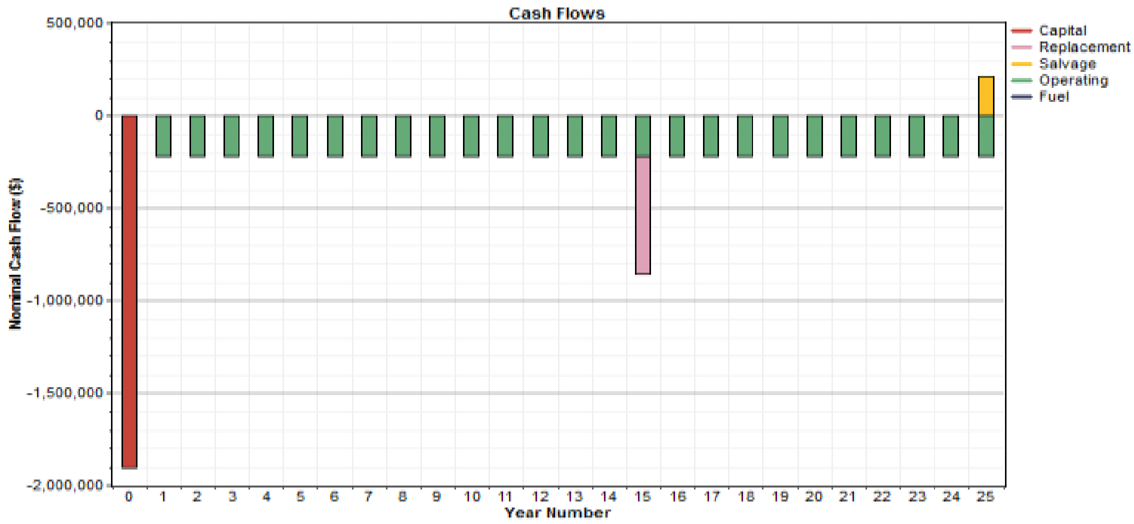
3. Cash flow of Load feeding by Grid and 50% from PV without SB.



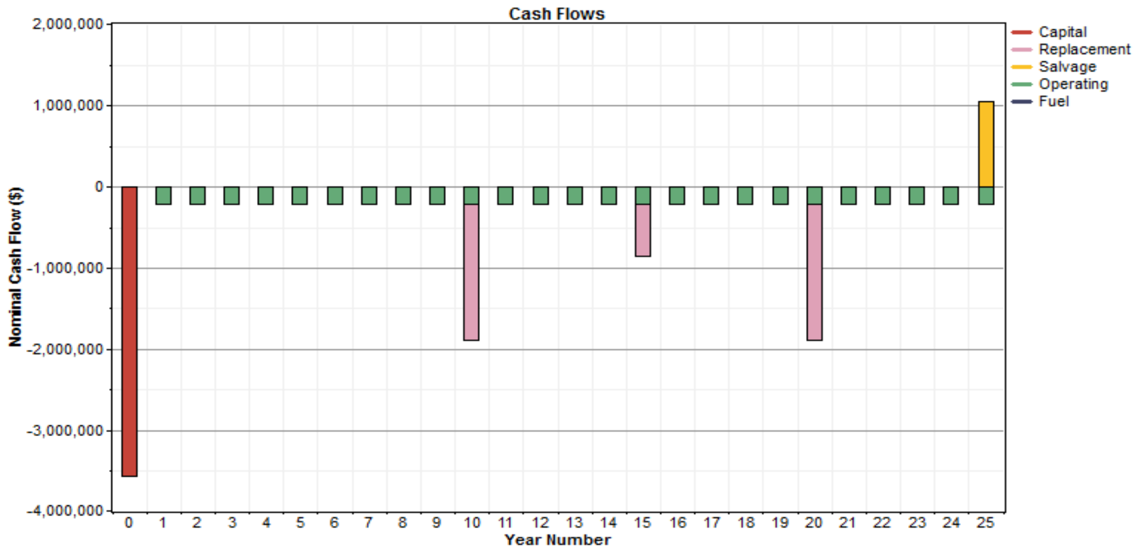
4. Cash flow of Load feeding by Grid and 50% from PV with SB.



