An-Najah National University
Faculty of Graduate Studies

Energy Conservation and Load Management Analysis in Nablus Electrical Network

By
Basel Moustafa Qasem Abdul-Haq

Supervisor
Dr. Imad H. Ibrik

Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Clean Energy and Conservation Strategy Engineering, Faculty of Graduate Studies, at An-Najah National University, Nablus, Palestine.
2010

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This Thesis was defended successfully on 20/5/2010 and approved by:

Committee Members	**Signature**
1. Dr. Imad Ibrik (Supervisor)	....
2. Dr. Abdel-Karim Daoud (External Examiner)	....
3. Dr. Waleed Al-Kokhon (Internal Examiner)	....

Dedication

To the soul of my father…………………

To my mother, wife, and sons…………..

To my brothers and sister……………….

To my friends and all colleagues……….

To every one works in this field………..

Acknowledgments

I would like to thank Dr. Imad H. Ibrik, the director of the Energy Research Center, the coordinator of this master program and also my supervisor, for his valuable suggestions, assistance, and for his great and continuous effort in helping me at all stages of this study.

My thanks and appreciations go also to the staff of Clean Energy and Conservation Strategy Engineering master program at An-Najah National University.

I also would like to thank my mother, wife, brothers and sister for their encouragement and support.

Finally, my thanks go to the engineers and employers at Nablus municipality in the electricity and water departments, especially Eng. Salam Zagha, director of NEDCO and Eng. Salah Sheikah.

الإقــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Energy Conservation and Load Management Analysis in Nablus Electrical Network

ترشيد الاستهلاك وتحليل إدارة الأحمال لشبكة كهرباء نابلس

اقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وان هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أية درجة علمية أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

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

Student's name:	**اسم الطالب:**
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Abbreviations

BcF	Billion cubic Feet
BG	British Gas Company
CFL	Compact Fluorescent Lamp
GJ	Giga joule
CO2	Carbon Dioxide gas
GPP	Gaza Power Plant
GWh	Gigawatt hour
HEM	High Efficient Motor
HEPCO	Hebron Electric Power Company
HPS	High Pressure Sodium
IEC	Israeli Electric Corporation
IRR	Internal Rate of Return
JD	Jordanian Dinar
JDECO	Jerusalem Distribution Electric Company
KV	Kilovolt
KVA	Kilovolt Ampere
KVAR	Kilovolt Ampere Reactive
KWh	Kilowatt hour
LPG	Liquified Petroleum Gas
LV	Low Voltage
MV	Medium Voltage
MVA	Megavolt Ampere
MW	Megawatt
MWh	Megawatt hour
NEDCO	Northern Electricity Distribution Company
NEMA	National Electrical Manufacturers Association
NIS	New Israeli Shekel
NPV	Net Present Value
O.H	Over Head
PCBS	Palestinian Central Bureau of Statistics
PEA	Palestinian Energy Authority
PETL	Palestine Energy Transmission Company Limited
PT	Palestinian Territories
PV	Photovoltaic
SELCO	Southern Electricity Company
SPBP	Simple Payback Period
SWH	Solar Water Heater
Tep	Ton of equivalent petrol = Toe (Ton of oil equivalent)
TJ	Terra Joule
Toe	Ton of oil equivalent
VSD	Variable Speed Drive
WB	West Bank

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Dr. Imad H. Ibrik

Abstract

The efficient use of electrical energy, energy conservation and electrical load management are not in a better condition in Palestine or in Nablus electrical network. In this thesis we tried through analyzing and evaluation of the energy consumption situation and by performing energy audits for several energy consuming sectors in Nablus electrical network, to prove that there is a good opportunity to save a considerable amount of consumed electrical energy. In addition, this study tries to find solutions to decrease the peak electrical demand of Nablus electrical network as the peak demand of the network is nearly equal to the available maximum capacity of the supply so as not to reach a situation that the electrical supply will be cut on consumers.

It was showed that there is an opportunity to save a considerable amount of electrical energy if energy conservation measures were implemented in water pumping sector, residential sector and street lighting sector. The total savings in electrical energy in all studied sectors in this thesis is around 14,860,269 kWh/year, associated with an investment cost of 15567303 NIS, and SPBP of less than two years.

The study also showed also that by implementing energy conservation measures and applying applicable load management techniques in the studied sectors, the peak demand of Nablus electrical demand can be decreased by 4.7%, and this percentage can be increased by applying a new electrical tariff structure.

Introduction

Energy resources and their availability are extremely significant for every country. Energy is considered to be an important component in the social, industrial, technological, economic, and sustainable development of any country. Among all forms of energy, electrical energy is regarded as high grade energy and has been the major driver for technological and economic development. In all developed countries, extensive programs for energy conservation, efficiency, and load management are planned and implemented for decades, and especially after year 1973. The impact of these programs on energy and demand reduction is tremendous.

Palestine is considered as one of the poorest countries considering the availability of energy resources. Nearly all main energy resources like fossil fuels and electricity are imported from Israel. This makes Israeli control the quantity, price, tariff, condition and form of each source of energy to Palestine.

In such a situation, energy conservation and load management in Palestine are indispensable tools from the economical and political point of view also.

In Nablus electrical network, the electrical energy consumption is in high level, and the peak load has reached the maximum available capacity from the electrical energy supply. And in this context energy conservation and load management are indispensable tools so as not to reach a point (in case of not reaching new power supply contracts) where the power company will be obliged to cut power on consumers with all its bad consequences.

The thesis subject comes to highlight the importance and the need for energy conservation and load management in Nablus electrical network through implementing energy conservation opportunities in residential, water pumping and street lighting sectors. And also investigate the effect of applying applicable load management techniques on Nablus network.

The main idea of this study is to examine the energy conservation and load management opportunities available in Nablus electrical network in Palestine based on energy audits, energy statistics and analysis.

The following are research objectives:

1- Determining the potential of energy saving in Nablus electrical Network.

2- Determining the potential of energy saving in residential, water pumping and street lighting sectors in Nablus electrical network.

3- Determining the potential of load management applicable techniques to lower the peak demand of Nablus electrical demand.

4- Determining the economic evaluation and analysis for those energy conservation and load management opportunities.

5- To find the barriers restricting the implementation of energy conservation and load management measures in Nablus electrical network.

6- Reduction of environmental pollution from energy sources through reducing energy consumption.

The methodologies and procedures used to accomplish research objectives include:

1- Studying theoretical background and literature review on energy efficiency and load management measures and techniques in electrical networks.

2- Data collection from Nablus municipality and other relevant reports concerning energy conservation and load management.

3- Energy analysis, technical audits and measurements were conducted by using the available instruments in Energy Research Center at An-Najah University.

In chapter one of this thesis, energy supply and demand in Palestine (West Bank and Gaza) is presented with emphasis on electrical energy. Data on electrical energy consuming sectors, supply sources and future plans are presented. Problems facing electrical energy sector, and especially in Nablus electrical network are discussed.

In chapter two, load management techniques in general are presented, and those applicable in Nablus electrical network are stated. The energy conservation measures that will be investigated in water pumping sector, residential sector and street lighting sector are presented.

Chapter three presents a general description of Nablus electrical network. Data on connection point capacities, network transformers, distribution networks, energy supplied, number of consumers and energy consumption in each sector is presented.

Chapter four presents energy management in water pumping system. Audits concerning the various energy conservation opportunities in this sector are presented. The opportunities investigated include, motor voltage levels, supply phase unbalance, motor loading, replacing conventional (standard) motors with high efficiency motors, power factor correction, mechanical efficiency of the pump and using variable speed drive (VSD) to control pump operation.

Chapter five presents energy audits in street Lighting sector. Audits concerning the various energy conservation opportunities are presented. These include removing of lamps, replacement of low efficient lamps with high efficient lamps, using better control systems and partial Night Street Lighting.

Chapter six presents energy audits in residential sector. Audits concerning the various energy conservation opportunities are presented.

These include replacing low efficient with high efficient refrigerators, replacing incandescent lamps (tungsten) with CFL lamps in the lighting system and power factor correction in the residential sector.

Chapter seven presents load management analysis in Nablus electrical network. Daily and yearly load curve for the network is drawn. The effect of applicable load management techniques and energy conservation measures the load curve is analyzed. And the new expected load curve is drawn.

Chapter eight presents an economical evaluation of energy management in Nablus electrical network. The economical evaluation for implementing each measure, each sector and all measures in all sectors is presented. The economical evaluation by present worth value (NPV), internal rate of return (IRR) and simple payback period (SPBP) is presented.

General conclusions and recommendations concerning results of this study are introduced and presented at the end of this thesis.

CHAPTER ONE

OVERVIEW OF ENERGY SITUATION IN PALESTINE

CHAPTER ONE
OVERVIEW OF ENERGY SITUATION IN PALESTINE

1.1 Energy Sources in Palestine

Palestine is considered as one of the poorest countries considering the availability of energy resources. Energy sources available are limited to solar energy utilized mainly thermally in heating water, biomass (wood and agricultural waste) for cooking and heating in rural areas. Natural gas has been discovered in December 2000 at Gaza shore by the British Gas Company (BG). BG has signed a 25-year contract to explore for gas and set up a gas network in the Palestinian Authority land [1]. The gas reserves are estimated to be around 1.4TcF[2], while the needs for gas by Gaza power station and other industrial, transport and household consumption was estimated at nearly 14.8BcF by year [3].

All other main resources like fossil fuels, either petroleum products or LPG, and electricity (85.76%) are imported from Israel.

1.2 Energy Consumption in Palestine

1.2.1 General

Energy consumption in Palestine is another aspect of difficult political and economical situation. Total energy consumption in 2008 was 51427.25 TJ [4] .This figure is small compared with energy consumption in the neighboring countries. Fig (1-1) shows total energy consumption in Palestine and neighboring countries [4], [5]. Total energy consumption in

Palestine (total energy requirements) did not exceed 53.86 quadrillion J in 2007, while this figure is 920 quadrillion J (nearly 17 times as much) in Israel.

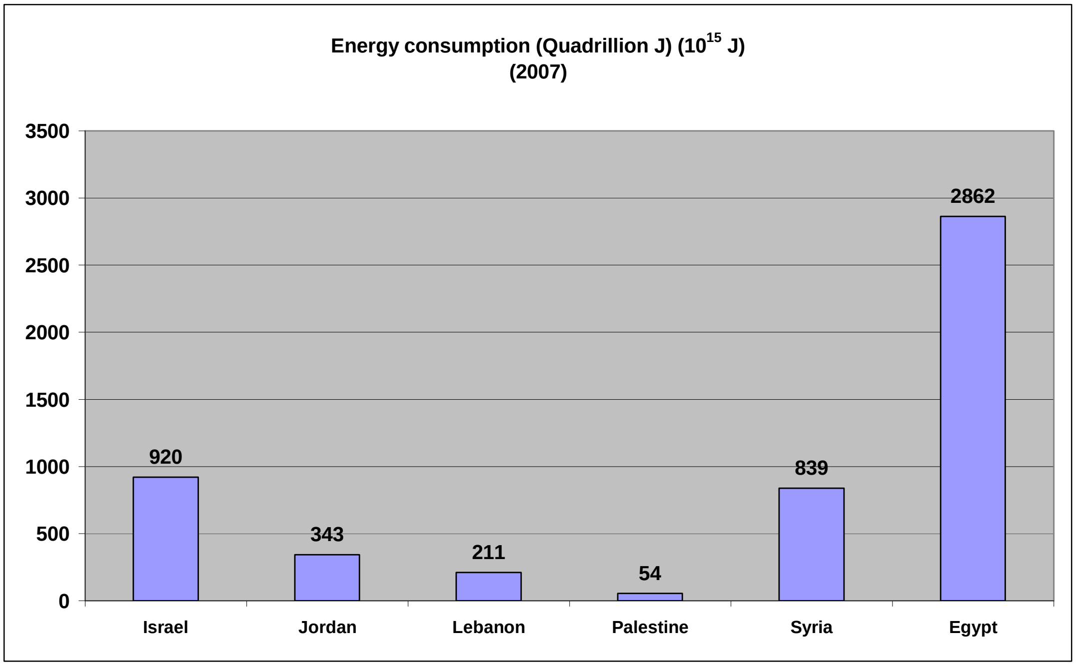

Figure (1.1): Total energy consumption in 2007 [4], [5].

On the other hand, energy consumption in Jordan (with nearly 5.8 million citizens) was 343 quadrillion Joul (6 times superior). Another indication of the energy consumption situation in Palestine is the energy consumption /capita in 2007, Fig (1-2) [5], [4]. It indicates that energy consumption/capita is the smallest in the region which is equal 14.2 GJ, while the neighboring Jordan 57.1 GJ and Israel 131.7 GJ which is 4 and 9.3 times superior respectively.

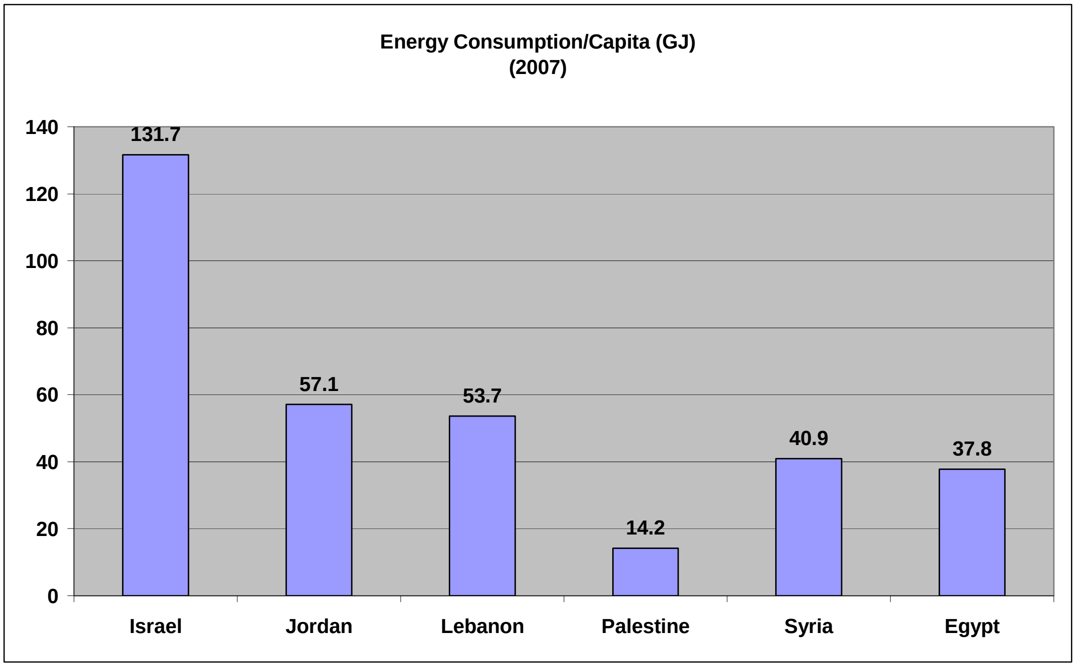

Figure (1.2): Energy consumption/capita in 2007 [5], [4].

1.2.2 Energy consumption in different sectors

Table 1-1 shows the general energy consumption and energy consumption of main sectors in Palestine in years 2001 – 2008.

Table (1.1): Energy consumption in Palestine from 2001- 2008 in (TJ) [4].

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total energy requirements	32115	32864	35886	51191	59375	51638	53863	51427
Primary production	5522	8105	9452	10166	9598	8260	8831	8413
Imports	26626	24773	26389	41032	49777	43362	45021	43147
Final energy consumption	27091	31292	36606	36168	35647	33551	35900	33983
Industry & Construction	2138	2043	2266	3497	2576	2557	1913	1942
Transport	5414	5970	6914	9314	9670	8983	9019	8989
Household & other sector	19539	23279	27426	23357	23401	22011	24968	23052

It includes all forms of energy encountered in economic and daily life in Palestine, which includes solar energy (used mainly in heating water in household), electricity, petroleum products (gasoline, kerosene, and diesel), LPG, olive cake (used for heating and cooking in rural areas), wood and coal. The average yearly growth of total energy requirements between the years 2001- 2008 was nearly 7%. While the average annual growth of the final energy consumption for the same period is about 3.3% (this difference is due to increase of losses estimate and the statistical difference). The percentage of participation of each sector in the final energy consumption is shown in (table 1.2).

Table (1.2): Participation of each sector in final energy consumption [4].

Year	2001	2002	2003	2004	2005	2006	2007	2008
Industry & Construction	7.9%	6.5%	6.2%	9.7%	7.2%	7.6%	5.3%	5.7%
Transport	20.0%	19.1%	18.9%	25.8%	27.1%	26.8%	25.1%	25.1%
Household & other sector	72.1%	74.4%	74.9%	64.6%	65.6%	65.6%	69.5%	67.8%

As obvious the participation of household and other sectors decreased after the year 2003, while the participation of the transport sector increased after that year, which is due to the increase in the economic activity after Intifada.

The breakdown of total final energy consumption in 2008 is shown in fig (1-3).

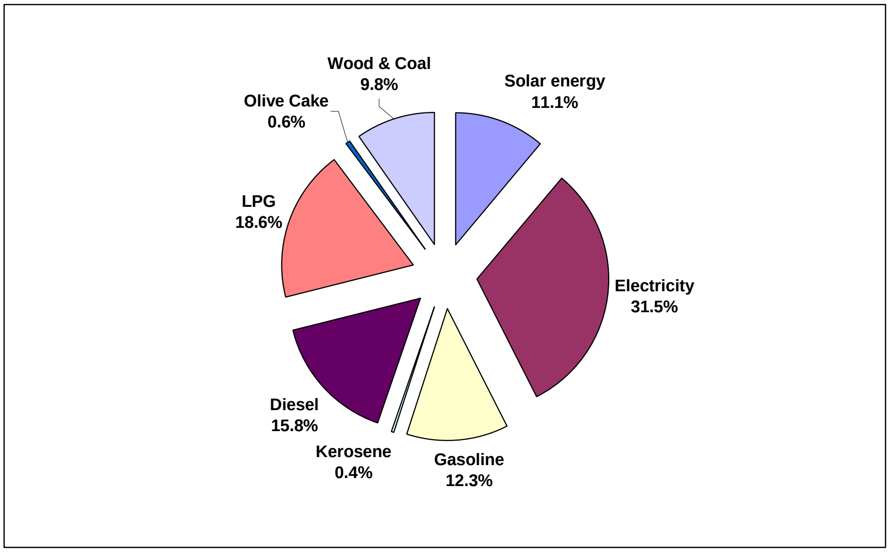

Figure (1.3): Breakdown of total final energy consumption in 2008 by source of energy in Palestine. [4].

It is obvious from figure 1.3 the effect of the high percentage of household and other services in final energy consumption, as this sector accounted for nearly all consumption of solar energy, LPG, olive cake and wood and about 70% of electricity consumption.

The breakdown of household energy consumption in 2008 by source of energy is shown in figure 1.4

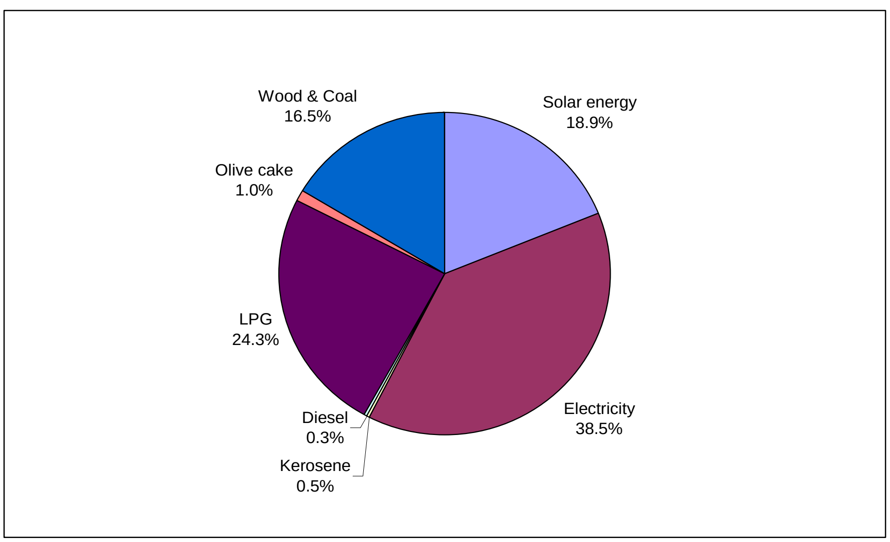

Figure (1.4): Breakdown of total final energy consumption in 2008 by source of energy in Palestine [4].

From figure 1.4, electricity accounts for 38.5% of total household energy consumption in 2008, followed by LPG, 24.3%.

1.3 Electricity situation in Palestine

1.3.1 Electrical energy consumption

Table (1.3) shows electricity imports, total electricity final consumption, and electricity consumption of household and industry & construction sectors in (TJ).

Table (1.3): Total electricity imports and final electricity consumption in (TJ). [4]

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total electrical energy imports	7499	8305	8336	9356	10306	11147	11478	13913
Household Electricity	6073	6317	6562	6803	6685	6585	7455	7875
Industry & Construction	336	523	670	1100	684	733	742	1063
Services electricity consumption	277	203	209	643	633	567	1494	1745
Electricity final consumption	7380	7696	7984	9328	8604	8498	10643	10985
Final energy consumption (include other energy sources)	27091	31292	36606	36168	35647	33551	35900	33983
Electricity final consumption / Final energy consumption	27.2%	24.6%	21.8%	25.8%	24.1%	25.3%	29.6%	32.3%
Household Electricity/ electricity final consumption	82.3%	82.1%	82.2%	72.9%	77.7%	77.5%	70.0%	71.7%

From table 1.3 it is obvious that the electricity accounts for over 25% of total yearly final consumption of energy taking all other sources into account, including cheap solar energy. It is clear also that household is the main consumer of electrical energy with an over of 70% in the minimum case. This explains the steady increase in total energy requirements (7%) in spite of the changing of economical and political situations, as household is less responsive to these changes .This also indicates the necessity of concentration on household in energy conservation programs.

Figure 1.5 shows the variation of electrical energy supplied to Palestine (from IEC, Jordan, Egypt and Gaza power plant) for the years 2001 to 2008 in GWh. The average yearly growth of electrical energy supply is nearly 10.6%, between the years 2001 – 2008.

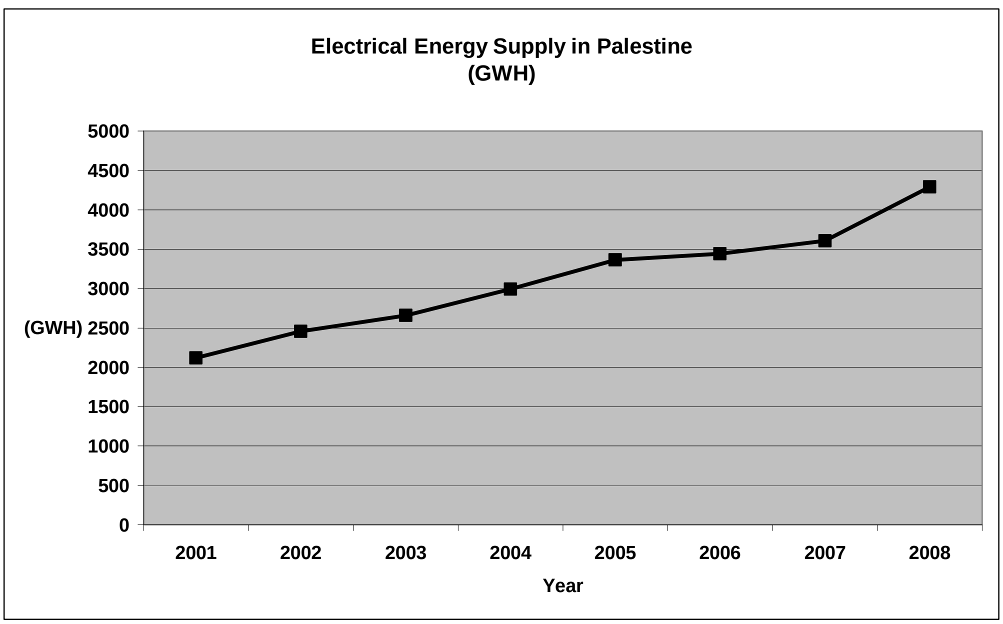

Figure (1.5): Variation of electrical energy supply in Palestine [4].

Another important figure for electrical energy consumption is the electrical energy consumption /capita. Fig (1-6) shows that electricity consumption/ capita is the smallest in the region, were Israel and Jordan

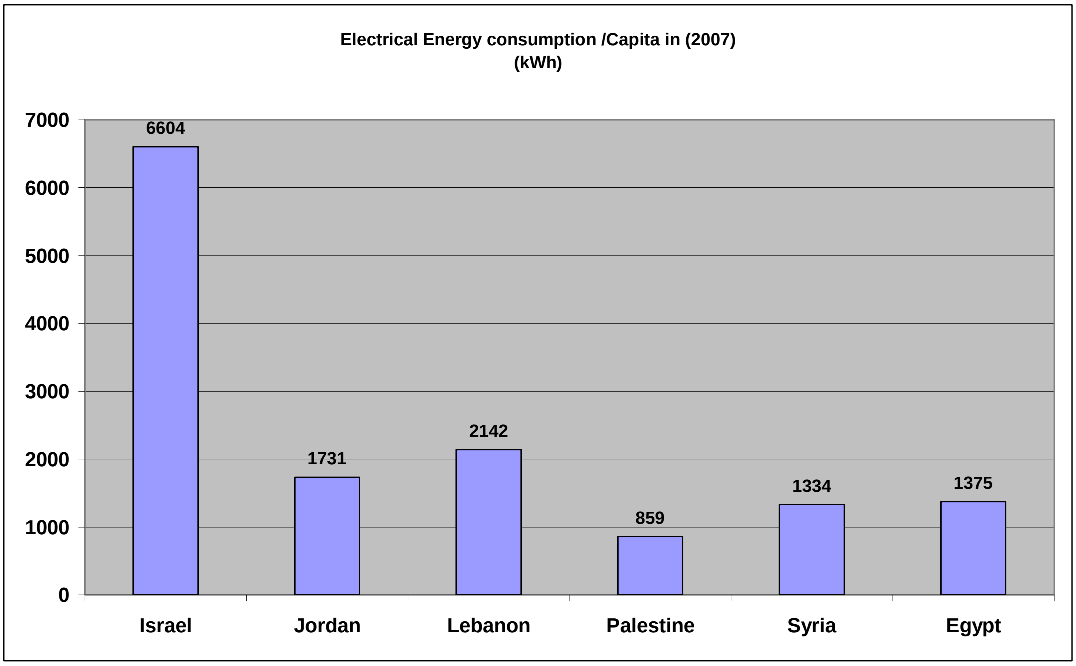

Figure (1.6): Electrical energy consumption/capita in 2007 [6].

are nearly eight and two times superior respectively.

1.3.2 Electricity supply

The national independent power supply is still under construction and rehabilitation. There is limited electrical power generation capacity in Palestine as most of the power is supplied by Israeli electric company (IEC). 85.57% of Electrical energy consumed in 2008 in Palestine was imported from Israel power plants via 22kV and 33kV feeders. Table (1.4) shows electrical energy sources and the percentage of each source in 2008.

Table (1.4): Electrical energy sources in Palestine (2008) [7].

Energy Source	Energy (MWh)	Percentage
Israel	3,666,100	85.76%
Jordan	64,340	1.5%
Egypt	134,370	3.14%
Gaza Power Station	410,312	9.6%
Total	4,275,122	100%

Because of the fragmentation of Palestine into two distinct separated zones, West Bank & Gaza have different energy supply options.

Electricity supply in the West Bank

Electrical power supply to the west bank comes from Israel, Jordan and local generators. The supply from Israel comes through three 161/33 KV substations, one in the south in area C close to Hebron, a second in the north in the Ariel settlement (area C) close to Nablus, and a third in Atarot industrial area (area C) near Jerusalem by 22kV and 33kV feeders [8]. The supply from Jordan comes through 33kV (can withstand 132kV) O.H line (20MW) to supply Jericho only. The remaining power is generated by decentralized small diesel generators. The maximum capacity of the West Bank is nearly 550 MVA, 30 % directly by the Israeli electric company (IEC), and 70% indirectly by IEC through Jerusalem Distribution Electric Company (JDECO). Among the localities connected to a public supply network, (IEC) supplies electricity directly in bulk to 272 localities, 152 received their electricity from (JDECO) which supplies electricity to East Jerusalem and in bulk to towns and villages in the West Bank, 22 from private generators, 68 from community councils and 61 from other sources .However, some 38 localities in the west bank are not connected to a public electricity network [9].

The electrical networks in the West Bank are all considered distribution networks which operates at 33kV, 22kV, 11 kV, 6.6 kV, 400V and supplied from the IEC 161/33 kV substations.

The present load in the West Bank is in the order of 400 to 500MW and is supplied from several points within the IEC network. Also, some Palestinian loads, especially in the northern area of West Bank, are supplied by distribution feeders from a 161kV substation inside Israel from which distribution feeders cross the border to supply Palestinian loads, such as the case of 22 kV feeders supplying Qalqilya and Tulkarm areas. Some 33 kV feeders from Beisan (in Israel) supply the Jenin and Tubas areas [8].

