INTEGRATED DEMAND SIDE MANAGEMENT IN NETWORK PLANNING

FOR UTILITY COMPANIES

A THESIS IN ENGINEERING SYSTEMS MANAGEMENT

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ABSTRACT

In the way of transferring from public benefits authorities to developers and investors, the annual growth rate will increase rapidly through a strategy of sustainable development. With the high economic growth, it is predicted that electricity demand will be also increased yearly. A major challenge for ADDC (Abu Dhabi Distribution Company) policy makers is to determine how best to provide the least energy to meet this extraordinary economic growth. Moreover the utilities should respond promptly and economically with new power capacity capital investments. The ADDC strategy in power system planning to meet the rise up in consumer demands is usually achieved by adding a new capacity, reinforcing or upgrading only the supply side structure. Furthermore ADDC at present doesn't have any control over demand side management of the load

This thesis investigates the implementation of Demand Side Management (DSM) as a strategy that is practiced in different countries around the world and develops a model that integrates the proposed strategy in network planning.

The finding of this study demonstrates the effect of integrating DSM during the network planning and design stages in utility companies on the network performance. The model will be based on the international experience in DSM applications with innovative modifications to account for the factors affecting network planning in a fast growing demand and high load diversity. The developed model will have a drastic change during the planning stage for future expansion in power system in Abu Dhabi.

The thesis aims also at providing comprehensive computational effort to achieve a breakthrough at Abu Dhabi Distribution Company in moving from traditional planning practice to advanced techniques where DSM is able to minimize the futuristic investment. Time of Day Tariff (TOD) technique as load management program can save both electricity consumption and the peak load. The study reflects how the customer load patterns change within the 24-hour day and accordingly within the year when the TOD introduced. A quantitative approach is result on saving peak load will increase the energy efficiency in power system and modify the load pattern within the day, moreover within the year. The study illustrated the benefit achieved to ADDC as the avoided extra cost in capital investments; better utilization of the existing assets and the avoided charge for the required demand would have a great impact as an attractive resource. Similarly DSM will have a great impact for the customers in a way of reducing their electricity bill in line with managing their load usage for better and higher efficiency utilization.

CONTENTS

LIST OF FIGURES

Figure Page

LIST OF TABLES

LIST OF ABBREVIATIONS

A/C-Air Conditioning

AADC-Al-Ain Distribution Company

AD-AbuDhabi

ADDC-AbuDhabi Distribution Company

ADWEA-AbuDhabi Water and Electricity Authority

AMR-Automatic Meter Reading

CAPEX-Capital Expenditures

CCP-Critical Peak Pricing

CFL-Compact fluorescent Lamps

DMS-Digital Management System

DSM-Demand Side Management

EPRI-Electric Power Research Institute

ER-Eastern Region

GENCOS-Generation Companies

GWh-Gega Watt Hour

HID-High Intensity Discharge

HV-High Voltage

HVAC-Heating, Ventilation, & Air Conditioning

KV-Kilo Volt

KVA-Kilo Volt Ampere

KW-Kilo Watt

KWh-Kilo Watt Hour

LDC-Load Dispatch Centre

LDN-Load Demand Notification

LV-Low Voltage

MW-Mega Watt

PB-Parsons Brinckerhoff Ltd

RCC-Regional Control Centre

RTP-Real Price Timing

SAIDI-System Average Interruptions Duration Index

SAIFI-System Average Interruptions Frequency Index

STLF-Short Term Load Forecast Function

TCA-Tabors Caramanis & Associates

TOD-Time Of Day

TOU-Time Of Use

TRANSCO-Transmission and Dispatch Company

V-Volt

VSD-Variable Speed Dives

WR-Western Region

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There are many people whom I would like to acknowledge for their assistance and support in completing this work, both technical and moral.

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To all those whose names may not be mentioned, their good deeds are always remembered and treasured.

DEDICATIONS

I dedicate this thesis in the loving memory of my father, Mohamed Khalfan, who encouraged me from an early age to set goals and achieve them.