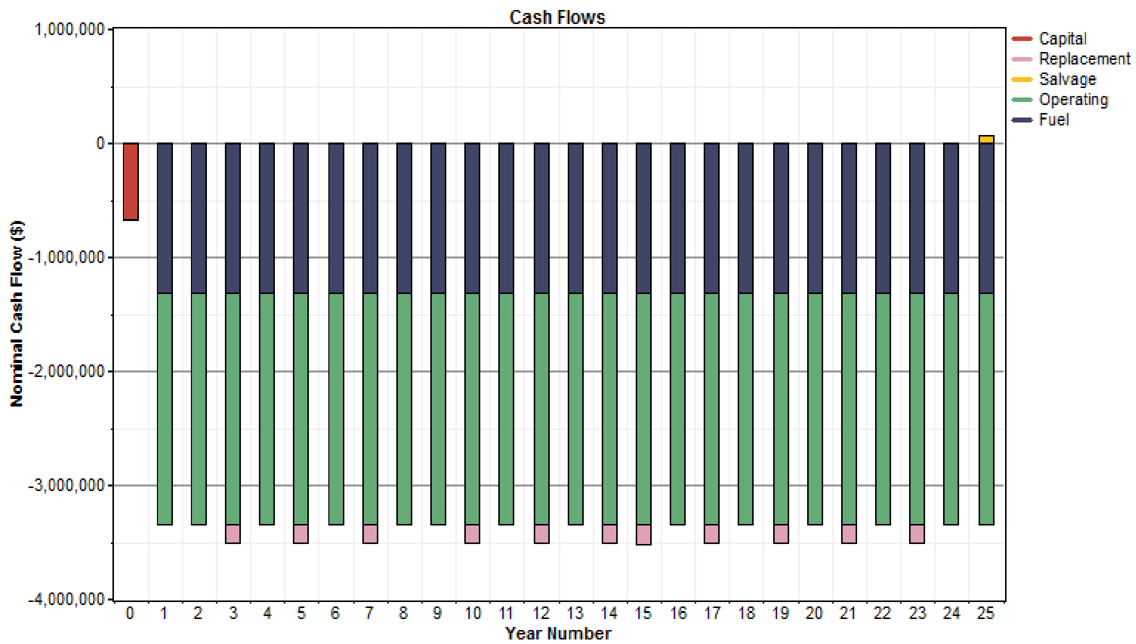
5. Cash flow of Load feeding by Grid and 75% from PV without SB.



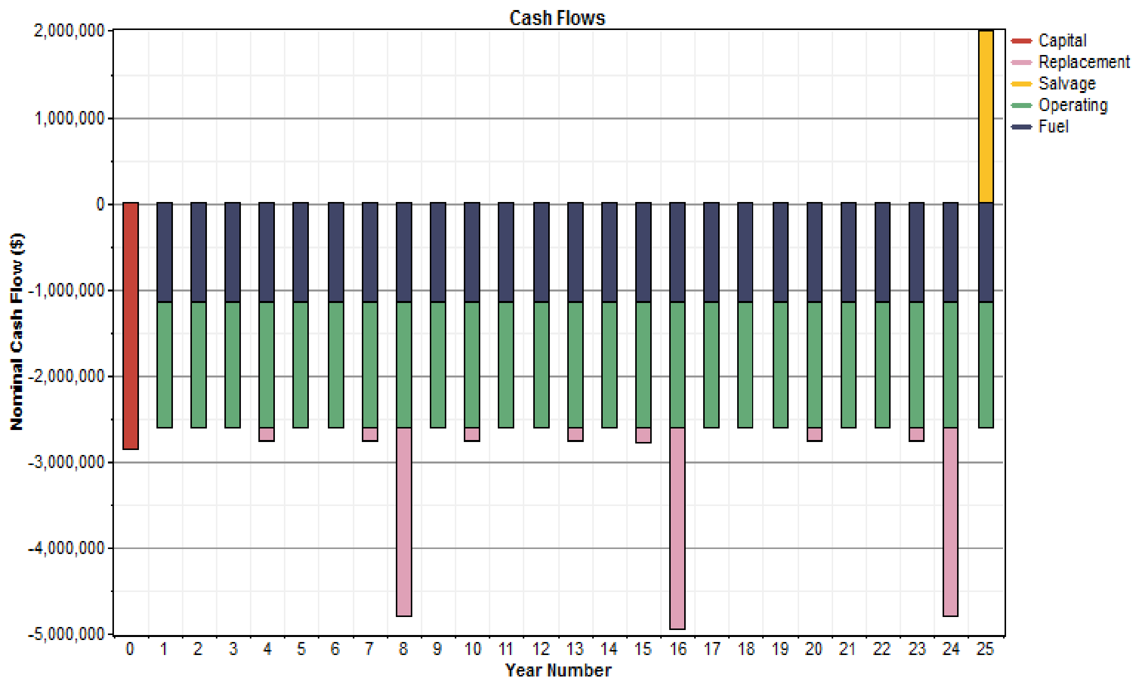
6. Cash flow of Load feeding by Grid and 75% from PV with SB.



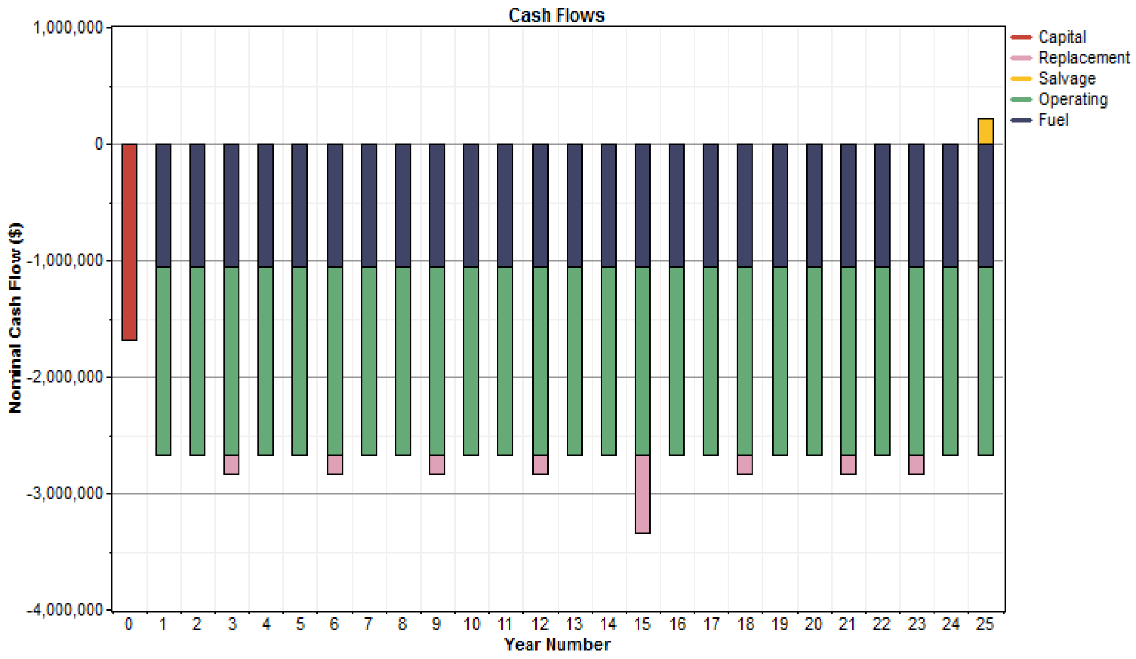
7. Cash flow of Load feeding by off grid hybrid system, 20% from PV and 60% from DG without SB.



