An-Najah National University

Faculty of Graduate Studies

Planning For Smart Grid For Palestine

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This Thesisis Submitted in partial fulfillment of the requirements for the Degree of master of Urban and Regional Planning, Faculty of Graduate studies, An-Najah National University, Nablus, Palestine.

2013

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إهداء

إلى الذي واجه نصبَ الحياة وشقاءها ليقرأ في عيون الأبناء لحظة سعادة .....

إلى من أخذ بيدي نحو تحقيق ما أصبو إليه .....

إلى الذي تحمل معي كل مشقة وتعب .....

إلى الذي أذكى جذور الأمل في نفسي .....

إلى روح والدي الغالي رحمه الله .....

إلى التي آثرت الأبناء على نفسها .....

إلى التي رسم حنانها ملامح شخصيتي .....

إلى من غرست بذور العزيمة والمحبة في حنايا روحي .....

إلى أمي الغالية .....

إلى القلوب التي تفيض بالمحبة الصادقة والعطاء الدافق .....

إلى الذين بهم ومعهم يصير للحياة معنى وللنجاح قيمة .....

إلى إخواني الأعزاء .....

وإلى روح أخي الغالي وعائلته رحمهم الله .....

تدنو اللحظات وتتفتح نوافذ المستقبل نحو ميادين الحياة الفسيحة .....

إلى من أمد إلي بيد العون والعطاء إلى من شجعني لترى رسالتي النور .....

إلى زوجي الغالي .....

إلى من رسموا إلي طريق العلم .....

إلى من أشعلوا لنا مصابيح النجاح ..... إلى أساتذتي الأفاضل .....

Acknowledgment

I should firstly express my great thanks to almighty Allah, who gave me power and made me able to accomplish this work.

My grateful thanks to all, who hand me help and support to collect the necessary data to fulfill my thesis.

I do express my thanks to my supervisor Dr. Mutasim Baba, for his continual support and guidance to carry out my work.

Another thank, to Dr. Ali Abdel Hameed the coordinator of Regional and Urban Planning Department in An-Najah National University, for his support and guidance.

Finally, I can't but express my great thanks to my family and my spouse for all what they offered me through courage, motivation and support all the years of study to accomplish this work.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان

Planning For Smart Grid For Palestine

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل درجة علمية أو بحث علمي أو بحثي لدى أي 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 الطالـب:**
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Date:	**التاريـــخ:**

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Abstract

With the advanced development in communications and computers, new trends and technologies came out in all aspects of life. For the electrical sector, Smart Grids became a major player for the development of power system and energy distribution. Now, this new technology has many applications that will result in energy conservation, reduction of CO2 emissions, better service and easy handling. Some of these applications may require advance technologies or high capital investment, but others may be applicable without much efforts or costs.

In this thesis, the researcher studied the Electrical Energy Sector in the Palestinian Territories through consumption, catering quantities by the Israeli Side to the Palestinian companies and the application of Smart Grid Networks in Electrical Energy Networks in Palestine.

The potential applications of Smart Grid in the local grids in Palestine includes but not limited to: Smart Metering, Demand Side Management and Distributed Generation including renewable sources. These applications can be applied without the need for a private communication

network for the electric utilities. The use of wide spread home area networks (HAN's) such as ADSL and BSA technologies will provide a tool that requires minimum installations and reduced costs.

The main conclusion that we can reach out of this research and study that there is an essential need for "immediate planning" for Smart Grids for all electric utilities in the West Bank. This planning must focus on choosing the feasible applications, right and economic communication technology and number of participating customers. The integration of distributed generation of power by photovoltaic systems to be installed in the West Bank through the "Palestinian Solar Initiative" is very important and essential.

Chapter 1

Introduction to Electrical System in Palestine

1.1 Introduction

Electricity is the most versatile form of energy available and it can be accessed by more than 5 billion people around the world through a series of tried-and-tested technologies.

Societies are demanding cleaner energy supplies to combat climate change and demand for electricity is rising. This means more electricity must be generated from traditional and renewable sources. Wind, solar, bio-fuel, and geothermal plants will all be needed, as well as oil, coal, gas and nuclear power plants.

Energy efficiency is arguably the fastest, most sustainable and cheapest way for reducing greenhouse gas emissions,[1] and there are other advantages. Not only are energy-efficient technologies already available, investment payback times are short and they enable energy savings to be made without compromising economic development. Statistics done by the International Energy Agency shows that between the years 2000-2007, electricity consumption rose about %2.5 percent and expected to be doubled by the year 2030, so the need for more energy is a normal reaction to our natural population growth. Societies are demanding cleaner energy supplies to combat climate change and to meet the demand for electricity. This is happening round the world and also in the Palestinian Occupied Territories.

Due to Israeli Occupation of the Palestinian Territories since 1967, the Palestinian economy has been suffering from distortions and lack of improvement. All sectors of Palestinian economy and infrastructure have suffered from negligence and destruction. One of the major sectors that have been affected is the electrical sector. Because the West Bank is classified as an overcrowded area, electricity consumption has risen sharply in the last decade. However, the Israelis (who provide the west bank people with electricity) do not provide the Palestinians with the required quantity. Energy planning in the West Bank is usually influenced by many factors such as: demographic, economical, load demand, fuel prices, fuel reliability, plant cost and political issues.

1.2 Energy in Palestine

1.2.1 Overview of the West Bank and Gaza Energy Sector

The West Bank and Gaza energy sector has characteristics that form the basis of the analysis presented in this thesis:

- Total energy consumption in West Bank and Gaza is small by regional standards, let alone international standards, which limits the scope for achieving economies of scale.
- West Bank and Gaza have different energy supply options.
- The electricity system in the West Bank consists of numerous isolated distribution systems that are not integrated into a distribution network, and it has no generation capacity or transmission network.

- There is no storage capacity for petroleum products in the West Bank and Gaza (plans for building some storage facilities are under preparation).
- Most energy demand (75%) is accounted for by the service and household sectors, since there is relatively little activity in industry and tourism.
- Nearly all energy is provided by electricity and petroleum products, most of which is purchased from Israel (some diversification is beginning to develop).
- In general, energy is lightly subsidized in comparison with most countries in the region, and energy prices reflect opportunity costs reasonably well.
- The only substantial domestic energy resource is the Gaza Marine gas field discovered offshore Gaza, which awaits development.
- The most critical institutional constraints arise in the electricity sector, where the development of the distribution companies in West Bank and Gaza is still in progress.

1.2.2 Electricity in West Bank

Electrical energy is usually provided to cities through private companies or municipal councils. But both get supply from the Israeli Electricity Company (IEC) which is the most important and unique power supplier.

The major problem of municipalities is paying debts, so they moved to use pr-paid meters.

Concerning the Palestinian National Authority Territories, there comes the Palestinian Energy Authority which is mainly supported by the World Bank; many Palestinian companies distribute electricity to cities in the West Bank.

After 2008, municipalities decided to unite their distribution departments by creating new power distribution companies. This effort resulted in the creation of four different power companies. The first one is the Northern Electricity Distribution Company (NEDCO), the second one is the Jerusalem District Electric Company (JDECO), the third one is Hebron Electric Power Company (HEPCO), and the Forth one is the Southern Electric Company (SELCO).

- Southern Electricity Company, which was established in 2002, and provides its services to Dura and Al-Thaheriyya in southern Hebron.

- Hebron Electric Power Company (HEPCO) which was established in 2000 and provides its services to Hebron and Halhul.

- Northern Electricity Distribution Company (NEDCO), which established in 2008 to feed Nablus, Tulkarem, Jenin and other northern villages councils of the West Bank.

- Jerusalem District Electric Company (JDECO), to feed central region of West Bank (Jerusalem, Ramallah, Bethlehem, and Jericho).

The establishment of these companies aimed at providing better services for customers in the West Bank and to reduce all types of losses; technical and non-technical. Information about power distribution in the areas of these companies is shown in Table (1.1).

Table (1.1) : Power distribution services in the West Bank

	The Northern Region	The Middle Region	The Southern Region	Totals
Responsive Municipalities	25 (52%)	15 (32.5%)	7 (15%)	46
Customer Base	98,548 (70.8%)	26,263 (18.9%)	14,339 (10.3%)	139,150
Pre-paid Meters	14,424 (77.7%)	2,419 (13%)	1,728 (9.3%)	18,571

It is noticed that, of the 46 responsive municipalities, from the table; the quarter of that number was located in the north, the others in the middle and in the Southern areas. Also, it is clear that around 70% of the customers are in the north, 18% in the middle and 12% in the South of West Bank.

The customers who already pay for their service before they get it are almost tenth of the whole total ratio. Most of them live in the North; the others are in the Middle Region and in the rest in the South.

Power Grid

The Palestinian power system lacks a backbone power line. Every area is fed with electricity from the Israeli Grid by a feeder as shown in the map in figure 1.1. This map shows that, the three ICE 161KV portions which feed all the West Bank area needs from electric power.

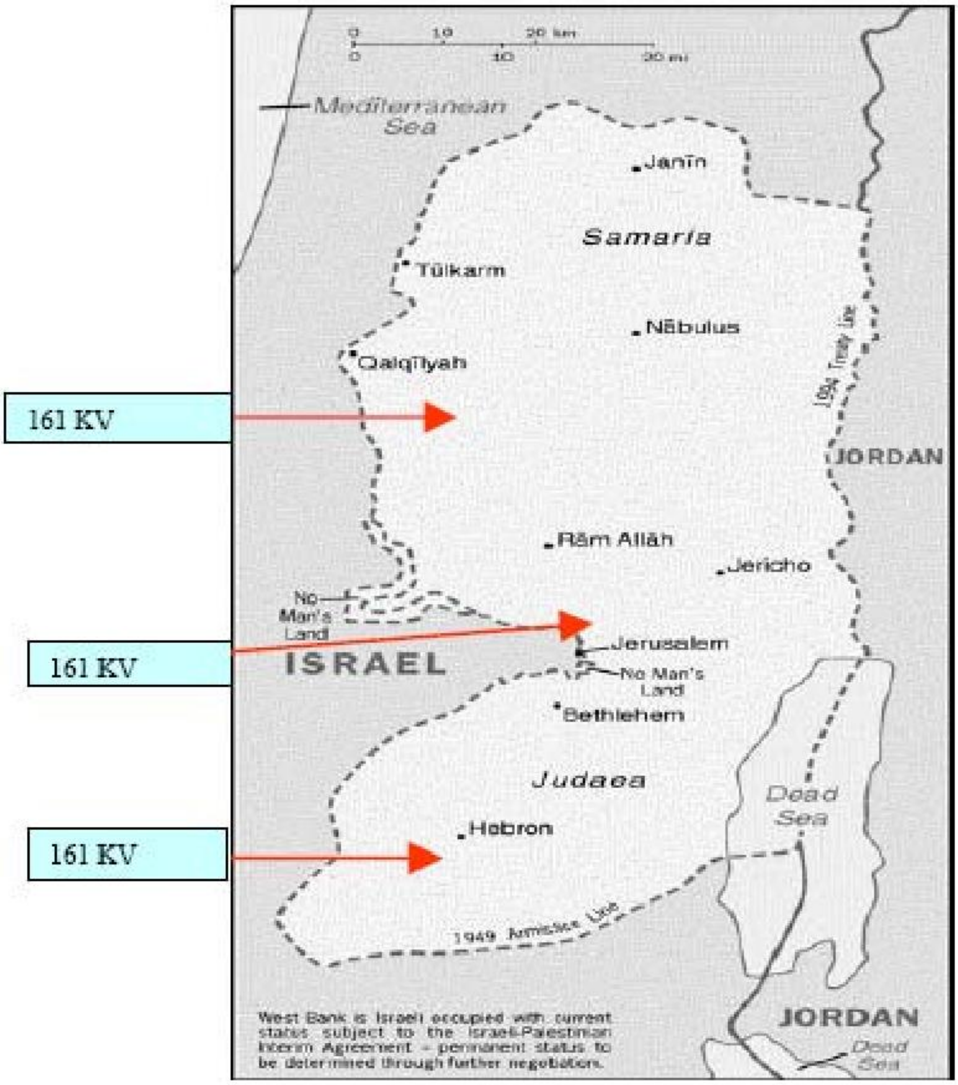


Figure 1.1: Main IEC Feeders to West Bank.

Source: Abu, Alkhair, Ayman

It is noticed that these lines do feed settlements in the first place which have full control on these lines.

It is also found that IEC feeds our cities like Tulkarem and Qalqelia with 161kv portions, meanwhile other cities like Junín and Tubas are fed by 33kv feeders from Bisan Area in Israel.

Based on information from the utilities and Nablus municipality, total billed electricity consumption in West Bank and Gaza amounted to about 2.5GWh in 2005. Households consumed between 60% and 75% of total electricity consumption, with commercial consumers making up the bulk of the remaining consumption. Household's share of total consumption is highest for SELCO, which services a relatively less developed area (with relatively lower commercial consumption), while it is lowest for JDECO which services the most affluent part of West Bank and Gaza, where much of the commercial activity is concentrated.

Average consumption per household is about 3,500 kWh per year. There are quite large geographical variations. For example, average consumption for SELCO is about 3,000 kWh. Among Nablus households, the average annual consumption is only about 2,000 kWh. These variations may reflect differences in billing efficiency as well as genuine differences in consumption levels. As the average household size in West Bank and Gaza is about 6 persons, the estimated per capita consumption is about 675 kWh/year. Average consumption is highest in cities, lower in villages and lowest in refugee camps. Commercial activities are most electricity intensive in the Hebron area, where the average annual consumption averaged about 41,000 kWh in 2006. This is more than twice the average level for this category in other areas possibly because of the high prevalence of energy intensive glass and pottery producers in Hebron.

1.2.3 Geographical Features

Away from the regulations imposed by the current political situation with

Table 1.2 Electricity Sales in West Bank and Gaza by Supplier 2005

	JDECO	SELCO	HEPCO	W. Bank Munic.[a]	of whic Nablus [a]	GEDCO	Grand Total
Total billed consumption (GWh)							
Households	503	35	110	213	73	591	1453
Commercial	363	14	77	227	78	305	985
Number of customers (1,000)							
Households	143	15	26	104	36	129	416
Commercial	31	1	2	29	10	17	80
Average consumption (MWh)							
Households	3.5	2.4	4.2	2.1	2.1	4.6	3.5
Commercial	11.8	18.7	43.8	7.9	7.9	17.6	12.4

Note (a): Data for Nablus is 2004. Total consumption by West Bank municipalities is estimated by assuming the same customer distribution and average consumption as for Nablus.
Source: PEA, Nablus Electricity Department, and World Bank Staff estimates.

various regional jurisdictions and resulted needs for Israelis to agree on The proposed locations, criteria used in the choice of location alternatives include, but are not limited to the following (not considering priority) orders: The existing infrastructure (i.e. both electrical and built-up areas)

- The load centers

- Developments in Planning (municipal infrastructure and industry)
- The site conditions (e.g. such as nature of landscape, ground and ecological conditions)

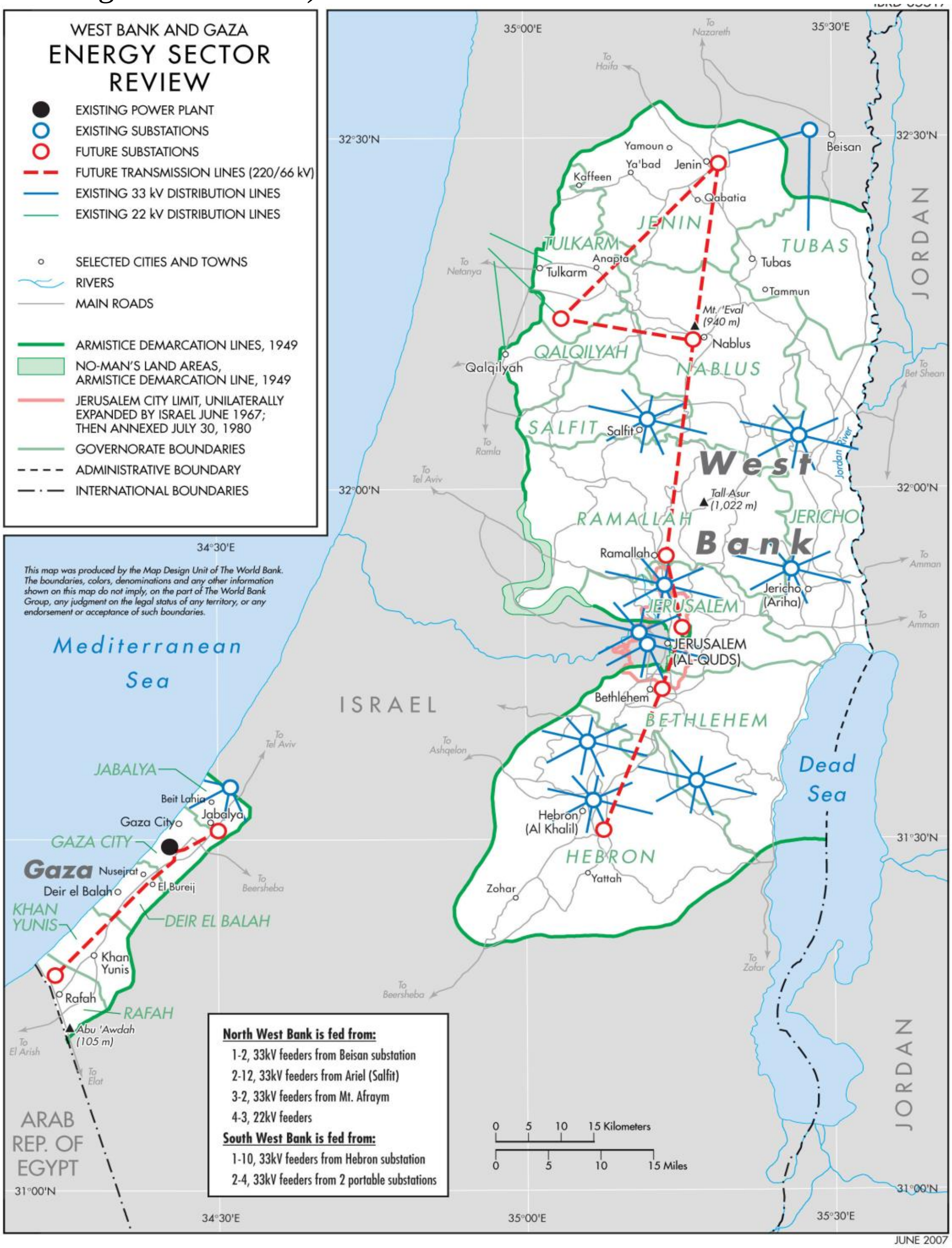


Figure 1.2: Electricity Supply System in West Bank and Gaza

Source: World Bank report No. 39695-G

Figure (1.3) overleaf shows the identified locations on the West Bank. Moving from north to south these are the two sites near Nablus, the four sites north of Jerusalem (JDECO) and the four sites in the south of

Hebron (HEPCO). Summarizing the results from the field survey the location alternatives, which appear to follow the least environmental and social impacts are the Nablus 1, JDECO 2 and 3 and the HEPCO 1 sites.

In contrast to Nablus 2, which lies on a stream bank (country areas), Nablus 1 is preferred because it is in an isolated and barren cleared area. Interference with biodiversity (e.g. nesting birds, ecological habitat) and potential adverse effects from pollutant releases is considered to be significantly less than for the Nablus 2 site.