To my mother S. Naser, who sacrificed much to make her children proud, and smiled with satisfaction when we did well.

To my brothers and sisters who give me all the helpfulness and constant support during my study years

CHAPTER 1

1 INTRODUCTION

1.1 Background and Motivation

The aim of an electrical distribution system is to distribute power from primary substations to meet the electrical demand of individual consumers as shown in Fig.1.1. Although the system planning and design engineers have some freewill in the selection of many factors that are necessary during the design stage of the distribution network, the only aspect over which the designer/operator has only limited control is the characteristics of the loads served. The maturity means of characterizing demand is therefore very useful in the planning of the future development of distribution networks and for economic/tariff considerations. Demand characteristics are typically defined in terms of their magnitudes and the way in which the load magnitude changes across a day and also the way in which it varies throughout the course of a year. The way in which demands of multi types of load are combined, the relationship between such demands, and the time of the day or year where the maximum demand may occur at times of high ambient temperature are important factors in network and system design. These factors are very essential in determining individual feeder, substation and total system demands.

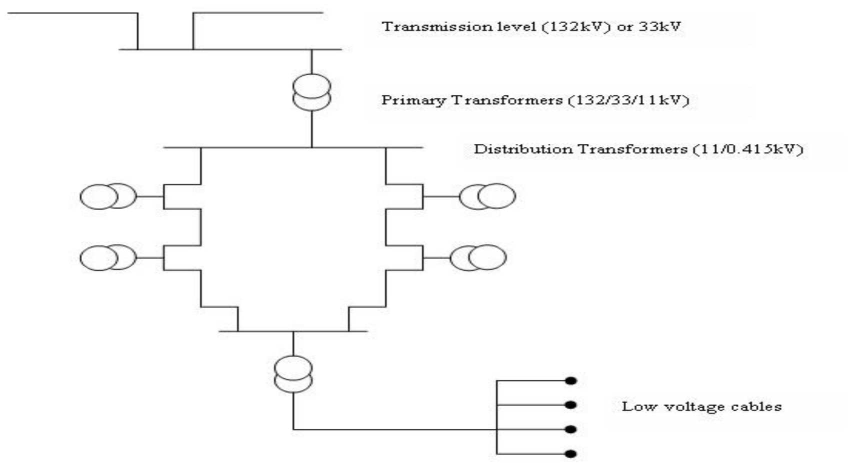


Fig.1.1 Simple Power System Structure

The demand profiles at the time of maximum needs form a convenient basis for determining the power supply requirements for prospective consumers.

This represents an important concern in Abu Dhabi distribution planning. The shape of the demand profile consequently enables the planner to take into account the maximum demand that needs to be served, as well as the duration of that demand, so that he can optimize the rating of the supply equipment. In general terms the main parameter that describes the shape of the profile is the Load Factor (LF), which is defined as the ratio of the average load during a specified period, to the peak load during that period. It is common practice in many countries to record demand profiles using half-hourly readings over 24-hour periods, this practice being partly determined by the sampling period of the available instrumentation equipment, i.e. half or quarter hour energy metering.

1.2 Statement of the problem

Changes in land ownership laws in 2005 and the release of surplus oil revenues for major infrastructure developments and mega projects have resulted in a development boom. This will require significant quantities of extra electricity and water capacity above the normal developments assumed in past forecasts. According to ADWEC estimates, there could be a shortfall in both power and water as early as 2010 as demand rises above supply. Electricity demand has been shifted five years forward, and additional capacity will be required in 2009 / 2010. This will aid privatisation and create more opportunities for investors. Beyond 2012, demand and capacity requirements are uncertain [17].

A major challenge for Abu Dhabi's policy makers is to determine how best to provide the necessary energy to fuel it's extraordinary economic growth. The traditional approach was based on increasing the supply of conventional energy resources, yet energy is not an economic output that must be maximized at all costs. Rather, it is an input to the generation of goods and services, such as heating, lighting, mobility, industrial products, and consumer goods. Reducing the input needed to provide these goods and services would have benefits that reverberate throughout Abu Dhabi’s economy also to avoid power shortages that threaten its continued economic growth. That's why it becomes more important than ever to find ways to use energy more efficiently.