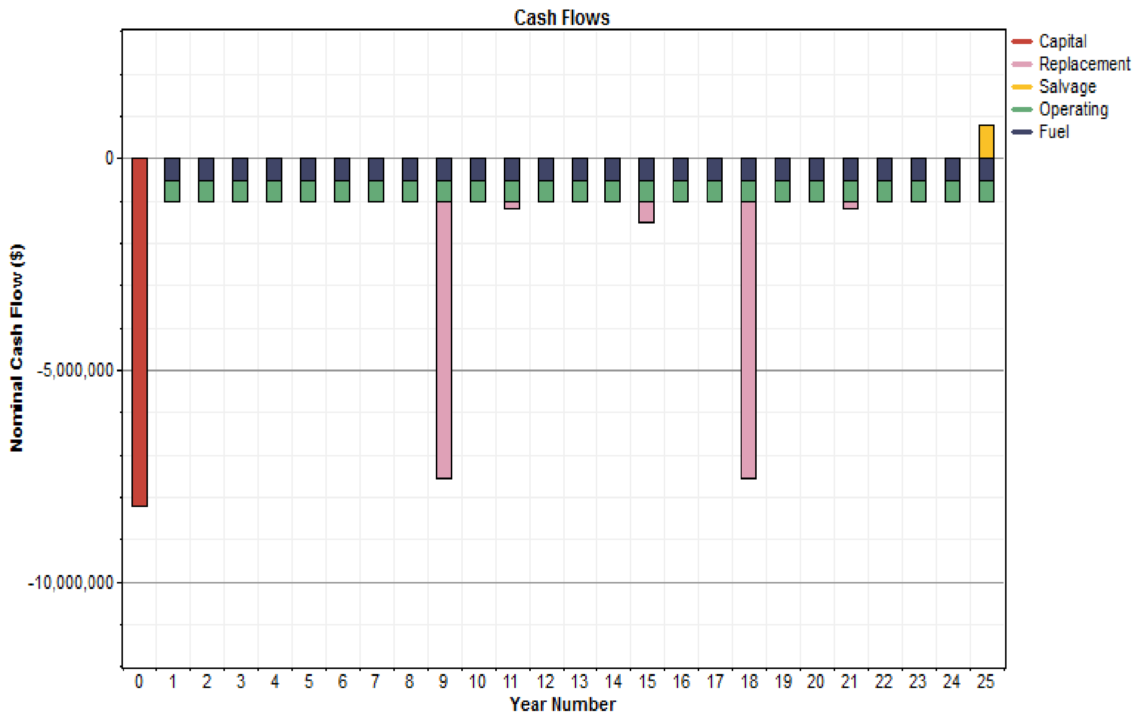
8. Cash flow of Load feeding by off grid hybrid system, 20% from PV and 60% from DG with SB.



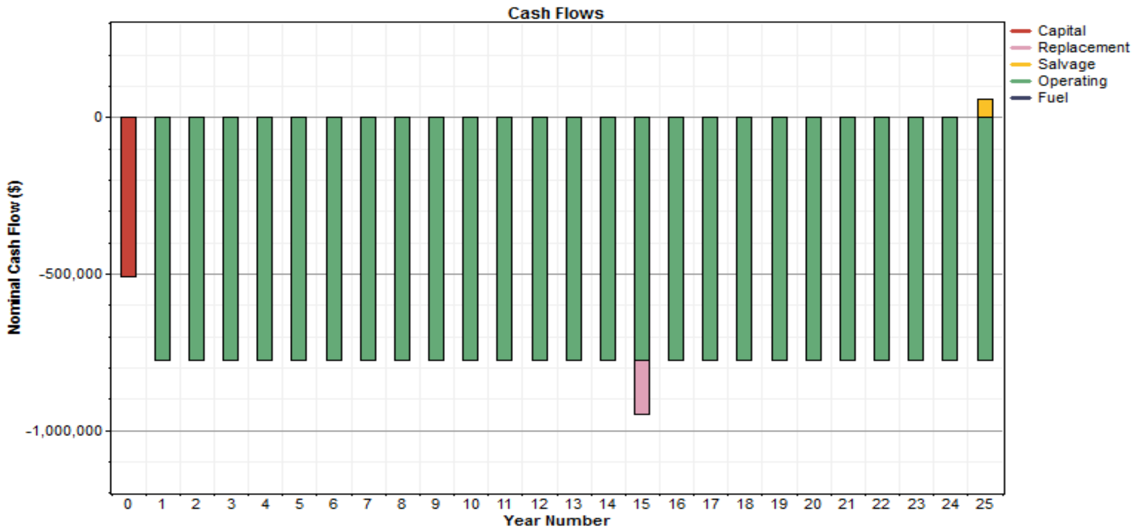
9. Cash flow of Load feeding by off grid hybrid system, 60% from PV and 20% from DG without SB.