As for the remaining sites these are all in urban areas and consequently mostly entail impacts keeping in mind the existing built-up and residential areas rather than adverse effects on ecological resources. In this case, the JDECO 2 and 3 sites are closely located next to the existing IEC 161/33 kV substation with ample distance (more than 500m to nearby roads and 1 km) to any residential areas. Similarly, the HEPCO 1 site is preferred because of its planned industrial development in this area as well as relative isolation as it is in an agricultural area. Considering the pass through the nature of the geology and role in

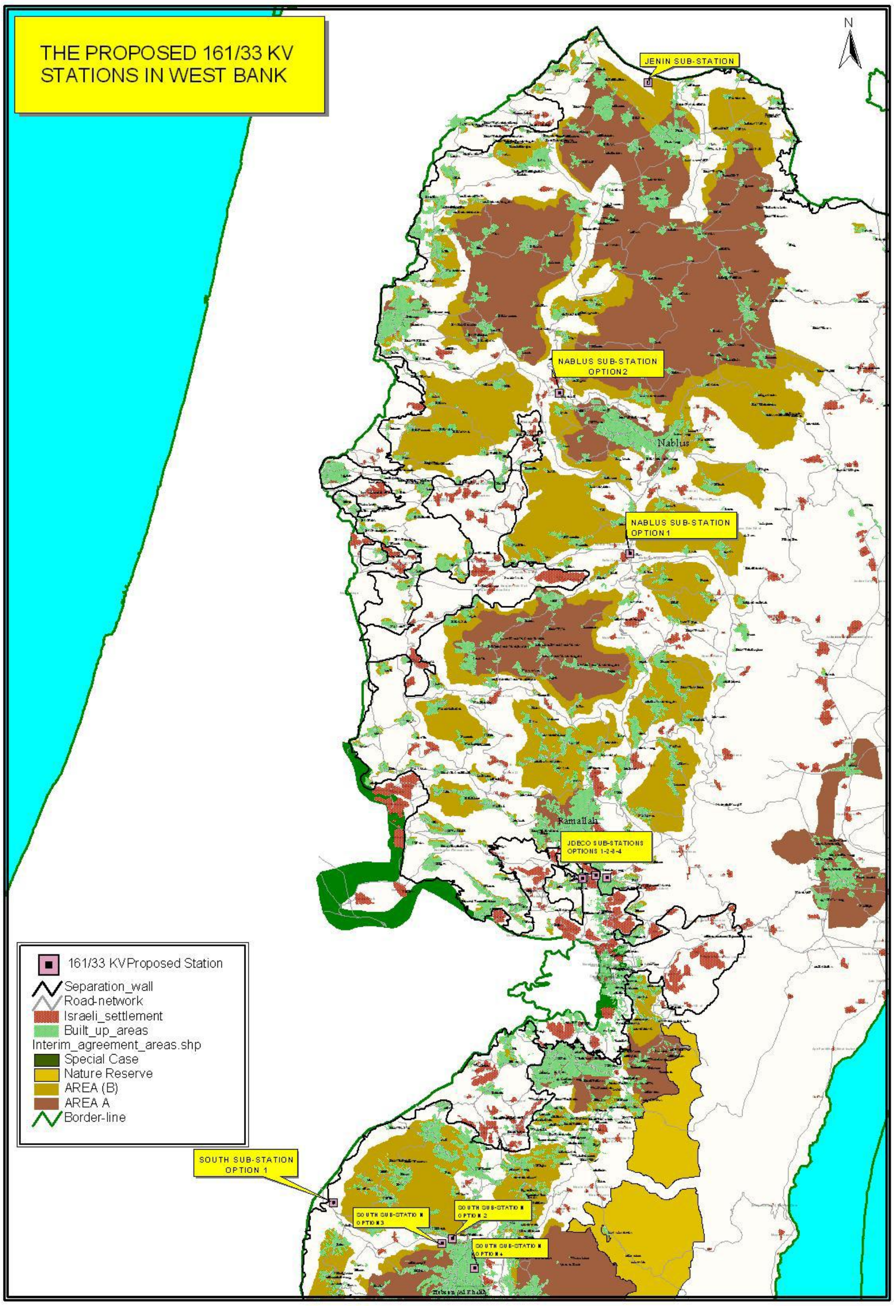


Figure 1.3 Substations in the West Bank

Source: World Bank, Final Report.

Recharging both local and regional aquifers – the basic water resource, special care will need to be taken to prevent pollution by (fuel and lubricants (oil like) from construction machinery). Similarly, the barren nature of the land and limited vegetation calls for extra care regards measures to minimize drifting (i.e. removal of soil) and as a result come the soil erosion. Site descriptions of the identified location alternatives are organized according to the order in which the sites were visited starting with the Nablus 1 and 2 options and moving North to Jenin followed by the site options near Hebron and Ramallah in the south.

1.2.4 Climate impacts

The weather in the West Bank (Palestinian Territories) plays an important role in controlling electric demand. The West Bank and surrounding areas have a Mediterranean climate characterized by long, hot, dry summers and short, cool and rainy winters, as modified locally by altitude and latitude. The climate is determined by the area’s location between the subtropical aridity qualities of Egypt and the subtropical humidity of the eastern Mediterranean. January is the coldest month, with temperatures from 5 C to 10 C, and August is the hottest month at 18 C to 38 C. The Middle Eastern summer is eased by breezes coming from the Mediterranean Sea. However, during the months of April, May and mid-June, the area experiences waves of hot, dry, sandy and dust "Khamaseen" winds which originate from the Arabian Desert. About 70 percent of the average rainfall in the country falls between November and March; June through August are often rainless. Rainfall is unevenly distributed, getting less sharply and quickly as one move southwards. In the extreme south, rainfall averages less than 100 millimeters annually; in the north, average annual rainfall is 1128 millimeters. January and February, it may take the form of snow at the higher elevations of the central highlands, including Jerusalem. The areas of the country most cultivated are those that receive more than 300 millimeters of rainfall annually; about one-third of the area is cultivable. However, the inconsistency of rainfall throughout the months and years requires that most vegetable cultivation be supplemented with irrigation to ensure normal growth. Palestine receives an average of seven hours of sunshine a day during the winter and thirteen hours during the summer. As a consequence, rooftop solar collectors are extensively used to capture solar energy and to replace limited and expensive available energy resources. The average annual relative humidity is 60% and reaches its highest rates during the months of January and February. In May, however, humidity levels are at their lowest. Night dew may occur in up to 180 days per year. An overview of the main weather parameters, temperature, precipitation, relative humidity and average wind speed is shown in Figure (1.4).

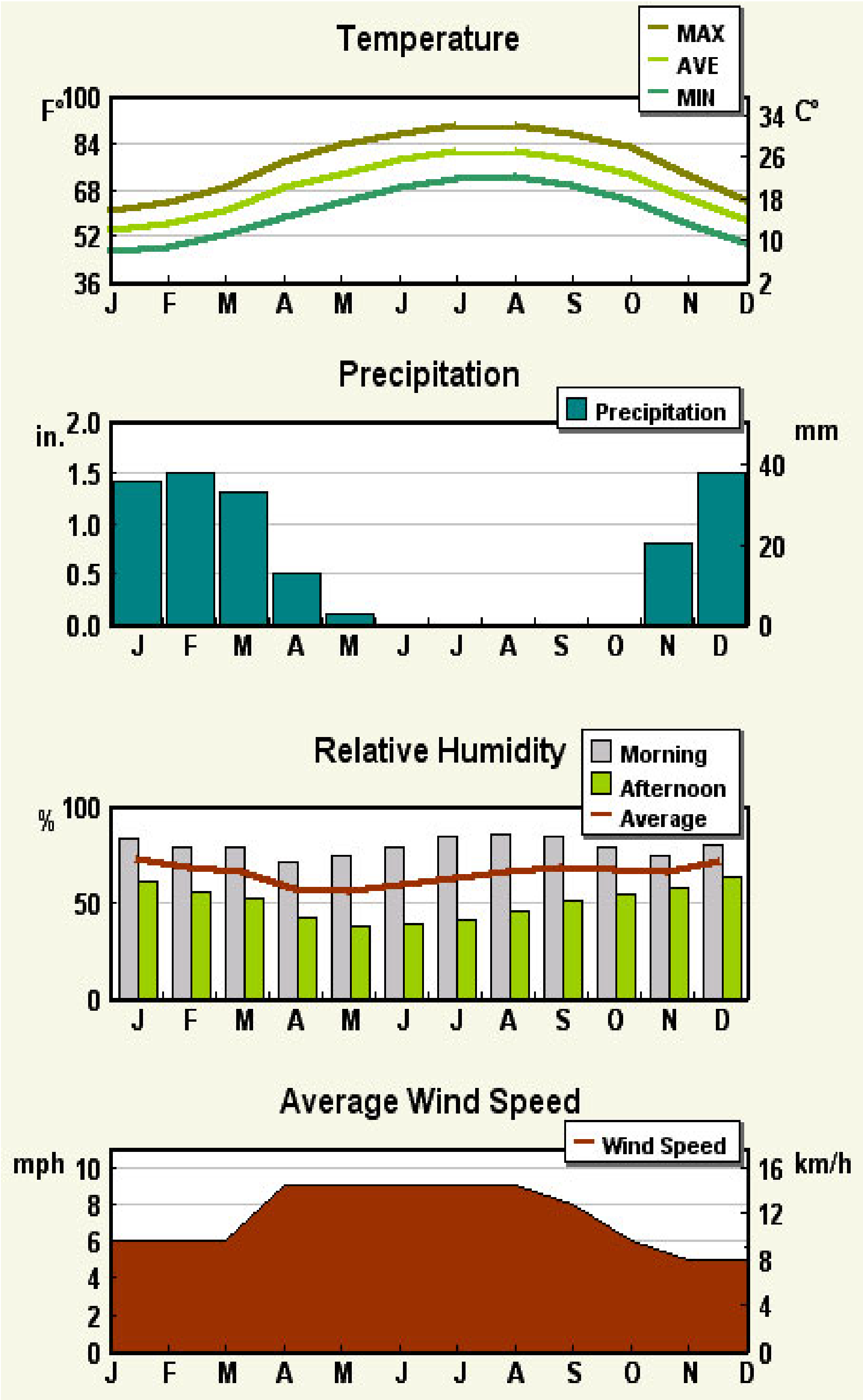


Figure 1.4 Summary of weather conditions in West Bank

Source: World Bank Final Report

Figure 1.5: West Bank IEC MV cables supplying load centers.

Source: PEA, Palestinian Energy Authority.

It was found that about 520,000 Customers are connected to the local grid and purchasing electric power in the West Bank in 2011. The total consumption of electric energy was 330GW/h in 2011.

The peak of energy consumption in the Palestinian territories takes place in summer. In Figure 1.5 it is clear that maximum demand for electrical energy in the city of Tulkarem is in August:

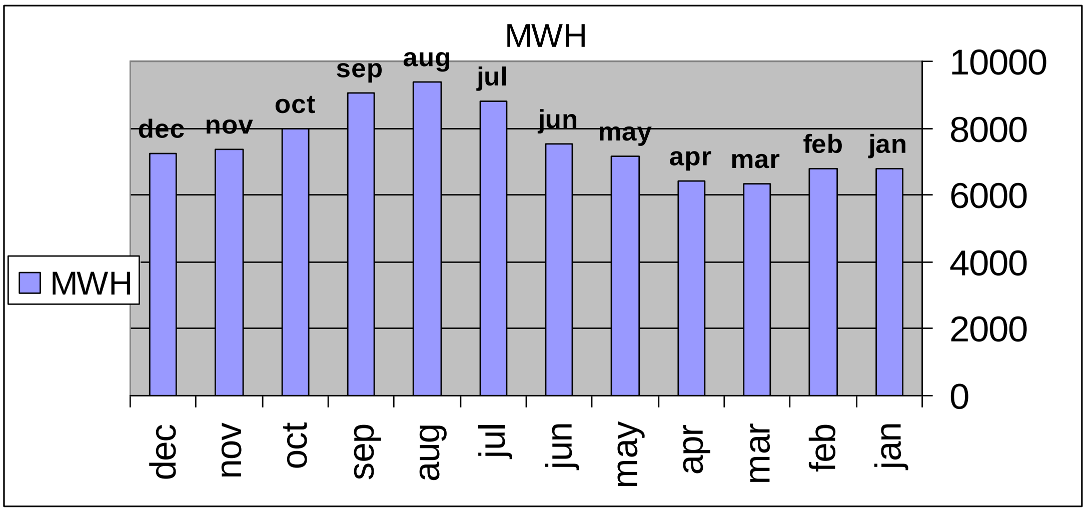


Figure 1.6 : Electric Energy Consumption In Tulkarem in 2012.

Source: (Tulkarem Municipality), 2012). Appendix 1.

The peak demand in summer is increasing sharply in the last few years. The sharp increase in number of air conditioning units installed in homes and offices has created different problems for suppliers and electric power distributers. These problems require intelligent measures to solve without the imminent need for huge investment. The existing power supply infrastructure can't afford to manage such measures and complexity, and so we have to make some changes for existing power grid. It needs to be equipped with advanced communications and information technologies to monitor, analyze and organize the supply and demand of electricity. This is what is meant by a smart grid.

1.3 THE IMPORTANCE OF THIS RESEARCH:

1- The lack of such studies in Palestine that explains the importance of smart grid for a better solution.
2- The importance of energy management in solving major problems facing in power supply in Palestine. Smart grid can be considered as a major tool for implementing energy management strategies.
3- Strategic planning for electric power in Palestine can be positively affected by introducing smart grid in different ways.
4- Building a data base for power consumption for each city, village, power distributor and even customers.
5- Smart grid can provide very valuable information needed for future, planning regarded consumption growth in each area.
6- Planning for integration renewable energy as a source of energy for Palestine.
7- Access to some international experiences and apply them on our community.

1.4 The Objectives of the Study:-

1- Study of potential applications of smart grid in Palestine.
2- Study of applicable communication networks that can be applied for this system.
3- Study of the impacts of smart grid on existing power system.

4- Study of the benefits of smart grids on future planning for power supply in Palestine.

1.5 Methodology

In this study, we have collected data and information about energy in Palestine and their applications. This included:

1. Collecting data regarding energy availability in Palestine from various related technical books and references.
2. Conducting measures to obtain data regarding Energy consumption in Palestine.
3. Collecting statistical information about actual Energy applications.
4. Study of energy used for heating and cooling of buildings.
5. Study of technical problems in the electric network and power system.
6. Study of different techniques that can be used for energy management measures.
7. Evaluating the economical impacts (reduction of energy imports)
8. Evaluating environmental impacts (reduction of gas emissions)
9. Office sources: these include books, references, studies, research, and theses on the topic of study.

1.6 Sources of Information and Data:

1. Sources of official and semi-official:

   These include information and statistics to be collected from official and semi-official relationships with the subject of study.

2. Electronic sources:

   These include websites that are interested in this topic, such as universities, Government official sites, NGO's organizations and and international bodies.

1.7 CONTENT OF THE STUDY:

In light of the goals and plan, the study mentioned above will be organized and summarized as follows:

Chapter (1): Introduction to planning and Energy.

Chapter (2): The Energy in Palestine.

Chapter (3): Smart Grid Infrastructure and applications

Chapter (4): How smart grid can solve the Energy problems.

Chapter (5): Smart grid potential Applications in Palestine

Chapter (6): Results, Conclusions & Recommendations

Chapter 2

Introduction to Smart Grid

2.1 Smart Grid Overview

The main aspect for the evolution of the power system is the need to face the on-going rising demand for electricity supply round the World while reducing carbon emissions to avoid irreversible changes to the earth's environment. All this must be fulfilled without com-promising the reliability of electricity supplies on which the world's economies are more and more dependent.

Most institutions and organizations were discussing how to develop and improve the power infrastructure. It is finally agreed that, to make use of smart grid efficiently, the question to be asked was "How to implement this idea technologically, economically and practically, or could it be achievable?"

As shown in a report to the International Energy Agency (IEA), it has been proposed that a number of scenarios for the future of global carbon emissions, annual emissions, in 2030 could be reduced from the current prediction of over 40 Gt (gigatons) CO_2 to just over 26 Gt by the implementation of a carefully studied and designed set of policies. These policies aim to limit global warming to 2°C above levels of industry before which should limit the effects of climate change to agreeable economic, social and environmental costs.

The main aim of applying smart grid, is the utmost use and manage of power transfer and capacity, this could be real if it was used intelligently and automatically for the supply and demand devices. Advanced and sufficient information is needed depending on technologies to increase the power grid, flexibility, availability and efficiency and decrease the need of utility infrastructure to be constructed.

2.2 Definition of smart grid

What is the Definition of a Smart Grid?

Smart Grid was defined according to the European Technology Platform Smart Grid (ETPSG) as follows: "A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies."

Depending on the ETPSG definition, Smart Grid uses innovative and new products and services joined together with intelligent monitoring, control, communication, and self-healing technologies to:- facilitate and manage the connection and operation of all sources of energy in a better way and more intelligently. To -Give consumers more options so they can help to optimize and reduce the energy use; to -Provide consumers with greater and more information about the choice of supply; to -reduce the environmental effect of the whole electricity supply system importantly; to -deliver levels of reliability and security of supply in a safe way.

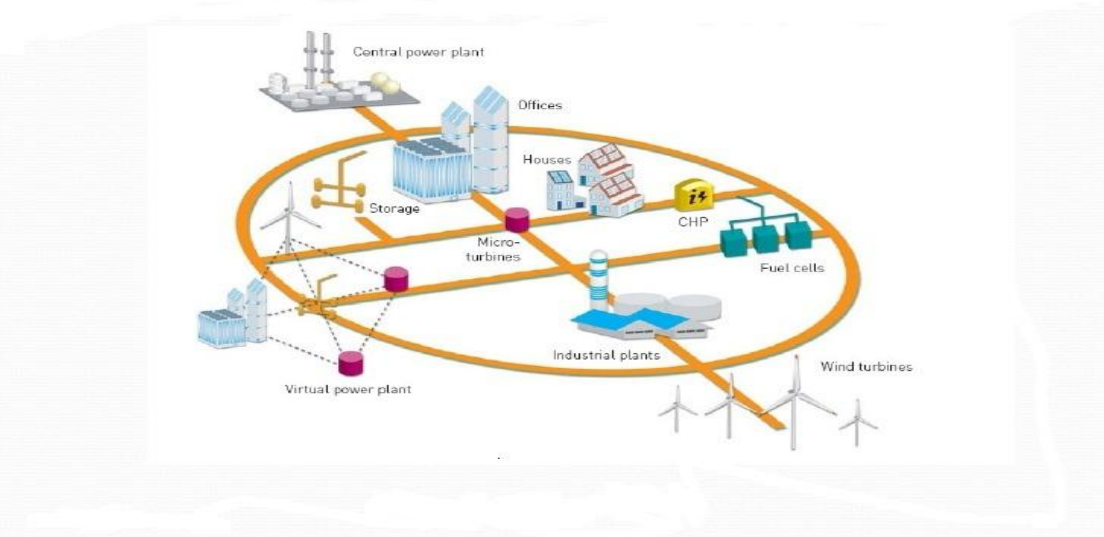


Figure 2.1: A View Of The Smart Grid

Source: http://www.slideshare.net/harshadd/smart-grids-an-introduction

So Smart Grid refers to what has become an effort to modernize the use of electrical grid to enhance its reliability, efficiency, security, and reduce the unwanted environmental impacts. These impacts include carbon emissions and the use of fossil fuels. These advancements will be achieved by upgrading the smart grid with information technologies. such as a two- way communication meters and sensors, and also advanced communication networks.

What are the Characteristics of a Smart Grid?

A Smart Grid will be basically different to current network operations of the old systems that the new grid will:

*Support wide-spread distributed energy resources by managing;

-Bi-directional flows of power and ongoing real-time information;

-Intermittent renewable generation;

-Supply and demand balancing within the distributed networks;

*Facilitate the participation of customers by;

-Enabling new technologies so consumers can monitor and control energy use automatically;

-Giving chances for consumers to take part in the market to meet the demand and response signals;

*Support increased penetration of Electric Vehicles.

Since smart grid and smart city inception are really influential and important, the electricity industry has focused on adapting supply to meet the forecasted demand. This focus on supply has resulted in an important portion of installed generation capacity and network infrastructure to provide with the highest level of demand on a small number of periods per year, and the last difference is:

What are the Drivers for a Smart Grid? Or what determines the uses of smart grid?

The elements that decides the developing of a Smart Grid can be grouped Into the following three parts, which are:

1. The policy of the local government, that's to say:

a) Climate change objectives and these include: Renewable Energy Targets, tariffs, and Emissions Trading Scheme.
b) Competitive economy objectives, that is, countries will need to invest and make use of any advantage or opportunities they have in this field to gain employment opportunities which are addressing the new industries.

c) Customer protection objectives, there is also a real need to make a balance for the needs of the country to grow energy supply and with the impact on consumers and vulnerable parts of the community to get a source that is reliable and affordable.

2. The requirements and customer's behavior, in this situation we can say that:

a) Increasing demand: meeting a higher peak of demand requires a significant investment by energy companies for the new generations and energy efficiency to afford a sufficient amount of energy.

b) Increasing of function needs, that is to say, so many changes have taken place such as policies, climate and technology, which in turn encouraged people to use more safe sources products of networks.

3. Industry and technology changes.

a) The affordability of the existing technology: the technologies of monitor and control have become really available in the new networks that are in a higher level.

b) The availability of new technologies: this quality actually has a double-edge sword, that it makes a positive (chance) and a negative one (thread) in the same way, so it has to be managed carefully. There are new network monitoring and controlling options, while new technologies for customers offering higher functionality have to be supported well, an example about this idea is the use of electric cars that need batteries to power, which in turn need to be charged , which also will use and need more electricity, so needs more monitoring and networks control.

c) The critical need to replace the old infrastructure: the networks that are used looks really old and the lost amount of current seems to be high, so to save as much as we could, there must have been a real hard work to change and replace the old network (infrastructure).