The ongoing high electricity consumption is not totally due to economic and past growth, but also to inefficient use caused, mainly, by: (1) large number of appliances in residential, commercial and industrial sectors and their high energy requirements; (2) old industrial machinery; (3) widespread usage practices[26].

One tool that has proven effective in many countries for delivering energy efficiency, but has not yet been widely adopted in Abu Dhabi officially, is Demand-Side Management (DSM). DSM is a mechanism in which a utility or some other state-designated entity uses funds derived from the electrical system to promote energy efficiency through targeted educational or incentive programs whose effects are measured quantitatively. In align with the energy efficiency measurement; this system basically is to introduce measures for the end users to economize the electricity consumption during peak load hours. This results in considerable load demand reduction during peak hours enabling the utility companies to meet increased load demand without adding new assets and therefore saving the costs.

1.3 Objective and Approach

DSM aims to change behaviors in order that electricity demand is more evenly expand without effecting production or the satisfaction of the user. This satisfaction is of course closely allied to the fact that we do have access to affordable power. Without DSM we will need additional power stations, all of which cost great amounts of money and like all business, the cost of which will lead to price increases. When doing a long-term asset management strategy the objective is to find the right balance between costs, condition and reliability. If too much resources are allocated for maintenance the lifecycle costs will be too high, and on the other hand, too little maintenance will inevitable lead to a slow deterioration that will result in a high risk of unacceptable outage and restoration cost [15]. Numerous studies in China and other countries have found that cost-effective DSM programs can reduce electricity use and peak demand by approximately 20% to 40% [4]. Cost-effective efficiency and load management measures could significantly improve the reliability of Abu Dhabi's electric system and close the gap between supply and demand, while lowering the economic costs of electric service. Moreover Demand Side Management refers to measures that modify end-use consumption. DSM programs are designed to modify either the level or pattern of electricity usage, reducing overall consumption through improved energy efficiency, or modifying the usage profile through load management. However, DSM can also involve the strategic addition of new load. At a macro level the goal of DSM is to optimize energy resources.

In comprehensive the primary objective is to lower total societal costs. Extended objectives include environmental improvement and increased economic competitiveness. At the local level, DSM can be employed for more specific purposes. These usually involve the avoidance or deferral of new electricity supply facilities, with the associated cost savings. Where supply constraints are immediate, DSM can be used to maintain system capabilities, or to free up capacity to serve new, presently unconnected customer [29].

1.4 Significance of the Thesis

The key purpose of this thesis is to develop a mechanism that integrates demand side management techniques into the network planning of distribution network in electric utility. A financial analysis for cost effective implementation of the DSM will be provided specially with the privatization environment where the focus on reducing the cost in line with the network reliability is the main objective. The tangible objectives for applying these techniques can be achieved by various programs, where they will introduce the energy efficiency, load shape flexibility, reducing the utility cost and customer satisfaction.

One of the programs is the energy efficiency program which can implement through targeted educational or incentive programs. Energy-efficiency programs reduce energy use, both during peak and off-peak periods, typically without affecting the quality of services provided. DSM energy efficiency programs can be implemented in a variety of ways, such as:

- Providing financial incentives to end-users to modify energy use or change end-use equipment to more advanced one to produce the same/or higher level of end-use services (e.g. switching to more efficient light bulbs or refrigerators) with less electricity. Also for example, energy-efficient lighting yields energy savings whenever the lights are on throughout the year, and energy-efficient motors and drive systems yield savings whenever they are operated.
- Entering into energy efficiency performance contracts and other third-party initiatives and it's already started in Abu Dhabi through distributing the AC by Tabreed Company where by reducing the AC load from the electrical distribution network that lead to reduce the overall load in our system specially the peak period.
- Educating end-users on available efficiency opportunities