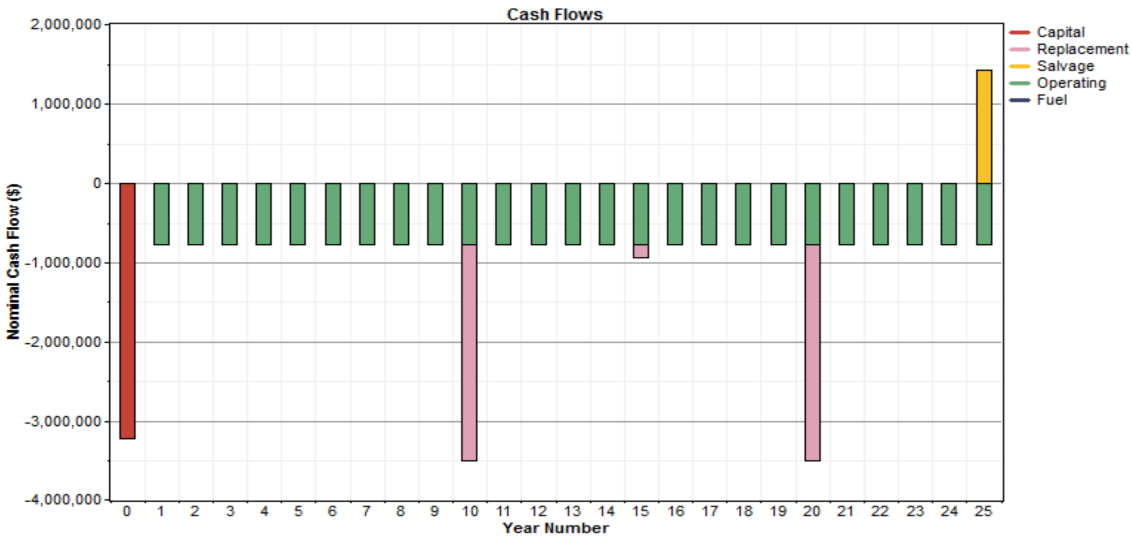
10. Cash flow of Load feeding by off grid hybrid system, 60% from PV and 20% from DG without SB.



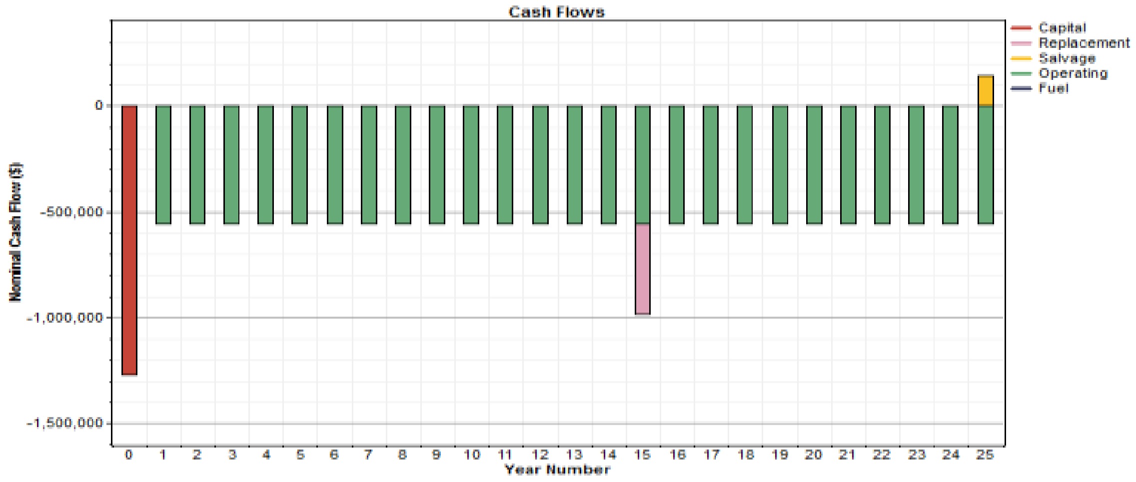
11. Cash flow of Load feeding by Grid and 25% from PV without SB.