2.3 How Will the Consumer Benefit from a Smart Grid?

In a smart grid, advanced technologies improve energy efficiency by managing demand so that it could match the need and the availability of electricity, and they feed up with renewable energy sources into the network without allowing changes in weather patterns to affect the stability or reliability of the supply. At the same time, using satellite, wireless and real-time communication, advanced technologies will make use of utilities to minimize the problems in the grid faster than they are able to today.

The key major benefits of smart grid which can be summarized in four categories are:-

1. Direct financial impact, including operating and capital cost savings and potential to lower bills for consumers.
2. Reliability, including fewer outages and injuries and improved power quality.

3. Environmental, by assisting customers to adapt to a carbon constrained future through.
4. Effective integration of renewable energy sources in the power system.
5. Customer empowerment, including greater transparency and choice, and distributed generation.
6. Supporting a growing economy: and this can be done through minimizing the increase in energy use and in turn costs.
7. Providing consumers with greater choice and the chance to have been about decisions of the energy use;

   - Consumers have the best opportunity to reduce their energy costs by changing their behavior; and using less energy in the peak times.
   - Moving to use a new kind of energy that, in this situation, suppliers will be able to offer a wider range of products based on a variety of factors such as the renewable sources of energy such as ‘green’ wind energy.

8. Increased reliability and flexibility to weather events through multiple generation sources and self-dealing capabilities in the network.
9. The fault of automatic location to lessen the need for customers to notify and call the supplier about power problems and enabling faster computerized maintenance.

10. Facilitating long term savings in electricity supplier operations that can be done to the consumer in the following ways:
    - Automatic meter reading.
    - Remote connection and disconnection
    - Load management – mainly during peak times to reduce the grid stresses of supply and demand loads .

Other benefits of the smart grid can be shifted towards the environment that can be summarized as follow:

1-Energy Conservation

a- Reduction in electricity usage by customers making informed decisions, for example, in a study made concerning this idea was in Canada– in 2006, a pilot project in Ontario, Canada, savings up to 6.5% were achieved with the introduction of real-time, home energy monitors.

b- One more example was in the United States of America which is the main consumer of electrical energy around the world, Pacific Northwest National Laboratory (in a 2010 study for the United States Department of Energy) found the Smart Grid provides the possibility to direct reductions in U.S. electricity sector consumption and emissions of 12 per cent in 2030, with further indirect reductions of 6 per cent. The study suggests that further work is needed to embed these reductions, so the result would be far greater if applied widely, technologically and efficiently.

c- Reduced transmission losses – through new technologies better managing electricity supply to reduce the amount of wasted power from long way electricity transmission.

d- Improved voltage regulation – by operating the grid at the lower end of the applicable voltage tolerance (230V) the magnitude of transmission and distribution losses can be reduced and this in turn would keep our devices better and more efficient.

2-CO2 Reduction

a- Customers who use the renewable energy plans, and information on CO2 generation will enable them and consumers to reduce their carbon footprint and so, a better and cleaner air in the environment and atmosphere.

b- Improved integration of renewable sources –is facilitated by the Smart Grid but the operation of weather dependent sources (solar, wind) can be further enhanced through optimizing operations using predictive weather information.

c- Plug in Hybrid Vehicles and Electric Vehicles (EV) – instead of fuel sources in vehicles with renewable energy sources has the opportunity to lower and reduce the amount of CO2 production.

d- Enhancing Smart Grid operations through Vehicle to Grid (V2G) technology facilitating the use of EV batteries for higher leveling and managing no consistent renewable energy generation could provide more benefits.

The smart grid will facilitate the use of large scale energy storage systems that will become more important. As renewable energy technologies spread and become widely used, large scale of energy storage will mitigate disruptions in electricity flow across the grid. As variable sources like solar and wind power ramp up and down with this capability, the smart grid will not only reserve power, but rout and transfer it even more efficiently.

The law asks us to:-

1. Increase the use of digital information and controls technologically but efficiently and safely.
2. Use the grid dynamically and make use of resources.
3. Develop and integrate the distributed resources.
4. Incorporate of demand- response, and demand-side resources.
5. Use smart metering, automation.
6. Make use of every piece of energy whatever it is coming from.
7. Give the consumers on-going control option.
8. Develop smart application and practice.
9. Identify and lower the barriers of using smart grid.

2.4 Why is it preferable to use the Smart Grid?

The Smart Grid system offers us the following qualities:

1. Activate consumer's participation.
2. Using generation and option storage power.
3. Developing new products and services.
4. Provide the needs in a digital economy of power quality.

5. Using assets utility and efficiency.
6. Expects and responds to system obstacles.

Since 1982, the growth in peak demand for electricity by the population growth, bigger houses, bigger TVs, air conditioners exceeded more and more, computer driven transmission growth by almost 25% per year. However, expenditure on research and development is considered as a first step towards innovation and renewal among the lowest of all industries.

2.5 The SMART Grid: what is it? What is not?

Intelligent definition: distributed generation is the use of technologies for small-scale energy generation located close to the load being served, can lower costs, improve reliability, reduce emissions and expand energy options.

But who is running the Grid? Transmission Organization (RTO) is a profit neutral organization responsible for making agreeability between supply and demand coordinates, controls and also controls the operations of the power system. The controlling area may comprise an ISO state or more. The role of these organizations is significant and necessary to make a real Smart Grid. ISO and RTO'S are considered to be an intelligent use of distribution such as another resource to manage safety and transmission system and make them more economic. "Lessons learned "from their experiences in building processes and technologies, etc., will be directly applicable to process on the Grid, of short term and long-term.

Chapter 3

Communications Requirements of Smart Grid Applications

3.1 Overview of Smart Grid and Communications Needs

Understanding the evolving communications requirements of electric utilities and other entities involved in the distribution, transmission, and generation of electricity will inform the development of Smart Grid policies. The Smart Grid will have many new applications for utilities, consumers, manufacturers, and others, and it will be composed of many interrelated systems. One of the main components of the Smart Grid is the integration with two-way communication systems, which allows for continuous monitoring of power consumption as well as scheduling of automated electricity use. In order to design any smart grid it is essential to gather information on how current communications needs can be met and what the expected network requirements would be with the adoption of new Smart Grid applications in Palestine.

Many communications and networking systems can be used to facilitate Smart Grid applications, including:

1- twisted-pair wires,
2- cable lines,
3- fiber optic lines and cables,
4- microwave communication systems,
5- mobile communications,
6- satellite communications,

7- Wi MAX,

8- power line carrier,

9- broadband over power line, as well as

10- Short-range in-home technologies such as Wi-Fi and ADSL.

The Smart Grid applications that might be built on such communications technologies include home area networks (HAN), wide area situational awareness (WASA) networks, supervisory control and data acquisition (SCADA) systems, distributed generation monitoring and control (DGMC), demand response and pricing systems (DRPS), and electric charging for plug-in electric vehicles. Utilities have employed some kinds of Smart Grid and demand control applications for long time, and these applications have used private communications networks.

Communication companies and network service providers are partnering with electric companies to provide communications for Smart Grid applications in many countries in the world. In general, commercial carriers have developed technological changes, such as the general movement toward integrated platforms and open standards for utility communications functions that have historically been proprietary. Commercial service providers have thus created opportunities for qualitatively better communication tools for Smart Grids, even where electric utilities have ultimately opted for their private networks.

It is important to note that electric utilities now deploying Smart Grid may be able to estimate their communications requirements for the short term implementations, future communications needs may be difficult to estimate due to the fast developments in grid technologies. Smart Grid technologies continue to evolve, and new applications of Smart Grid technologies may require both a quantitative and a qualitative change in communications requirements. The purpose of this chapter is to study all communication technologies that can be integrated with future Smart Grid in Palestine. Also, studying of technical and non-technical problems that the electric utility will face while deploying a specific communication technology will enable the planners in selecting the most practical and potential communication technology.. This study therefore makes recommendations based on projections of future communications needs, with the goal of identifying potential roadblocks to implementation, be they regulatory, technological, or otherwise, and proposing Smart Grid deployment strategies that will avoid them.

3.2 Communications Requirements of Smart Grid Applications

The Smart Grid will likely employ a variety of communications technologies, many of which will have multiple applications. Particular technology characteristics can best be reviewed in the context of where it may be used within the Smart Grid. Based on work previously completed by both NIST and FERC, as well as the comments received from stakeholders, There are six functional categories into which most, if not all, Smart Grid applications fall:

a) advanced metering infrastructure,
b) demand response,

c) wide-area situational awareness,

d) distributed energy resources and storage,

e) electric transportation, and

f) distribution grid management.

The following sections investigate the communications requirements of each of these categories and estimate the relative level of various technologies in meeting these requirements. It is important to note that more than one application may in some cases be able to function on the same network, and the accurate estimation of the requirements for a given communications technology as applied to the Smart Grid would require the different requirements of component uses to be considered together.

3.2.1 Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) allows utilities to collect date, make measurements, and analyze energy consumption data for power grid management, billing purposes and outage notification, via two-way communications. While the old system which is called Automatic Meter Reading (AMR), still widely used, uses one-way communications for meter readings primarily for monthly billing purposes, AMI can be used to provide consumers with information about energy consumption data, comparisons of energy consumption in similar households, pricing information, and suggested energy management tools to reducing peak load using customer displays.

For certain applications, such as full energy management analysis and near-real-time data feedback, AMI will be required. AMI networks, however, still under development and require huge investment to build out fully. Other alternatives to AMI are therefore are listed below in the context of residential and commercial applications, the following fig. (3.1) shows the structure of the AMI and its usage.

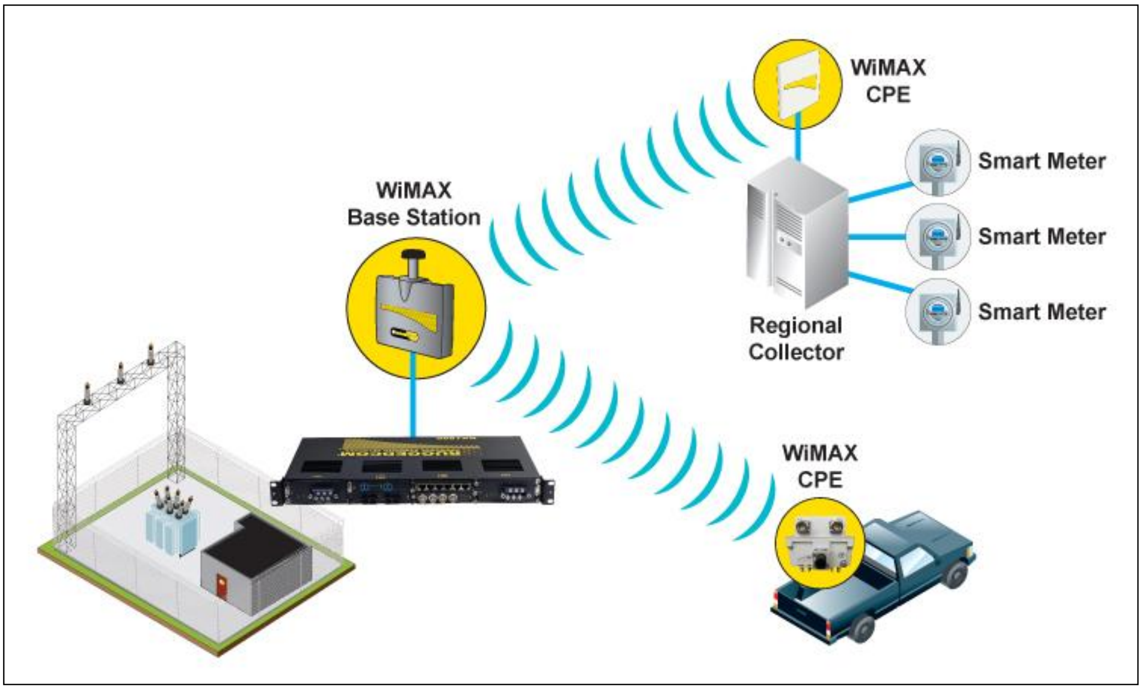


Fig (3.1) AMI communication networks

Source: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP02Wireless

Moreover, the following figure [fig. 3.2] shows the old meter reading arrangements.

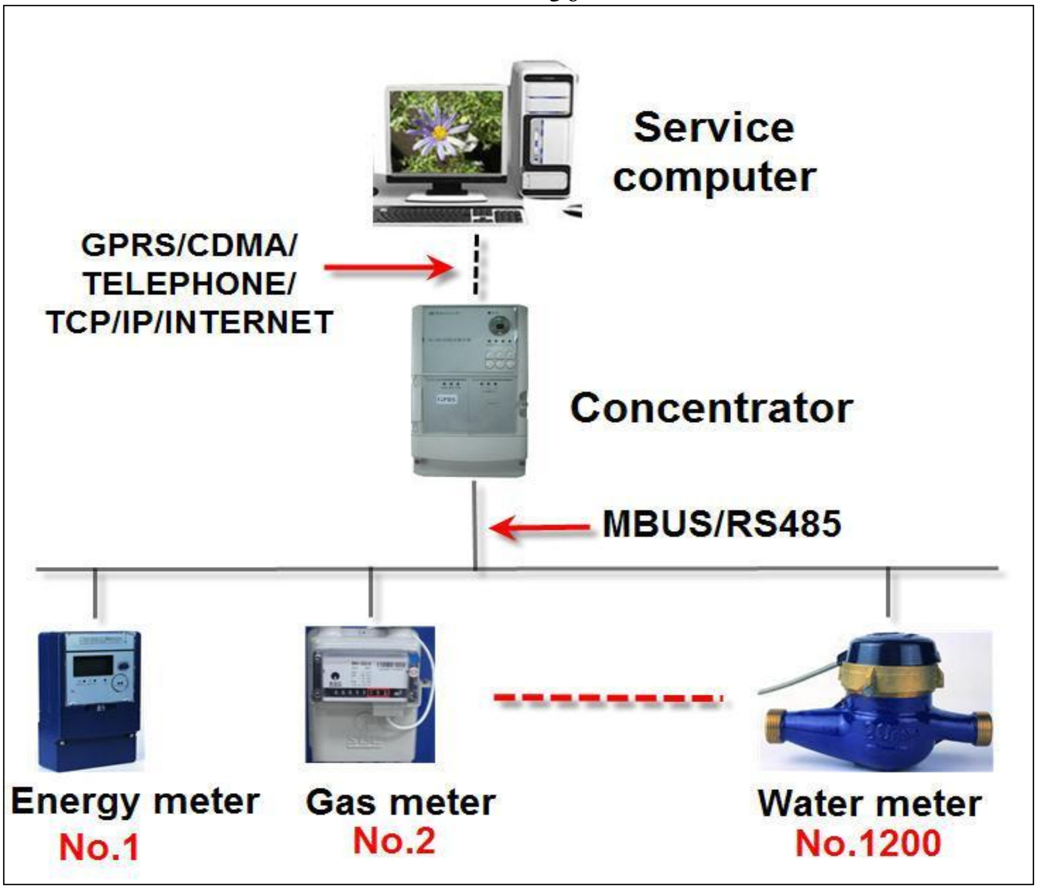


Figure 3.2: Automatic Meter Reading AMR system arrangement

Source: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP02Wireless

3.2.1.1 Technologies for customer-side networking

The main purpose of Home Area Networks (HANs) is to connect the smart meter, smart appliances, electric vehicles, and on-site power generation (mainly from PV or wind turbine) or storage, both for customers displays, controls, and data uploads, and to allow for automated energy management of energy loads during peak demand periods. For most residential or office applications, communications needs are modest. The amount of data being transferred at any one moment will likely consist only of the instantaneous power consumption (in watts) of each device, and thus the bandwidth needs to accomplish this will be small and ranges between 10 and 100 kbps per node/device. This requirement could increase quickly, however, for large homes or office buildings, so the networking system selected should be suitably scalable as well.

Likewise, the delay between the moment instantaneous energy use is measured and the moment at which that information is shown on the display, is not critical. Experts believe that the ideal latency for in-home applications should be between 2 and 15 seconds. Energy-end-use management and reduction in energy use, one of the outcomes of customer displays, does not rely on instantaneous information, so clearly much higher latencies might be reasonable. If consumers are expected to change behaviors based on the information, then reasonable timeliness of information is still important. Also, delays may affect the value of information for some applications that depend on the information, such as demand response.

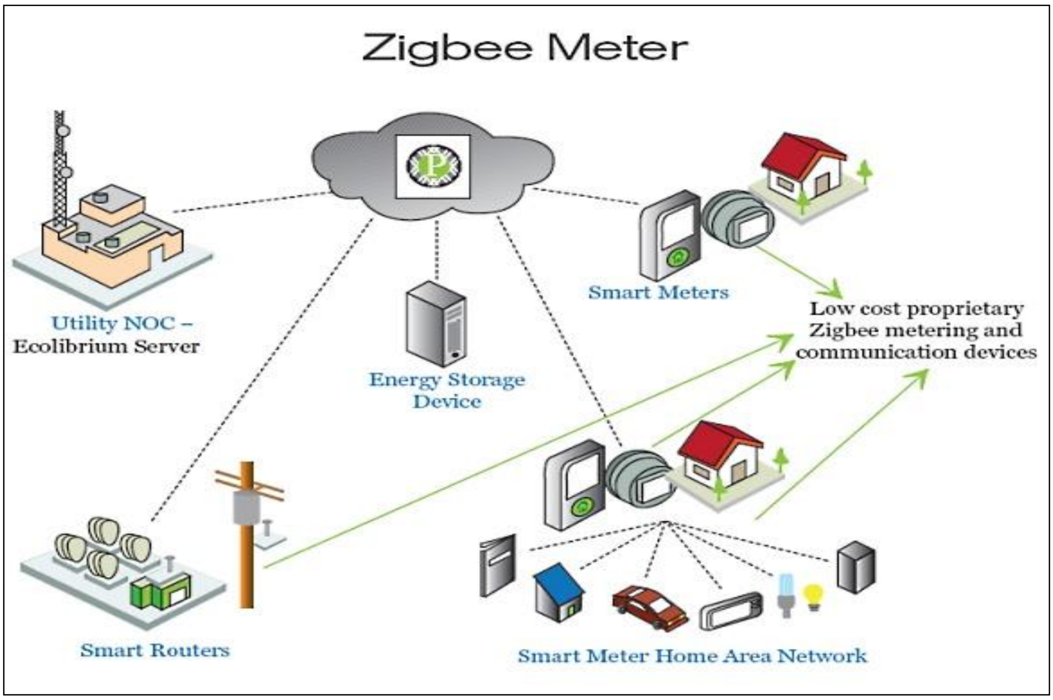


Figure 3.3 :Zigbee network application in smart meters

Source: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP02Wireless

The communications needs of in-home applications can be carried out by low-power and short-distance technologies. Technologies widely used or considered for this type of communication include:

- 2.4 GHz WiFi,
- the common 802.11 wireless networking protocol,
- ZigBee, which is based on the wireless IEEE 802.15.4 standard and is a close technological cousin of the ubiquitous Bluetooth protocol,
- and HomePlug, a form of power line networking that carries data over the existing electrical wiring in the building.

While the industry has not yet converged on a standard, the predominant technology used in installations today is ZigBee, followed by HomePlug.44

ZigBee offers the advantage of being wireless while requiring very little power, and both technologies, despite being relatively low-bandwidth, are cost-effective and flexible, although each is accompanied by their individual challenges. These characteristics will be critical if the HAN is to communicate with smart appliances in the home, which will in turn allow various consumer applications, such as remote monitoring and control of a home's thermostat or appliances via smart phone.

Home Area Networks HAN application in Smart Grid is illustrated in Fig. (3.4).