Load management programs involve reducing loads on a utility's system during periods of peak power consumption or allowing customers to reduce electricity use in response to price signals. Such programs use mechanisms like interruptible load tariffs, time-of-use rates, real-time pricing, direct load control, and voluntary demand response programs [6]. Moreover one method to achieve that is the load shedding in air conditioning where for example switch off one chiller of three during the peak hours. In general load management programs can be effective in reducing peak demand, which in turn helps to reduce utility construction costs as well as lower electric rates. Yet load management programs are largely short-term responses that alone do not exhaust the cost-effective demand-side potential. The multiple long-term benefits that investments in energy efficiency can bring to the entire electric system are often overlooked. Combining load management programs with end-use energy efficiency programs can heighten the effectiveness of both approaches and lead to the greatest demand reductions.

1.5 Thesis Organization

This thesis investigates how the demand side management can be integrated in utility companies such as in Abu Dhabi Distribution Company (ADDC). Introduction and identification of such a new technique is introduced in this chapter. In addition, thesis background and motivation, the statement pf the problem, research objectives as well as significance of the research are also presented in this chapter. Chapter two will comprise of open literature review pertains to the main stream of the thesis. It includes demand side management practices and objectives. It also illustrates in general the demand side management technique, familiar tools used globally and the findings obtained from applying this new technique. Chapter three will introduce the reader to ADDC as a utility company where this study is implemented. This chapter includes structure of power system in Abu-Dhabi, power demand growth, existing distribution networks, and system utilization metrics. Chapter four will explain the load forecast, the model used and the results distinguished by the load categories of residential, commercial, agricultural and industrial. Chapter five is discussing the load characterization in AbuDhabi and how is the load pattern changing within 24-hours a day or within the season (mainly winter and summer). Furthermore this chapter investigates how the load is distributed within one category, e.g. lighting, A/C, sockets and water heater. The percentage of each load will be calculated and the results will show how impact and contribution within the hourly load pattern. Chapter six is the core chapter where the main study of the demand side management techniques is presented by two tools. One of presented tools is the Time of Day Tariff tool in a residential load category as one of load management technique that intends to modify the load pattern for the customers. This chapter also indicates how the load forecast affects the peak loads after integrating the DSM with the planning strategy and the benefits that are generated after implementation. Energy Efficiency Culture is chosen as example of the energy management technique to investigate how changing the customer's behavior will lead to better, cheap and efficient energy. Chapter seven is the conclusion for this study and the recommendations for any future study or execution of this new technique in ADDC.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Background

The rising power demand by rapid economic growth required many countries to make significant investments in power generation, transmission, and distribution systems. The Electric Power Research Institute (EPRI) estimates that the cost to upgrade transmission and distribution to relieve constrained lines and meet growing power demands could reach US$100 billion. In addition to the massive amount of work needed, the difficulty and time frame required to site and install new power lines means that load relief via construction is years away. Since significant investment is required and quick fixes don't exist to meet the industry's long-term energy needs, utilities should be seriously considering demand-side management (DSM) as a viable part of the integrated solution [13].

In practice, “Demand-side Management” (DSM) is one of applicable idea leads to energy efficiency by reducing the end-users’ power demand through offering special programs. DSM programs offer clear benefits to stakeholder, i.e. households, enterprises, utilities and also societies. Nevertheless, being an innovative idea dealing with public acceptability makes DSM faces to numerous barriers to overcome. On the mean time, there are policy approaches to encourage DSM program to reasonable success by reason of the concept of services and incentives referring to government or utility program to support the idea as well as the significant role of end-users [16].

2.2 Demand Side Management Objectives

There are several objectives of DSM initiatives which can be narrowed to:-

• Reduce demand on the system and better utilize existing and future assets: Specifically targeted measures for peak load periods will not only help reduce the load when the risk of outage is highest, but can help defer capital expansion of the system which would eventually be reflected in the rate base and customer bills.

• Reduce system losses: By selectively targeting measures to manage peak demand the LDC reduces system losses, which are highest during peak demand.

• Reduce resource consumption: A reduction in load during peak periods offers higher levels of resource savings in terms of generation fuel because it requires much more power to deliver required energy at peak load.