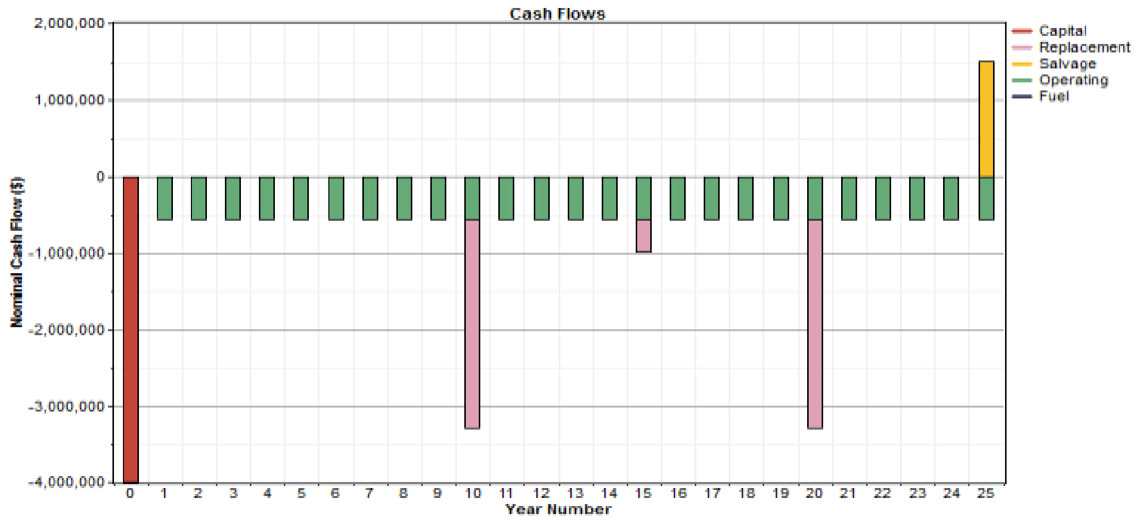
12. Cash flow of Load feeding by Grid and 25% from PV with SB.



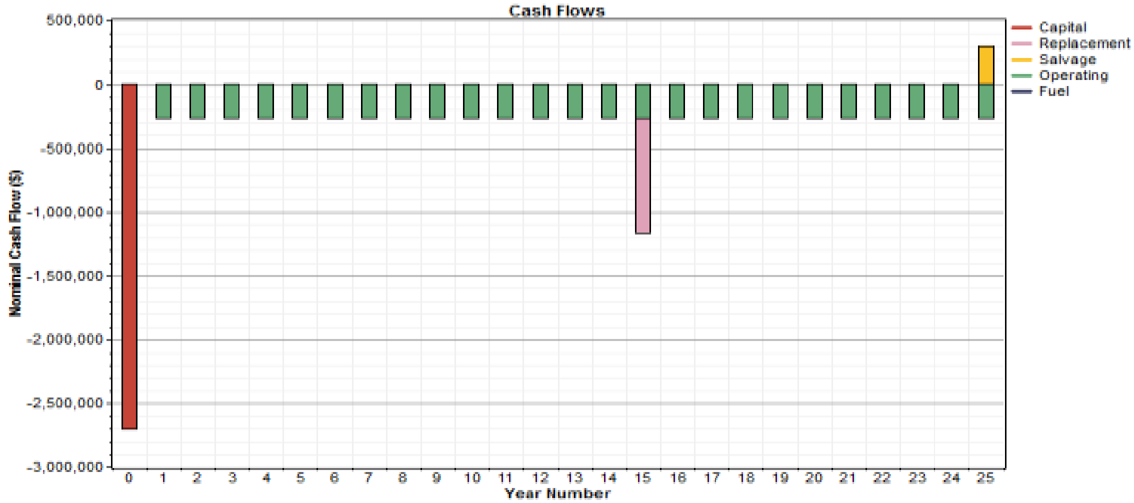
13. Cash flow of Load feeding by Grid and 50% from PV without SB.



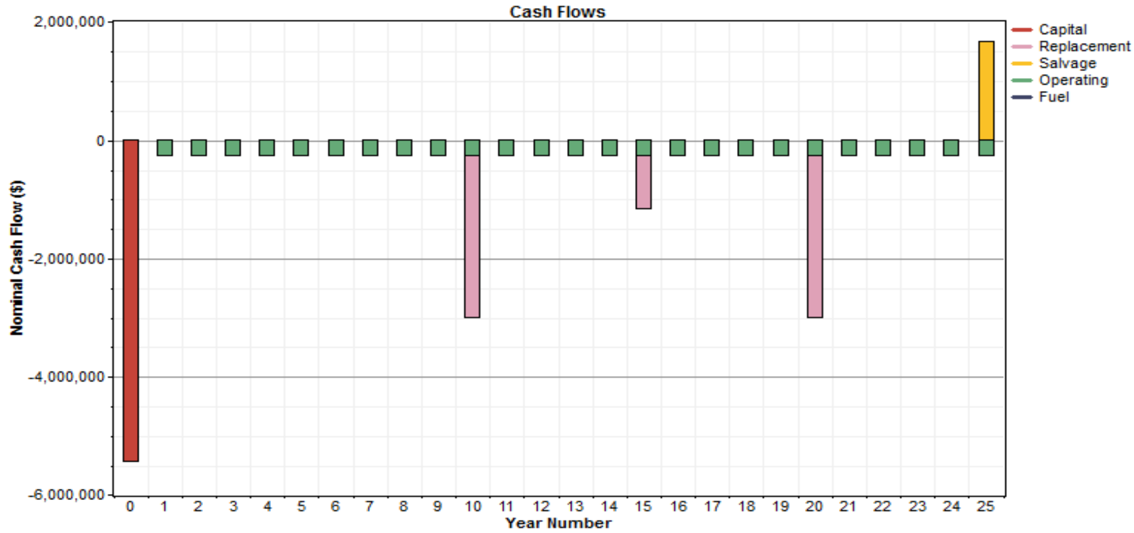
14. Cash flow of Load feeding by Grid and 50% from PV with SB.