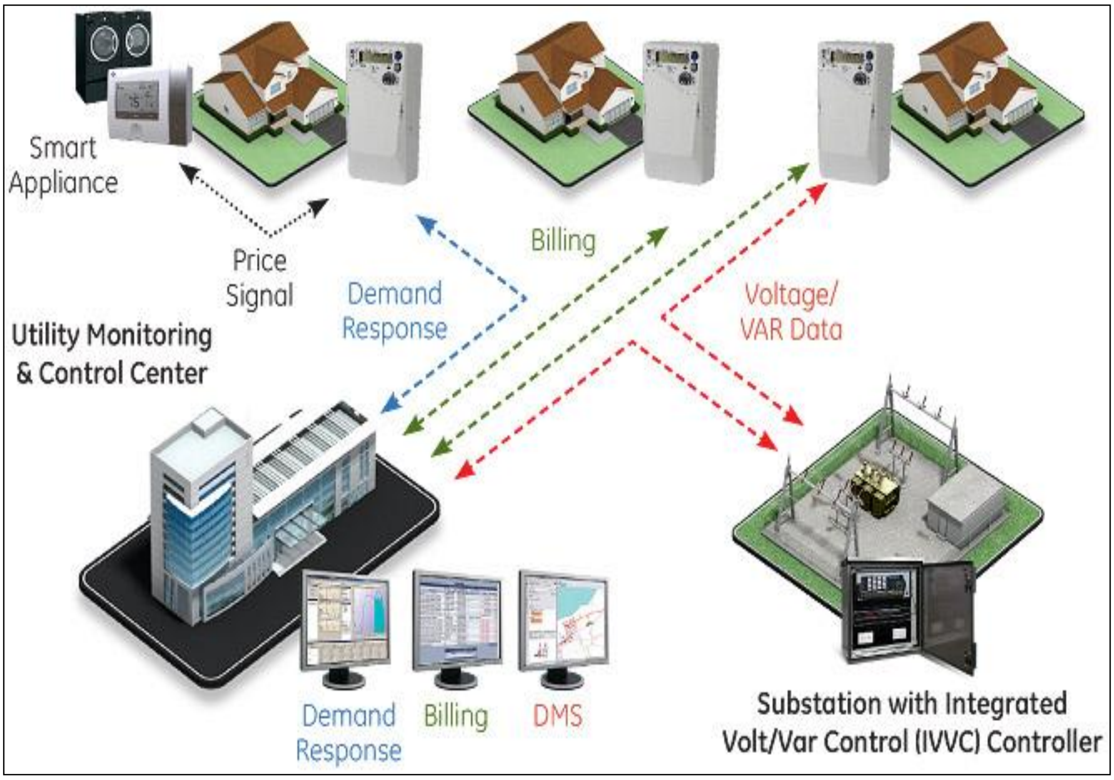


Figure 3.4: Home Area Networks HAN application in Smart Grid.

Source: http://www.utc.org/fileshare/files/34/Research/white_papers/2005

Ultimately, a key goal for in-home networking communications may be interoperability between Smart Grid communications technologies. While a thorough analysis of the various benefits and drawbacks of network technologies is beyond the scope of this report, it is worth noting that a number of stakeholders have recommended standardizing on the use of the internet protocol (IP) for Smart Grid communications.

As noted above, in-home applications can leverage AMI networks, but can also exist separately from such utility-driven systems. For instance, both traditional meters and AMR meters can be connected to the HAN via bolt-on technologies. For example, products may leverage a website working in concert with a Wi-Fi enabled sensor that reads traditional meters to allow consumers to monitor their energy use, compare their energy consumption with neighboring homes, and learn how to improve energy efficiency. Other approaches will involve a more extensive suite of hardware and software products to enable additional Smart Grid consumer applications. For example, consumers might view their home energy consumption and electricity pricing in real-time via a wall-mounted display, control certain appliances and thermostats remotely via smart phone, and shut off conventional appliances through the use of ZigBee-connected outlets.

3.2.1.2 Technologies for hand off of information from the premises

The utility network would have four components in the Smart Grid architecture:

1) the core backbone – the primary path to the utility data center.

2) backhaul distribution – the center point for neighborhood data.
3) the access point – such as the smart meter; and.
4) the HAN – the home area network.

Communications between the smart meter and the other devices on the HAN were discussed in the previous section. The next step in the network is to transfer this information away from the building to a centralized point. The centralized point be a substation, a utility pole-mounted device, or a communications tower. Bandwidth requirements will be the 10-100 kbps range per device in the home or office. This will increase quickly if appliance-level data points as opposed to whole-home data are transmitted to the central collection point.

Early AMI installations traditionally had been serviced by power line carrier (PLC) technology, which is used for relaying meter data and other internal communications over a utility's power lines. PLC is still the most common conduit for AMI functions in rural, low-density areas, where wireless coverage is less available. While PLC is low cost and can reach all utility customers in a territory, it has very low bandwidth (often below 20 kbps) and requires hopping of the PLC signal around transformers by using a bridge, for instance via a wireless connection, that bypasses this grid element that would normally scramble the PLC signal. The bandwidth provided by PLC may not be adequate to meet the requirements of real-time AMI at the per-device level (up to 100 kbps per device).

The transfer of data from central collection points to the utility typically is done over private networks. Data transfer can be done using different technologies, such as fiber, T1, or microwave networks. Star networks may also be used for data transfer from the hub to the utility, often using commercial wireless connectivity.

For more advanced applications such as real-time pricing, which would bill for electricity at the current rate, a two-way communications system is needed. Data transfer from a centralized collection point to a utility is likely to have bandwidth requirements around 500 kbps.

An open question remains, however, whether such two-way communications must be truly “real-time”; such consumption data may be of more use if limited to the HAN, which can act locally to manage energy consuming devices and appliances, with only aggregated data being backhauled to the utility, perhaps on an hourly or less frequent basis. Indeed, in the opinion of many experts, backhauling real-time or near-real-time data from the billions of devices that may eventually be connected to the Smart Grid would require not only tremendous bandwidth, but also data storage capacities well beyond the current installed base, making the undertaking economically infeasible.

3.2.2 Demand Response

Energy management techniques that can be used widely include the increasing implementation of demand response (DR). Demand response is the reduction of the consumption of electric energy by customers in response to an increase in the price of electricity or implementing of penalties. Demand response can reduce peak loads effectively. Demand response programs can be implemented for all types of customers small or large.

Customers demand response can be done in different forms. With direct load control (DLC), customers agree to have their consumption of electricity automatically reduced at times of peak load, by turning off some of their appliances. Automated DR; a more advanced version of DR, allows home or office equipment to respond to dynamic conditions on the grid, shifting load consumption in almost real-time. The DR device can be an energy management system or a smart appliance, the latter referred to as “prices to devices” because it sends pricing information directly to the appliance, which responds accordingly without an explicit control command. Another variation of demand response is the delivery of dynamic pricing to the customer. With such pricing, the customer has the option to reduce electrical consumption manually.

The communications requirements of DR applications may vary depending on the intelligence of the system desired. In simple cases such as DLC (direct load control), DR simply sends a shut-off command to equipment, such as an air conditioner or hot water heater. In such case, bandwidth requirements for this type of application are quite low and are easily handled by existing network infrastructure.

Some experts have estimated future bandwidth requirements of DR systems to be similar to AMI, and range from 14 kbps to 100 kbps per node/device, or perhaps even higher. Other experts have estimated bandwidth requirements to be lower than AMI, on the order of 120 bytes per control signal. {10} If next-generation DR systems work parallel with AMI, then the total bandwidth requirements of DR would likely be at least as high as AMI.

Another important factor in addition to bandwidth for DR purposes is consistent latency or time delay. Estimates of the latency requirements of DR fall into a wide range, from as little as 500ms, to 2 seconds, up to several minutes.{10} The difference is likely due to the various potential applications of DR. Certain iterations of DR may be considered "mission critical," in that failure to reduce power consumption will lead to a system overload situation. In such case, relatively lower latencies may be necessary. If DR is used as a load balancing tool, however, the responsiveness of the system may not be critical, and thus latency could be higher.

3.2.3 Wide-Area Situational Awareness

With increasing demand on the power supply system, as well as the need for improved reliability, prevention of power failure is one of the major goals of the Smart Grid. Improving wide area monitoring and situational awareness is necessary to achieve this objective. Any interruption in the power supply in one area can quickly change into a widespread problem, with cascading and destroying consequences. Additionally, information about the power supply in other close areas can help utilities manage the economic operation of the grid. Wide area situational awareness (WASA) refers to the implementation of a set of technologies designed to improve the monitoring of the power system across large geographic areas – effectively providing grid operators with a broad and dynamic picture of the functioning of the grid.

Synchronized Phasor Measurements (Synchrophasors) are one of the major new wide area measurement technologies being deployed. Although synchrophasor technology is being incorporated into other Smart Grid technologies, the chief kind of synchrophasor deployment uses phasor measurement units (PMUs). PMUs provide precise voltage and current phasor measurements – sampling as her frequently as 60 times per second – with time stamps synchronized to a common clock. The frequency of the readings, coupled most importantly with the fact that readings from disparate locations can be time-tagged and compared to form an aggregate snapshot of the state of the power supply at any one time, enable real-time wide area monitoring of the power system. Data from synchrophasors are sent to phasor data concentrators, and then subsequently distributed to end users for various power monitoring applications.

The communications requirements of synchrophasors vary depending on the nature of data being transmitted. For real-time monitoring and control, latency requirements are very low. Some experts suggest that the maximum latency for these applications is 20 milliseconds, although others think that it is below 200 milliseconds. For other data transfer such as post-event or historical data, low latency is less important.

In terms of data requirements, it is estimated that synchrophasors will require between 600 kbps and 1500 kbps.{10}

There are several communications network technologies for networking synchrophasors. They include: microwave, fiber optics, and even broadband over power line (BPL).

3.2.4 Distributed Energy Resources and Storage

One of the promises of the Smart Grid is better and more uniform integration of distributed energy resources (DER) into the grid, most notably on-grid renewable energy sources. In some markets, distributed renewables are already experiencing tremendous growth. As DER becomes a more significant percentage of the energy supply, reliable communications will be required to monitor and effectively use these resources. DER, however, extend beyond renewable energy, and may include electric vehicle batteries, combined heat and power (CHP), uninterruptible power supplies (UPS), utility-scale energy storage (USES) and community energy storage (CES). While the focus is often on these smaller-scale applications, the control of larger distributed generation sites, for instance commercial-scale wind turbine farms, will also require new communications to tie them into existing communications systems, as they are often located in remote locations, far from existing utility infrastructure.

These new energy technologies will require a grid very different from today's uni-directional system. The energy flow will be multi-directional, from utility to home, home to utility, or even home to home, and there will inevitably be greater variability in the energy supply. Renewable electricity generation is variable by nature, and is likely to be even more unpredictable when operated on a small scale. Due to this more complex control situation, effective communications technologies will be critical in such applications. One required technology will be real-time net metering, which will precisely measure the electricity purchased from the grid minus the energy generated locally and provided to a home or office by energy sources such as roof photovoltaic. Perhaps even more important, when customer's energy production is injected into (sold to) the grid, utilities will need to effectively allocate that energy using communications technologies that provide information on instantaneous electricity generation at different locations in the grid. Utilities may even build into their systems the capacity to do short-term DER generation forecasts based on weather and the time of day.

The bandwidth required for DER is expected to be along the same lines as that required for AMI, i.e. 9.6 kbps to 56 kbps, with this bandwidth requirement allocated per individual distributed source.[xx] The increasing use of DER will mean that there will be multiple energy sources feeding the distribution grid at multiple locations, complicating service restoration efforts.

Also, the required latency will range starting as high as 15 seconds. Other estimates suggest that latency will need to be in the 300 milliseconds to 2 second range. {10}

Some experts have suggested that AMI systems currently in development will be able to support the integration of DER into the grid, for instance through the use of ZigBee or other HAN technologies, as discussed in the AMI section above

3.2.5 Electric Transportation

The mass-marketing of electric vehicles (EVs) holds much promise in regard to emissions reductions and energy independence, but it also poses a significant management challenge to utilities across the country. The ability to provide sufficient electricity supply for such vehicles will depend in large part on the ability to effectively manage supply and demand, a core benefit of the Smart Grid. It is unlikely that many utilities, for instance, could currently provide the peak capacity required to charge a significant number of Electric Vehicles at the same time of day (e.g., the after work hours of 5 p.m. to 7 p.m.). Electric vehicles present new opportunities as well, however, in that they offer the potential to function as an energy storage device, thus playing a unique role in balancing demands on the Smart Grid. Electric Vehicles can absorb excess supply during periods of low demand and feed that energy back into the grid when necessary. Selecting the appropriate communications technologies to allow for the effective integration of Electric Vehicles into the grid will be critical.

3.2.6 Communications needs presented by Electric Vehicles

The successful rollout of Electric Vehicles will demand reliable, two-way communications networks. In addition to certain levels of bandwidth, latency, reliability, and security, Electric Vehicles present an additional requirement not required in most Smart Grid applications, namely mobility. Because most Electric Vehicles will likely charge at a variety of locations, including their home premises, office parking lots, and other public or private locations during long-distance travel, it will be important to maintain compatibility of communications technologies. The requirements for Electric Vehicles communications will not be all that different from other home applications, however, and many of the same communications technologies will likely be used. It is estimated that the bandwidth required for both load balancing and billing purposes will be between 9.6 kbps and 56 kbps, although for effective demand response system integration, the 100 kbps bandwidth noted previously for DR applications may be a good target. Estimates of latency requirements provided by some experts ranged from 2 seconds to five minutes, and the difference is likely due to whether billing was viewed as the main purpose or whether DR applications were factored into the estimate.

3.2.7 Distribution Grid Management

3.2.7.1 Distribution Automation

Historically, there has been little “intelligence” in the distribution side of the electric grid. Distribution automation (DA) allows utilities to remotely monitor and control equipment in its distribution network through automated decision-making, providing more effective fault detection and power restoration. DA includes control center-based control and monitoring systems, such as distribution SCADA or distribution management systems, and distribution automation field equipment, ranging from remote terminal units to intelligent electronic devices such as circuit breakers, transformers, switches and capacitors that can be remotely monitored, if not also remotely controlled or operated.

Utilities have or will use a variety of communications technologies to provide DA operations.

3.2.7.2 Substation Automation

In order to monitor and control the function of the grid, utilities install Supervisory Control and Data Acquisition (SCADA) equipment at each switching station and substation. SCADA provides voltage and current measurements at critical grid nodes every two to four seconds.[xx] SCADA systems require minimal time delay and latency. Most systems, SCADA systems require latency levels of less than 100 milliseconds for command and control applications.{10} Additionally, satellite services are also used to meet the communications needs of SCADA systems in remote or rural locations.

In terms of communications requirements, one of the factors that favors wireless technologies is that substations are natural inherently hazardous electrical environments.

The following (3.1)table summarizes all communication requirements of different Smart Grid technologies, deployments and applications.

Table (3.1) Summery of communication requirements of Smart Grid applications

Application	Network Requirements				
	Bandwidth	Latency	Reliability	Security	Backup Power
AMI	10-100 kbps/node, 500 kbps for backhaul	2-15 sec	99-99.99%	High	Not necessary
Demand Response	14kbps- 100 kbps per node/device	500 ms-several minutes	99-99.99%	High	Not necessary
Wide Area Situational Awareness	600-1500 kbps	20 ms-200 ms	99.999-99.9999%	High	24 hour supply
Distribution Energy Resources and Storage	9.6-56 kbps	20 ms-15 sec	99-99.99%	High	1 hour
Electric Transportation	9.6-56 kbps, 100 kbps is a good target	2 sec-5 min	99-99.99%	Relatively high	Not necessary
Distribution Grid Management	9.6-100 kbps	100 ms-2 sec	99-99.999%	High	24-72 hours

Source:*http://www.utc.org/fileshare/files/34/Research/white_papers/2005_-_UTC_-_HURRICANES_ OF_2005_PERFORMANCE_OF_GULF_COAST_CIC_NE*

3.3 Communication System Essentials for Smart Grid

A. Reliability

As has been noted throughout, one of the most significant benefits of Smart Grid technologies is to increase the reliability of the electric power grid. As a result, and quite understandably, in selecting among alternatives for the

Smart Grid communications needs, utilities do not want to introduce any elements that could potentially compromise reliability. The most-discussed issues in the comments regarding reliability were back up power for communications services, priority of service in the event of either power failure or congestion, and overall communications network design and management.

B. Availability of Spectrum

As discussed, wireless communications technologies have advantages over other technologies for some Smart Grid applications and infrastructure. Also, the wide spread of Smart Grid technologies is likely to increase utilities' demand for wireless services. This includes the use of utilities' own networks or using those of commercial telecommunication service providers. An important factor to consider is access to radio spectrum. For wireless services, spectrum translates into capacity. Without sufficient capacity, the expected increases in demand for wireless services may not be able to be met. As a result, it is important to review current options for spectrum access and identify any issues that could create roadblocks or that warrant further action.

3.4 Planning for Smart Grid Communications in Palestine

There are a number of technologies that have been discussed in this chapter. It is clear that it is possible to enable Smart Grid communication, with both wired and wireless networks. Although wired technologies such as power line communication (PLC) are attractive to utilities for obvious reasons, the capital requirements have generally proved to be an obstacle for adoption. On other side, wireless systems provide a cost-effective option that can be both reliable and scalable. However, wireless technologies may face different problems including bandwidth requirements and spectrum availability. Israeli control of wireless communications in Palestine at this moment may create a great obstacle towards adoption of any wireless technique.

Home Area Networks (HAN) may be the most possible communication system that any Palestinian Smart Grid may rely on. ADSL networks are well-established in urban and rural areas in West Bank and Gaza Strip. The existence of such networks will reduce the need for capital cost for deploying communication system for the grid. However, electric utilities may choose between establishing their own centralized points or to use networks of commercial service providers.

Chapter 4
Solar Energy and Smart Grid

4.1. Introduction

Solar energy is an important renewable energy due to its availability, continuity, and cleanness. Palestine is characterized by high solar radiation among regions in the world because its location at 32º makes it in the earth sun belt area that has high potential solar energy. However, solar radiation intensity changes from one season to another. The distribution of total radiation on a horizontal surface over a day was examined by Liu and Jordan [11] who showed that the ratio of hourly to daily radiation could be correlated with the local day length and hour angle which differs through the year. The results of Liu and Jordan were confirmed by Collars- Pereira and Rabl [12] using a wider database for the average distribution of solar radiation associated with different coordinates of time and location axis.

Due to high and reliable solar insulation in Palestine (estimated at 5.5 kWh/m2·day), a domestic usage for solar energy in Palestine has high potential for about 330 sunny days per year using solar water collectors [21]. Solar irradiance varies with Julian day, hour of the day and tilt angel of collector due to the various sun positions under the unpredictable weather conditions [22]. Shariah et al. [23] showed that the yearly optimum angle in Palestine is less than the latitude by about 7°. However, that value cannot be considered as a fixed one for all months of the year. A better place for solar energy is located in the southern Palestinian areas near the desert of Naqab. In that area, the yearly average daily sunshine is 9.3 hours as measured at Bir-Sabe' region, which is located on 32° latitude. For optimum solar gain, solar panels are to be installed at 32° tilt angle with the horizontal facing south. Adjustments of ±15° in the tilt angle of the solar panels are needed to track the sun's seasonal variations. [24].

This chapter focuses on solar energy availability in Palestine and its correlation with power demand. In other words, we will prove that power generation at daytime is synchronized with peak demands specially in summer when consumption increases sharply at noon time. Air conditioning systems are responsible for sharp increase in power demand at daytime.

4.2 Methodology and Approach

Due to the sun travel along the year, the sun irradiations are different throughout the seasons. Therefore the solar panels should be dynamically inclined with different angles during seasons depending upon solar energy data sets and modeling techniques. The information about solar energy, sun shine hours, temperature, and electricity has been gathered from different organizations namely: Palestinian Energy Research Center (PERC), Ministry of Energy and Mineral Resources, Palestine Meteorological Department, and time and date calendar website. Simulation tools ECOTECT software will be used for modeling solar energy with inclination angle of panel in Palestine. In this work, seasons in Palestine are categorized as the following: Winter (December to February), Spring

(March and April, May), Summer (June to August), and Fall (September and November).

The solar energy is optimized each season to highest energy value with specific angle of inclination. The optimization procedure is done using energy modeling of the ECOTECT program with weather data for the specific location in Palestine. The value of the solar energy cultivated for every season on the year is compared with the electricity consumed in residential buildings in Palestine to check whether solar system can conquer electricity consumption or not.

4.3 Solar Energy and Electricity in Palestine

One of the aspects of this research is to prove that the collected solar energy compensates the electrical energy consumption in residential buildings. Table (4.1) [25]. Other scope is to make one scenario for solar energy exaggeration by dynamically optimizing cell angle of inclination through the year, and other scenario for electrical energy consumption reduction by daily wise management. The idea of using solar renewable energy is to reduce using fossil fuels. Fossil fuel depletes and costly increases with the time, furthermore it causes environmental problems such as global warming. The focus upon the sun energy utilization entails the approach of cultivating sunshine efficiently. Therefore solar cells must be oriented and distributed effectively. The savings of electricity can be enhanced by adjusting the daily habits of wakeup and sleep. The daylight period assist in utilizing the natural sunlight instead of electricity [B.3]. The implementation of Daylight Saving Time (DST) creates an additional hour of higher outdoor air temperature and solar radiation during the primary cooling times of the evening [26]. California Energy Commission [27,28] conducted a simulation based study to examine the effects of DST on statewide electricity consumption. Consequently by concise management, collecting sun irradiation and fitting the daily man activities to sunshine will compensate electricity for residential building.