• Reduce emissions: The reduction in generation at peak periods will bring an additional benefit of a reduction in the associated environmental emissions.

• Reduce customer bills: Targeted incentives to reduce peak load will have the effect of reducing customer bills, particularly for industrial and commercial customers who must pay high market prices during peak load periods.

• Promote efficiency: Targeted peak load measures can improve system load factor, which again results in higher overall system efficiency [21].

2.3 Demand Side Management Practices

More than 30 countries around the world have successfully applied DSM to increase energy savings, reduce the need for new power plants, improve economy and reliability in power network operation, control tariff escalation, lower customer electric expenses, save energy resources, and improve environmental quality. DSM has become an important strategy for achieving sustainable energy and electricity development. DSM is now used and useful for all consuming sectors such as residential buildings (including special efforts for low-income or hard-to-reach populations), commercial and institutional buildings, governmental sectors, and industrial plants.

For example Australia is entering a period of intensive electricity infrastructure renewal and expansion. Aging electricity assets, a growing economy, changing population distribution and changing consumption patterns are all driving the need for upgraded infrastructure. The investment and operating choices made will have significant implications for consumers, investors (including States owning major electricity companies), the environment, and the economy as a whole. In the coming decade, government and private parties are expected to invest about $30 billion in new electricity infrastructure to meet the growing needs of Australia's vibrant economy. Notably, while much of these projected costs could be avoided by demand management; there is little indication of anticipated DM investment [19].

Europeans are going to hear a lot more about how to achieve sustainable energy consumption, installing energy saving lamps, replacing the old boiler, getting rid of the old fridge, insulating the roof. The promotion is part of a new Sustainable Over the next four years, Europe's executive branch will promote action to meeting its energy policy aims - an increase in the share of renewable energy up to 12 percent by 2010 and the saving of 20 percent of energy consumption by 2020 [5].

Many program and policy alternatives exist for implementing DSM measures. Among the options are utility-operated DSM programs, government-operated DSM programs, regulations, and standards. Each of these approaches has a useful role to play. Equally important, utility and non-utility approaches can work together, and such joint approaches are often the most powerful method for overcoming market barriers. For example, utility programs can make regulatory approaches more effective and palatable by bearing some of the costs of compliance and enforcement, for example, in new buildings. Also, utility programs can increase the market penetration of new technologies to the point where they are used by the majority of customers and mandatory government efficiency standards can take over, a point that might not be reached until years later without utility programs [20].

2.4 Demand Side Management Programs and Tools

In the past, the primary objective of most DM programs was to provide cost-effective energy and capacity resources to help defer the need for new sources of power, including generating facilities, power purchases, and transmission and distribution capacity additions. However, due to changes occurring within the industry, electric utilities are also using DM to enhance customer service [25].

Accordingly, DSM programs generally fall into two main categories:

- Energy efficiency and conservation which is programs to reduce energy use by improving the efficiency of equipment (lighting and motors, for example), buildings, and industrial processes. There are a large variety of load equipments and applications that can be switched on or off at a particular times to reduce electricity demand from the network.
- Load management which is programs to redistribute energy demand to lessen peak demand and hence reduce peak load on generation and transmission facilities and, sometimes to fill in troughs (to strategically increase energy use during periods of low electricity demand.). Examples include load shifting programs (reducing air conditioning loads during periods of peak demand and shifting these loads to less critical periods), time-of-use rates (charging more for electricity during periods of peak demand), and interruptible rates (providing rate discounts in exchange for the right to reduce customers' electricity

allocation during the few hours each year with the highest electricity demand).

Demand-side planning and management incorporate all utility activities that are designed to influence customer use of electricity in ways that are mutually beneficial to the customer and the utility. By actively influencing the demand for electricity, the utility can help assure efficient use of the electric system and provide a broader range of choices for customers. Demand-side programs are those products, services, tariffs, regulations, policies, or any combinations of these that will influence the time, pattern, and magnitude of participating customers' electrical loads [8]. The demand-side planning and management process is dynamic, flexible, comprehensive, and must accommodate changing conditions.