15. Cash flow of Load feeding by Grid and 75% from PV without SB.



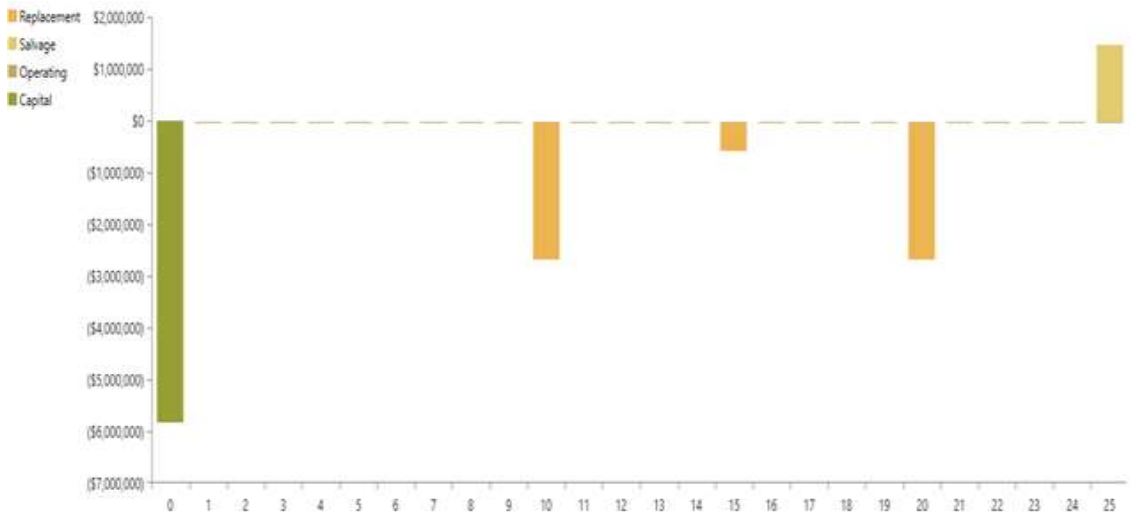
16. Cash flow of Load feeding by Grid and 75% from PV with SB.



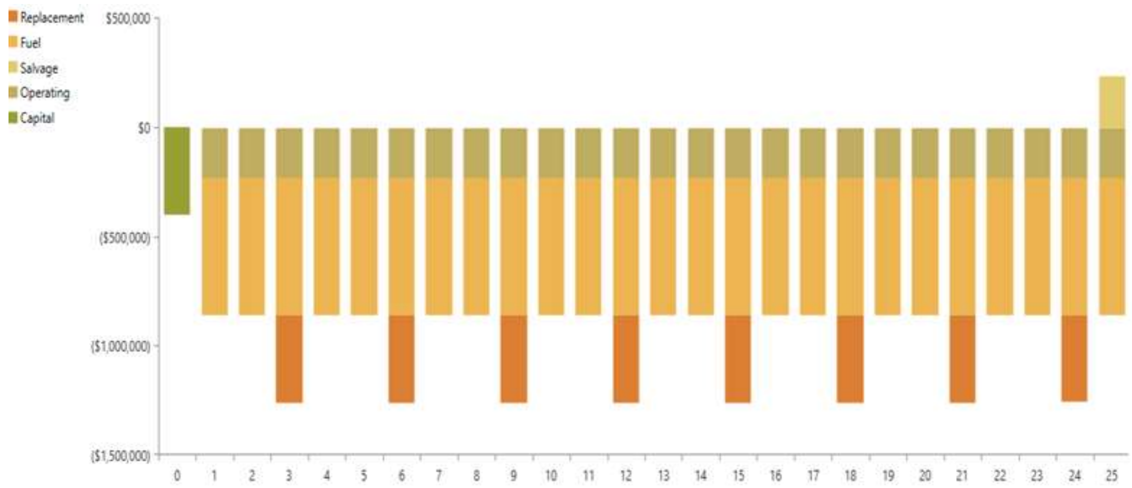
Appendix (8)