Table 4.1 Annual consumption of electricity by activity in residential buildings

Equipments	Capacity (Watt)	Owners%	Service hours/day			Service days/year	Operation hours/year	Consumption (kWh per customer)
			Summer	Winter	Avg.			
Lighting	220.0	100%	7.0	6.0	6.5	365	2373	522
Refrigerator	250.0	90%	16.0	8.0	12.0	365	4380	985.5
TV	90.0	100%	12.0	7.0	9.5	355	3372	288.3
W. Machine	450.0	90%	2.0	2.0	2.0	110	220	89.1
Iron	1000.0	90%	1.0	1.0	1.0	130	130	117.0
Fan	80.0	70%	14.0	0.0	7.0	60	420	23.5
Water Pump	400.0	20%	1.5	1.5	1.5	90	135	10.8
Freezer	350.0	20%	10.0	2.0	6.0	360	2160	113.4
Water Cooler	200.0	10%	2.0	0.0	1.0	90	90	0.9
Vacuum Cleaner	1000.0	20%	1.0	1.0	1.0	120	120	24.0
Washing Dryer	1000.0	3%	0.5	0.5	0.5	110	55	1.65
Hair Dryer	300.0	50%	0.5	0.5	0.5	100	50	7.5
Heater	1500.0	3%	1.0	1.0	1.0	60	60	2.7
Geyser	2000.0	20%	1.0	5.0	3.0	160	480	192.0
Air Condition	2500.0	10%	10.0	0.0	5.0	70	350	96.3
Total								**2475**

Source:http://www.utc.org/fileshare/files/34/Research/white_papers/2005_-_UTC_-_HURRICANES_OF_2005_PERFORMANCE_OF_GULF_COAST_CIC_NE

4. 4 Solar Irradiation Data

To find out the solar potential available at different districts in Palestine, information on solar irradiance on both, annual and hourly time scale and ambient temperature are needed Based on this, the expected output power of PV generators characterized by its components (module type, inverter Type and the orientation of its modules, can be modeled. This chapter discussed the modeling tools for solar irradiation of four districts in Palestine (Ramallah, Jerusalem, Jericho and Bethlehem) and the method that used to model the output power of the PV generator and in the next chapter discussed the option to use PV-generators production to partly cover the load of the electric supply grid in selected Palestinian districts.

4.4.1 Modeling Solar Irradiation Data

The output power of a PV device depends on the incoming solar irradiance. The mean value of solar irradiation per unit area oriented perpendicular to the sun direction that arrives in the upper level of earth's atmosphere is known as the solar constant and it is estimated at 1367 W/m^2[26]. However, the solar insolation at ground level is modified by different factors such as latitude, the day of the year, daytime, cloud coverage and the state of the atmosphere. The irradiance has two components; the direct and the diffused. The term diffuse irradiation means the irradiation that is scattered by clouds, water vapor, snow and anything else in the earth or atmosphere, while with direct irradiation the irradiation is coming directly from the sun disk. Recorded solar irradiation data at specific sites are required in order to compute the total output power of a solar cell, but detailed atmospheric records are not available in many locations around the world. When actual data are unavailable at a certain location, methods for generation of synthetic data can be used to simulate the hourly solar irradiation data for a large number of years.

4.4.2 Data Sources

There are generally three different methods to estimate the solar resource in a specific location:

1- to conduct ground measurements,

2- to assess radiation based on satellite observations, or

3- to use stochastic modeling based on measured average values.

Some well-known available online web applications such as PVGIS use data from ground measurements in their first databases. New databases that are being incorporated in such applications come from satellite databases like Meteosat. Satellite data is not as accurate as ground measurements but it offers the best coverage and regular calculations for different territories. Satellite data covering Palestine territories comes from Meteosat satellites, which covers most of Africa and Middle East.

For this master thesis ground measurements are not yet available. Therefore, only the other two sources have been used providing satellite data and stochastic modeling results.

4.4.3 Solar energy simulation

To estimate potential power generation by grid-connected PV modules, PVGIS online simulator was used. PVGIS [PV-Geographical information Systemg] data base has been setup by Joint Research Center (JRC) (Figure 4.1) to give solar irradiance data with a continues spatial coverage for Europe and Africa. These data are based on calculations from satellite images. The database represents a total of 12 years of data from 1998 to 2010. In this study we simulated for the special case of Tulkarem-City (32°18’ North and 35.02 East) in West bank

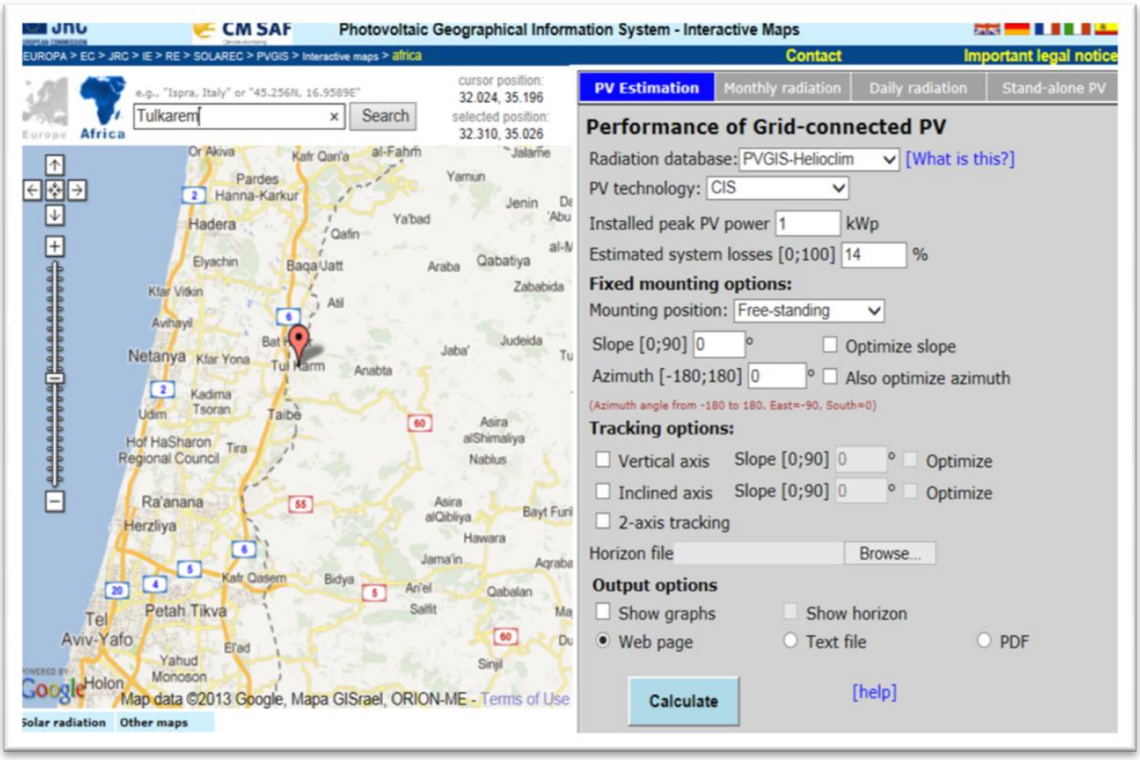


Figure 4.1 Estimating the irradiation at Tulkarem area using PVGIS web site

[source:http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=en&map=africa

4.4.3.1 Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: Tulkarem 32°18'45" North, 35°1'13" East,

Elevation: 70 m a.s.l.,

Solar radiation database used: PVGIS-helioclim

Nominal power of the PV system: 5.0 kW (crystalline silicon)

Estimated losses due to temperature and low irradiance:

11.9% (using local ambient temperature)

Estimated loss due to angular reflectance effects: 2.7%

Other losses (cables, inverter etc.): 14.0%

Combined PV system losses: 26.3%

Table 4.2 Simulation results for PV grid connected system (Fixed system)

	Fixed system: inclination=32 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	3.43	106	4.45	138
Feb	4.05	113	5.31	149
Mar	4.51	140	6.02	187
Apr	4.71	141	6.28	189
May	5.32	165	7.33	227
Jun	5.53	166	7.75	232
Jul	5.42	168	7.61	236
Aug	5.35	166	7.54	234
Sep	5.20	156	7.25	218
Oct	4.74	147	6.50	202
Nov	3.82	114	5.08	152
Dec	3.12	96.8	4.06	126
Year	4.60	140	6.27	191
Total for year		1680		2290

E_d: Average daily electricity production from the given system (kWh)E_m: Average monthly electricity production from the given system (kWh)

H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

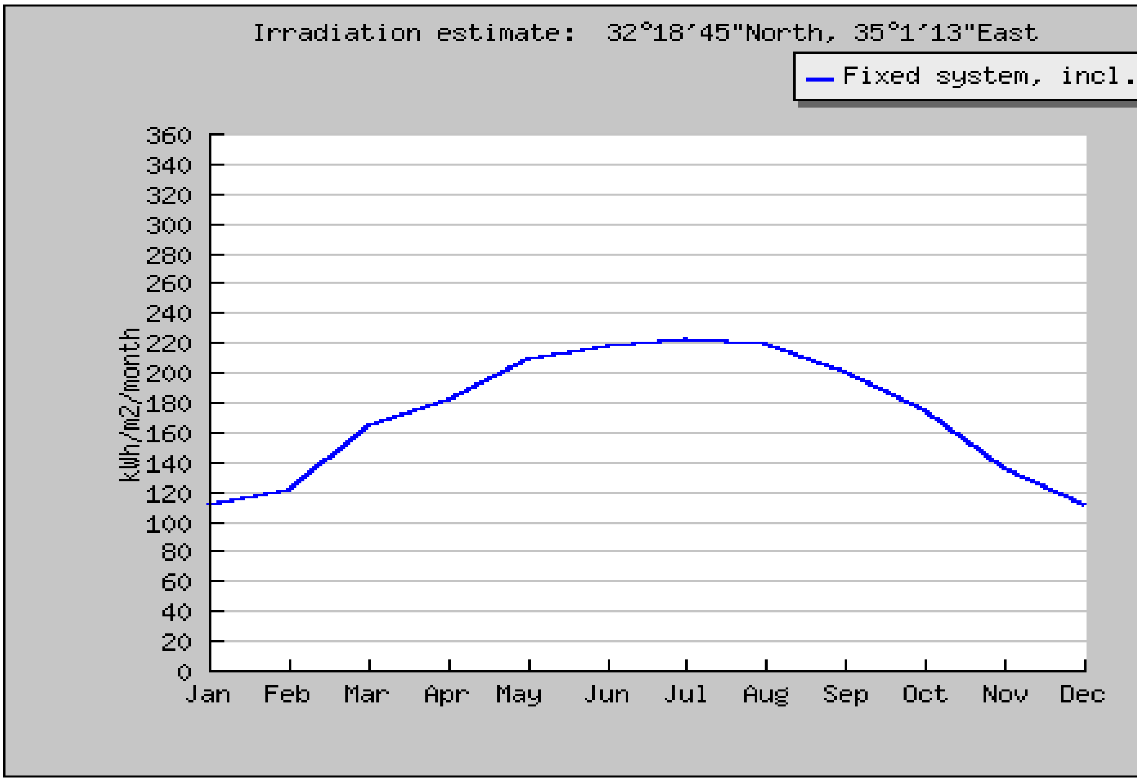


Figure 4. 2 : Monthly energy output from fixed-angle PV system

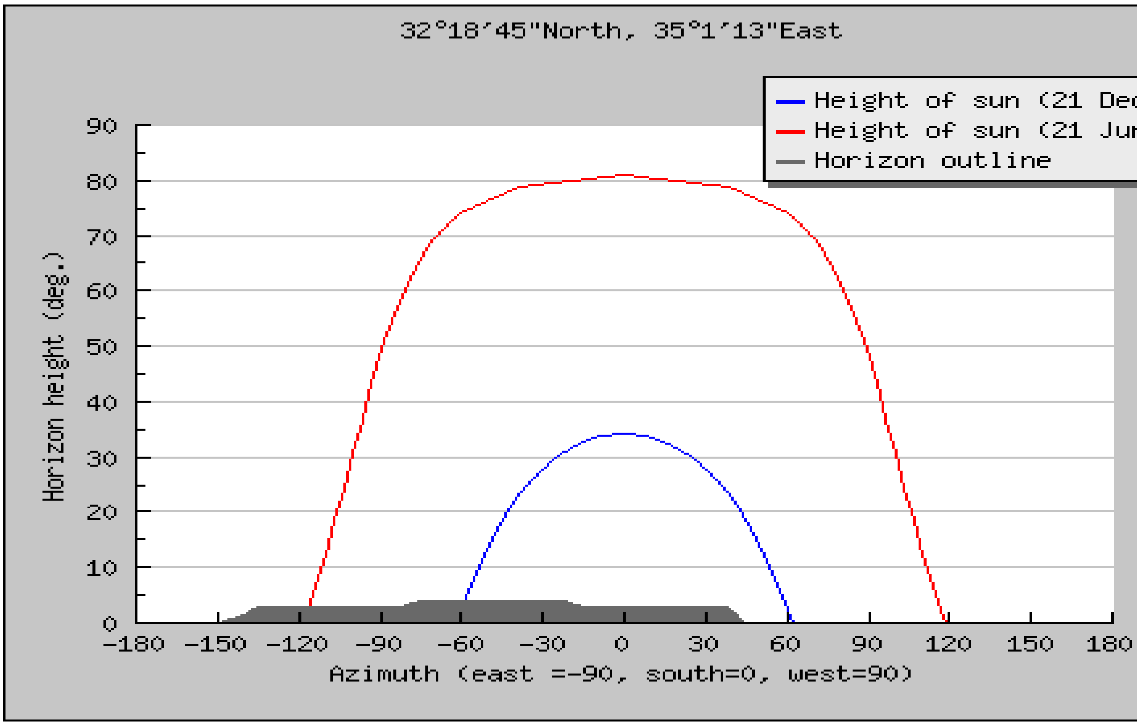


Figure 4.3: Sun altitude (height) for Summer and Winter with horizon outline.

Incident global irradiation for the chosen location

Table 4.3 Incident Global irradiation for Tulkarem

Month	Hh	Hopt	H(90)	DNI	Iopt	TL	D/G
Jan	2560	3580	3350	3070	55	3.8	0.46
Feb	3370	4310	3520	3560	47	3.7	0.45
Mar	4610	5300	3490	4330	35	3.8	0.43
Apr	5840	6040	2950	5050	20	4.5	0.41
May	7090	6760	2390	6160	7	4.4	0.38
Jun	7980	7290	2120	7110	-1	4.4	0.35
Jul	7690	7170	2270	6790	2	4.7	0.36
Aug	7040	7060	2960	6380	15	4.7	0.36
Sep	5980	6670	3940	5760	30	4.8	0.37
Oct	4500	5640	4320	4810	44	4.4	0.39
Nov	3230	4500	4120	3940	54	3.8	0.42
Dec	2460	3580	3490	3120	58	4.1	0.45
Year	5210	5660	3240	5010	28	4.3	0.39

Hh: Irradiation on horizontal plane (Wh/m2/day)

Hopt: Irradiation on optimally inclined plane (Wh/m2/day)

H(90): Irradiation on plane at angle: 90deg. (Wh/m2/day)

DNI: Direct normal irradiation (Wh/m2/day)

Iopt: Optimal inclination (deg.)

TL: Linke turbidity (-)

D/G: Ratio of diffuse to global irradiation (-)