In principle the electricity is supplied to the Palestinian loads at 33kV or 22kV through IEC owned MV lines. In most cases, the PEA and the Palestinian utilities do not have control of the supply through the transmission or the distribution lines that extend from the 161kV substations. Palestinian control begins in most cases after the connection point with these feeders, which are metered for billing purposes by IEC to the utilities and municipalities. These connection points are also mixed between LV and MV. The difference is that if the connection point is on the MV side, then the Palestinian utilities can extend the MV network and install transformers and LV lines, whereas if the connection point is on the LV side, the Palestinian utilities cannot expand the LV network. The inability to extend the MV and LV networks has contributed to network deficiencies, such as very low voltage and high technical losses [8].

The capacity contracted with the IEC was in the early 2007 about 600 MVA for the West Bank, 125 MVA for the north, 95 MVA for the south, and 380 MVA for the central part (JDECO). The situation does not change.

The IEC for the time being rejects most of the Palestinian requests in the northern and southern regions to increase the capacity of the existing connection points or to add new connection points, claiming lack of capacity in the existing 161kV substations or overloading of its distribution feeders. This in turn has created a supply bottleneck to meet the growth of demand, and it is expected that this year the peak demand in the northern region will be higher than the available contracted capacity with IEC, which will be obliged to carry out load shedding in some areas. And what makes the situation urgent is the fact of the fragmentation of the distribution system in the northern and the southern regions, the connection points are not physically connected by an integrated network that will allow the transfer of any unused capacity from one point to another or the use of one point as a backup to another point in case of an emergency situation. In the case of JDECO, this situation is not present due to the existence of an integrated network. The lack in integration in the Palestinian networks is at the Palestinian side, although this integration exists through the Israeli network, but this possibility to provide backup has never been utilized. The area most affected with lack of capacity will be the Nablus area, which is the main load center in the northern region.

Electricity supply in Gaza Stripe

Electrical power supply to the Gaza Stripe comes from the Israel, Egypt and Gaza Power Plant (GPP). The maximum load of Gaza Stripe is around 260-270 MW. Gaza is connected to the Israeli power grid at 10 points along the border from north to south, via 22 kilovolt transmission lines with total capacity of some 120MW. The supply from Egypt comes through 33KV O.H line (19MW) to supply Rafah only. Gaza Power Plant was constructed with generation capacity of 140 MW at first phase. This station is now partially operational producing (60 MW).This indicates the presence of unserved demand in Gaza Stripe. Table 1-5 shows demand and deficit in electrical power in Gaza Stripe.

Table (1-5): Demand and deficit in electrical power in Gaza [10].

Source	**Available power (MW)**
IEC	120
Egypt	17
Gaza Power Station	60
Total	199
Demand & Deficit	
Demand	260-270
Deficit	≈ 25%

The main source of fuel for this station is supposed to be natural gas. But due to political obstacles which caused the project of producing gas from the shore of Gaza to halt, the station uses diesel for energy production. This makes GPP produces electricity at high prices compared to the price of electricity purchased from Israel. The power grid in Gaza is in a debilitated condition and requires sizeable investment for rehabilitation and upgrades.

1.3.3 Electric Utilities in Palestine

The electricity sector in Palestine is somewhat fragmented. In the West Bank there no substantial generating capacity and the only generating capacity is Gaza Power Plant (GPP) in Gaza. In the northern part of the West Bank, electricity distribution used to be a municipal responsibility. But for the institutional setup and reform of the electrical energy sector, NEDCO has been established to serve northern West Bank. So now we have five free- standing utilities that are responsible for electricity distribution in West Bank and Gaza. These utilities are:

1- Gaza Distribution Company (GEDCO), established in 1999 – with the assistance of Norway. It is the sole provider of electricity services in Gaza.

2- Hebron Electric Power Co. (HEPCO), covers Hebron and Halhul area in the southern part of the West Bank.

3- Southern Electricity Company (SELCO), established in 2002- with the assistance of the World Bank, covers the remaining southern of the West Bank.

4- Northern Electricity Distribution Company (NEDCO), established in 2008-with the assistance of Norway and Sweden, covers the northern part of the West Bank.

5- Jerusalem Distribution Electric Company (JDECO), services East Jerusalem and the central West Bank.

Figure 1.7 shows the geographical area of each utility.

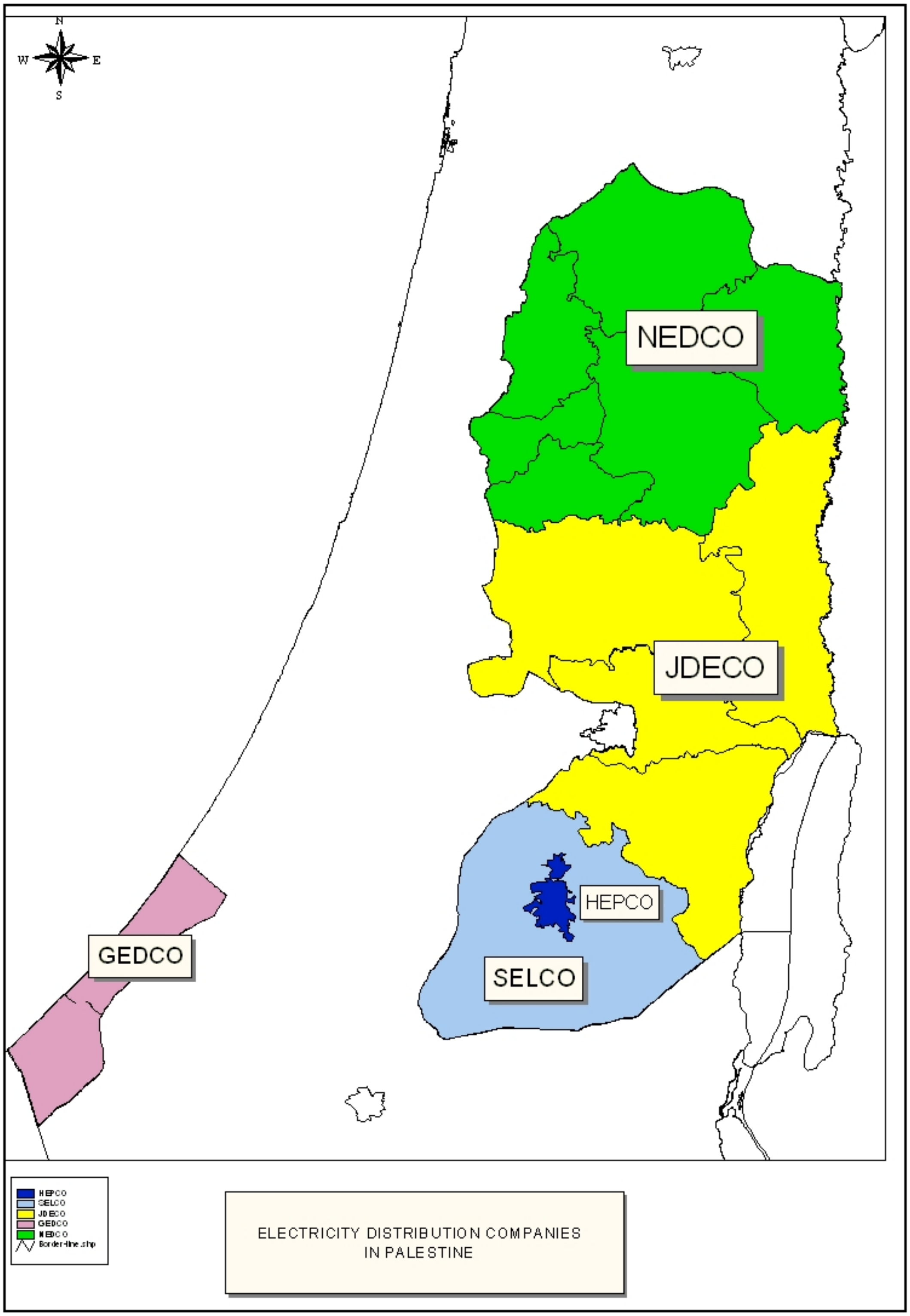

Figure (1.7): Geographical area for each electric utility in Palestine.

1.3.4 Future plans for electricity sector

Future plans in the West Bank

A project is in its way to be implemented and that costs US$140.1 million that include installing and supplying of four new 161/33/22kV bulk supply substations in the northern, central and southern West Bank [11]. These substations will substitute all other existing connecting points with IEC company which works on 22, 33 kV and 400V, and which currently supply Palestinian cities and villages. The West Bank will be supplied then at the high voltage tariff which is lower than the current flat tariff, and it also will drop technical losses sharply in addition to that it will solve shortage of available supply capacity for some time. Installing of these substations will be accompanied by rehabilitation of all distribution networks in all utilities in the West Bank that will be supplied by these substations. This project aims also to strengthen the newly established Northern Electric Distribution Company (NEDCO). This project also facilitates the project of connecting Palestinian network with the Jordanian network in the future. This alternative which is considered seriously , especially as we know that in October 2008, Palestine became a full member of the 7 countries interconnection project and become the country number eight; the countries are Jordan, Egypt, Syria, Lebanon, Iraq, Libya, Turkey and Palestine. This membership will allow Palestine to be connected to the grid of these countries at a large scale, specially connecting Gaza to Egypt and West Bank to Jordan.

The project will assist in the establishment of a new transmission company, Palestine Energy Transmission Company Ltd. (PETL) which would eventually own, operate and develop the transmission network. PETL would enter into power-purchase agreements with independent and semi-independent generating companies and from neighboring countries, and would sell power to regional distribution utilities.

In order to increase system capacity and reduce supply dependency on Israel by domestic power generation, two power plants are planned to be constructed will be created in West Bank which are:

1- Jayyus power plant in the north, near Qalqiliya.

2- Turqumia power plant in the south, west of Hebron.

Future plans in the Gaza Strip

A 161kV high voltage transmission line is being planned to be constructed that will interconnect Gaza in the north. The high voltage connection is expected to reduce the price of electricity for the Palestinians by supplying electricity at a lower tariff and by reducing technical losses in the power network. GEDCO is seeking a long term commercial agreement with the IEC to buy electricity to Gaza through this new link. A plan to connect the distribution grid of Gaza in the south (Rafah area) to the Egyptian distribution grid through a 220 kV interconnection has been considered. Expanding the capacity of the GPP (can be expanded to 560 MVA) in the future with the possibility of operating it on natural gas imported from Egypt or extracted from the shore of Gaza will be highly probable alternative that will both increase the electrical generating capacity on one hand, and will lower electricity cost on the other hand.

1.4 Energy Problems in Palestine

1.4.1 General

The political situation in Palestine and the economic bad conditions arises from it which continued for decades create chronic energy problems which need huge efforts and large investments to solve. Solving of these problems will depend on future political situation in addition to economic and other factors. Among the general energy problems

1- Energy resources are scarce or nonexistent. The only substantial energy source other than solar energy is natural gas discovered at the shore of Gaza.

2- The bulk of energy consumption (petroleum products and electricity) is monopolized by the Israeli authority and the supply of it is dependent on political situations some times.

3-There is no storage capacity for petroleum products in the West Bank and Gaza.

4- Energy prices are the higher among all neighboring countries, and it is difficult to achieve economics of scale in energy, as the total energy consumption is small

5- Renewable energy can be utilized to a larger extent.

6- Environmental pollution due to conventional energy resources, inefficient use of energy, inefficient and old technology.

7- Lack of actual, systematic, formal data on energy consumption and demand.

1.4.2 Electrical energy problems

The electrical system in Palestine consists of numerous isolated electrical distribution networks that need to be integrated in one power system. This situation stimulates many other problems like high technical losses, shortage of supply capacity, power outages, voltage drop and others. And there is a need for the development of the distribution companies in West Bank which is still in progress.

The major electrical energy problems can be summarized in:

1- Lack of supply capacity of electrical energy to meet present and future needs. This problem faces both West Bank and Gaza. But it is a serious problem in northern West Bank, especially Nablus area.

2- Electrical networks need major rehabilitation and development.

3- Absence in generating capacity in the West Bank, and the need to increase generating capacity in Gaza.

4- Energy prices are very high compared with regional and international prices.

5- High transmission and distribution losses (technical and non technical) which is considered an important and emergent problem.

The mentioned above problem of lack of supply capacity, Nablus has reached maximum supply capacity, and there is a urgent need to increase this capacity. Energy conservation and load management can help in reducing peak demand and postpone the moment of reaching a demand more than the available supply.

CHAPTER TWO

ENERGY CONSERVATION AND LOAD MANAGEMENT PROCEDURES IN ELECTRICAL NETWORKS

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Energy is considered to be an important component in the social, industrial, technological, economic, and sustainable development of any country. This makes energy resources and their availability extremely significant for every country. Electrical energy is regarded as high grade energy and has been the major driver for technological and economic development. Palestine energy resources are scarce and limited. All energy resources (especially petroleum and electricity) are imported from Israel. And sometimes the supply of these energy resources from Israel is governed by political considerations.

The electrical energy sector in Palestine faces many problems and obstacles. Electrical networks needs rehabilitation, price of electricity is high, lack of generating capacity, electrical losses are high in addition to the shortage in supply capacity and other problems. These problems in electrical supply exists at the same time that we have a continual growth in the demand on electrical energy. In Nablus, the problem of electrical supply capacity is an urgent problem that needs to be solved. In general, and for utilities facing load growth, energy conservation and load management can provide an effective means to reduce energy consumption and load demand and consequently postpone reaching the need for new power supply contracts or the need of construction of new generating or distributing facilities.

2.1 Load management in electrical networks

2.1.1 Introduction

Load management is defined as sets of objectives designed to control and modifies the patterns of demands of various consumers of a power utility [12]. Applying this control and modification enables the supply system to meet the demand at all times in most economic manner. Load management shifts demand for power from periods of peak demand to periods of less demand. Load management can be applied to all the loads experienced by a power utility including Industrial loads, cooling loads, heating loads and lighting loads. These loads vary by day, month and season. This means that load on the system is always changing with the time and is never constant. Thus power utilities always keep an eye on the average load and maximum load of their system.

Load management encompasses a broad range of measures to encourage consumers to voluntarily modify their consumption without compromising service quality or customer satisfaction. Tariffs can be designed to stimulate a shift in consumption to off-peak periods.

Load management strategies for the electrical network may be more difficult to organize with the consumers due to the different interests of the different consumers and the need for agreement that may contradict with the interests of both the supplier and the consumer. The situation in Palestine for this issue is more difficult as the suppliers of electrical energy are not who generate it, and so the benefit for them is not so great to motivate them to apply load management.

In the situation of Nablus Electrical Network, this subject of great importance now as the peak demand of the load reaches the maximum power available at the supply. It also helps in postponing the installation of higher capacity main transformers and switchgear.

2.1.2 Techniques of load management in electrical networks

Peak clipping

Peak clipping means reduction of load during peak periods to get the load profile as desired by the utility. This load reduction on the part of consumers is directly controlled by the utility and is usually enforced at peak times i.e. when usage of electric appliances by consumers is at its maximum. The shape of load profile through the peak clipping technique is given in fig 2-1.

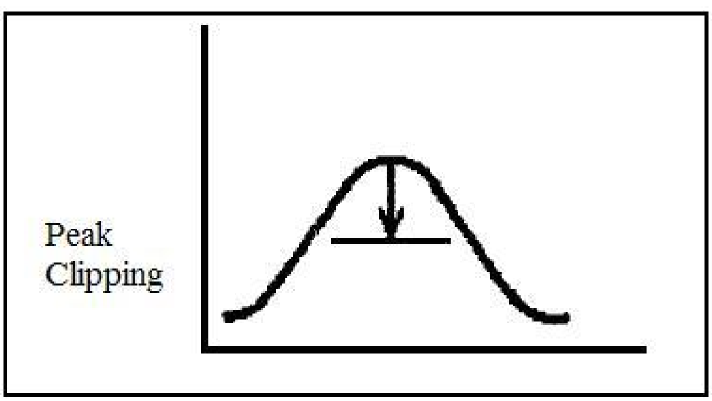

Figure (2.1): Peak clipping technique

Peak clipping can be achieved by Load shedding, this is shutting down certain pre-arranged electric loads or devices if a certain upper threshold of electric demand is approached. This is achieved in some countries by contractual agreements with industry to reduce consumption when needed (usually just a few times a year) during peak load hours, or by direct control of demand by interrupting supply to individual appliances or equipment on customer premises at the time of peak hours. This is achieved in some countries by utility controlled dispensable loads (typically radio controlled shut-off switches on residential water and space heat). This type of control usually reduces the demand of residential customers. Time-of-use Rate or tariff can achieve peak clipping at expected peak load hours.

Load shifting

Using this technique peak loads are moved to off peak time periods without necessarily changing overall consumption. Load shifting combines the benefits of peak clipping and valley filling by moving existing loads from on-peak hours to off peak hours. The shape of load profile through load shifting technique is given in fig 2-2.

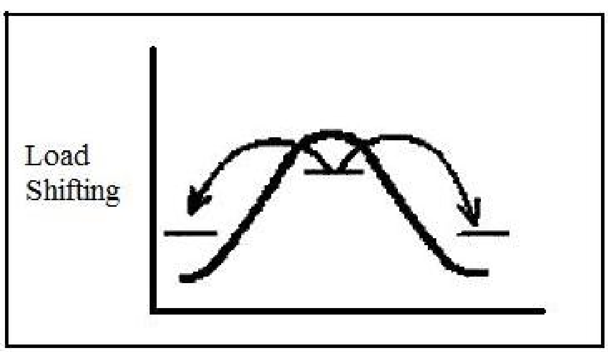

Figure (2.2): Load shifting technique

Load shifting can be achieved by Energy Storage and Time-of-use tariff.

Strategic conservation

The demand is lowered at peak and off peak period times. This is achieved by using different conservation techniques .This strategy tends to reduce demand at all times.

Suitable tariff structure

Electrical power tariffs are generally made up of two components: energy and demand. These two components are aimed at recovering the cost of supplying the energy to the consumer. The energy component reflects the cost of generation of the energy, while the demand charge reflects the cost of infrastructure to bring the energy to the consumer.

The utility can influence its customers load profile by providing financial incentives through the prices charged for electricity i.e. tariff. There are many tariff structures that can be used by the electric utility. The utility can select the tariff structure that can make the customers change their consumption magnitude and time so as to get the desired load curve. The cost of energy may vary during the day, in which case reference is made to time-related or time-of-use tariffs.

2.2 Energy conservation measures in electrical networks

2.2.1 Introduction

Energy conservation is the practice of decreasing the quantity of energy used. It may be achieved through efficient energy use, in which case energy use is decreased while achieving a similar outcome (Energy Efficiency), or by reduced consumption of energy services [13].

Energy conservation is a key element of energy policy and appears to be one of the most effective ways to improve end-use energy efficiency, and to reduce energy consumption. This is why many countries have recently started developing aggressive energy conservation programs to reduce the energy intensity of their infrastructures.

Energy conservation make businesses more competitive, reduce manufacturing cost, and allow consumers to save money. And ultimately improve upon their economic performances.

Saving in energy consumption through energy conservation reduces the atmospheric emissions from fossil fuel electric power plants and industrial facilities. This will decrease CO2 emissions which will have a positive impact on environment.

Furthermore, energy conservation is vital for sustainable development and should be implemented by all possible means, despite the fact that it has its own limitations. This is required not only for us, but for the next generation as well. Considering these important contributions, the energy conservation phenomenon should be discussed in a comprehensive perspective.

Dr. I. Ibrik and Prof. Dr. M. Mahmoud have identified that implementing of a national project in Palestine aiming at energy efficiency improvement in residential and industrial sectors as well as in public utilities, which include wide range of diversified audits and power measurements, had led to a high potential of energy saving. Measurement and audit results had shown that the total conservation potential in these sectors is around 15% of the total energy consumption [14].

In the USA, extensive programs for energy conservation, efficiency, and load management are planned and implemented for decades, and especially after year 1973. The impact of these programs on demand reduction is tremendous

2.2.2 Energy conservation measures in water pumping system

In studies that have been conducted for energy saving, pumping systems is considered one of the areas of high potential energy saving. According to a study that American Hydraulics Institute has made, 20% of the consumed energy has been consumed by pumps in developed countries. It has been explained that 30% of this energy can be saved through good design of systems and choosing suitable pumps [15].

The main components of the water pumping system are:

1- Prime movers: electric motors.

2- Pumps, usually centrifugal pumps.

3- Valves, used to control the flow in the system.

4- Other fittings, pipes, controls and instrumentation.

5- End-users, homes factories…, which have different requirements (e.g. pressure, flow) and therefore determine the pumping system components and configuration.

Electric motors

Electric motors used for driving pumps in Nablus water pumping system are three phase squirrel cage induction motors. Induction machines are perhaps the most widely used of all electric motors. They are generally simple to build and rugged, stable operation under load, and generally satisfactory efficiency.

The synchronous speed N_S is defined as

$$Ns = 120\, f / p \qquad (2.1)$$

Ns = synchronous speed (rpm)

f = frequency of the supply (Hz)

p = number of poles

s is the slip, defined as

$$s = (N_S - N_m) / N_S = (\omega_s - \omega_m) / \omega_s \qquad (2.2)$$

N_S: synchronous speed (rpm)

N_m: motor speed (rpm)

ω_s: synchronous angular speed (rad/sec)

ω_m: angular speed of the motor (rad/sec)

The equivalent circuit of three phase induction motor is shown in figure (2.3)

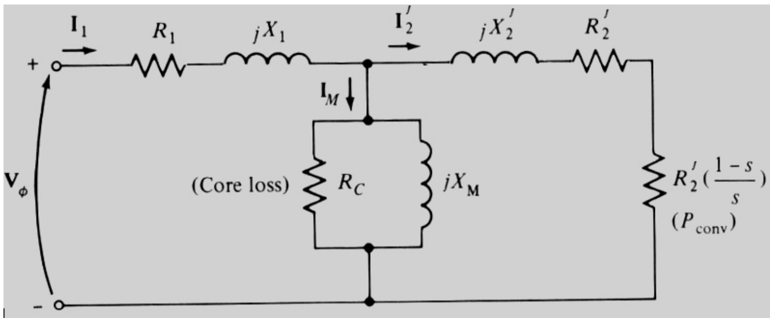

Figure (2.3): The equivalent circuit for the induction motor

Where:

R_1: resistance of the stator

X_1: leakage reactance of the stator

R_2': rotor resistance referred to the stator

X_2': blocked rotor reactance referred to the stator

X_M: reactance that account for magnetizing current

R_C: resistance that account for core loss

The motor power is given by the following equation

$$P_d = T_d \omega_m \qquad (2.3)$$

Where:

P_d: developed power

T_d: developed torque

The equation that gives the developed power for the induction motor is

$$P_d = 3|I_1|^2\left[\left(R_1 + \frac{R_2^{'}}{s}\right) - \left(R_1 + R_2^{'}\right)\right] = 3\frac{1-s}{s}R_2^{'}|I_1|^2 \qquad (2.4)$$

And the equation that gives the developed torque for the induction motor is

$$T_d = \frac{3}{\omega_s}\frac{R_2^{'}}{s}\frac{|V_\phi|^2}{\left(R_1 + \frac{R_2^{'}}{s}\right)^2 + \left(X_1 + X_2^{'}\right)^2} \qquad (2.5)$$

If the motor is supplied from a fixed voltage at a constant frequency, the developed torque is a function of the slip and the torque – speed characteristics can be determined from equation (2.5). A typical plot of developed torque as a function of slip or speed is shown in figure (2.4).

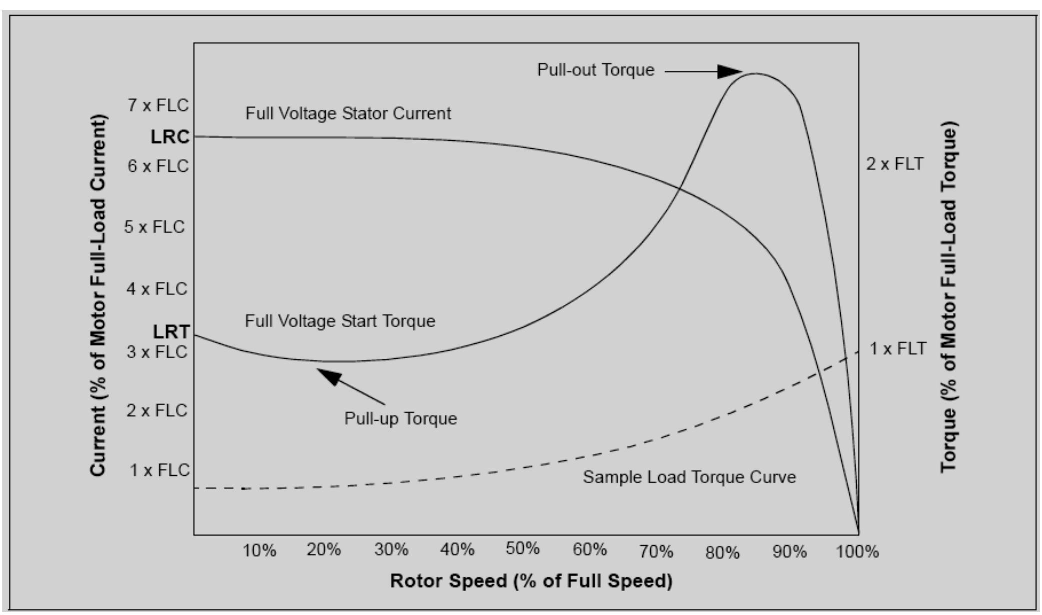

Figure (2.4): Typical torque – speed characteristics of induction motor.

From equation (2.1), the speed of an AC motor is determined for the most part by two factors: the applied frequency and the number f poles. Usually the number of poles is constant and the only way to vary the speed is to change the applied frequency. Changing the frequency is the primary function of the variable frequency drive (VFD), as it is called variable speed drive (VSD). However, one must consider that the impedance of a motor in determined by the inductive reactance of the windings. Refer to equation (2.6).

$$X_L = 2\pi\, f\, L \tag{2.6}$$

Where:

X_L = Inductive reactance in Ohms

f = Line frequency

L = inductance

This means that if the frequency applied to the motor is reduced, the reactance and therefore impedance of the motor is reduced. In order to keep current under control we must lower the applied voltage to the motor as the frequency is reduced. This is where we get the phrase “volts per hertz”. The most common method of controlling the applied voltage and frequency is with a pulse width modulated “PWM” technique. With this method, a DC voltage is applied to the motor windings in time controlled pulses in order to achieve current that approximates a sine wave of the desired frequency. IGBTs or Isolated Gate Bipolar Transistors are the latest technology and offer the ability to switch the PWM pulses very fast. This allows several thousand pulses to be applied in one cycle of the applied motor frequency. More pulses in a given cycle result in a smoother current waveform and better motor performance.

Pumps

Although pumps are available in a wide range of types, sizes, and materials, they can be broadly classified into the two categories, positive displacement and centrifugal. These categories relate to the manner in which the pumps add energy to the working fluid.

The pumps used in Nablus water pumping system are centrifugal pumps. Centrifugal pumps work by adding kinetic energy to a fluid using a spinning impeller. As the fluid slows in the diffuser section of the pump, the kinetic energy of the fluid is converted into pressure.

Centrifugal pumps have variable flow rates even when rotating at a constant speed. The performance of a centrifugal pump is typically described by a graph plotting the pressure generated by the pump (measured in terms of head) over a range of flow rates. Figure (2.5) shows a performance curve for a typical centrifugal pump. The curve shows that head gradually decreases with increasing flow. As the resistance of a system increases, the head will also increase. This in turn causes the flow rate to decrease and will eventually reach zero. A zero flow rate is only acceptable for a very short period without causing to the pump to burn out.

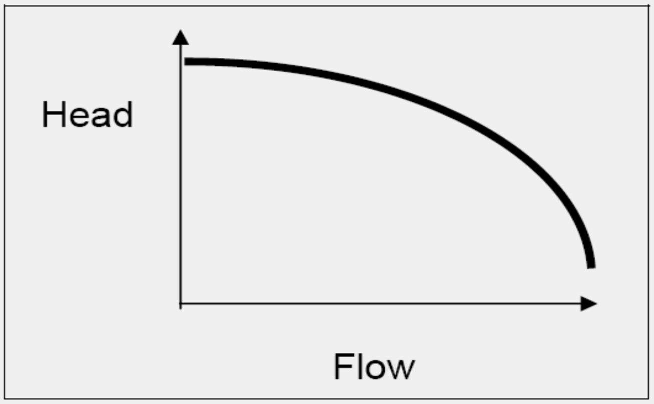

Figure (2.5): Typical pump performance curve.

Pressure is needed to pump the liquid through the system at a certain rate. This pressure has to be high enough to overcome the resistance of the system, which is also called “head”. The total head is the sum of static head and friction head.

In most cases the total head of a system is a combination of static head and friction head, the curve of it with flow is called system curve as shown in the Figure (2.6).