Load Feeding by Off-grid Solar Power System

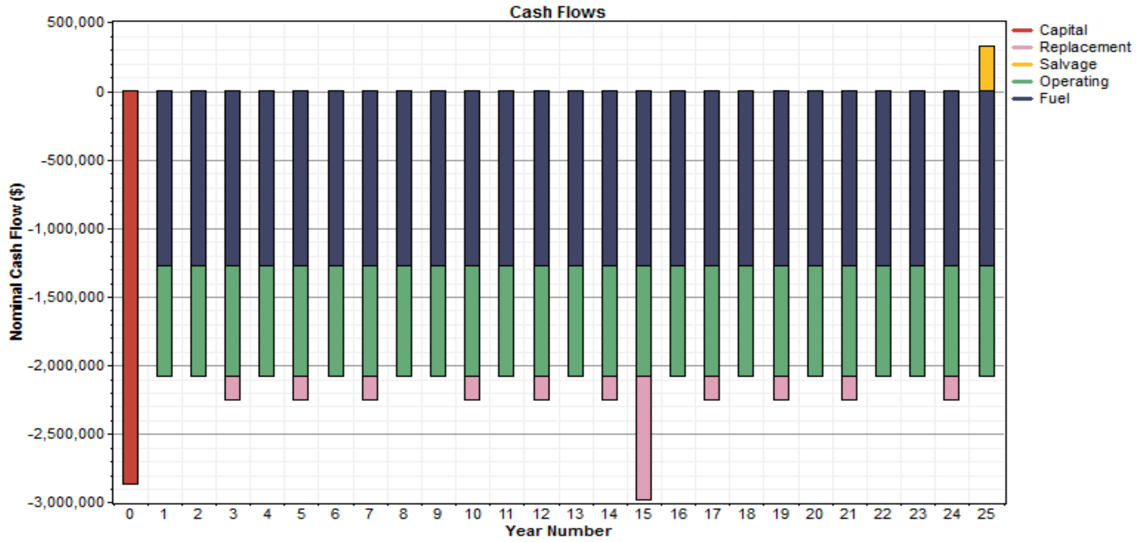
1. Load Feeding by Off-grid Solar Power System.



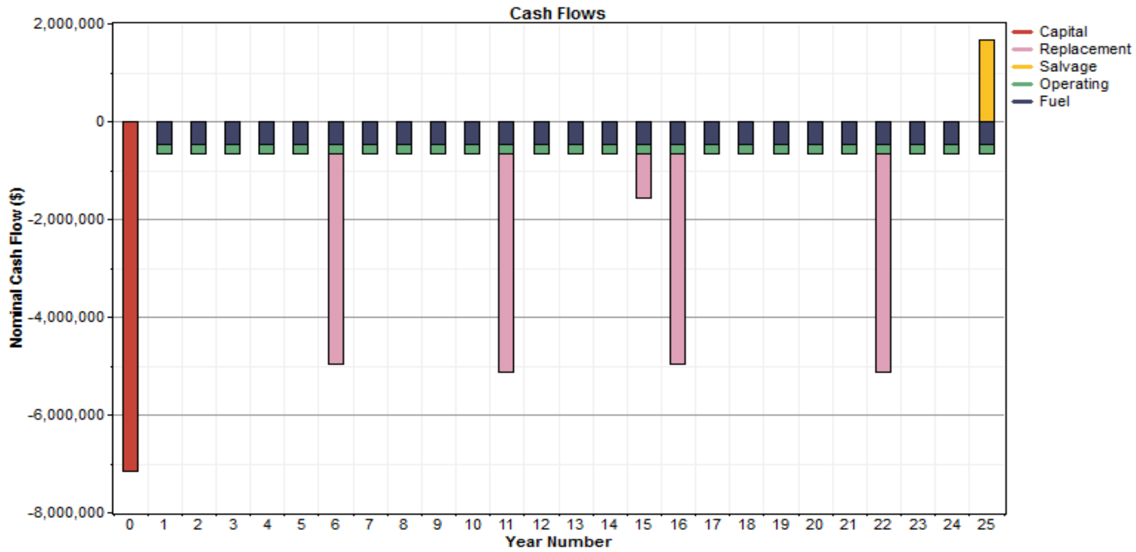
2. Load Feeding by diesel generators.



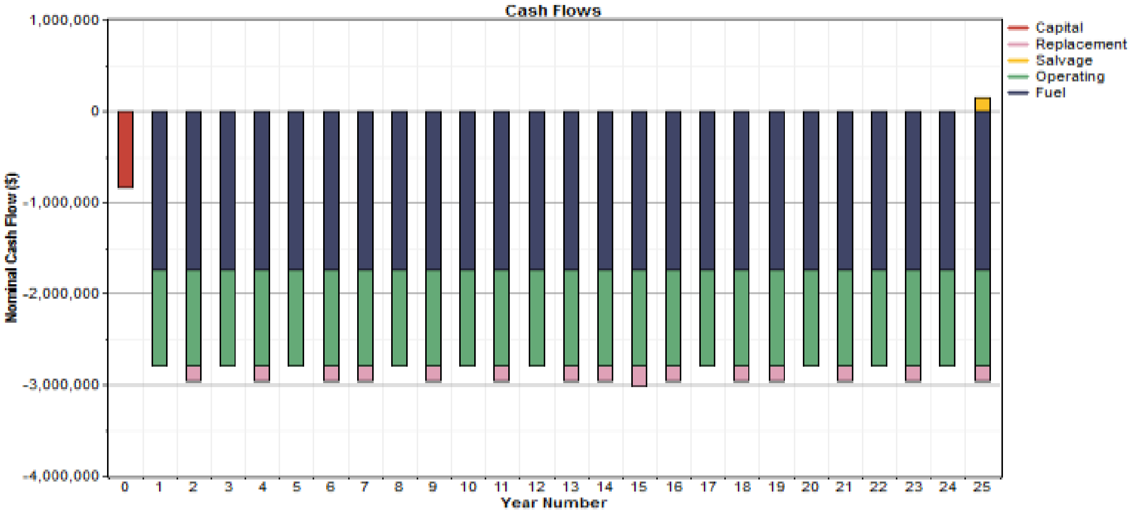
3. Load feeding by 25% Gensets and 75% PV system without SB.