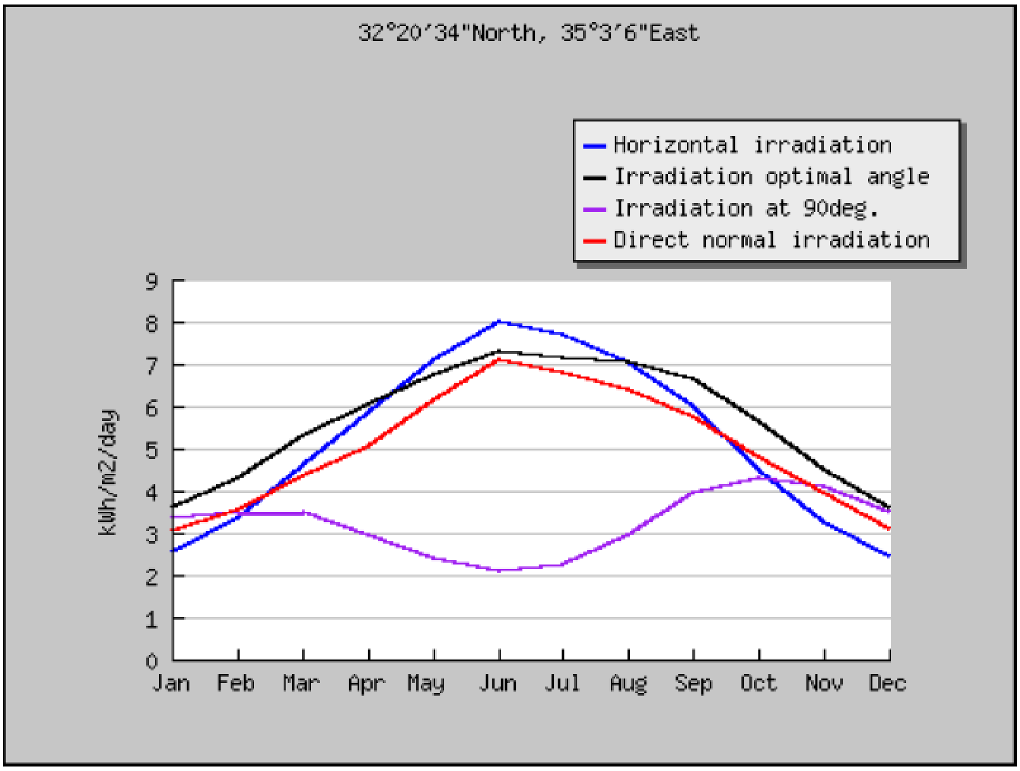


Figure 4.4 Irradiance at different inclination angles

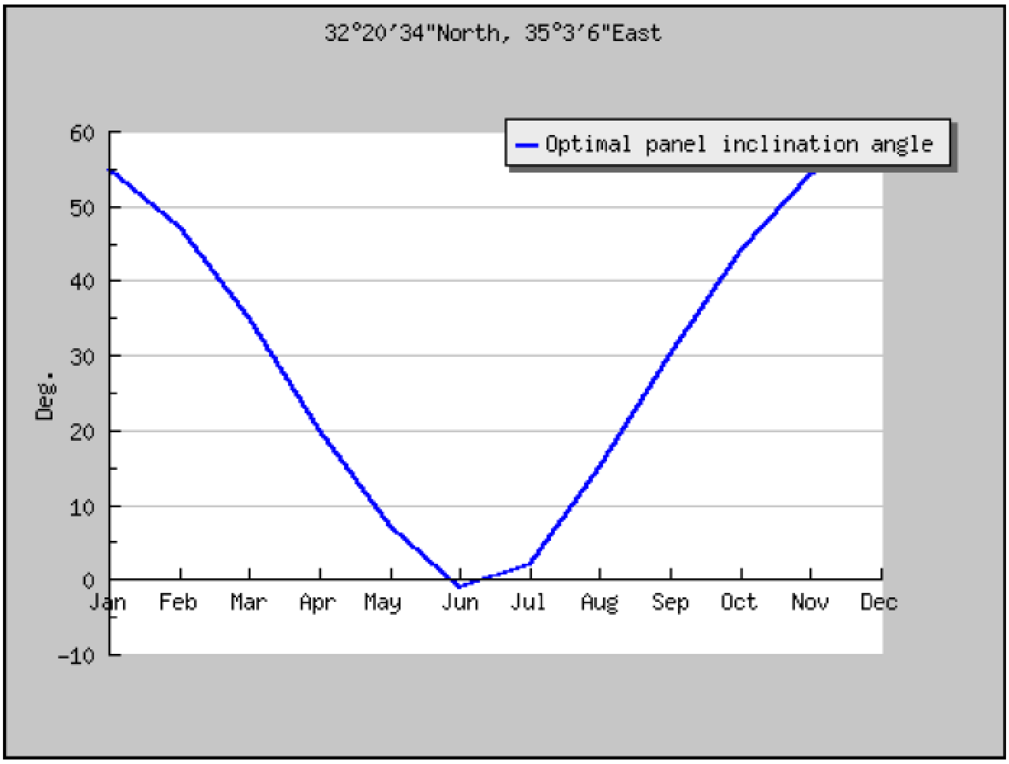


Figure 4.5 Optimal monthly PV panel inclination angle

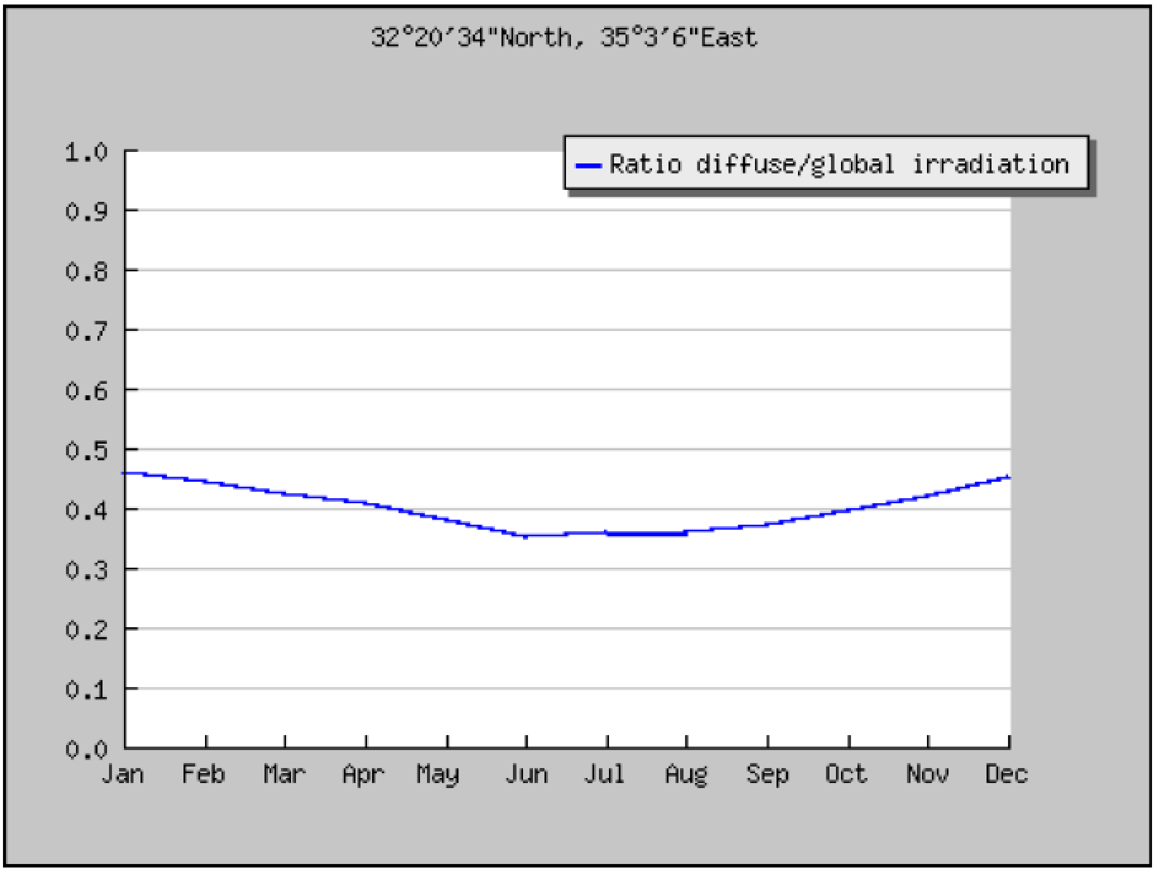


Figure 4.6 Monthly ratio of diffuse/global irradiation in Tulkarem

Note:

All tables and figures shown before are generated by the Web-Link PVGIS for solar simulation.

http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=en&map=africa

4.5 RENEWABLE ENERGY INTEGRATION USING A SMART GRID

Weather-driven renewable energy sources require new operational procedures. Conventional power plants can be operated in accordance with the needs of the power system; the present power system operating procedures were designed with this in mind. Renewable energy sources such as solar or wind are variable and thus the operating schedules for such plants are largely dictated by the changing “fuel” supply. This is especially pertinent in the case of photovoltaic, wind and hydro, none of which have inherent storage in their power plant design. These systems cannot be controlled in similar manner as a conventional generation facility.

With low levels of wind or solar energy penetration the overall effect on grid operations is limited, but as the penetration levels increase their effect will increase. It has been realized that as the penetration levels increase, more advanced control of the power system will be needed to maintain system reliability [26]. These controls include more efficient use of transmission, use of demand response and intelligent energy storage, all of which can be enabled through the application of a smart grid. In fact, the ability to integrate renewable energy in the power system is one of the driving factors in some smart grid installations. Xcel Energy’s Smart Grid City white paper specifically communicates that a key aspect to its renewable energy integration plan involves a smart grid:

“The ability to communicate (via a smart grid) and new improvements in storage (cheaper, longer lasting, higher capacity batteries) allows for a creation of a new market instrument. A smart grid with advanced energy storage reduces the variability associated with renewable energy, enabling more renewable energy on the grid, thus reducing emissions.” [18]

4.6 ASSESSING RENEWABLE ENERGY IN A SMART GRID

A smart grid must be intelligent and has the capability able to make ‘smart’ decisions. These decisions must be based on real data and information. However, not all of that information and data has to be instantaneous with zero latency. In fact, when designing a Smart Grid some limitations must be taken into consideration. These limitations can be physical, contractual or even political. Without enabling the smart grid to properly handle these limitations, the smart grid would not perform correctly.

A smart grid may need to perform certain kinds of energy management procedures such as load curtailment or peak clipping. In such cases, no customer is going to be happy to accept such an agreement without assurance that the number of interruptions is very limited. Similarly, storage may be purchased to allow for better operation of localized portions of the power system (taking strain off transmission during constrained periods) or even utilizing storage that is designed to support the power system as a whole. Alternatively, the storage may be sourced from UPS’s or electric-vehicle-to-grid arrangements, but again an agreement must be made on how often the system can cycle the batteries and how much it is allowed to draw them down.

Such system design decisions, whether in terms of contractual agreements or the installment of physical equipment, must be based on accurate information about the degree of flexibility that is required. If high levels of non-scheduled renewable energy are employed in the system, these will tend to dominate the flexibility requirements and so careful assessment of the renewable energy resources is vital when setting-up a smart grid, re-negotiating contracts or considering installation of physical equipment. In essence, an assessment of the variability of renewable energy and the effects on the power system must be performed.

Integration models are being developed recently and as the level of sophistication increases, and similarly modeling the “fuel” that drives the renewable energy [19]. Forecasting of behavior of long-term patterns of renewable sources will depend on historical data about their behavior in the past. Unfortunately, long-term records of renewable energy production are not available for most locations in Palestine. Number of such plans is small, and most plants have only been operational for a few years at most. Also, the growth rate of new renewable energy generation is still a small portion of total energy consumption. In fact, it is usually not even possible to obtain long-term, on-site meteorological data [20]. Thus, an alternative must be used to be able to obtain the historical information used to determine the requirements for the smart grid. IEEE Transactions on Power Systems had a Special Section on Wind Energy in 2007 including the paper “Utility Wind Integration and Operating Impact State of the Art” [21] which stated:

“A state-of-the-art wind-integration study typically devotes a significant effort to obtaining wind data that are derived from large-scale meteorological modeling...”

Each renewable energy project (or region) has specific variability patterns that are typical depending the time of day and time of year. The energy output is based on the local weather patterns, which change depending on the seasonal and daily influences.

4.7 Forecasting Renewable Energy IN A SMART GRID

Smart grids forecasts for future requirements are essential for preparing the flexible systems to behave in the appropriate manner. Non-scheduled, or unpredicted renewable energy resources will add another variable to an already complicated balancing act. The fact that these sources of generation cannot be dispatched in the traditional methods may cause problems for conventional system operation. A smart grid takes advantage of potential improvements that can be made to conventional operation through the use of communications and information. While renewable energy cannot be operated in a conventional manner, its behavior can be predicted (such as solar energy in summer) and the forecast information is exactly the kind of information that a smart grid must use to improve system efficiency.

In fact, as renewable energy penetration levels continue to increase, non-scheduled renewable energy may become the single largest source of variability on the power system. This makes the employment of accurate renewable energy forecasting a key component of a smart grid. In a smart grid, decisions are dynamically made based on information about power generation and demand. In the case of renewable energy integration, forecasting of generation and loads is very essential for the operation of the smart grid. Meteorological factors have great impacts on renewable energy generation and thus it is inherently variable. This variability occurs across all of the time frames of utility operation from real-time minute-to-minute fluctuations through to yearly variation affecting long-term planning. However, recent wind integration studies have shown that the variations that have major effects on power system reliability operations and costs of operation are those in the hourly and daily timeframe [21]. These two times frames are directly related to the ancillary services of load following and unit commitment; consequently, the state-of-the-art wind energy prediction systems focus on these timescales in order to meet the needs of the systems operators and market traders.

In a smart grid, human efforts that are made to manage system operation will be replaced by computers and other intelligent units that have faster response time and can process huge amounts of data. In addition to that, the use of a smart grid will improve the forecasts of renewable energy generation. Expert-system based forecasts or time-series based forecasts use huge amounts of data and the more reliable and timely the data transfer, the greater the accuracy of the forecasts – especially for short-term forecasts. The day-ahead forecasts are typically created in a similar way to the assessment work mentioned previously using numerical weather prediction models to downscale information from coarse resolution global weather models. These models are tuned using data if that data is available. In a smart grid, the data would certainly be available. However, it is the one hour-ahead forecast that help with the load following of the power system that gain the most in a smart grid. Typically the one hour-ahead forecasts employ statistical methods primarily based on the most recent observations. The first phase in developing this type of forecast consists of identifying, compiling and integrating data from a wide variety of sources: location of the renewable source, historical database observation records, etc. The second phase consists of developing and training various self-learning forecasting methods using all the available data.

The final product provides a timely, relevant and accurate forecast. Taking advantage of a vast communication network the forecast of renewable energy will be able to utilize this information from an even wider set of sources. Furthermore, it also opens other opportunities such as using weather forecasting information to forecast transmission line ratings to allow for the dynamic rating (and planning) of transmission will allow a much more efficient use of the existing infrastructure.

4.8 Smart Grid and renewable energy in Palestine

Palestine is one of places that it is recognized of high solar radiation. The solar energy cultivation needs to be optimized by taking in consideration the angle of solar cell inclination. As the sun travels in its orbital alignment through the year, the angle of inclination needs to be dynamically variable. The angle of inclination and solar energy in this research is optimized for each month and so for each season. According to Palestine the sun energy is worthy for all four seasons. The results of this research show that the solar energy can serve the residential building consumption of electricity.

In fine, the area occupied by solar panels, the solar energy conversion efficiency, and the angle of inclination are important parameters in combining solar energy concept in the design of building, and that is an important step in sustainable development of energy.

Chapter 5

Smart grid potential Applications in Palestine

In this chapter, we will focus on the potential applications of Smart Grid in Palestine, and in specific in the West Bank. From all applications of Smart Grid as discussed in chapter 2 and Chapter 3, it is clear that there are three applications that can be implemented with little efforts and reasonable costs. These applications are:

1- Smart power metering,

2- Demand side management and peak control.

3- Integration with distributed power generation using renewable energy.

The main key for the success of these applications is the right selection of communication network for the system. As discussed in chapter 3, wireless and satellite communications are out of reach at this time for political and economical constraints.

5.1 Potential Communication Tool for the Palestinian Smart Grids

There are three practical communication systems that can be used for the special case of Palestine:

1- HAN network system (Home Area Network)

2- PLC (Power Line Carrier)

3- SIM mobile communication technology.

HAN network is based on available internet network. The internet communication system is based on ADSL which is a type of digital subscriber line (DSL) technology that enables faster data transmission over copper telephone lines. Recent surveys in 2012 [31] have shown that more than 60% of residential and office customers for the wired telecommunication company are connected to the Internet using ADSL technology and telephone wires to the company. Recently the local telecommunication company (Paltel) has switched to a new technology called the BSA (Bit-Stream Access) which has better features than ADSL technology. Bit-stream access refers to the situation where a wire line incumbent installs a high-speed access link to the customer's premises (e.g., by installing ADSL equipment in the local access network) and then makes this access link available to third parties, to enable them to provide high speed services to customers. This type of access does not entail any third-party access to the copper pair in the local loop.

5.2 Potential Applications of Smart Grid in West Bank

In this research we suggest three potential applications for Smart Grids in Palestine and in West Bank in specific. These applications can be implemented with reasonable investment and using existing communication technologies. The potential applications are:

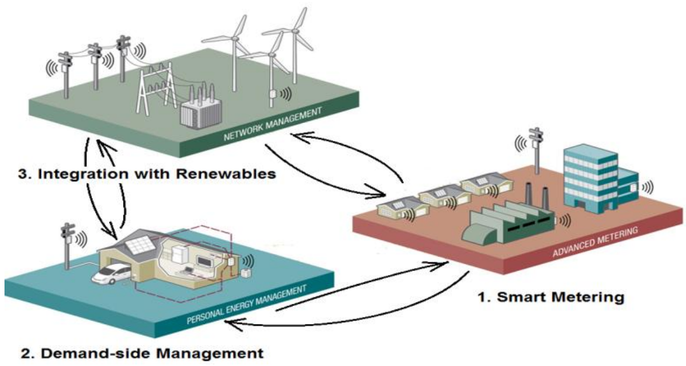
1- Smart metering of power,
2- Demand side management for peak control.
3- Integration of distributed generation and renewable sources.

These applications do not require changes in existing power grids which are isolated for each city and village. However, to make these applications possible the following requirements have to be met:

1- Centralized unit to be established at utility control vicinity. All computers to make decisions execute actions and make data acquisition and analysis will be located in this center.
2- Selection of suitable communication tools such as HAN or PLC.
3- Installation of communication tools at the central unit and customer premises.
4- Installations of remote units at customer side including smart meters and control units.

5.2.1 Smart Metering

Smart meters are to be installed in every home in the West Bank in 10 to 15 years. The following Fig. (5.1) shows the potential applications of Smart Grid technology in Palestine.



Figre 5.1: Potential applications of Smart Grid technology in Palestine

Smart meters are a new kind of energy meter that uses communication technologies for remote monitoring and data transfer. Smart meters are a replacement for traditional electromechanical meters and prepaid digital meters. Smart meters send electronic meter readings to energy supplier automatically. In addition to electricity smart, gas smart also can be replaced with Smart Gas Meters.

A smart meter works by communicating directly with energy supplier, so the distribution company or municipality will always have an accurate meter reading and there's no need for an employer to take a meter reading. Smart meters can work in a variety of different ways, the following Fig. (5.2) shows a smart meter.

Figure 5.2: Smart meter

There are many benefits that can be gained by installing smart meters. The main benefits include:

- No-one has to come round to read customer meter.
- Customer bills will be accurate - no more estimated bills or over or under-paying.
- Power off any customer will be decided upon specific decision strategy programmed at the central units.

It has to be clear for all planners that smart meters by themselves won't save money, but they may come with add-ons like energy monitoring or computer software that could. These systems will enable end-users (customers) to see how much energy they are using at different times of the day, week, month, or year. This may help them to cut their energy usage and bills by highlighting ways they can be more energy efficient.

Smart meters could also mean lower electricity bills, because they will help energy companies to run more efficiently. If energy companies have a more accurate picture of how much energy the country uses and when they use it, they will be able to make sure they have the right amount of energy at the right time. This includes postponing heavy energy consumption at peak hours to avoid penalties or power failure.

Smart meters could also lead to the creation of innovative new energy tariffs, or personalized plans individually tailored to fit customer's lifestyle or work schedule and energy usage.

With the fast development in computer and communication technologies, we can plan for smart meters to be in every home by 2020 in West Bank.

However, it is still unclear who is going to do that decision; the electric companies or the Palestinian Energy Authority. The Government has to make decision on that and it is possible that the mass roll-out of smart meters may begin by 2014.

However, in the meantime, JEDCO has announced that it is planning to sign a contract with Smart Meter to offer one of the first plans on the market for smart meter installation in its mandate vicinity.

5.2.2 Demand-side Management for Peak Control

Most of electric power consumed in the West Bank and Gaza is purchased from Israel. The electricity system in the West Bank consists of numerous isolated distribution systems owned and operated by municipalities and village councils, and it has no significant generation or transmission capacity. Each municipality or council has singed a Purchase Agreement with the Israeli Electric Company (IEC) to regulate supply conditions of power to that local grid. In addition to technical requirements, these agreements include:

1- Flat rate tariff of electricity which is much higher than in Israel
2- The upper Limit for Peak demand of electricity for the city or village
3- Penalties for Power factor violations

As Palestinian customers are considered of least priority for IEC, and according to the purchase agreements, IEC shuts down power supply to any Palestinian city or village if demand exceeds the specified peak limit specified to the distributor. This resulted in a large number of hours of blackouts in many cities and villages in the West Bank at peak days, mainly in summers in the last decade. For example, in summer of 2008, Tulkarm city had more than 300 hours of blackouts mainly at noon times. The city municipality was forced to pay hundreds of thousands of dollars to purchase extra capacity from IEC. With the exponential increase in number of installed air conditioning units (A/C units), the new specified peak is expected to be exceeded this year and following years. In this research, we have proposed a solution for the problem for Palestinians customers of using smart grid technology. While it is very difficult to install a special communication network for the smart grid, we propose to use the wide spread ADSL internet as a communication tool for this purpose. According to Patel (the Palestinian telecommunication company) there are more than 96,000 residential and commercial ADSL customers in the West Bank. Also, according to our survey, most of those customers have installed air conditioning units at their offices or homes where ADSL is available. In addition to that, around 67% of power customers are using prepaid digital power meters.

1. The proposed smart system

The proposed smart system has the following components:

1- Central computer (server of power distributor) which is used to monitor continuously the total demand of power distributor, to communicate with remote load units and to carry out the energy management software applications. This is connected to the main digital meter from one side and to the ADSL internet from the other side.

2- ADSL internet, which is the backbone communication tool for this system. ADSL is wide spread in the West Bank with more than 96,000 subscribers in the residential and commercial sectors.

3- Embedded Control Unit (ECU) which is installed at the end user side. This locally designed unit is connected to the digital meter, the Internet modem and to the A/C unit to be controlled. The following Fig. (5.3) shows a simplified schemes of the proposed system.

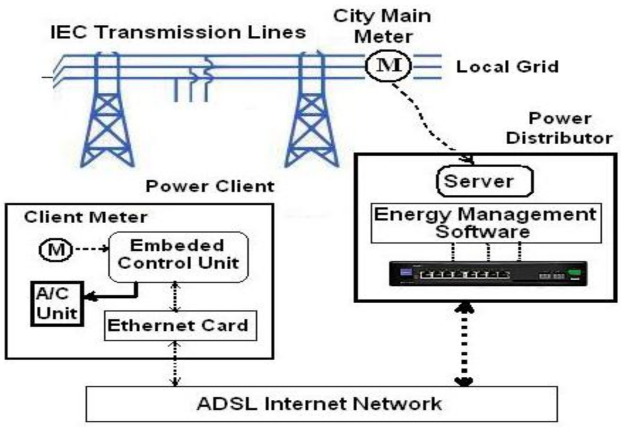


Figure 5.3: Simplified scheme of the proposed system

Figure (5.3) illustrates the scheme of the proposed system. The needed number of customers to be connected to this system will be decided according to maximum power to be shed. If the customers are grouped into ten groups, then each group will include N customers according to following equation:

$$N = \frac{\text{Maximum Load to be shed (KW)}}{(\text{Average consumption of (A/C's) of customer (KW)}) * 10} \quad \text{.....(1)}$$

In such case, the customers with large A/C units and connected to the Internet will be selected. According to our survey, almost all of the investigated customers have no objections for this proposal. They think that they prefer few minutes per hour without air conditioning over complete blackouts for few hours.

2. Required communication technology

The system consists of a centralized server and a set of remote and distributed objects (clients) that communicate directly to each other via Internet. The middleware provides a uniform, generic and fully specified application protocol. TCP/IP protocol has been selected for its wide applications and simplicity for transmitting data and control codes. The main server which is owned by the power distributor has a fixed IP address which will be used by all remote units for sending data to the server or to receive control codes from it.

At the client side, an Embedded Control Unit (ECU) must be linked to the digital meter via an interface. A built-in Ethernet network interface can be used to connect the ECU to the internet modem of the client. Triacs or relays can be used to control customers loads (in this case the Air Conditioning units). The server of the power distributor sends a request signal to each ECU when consumption level is reaching a critical level close to specified peak limit of the distributer. To guarantee continuity of communication, each remote unit addresses the central server several times a day, and makes registration that includes a username and a password.