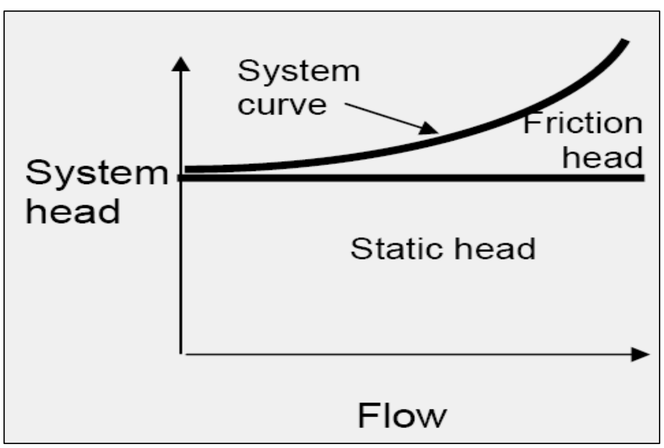

Figure (2.6): System curve with static and friction head

The rate of flow at a certain head is called the duty point. The pump performance curve is made up of many duty points. The pump operating point is determined by the intersection of the system curve and the pump curve as shown in Figure (2.7).

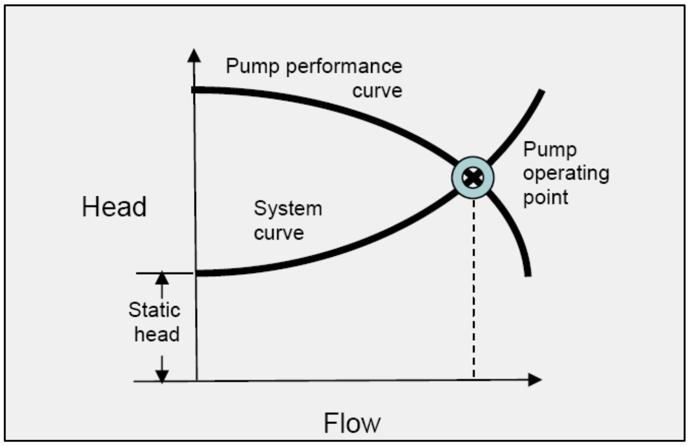

Figure (2.7): Operating point of the pump.

A centrifugal pump's rotating impeller generates head. The impeller's peripheral velocity is directly related to shaft rotational speed. Therefore varying the rotational speed has a direct effect on the performance of the pump.

The pump performance parameters (flow rate, head, and power) will change with varying rotating speeds. To safely control a pump at different speeds it is therefore important to understand the relationships between the two. The equations that explain these relationships are known as the "Affinity Laws":

* Flow rate (Q) is proportional to the rotating speed (N), $Q \sim N$

* Head (H) is proportional to the square of the rotating speed, $H \sim N^2$

* Power (P) is proportional to the cube of the rotating speed, $P \sim N^3$

As can be seen from the previous laws, a small reduction in speed of the centrifugal pump will result in a very large reduction in power consumption. This forms the basis for energy conservation in centrifugal pumps with varying flow requirements.

Following are some of the points that will be investigated which are related to energy saving opportunities in the pumping systems

1- Maintaining motor voltage levels:

Voltage at the motor should be kept as close to the nameplate value as possible, with a maximum deviation of 5%. Although motors are designed to operate within 10% of nameplate voltage, large variations significantly reduce efficiency, power factor, and service life (see Figure 2.8).

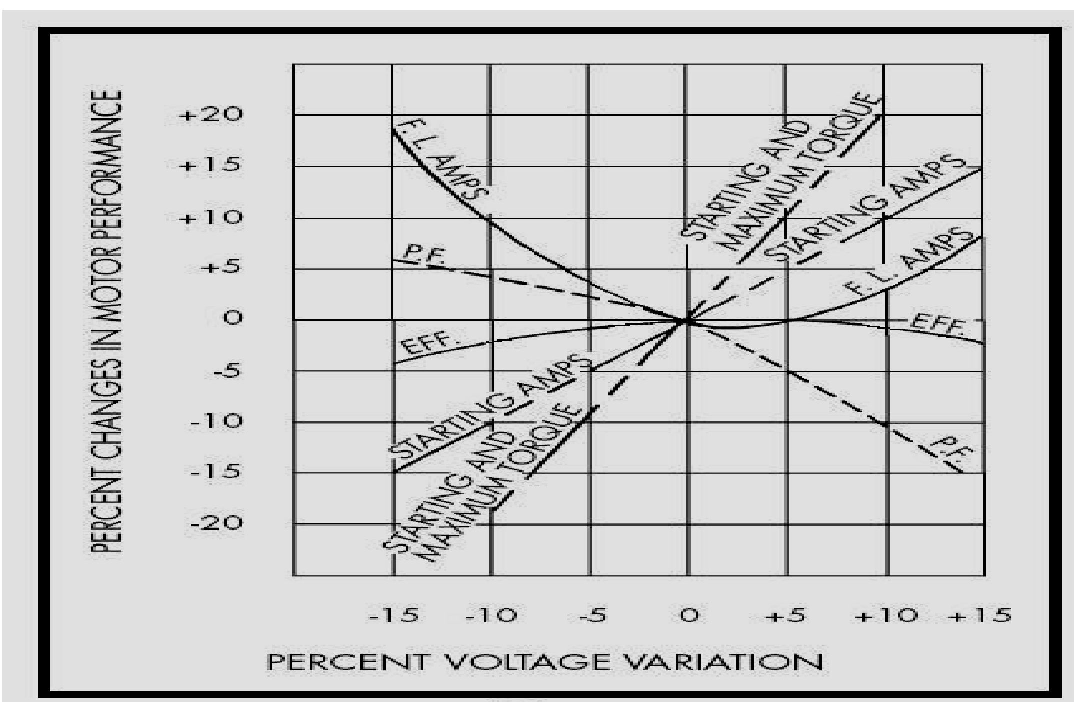

Figure (2.8): Effect of voltage variation on motor performance [16].

When operating at less than 95% of design voltage, motors typically loose 2 to 4 points of efficiency. Running a motor above its design voltage also reduces power factor and efficiency but the effect of voltage reduction is greater as shown in figure (2.5).

2- Minimize supply phase unbalance:

Voltage unbalance describes the condition when the voltages of all phases of a 3-phase power supply are not equal. Phase balance should be within 1% to avoid de rating of the motor. Voltage unbalance is defined by the National Electrical Manufacturers Association (NEMA) as 100 times the maximum deviation of the line voltage from the average voltage on a three-phase system divided by the average voltage. The following table 2.1 illustrates the effect of supply phase unbalance on the efficiency of the motor:

Table (2.1): Effect of supply voltage unbalance on motor efficiency [17].

% Voltage unbalance	Efficiency reduction
0	--
1	Up to 1/2%
2	1-2%
3	2-3%
4	3-4%
5	5% or more

3- Maintain high power factor:

Low power factor reduces the efficiency of the electrical distribution system both within and outside the facility containing the motors. In addition to the fact that low power factor cost money in the form of penalty imposed by the supplier on the consumer. The benefits that can be achieved by correcting the power factor to an acceptable high value can be summarized by :

- Reduction of electricity bills by avoiding paying penalty fee.
- Reduction of I^2R losses in transformers and distribution equipment and cables.
- Reduction of voltage drop in cables.
- Extra kVA available from the existing supply.
- Extra kVA available in the rating of distribution equipment and cables.
- Environmental benefit. Reduction of power consumption due to improved energy efficiency, reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations.

Power factor correction is achieved by the addition of capacitors in parallel with the connected motor or lighting circuits and can be applied at the equipment, distribution board or at the origin of the installation.

4- Replacing an oversized and under loaded electric motor:

Most electric motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of rated load. A motor's efficiency tends to decrease dramatically below about 50% load. However, the range of good efficiency varies with individual motors and tends to extend over a broader range for larger motors, as shown in Figure (2.9). A motor is considered under loaded when it is in the range where efficiency drops significantly with decreasing load. Operating motors under loaded causes the power factor to decrease, and as load decreases, the power factor tends to fall off more rapidly than the efficiency under part-load conditions. Therefore, if motors are oversized, the need for power factor correction becomes greater.

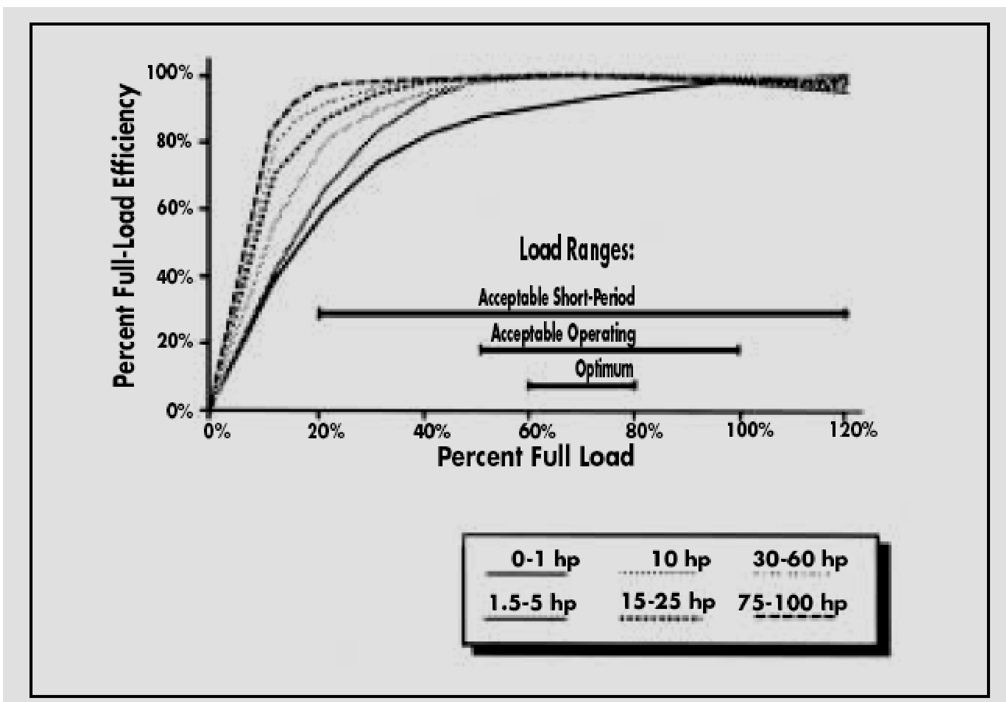

Figure (2.9): Motor part load efficiency (as function of % full load efficiency) [18].

In general, it is recommend to survey and test all motors operating over 1000 hours per year. Using the analysis results, the motors are divided into the following categories:

- Motors that are significantly oversized and under loaded—replace with more efficient, properly sized models at the next opportunity, such as scheduled plant downtime.

- Motors that are moderately oversized and under loaded—replace with more efficient, properly sized models when they fail.

- Motors that are properly sized but standard efficiency—replace most of these with energy-efficient models when they fail

The cost effectiveness of an energy-efficient motor purchase depends on the number of hours the motor is used, the price of electricity, and the price of buying an energy-efficient motor. To determine loading of the motor

Loading of the motor %:

$$= (P_{in} / P_{fl}) \times 100\% \qquad (2.7)$$

Where

P_{in} = Measured three-phase power in kW

P_{fl} = Input power at full-rated load in kW

Full load power(kW) (P_{fl}) =

$$P_{fl} = P_{mech} * 0.746 / \eta_{fl} \qquad (2.8)$$

Where:

P_{mech} = Nameplate rated horsepower (Motor Size (hp))

η_{fl} = Efficiency at full-rated load

5- Replacing conventional (standard) motors with high efficiency motors:

As most of the water pumps have high rating motors and operate long time annually, so their annual energy consumption is very high, so by replacing conventional (standard) motors with high efficiency motors, saved energy is expected to be reasonable.

A high efficiency motor produces the shaft output power, but uses less input power than standard motor. High efficiency motors must have a nominal full load efficiency that meet or exceed the high efficient motor standards in Europe or USA.

The cost of the high efficiency motors is 15-30% more than standard motors, and they are 2-8% more efficient than the standard motor.

The right time to consider buying high efficient motors is:

* During new installation

* Instead of rewinding burnt standard motors.

* To replace an existing standard motor (conventional) motor if the payback period is less than (5) years, this would be applicable under the following conditions:

  - High rating motors.

  - High output operating load percentage.

- Annual operating hours high

- Cost of kWh is high (like the situation in Palestine)

Energy savings using energy efficient motor:

Energy Savings = $hp_{(M)}$ x loading x 0.746 x hours x $(1/\eta std - 1/\eta_{HEM})$

$$= E_{(CONSUMED)} \times \eta_{STD} \times (1/\eta_{STD} - 1/\eta_{HEM}) \quad (2.9)$$

$hp_{(M)}$: Rated output power of the motor

ηstd : Efficiency of standard motor

η_{HEM}: Efficiency of the high efficient motor

Power reduction = $hp_{(M)} \times$ loading $\times 0.746 \times (1/\eta_{STD} - 1/\eta_{HEM})$ (2.10)

6- Using VSD with pumps:

The most commonly used method to reduce pump speed is Variable Frequency Drives (VFD). Variable speed drive provides one of the best available options to improve pumping efficiency. They are ideally suited for variable-torque loads from centrifugal pumps, fans, and blowers when the system load requirements (head, flow, or both) vary with time.

To understand how varying speed changes the duty point, the pump and system curves are overlaid. Two systems are considered, one with only friction loss and another where static head is high in relation to friction head. It will be seen that the benefits are different. In systems with friction head (figure 2.10), reducing speed in the friction loss system moves the intersection point on the system curve along a line of constant efficiency.

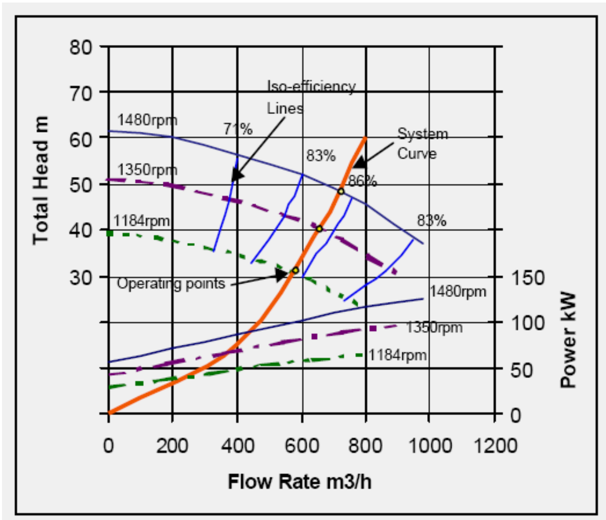

Figure (2.10): Performance of the pump with friction head systems.

The operating point of the pump, relative to its best efficiency point, remains constant and the pump continues to operate in its ideal region. The affinity laws are obeyed which means that there is a substantial reduction in power absorbed accompanying the reduction in flow and head, making variable speed the ideal control method for systems with friction loss [19].

Figure (2.11) shows a system where static head is high, the operating point for the pump moves relative to the lines of constant pump efficiency when the speed is changed. The reduction in flow is no longer proportional to speed. A small turn down in speed could give a big reduction in flow rate and pump efficiency, which could result in the pump operating in a region where it could be damaged if it ran for an extended period of time even at the lower speed. At the lowest speed illustrated, (1184 rpm), the pump does not generate sufficient head to pump any liquid into the system, i.e. pump efficiency and flow rate are zero and with energy still being input to the liquid, the pump becomes a water heater and damaging temperatures can quickly be reached [19].

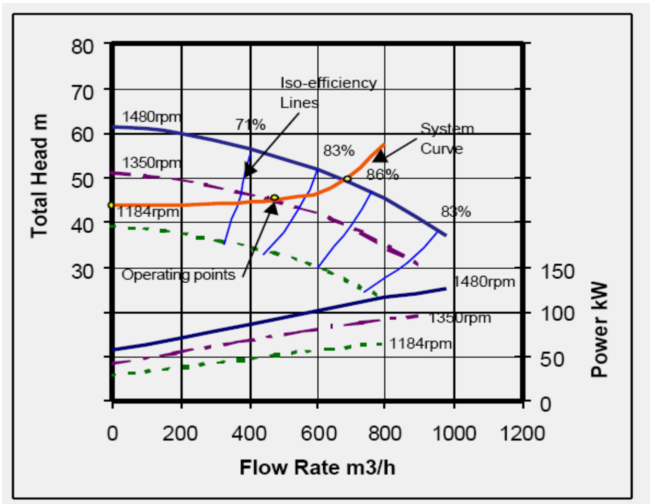

Figure (2.11): Performance of the pump with high static head systems.

The drop in pump efficiency during speed reduction in a system with static head reduces the economic benefits of variable speed control. There may still be overall benefits but economics should be examined on a case -by -case basis.

Conditions that tend to make VSD (VFD) s cost-effective include the following:

- ***High horsepower*** (greater than 15 to 30 hp) — the higher the pump horsepower, the more cost-effective the VSD application.

- ***Load type***—Centrifugal loads with variable-torque requirements (such as centrifugal pumps or fans) have the greatest potential for energy savings. VSD s can be cost-effective on positive displacement pumps, but the savings will generally not be as great as with centrifugal loads.

• ***Operating hours***—In general, VSD s are cost-effective only on pumps that operate for at least 2,000 hours per year at average utility rates.

• ***High utility rates***— higher utility energy charges provide a more rapid payback on an investment in a VSD.

• ***Low static head***—VSD s are ideal for circulating pumping systems in which the system curve is defined by dynamic or friction head losses. They can also be effective in static-dominated systems—but only when the pump is carefully selected. A thorough understanding of pump and system interactions is critical for such applications.

As said earlier the energy savings are unquestionable in systems dominated by friction losses, such as water circulating systems. In such systems, the pumps operate at a constant efficiency irrespective of the pump speed. However, in systems dominated by static head, the pump efficiency changes with the speed. It is typically reduced at lower speeds and hence energy savings may not always be realized.

2.2.3 Energy conservation measures in Street lighting sector

The lighting system in Nablus municipal electric network is used mainly for lighting streets at night. High intensity discharge (HID) lamps are commonly used, including metal halide, high pressure sodium and mercury vapor lamps. Following are some of the energy saving opportunities in the lighting system

- Reducing the number of lighting lamps: this opportunity can be done in two schemes:

1- Reducing number of lights while getting suitable illumination level, this can be accomplished by measuring the illumination level and compare it with international standards for illumination , and removing any extra lamps with their ballasts.

2- Reducing the number of lights illuminated during certain hours at night,

- Install high efficiency lighting lamps: substituting less efficient mercury vapor lamps with the corresponding lower wattage high pressure sodium.

- Effective control by installing a more precise apparatus to control lighting lamps only at the required dark hours.

2.2.4 Energy conservation measures in Residential sector

1- Replacing low efficient refrigerators by high efficient refrigerators:

Refrigerators consume the most energy of all household appliances as they are always on. Due to recent improvements, characteristics of new energy efficient refrigerators include better insulation, better seals, more efficient compressors, and more precise temperature/defrost controls. Today’s refrigerators use much less energy than older models which reach less than half the energy consumed by similar older models. So replacing the older low efficient refrigerators with the new high efficient refrigerators will save both energy consumed and the power demand in the electrical network.

2- Replacing incandescent lamps by CFL lamps:

Incandescent lamps are still used in our homes. CFL lamps use 75 percent less energy and lasts about 10 times longer than comparable incandescent lamps. So replacing the older incandescent lamps with CFL lamps will save energy and power in the electrical network.

3- Reducing standby power and energy losses

Electrical appliances used in homes and offices consume some energy when they are left on standby mode or even switched off. This loss can range from 0.1W to 10W depending on the appliance and its model. Although this energy consumption seems to be small but it became significant as it is aggregated due to existence of many appliances at home. And the energy consumed due to standby became more significant at city or country level. this standby energy and power can be reduced by better consumer awareness which will lead to a behavior change that will make the consumer shut down the appliance completely when it is not in use, and will make the customer to buy the more energy efficient appliances that have very small standby energy loss.

CHAPTER THREE

DESCRIPTION OF NABLUS ELECTRICAL NETWORK

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3-1 General

Nablus electrical grid supplies the whole city in addition to about 18 villages surrounding it and the four refugee camps. This network extended over an area of 30 km East- West and 25 km North – South.

Nowadays all part of the system is supplied from the Israeli Electric corporation, while in past before the year 1982, part of the network were fed from a locally generating station in the center of the city, but now the station supplying small parts of loads when power is switched off from Israeli side, specially the water pump, station, hospitals, and some other sensitive loads.

3.2 Supply and distribution system

Nablus electrical network is supplied by electrical energy from four main IEC in feeds:

1- The first is situated in east Nablus near Asker.

2- The second is Odala which does not have substation, the voltage is 33 kV, and the power is distributed directly to distribution transformers 33/0.4 kV .

3- The third is Quseen point near Quseen junction.

4- The fourth is Inab connection point .

The capacity of each connection point is as in table 3.1

Table (3.1): Capacity of each connection point for Nablus electrical network

Connection point	Official rated capacity
Askar	23 MVA
Odala	13 MVA
Quseen	16 MVA
Inab	5 MVA

Nablus municipality operates three 33/6.6 kV substations equipped with transfomers. all these transformers are rated at 10 MVA with automatic tap –changer under load. The supply distributes through nineteen 6.6 kV and four 33 kV feeders. The city of Nablus is fed at 6.6 kV while outlying load is supplied via 33/ 0.4 kV distribution transformers.

The one line diagram of the system that contains the main parts of the network is shown in the fig 3.1.

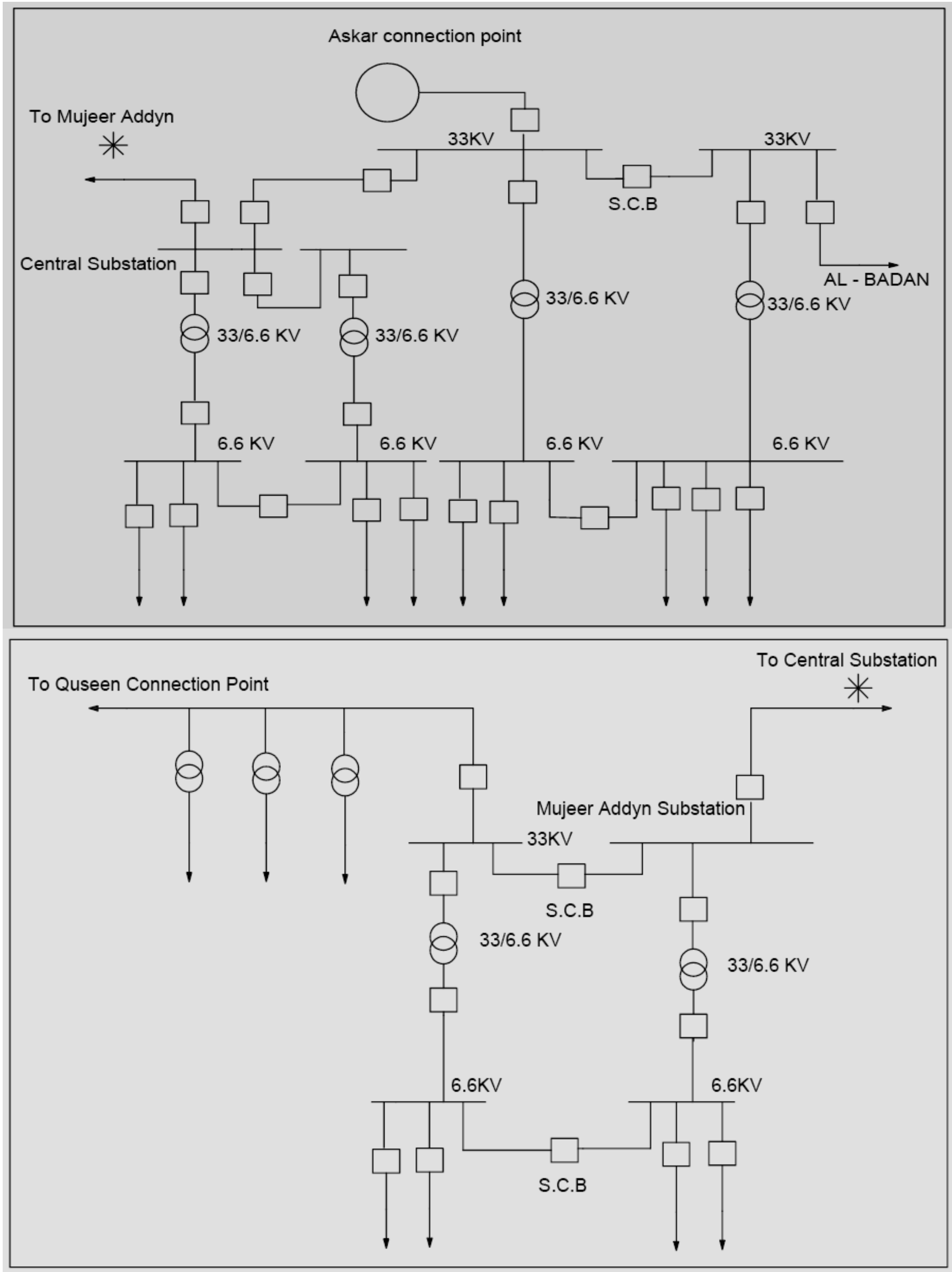

Figure (3.1): One line diagram of the main parts of the Nablus electrical network.

Distribution transformers:

There are 350 distribution transformers installed in Nablus system at 33kV or 11– 6.6kV all with 400 volts secondary. Both outdoor pole mounted and indoor types are used. The impedance of these transformers is in the region of 4%. The majority of the transformers have + / - 5% tap range, with tap steps of 2.5% and are generally set to give maximum voltage boost to low voltage.

Distribution networks:

1- Low voltage feeders and networks (565 km).

2- Medium underground 11kV (98 km).

3- Medium underground 33kV (7.5 km).

4- Medium overhead 33kV (115 km).

3.3 Energy Consumption

The following table 3.2 shows the electrical energy imports and the invoiced electrical energy and losses for the years from 2000 – 2008.

Table (3.2): Electrical energy imports and the invoiced electrical energy and losses for the years from 2000 – 2008

year	electrical energy generated and imported (KWh)	electrical energy invoiced (KWh)	losses	losses percentage
2000	167675335	150603904	17071431	10.18%
2001	162916987	146341888	16575099	10.17%
2002	134831580	127597857	7233723	5.37%
2003	165266580	145807641	19458939	11.77%
2004	176486550	151317014	25169536	14.26%
2005	191525830	170283858	21241972	11.09%
2006	209490820	180222582	29268238	13.97%
2007	226844510	196417456	30427054	13.41%
2008	236821270	209714328	27106942	11.45%

The electrical energy imports (requirements) for Nablus network increase by an average percentage of 5.1% annually. Figure 3.2 shows variation of energy imports in Nablus electrical network.

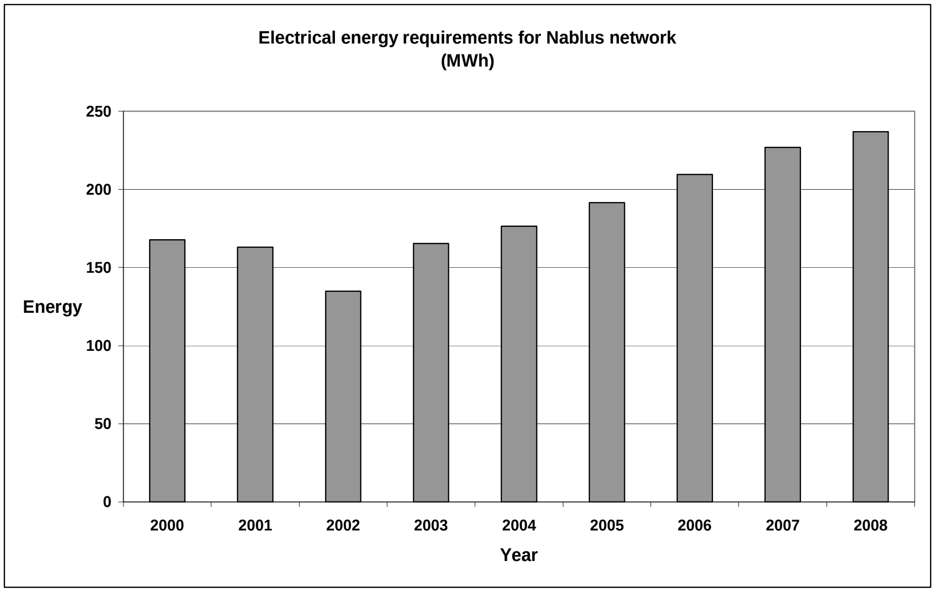

Figure (3.2): Variation in energy requirements for Nablus electrical network during the years 2000-2008.

Variation in the energy losses in Nablus electrical network is shown in figure 3.3.

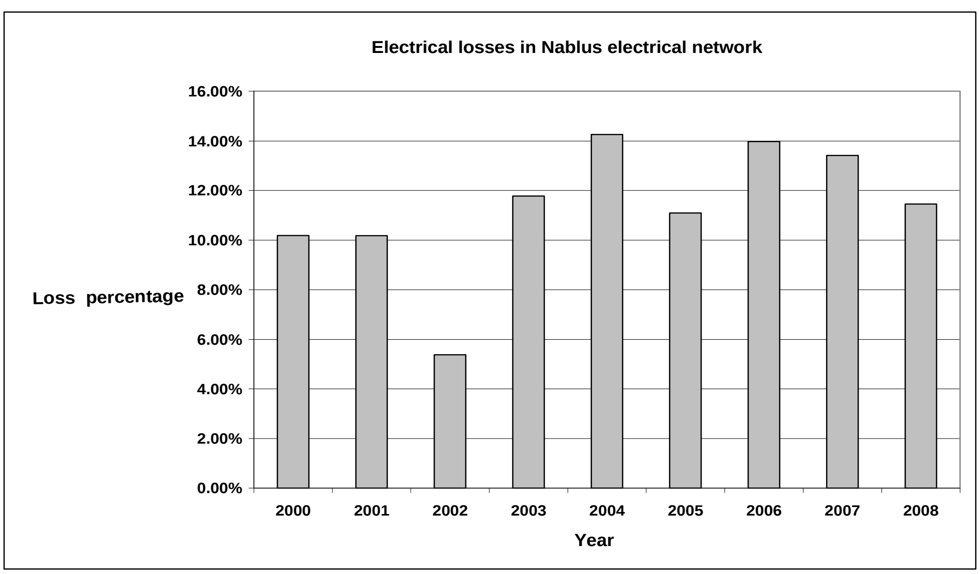

Figure (3.3): Variation in the energy losses in Nablus electrical network during the years 2000-2008.