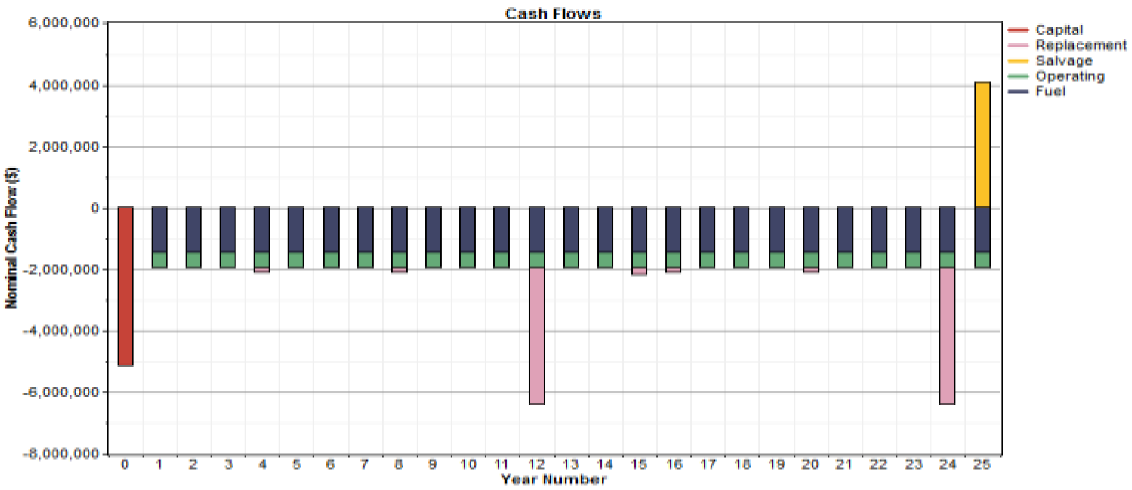
4. Load feeding by 25% Gensets and 75% PV system with SB.



5. Load feeding by 75% Gensets and 25% PV system without SB.



6. Load feeding by 75% Gensets and 25% PV system with SB.



جامعة النجاح الوطنية

كلية الدراسات العليا

إدارة شبكات الكهرباء بوجود مولدات الديزل وأنظمة الخلايا الشمسية/ دراسة حالة " مستشفى النجاح الوطني الجامعي "

إعداد

أحمد نبهان عبد الرزاق جلاد

إشراف

د. عماد بريك

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2017

إدارة شبكات الكهرباء بوجود مولدات الديزل وأنظمة الخلايا الشمسية / دراسة حالة "

مستشفى النجاح الوطني الجامعي "

إعداد

أحمد نبهان عبد الرزاق جلاد

إشراف

د. عماد بريك

الملخص

هذه الرسالة قامت على اساس البحث عن الحلول والمقترحات البديلة التي بدورها قد تساعد في تخطي وحل وتقليل اثر جميع المعوقات والتحديات التي تواجه وقد تواجه شبكات الكهرباء في فلسطين من تحديات في الحصول على الطاقة او تحديات في نقص القدرة الكهربائية وبالأخص مشكلة زيادة الطلب في اوقات ذروة الحمل الكهربائي وانقطاع التيار الكهربائي بفعل ذلك, والتفكير جيدا في كيفية تقليل الاثر والعواقب المترتبة على هذه التحديات بطرق مختلفة سواء اكانت اقتصادية او غير اقتصادية حسب الظروف المتاحة بهدف الوصول الى نتائج تقلل من نقص القدرة وتساعد في حل مشاكل ارتفاع الطلب الكهربائي في اوقات ذروة الحمل, وذلك بعد تحليل لكل من التحديات المواجه لشبكات الكهرباء في فلسطين وتفصيل جميع سبل ادارة الطاقة وتطويرها واستخدام وعرض كافة المنهجيات المساعدة في تقليل القدرات الكهربائية والاستهلاك الكهربائي, بواسطة اخد عينات وأماكن كحالات دراسية تساعد في التحليل والوصول الى نتائج كما هو الحال في مستشفى جامعة النجاح الوطني في مدينة نابلس الذي تم دراسة حمله اليومي والتفكير في تطبيق جميع سبل الترشيد ومنهجيات ادارة الطاقة الممكنة والسعي لتطبيق انظمة تعرفة مختلفة مثل التعرفة المتغيرة مع الوقت بفعل الاستهلاك شريطة ان يتبع خطوات الترشيد المقترحة في هذه الرسالة ومحاولة تغطية حمله وقت الذروة بواسطة استخدام مولدات الكهرباء وأنظمة الخلايا الشمسية المربوطة على الشبكة الكهربائية او غير المربوطة لنحصل على افضل خيار وبأقل تكلفة انتاج للطاقة والتي كانت بنسبة 75% من الخلايا الشمسية بوجود الشبكة بدون الحاجة لاستخدام البطاريات المخزنة للطاقة وكذلك نفس النتيجة بواسطة 25% تغذية للحمل من خلال استخدام

مولدات الديزل الكهربائية و 75% من انظمة الخلايا الشمسية وذلك للأنظمة المستقلة غير مربوطة على الشبكة.