This is essential to ensure that remote units are ready for data communication and to provide their IP addresses the many not be fixed and may change frequently.

3. System Operation

This system will operate at times of risk of Peak limit violation. The computerized central unit will keep monitoring the overall power consumption of the utility. If this consumption is rising up and there is a possibility of exceeding the peak limit then it will activate the energy management tool. The operation of this application will be discussed here for one isolated grid in the West Bank which is the Grid of Tulkarm city. Tulkarm city is connected to IEC and the peak limit was sit at 17 MW. Recently (in 2012) this was raised to 22 MW. In summer, and due to the sharp increase in number of Air conditioning units installed in the city, peak limit has been violated several times, which resulted in power interruption frequently in summer months.

Daily Load Curves

The possible application of the proposed system for solving Peak blackouts was studied and simulated for the special case of Tulkarm city. The data for hourly consumption have been collected from different sources including Municipality of Tulkarm; the electric distributor, Palestinian Energy Authority and research studies. Fig. (5.4) shows a typical load curve for the city in a typical day in winter. Note that the peak demand of the city in winter is far below the Peak Limit as specified by IEC. It is very rare that this limit is exceeded as Tulkarm area is relatively warm in winter. Figure 5.5 shows a sample of the load curve in a hot day in summer. It is clear that the Peak Limit restriction has been violated between 10:00 am and 2:00 pm. In most cases this will result in a harsh penalty by IEC by cutting off power supply to the city for many hours as estimated by IEC. It is our estimation that the load may exceed the peak limit by less than 3 MW only, but this is a justified reason for IEC; which suffers power shortage in summer, to cut off power for local Palestinian power distributors.

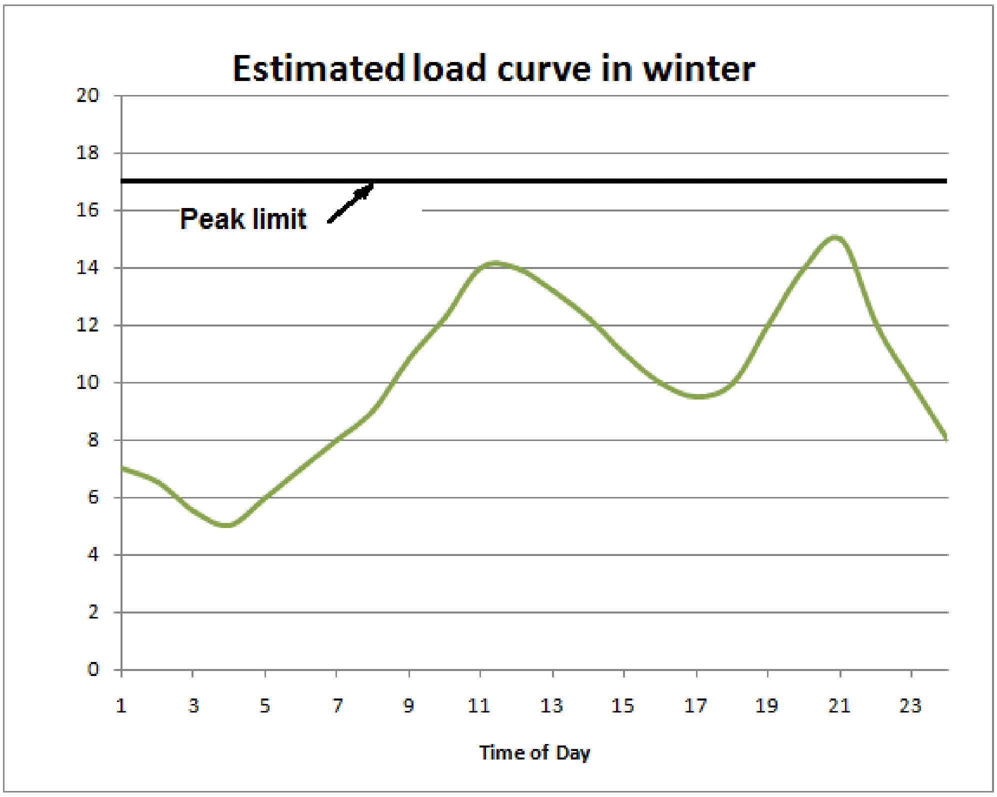


Figure 5.4: Estimated load curve for Tulkarm in a typical day in winter

1. In order to estimate the daily load curve in summer without including Air Conditioning consumption, the following method was used: By selecting 20 residential and commercial customers and comparing their power consumption at different times with air conditioning units turned (On and Off).
2. The hourly demands for those units were estimated by multiplying the total load capacity of all A/C units connected to one substation with the hourly Load Factors for monitored air conditioning units (two units in this case) at the same time in the same area.

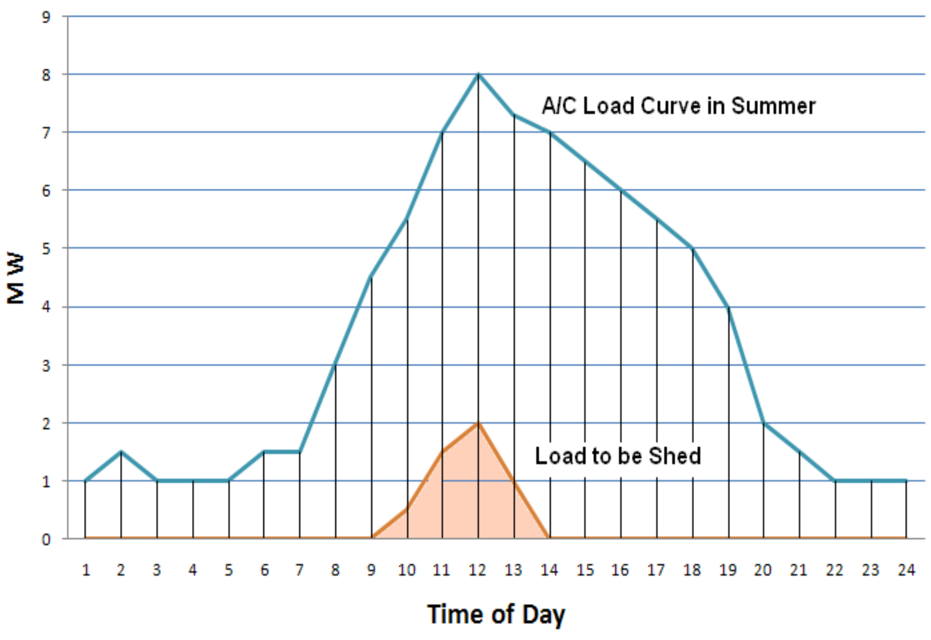


Figure 5.5: Load curve for Tulkarm in summer

From figure (5.6) and according to equation (1) the total number of customers may not exceed 2000. This is due to the fact that the load to be shed is always less than 3 MW, which is much less than the estimated load of air conditioners in the city. Average load of A/C units per customer was estimated at 1.5 KW.

From the curve, it is clear that power consumption of air conditioning units increases total demand by more than 50% at noon hours, which is the main reason for exceeding the peak limit and the cause for power blackouts at hot days. It is important to note that most of electric power is consumed in the residential and commercial sectors at day time.

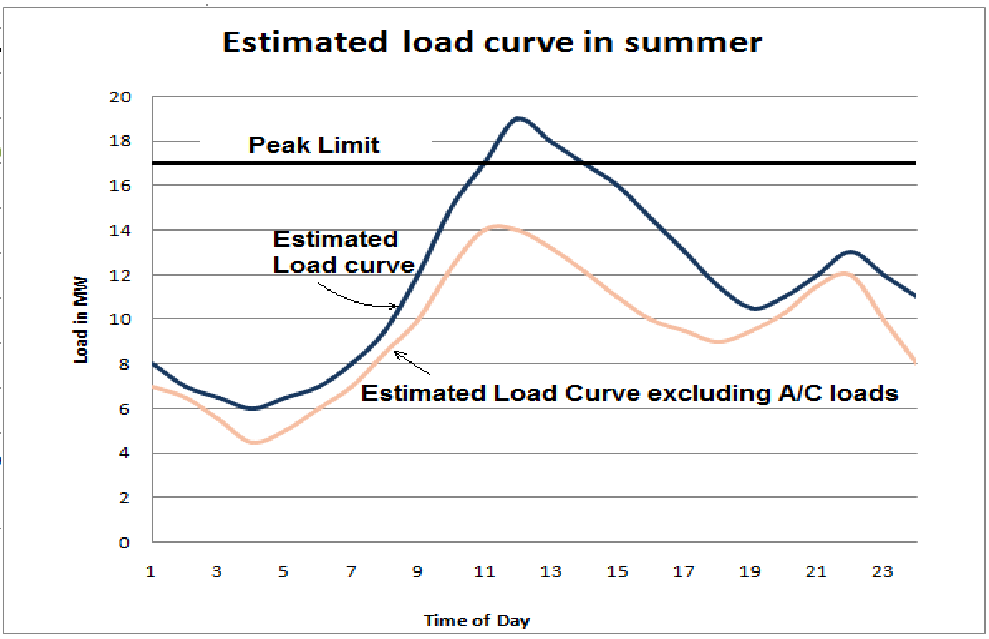


Figure 5.6: Load curves of A/C units in a hot summer day in Tulkarm

Demand Side Management

In order to avoid blackouts, it is necessary to reduce total consumption of power distributor to be below the peak limit. This can be achieved by forcing some of those A/C units to turn off for limited periods of time. This procedure will be circulated among the groups of customers for the expected period of peak violation. With continuous monitoring of total consumption of the power distributor, the Energy Management software will be able to estimate the number of units to be turned off and the period for that. All of this will be done by the main server of the power distributor. The need for short term load forecasting is not important. All decisions can be made instantaneously based on real data collected from main meter of the distributor. The energy management will be activated whenever the total demand is approaching the specified peak limit. Also, the impact of demand side management on total demand can be seen immediately. Increasing or decreasing the number of controlled units and the periods of time is decided according to this impact.

Impact of DSM on Load Curve

Based on summer load curve for Tulkarm city, load shed for a period ranges between 5 and 10 minutes were simulated according to the following procedure:

- DSM will be activated when load demand exceeds 16.5 MW.
- Customers are grouped into 10 groups according to their number (using last digit of unit number from 0 to 9). Each group consists of around 200 customers with total A/C load around 300 KW.
-

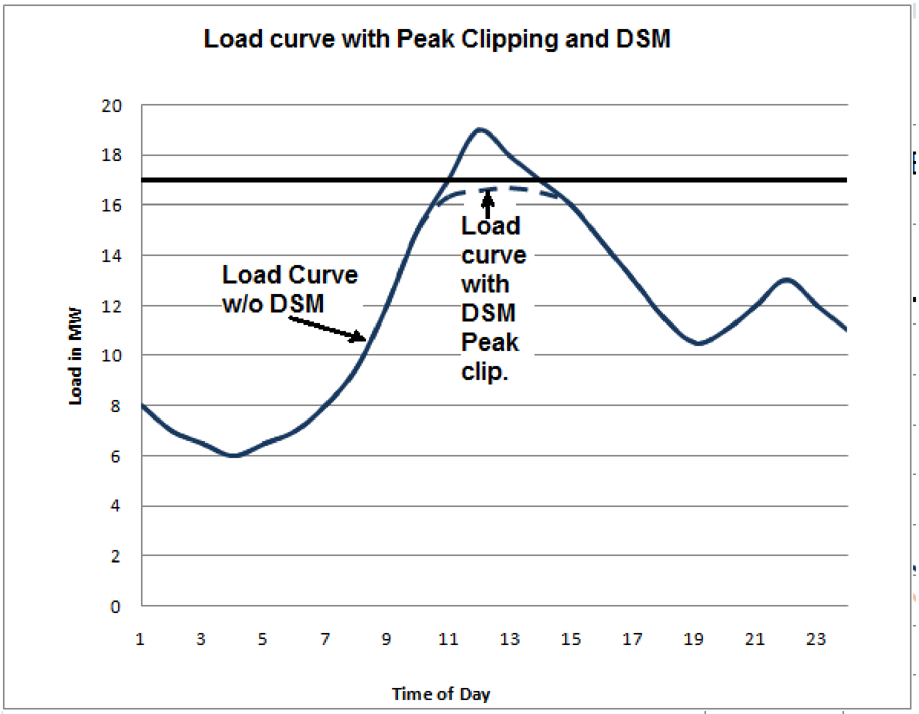


Figure 5.7: Impact of demand side management on load curve.

Load shed will be circulated among all groups for 6 minutes period for each group (10% of all customers).

- When measured load is higher than 16.75MW, the number of controlled groups will be increased by one. In other words; another 10% of the customers will be included to controlled groups.
- When the measured load goes below 16.5, number of controlled groups will be reduced by one.
- When number of controlled groups becomes zero, then DSM is completed and stopped.

The impact of this procedure on load curve is illustrated in Figure 5.7.

Reliability and Security

The communicating devices in the system rely on the communication backbone in their respective domains to send and receive data and control codes to maintain system stability. The ADSL internet reliability is affected by a number of possible failures. These failures include time-out failures, network failures, and resource failures. The ECU repeats data sending if there is no acknowledgment signal is received from main server for more than 30 seconds. To prevent long term shut off of A/C units, the ECU turns the controlled A/C unit ON automatically after 10 minutes if data communication with server is halted for any reason.

Security of information is guaranteed by data coding and log-in procedure for each remote unit. In this case, security level has been improved by authorized access to the real time data and control functions, and use of encryption algorithms to prevent spoofing.

5.2.3 Integration with Distributed Generation and Renewable Sources

So far, all electric power fed to the local grids come from one source which is the IEC. However, the only possible local generation that is easing in the horizon is the Photovoltaic systems. The “new Palestinian Solar Initiative” (PSI) was implemented in summer 2012. The PSI sets a goal in which 10% of electricity in the Palestinian territories is going to be generated through renewable sources by the year 2020. According to the Dr. Kittaneh, Minister of the Palestinian Energy Authority, the technology for solar energy generation was ready and the allocation of incentives for private sector investment in renewable energy has been approved by the Palestinian Authority. The project will include the installation of hundreds of on-grid Photovoltaic Panels, several Wind system, supply of concentrated solar readers to produce and update the Palestinian solar ATLAS necessary for designing and planning new project activities for potential and future investments. The project will also contribute to raising awareness, mobilizing resources and enforcing the Palestinian Authority's efforts towards achieving clean and secure energy.

The initiative's target is to achieve 5 MW of solar renewable energy up to the year 2015 through installing PV panels at the rooftops of Palestinian households all over the West Bank. The plan of the implementation of the initiative is illustrated in Table (5.1) From this table, we can conclude that by the year 2020 around 20 MW of electric power will be generated by small PV panels located at rooftops of houses. One third of this (around 7.5 MW) will be generated in Northern West Bank [39]. So, we can conclude that at least 2MW of this generation will be located in Tulkarm. This amount of generation may help in solving some of the grid problems; mainly in summer, such as Peak Limit violation.

Table 5.1 Plan for implementing 'Palestinian Solar Initiative'.

RE Technology	2015 Capacity (MW)	2020 Capacity (MW)
On ground PV	5	25
PV small	5	20
CSP	5	20
Biogas landfill	6	18
Biogas animal	0.5	3
Small-scale wind	1	4
Wind mills	2.5	40
Total (MW)	**25**	**130**

Palestinian Solar Initiative Plan

Location	Installed Capacity (MW)
Northern West Bank	1.5
Central West Bank	2.0
Southern West Bank	1.5
Total (MW)	5

5.3 Smart Grid and the "Palestinian Solar Initiative"

The integration of renewable sources to the Smart Grid requires efficient storage system. The direct power injection of PV or Wind generation electricity may be useful in certain times but this case may not be the case for all times. It is important to use the generated power at the daily peak to reduce cost and to prevent power failure or blackouts. This is illustrated in figure 5.8.

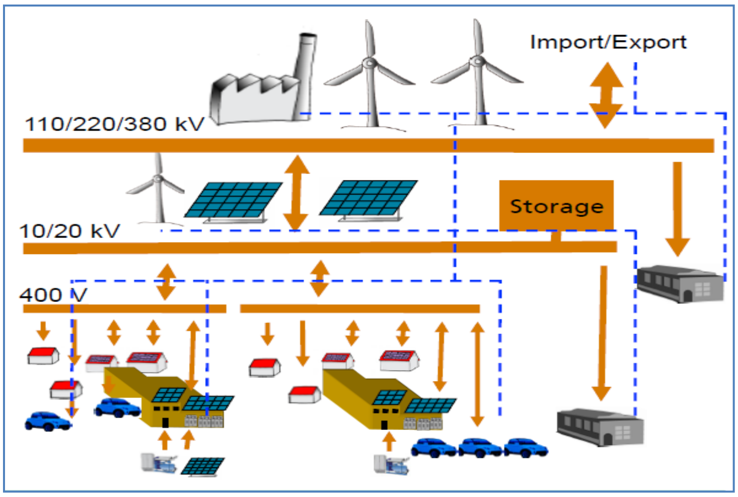


Figure 5.8 :Smart Grid integration with PV and Wind sources

The selection of inverters is crucial and they have to be smart as they:

- monitor the PV array, track the maximum power and operate at that point,
- sense the presence of the grid, synchronize to and inject a current in phase with the voltage,
- monitor the grid and disconnect in case of trouble (e.g., swings in voltage or frequency). The following Fig. (5.9) shows the Smart Grid Tied PV Inverters.

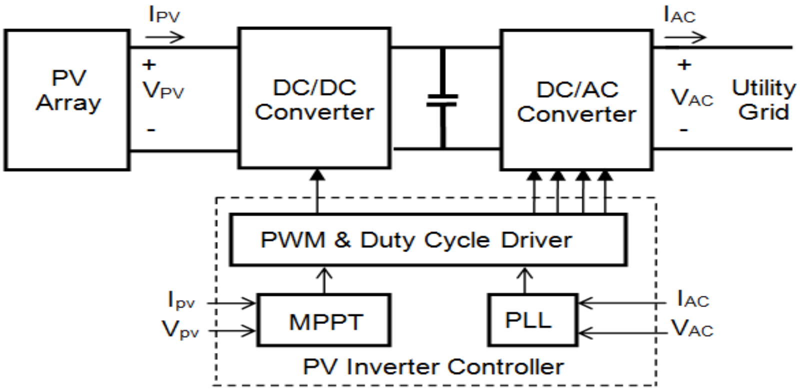


Figure 5.9: Smart Grid-Tied PV Inverters

5.3.1 Weather impact on PV output

Cloud coverage has great impact on PV output, and PV power output variability follows solar irradiance variability. Dramatic variations in power swings can occur during partly cloudy conditions, and there is a growing concern about the effects this may have on the normal operation of the utility grid. Some industry professionals believe that this issue could limit the penetration of grid-connected PV. Figure (5.10) shows that PV output follows solar irradiance on horizontal plane.

Smart Grid will offer a solution for this problem of fluctuation in the following steps:

1- In case of sunny days and lack of peak problems, normal operation of inverter is possible and electricity will be injected to the grid.

2- In cloudy days with variation in output power of PV system, all generated power will be stored in batteries or any other storage system.

3- At times of peak demand, the stored energy will be transferred to the inverter and then injected to the grid.

Smart meters will be used to monitor energy flow from the PV system or storage system to the Grid.

Finally, the framework of the planned PV systems in the West Bank can be summerized in Figure 5.10 shown bellow.