3.4 Energy consumers and sectors

Number of consumers

The following table 3.3 shows the categories of electricity consumers and the number of each category in the year 2008.

Table (3.3): Number of consumers in different consumers categories in the year 2008.

	Year	Residential	Staircase	Commercial	Industrial	Institutions	Total
1	2008	39794	2180	8547	1340	779	52640

Electrical energy consumption by sector:

The following table 3.4 shows total electrical energy consumption in Nablus network by sector during the year 2008

Table (3.4): Electrical energy consumption in Nablus network by sector during the year 2008

Name of sector	Energy Consumed (kWh)	Percentage of the total consumption
Residential	102,231,048	49.42%
Villages/connection points	12,057,167	6.83%
Commercial	17,347,191	8.39%
Industrial	30,423,024	14.71%
Street lighting	5,127,673	2.48%
Institutions	18,119,719	8.76%
Pumping system	21,553,866	10.42%
Total	206,859,688	100%

Figure 3.4 shows a pie diagram for energy consumption by the different sectors.

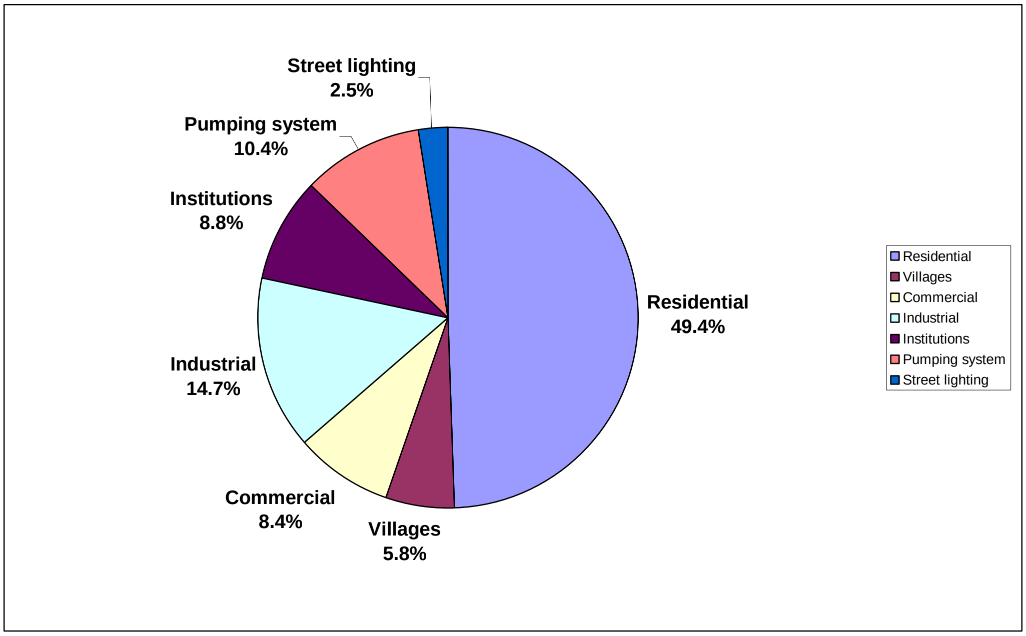

Figure (3.4): Pie diagram of energy consumption of the different sectors during year 2008 in Nablus electrical network.

CHAPTER FOUR

ENERGY MANAGEMENT IN WATER PUMPING SECTOR IN NABLUS ELECTRICAL NETWORK

CHAPTER FOUR

ENERGY MANAGEMENT IN WATER PUMPING SECTOR IN NABLUS ELECTRICAL NETWORK

4.1 Introduction

Water pumping system in Nablus electrical network aims to supply water to various water consumers. The water supply to the system comes from four deep wells, Al-Badan, Audala, Far'a, and Deir-sharaf, all of them are outside the city. The wells cover an average of 80% of the present water production, and the other 20% comes from six springs inside Nablus city boundaries. The water produced from wells and springs is drawn to storage tanks (reservoirs) inside the city. The operating sixteen storage tanks are mostly combined with pumping stations to distribute water to consumers. The storage tanks have an effective volume of 17622 m^3 which covers the daily water consumption of the city. The total water production in Nablus was in the year 2008 7,615,276 m^3 with an electrical energy consumption of 21,553,866 kWh. The electrical energy consumption for water pumping represents 10.42% of the total electrical energy consumption of Nablus electrical network. This consumption is more than the consumption of the commercial (8.39%) or institutional (8.76%) sectors. So investigating possible energy conservation opportunities in water pumping is important, especially if we take into account that this sector is institutionalized and any relevant possible energy conservation measures can be implemented.

In order to facilitate the study of the water pumping sector in Nablus electrical network, the pumping system will be divided into the following categories: well pumps, booster pumps and distribution pumps as in figure (4.1). Pumps used to pump water from springs will be included with the distribution pumps as most of these pumps are included in the pumping stations in the storage tanks.

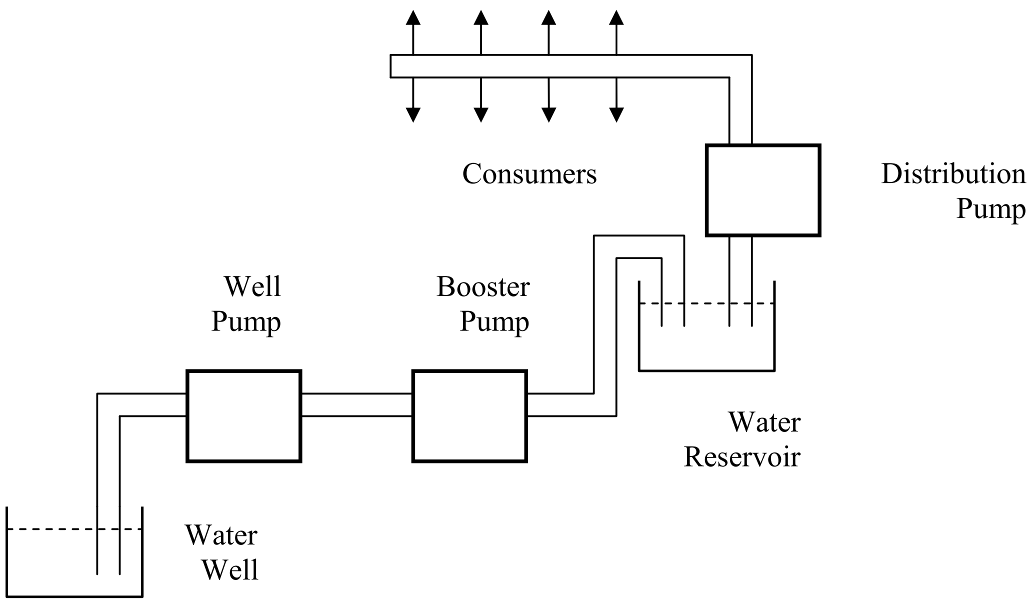

Figure (4.1): Functional block diagram of the pumping sector.

A chart that illustrates energy management opportunities in the pumping sector of Nablus electrical network is shown in figure (4.2).

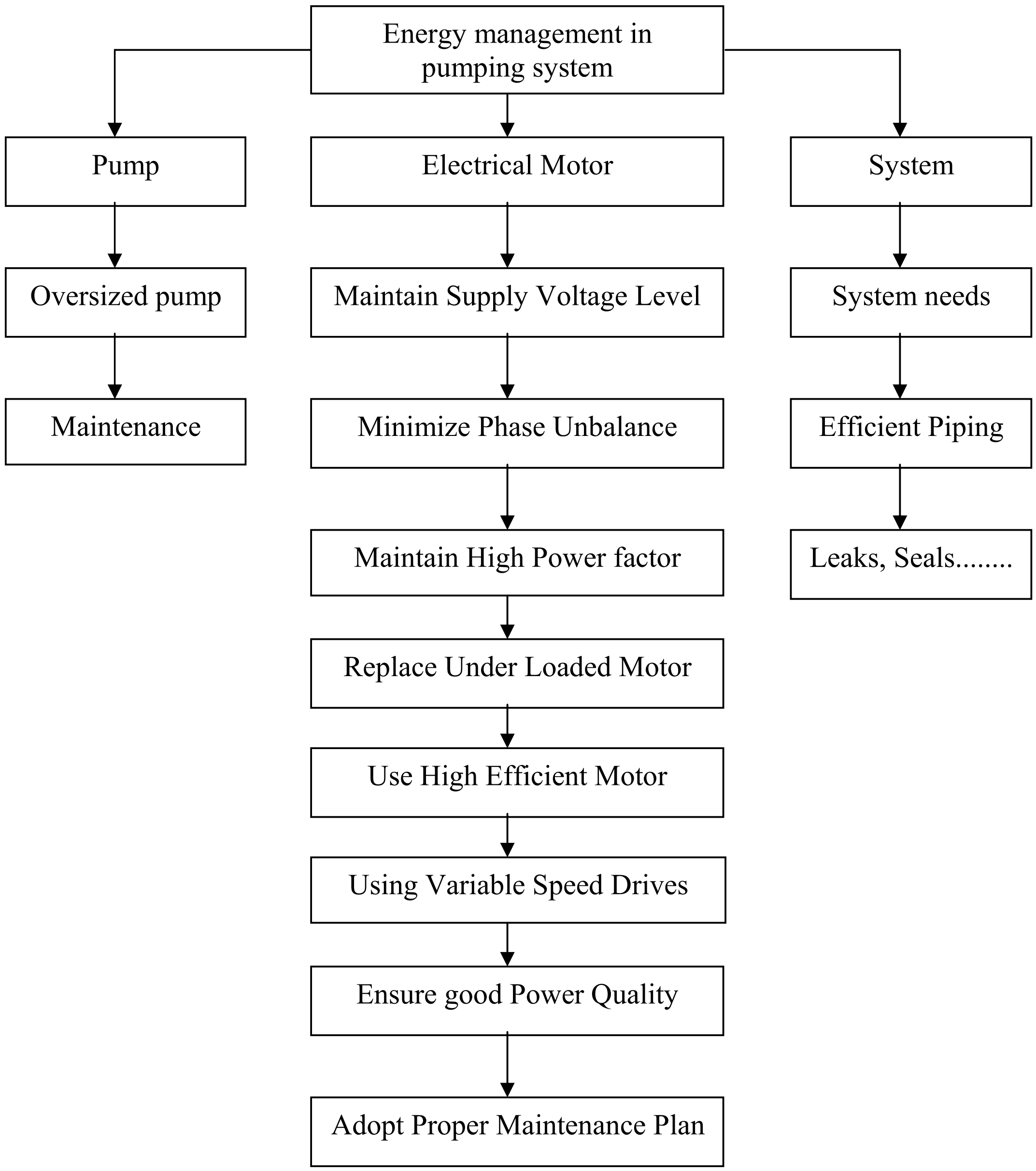

Figure (4.2): Chart that illustrate energy management opportunities in the pumping sector of Nablus electrical network.

4.2 Energy Auditing in Well Pumps

These pumps draw water from underground natural water reservoirs to the surface level. There are four pumps that are used to pump water from the four deep wells that supply water to Nablus water pumping system.

These wells are Al-Badan well pump, Audala well pump, Far'a well pump and Deir-Sharaf well pump. The ratings of the motors that operate these pumps are 600hp, 500hp, 500hp, and 400hp respectively. The energy consumed by these pumps in the year 2008 was 2,084,211, 1,321,463, 1,140,000 and 1,558,462 kWh per year respectively. The total energy consumed is about 6,104,136 kWh which is about 28.3% of the energy consumed by the total pumping system.

Well pumps are characterized by relatively constant loading as the flow rate of water is constant and the head is relatively constant.

Case study

Al-Badan well pump was taken as a case study for well pumps. The pump operation was investigated for the following operating conditions that affect the energy consumption of the pump.

Motor voltage levels

The nameplate of Al-Badan well pump 3 phase induction motor, appendix (B-1),

HORSEPOWER	600	**MOTOR RPM**	1478	**PHASE**	3	**NOM.EFF**	____
FREQUENCY	50	**AMPS**	806	**AT**	380V	**S.F**	1.15

The voltage level at Al-Badan well pump motor was measured for nearly 24 hours using the energy analyzer device at the motor switchboard.

The voltage deviation percentage was calculated by taking the values of the measured phase voltages V1, V2, V3, and then we calculate the deviation of these voltages from 220V as percentage from 220V.

For the measured voltages at 20:13 PM on 29/7/2009,

V1= 232.3V , V2= 231.3V , V3= 232.9V

The voltage deviation in this pump:

So $\Delta V1 = (V1 - 220) / 220 \times 100\%$ (4.1)

$= (232.3 – 220) \times 100\% = +5.59\%$

Then we calculate $\Delta V2$ and $\Delta V2$ in the same way.

During the period of investigation, appendix (A-1), the voltage deviation for the three phases from nameplate values was found as illustrated in table (4.1).

Table (4.1): Maximum voltage deviation for the three phases (from nameplate values) at Al-Badan well pump motor

	ΔV1	**ΔV2**	**ΔV3**
Deviation at maximum voltage level	+7.54%	+7.02%	+7.81%
Deviation at minimum voltage level	+2.41%	+2.18%	+2.95%

The deviation at the maximum voltage level is relatively higher than the recommended maximum deviation (5%). The effect of this deviation on the efficiency of the motor is expected to be small, because the amount of deviation is relatively small, it is in the increasing direction and not in the decreasing direction, this deviation occurs during midnight and early morning hours only in addition to the fact that the voltages are measured at the switchboard and not the motor terminals (the motor terminals are 20 m from switchboard).

In general it is recommended decrease the voltage levels by not more than 5% by adjusting the tap changer at the supplying transformer.

Supply phase unbalance

The voltage unbalance for the supply of the motor was computed from the measured data by the energy analyzer. Voltage unbalance is defined by the National Electrical Manufacturers Association (NEMA) as 100 times the maximum deviation of the line voltage from the average voltage on a three-phase system divided by the average voltage. So the unbalance is calculated using the following formula Voltage

$$\text{Unbalance} = (100\times\text{max deviation from average voltage})/\text{average voltage} \quad (4.2)$$

For the measured voltages at 20:13 PM on 29/7/2009,

V1= 232.33V , V2= 231.32V , V3= 232.87V

Average voltage = 232.17V

$|\Delta V1| = 0.16V$, $|\Delta V2| = 0.85V$, $|\Delta V3| = 0.7V$

Voltage unbalance = (100 × 0.85) / 232.17 = 0.37%

The obtained results are illustrated in table (4.2), (appendix A-2),

Table (4.2): voltage unbalance at Al-Badan well pump motor

Maximum voltage unbalance	Minimum voltage unbalance
0.43%	0.33%

The percentage of the unbalance is small and less than 0.5% which is within the recommended values. So this factor will have no effect on the efficiency and the energy consumption of the motor.

Motor loading

The loading of Al-Badan well pump motor at any moment could be found by dividing the input power to the motor in KW by input power at full rated load in KW.

For the measured data at 14:13 PM on 28/7/2009,

Pin= 277.9 kW

The value of efficiency of the motor was equal to η_{fl} =0.95 after consulting the catalog of the motor manufacturer.

Using equation (2.2) to calculate input power

$P_{fl} = (hp_{(M)} \times 0.746) / \eta_{fl} = (600 \times 0.746) / 0.95 = 471.15$ kW

Using equation (2.1) to calculate loading

Loading % = $(P_{in} / P_{fl}) \times 100\% = (277.9/471.15) \times 100\%$

$= 59\%$

During period of investigation, the computed value of loading was found to be nearly constant at 59% (appendix A-3).

This result is considered to be good, as taking into account the high rating of the motor, the range of high efficiency of the motor will extend to less than half load. . So loading of the investigated motor will have no effect on the efficiency and the energy consumption of the motor.

Replacing conventional (standard) motors with high efficiency motors

For the case of Al-Badan well pump

The power rating = (600hp)

The comparable high efficient motor has an efficiency equals to

$\eta_{HEM} = 0.962$

The installed (standard) motor efficiency = $\eta_{STD} = 0.95$

Loading of the motor = 0.59

Energy consumed / year = 2084211 kWh (from Nablus municipality)

Using equation (2.4) to compute power reduction,

Power reduction ΔP =

$$= 600 \times 0.59 \times 0.746 \times (1 / 0.95 - 1/0.962)$$

$$= 3.47 \text{ kW}$$

Using equation (2.3) to compute energy savings,

Energy Savings ΔE / year =

$$= \text{Energy consumed/year} \times 0.95 \times (1 / 0.95 - 1/0.962)$$

$$= 2084211 \times 0.95 \times (1 / 0.95 - 1/0.962)$$

$$= 25998 \text{ kWh /year}$$

Price of the saved energy = 25998 × 0.76 = 19758 NIS

Price of the comparable high efficient motor = 135686 NIS

SPBP = 135686 / 19758 = 6.9 years

This result indicates that we can't recommend changing the motor now, but the changing of the motor shall be considered in case of the need to rewind or replace the motor if it burnt or damaged.

In case of the need to replace the motor, the price of the standard comparable motor is 116719 NIS.

The difference in price between the two = 135686 – 116719 =18967 NIS

SPBP = 18967 / 19758 ≈ 1 year (immediately recommended)

In case of the need to rewind the motor, the average cost of rewinding the motor is approximately

Cost of rewinding the motor = 600 hp × 100 NIS/hp

= 60000 NIS

The difference between the price of the high efficient motor and the rewinding cost =

= 135686 – 60000 =75686 NIS

SPBP = 75686 / 19758 ≈ 3.8 year (replace now)

We compute the power and energy saved by replacing all well pump motors with high efficient motors from the data supplied by the municipality concerning energy consumption and the results are in table (4.3).

Table (4.3): Energy saved by replacing well pump motors by high efficient motor (HEM)*

Name of pumping station	Symbol of motor	Motor rating (hp)	Annual motor consumption (kWh)	Existing motor efficiency η_{STD}	Efficiency of HEM η_{HEM}	Saved Demand (kW)	Saved Energy (kWh)
Badan	BA.W1	600	2084211	0.95	0.962	3.5	25998
Far'a	FA.W1	500	1140000	0.945	0.962	4.2	20146
Deir Sharaf	DS.W1	400	1558462	0.936	0.958	4.4	35789
Audala	AU.W1	500	1321463	0.95	0.962	2.9	16484

***Data computed with assumed loading of 0.6 for all motors as Badan well motor.**

The cost effectiveness for well pump motor replacement with high efficient motors is shown in table (4.4)

Table (4.4): Cost-effectiveness analysis of replacing existing motor well pumps with high efficient motors

Name of pumping station	Symbol of motor	Saved Energy (kWh/year)	Saving in Elect. Bill (NIS/year)	Investment Price of high efficient motor (NIS)	SPPB (years)	Recommendation
Badan	BA.W1	25998	19759	135686	6.9	Replace when burnt
Far'a	FA.W1	20146	15311	103961	6.8	Replace when burnt
Deir Sharaf	DS.W1	35789	27200	91564	3.4	Replace now
Audala	AU.W1	16484	12528	103961	8.3	Replace when burnt

The results indicates that the SPBP of Deir Sharaf pump motor is nearly 3.4 years, which mean that it is an average cost opportunity, so it must be evaluated thoroughly because it may be better to replace it.

Power factor correction

The power factor penalties imposed by the IEC on electricity consumers are and which is planned to be imposed on consumers in Palestine are according to table (4.5)

Table (4.5): Power factor proposed penalties in Palestine

Power Factor value	Penalty
92% or more	None
Less than 92% to 80%	1% of the total bill for every 0.01 of power factor less than 92%
Less than 80% to 70%	1.25% of the total bill for every 0.01 0f power factor less than 92%
Less than 70%	1.5% of the total bill for every 0.01 of power factor less than 92%

The power factor of the Al-Badan well pump motor was measured by the energy analyzer to be nearly 0.8. The rating of the capacitors required to raise the power factor to 0.92 was computed from the measured data.

During the inspection period the loading was almost constant and the power factor of the motor was nearly constant. The values of the PF and the required rating of the capacitor bank to raise the power factor to 0.92 are shown in table (4.6), (appendix A-3).

Table (4.6): Values of power factor and rating of capacitors required to correct power factor to 0.92 for Badan motor pump.

PF(minimum)	Qc (kVAR)
0.79	98.24
PF(maximum)	Qc (kVAR)
0.82	78.96

As the power factor is nearly constant (about 0.8), it is suggested to connect a constant capacitor bank of 100 kVAR.The new power factor of the motor is calculated after connecting the fixed 100 kVAR bank, and it is found that the power factor will be in the range of 0.92 – 0.94 all the time which is acceptable.

The cost of capacitor bank = 320 $ =1200 NIS

The cost of additional accessories = 100 $ = 375 NIS

Total cost of installing capacitors = 420 $ = 1575NIS

The avoided penalty by installing the capacitor bank is as follows:

Avoided penalties =
= 1 × (Improved power factor – Old power factor) ×
Electricity consumption (kWh/year) × cost of kWh (4.3)

$$=1 \times (0.92 - 0.8) \times 2084211 \times 0.76$$

$$= 190080 \text{ NIS}$$

SPBP = 3 days

4.3 Energy Auditing in booster Pumps

These pumps draw the water at the surface level that was drawn from underground wells by well pumps to the storage tanks inside the city. For each well pump mentioned above, there is an associated booster pump, except Al Far'a well pump which has an associated two booster pumps, one to draw water from Far'a to Al Badan, and the other draw water from Al Badan to Ein Dafna storage tank in Nablus. So we have five booster pumps Al-Badan booster pump (600hp), Audala booster pump (200hp), Far'a booster pump to Al-Badan (200hp) and Far'a booster pump from Al-Badan (500hp) and Deir-Sharaf booster pump (200hp). The energy consumed by booster pumps annually reaches 5,699,237 kWh.

These pumps resemble well pumps in the fact that they have constant loading since both the flow rate of water and the head of the pump are constant.

Case study

Al-Badan booster pump was taken as a case study for booster pumps. The pump motor operation was investigated for the operating conditions that were studied in the case of well pumps in addition to investigating the mechanical efficiency of the pump.

Motor voltage levels

The nameplate of Al-Badan booster pump 3 phase induction motor, appendix (B-2),

HORSEPOWER	600	**MOTOR RPM**	1485	**PHASE**	3		**NOM.EFF**	__
FREQUENCY	50	**AMPS**	809	**AT**	380**V**		**S.F**	**1.15**

The same procedure that was used with well pump was used with this pump, and the results are shown in table (4.7), and appendix (A-4).

Table (4.7): Maximum voltage deviation for the three phases (from nameplate values) at Al-Badan booster pump motor

	ΔV1	**ΔV2**	**ΔV3**
Deviation at maximum voltage level	+8.68%	+9.67%	+9.84%
Deviation at minimum voltage level	+2.64%	+3.88%	+3.72%

The results indicate a deviation of supply voltages from nameplate voltages of the motor in the rising direction. This will have some effect on efficiency and energy consumption during periods when the deviation is more than 5%. In general it is recommended decrease the voltage levels by not more than 5% by adjusting the tap changer at the supplying transformer.

Supply phase unbalance

The supply phase unbalance for this booster was analyzed and the results are illustrated in table (4.8), and appendix (A-5).

Table (4.8): voltage unbalance at Al-Badan well booster motor

Maximum voltage unbalance	**Minimum voltage unbalance**
0.76%	0.65%

The percentage of the unbalance is also small and less than 1% which is within the recommended values. So this factor will have no effect on the efficiency and the energy consumption of the motor.

Motor loading

The results that was obtained from audited data concerning the loading of Al Badan booster pump motor indicates that during the period of investigation, the computed value of loading was found to be nearly constant at 0.62%, (appendix A-6). This result is considered to be good and will have no effect on the efficiency and the energy consumption of the motor.

Replacing conventional (standard) motors with high efficiency motors

The energy saved by replacing all booster pump motors from the data supplied by the municipality concerning energy consumption and the results are in table (4.9).

Table (4.9): Energy saved by replacing booster pump motors by high efficient motor (HEM)

Name of pumping station	Symbol of motor	Motor rating (hp)	Annual motor consumption (kWh)	Existing motor efficiency η_{STD}	Efficiency of HEM η_{HEM}	Saved Demand (kW)	Saved Energy (kWh)
Badan	BA.B1	500	2259474	0.95	0.962	3.0	28185
Far'a	FA.B1	200	535714	0.924	0.958	3.6	19013
Far'a	FA.B11	500	1925368	0.95	0.962	3.0	24017
Deir Sharaf	DS.B1	200	978681	0.924	0.958	3.6	34734
Audala	AU.B1	200	----	0.95	0.958	0.8	0

***data computed with assumed loading of 0.62 for all motors as Badan booster motor.**

The cost effectiveness for motor replacement with high efficient motors is shown in table (4.10).

Table (4.10): Cost-effectiveness analysis of replacing existing motor booster pumps with high efficient motors

Name of pumping station	Symbol of motor	Saved Energy (kWh/year)	Saving in Elect. Bill (NIS/year)	Investment Price of high efficient motor (NIS)	SPPB (years)	Recommendation
Badan	BA.B1	28185	21420	103961	4.9	Consider replacement
Far'a	FA.B1	19013	14450	36818	2.5	Replace now
Far'a	FA.B11	24017	18253	103961	5.7	Replace when burnt
Deir Sharaf	DS.B1	34734	26398	36818	1.4	Replace now
Audala*	AU.B1	0	0	36818		

*** seldom works**

The results indicate that the SPBP of Deir Sharaf booster pumps motor SPBP is 1.4 years, which mean that it must be replaced now. Far'a booster motor (FA.B1) is considered as an average cost opportunity and it must be evaluated and considers replacing it by high efficient motor.

Power factor correction

The results obtained from the energy analyzer indicate that the loading was almost constant and the power factor of the motor was nearly constant at about 0.9. The values of the PF and the required rating of the capacitor bank to raise the power factor to 0.92 are shown in table (4.11), (appendix A-6).

Table (4.11): Values of power factor and rating of capacitors required to correct power factor to 0.92 for Al Badan booster pump motor

PF(minimum)	Qc (kVAR)
0.89	13.88
PF(maximum)	Qc (kVAR)
0.9	17.51

As the power factor is nearly constant (about 0.9), it is suggested to connect a constant capacitor bank of 25 kVAR.

The new power factor of the motor is calculated after connecting the fixed 20 kVAR bank, and it is found that the power factor will be in the range of 0.93 all the time which is acceptable.

The cost of capacitor bank = 300 NIS

The cost of additional accessories = 200 NIS

Total cost of installing capacitors = 500 NIS

The avoided penalty by installing the capacitor bank are computed using equation (4.3)

$$=1.0 \times (0.92 - 0.9) \times 2259474 \times 0.76$$

$$= 34344 \text{ NIS}$$

SPBP = 5.3 days

Estimating mechanical efficiency of the pump

To evaluate the mechanical efficiency of the pump, in addition to the electrical variables of the pump that the energy analyzer gives us like power and current etc, we measured the pressure of water at the inlet of the pump Pr_i, the pressure of water at the outlet of the pump Pr_o, flow rate of water Q, temperature of the inlet water T_1, temperature of the outlet water T_2.

The mechanical power delivered to the liquid is given by the following formula (if there is small difference between T_1 and T_2)

$P_f = Q \times (Pr_o - Pr_i) / 36$ [15] (4.4)

Where

P_f = the power that has been given to the liquid, kW

Pr_o = fluid outlet pressure, bar

Pr_i = fluid inlet pressure, bar

Q = flow rate, tone/h

If the efficiency of the motor is η_m, and efficiency of the pump η_p,

Then η_{mp} : efficiency of motor – pump(wire to water) will equal

$\eta_{mp} = P_f / P_e$ (4.5)

where

P_f = the power that has been imparted to the liquid, kW.

P_e = pump input electrical power, kW.

From the data measured we have for example at 30/07/09 11:13,

P_e =295.28 kW , Pr_o = 40.5 bar, Pr_i = 3.5 bar,

$Q = 175.54\ m^3/h \approx 175.54$ tone/h

$$P_f = Q \times (Pr_o - Pr_i) / 36 = 175.54 \times (40.5 - 3.5) /36$$

$$= 180.42\ kW$$

$$\eta_{mp} = P_f / P_e = 180.42 / 295.28 = 0.61$$

The wire to fluid η_{mp} was computed for all the data measured during the inspection period and the complete results in (appendix A-7) shows that the value of η_{mp} is nearly constant around 60.6%. The classification of acceptable overall efficiencies of pumping plants is shown in the table (4.12), [20].

Table (4.12): Typical overall pumping plant efficiency Classifications [20]

Motor HP	Low	Fair	Good	Excellent
3-7.5	<44.0	44-49.9	50-54.9	>54.9
10	<46.0	46-52.9	53-57.9	>57.9
15	<47.1	48-53.9	54-59.9	>59.9
20-25	<48.0	50-56.9	57-60.9	>60.9
30-50	<52.1	52.1-58.9	59-61.9	>61.9
60-75	<56.0	56-60.9	61-65.9	>65.9
100	<57.3	57.3-62.9	63-66.9	>66.9
150	<58.1	58.1-63.4	63.5-68.9	>68.9
200	<59.1	59.1-63.8	63.9-69.4	>69.4
250	<59.1	59.1-63.8	63.9-69.4	>69.4
300	<60.0	60-64.0	64.1-69.9	>69.9

The table indicates that as rating of motor increases, overall efficiency must increase. So we conclude that the overall efficiency we have for Al Badan booster (500hp) which equal to 60.6% will be considered low and actions must be taken to increase this efficiency to 68% as an intermediate value. These actions include repairing or maintaining the mechanical part of the pump.

Energy saved by increasing overall efficiency to 68%

$$\Delta E = E_{(NOW)} \times \eta_{(OLD)} \left(1/\eta_{(OLD)} - 1/\eta_{(NEW)} \right) \qquad (4.6)$$

$\Delta E = 2259474 \times 0.606\ (1/0.606 - 1/0.68)$

$= 245884$ kWh.

Money saved by increasing pump efficiency =

$= 245884 \times 0.76 = 186872$ NIS

4.4 Energy Auditing in distribution Pumps

These pumps draw water from water tanks (reservoirs) distributed in Nablus city and pump it to water consumers like homes, factories……etc. The number of these pumps reaches 23 and the ratings of the motors driving these pumps are smaller than those used in well and booster pumps. These ratings range from 50 to 300hp with an annual electrical energy consumed reaches 6,739,468 kWh. Distribution pumps are characterized by variable loading since the water flow is variable because it depends on consumers demand and consequently the head of the pump is variable during operation to pump water to the same area. The system curve that the pumps work on is also variable as we have various topographical natures for each pump.

Case study

Al Juneid distribution pump was taken as a case study for distribution pumps. The pump motor operation was investigated for the major operating conditions that were studied in the case of well and booster pumps in addition to investigating the effect of using variable speed drives (VSD's) to control operation of distribution pumps on energy consumption of the pump.

Al Juneid distribution pump was operated until 31/8/2009 on a standard motor with the following nameplate values, appendix (B-3),

HORSEPOWER	225	**MOTOR RPM**	1475	**PHASE**	3	**NOM.EFF**	**0.93**
FREQUENCY	50	**AMPS**	298	**AT**	400**V**	**S.F**	**1.15**

Then the motor was replaced by an energy efficient inverter duty motor with the following nameplate values, appendix (B-4),

HORSEPOWER	250	**MOTOR RPM**	1495	**PHASE**	3	**NOM.EFF**	**0.958**
FREQUENCY	50	**AMPS**	318	**AT**	400**V**	**S.F**	**1.15**

The pumping station was operated on this motor for nearly 20 days without VSD control. Then the motor was operated with VSD control. Data concerning energy consumption of the motor was collected during all three periods for the purpose of analysis and comparison.

Motor voltage levels

The same procedure used previously was used with this pump, and the results are shown in table (4.13), appendix (A-8).

Table (4.13): Maximum voltage deviation for the three phases (from nameplate values) at Al Juneid distribution pump motor

	ΔV1	**ΔV2**	**ΔV3**
Deviation at maximum voltage level	+3.52%	+3.78%	+3.57%
Deviation at minimum voltage level	+2.04%	+2.3%	+1.7%

The results indicate a deviation of supply voltages from nameplate voltages within the standard conditions. So the motor work within standard conditions (ΔV < +5%), and supply voltage variations has no effect on efficiency and energy consumption of the motor.

Supply phase unbalance

The results for supply phase unbalance analysis for this distribution pump are illustrated in table (4.14), appendix (A-9).

Table (4.14): Voltage unbalance at Al Juneid distribution pump motor

Maximum voltage unbalance	**Minimum voltage unbalance**
0.38%	0.14%

The percentage of the unbalance is also small and less than 0.5% which is within the recommended values. So this factor will have no effect on the efficiency and the energy consumption of the motor.

Motor loading

The loading of this motor was found to range from 0.92 – 1(the data was measured on the old 225hp motor), appendix (A-10). This means that the motor is working at full load. The efficiency of the motor will be the full load efficiency. The result has no adverse effect on efficiency or energy consumption of the motor. But this means that if this motor is to be installed again, it must be observed as not to become overloaded. The new motor that was installed has a slightly bigger rating (250hp) which has a more suitable rating to the load.

Replacing conventional (standard) motors with high efficiency motors

The energy saved by replacing all distribution pumps motors from the data supplied by the municipality concerning energy consumption and the results are in table (4.15).

Table (4.15): Energy saved by replacing distribution pump motors by high efficient motor (HEM)*

Name of pumping station	Symbol of motor	Motor rating (HP)	Annual motor consumption (kWh)	Existing motor efficiency η_{STD}	Efficiency of HEM η_{HEM}	Saved Demand (kW)	Saved Energy (kWh)
Ein Dafna	ED.B1	200	493903	0.945	0.958	1.7	6702
Ein Dafna	ED.B2	300	1082016	0.95	0.958	1.6	9036
Ein Dafna	ED.B3	300	647873	0.945	0.958	2.6	8792
New Reservoir	NR.B1	300	898105	0.95	0.958	1.6	7500
New Reservoir	NR.B2	300	541587	0.945	0.958	2.6	7349
Ein Beit Elma	EB.B1	300	35657	0.945	0.958	2.6	484
Ein Beit Elma	EBN.B1	300	996903	0.945	0.958	2.6	13528
Ein Beit Elma	EBN.B2	200	449550	0.945	0.958	1.7	6100
Ein Beit Elma	EBN.B3	100	78430	0.93	0.954	1.6	1973
Ein Beit Elma	EBN.B4	100	82376	0.93	0.954	1.6	2072
Ras El Ein	RE.B1	125	282182	0.924	0.954	2.5	8874
Ras El Ein	RE.B2	200	13000	0.936	0.958	2.9	299
Ein Al Asal	EA.B1	50	57020	0.91	0.945	1.2	2112
Aljanoobi	HJN.B1	200	415355	0.924	0.958	4.6	14741
Aljanoobi	HJN.B2	85	51868	0.902	0.95	2.8	2621
Alshamali	HS.B1	125	154645	0.93	0.954	2.0	3890
Alshamali	HS.B2	75	2774	0.917	0.95	1.7	96
Al Qaryon	QR.B1	50	137455	0.902	0.945	1.5	6255
Al Qaryon	QR.B2	38	0	0.895	0.941	1.2	0
Al Qaryon	QR.B3	80	19786	0.917	0.95	1.8	687
Alsumara	SM.B1	175	338693	0.925	0.958	3.9	11667
Alsumara	SM.B2	125	25394	0.93	0.954	2.0	639
Aljuneid	JD.B1	225	362008	0.93	0.958	4.2	10581

***data computed with assumed loading of 0.8 for all motors.**

The cost effectiveness for motor replacement with high efficient motors is shown in table (4.16).

Table (4.16): Cost-effectiveness analysis of replacing existing motor distribution pumps with high efficient motors

Name of pumping station	Symbol of motor	Saved Energy (kWh/year)	Saving in Elect. Bill (NIS/year)	Investment Price of high efficient motor (NIS)	SPPB (years)	Recommendation
Ein Dafna	ED.B1	6702	5094	36818	7.2	Replace when burnt
Ein Dafna	ED.B2	9036	6867	74738	10.9	Replace when burnt
Ein Dafna	ED.B3	8792	6682	74738	11.2	Replace when burnt
New Reservoir	NR.B1	7500	5700	74738	13.1	Replace when burnt
New Reservoir	NR.B2	7349	5585	74738	13.4	Replace when burnt
Ein Beit Elma	EB.B1	484	368	74738	203.2	Replace when burnt
Ein Beit Elma	EBN.B1	13528	10281	74738	7.3	Replace when burnt
Ein Beit Elma	EBN.B2	6100	4636	36818	7.9	Replace when burnt
Ein Beit Elma	EBN.B3	1973	1500	18690	12.5	Replace when burnt
Ein Beit Elma	EBN.B4	2072	1575	18690	11.9	Replace when burnt
Ras El Ein	RE.B1	8874	6744	22579	3.3	Replace now
Ras El Ein	RE.B2	299	227	36818	162.3	Replace when burnt
Ein Al Asal	EA.B1	2112	1605	10980	6.8	Replace when burnt
Aljanoobi	HJN.B1	14741	11203	36818	3.3	Replace now
Aljanoobi	HJN.B2	2621	1992	18690	9.4	Replace when burnt
Alshamali	HS.B1	3890	2957	22579	7.6	Replace when burnt
Alshamali	HS.B2	96	73	14798	202.0	Replace when burnt
Al Qaryon	QR.B1	6255	4753	10980	2.3	Replace now
Al Qaryon*	QR.B2	0	0	9255		
Al Qaryon	QR.B3	687	522	18690	35.8	Replace when burnt
Alsumara	SM.B1	11667	8867	36818	4.2	Replace now
Alsumara	SM.B2	639	486	22579	46.5	Replace when burnt
Aljuneid	JD.B1	10581	8041	36818	4.6	Replace now

*** Seldom operated**

The results indicate that the SPBP of some pumps is very large because the motors installed have high efficiency or the power consumed is small (operating hours per year are small) . Where other pump motors SPBP is less than 5 years, which is considered as an average cost opportunity and it must be evaluated thoroughly and are candidates for replacing them by high efficient motors.

Power factor correction

The measured power factor of the motor was nearly constant (about 0.85). The values of the PF and the required rating of the capacitor bank to raise the power factor to 0.92 are shown in table (4.17), appendix (A-10).

Table (4.17): Values of power factor and rating of capacitors required to correct power factor to 0.92 for Al Juneid distribution pump motor

PF(minimum)	Qc (kVAR)
0.84	36.58
PF(maximum)	Qc (kVAR)
0.85	33.83

As the power factor is nearly constant (about 0.85), it is suggested to connect a constant capacitor bank of 40 kVAR.

The new power factor of the motor is calculated after connecting the fixed 40 kVAR bank, and it is found that the power factor will be in the range of 0.93 all the time which is acceptable.

The cost of capacitor bank = 600 NIS

The cost of additional accessories = 270 NIS

Total cost of installing capacitors = 870 NIS

The avoided penalty by installing the capacitor bank are computed using equation (4.3)

$$=1.0 \times (0.92 - 0.85) \times 362008 \times 0.76$$

$$= 19259 \text{ NIS}$$

SPBP = 16.5 days

Using VSD to control pump operation

The effect of using VSD to control pump operation on energy saving was studied at Al Juneid pumping station. Energy consumption of the pump was measured in three operating schemes of the pump, appendix (A-11), the results were as follows

1- From 5/7/2009 to 31/8/2009 the pump was driven by the old standard efficiency motor, the pump draws 72460 m^3 with a total energy consumption of 60220 kWh. The specific energy consumption per m^3 is 0.83 kWh/m^3.

2- From 31/8/2009 to 15/9/2009 the pump was driven by energy efficient motor without VSD control, the pump draws 16090 m^3 with a total energy consumption of 12640 kWh. The specific energy consumption per m^3 is 0.79 kWh/m^3.

3- 18/9/2009 to 3/1/2010 the pump was driven by energy efficient motor with VSD control, the pump draws 105330 m^3 with a total energy consumption of 102900 kWh. The specific energy consumption per m^3 is 0.98 kWh/ m^3.

Table (4.18) summarizes the results above

Table (4.18): specific energy consumption of Al Juneid pumping station with different operating schemes

	Water pumped m^3	**Energy consumed kWh**	**Specific energy kWh/m^3**
Pump works with old Standard motor	72460	60220	0.83
Pump works with energy efficient Motor without VSD control	16090	12640	0.79
Pump works with energy efficient Motor with VSD control	105330	102900	0.98

From the results above it is obvious that the current operating scheme with VSD control is the least efficient energy scheme, and the more efficient energy operating scheme is to operate a high efficient motor without VSD control.

This may seem contrary to the wide spread idea that VSD control of pump operation will save energy. This result can be attributed to the following reasons:

1- Nablus is mountainous city, so the system curve of Nablus will have a high static head. This high static head as explained in chapter 3 will cause the operating point of the pump to move to a lower efficiency point as the VSD lowers the speed of pump to control the flow or the head of the pump.

2- The VSD is an electronic device that has efficiency of 95% to 97%, so adding the VSD to the system will decrease the overall system efficiency. And unless the VSD operation will add significant energy savings, the overall system will suffer from a decrease in efficiency.

So the decision to use VSD control on pumps in Nablus city has to be considered case by case.

4.5 Summary

* Further detailed audits are needed concerning measuring the mechanical efficiency of the pumps, as our audit concerning the efficiency of Al-Badan booster pump revealed an energy saving opportunity of 245884 kWh/year, which represent about 11% of the total annual energy consumption of this pump.

* The energy saving opportunity in using VSD control in pumps must be evaluated on case by case. The audit at Al Juneid pumping station revealed wasting of energy by using of VSD to control pump operation.

* Table (4.19) shows the energy and power saved for each motor with a SPBP less than five years, in addition to the total energy and power saved.

Table (4.19): Energy and power saved for each motor with a SPBP less than five years

Name of pumping station	Symbol of motor	Saved Energy (kWh/year)	Saved Power (kW)	Saving in Elect. Bill (NIS/year)	Investment price of high efficient motor (NIS)	SPBP (years)
Deir Sharaf	DS.W1	35789	4.4	27200	91564	3.4
Badan	BA.B1	28185	3.0	21420	103961	4.9
Far'a	FA.B1	19013	3.6	14450	36818	2.5
Deir Sharaf	DS.B1	34734	3.6	26398	36818	1.4
Ras El Ein	RE.B1	8874	2.5	6744	22579	3.3
Aljanoobi	HJN.B1	14741	4.6	11203	36818	3.3
Al Qaryon	QR.B1	6255	1.5	4753	10980	2.3
Alsumara	SM.B1	11667	3.9	8867	36818	4.2
Aljuneid	JD.B1	10581	4.2	8041	36818	4.6
Total		169838	31.3	129077	413171	3.2

CHAPTER FIVE

ENERGY AUDITS IN STREET LIGHTING SECTOR IN NABLUS ELECTRICAL NETWORK

CHAPTER FIVE

ENERGY AUDITS IN STREET LIGHTING SECTOR IN NABLUS ELECTRICAL NETWORK

5.1 Introduction

Municipalities install street lighting for several reasons. These reasons include increasing feel of safety and security; reduce vehicular accidents, and other commercial and aesthetic reasons. Effective energy use in street lighting includes using efficient lamp technologies, good control systems and efficient designs concerning fixture photometrics and other factors concerned with the purpose of street lighting at the specific location.

5.2 Energy conservation opportunities investigated by removing of lamps

The illumination level was measured in different locations in the city and the illumination level was compared with standard illumination levels

Table (5.1) illustrates the measured illumination levels at various locations in Nablus city.

Table (5.1): Measured illumination levels at various locations in Nablus city

Category	Area name	Measured values (lux)	Average (lux)
Main commercial Areas	Commercial center	58.8,82,76,74,71	69.7
	Aldawar & Nablus center	72,72,75,63,72,74,63	70.14
	Sofian street	40,42,32	38
Main streets	Alwatani hospital	26.5,35.5,32	31.33
	Haj-nimr mosque	40,32,12, 13	24
local streets	Bilaybos al awsat	9.5,11,8.7,9	9.55
	Alsika street	9.4,8.7,7.1,10.5	8.92
	Aseara street	8,7,14,11,17	11.4

The recommended illumination levels for outdoor and street lighting are shown in table (5.2).

Table (5.2): Recommended illumination levels for outdoor and street lighting.

Category	Average luminous intensity (lux)
Commercial Areas	22-130 *
Main street	22 §
local street	10 §

*** Reference [21].**

§ Reference [22].

Comparing the recommended illumination levels with those measured at different locations in Nablus city, we conclude the following:

- The illumination levels at the main commercial centers can be considered within the standard illumination levels. Generally, increased illumination is provided in shopping areas for decorative reasons and to make the use of these areas more appealing and to increase the perception of safety.

- The illumination levels in main and local streets are also within the standard illumination levels. The need for increased illumination at certain junctions and sectors in the streets is applied by the municipality.

So number of lamps is not recommended to be reduced as this will decrease the acceptable illumination level.

5.3 Energy conservation opportunities investigated by replacement of low efficient lamps with high efficient lamps

The lighting fixtures installed for lighting streets in Nablus electrical network are shown in table (5.3).

Table (5.3): Lighting fixtures installed for lighting streets in Nablus electrical network.

Type of fixture	Power (W)	Number
Mercury vapour	100W	17
	125W	1454
	160W	7
High pressure sodium	70W	53
	100W	1749
	250W	2323
	400W	71
Metal halide	400W	45
	1000W	30
	1500W	8
CFL	23W	44

The low efficient mercury lamps were suggested to be replaced by with the high efficient high pressure sodium lamps. Then the saving per year and S.P.B.P was computed as shown in the following table (5.4).

Table (5.4): Economical comparison between 150W mercury lamp and 70W HPS lamp.

	Mercury lamp	**High pressure sodium lamp**
Price (NIS)	150	300
Power (W)	125	70
Efficacy (lm/W)	30 - 60	80 - 140
Lumen output	6000≈	≈ 6000
Life cycle(hour)	Av.24000h	+ 24000h
Energy consumption (kWh/24000h)	(125×24000)/1000 = 3000	(70×24000)/1000 1680
Cost of energy(NIS)	3000×0.76=2280	1680×0.76=1276.8
Total cost / 24000h	2280+150=2430	1276.8+300=1576.8
Saving/ 24000h (NIS)		2430 -1576.8=853.2

If we replace all the low efficient mercury lamps with the high efficient high pressure sodium lamps, savings in power and energy accomplished will be as shown in table (5.5).

Table (5.5): Saving in power and energy by replacing mercury lamps by high pressure sodium lamps in Nablus street lighting sector.

	Existing lamps			Suggested lamps		
	type	P (W)	NO.	type	P (W)	NO.
Item	mercury	125	1454	HPS	70	1454
Power(total) (kW)	181.75			101.78		
Power saving (ΔP) (kW)	181.75 – 101.78 = 79.97kW					
Energy(total) kWh/4000h(year)	181.75 × 4000 = 727000			101.78 × 4000 = 407120		
Energy saving (ΔE) (kWh)/year				727000 – 407120 = 319880		
Money saving /year (NIS)				319880 × 0.76 = 243109		
Investment cost (NIS)				300×1454 = 436200		
SPBP =(Cost /savings/year) (year)				436200/243109= 1.79 year		

5.4 Energy conservation opportunities investigated in using better control systems

Controlling of street lighting lamps is usually accomplished usually by one of the following controllers:

1- Photocell switching: photo sensors operate by sensing the quantity of light in an area and switching on or off the lighting lamps. The least expensive type of photocell uses cadmium-sulfide light dependent resistors (LDR) cells that degrade from exposure to sunlight and lose sensitivity after being in service for a few years. The switch off illuminance of these devices is some 3-5 times than switch on illuminance which is 30-60 lux. This loss of sensitivity adds to the operating time of the lamps each day when compared with newer electronic types which depends on solid state light sensors, like photo diodes and photo transistors.

2- Time controls (or time controls combined with photocell switching) which is more preferred as the dusk and dawn times are variable through the year. This arrangement also solves the problem of added on time due to loss of sensitivity of the photocells and add other control option such as turning off lights after midnight for example.

3- Smart (intelligent) street lighting controls: These systems are programmable and automatically react to external factors, such as traffic density, road conditions and the weather. For example, the level of lighting can be increased when there are a lot of cars traveling on a specific stretch of road. It is also possible to dim the lighting at night when fewer cars or other road users are on the roads. This new technology is highly energy-efficient and therefore also cost-efficient as it provides light when and where it is needed most.

The time of switching on and switching off of the street lights in Nablus city was watched, and the result was that there is a bad control system that controls the operation of street lights.

The survey was conducted on 17/1/2010 in the early morning. This day has a Sunrise time: 6:38 AM, and a Sunset time: 5:03 AM, the sky was clear with no clouds.

At 6:10 AM the natural illumination level was 9 lux and because of the uniformity of this illumination, it can be considered as sufficient level. But until this level of illumination all lamps in the city were on. All the lamps continued to be on until 6:27 AM when the first few lamps go off at an illumination level of 60 luxs. But the high majority of the lamps continued to be on at 6:48 with an illumination level of 983 luxs. More than half of the lamps still to be on at 7:00 AM although the illumination was more than 1800 luxes, and some continued to be on until 7:15 AM although the illumination level reached 2930 luxs.

The lamps were watched at the end of the day also. It was observed that the lamps go on at 4:51PM, although the illumination level was 159 lux although the illumination reached 11 lux at 5:15.

So we can conclude that we have at least a total of one hour operation wasted. From the above table of fixtures installed:

kW (of all lamps) = 1033.34 kW

kWh Savings/day = 1033.34 kWh

kWh Savings/year = 1033.34 × 365 = 377,169 kWh.

Money saving from replacing photocells/year =

= 377169 × 0.76

= 286648 NIS

Total number of photocells = 340

Cost of new effective photocell = 80 NIS

Investment = cost of total photocells = 340 × 80 = 27200 NIS

SPBP = Investment/(saving/year) = 27200/286648 = 0.1 year

5.5 Energy conservation opportunities investigated in partial Night Street Lighting

At least one half, and perhaps more of Nablus streetlights do not serve a public safety need in the late night/early morning hours, when pedestrian traffic is nonexistent and vehicular traffic volume is tremendously reduced. Streetlights suitable for partial night lighting could be identified, and electronic photocells with timer capable of turning off the specified streetlight at specific hours could be installed.

Case study

In Aseara street in Nablus city the total number of HPS 250W installed is 20 lamp 25 m apart. If a photocell with timer is installed that will shut down half of the lights from midnight to morning, so that the first stays on, the second off and so on. The additional equipment needed in addition to the existing photocell and contactor, an ABC 25mm^2 cable with two conductors is needed to be installed in addition to a timer and a contactor

Table (5.6) shows the costs and revenues of such an arrangement.

Table (5.6): Power and energy savings by implementing partial street lighting to the case study.

Total No. of lamps in the street	20
No of lamps off partially	10
Wattage of the lamp	250W
Energy consumption of all lamps/ year (kWh)	(20×250×4000)/1000 =20000
No. of hours gained(average)(hour)	5.5
Energy saving/year (kWh)	(250×10×5.5×365)/1000 = 5019
Power saved (kW)	(250 ×10)/1000 = 2.5
Percentage of energy saving	5019/20000 = 25.1%
Cost of energy saved (NIS)	5019×0.76 = 3814.4
Cost of cable (NIS)	475×5=2375
Cost of contactor (NIS)	120
Cost of timer (NIS)	120
Total cost (NIS)	2615
SPBP (cost/saving)/year	2615/3814.4 = 8.2 month

So applying partial night street lighting to all lighting fixtures on the network will yield a 25.1% energy saving. Assuming that this procedure will be applied on 80% of the lighting fixtures, as the other 20% are installed at locations that are needed to be illuminated all night period for security or other reasons.

Total lighting load = 5,127,673 kWh

Total lighting power = 1033.34 kW (using table (5.3) information)

Total power saved = $\frac{50}{100} \times \frac{80}{100} \times 1033.34$

= 413.3 kW

Energy saving by partial lighting = $\frac{25.1}{100} \times \frac{80}{100} \times 5127673$

= 1029637 kWh/year

Money saving/year = 1029637 × 0.76 = 782524 NIS

Cost of equipment = $\frac{5127673 kWh / year}{20000 kWh / 20 lamp} \times \frac{2615 NIS / 20 lamp}{1} \times 0.8$

= 536355 NIS

SPBP = Cost /(Saving/year) = 536355 / 782524

= 0.69 year

CHAPTER SIX

ENERGY AUDITS IN RESIDENTIAL SECTOR IN NABLUS ELECTRICAL NETWORK

CHAPTER SIX

ENERGY AUDITS IN RESIDENTIAL SECTOR IN NABLUS ELECTRICAL NETWORK

6.1 Introduction

Residential sector is the largest energy consuming sector in Nablus electrical network. It contributes 49.42% of the total energy consumption of the network. Implementing energy conservation measures at this sector is difficult because this sector is scattered between large different individuals and not institutionalized, the electrical equipment used have relatively small ratings and the equipment used are related with personal and everyday living of the individuals. The individual interests, economic situation and the desired level of living govern the number electrical appliances used. So this also will govern the energy consumption and decisions on energy saving. The following energy conservation measures are investigated in the residential sector.

6.2 Energy conservation opportunities investigated in replacing low efficient with high efficient refrigerators

The refrigerator forms mostly the largest load in residential sector as it consumes between 30-40% of the electrical energy consumed in the household. As indicated by a survey that was done on 15 random houses, high percentage of households still uses inefficient refrigerators. Table (6.1) shows the existing refrigerators and their energy consumption.

Table (6.1): Refrigerator models, size and energy consumption/day in the sample 15 houses.

House No.	Type	Size (Liter)	Energy consumption /day (kWh)
1	Amcor	320	2.7
2	Tadiran	440	3.5
3	XL	512	3.6
4	Metag	530	1.9
5	Sharp	455	1.67
6	Tadiran	320	2.9
7	Frigidire	375	2.7
8	Kelvinator	521	1.67
9	Amcor	440	2.9
10	LG	385	1.45
11	XL	550	3.8
12	Coldkeep	374	2.7
13	LG	320	1.3
14	Tadiran	50	4.2
15	Beko	345	1.6

Table (6.2) illustrates a comparison between low efficient and high efficient refrigerators, in which energy savings per year and S.P.B.P for replacing low efficient refrigerator by high efficient one.

Table (6.2): Comparison between low efficient and high efficient refrigerators.

	Low efficient (Old Amcor 320)	High efficient (New Beko 345)
Price (NIS)	700	2100
Energy consumption (kWh/day)	2.7	1.6
Life cycle(year)	4	14
Investment = Price difference (NIS)	2100 – 700 = 1400	
Fixed cost / year (NIS)	700/4= 175	2100/14=150
Cost of energy/year (NIS)	2.7×0.76×365=749	1.6×0.76×365=443.8
Total cost / year	175+749=924	150+443.8=593.8
Saving/ year (NIS)		924 – 593.8 = 330.2
Investment = Price difference (NIS)	2100 – 700 = 1400	
S.P.B.P	Investment/ (saving/year)	1400 / 330.2 = 4.23
Energy saving per year (kWh)		(2.7 – 1.6) × 365 = 402

The inefficient refrigerators (whose energy consumption > 2.5 kWh/day) was suggested to be replaced by an efficient new models. Then the saving per year and S.P.B.P was computed as shown in the following tables. The calculations for the suggested refrigerators are shown in the following table (6.3).

Table (6.3): Energy consumption/year and total cost/year for existing low efficient refrigerators in the sample 15 houses.

EXISTING						
House NO.	**Model**	**Size (Liter)**	**Energy consumption (kWh/day)**	**Cost (NIS)**	**Energy consumption (kWh/year)**	**Total cost/year (NIS)**
1	Amcor	320	2.7	700	986	924
2	Tadiran	440	3.5	800	1278	1171
3	XL	512	3.6	900	1314	1224
6	Tadiran	320	2.9	700	1059	979
7	Frigidire	375	2.7	700	986	924
9	Amcor	440	2.9	800	1059	1004
11	XL	550	3.8	900	1387	1279
12	Coldkeep	374	2.7	700	986	924
14	Tadiran	500	4.2	900	1533	1390
Total					10585	

The calculations for the suggested refrigerators are shown in the following table (6.4).

Table (6.4): Energy consumption/year and total cost/year for suggested high efficient refrigerators in the sample 15 houses.

SUGGESTED						
House NO.	**TYPE**	**Size Liter**	**Energy consumption (kWh/day)**	**Cost (NIS)**	**Energy consumption (kWh/day)**	**Total cost/year (NIS)**
1	Beko	345	1.6	2100	584	594
2	Samsung	440	1.6	2700	584	637
3	LG	524	1.42	4200	518	694
6	Beko	345	1.6	2100	584	594
7	Beko	375	1.6	2400	584	615
9	Samsung	440	1.6	2700	584	637
11	LG	563	1.42	4500	518	715
12	Beko	375	1.6	2400	584	615
14	LG	524	1.42	4200	518	694
Total					5059	

The economic comparison between the existed and the suggested refrigerators are shown in the table (6.5)

Table (6.5): Economic comparison between the existed and the suggested refrigerators in the sample 15 houses.

House NO.	Saving /year (NIS)	Investment (NIS)	SPBP (year)
1	330.14	1400	4.2
2	534.203	1900	3.6
3	529.732	3300	6.2
6	385.62	1400	3.6
7	308.711	1700	5.5
9	367.763	1900	5.2
11	563.783	3600	6.4
12	308.711	1700	5.5
14	696.172	3300	4.7
Total	4024.84	20200	5

The energy saving/year for the above calculation will be equal to

= energy consumption (existing inefficient ref.)(table 6.3)

─ energy consumption (suggested efficient ref.) table(6.4) (6.1)

Energy saving/year = 10585 – 5059 = 5526 kWh/year.