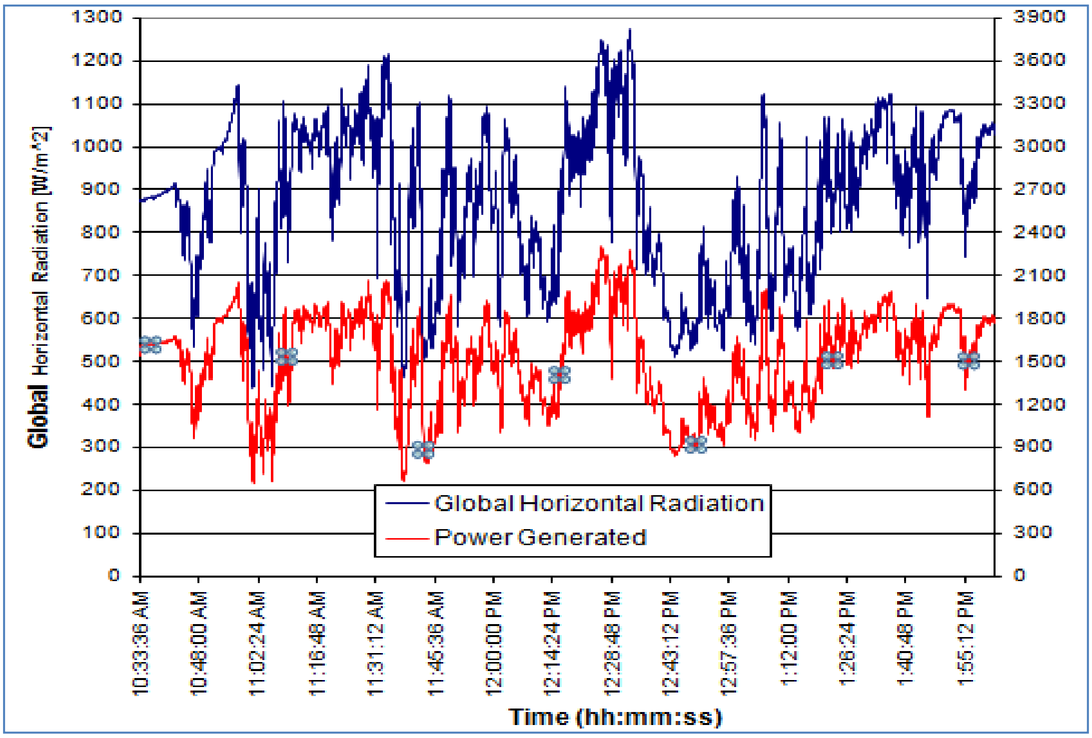


Figure 5.10: Sample output of PV output in a cloudy day

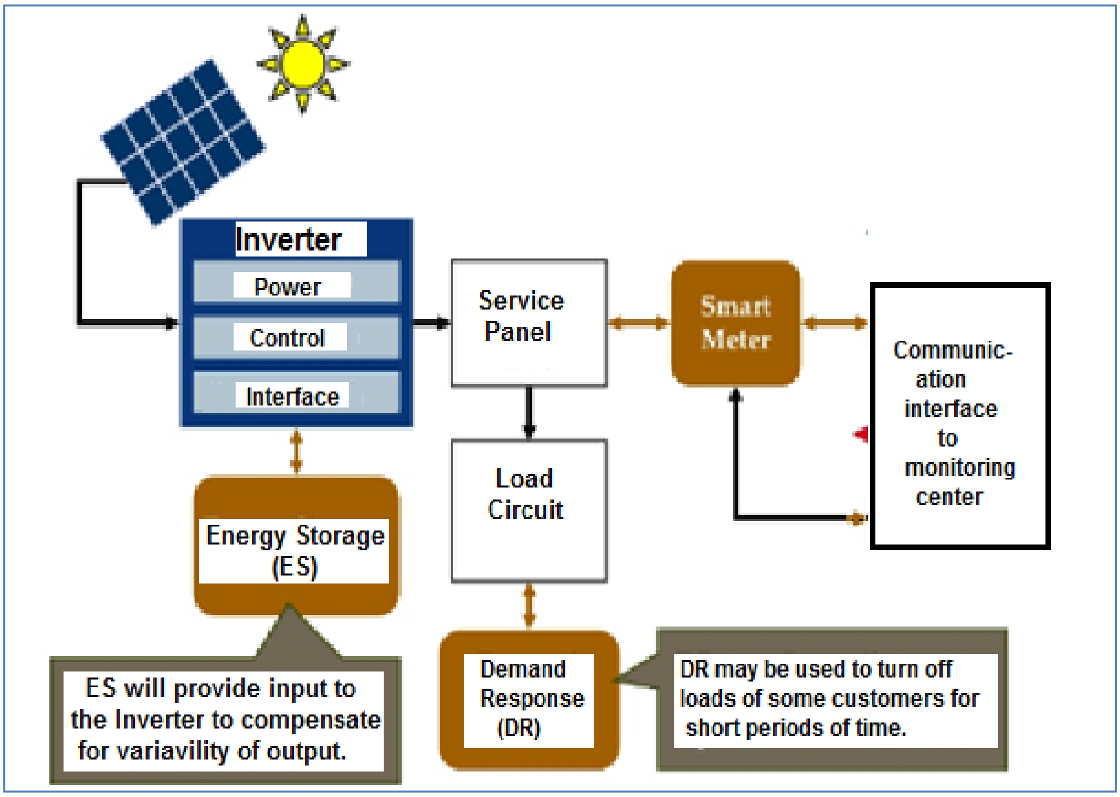


Figure 5.11: Framework of the PV-system and Smart Grid in West Bank.

Chapter 6

Result Analysis, Conclusions and Recommendations

1. Results analysis

In this study we investigated the new technology of Smart Grids, their requirements, potential applications and impact of electric utilities and their services. From this study we found that the main requirement of any Smart Grid is the availability of efficient and cost effective communication tool. In general, the electric utility may have its own communication system or may use any available commercial service provider. Planning for any Smart Grid in Palestine or any other country will be based on the expert decision about the communication tool, its reliability, availability and security.

Also, we found that investing in Smart Grids will have positive economical and environmental impacts. The implementation on Smart Metering will enable the electric utilities to do the followings:

- Reading data regarding instantaneous power consumption and total monthly energy consumption in very short periods of times (seconds or minutes).
- Reading can be done remotely without the need for employers to go to customer's homes and offices.
- Monitoring of customer consumption will help electric utilities to reduce black losses.

Displays at customer side will provide him with valuable information that will help in any activity for employing demand side management for reducing customer's consumption or to avoid utilities peak.

However, for planning to Smart Metering it is important to take into consideration the required investment needed to purchase hundreds of thousands of smart meter units. Also, the investment in the centralized monitoring unit must be considered.

For the case of Demand-Side Management we found that there is a potential application for this tool in Palestine. The Palestinian utilities as power distribution cooperatives are facing several problems due to the regulations and restrictions of the main supplier of electricity; the IEC. In this study we have proposed a system that can convert any isolated power grid in West Bank into a smart grid using wide-spread ADSL or BSA internet as a communication tool. Also, an embedded control unit with an interface can convert a regular digital meter into a smart meter which is capable of transferring metering data to the central monitoring unit of the main supplier. Demand Side Management protocols such as peak clipping can be implemented in this system using control capabilities of the control unit. Reliability of system depends mainly on reliability and security of the Internet in the grid vicinity. Finally, simulation results show that such system can provide a smart solution to the power blackouts at Peak Hours through the implementation of demand side management scenarios designed for this purpose.

For the third application; which is the integration with distributed power generators, we found that PV solar units can be considered for such application. Palestine is one of places that it is recognized of high solar radiation. The results of this research show that the solar energy can serve the residential building consumption of electricity. In fine, the area occupied by solar panels, the solar energy conversion efficiency, and the angle of inclination are important parameters in combining solar energy concept in the design of smart building, and that is an important step in the integration with the Smart Grid.

6.2 Conclusions

From the previous discussions and analysis we can conclude the followings: Smart Grid technology can be achieved in Palestine if done with thorough investigation and strategic planning. It is impractical in not economical of establishing a private communications system for the electric utilities for the proposed Smart Grid.

Available communication systems provided by commercial service providers, such as Internet HAN and SIM mobile systems may be sufficient for the requirements of the proposed applications of Smart Grid in Palestine, the most potential applications of Smart Grids in Palestine are: Smart Metering, Demand-Side Management and load control Integration of distributed sources, and in specific Solar PV systems. PV and other Renewables will have a significant share of our future energy system. With intelligent integration of these systems in the electric utility using Smart Grids and storage, is possible to provide practical solution to major problems such as Peak Limit violations. With the “Palestinian Solar Initiative”, it is the right time to think about integration and how to allocate storage capacities. Also electric and thermal coupled process can be used for storage. On local level grid restrictions can be guaranteed also by Smart Grid methods and not only grid extensions. Smart Grid methods have various advantages and drawbacks

6.3 Recommendations

According to the findings of this study, the researcher believes that more work has to be done on the planning and technical levels. The following recommendations are suggested for future work to be done by electric utilities, decision makers and researchers:

Selection of one application to be a pilot project, and this project must have full technical, economical and environmental analysis.

The utilities must allocate special fund for the future implementation of Smart Grid applications. If funds are available from other sources such as donors or government, then it is the duty of electric companies to prepare practical proposals to get such funds.

Further studies have to be done by other graduate students about feasibility of other applications in Palestine as new technologies are emerging locally and worldwide such as electric vehicles.

The integration of the approved “Palestinian Solar Initiative” for installing hundreds of photovoltaic panels at rooftops of household customers with Smart Grid is very vital and it has to be done without delay at this planning level.

References

1- Kandel .A. and D. Metz, **The Effects of Daylight Saving Time on California Electricity Use**, California Energy Commission, (2001).

2- Kandel,A, **Electricity Savings from Early Daylight Saving Time**, California Energy Commission, 2001.

3- Shariah,A. Al-Akhras, M. A. and Al-Omari, I. A. **Optimizing the Tilt Angle of Solar Collectors**, ***Renewable Energy***, Vol. 26, No. 4, 2002, pp. 587-598. doi:10.1016/S0960-1481(01)00106-9.

4- Abu Alkhair, Ayman, **The Current Status of Energy Sector In Palestine With Aspicial Focus On the Electricity Sector**, Palestine, 2006.

5- Argonne National Laboratory U.S, **Fact Sheet Smart Grid**, Mar, 2010.

6- Liu, B. Y. H. and Jordan,R. C. **The Interrelationship and Characteristic Distribution of Direct, Diffuse and Total Solar Radiation**,” ***Solar Energy***, Vol. 4, No. 3, 1960, pp. 1-19. doi:10.1016/0038-092X(60)90062-1.

7- Baba, Mutasim Fuad. **Smart Grid with ADSL connection For Solving Peak Black** outs In The West Bank. Building Engineering Department, An-Najah University, Proceeding of REVET confecence – Thuisia ,2013, Nablus-Palestine.

8- Clark W. Gellings, John H. Chamberlin, "***Demand Side Management – Concepts and Methods***", The Fairmont Press/Presentice Hall, USA 1993.

9- Li. D. H. W. and Lam, J. C. **An Analysis of Climatic Variables and Design Implications**, ***Architectural Science Review***, Vol. 42, No. 1, 1999, pp. 15-25. doi:10.1080/00038628.1999.9696844.

10- Bernardon,D. P. Garcia,V. J. Ferreira,A. S. and Canha,L. N. "**Multicriteria Distribution Network Reconfiguration Considering Subtransmission Analysis**," *IEEE Transactions on Power Delivery*, vol. 25, no. 4, pp. 2684–2691, October 2010.

11- Villa,D. Martin,C. Villanueva,F. J. Moya, F. and Lopez,J. C. "**A Dynamically Reconfigurable Architecture for Smart Grids**", *IEEE Transactions on Consumer Electronics*, - volume 57 – pp 411-419 - May 2011

12- Dajani, Wafa, **The West Bank Muncipal Electricity Operation**, Ramallah, August 28, 2008.

13- Saraf, G. R. and Hamad,F. A. W. **Optimum Tilt Angle for a Flat Plate Solar Collector**, ***Energy Conversion and Management***, Vol. 28, No. 2, 1988, pp. 185-191. doi:10.1016/0196-8904(88)90044-1.

14- Gunerhan, H. and A. Hepbasli, **Determination of the Optimum Tilt Angle of Solar Collectors for Building Applications, *Building and Environment***, Vol. 42, No. 2, 2007, pp. 779-783. doi:10.1016/j.buildenv.2005.09.012 .

15- Singh .H. N and Tiwari,G. N. **Evaluation of Cloudiness, Haziness Factor for Composite Climate**, ***Energy***, Vol. 30, No. 9, 2005, pp. 1589-1601. doi:10.1016/j.energy.2004.04.036 .

16- Department of the Environment, **Heritage & The Arts**, Australian Government, 2010.

17- Israel Electricity Authority, ***Electricity Report*** 2010.

18- Jarras,J. **Feasibility of a Fund for Financing Solar Water Heaters and Projects Related to the Promotion of Renewable Energies in Palestine,** ***MEMR Press***, Amman, 1987.

19- Gopinathan,K. K. **Solar Radiation on Variously Oriented Sloping Surfaces,** ***Solar Energy***, Vol. 47, No. 3, 1991, pp. 173-179. doi:10.1016/0038-092X(91)90076-9.

20- Lafi Said, Niddal, **Electrical Energy Planning For The West Bank Under Uncertainties**, Master Thesis, An-Najah National University, Nablus, 1999.

21- Yakup, M. Ab. H. M. and Malik,A. Q. **Optimum Tilt Angle and Orientation for Solar Collector in Brunei Darussalam,** ***Renewable Energy***, Vol. 24, No. 2, 2001, pp. 223-234. doi:10.1016/S0960-1481(00)00168-3.

22- Collares-Pereira, M. and Rabl,A. **The Average Distribution of Solar Radiation Correlation between Diffuse and Hemispherical and between Daily and Hourly Isolation Values,** ***Solar Energy***, Vol. 22, No. 2, 1979, pp. 155-164. doi:10.1016/0038-092X(79)90100-2.

23- Pipattanasomporn,M. Feroze,H. and Rahman,S. “**Multi-agent systems in a distributed smart grid: Design and implementation**” *in 2009IEEE/PES Power Systems Conference and Exposition.* IEEE, 2009

24- Marc Goldsmith &Associates LLC, Marc W. Goldsmith, Kenneth Horne, Jason Hanna, Rich Simons, Karen Hamilton, **Smart Grid Technology Options**, Feb 1, 2010, public May 21, 2010.

25- Meteorological Department, **Climate Division**, Palestine Climatic Data, 2007.

26- Ministry of Energy and Mineral Resources MEMR, **Analytical Study Report, Palestine**, 1996.

27- Nijegorodov,N. Devan,K. R. S. Jain, P. K. and Carlsson,S. **Atmospheric Transmittance Models and an Ana- lytical Method to Predict the Optimum Slope of an Absorber Plate, Variously Orientated at Any Latitude,** ***Re- newable Energy***, Vol. 4, No. 5, 1994, pp. 529-543.

28- National Rural Electric Cooperative Association, **Comments – Request for Information on Smart Grid Communications Requirements**, 15 (July 12, 2010).

29- Palestine News and Info, **reports about PALTEL and internet in Palestine**, http://www.wafainfo.ps/atemplate.aspx?id=2788

30- **Palestinian** Central **Bureau of Statistics**, "**Survey on energy in households**", report in Arabic 2007.

31- Palestinian Energy and Natural Resources Authority, "**Palestinian Solar Initiative**", Project documents, prepared by PwC, 31/1/2012.

32- Palestinian Energy Authority, PEA, ***Internal Report***, 2002.

33- Akella,R. Meng,F. Ditch,D. McMillin,B. and Crow,M. "**Distributed Power Balancing for the FREEDM System", *Smart Grid Communications (SmartGridComm)***, *2010 First IEEE International Conference on*, pp. 7–12, October 2010.

34- Hassan, R. and Radman,G. "**Survey on Smart Grid**," in Proceedings of the IEEE SoutheastCon 2010 (SoutheastCon). IEEE, 2010.

35- Soulayman,S. Sh. **On the Optimum Tilt of Solar Absorber Plates, *Renewable Energy***, Vol. 1, No. 3-4, 1991, pp. 551-554. doi:10.1016/0960-1481(91)90070-6 .

36- Y. Goldreich **The climate of Israel: observation, research and applications** Springer 2003.

37- USA Department of Energy , **Communications Requirements of Smart Grid Technologies**, report prepared by doe, October, 2010.

38- **West Bank and Gaza Energy Sector Review**, World Bank report, Report No. 39695-GZ. May, 2007.

39- World Bank, Final Report, **Palestine Electric Utility Management Project (EUMP)**, February, 2008.

40- Shimoda, Asahi,Y. T. Taniguchi A. and Mizuno,M. **Evaluation of City-Scale Impact of Residential Energy Conservation Measures**

Using the Detailed End-Use Simulation Model, Energy, Vol. 32, No. 9, 2007, pp. 1617-1633. doi:10.1016/j.energy.2007.01.007.

Internet Website

1- Wireless Communications for the Smart Grid," NIST Smart Grid Collaboratio Site, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP02Wireless.

2- United Telecom Council, Hurricanes of 2005: Performance of Gulf Coast Critical Infrastructure Communications Networks, 2, 24 (Nov. 2006), available at: http://www.utc.org/fileshare/files/34/Research/white_papers/2005__UTC_HURRICANES_OF_2005_PERFORMANCE_OF_GULF_COAST_CIC_NE.

3- Wikipedia. Daylight Saving Time, 2012. http://en.wikipedia.org/wiki/Daylight_saving_time.

Appendix

Appendix(1)

Total Retait KW	
Month & Year	
1-1-2012	6,431,705
1-2-2012	6,502,846
1-3-2012	5,961,159
1-4-2012	5,998,961
1-5-2012	6,726,685
1-6-2012	7,078,944
1-7-2012	8,364,674
1-8-2012	8,931,708
1-9-2012	8,468,968
1-10-2012	7,542,044
1-11-2012	6,852,292
1-12-2012	6,864,484
Total Monthly Consumption = 85,724,470 KW	

Source: (Tulkarem Municipality), 2012).

جامعة النجاح الوطنية

كلية الدراسات العليا

التخطيط لشبكة الكهرباء الذكية في فلسطين

إعداد

غدير أحمد عبد الكريم عبده

إشراف

الدكتور معتصم بعباع

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة التخطيط الحضري والإقليمي من كلية الدراسات العليا في جامعة النجاح الوطنية، نابلس – فلسطين.

2013 م

التخطيط لشبكة الكهرباء الذكية في فلسطين

إعداد

غدير أحمد عبد الكريم عبده

إشراف

الدكتور معتصم بعباع

الملخص

مع التطور التكنولوجي الكبير الذي شهده قطاع الحواسيب والاتصالات بالفترة القصيرة السابقة، ظهرت تطبيقات مختلفة جديدة في مختلف مناحي الحياة. ومن أبرز هذه الطبيقات تطور ما يعرف بالشبكة الكهربائية الذكية التي أصبحت تسهم في تطوير قطاع الطاقة الكهربائية بشكل كبير. كذلك فقد برز لها العديد من التطبيقات التي تسهم في ترشيد الطاقة وتقليل تكلفة الانتاج، تقليل انبعاث غاز ثاني أكسيد الكربون وتوفير خدمة أفضل للمستهلكين وبجهد أقل. وبالرغم من أن بعض تطبيقات الشبكات الكية قد تتطلب معدات متطورة ومجهود كبير إضافة إلى استثمارات كبيرة، إلا أن بعض التطبيقات أخرى تكون سهلة التنفيذ ولا تحتاج إلى تكلفة عالية أو تعديلات كبيرة على شبكات الكهرباء الموجودة حاليا.

في هذه الرسالة، قامت الباحثة بدراسة النظام الكهربائي القائم حاليا في المناطق الفلسطينية وكذلك علاقته مع شركة الكهرباء الاسرائيلية والتي هي المزود الرئيس للقدرة الكهربائية لكافة شبكات التوزيع المتوفرة، كما أنها قامت بعمل مسح لكافة التطبيقات المعروفة عالميا للشبكات الذكية لمعرفة وتحديد تلك الممكنة منها طبقا لما هو متوفر حاليا، آخذة بعين الاعتبار كافة المعيقات الاقتصادية والسياسية والفنية.

لقد تبين من خلال هذه الدراسة أن أهم التطبيقات الممكنة في فلسطين تشمل كلا من : العدادات الذكية وقراءتها عن بعد دون الحاجة لموظف قراءة العدادات، إدارة وترشيد الطاقة من خلال تقنيات وآليات محددة، وكذلك التكامل مع محطات توليد الطاقة المحلية المتنوع انتشارها خاصة من الخلايا الشمسية وطاقة الرياح.

الخلاصة التي يمكن الوصول اليها من هذا البحث أنه لا بد من التخطيط الدقيق من أجل توفير شبكات ذكية لتتكامل مع كافة الشبكات الكهربائية الموجودة في كافة المناطق الفلسطينية، ويجب أن يتم هذا التخطيط بأسرع وقت ممكن للاستفادة من التقنيات الحديثة المتوفرة خاصة في قطاع الاتصالات، وعملية التخطيط هذه يجب أن تركز على تحديد التطبيقات العملية الممكنة من الناحيتين الفنية والاقتصادية، وإختيار أفضل وسائل الاتصال الممكنة، وأخيرا وليس آخرا العمل على ضرورة توفير التكامل مع محطات الطاقة الشمسية والتي يتم التخطيط لها ضمن مشروع "المبادرة الفلسطينية للطاقة الشمسية".