From the calculation, we find that we have an average of 5526 kWh of energy conserved by the 15 houses surveyed. So taking into account that we have a nearly total of 40000 residential consumers, then the expected annual energy saving

Annual energy saving: (40000/ 15) × 5526 = 14,736,000 kWh.

Of course the process that all low efficient refrigerator owners will replace their refrigerators with high efficient ones is impractical. But we suggest a project financed by the governmental or donor agencies to replace for example 3000 low efficient with high efficient refrigerators.

The project is based an awareness campaign for citizens to convince them that part of the monthly payment they pay for the price of the new high efficient refrigerator (60 NIS for example) is actually partly paid indirectly by the savings attained from energy consumption savings.

Table (6.6) illustrate saving and payments for this project

Table (6.6): Economic evaluation of the project of substituting 3000 low efficient refrigerators by high efficient refrigerators.

	High efficient refrigerators proposed	
Models proposed	Beko 345	Samsung 440
Energy consumption of efficient refrigerators (kWh/day)	1.6	1.6
Number to be replaced	1500	1500
Price of efficient refrigerators	2100	2700
Monthly payment/customer (NIS)	50	60
Number of payments needed (months)	2100/50 = 42	2700/60 = 45
Average energy consumption of replaced refrigerators (kWh/day)	2.7	3
Energy saving/day (kWh)	2.7-1.6 = 1.1	3-1.6 = 1.4
Energy saving/month (kWh)	30×1.1 = 33	30×1.4 = 42
Money saving / month(NIS)	33×0.76= 25.08	42×0.76= 31.92
Actual money paid/monthly (NIS)	50 – 25.08 = 24.92	60 – 31.92 = 28.08
Actual money paid by customer for refrigerator price (NIS)	24.92×42 = 1046.64	28.08×45 = 1263.6
Total energy saved/year (kWh)	1500×365×1.1 = 602250	1500×365×1.4 = 766500
Total Energy saved (kWh)/year	602250 + 766500 = 1,368,750	
Total money saved/year (NIS)	1368750 × 0.76 = 1040250	
Power saved (kW)	1368750/8760 = 156.25	
Cost of all refrigerators (NIS)	1500×2100 + 1500×2700 = 7,200,000	
SPBP (year)	7200000/1040250 = 6.9	

The computed SPBP represent the worst case, as the energy consumption of older models usually more than stated which gives more energy savings, no salvage prices were computed for older models, in addition to that the project has other desirable benefits to consumers that is not evaluated.

6.3 Energy conservation in the lighting system

The lighting system is considered one of main electrical loads in the residential sector. There are considerable chances for energy conservation in the field of lighting. The main one is replacing incandescent lamps (tungsten) with CFL lamps. Table (6.7) illustrate a comparison in power and energy consumption and cost between incandescent and CFL lamps.

Table (6.7): Comparison in power and energy consumption and cost between incandescent and CFL lamps

	Incandescent lamp	**CFL LAMP**
Price (NIS)	2	20
Power (W)	100	23
Life cycle(hour)	1000	10000
Energy consumption (kWh/10000h)	(100×10000)/1000 =1000	(23×10000)/1000 =230
Cost of energy(NIS)	1000×0.76=760	230×0.76=174.8
Investment/10000h (NIS)	2×10 =20	20
Total cost / 10000h	20+760=780	20+174.8=194.8
Saving/ 10000h (NIS)		780-194.8=585.2

In the survey that was done on 15 random houses, the lighting lamps installed were as indicated in table (6.8)

Table (6.8): Lighting lamps installed in the sample 15 houses.

	Incandescent Lamps			Fluorescent lamps		CFL lamps	
Home NO.	**60W**	**75W**	**100W**	**36W**	**40W**	**18W**	**23W**
1	6	5		10		2	
2		5	2	2	6		
3	3	4		8	2	3	
4	6	3		11		2	2
5	2	4	2	4	7		
6	4	3		6	4		
7		3	2	6	4		
8	7	2	1	4	4	2	3
9	3	6	2	8			
10		4	4	5	2	2	2
11	3	3	2	10			
12	2	6		6	2		
13	3	3	1	3	4	4	
14	4	5	2	7	2		
15	3	4	1	8		2	2
Total	46	60	19	98	37	17	9

Substituting the incandescent lamps with CFL lamps of the same illumination as in the following table (6.9).

Table (6.9): Substitution table of incandescent lamps with CFL lamps.

Incandescent lamp	Equivalent CFL lamp
60W	13W
75W	18W
100W	23W

The following table shows the savings in power and energy by replacing the incandescent lamps with CFL lamps in the audited homes for average operation time of 550 hours annually. The calculations for the existing incandescent lamps are shown in table (6.10).

Table (6.10): Energy calculation for the existing incandescent lamps.

Item	Type	Power (W)	No.	Total power (kW)	Energy consumption/year (kWh)
1	Incandescent	60	46	2.76	1518
2	Incandescent	75	60	4.5	2475
3	Incandescent	100	19	1.9	1045
Total				9.16	5038

The calculations for the suggested CFL lamps for the same time period is shown in table (6.11).

Table (6.11): Energy calculation for the suggested CFL lamps.

Item	Type	Power (W)	No.	Total power (kW)	Energy consumption/year (kWh)
1	CFL	13	46	0.598	328.9
2	CFL	18	60	1.08	594
3	CFL	23	19	0.437	240.35
Total			125	2.115	1163.25

Saved energy/15 houses surveyed=

= energy consumed (incand.) ─ energy consumed(CFL) (6.2)

= 5038 – 1163.25 = 3874.75 kWh annually for the 15 audited houses.

Taking into account that we have a nearly total of 40000 residential consumers, then the expected annual energy saving

Annual energy saving: (40000/ 15) × 3874.75 = 10,332,667 kWh.

Annual savings = 10,332,667 × 0.76 = 7852826.9 NIS

Investment = (20×125×40000) /15 = 6666666.7 NIS

SPBP = 6666666.7 / 7852826.9 = 0.85 year ≈ 10 months.

This energy saving will spread between all the 40000 consumers mainly during night hours and also during day hours in some houses, if we consider that we have three intervals:

1- 25% of energy saving for 10 hours from morning to after noon.

2- 67% of energy saving for 8 hours from early after noon to mid night.

3- 8% of energy conservation for 6 hours from midnight to early morning.

Then the power reduction in each interval will be (diversity factor =2.74)

$P1 = (0.25 \times 10332667) / (10 \times 365 \times 2.74) = 258$ kW

$P2 = (0.67 \times 10332667) / (8 \times 365 \times 2.74) = 865$ kW

$P3 = (0.08 \times 10332667) / (6 \times 365 \times 2.74) = 138$ kW

6.4 Energy conservation in power factor correction in the residential sector

The effects of the low power factor are previously explained in the third chapter. The average power factor can be considered in the residential sector to be equal to 0.88. To estimate the effect of raising the power factor to 0.95 on the losses of the low voltage distribution network, let us assume that we have a typical residential distribution feeder with the following characteristics:

Aluminum conductor steal- reinforced (ACSR), three phase overhead line:

$r = 0.153\ \Omega/km$, $3 \times 185\ mm^2$, 400V, $I_{(rated)} = 535A$.

Total feeder length = L = 1000m

Number of total consumers = 90 (30 consumer per phase).

Distance between individual consumers = $L_1 = L_2 = \ldots L_n = 33.3m$.

Resistance of line portion $R = R_1 = R_2 = \ldots R_n = 5.1 \times 10^{-3}\ \Omega$. (assuming the same distance between the 30 consumers/phase on the 1000m length feeder)

The feeder line is illustrated in figure (6.1).

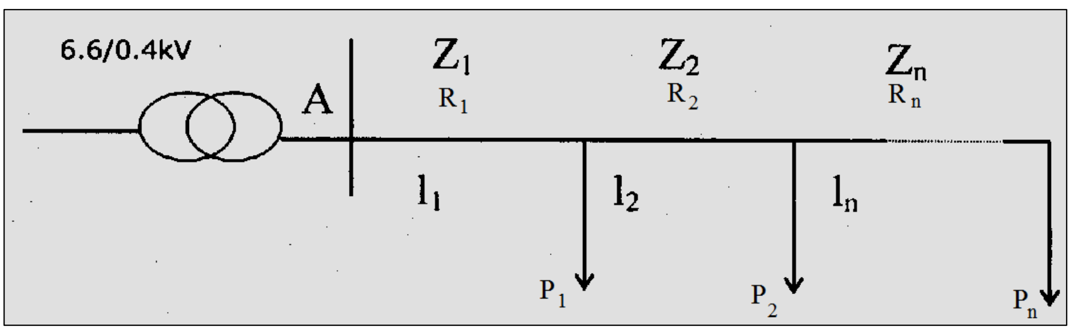

Figure (6.1): Diagram of a typical residential feeder.

The following values can be considered as real averages for this typical case

V = 230 V , $P_{max(average)}$ = 1.5 kW , cosφ =0.88 , load factor =0.6

$$\text{Load factor (LF)} = \frac{P(average)}{P(\max)} \qquad (6.3)$$

$$P(average) = \text{Load factor (LF)} \times P(\max) \qquad (6.4)$$

P(average) = 0.6 ×1500 = 900W

In this case the active power losses are given by the following equation

$$\Delta P = R\sum_{i=1}^{n}(iI)^2 \quad [23] \tag{6.5}$$

Where

$$I = \frac{P}{V\cos\varphi} \tag{6.6}$$

Then

$$\Delta P = \frac{RP^2}{V^2\cos^2\varphi}\sum_{i=1}^{n}(i)^2 \tag{6.7}$$

At power factor = 0.88, the active power losses by using equation (6.7)

$$\Delta P_1 = \frac{(5.1\times10^{-3})(900)^2}{(230)^2(0.88)^2}\sum_{i=1}^{30}(i)^2 = 953.5\text{W}$$

Improving the power factor of each household to 0.95, the total power losses in the feeder will be using equation (6.7)

$$\Delta P_2 = \frac{(5.1\times10^{-3})(900)^2}{(230)^2(0.95)^2}\sum_{i=1}^{30}(i)^2 = 818.1\text{W}$$

So the total power saving in one phase

$$\Delta P_{sav} = \Delta P_1 - \Delta P_2 \tag{6.8}$$

$$= 953.5 - 818.1 = 135.4\text{W}$$

The total power saving in the three phase is

Total $\Delta P_{sav} = 135.4 \times 3 = 406.2\text{W}$

The percentage of energy saving through improving the power factor from 0.88 to 0.95 will be

$$\% \, \Delta P_{sav} = \frac{135.4}{953.5} \times 100\% = 14.2 \, \%$$

The yearly energy consumption of the residential sector in Nablus municipality network equals to 102,231,048 kWh/year.

Average load power = 102231048 / 8760 = 11670 kW

Total supplied energy to the residential sector = Total Consumption / (1− % energy loss) (6.9)

Assuming a typical technical energy loss of 8%,

Total supplied energy = 102231048 / (100% − 8%)

to the residential sector

= 111120704 kWh

Average power (residential)

$$\text{supplied } (P_{(av)}) = \frac{111120704 \, kWh/year}{8760 \, h/year} = 12685 \text{ kW}$$

Assuming roughly that the technical energy loss will correspond to similar power loss, then power saving in residential sector in Nablus network will be equal

Power saving ΔP = (6.10)

= % ΔP (typical case above) × Total (% of losses in network) × Average power ($P_{(av)}$) in residential sector

Power saving $\Delta P = \frac{14.2}{100} \times \frac{8}{100} \times 12685 = 144$ kW

Energy losses due to residential consumption = 0.08 × Total energy supplied to the residential sector (6.11)

$= 111120704 \times 0.08 = 8889656$ kWh

If we will improve the power factor (p.f) in residential sector in Nablus electrical network, we will achieve the following energy saving,

ΔE_{saved} = Energy saving % from typical above feeder × Total energy loss (6.12)

ΔE_{saved} = 14.2 % × 8889656 =1,262,331 kWh/year

Money saving from power factor correction/year

= 1262331 kWh/year × 0.76 NIS/ kWh

= 959372 NIS/year

The needed capacitors to accomplish the power factor correction equals

$$KVAR_{(capacitors)} = P_{(Load)} (\tan\varphi_1 - \tan\varphi_2) \quad (6.13)$$

$= 11670 (0.54 - 0.33)$

= 2451 kVAR

The necessary investment to correct the power factor from 0.88 to 0.95 in the residential sector (1 kVAR costs ≈ 79.5 NIS)

Investment to correct power factor = 2451 × 79.5 = 194855 NIS

SPBP = Investment / (saving/year)

= 194855 / 959371 = 0.20 year

To correct the power factor the following measures are proposed

1- Obligation of each household owner to install compensation capacitors in fluorescent lamps.

2- Installation of proper variable capacitors at the distribution board of the residential buildings.

3- Installation of suitable sized variable capacitors at the poles supplying power to the residential premises.

6.5 Summary

Energy conservation in the residential sector is very important as it is the largest energy consuming sector. As this sector is not institutionalized, achieving valuable energy conservation needs different supportive tools. These tools include carefully designed awareness campaigns in televisions, newspaper, and internet and so on. Publicity handouts and brochures should be distributed. Energy regulations concerning efficient building design, prohibiting low efficient appliances, adopting and advertisement of energy labels for electrical apparatus is an important and vital tool in energy conservation in the residential sector.

CHAPTER SEVEN

LOAD MANAGEMENT IN NABLUS ELECTRICAL NETWORK

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LOAD MANAGEMENT IN NABLUS ELECTRICAL NETWORK

7.1 Introduction

The demand available for Nablus electrical network equals to 57MVA while the maximum demand has reached more than 57MVA. So actions have to be taken before reaching above this maximum demand so as not to reach a situation that there is a deficit in demand, and then to be obliged to cut electricity on consumers. Reaching the point of cutting electricity on consumers will affect everyday society activities in all living aspects, and has a severe impact on production levels in all sectors of the economy.

7.2 Load curves for Nablus electrical network

The loads of the power system vary by day month and season. This means that load on the system is always changing with the time and is never constant. The load curve is a curve showing the variation of the load on the power system with respect to time. If the time is a day, then we have daily load curve. We also have monthly or yearly load curves.

The daily load curve for Nablus electrical network is shown in figure (7.1)

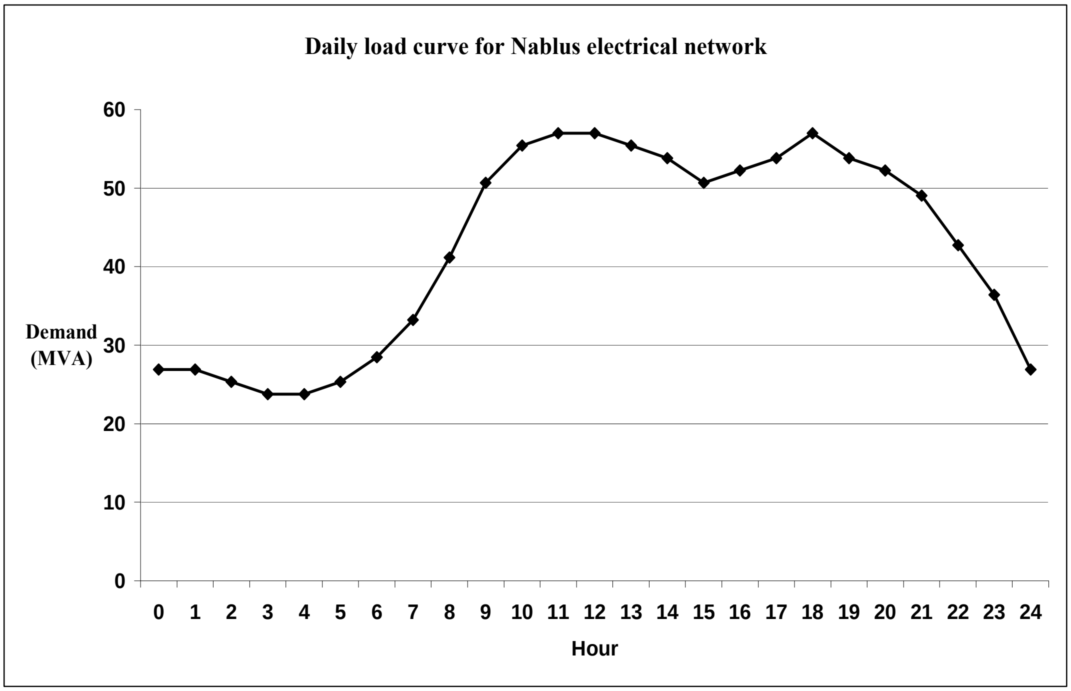

Figure (7.1): Daily load curve of Nablus electrical network.

Examining the daily load curve, we notice that we have two peaks and one valley. The peaks occur at 11- 12 am and 6 pm. The valley occurs at 3-4 am at early morning. The maximum demand is equal to 57MVA, and minimum demand equal 23.75 MVA.

The daily load factor for the network is given by the following formula

$$\text{Load factor} = \text{average load} / \text{maximum demand} \quad (7.1)$$

$$= 43 / 57$$

$$= 0.75$$

The load factor is relatively acceptable since it is not largely less than one. Higher load factor means, the lower will be the rise of the peak value in the load curve from the average value. This means better load profile, less load management needed or available and finally better utilization of generating and distribution equipment and switchgear.

The yearly load curve for the network is shown in figure (7.2)

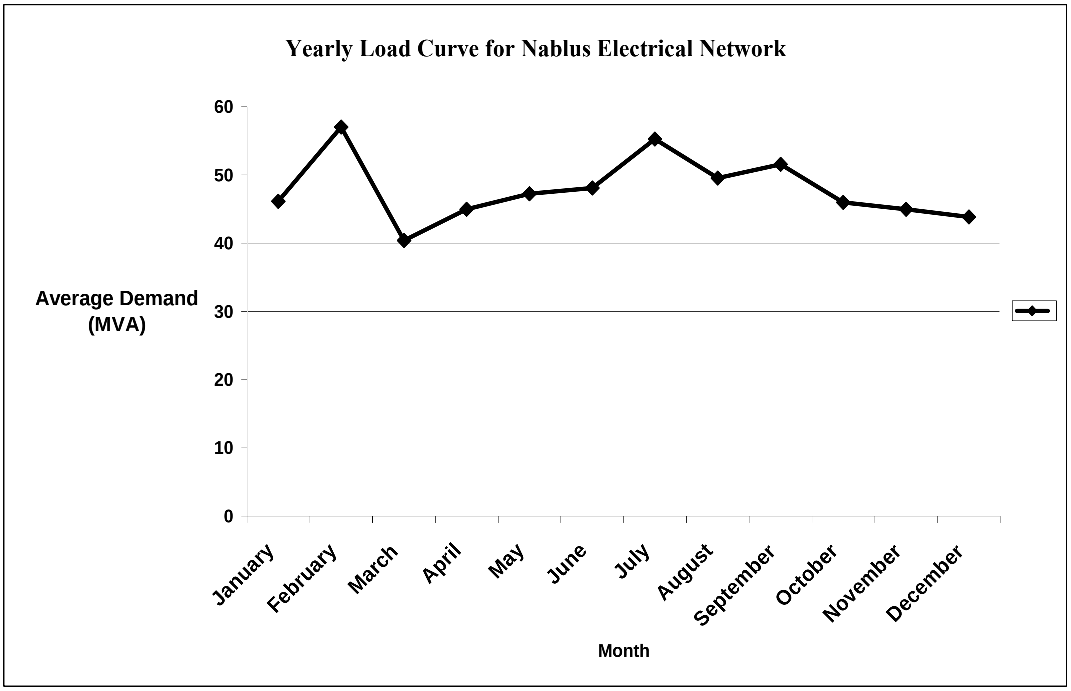

Figure (7.2): Yearly load curve of Nablus electrical network.

From the curve it is obvious that there two peaks one at July and one at February.

7.3 Techniques of load management

Peak Clipping

Applying load clipping technique is done usually upon reaching the maximum demand actually. It will help if the electrical distribution company can arrange contractual agreements with industry or other consumers to reduce consumption when maximum demand has been reached as this method is applied in many countries. This method may seem to be difficult to apply in our country. But if maximum demand has been reached in the evening hours, the street lighting may be reduced or cutoff, before shutting electricity on a prearranged not critical consumers.

Load Shifting

Using this technique peak loads are moved to off peak time periods. This technique can be applied by arranging with the pumping system as to operate the system in a schedule that will avoid certain expected peak hours during the year. Table (7.1) illustrates approximate average daily operating hours and power consumption for the distribution pumps. There is a good opportunity to shift a good demand by arranging a schedule to operate these pumps in low demand hours.

Table (7.1): Average operating hours, average power consumed and the total average power consumed for distribution pumps *.

Name of pumping station	Symbol of motor	hp	Average operating hours (Daily)	Power (kW)	Power × operating hours
Ein Dafna	ED.B1	200	10.71	126.31	1353.16
Ein Dafna	ED.B3	300	15.73	188.46	2964.43
New Reservoir	NR.B1	300	9.37	189.46	1774.99
New Reservoir	NR.B2	300	13.06	188.46	2460.56
Ein Beit Elma	EB.B1	300	7.83	189.46	1483.80
Ein Beit Elma	EBN.B1	300	0.52	189.46	97.69
Ein Beit Elma	EBN.B2	200	14.42	189.46	2731.24
Ein Beit Elma	EBN.B3	100	9.75	126.31	1231.64
Ein Beit Elma	EBN.B4	100	3.35	64.17	214.88
Ras El Ein	RE.B1	125	3.52	64.17	225.69
Ras El Ein	RE.B2	200	9.58	80.74	773.10
Ein Al Asal	EA.B1	50	0.28	127.52	35.62
Aljanoobi	HJN.B1	200	4.76	32.79	156.22
Aljanoobi	HJN.B2	85	8.81	129.18	1137.96
Alshamali	HS.B1	125	2.53	56.24	142.10
Alshamali	HS.B2	75	5.28	80.22	423.69
Al Qaryon	QR.B1	50	0.16	48.81	7.60
Al Qaryon	QR.B2	38	11.38	33.08	376.59
Al Qaryon	QR.B3	80	0.00	25.34	0.00
Alsumara	SM.B1	175	1.04	52.07	54.21
Alsumara	SM.B2	125	8.22	112.91	927.93
Aljuneid	JD.B1	225	0.87	80.22	69.57
Sum					18642.66
Average power during 24 hours			18642.66 / 24 = 776.78		

***Based on loading factor of 0.8 for motors**

The average power of operating these pumps during the 24 hours is computed as shown in the table (7.1) by summing power multiplied by the operating hours for all pumps and dividing the result by 24 hours. The result which is 776.78 kW represents the average expected load (power) that can be shifted from high demand hours to low demand hours. This corresponds to an average demand of 776.78 /0.88 = 882.7 kVA.

Energy Storage

Filling reservoirs and operating pumps at off-peak times helps spread energy loads throughout the day and helps reduce the need for new energy resources. This may need to establish water reservoirs with suitable storage size which can be filled during low demand periods while operating pumps at full load with maximum efficiency. And as Nablus is a mountainous city, taking into account to build these reservoirs at suitable height in the city, then the distribution of water will be accomplished by gravity at any required time and thus saving demand and energy.

Energy conservation in different sectors

Energy management opportunities in the sectors studied in this thesis can be summarized in the chart in figure (7.3).

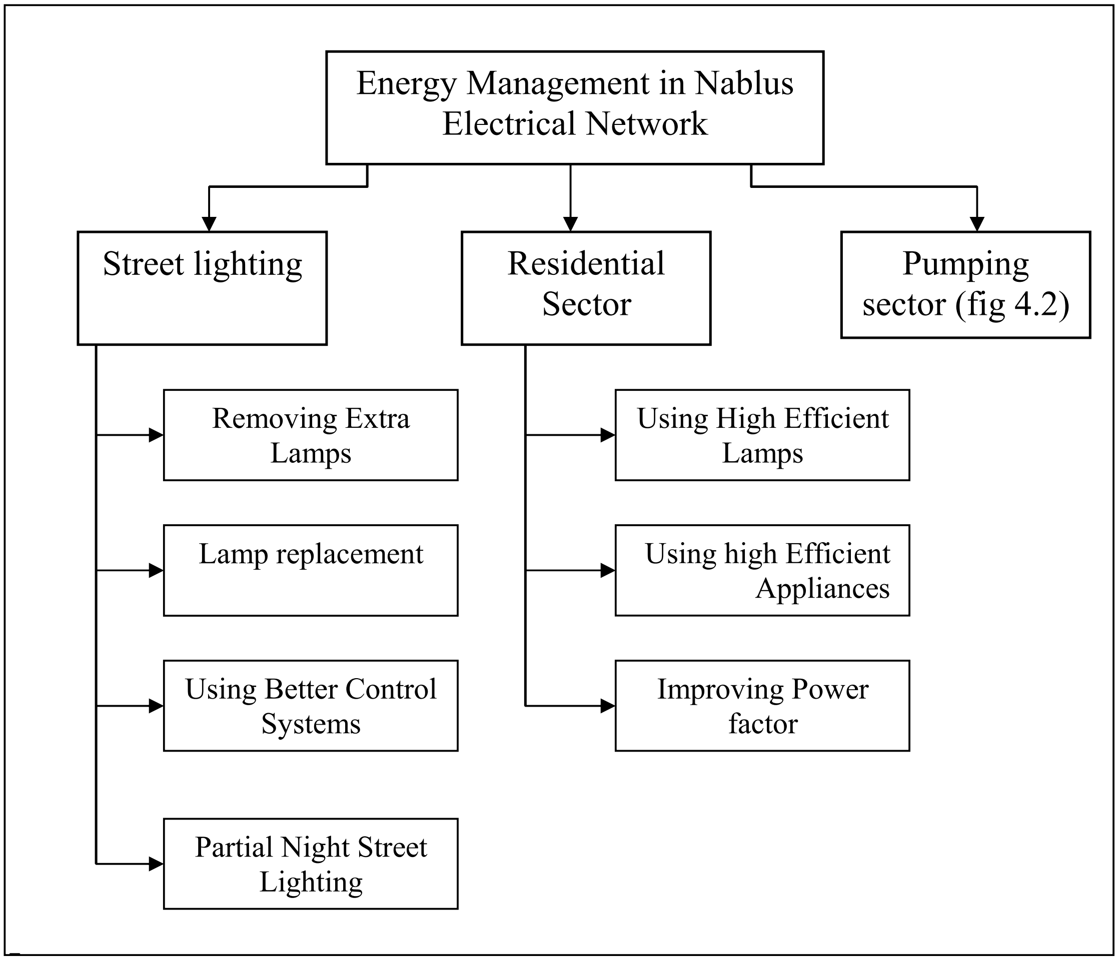

Figure (7.3): Energy management opportunities in Nablus electrical network

Energy conservation measures in the various sectors discussed before save energy and it will also lower the power demand. Table (7.2) shows demand saving in each sector.

Table (7.2): Demand saving by implementing specified energy saving measures in stated sectors

Sector		Power Saving (kW)	Demand saving (kVA)
Water pumping	Efficient motors	31.3	38.10
Street lighting (Demand will be reduced by 10% when measures implemented at the same time)	Lamp replacement	79.97	90.86
	Control systems	1033.34	1174.25
	Partial lighting	413.3	469.66
Residential	Replacing of 3000 refrigerators	156.3	177.61
	Incandescent to CFL replacement*	258	
		865	
		138	
	Power factor correction	144	163.64

*** depend on time, reference to page (106)**

The total power and demand reduction can't be attained by numerically adding power or demand reduction from each sector, since each sector affects power and demand at different times which may coincide or not. The effect of these demand reductions and the reductions from shifting pumping motors will be evaluated on the load curve of Nablus electrical network in the following sections.

Suitable tariff structure

This is an important tool for energy management that can be utilized to shape the load profile in the desired direction. The tariff used for electricity in Nablus is simple block tariff as shown in the table (7.3)

Table (7.3): Current tariff structure in Nablus network

Energy consumption (kWh)	Price /kWh (NIS)
0 – 50	0.72
> 51	0.76

This tariff has no impact on the consumers to change their demand profile or the demand time. There is a need for a new tariff that will stimulate consumers so that they will change there demand pattern in a way that will benefit the network in regard to lower the peak demand on the network. The tariff structures that can accomplish this are numerous, but most of them are based on the following two tariff structures.

Demand tariff (or two part tariff):

This tariff charges the customer for the amount of energy consumed as well as the maximum demand for the consumer. So in this tariff the total charges that the consumer pays are split into two components. The first component depends on demand which may be fixed or variable, and in the second case the consumer is charged on the maximum demand. The second component depends on the energy units (kWh) consumed by the consumer.

Time-of-use rate (TOU)

This rate design features different energy consumption prices that vary by time period, being higher in peak periods and lower in off-peak period. Energy charges can be made to vary seasonally and/or on a daily basis. The simplest rate involves just two pricing periods, a peak period and an off-peak period.

7.4 Effect of implementing energy conservation and load management measures on the daily load curve

The effect of each conservation measure on the demand of the network is illustrated in table (7.4). The time of effect of every conservation measure is different. Load shifting by scheduling operation of the water pumps at low demand hours will also contribute to demand reduction. To evaluate the effect of all these we construct a table and the time occurrence during the day of every measure as shown in the table as shown in table (7.4).

Table (7.4): Effect of demand reductions from various saving measures and load shifting on the demand at each hour of the day*.

Hour of day	Original demand (MVA)	Street lights lamp replace. (MVA)	Street light control systems (MVA)	Street light partial lighting (MVA)	Resid Refrg. Replc (MVA)	Resid. Incand /CFL (MVA)	Resid. P.F correc. (MVA)	Pump. Motors Shifting (MVA)	New demand (MVA)
0	26.92	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	26.82
1	26.92	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	26.82
2	25.33	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	25.23
3	23.75	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	23.65
4	23.75	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	23.65
5	25.33	-0.08		-0.42	-0.18	-0.14	-0.16	0.883	25.23
6	28.50	-0.08	-0.53		-0.18	-0.26	-0.16	0.883	28.17
7	33.25				-0.18	-0.26	-0.16		32.65
8	41.17				-0.18	-0.26	-0.16		40.57
9	50.67				-0.18	-0.26	-0.16		50.07
10	55.42				-0.18	-0.26	-0.16	-0.883	53.93
11	57.00				-0.18	-0.26	-0.16	-0.883	55.52
12	57.00				-0.18	-0.26	-0.16	-0.883	55.52
13	55.42				-0.18	-0.26	-0.16	-0.883	53.93
14	53.83				-0.18	-0.26	-0.16		53.23
15	50.67				-0.18	-0.26	-0.16		50.07
16	52.25				-0.18	-0.87	-0.16		51.04
17	53.83				-0.18	-0.87	-0.16	-0.883	51.74
18	57.00	-0.08	-0.53		-0.18	-0.87	-0.16	-0.883	54.30
19	53.83	-0.08			-0.18	-0.87	-0.16	-0.883	51.66
20	52.25	-0.08			-0.18	-0.87	-0.16		50.96
21	49.08	-0.08			-0.18	-0.87	-0.16		47.80
22	42.75	-0.08			-0.18	-0.87	-0.16		41.46
23	36.42	-0.08			-0.18	-0.87	-0.16		35.13
24	26.92	-0.08		-0.42	-0.18	-0.14	-0.16		25.93

*** Effect of standard/HEM replacement neglected.**

Figure (7.4) shows the current and the expected daily load curve.

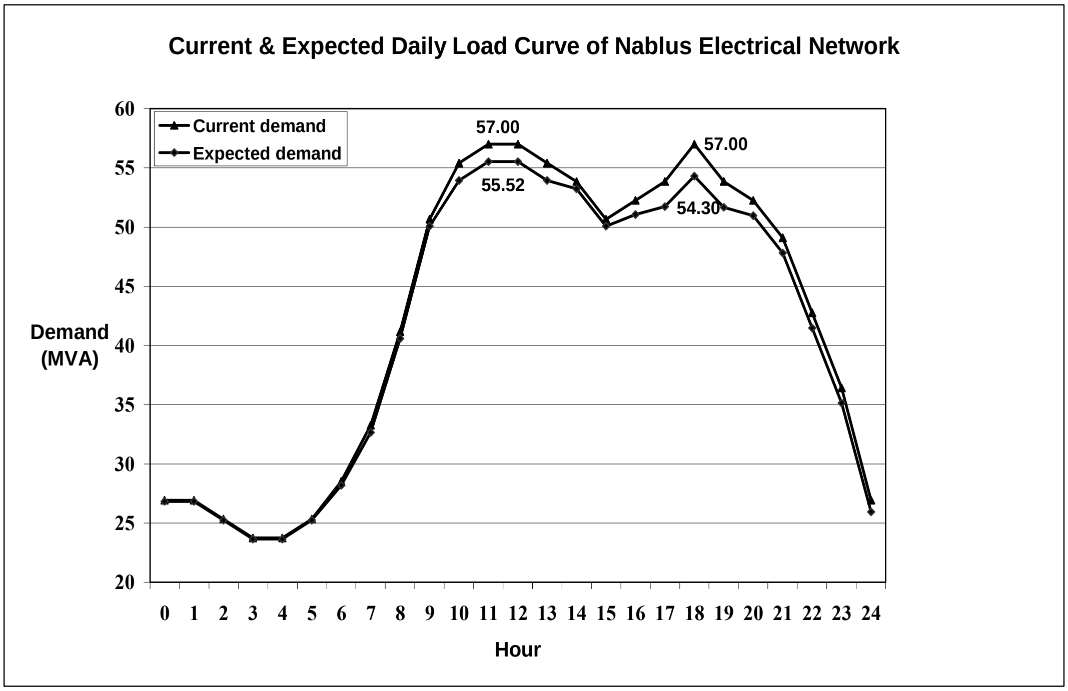

Figure (7.4): Current and expected load curve for Nablus electrical network.

The morning peak reduction = 57 – 55.52 = 1.48 MVA. It corresponds to 2.6% reduction in demand. The after noon peak reduction is 57 – 54.30 = 2.7 MVA which corresponds to 4.7% reduction in demand.

Effect of energy conservation of other sectors

Energy conservation in other energy consuming sectors will contribute both to energy conservation and load management. A study conducted on the industrial sector which included three of the large factories in Nablus has the results shown in table (7.5) [21].

Table (7.5): Energy saving expected in three big factories in Nablus.

Factory name	Electric Energy Consumption (kWh/y)	Savings (kWh)	Percentage (%)
Al Safa dairy factory	626340	54342	8.7%
Al Carton factory	263068	14808	5.6%
Al Arz ice cream factory	1093780	70959	6.5%
Total	1983188	140109	7.1%

This shows that there is an energy saving opportunity of about 7%. Taking into account that the industrial sector in Nablus network consumes about 30423024 kWh/year, then

Energy saving from industrial sector = 7% × 30423024 = 2129612 kWh.

Estimated working hours in the industrial sector/year = 3000 hour

Demand reduction = 2129612 / (3000 ×0.88) ≈ 807 kVA, (P.F≈0.88)

The occurrence of this reduction will be during 11- 12 am peak. So the new peak will be equal to 55.52 – 0.807 = 54.71 MVA.

Demand reduction = 57 – 54.71 = 2.29 MVA ≈ 4%

7.5 Summary

The study reveals that there is an opportunity to lower the peak demand in Nablus electrical network through load management techniques. A new tariff structure designed to stimulate energy consumption at low peak hours will have a great effect on demand reduction. Energy conservation techniques implemented in the mentioned sectors and on other energy consuming sectors contribute also to the demand reduction.

CHAPTER EIGHT

ECONOMICAL EVALUATION OF ENERGY MANAGEMENT IN NABLUS ELECTRICAL NETWORK

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ECONOMICAL EVALUATION OF ENERGY MANAGEMENT IN NABLUS ELECTRICAL NETWORK

8.1 Introduction

The basis for most engineering decisions is economics, besides other social, scientific and environmental factors. So any planned project must be feasible from the economic point of view in order to justify money investments in this project. In this chapter we will make financial analysis for energy saving measures in audited sectors that was encountered in the previous chapters. The SPBP was computed for every energy saving measure in every sector. But here SPBP will be computed for each complete sector in addition to the economic assessment of each sector by present worth (PW) and rate of return (ROR).

The present worth (P.W) or net present value (NPV) method for economy study is based on the on computing of equivalent worth of all cash flows relative to a base point (present) at an interest rate i%,

$$\text{PW(NPV)} = \sum_{k=0}^{N} Rk(P/F, i\%, k) - \sum_{k=0}^{N} Dk(P/F, i\%, k) \qquad (8.1)$$

Where R_k = net receipts for the kth year.

D_k = net disbursements for the kth year.

N = project life

So as long as NPV ≥ 0, the project is justified.

The ROR method involves finding the internal rate of return (IRR) for the project. The IRR is the interest rate at which the present worth of the cash inflow equals the present worth of the cash outflows. Expressed in general, the IRR is the i% at which,

$$\sum_{k=0}^{N} Rk(P/F, i\%, k) = \sum_{k=0}^{N} Dk(P/F, i\%, k) \quad (8.2)$$

Where R_k = net receipts for the kth year.

D_k = net disbursements for the kth year.

N = project life

8.2 Financial analysis for the pumping sector

The energy saving measures and the energy saving from each measure in addition to the money saving and investment are shown for the water pumping sector in table (8.1).

Table (8.1): Energy saving, money saving and investment from replacing standard motors by HEM in water pumping sector

Sector	Saving measure	Energy saving (kWh/year)	Money saving (NIS/year)	Investment (NIS)	Life cycle (year)
Water pumping	Standard/HEM Motors replacement	169838	129077	413171	14

The cash flow for the life cycle of the pumping sector is shown in fig (8.1). table (8.2) shows also the cash flow in table form in addition to the results of the financial analysis for this sector .

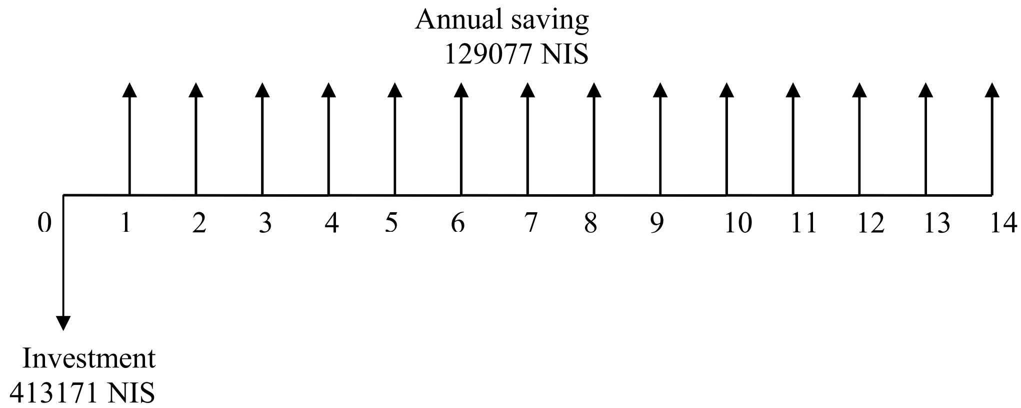

Fig (8.1): Cash flow diagram for the pumping sector

Table (8.2): Cash flow for the life cycle and the results of the financial analysis of the water pumping sector

Pumping system audit financial analysis			
Life cycle		**14 years**	
Discount rate		**10%**	
Year	**Income (NIS)**	**Capital (NIS)**	**Cash flow (NIS)**
0	0	−413171	-413171
1	129077		129077
2	129077		129077
3	129077		129077
4	129077		129077
5	129077		129077
6	129077		129077
7	129077		129077
8	129077		129077
9	129077		129077
10	129077		129077
11	129077		129077
12	129077		129077
13	129077		129077
14	129077		129077
Present worth (NIS)		NPV	537,699
Internal rate of return		IRR	30.5%
Simple Payback period		SPBP	3.20

The financial results show that implementing the project is feasible, as:

Present worth is positive with high value.

Internal rate of return is high (30.5%) which represent a good investment opportunity.

SPBP = 3.2 which is < 5 years

8.3 Financial analysis for the street lighting sector

The energy saving measures and the energy saving from each measure in addition to the money saving and investment are shown for the street lighting sector in table (8.3)

Table (8.3): Energy saving, money saving and investment from implementing specified energy conservation measures in street lighting sector.

Sector	Saving measure	Energy saving (kWh/year)	Money saving (NIS/year)	Investment (NIS)	SPBP (year)	Life cycle (year)
Street lighting	Mercury/ HPS lamps replacement	319880	243109	436200	1.79	7
	Using better control systems	377169	286648	27200	0.1	7
	Partial lighting	1029637	782524	536355	0.69	14
Total		0.9×1726686 =1554017*	1181053*	999755	0.85	14

*The real total energy saving in street lighting will be taken to equal 90% of the sum of the energy saving from the three saving measures in this sector in order to account for the reduction in energy saving by implementing the three measures at the same time as they are interconnected in operation.

The cash flow for the income by implementing mentioned saving measures in the residential sector and taking into account the different life cycles of the different measures are shown in table (8.4)

Table (8.4): Cash flow of income for the specified conservation measures during the life cycle of the street lighting sector.

Year	Total income (NIS)
0	0
1	1181053
2	1181053
3	1181053
4	1181053
5	1181053
6	1181053
7	1181053
8	1181053
9	1181053
10	1181053
11	1181053
12	1181053
13	1181053
14	1181051

The cash flow for the capital (investment) by implementing mentioned saving measures in the street lighting sector and taking into account the different life cycles of the different measures are shown in table (8.5)

Table (8.5): Cash flow of investment (capital) for the specified conservation measures during the life cycle of the street lighting sector.

Year	Investment HPS/Mercury (NIS)	Investment control systems (NIS)	Investment Partial lighting (NIS)	Total investment (NIS)
0	436200	27200	536355	999755
1				0
2				0
3				0
4				0
5				0
6				0
7	436200	27200		463400
8				0
9				0
10				0
11				0
12				0
13				0
14				0

The cash flow for the life cycle of the street lighting sector and the results of the financial analysis for this sector are shown in table (8.6)

Table (8.6): Cash flow for the life cycle and the results of the financial analysis of the street lighting sector

Street lighting audit financial analysis			
Life cycle		14 years	
Discount rate		10%	
Year	Income (NIS)	Capital (NIS)	Cash flow (NIS)
0	0	-999755	-999755
1	1181053	0	1181053
2	1181053	0	1181053
3	1181053	0	1181053
4	1181053	0	1181053
5	1181053	0	1181053
6	1181053	0	1181053
7	1181053	-463400	717653
8	1181053	0	1181053
9	1181053	0	1181053
10	1181053	0	1181053
11	1181053	0	1181053
12	1181053	0	1181053
13	1181053	0	1181053
14	1181053	0	1181053
Present worth (NIS)		NPV	7462896
Internal rate of return		IRR	118%
Simple Payback period		SPBP	0.85

The financial results show that implementing the project is feasible, as:

Present worth is positive with high value.

Internal rate of return is high (118%) which represent a good investment opportunity.

SPBP = 0.85 which is < 5 years

8.4 Financial analysis for the residential sector

The energy saving measures and the energy saving from each measure in addition to the money saving and investment are shown for the residential sector in table (8.7)

Table (8.7): Energy saving, money saving and investment from implementing specified energy conservation measures in residential sector.

Sector	Saving measure	Energy saving (kWh/year)	Money saving (NIS/year)	Investment (NIS)	SPBP (year)	Life cycle (year)
Residential	Using efficient refrigerators	1368750	1040250	7200000	6.92	14
	Incandescent/ CFL lamps replacement	10332667	7852827	6666667	0.85	7
	Power factor correction	1262331	959372	194855	0.20	14
Total		12963748	9852449	14061522	1.43	14

The cash flow for the income by implementing mentioned saving measures in the residential sector and taking into account the different life cycles of the different measures are shown in table (8.8)

Table (8.8): Cash flow of income for the specified conservation measures during the life cycle of the residential sector.

Year	Income (refrigerators) (NIS)	Income (Pf correction) (NIS)	Income (CFL) (NIS)	Total income (NIS)
0	0	0	0	0
1	1040250	959372	7852827	9852449
2	1040250	959372	7852827	9852449
3	1040250	959372	7852827	9852449
4	1040250	959372	7852827	9852449
5	1040250	959372	7852827	9852449
6	1040250	959372	7852827	9852449
7	1040250	959372	7852827	9852449
8	1040250	959372	7852827	9852449
9	1040250	959372	7852827	9852449
10	1040250	959372	7852827	9852449
11	1040250	959372	7852827	9852449
12	1040250	959372	7852827	9852449
13	1040250	959372	7852827	9852449
14	1040250	959372	7852827	9852449

The cash flow for the capital (investment) by implementing mentioned saving measures in the residential sector and taking into account the different life cycles of the different measures are shown in table (8.9)

Table (8.9): Cash flow of investment (capital) for the specified conservation measures during the life cycle of the residential sector.

Year	Investment (refrigerators) (NIS	Investment (Pf correction) (NIS)	Investment (CFL) (NIS)	total investment (NIS)
0	7200000	194855	6666667	14061522
1				0
2				0
3				0
4				0
5				0
6				0
7			6666667	6666667
8				0
9				0
10				0
11				0
12				0
13				0
14				0

The cash flow for the life cycle of the residential sector and the results of the financial analysis for this sector are shown in table (8.10)

Table (8.10): Cash flow for the life cycle and the results of the financial analysis of the residential sector

Residential sector audit financial analysis			
Life cycle		**14 years**	
Discount rate		**10%**	
Year	**Total income**	**Capital (NIS)**	**Cash flow (NIS)**
0	0	-14061522	-14061522
1	9852449	0	9852449
2	9852449	0	9852449
3	9852449	0	9852449
4	9852449	0	9852449
5	9852449	0	9852449
6	9852449	0	9852449
7	9852449	-6666667	3185782
8	9852449	0	9852449
9	9852449	0	9852449
10	9852449	0	9852449
11	9852449	0	9852449
12	9852449	0	9852449
13	9852449	0	9852449
14	9852449	0	9852449
Present worth (NIS)		NPV	55097336
Internal rate of return		IRR	69%
Simple Payback period		SPBP	1.43

The financial results show that implementing the project is feasible, as:

Present worth is positive with high value.

Internal rate of return is high (69%) which represent a good investment opportunity.

SPBP = 1.43 which is < 5 years

These results are based on the assumption that the residential consumers will all change incandescent lamps to CFL lamps which is difficult to implement totally. An intensive awareness campaign with a financed project may help greatly in this regard.

8.5 Financial analysis for all studied sectors (water pumping, residential and street lighting)

The studied sectors and the energy saving from each sector in addition to the money saving and investment are shown in table (8.11)

Table (8.11): Energy saving, money saving and investment from implementing energy conservation measures in the specified sectors.

Sector	Energy saving (kWh/year)	Money saving (NIS/year)	Investment (NIS)	SPBP (year)	Life cycle (year)
Water pumping	169838	129077	413171	3.20	14
Residential	12963748	9852449	14061522	1.43	14
Street Lighting	1554017	1181053	999755	0.85	14
Total	14860269	11225218	15567303	1.39	14

The cash flow for each sector and the total cash flow for all sectors and the results of the financial analysis for all sectors are shown in table (8.12)

Table (8.12): Cash flow for the life cycle and the results of the financial analysis of all sectors

Final financial analysis for all studied sectors				
Life cycle			14 years	
Discount rate			10%	
Year	Cash flow pumping (NIS)	Cash flow street (NIS)	Cash flow residential (NIS)	Total cash flow (NIS)
0	-413171	-999755	-14061522	-15474448
1	129077	1181053	9852449	11162578
2	129077	1181053	9852449	11162578
3	129077	1181053	9852449	11162578
4	129077	1181053	9852449	11162578
5	129077	1181053	9852449	11162578
6	129077	1181053	9852449	11162578
7	129077	717653	3185782	4032512
8	129077	1181053	9852449	11162578
9	129077	1181053	9852449	11162578
10	129077	1181053	9852449	11162578
11	129077	1181053	9852449	11162578
12	129077	1181053	9852449	11162578
13	129077	1181053	9852449	11162578
14	129077	1181053	9852449	11162578
Present worth (NIS)			NPV	63,097,931
Internal rate of return			IRR	71%
Simple Payback period			SPBP	1.39

The financial results show that implementing the project is feasible, as:

Present worth is positive with high value.

Internal rate of return is high (71%) which represent a good investment opportunity.

SPBP = 1.39 which is < 5 years.

8.6 Summary

The study revealed that there is a reasonable and good opportunity to implement the conservation and load management measures studied. The results indicate that implementing these measures is not only feasible from the economic and technical point of views, but it is also attractive from these points of views. Implementation has also other economical and environmental positive impacts. Saving energy will decrease and reducing peak demand will decrease our dependence Israel electrical energy sources which have a positive political impacts. It also reduces CO2 emissions from fossil fuel electric power plants which has a good environmental impact.

Conclusions & Recommendations

Conclusions

The study on energy conservation and load management in Nablus electrical network revealed that there is an opportunity to save energy and lower the peak demand. There still measures that can be taken to improve the present situation in Nablus electrical network.

Concerning energy conservation, the measures that the study recommends to be implemented yield energy savings of 14860269 kWh/ year.

The total energy consumption in Nablus electrical network during the year 2008 was 206859688 kWh/ year. Then the percentage of energy saving is 7.2 %.

The investment cost needed to implement all energy conservation measures suggested in the study is about 15567303 NIS, and the S.P.B.P for implementing the suggested measures is less than two years.

As mentioned, this represent saving opportunities by the measures suggested in this study. Greater savings can be accomplished by taking long term measures to implement saving opportunities in the studied sectors, like replacing high proportion of the low efficient refrigerators, more utilization of solar energy or LPG in heating water instead of electricity, encouraging of using high efficient fluorescent fixtures with solid state ballast, awareness to lower standby appliance power and others.

Energy saving measures in other sectors will contribute to the total energy saving. A study made on the industrial sector revealed an opportunity to save 7% of energy consumed in industrial sector, which is equal to 2129612 kWh. Taking this saving into account, then the total energy saving percentage is expected to be 8.2 %.

Energy conservation measures in commercial and institutional sectors will increase energy saving percentage. In fact, from above results and discussion we can conclude that an energy saving percentage of about 10 -15% can be accomplished through immediate and long term planning.

For peak demand reduction the study revealed that implementing load management measures suggested in the studied sectors can accomplish a peak demand reduction of 1.48 MVA in the morning peak, and 2.7 MVA in the evening peak. This represents a reduction percentage of 2.7% and 4.7% respectively. A higher percentage of peak demand reduction can be accomplished through taking long term energy conservation measures in the studied sectors and in other sectors on one hand, and taking measures to stimulate consumers to change their demand pattern through implementing new electrical tariff structure.

Recommendations

The following recommendations are drawn out of this research, some of them are directed to the researchers while the others are directed to decision makers.

1- Detailed energy analysis for residential sector.

2- Detailed energy analysis for the distribution network of Nablus.

3- Developing a national strategy and policy for energy conservation and load management

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Appendices

Appendix A-1: Calculations & energy analyzer data for voltage variation at Al-Badan well Motor pump.

Voltage Variation						
Date & Time	**V1 (V)**	**V2 (V)**	**V3 (V)**	**ΔV1%**	**ΔV2%**	**ΔV3%**
28/07/09 11:13	227.1	226.6	228.1	3.20%	2.99%	3.66%
28/07/09 12:13	226.7	226.2	227.6	3.02%	2.80%	3.46%
28/07/09 13:13	225.6	224.9	226.7	2.55%	2.23%	3.02%
28/07/09 14:13	227.0	226.3	228.1	3.17%	2.85%	3.66%
28/07/09 15:13	230.1	229.4	231.2	4.59%	4.28%	5.08%
28/07/09 16:13	232.4	231.8	233.5	5.62%	5.35%	6.14%
28/07/09 17:13	234.7	234.1	235.8	6.70%	6.42%	7.16%
28/07/09 18:13	236.1	235.4	237.2	7.32%	7.02%	7.81%
28/07/09 19:13	234.1	233.3	235.1	6.39%	6.05%	6.85%
28/07/09 20:13	232.3	231.3	232.9	5.61%	5.14%	5.85%
28/07/09 21:13	234.3	233.3	234.5	6.52%	6.02%	6.59%
28/07/09 22:13	234.7	233.6	234.8	6.67%	6.16%	6.71%
28/07/09 23:13	236.6	235.4	236.7	7.54%	6.98%	7.59%
29/07/09 00:13	235.5	234.3	235.8	7.02%	6.51%	7.17%
29/07/09 01:13	225.8	225.3	226.9	2.64%	2.41%	3.14%
29/07/09 02:13	226.3	225.8	227.5	2.86%	2.64%	3.41%
29/07/09 03:13	225.8	225.5	227.1	2.64%	2.50%	3.23%
29/07/09 04:13	225.5	225.1	226.7	2.50%	2.32%	3.05%
29/07/09 05:13	225.3	224.8	226.5	2.41%	2.18%	2.95%
29/07/09 06:13	226.4	226.2	227.5	2.91%	2.82%	3.41%
29/07/09 07:13	226.6	226.3	227.7	3.00%	2.86%	3.50%
29/07/09 08:13	226.6	226.4	227.7	3.00%	2.91%	3.50%
29/07/09 09:13	227.0	226.7	228.1	3.18%	3.05%	3.68%
29/07/09 10:13	227.3	227.0	228.4	3.32%	3.18%	3.82%
29/07/09 11:13	227.8	227.3	228.8	3.55%	3.32%	4.00%
29/07/09 12:13	227.8	227.4	228.8	3.55%	3.36%	4.00%
29/07/09 13:13	227.2	226.8	228.2	3.27%	3.09%	3.73%
29/07/09 14:13	226.9	226.5	227.9	3.14%	2.95%	3.59%
29/07/09 15:13	226.6	226.2	227.6	3.00%	2.82%	3.45%
29/07/09 16:13	226.9	226.5	227.9	3.14%	2.95%	3.59%
			max	7.54%	7.02%	7.81%
			min	2.41%	2.18%	2.95%

Appendix A-2: Calculations & energy analyzer data for voltage unbalance at Al-Badan well Motor pump.

Voltage Unbalance									
Date & Time	**V1 (V)**	**V2 (V)**	**V3 (V)**	**Vav**	**ΔV1**	**ΔV2**	**ΔV3**	**Max Δ**	**Unbalance**
28/07/09 11:13	227.1	226.6	228.1	227.2	0.18	0.64	0.82	0.82	0.36%
28/07/09 12:13	226.7	226.2	227.6	226.8	0.16	0.66	0.81	0.81	0.36%
28/07/09 13:13	225.6	224.9	226.7	225.7	0.11	0.81	0.92	0.92	0.41%
28/07/09 14:13	227.0	226.3	228.1	227.1	0.12	0.83	0.95	0.95	0.42%
28/07/09 15:13	230.1	229.4	231.2	230.2	0.13	0.81	0.94	0.94	0.41%
28/07/09 16:13	232.4	231.8	233.5	232.5	0.18	0.78	0.96	0.96	0.41%
28/07/09 17:13	234.7	234.1	235.8	234.9	0.13	0.75	0.88	0.88	0.38%
28/07/09 18:13	236.1	235.4	237.2	236.2	0.14	0.81	0.94	0.94	0.40%
28/07/09 19:13	234.1	233.3	235.1	234.1	0.09	0.83	0.92	0.92	0.39%
28/07/09 20:13	232.3	231.3	232.9	232.2	0.16	0.86	0.69	0.86	0.37%
28/07/09 21:13	234.3	233.3	234.5	234.0	0.31	0.78	0.47	0.78	0.33%
28/07/09 22:13	234.7	233.6	234.8	234.3	0.35	0.78	0.43	0.78	0.33%
28/07/09 23:13	236.6	235.4	236.7	236.2	0.37	0.85	0.48	0.85	0.36%
29/07/09 00:13	235.5	234.3	235.8	235.2	0.27	0.87	0.60	0.87	0.37%
29/07/09 01:13	225.8	225.3	226.9	226.0	0.20	0.70	0.90	0.90	0.40%
29/07/09 02:13	226.3	225.8	227.5	226.5	0.23	0.73	0.97	0.97	0.43%
29/07/09 03:13	225.8	225.5	227.1	226.1	0.33	0.63	0.97	0.97	0.43%
29/07/09 04:13	225.5	225.1	226.7	225.8	0.27	0.67	0.93	0.93	0.41%
29/07/09 05:13	225.3	224.8	226.5	225.5	0.23	0.73	0.97	0.97	0.43%
29/07/09 06:13	226.4	226.2	227.5	226.7	0.30	0.50	0.80	0.80	0.35%
29/07/09 07:13	226.6	226.3	227.7	226.9	0.27	0.57	0.83	0.83	0.37%
29/07/09 08:13	226.6	226.4	227.7	226.9	0.30	0.50	0.80	0.80	0.35%
29/07/09 09:13	227.0	226.7	228.1	227.3	0.27	0.57	0.83	0.83	0.37%
29/07/09 10:13	227.3	227.0	228.4	227.6	0.27	0.57	0.83	0.83	0.37%
29/07/09 11:13	227.8	227.3	228.8	228.0	0.17	0.67	0.83	0.83	0.37%
29/07/09 12:13	227.8	227.4	228.8	228.0	0.20	0.60	0.80	0.80	0.35%
29/07/09 13:13	227.2	226.8	228.2	227.4	0.20	0.60	0.80	0.80	0.35%
29/07/09 14:13	226.9	226.5	227.9	227.1	0.20	0.60	0.80	0.80	0.35%
29/07/09 15:13	226.6	226.2	227.6	226.8	0.20	0.60	0.80	0.80	0.35%
29/07/09 16:13	226.9	226.5	227.9	227.1	0.20	0.60	0.80	0.80	0.35%
								MAX	0.43%
								MIN	0.33%

Appendix A-3: Calculations & energy analyzer data for power factor correction and loading at Al-Badan well Motor pump.

Date & Time	St (kVA)	Pt (kW)	PRESENT P.F	QC NEEDED At present PF (KVAR)	PF AT QC=100 KVAR	Loading %
28/07/09 11:13	342.1	276.7	0.81	83.21	0.94	58.8%
28/07/09 12:13	342.6	277.5	0.81	82.76	0.94	58.9%
28/07/09 13:13	341.4	277.0	0.81	81.47	0.94	58.8%
28/07/09 14:13	343.3	277.9	0.81	83.09	0.94	59.0%
28/07/09 15:13	346.8	278.7	0.80	87.61	0.93	59.2%
28/07/09 16:13	348.8	278.3	0.80	91.65	0.93	59.1%
28/07/09 17:13	351.3	278.3	0.79	95.78	0.92	59.1%
28/07/09 18:13	352.5	278.1	0.79	98.22	0.92	59.0%
28/07/09 19:13	350.2	278.0	0.79	94.60	0.93	59.0%
28/07/09 20:13	348.1	277.9	0.80	91.25	0.93	59.0%
28/07/09 21:13	349.9	277.8	0.79	94.36	0.93	59.0%
28/07/09 22:13	347.1	274.7	0.79	95.13	0.93	58.3%
28/07/09 23:13	349.3	274.9	0.79	98.28	0.92	58.4%
29/07/09 00:13	348.1	274.9	0.79	96.42	0.92	58.4%
29/07/09 01:13	341.9	278.5	0.81	79.69	0.94	59.1%
29/07/09 02:13	342.3	278.5	0.81	80.37	0.94	59.1%
29/07/09 03:13	342.0	278.5	0.81	79.86	0.94	59.1%
29/07/09 04:13	341.6	278.3	0.81	79.53	0.94	59.1%
29/07/09 05:13	341.8	278.8	0.82	78.96	0.94	59.2%
29/07/09 06:13	343.0	279.1	0.81	80.48	0.94	59.3%
29/07/09 07:13	343.5	279.2	0.81	81.16	0.94	59.3%
29/07/09 08:13	343.2	279.6	0.81	79.91	0.94	59.4%
29/07/09 09:13	344.5	279.6	0.81	82.15	0.94	59.4%
29/07/09 10:13	343.8	279.5	0.81	81.13	0.94	59.3%
29/07/09 11:13	344.8	279.4	0.81	83.02	0.94	59.3%
29/07/09 12:13	344.4	279.8	0.81	81.61	0.94	59.4%
29/07/09 13:13	344.5	279.7	0.81	81.97	0.94	59.4%
29/07/09 14:13	343.6	279.9	0.81	80.05	0.94	59.4%
29/07/09 15:13	343.9	279.3	0.81	81.66	0.94	59.3%
29/07/09 16:13	343.6	279.9	0.81	80.05	0.94	59.4%

Appendix A-4: Calculations & energy analyzer data for voltage variation at Al-Badan booster Motor pump.

Voltage Variation						
Date & Time	**V1 (V)**	**V2 (V)**	**V3 (V)**	**ΔV1%**	**ΔV2%**	**ΔV3%**
30/07/09 11:13	226.4	229.0667	228.65	2.91%	4.12%	3.93%
30/07/09 12:13	226.1583	228.85	228.4333	2.80%	4.02%	3.83%
30/07/09 13:13	226.25	228.975	228.6917	2.84%	4.08%	3.95%
30/07/09 14:13	225.8083	228.5417	228.1917	2.64%	3.88%	3.72%
30/07/09 15:13	229.9917	232.8167	232.4	4.54%	5.83%	5.64%
30/07/09 16:13	232.2583	235.025	234.725	5.57%	6.83%	6.69%
30/07/09 17:13	233.8417	236.6	236.3333	6.29%	7.55%	7.42%
30/07/09 18:13	232.1333	234.9167	234.6917	5.52%	6.78%	6.68%
30/07/09 19:13	229.4667	232.0333	232.1333	4.30%	5.47%	5.52%
30/07/09 20:13	232.0417	234.2917	234.8167	5.47%	6.50%	6.73%
30/07/09 21:13	233.3583	235.5417	236.1917	6.07%	7.06%	7.36%
30/07/09 22:13	232.3	234.6417	235.1417	5.59%	6.66%	6.88%
30/07/09 23:13	235.1583	237.475	237.9667	6.89%	7.94%	8.17%
30/07/09 00:13	237.25	239.5	239.9417	7.84%	8.86%	9.06%
31/07/09 01:13	238.5	240.7333	241.2083	8.41%	9.42%	9.64%
31/07/09 02:13	238.9583	241.1167	241.5417	8.62%	9.60%	9.79%
31/07/09 03:13	239.0917	241.275	241.6583	8.68%	9.67%	9.84%
31/07/09 04:13	239.025	241.1583	241.5833	8.65%	9.62%	9.81%
31/07/09 05:13	237.75	240.0333	240.2083	8.07%	9.11%	9.19%
31/07/09 06:13	234.6167	236.9333	236.95	6.64%	7.70%	7.70%
31/07/09 07:13	229.325	231.7917	231.6	4.24%	5.36%	5.27%
			max	8.68%	9.67%	9.84%
			min	2.64%	3.88%	3.72%

Appendix A-5: Calculations & energy analyzer data for voltage unbalance at Al-Badan booster Motor pump.

Voltage Unbalance									
Date & Time	V1 (V)	V2 (V)	V3 (V)	Vav	ΔV1	ΔV2	ΔV3	Max Δ	Unbalance
30/07/09 11:13	226.4	229.1	228.7	228.0	1.64	1.03	0.61	1.64	0.72%
30/07/09 12:13	226.2	228.9	228.4	227.8	1.66	1.04	0.62	1.66	0.73%
30/07/09 13:13	226.3	229.0	228.7	228.0	1.72	1.00	0.72	1.72	0.76%
30/07/09 14:13	225.8	228.5	228.2	227.5	1.71	1.03	0.68	1.71	0.75%
30/07/09 15:13	230.0	232.8	232.4	231.7	1.74	1.08	0.66	1.74	0.75%
30/07/09 16:13	232.3	235.0	234.7	234.0	1.74	1.02	0.72	1.74	0.75%
30/07/09 17:13	233.8	236.6	236.3	235.6	1.75	1.01	0.74	1.75	0.74%
30/07/09 18:13	232.1	234.9	234.7	233.9	1.78	1.00	0.78	1.78	0.76%
30/07/09 19:13	229.5	232.0	232.1	231.2	1.74	0.82	0.92	1.74	0.75%
30/07/09 20:13	232.0	234.3	234.8	233.7	1.67	0.58	1.10	1.67	0.72%
30/07/09 21:13	233.4	235.5	236.2	235.0	1.67	0.51	1.16	1.67	0.71%
30/07/09 22:13	232.3	234.6	235.1	234.0	1.73	0.61	1.11	1.73	0.74%
30/07/09 23:13	235.2	237.5	238.0	236.9	1.71	0.61	1.10	1.71	0.72%
30/07/09 00:13	237.3	239.5	239.9	238.9	1.65	0.60	1.04	1.65	0.69%
31/07/09 01:13	238.5	240.7	241.2	240.1	1.65	0.59	1.06	1.65	0.69%
31/07/09 02:13	239.0	241.1	241.5	240.5	1.58	0.58	1.00	1.58	0.66%
31/07/09 03:13	239.1	241.3	241.7	240.7	1.58	0.60	0.98	1.58	0.66%
31/07/09 04:13	239.0	241.2	241.6	240.6	1.56	0.57	0.99	1.56	0.65%
31/07/09 05:13	237.8	240.0	240.2	239.3	1.58	0.70	0.88	1.58	0.66%
31/07/09 06:13	234.6	236.9	237.0	236.2	1.55	0.77	0.78	1.55	0.66%
31/07/09 07:13	229.3	231.8	231.6	230.9	1.58	0.89	0.69	1.58	0.68%
								MAX	0.76%
								MIN	0.65%

Appendix A-6: Calculations & energy analyzer data for power factor correction and loading at Al-Badan booster Motor pump.

Date & Time	St (kVA)	Pt (kW)	PRESENT P.F	QC NEEDED At present PF (KVAR)	PF AT QC=25 KVAR	Loading %
30/07/09 11:13	326.6	295.3	0.90	13.88	0.93	0.63
30/07/09 12:13	327.3	295.9	0.90	13.80	0.93	0.63
30/07/09 13:13	327.6	296.2	0.90	13.82	0.93	0.63
30/07/09 14:13	326.9	295.6	0.90	13.76	0.93	0.63
30/07/09 15:13	332.0	295.2	0.89	25.48	0.92	0.63
30/07/09 16:13	327.7	295.6	0.90	15.58	0.93	0.63
30/07/09 17:13	334.0	297.4	0.89	25.67	0.92	0.63
30/07/09 18:13	329.3	297.1	0.90	15.43	0.93	0.63
30/07/09 19:13	328.0	296.2	0.90	14.59	0.93	0.63
30/07/09 20:13	328.3	296.3	0.90	15.21	0.93	0.63
30/07/09 21:13	327.0	294.9	0.90	15.71	0.93	0.63
30/07/09 22:13	325.8	294.0	0.90	15.31	0.93	0.62
30/07/09 23:13	325.5	293.3	0.90	16.19	0.93	0.62
30/07/09 00:13	325.0	292.6	0.90	16.91	0.93	0.62
31/07/09 01:13	325.5	292.8	0.90	17.40	0.93	0.62
31/07/09 02:13	325.9	293.1	0.90	17.41	0.93	0.62
31/07/09 03:13	326.3	293.5	0.90	17.51	0.93	0.62
31/07/09 04:13	328.6	295.7	0.90	17.31	0.93	0.63
31/07/09 05:13	327.0	294.3	0.90	17.10	0.93	0.62
31/07/09 06:13	326.1	293.9	0.90	15.99	0.93	0.62
31/07/09 07:13	324.2	292.8	0.90	14.40	0.93	0.62
			Min	25.67		
			Max	13.88		

Appendix A-7: Calculations & energy analyzer data for evaluating the efficiency of the pump of Al-Badan booster.

Date & Time	Water Flow Rate (m3)	Inlet Pressure (Bar)	Pressure Outlet (Bar)	Pout (KW)	Pin (KW)	Total efficiency (Wire to water)
30/07/09 11:13	175.54	3.5	40.5	180.42	295.3	0.61
30/07/09 12:13	175.85	3.5	40.5	180.73	295.9	0.61
30/07/09 13:13	175.32	3.5	40.5	180.19	296.2	0.61
30/07/09 14:13	174.09	3.25	40.5	180.13	295.6	0.61
30/07/09 15:13	174.48	3.25	40.5	180.54	295.2	0.61
30/07/09 16:13	173.86	3.25	40.5	179.90	295.6	0.61
30/07/09 17:13	174.29	3.25	40.5	180.34	297.4	0.61
30/07/09 18:13	173.79	3.25	40.5	179.82	297.1	0.61
30/07/09 19:13	173.18	3.25	40.5	179.19	296.2	0.60
30/07/09 20:13	173.02	3.25	40.5	179.03	296.3	0.60
30/07/09 21:13	170.44	3.75	41	176.36	294.9	0.60
30/07/09 22:13	169.33	4.25	41.75	176.39	294.0	0.60
30/07/09 23:13	169.37	4.25	42	177.60	293.3	0.61
30/07/09 00:13	169.07	4.25	42	177.29	292.6	0.61
31/07/09 01:13	170.31	4.25	42	178.59	292.8	0.61
31/07/09 02:13	170.3	4.25	42	178.58	293.1	0.61
31/07/09 03:13	169.27	4.25	42	177.50	293.5	0.60
31/07/09 04:13	171.15	4.25	42	179.47	295.7	0.61
31/07/09 05:13	170.16	4.25	42	178.43	294.3	0.61
31/07/09 06:13	171.06	4.25	42	179.38	293.9	0.61
31/07/09 07:13	168.98	4.25	42	177.19	292.8	0.61

Appendix A-8: Calculations & energy analyzer data for voltage variation at Al-Juneid distribution Motor pump.

Voltage Variation						
Date & Time	**V1 (V)**	**V2 (V)**	**V3 (V)**	**ΔV1%**	**ΔV2%**	**ΔV3%**
05/08/09 17:31	235.6	236.7	235.1	2.43%	2.91%	2.22%
05/08/09 18:31	236.6	237.5	236.2	2.87%	3.26%	2.70%
05/08/09 21:55	234.7	235.4	233.9	2.04%	2.35%	1.70%
05/08/09 22:55	235	235.3	234.5	2.17%	2.30%	1.96%
05/08/09 23:55	236.9	237.3	236.7	3.00%	3.17%	2.91%
06/08/09 00:55	235.7	236.2	235.7	2.48%	2.70%	2.48%
06/08/09 01:55	238.1	238.7	238.2	3.52%	3.78%	3.57%
06/08/09 02:55	237.7	238.5	237.9	3.35%	3.70%	3.43%
06/08/09 03:55	237.1	237.9	237.2	3.09%	3.43%	3.13%
			max	3.52%	3.78%	3.57%
			min	2.04%	2.30%	1.70%

Appendix A-9: Calculations & energy analyzer data for voltage unbalance at Al-Junied distribution Motor pump.

Voltage Unbalance									
Date & Time	**V1 (V)**	**V2 (V)**	**V3 (V)**	**Vav**	**ΔV1**	**ΔV2**	**ΔV3**	**Max Δ**	**Unbal ance**
05/08/09 17:31	235.6	236.7	235.1	235.8	0.20	0.90	0.70	0.90	0.38%
05/08/09 18:31	236.6	237.5	236.2	236.8	0.17	0.73	0.57	0.73	0.31%
05/08/09 21:55	234.7	235.4	233.9	234.7	0.03	0.73	0.77	0.77	0.33%
05/08/09 22:55	235	235.3	234.5	234.9	0.07	0.37	0.43	0.43	0.18%
05/08/09 23:55	236.9	237.3	236.7	237.0	0.07	0.33	0.27	0.33	0.14%
06/08/09 00:55	235.7	236.2	235.7	235.9	0.17	0.33	0.17	0.33	0.14%
06/08/09 01:55	238.1	238.7	238.2	238.3	0.23	0.37	0.13	0.37	0.15%
06/08/09 02:55	237.7	238.5	237.9	238.0	0.33	0.47	0.13	0.47	0.20%
06/08/09 03:55	237.1	237.9	237.2	237.4	0.30	0.50	0.20	0.50	0.21%
								MAX	0.38%
								MIN	0.14%

Appendix A-10: Calculations & energy analyzer data for power factor correction and loading at Al-Juneid Motor pump.

Date & Time	St (kVA)	Pt (kW)	PRESENT P.F	QC NEEDED At present PF (KVAR)	PF AT QC=40 KVAR	Loading %
05/08/09 17:31	211900	179900	0.85	35.33	0.93	0.9968
05/08/09 18:31	206100	174400	0.85	35.53	0.93	0.9663
05/08/09 21:55	196500	166300	0.85	33.83	0.93	0.9214
05/08/09 22:55	196300	166000	0.85	34.06	0.93	0.9198
05/08/09 23:55	196500	165500	0.84	35.43	0.93	0.917
06/08/09 00:55	196400	165900	0.84	34.45	0.93	0.9192
06/08/09 01:55	196800	165200	0.84	36.58	0.93	0.9153
06/08/09 02:55	196000	164500	0.84	36.49	0.93	0.9115
06/08/09 03:55	195100	163900	0.84	36.01	0.93	0.9081

Appendix A-11: data and calculations of specific energy consumption (kWh/m^3) for Al-Juneid distribution pump motor.

Date	Water meter	Energy meter	Marginal specific energy kWh/m^3	cumulative specific energy kWh/m^3
05/07/09	111967	5031.8		
06/07/09	112329	5047.5	0.867	0.867
08/07/09	112493	5054.2	0.817	0.852
11/07/09	112924	5071.2	0.789	0.823
13/07/09	113088	5080.7	1.159	0.872
15/07/09	113504	5096.3	0.750	0.839
17/07/09	113660	5102.8	0.833	0.839
20/07/09	114210	5127.2	0.887	0.851
22/07/09	114643	5144.3	0.790	0.841
25/07/09	114725	5149.1	1.171	0.851
27/07/09	115101	5164.4	0.814	0.846
01/08/09	115694	5185.1	0.698	0.823
05/08/09	116234	5208.1	0.852	0.826
10/08/09	116807	5229.4	0.743	0.817
12/08/09	116916	5234.3	0.899	0.818
15/08/09	117162	5245.2	0.886	0.822
17/08/09	117555	5261.6	0.835	0.822
21/08/09	118066	5283.8	0.869	0.826
25/08/09	118478	5302.3	0.898	0.831
26/08/09	118715	5312.1	0.827	0.831
31/08/09	119213	5332.9	0.835	0.831

Case 1: pump working on standard motor without VSD control

Case 1: pump working on high efficient motor (HEM) without VSD control

Date	Water meter	Energy meter	Marginal specific energy kWh/m^3	cumulative specific energy kWh/m^3
31/08/09	119213	5332.9		
04/09/09	119722	5351.6	0.735	0.735
07/09/09	119818	5356.3	0.979	0.774
09/09/09	120303	5373.4	0.705	0.743
14/09/09	120822	5396.1	0.875	0.786

Case 3: pump working on high efficient motor (HEM) with VSD control

Date	Water meter	Energy meter	Marginal specific energy KWH/m^3	cumulative specific energy KWH/m
14/09/09	120822	5396.1		
18/09/09	121451	5422.1	0.827	0.827
23/09/09	121867	5442.6	0.986	0.890
28/09/09	122418	5467.5	0.904	0.895
02/10/09	122994	5491.7	0.840	0.880
05/10/09	123111	5497.3	0.957	0.884
07/10/09	123450	5511.8	0.855	0.881
12/10/09	123987	5534.6	0.849	0.875
16/10/09	124550	5559.7	0.892	0.878
19/10/09	124993	5581.2	0.971	0.888
24/10/09	125472	5603.8	0.944	0.893
30/10/09	125911	5625.1	0.970	0.900
02/11/09	126288	5643.0	0.950	0.903
06/11/09	126510	5653.8	0.973	0.906
09/11/09	126773	5665.7	0.905	0.906
11/11/09	127139	5681.5	0.863	0.904
16/11/09	127381	5695.6	1.165	0.913
18/11/09	127395	5697.5	2.714	0.917
20/11/09	127510	5703.9	1.113	0.920
23/11/09	127752	5715.9	0.992	0.923
25/11/09	127878	5723.8	1.254	0.929
28/11/09	128173	5737.6	0.936	0.929
02/12/09	128523	5760.1	1.286	0.945
04/12/09	128798	5774.1	1.018	0.948
07/12/09	129027	5787.5	1.170	0.954
09/12/09	129060	5789.2	1.030	0.954
11/12/09	129377	5803.6	0.909	0.953
14/12/09	129414	5807.1	1.892	0.957
18/12/09	129760	5824.8	1.023	0.959
21/12/09	130158	5846.1	1.070	0.964
24/12/09	130417	5859.4	1.027	0.966
24/12/09	130509	5865.8	1.391	0.970
28/12/09	130875	5885.1	1.055	0.973
03/01/10	131355	5910.6	1.063	0.977

Appendix B-1: Nameplate values of Al Badan well pump motor

NABLUS MUNICIPALITY / WATER DPT

NAMEPLATE AND INSTALLATION INFORMATION

MANUFACTURER U.S Motors

SERIAL NUMBER G49463 / U08U1310021R - 1 NRR

HORSEPOWER 600 **MOTOR RPM** 1478 **PHASE** 3 **NOM.EFF** ____

FREQUENCY 50 **AMPS** 806 **AT** 380 **V** **S.F** 1.15

DESIGN ________ **CODE** A **TYPE** HU **FRAME** 5809P

UPPER BEARING 29430-EJ **LOWER BEARING** 6220-J

DATE PURCHASED **PURCHASED FROM**

1st INSTALLATION DATE **AT** **BY**

MOTOR RESISTANCE LINE TO LINE AT TIME OF 1ST INST. Ω Ω Ω

INSULATION TO GROUND READING AT TIME OF 1ST INST. Ω Ω Ω

RECORD OF MAINTENANCE

GRADE AND TYPE OF LUBRICANT USED SHC 629 AND GREASE

RELUB DATE	INSULAT. RERSIST.		OVERHAUL OR REPAIR		
	DATE	M.Ω	DATE	ACTION	LOC No
10.07.01					BA.W1
05.01.04			23.06.05	Was dismounted after oil leakage.	MT&R W
10.07.05			10.07.05	Replacement of bearings	ST-BY
21.09.05			18.09.05	Put in service.	BA.W1
09.12.06			18.09.05	Dismounted after 30 min because of hot & noisy bearings.	MT&R W
			21.09.05	Cleaning of bearings and oil basin and changing of oil type.	ST-BY
			28.11.05	Put in service.	BA.W1
			30.11.05	Dismounted after 30 min because of hot & noisy bearings.	MT&R W
			04.12.05	Restoring of the original bearings to be tested later.	ST-BY
			09.12.06	Put in service.	BA.W1
02 .01 .08					
26.3.09					

11/07/2001 C:\My Documents\MOTOR\Ba\BA.W1.doc

Appendix B-2: Nameplate values of Al Badan booster pump motor

NABLUS MUNICIPALITY / WATER DPT

NAMEPLATE AND INSTALLATION INFORMATION

MANUFACTURER U.S. Motors

SERIAL NUMBER CE 1270086 - 771 80 - 02550 NRR (3)

HORSEPOWER 600 **MOTOR RPM** 1485 **PHASE** 3 **NOM.EFF** ________

FREQUENCY 50 **AMPS** 809 **AT** 380 **V** **S.F** 1.15

DESIGN B **CODE** A **TYPE** HU **FRAME** Y6808 P

UPPER BEARING 29438MC **LOWER BEARING** 6238J

DATE PURCHASED **PURCHASED FROM**

1st INSTALLATION DATE **AT** **BY**

MOTOR RESISTANCE LINE TO LINE AT TIME OF 1ST INST. Ω Ω Ω

INSULATION TO GROUND READING AT TIME OF 1ST INST. Ω Ω Ω

RECORD OF MAINTENANCE

GRADE AND TYPE OF LUBRICANT USED PAZLUS SEP 100 & Grease

RELUB DATE	INSULAT. RERSIST.		OVERHAUL OR REPAIR		
	DATE	M.Ω	DATE	ACTION	LOC No
06.12.98					FA.B2
02.06.05			15.05.05	Was dismounted after discovering an oil leakage	MT&RW
10.12.06			02.06.05	Repair & treatment of oil leakage.	ST-BY
			29.11.05	Was put in service.	BA.B1
			24.12.05	Was dismounted after discovering an oil and water mixture	MT&RW
			31.08.06	Repair & treatment of oil leakage.	ST-BY
			31.08.08	Was put in service.	BA.B1

15/07/2001 C:\My Documents\MOTOR\FA\FA.W1.doc

Appendix B-3: Nameplate values of old Al Juneid pump motor

NABLUS MUNICIPALITY / WATER DPT

NAMEPLATE AND INSTALLATION INFORMATION

MANUFACTURER U.S. Motors .

SERIAL NUMBER H02 41076917 - 100R - 01

HORSEPOWER 225 **MOTOR RPM** 1475 **PHASE** 3 **NOM.EFF** 93

FREQUENCY 50 **AMPS** 298 **AT** 400 **V** **S.F** 1.15

DESIGN # **CODE** G **TYPE** RU **FRAME** H445TP

UPPER BEARING 7322-BEM *2 **LOWER BEARING** 6215-J.

DATE PURCHASED 03.04 **PURCHASED FROM** EMERSON Co. / GTZ/ By Eng Saed Odeh

1st INSTALLATION DATE 21.12.04 **AT** JD.B1 **BY** Electromechanical section

MOTOR RESISTANCE LINE TO LINE AT TIME OF 1ST INST. 0.01 Ω 0.01 Ω 0.01 Ω

INSULATION TO GROUND READING AT TIME OF 1ST INST. ∞ Ω ∞ Ω ∞ Ω

RECORD OF MAINTENANCE

GRADE AND TYPE OF LUBRICANT USED PAZLUS SEP 100 & Grease

RELUB DATE	INSULAT. RERSIST.		OVERHAUL OR REPAIR		
31.03.04	DATE	M.Ω	DATE	ACTION	LOC No
07.11.05			21.12.04	Was operated for 1st. time as a booster	JD.B1
19.12.06			20.07.2008	Stopped and dismounted after insulation breakdown.	MT&RW
16 .01 .08			28.07.08	Was sent for repair (rewinding)	MT&RW
			04.10.08	Was received after maintenance	ST-BY
			29.12.08	Put in service as a booster driver.	JD.B1
			10.01.09	Stopped and dismounted because of vibration, so to be sent back for repair.	MT&RW
			14.01.09	Sent back for maintenance by insurance co.	MT&RW
			16.03.09	Was received after repair	ST-BY
			21.03.2009	Put in service after maintenance	JD.B1
21.03.09			01.09.2009	Stopped and dismounted in order to install inverter duty motor supplied by Abu Hatab Co.	ST-BY

Appendix B-4: Nameplate values of efficient new Al Juneid pump motor

NABLUS MUNICIPALITY / WATER DPT

NAMEPLATE AND INSTALLATION INFORMATION

MANUFACTURER U.S. MOTORS

SERIAL NUMBER P047352259-0001 R0001

HORSEPOWER 250 **MOTOR RPM** 1485 **PHASE** 3 **NOM.EFF** 95.4

FREQUENCY 50 **AMPS** 318.0 **AT** 400 **V** **S.F** 1.15

DESIGN B **CODE** H **TYPE** HU **FRAME** 447TP

UPPER BEARING 7226-BCB **LOWER BEARING** 6219-J

DATE PURCHASED 29.07.09 **PURCHASED FROM** Abu Hatab Co.

1st INSTALLATION DATE 01.09.09 **AT** JD.B1 **BY** WATER DEPARTMENT

MOTOR RESISTANCE LINE TO LINE AT TIME OF 1ST INST. 0.03 Ω 0.03 Ω 0.03 Ω

INSULATION TO GROUND READING AT TIME OF 1ST INST. 100 MΩ 100 MΩ 100 MΩ

RECORD OF MAINTENANCE

GRADE AND TYPE OF LUBRICANT USED DELEK DELSPEN 68 & Grease

RELUB DATE	INSULAT. RERSIST.		OVERHAUL OR REPAIR		
	DATE	M.Ω	DATE	ACTION	LOC No
			29.07.09	Delivered by Abu Hatab Co.	ST-BY
			01.09.09	First operation as a booster	JD.B1

جامعة النجاح الوطنية
كلية الدراسات العليا

ترشيد الاستهلاك وتحليل إدارة الأحمال لشبكة كهرباء نابلس

إعداد
باسل مصطفى قاسم عبد الحق

إشراف
د. عماد بريك

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الإستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2010م

ترشيد الاستهلاك وتحليل إدارة الأحمال لشبكة كهرباء نابلس

إعداد

باسل مصطفى قاسم عبد الحق

إشراف

د. عماد بريك

الملخص

يعتمد الحصول على الطاقة الكهربائية على مصادر وقود آخذة في النفاذ وتسبب تلوثا ضارا بالبيئة, بالإضافة إلى التكلفة العالية للوقود ومعدات التوليد والنقل والتوزيع. لذلك, وعلى نطاق عالمي, أصبحت طرق ووسائل ترشيد استهلاك الطاقة الكهربائية وكذلك طرق ووسائل إدارة الأحمال الكهربائية من أهم الأمور التي يتم التركيز عليها من اجل تقليل كمية الوقود اللازم من جهة, والاستخدام الاقتصادي والفني الأمثل للمعدات المستخدمة من الجهة الأخرى.

إن كفاءة استخدام الطاقة الكهربائية وترشيد استهلاكها وطرق إدارة أحمالها بحاجة إلى دراسة معمقة في فلسطين. وكنموذج سوف نقوم بدراسة شبكة كهرباء نابلس.

تحاول هذه الأطروحة التطرق إلى عملية تحليل وتقييم لوضع استهلاك الطاقة في شبكة كهرباء نابلس من خلال انجاز عمليات تدقيق على الطاقة في عدة قطاعات مستهلكة للطاقة في شبكة كهرباء نابلس, بغرض ترشيد وتحسين كفاءة الطاقة المستهلكة. أيضا تحاول هذه الدراسة البحث في إمكانية إيجاد الحلول لتقليل الحمل الأعظم لشبكة كهرباء نابلس، حيث أصبح الحمل الأعظم الذي تسحبه الشبكة مساويا للسعة العظمى المتاحة من مصدر القدرة الكهربائية , وذلك لتلافي الوصول إلى وضع يتم فيه فصل الطاقة الكهربائية عن قسم من المستهلكين.

من خلال البحث تم التوصل إلى انه يمكن توفير كمية لا يستهان بها من الطاقة إذا ما تم تطبيق بعض إجراءات ترشيد الطاقة في قطاعات ضخ المياه, الأحمال المنزلية وإنارة الشوارع, حيث بلغت كمية الطاقة التي يمكن توفيرها في هذه القطاعات إلى 14860269 كيلوواط/ ساعه, بتكلفة استثمارية تساوي 15567303 شيكل, أي أن فترة استرجاع راس المال لن تتجاوز السنتين.

كما أثبتت هذه الدراسة انه وبتطبيق إجراءات ترشيد الطاقة واتخاذ بعض إجراءات إدارة الأحمال الكهربائية في القطاعات المذكورة, فانه يمكن تقليل الحمل الأعظم لشبكة كهرباء نابلس بنسبة 4.7% مع إمكانية زيادة هذه النسبة باتخاذ بعض الإجراءات الأخرى أهمها تطبيق نظـــام تعرفة جديد للطاقة الكهربائية.