The process of demand-side planning and management includes establishing demand management objectives, screening various options, evaluating the options for those with the most potential, implementing the chosen DSM programs, and monitoring their impacts. The details of each step are shown in Figure 2.1.

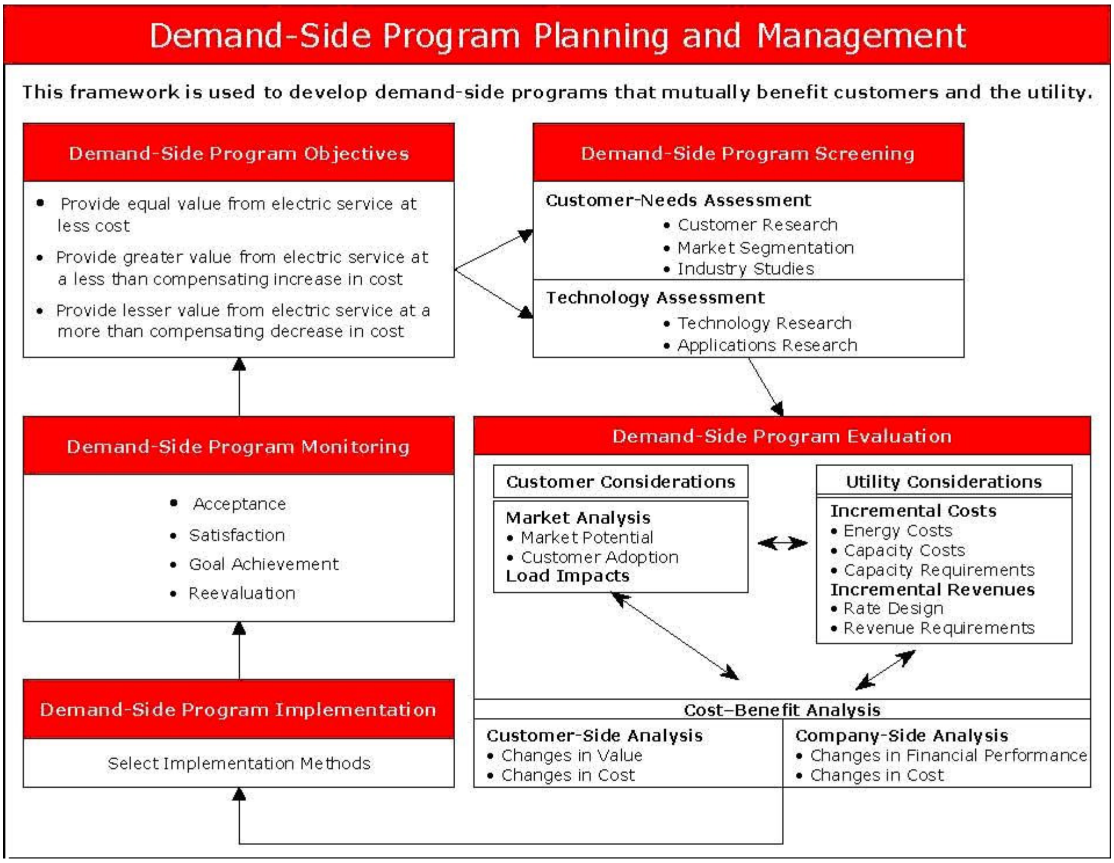


Fig.2.1 DSM Program planning & management [8]

2.4.1 Energy Efficiency

DSM programs that are aimed at reducing the energy used by specific end- use devices and systems, typically without affecting the services provided is called energy efficiency. These programs reduce overall electricity consumption (reported in megawatt hours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technologically more advanced equipment to produce the same level of end-use services (e.g., lighting, heating, motor drive) with less electricity. Examples include energy saving appliances and lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

2.4.1.1 Industrial

2.4.1.1.1 High Efficiency Motors

High efficiency motors and Variable Speed Drives (VSDs) can cost-effectively improve industrial energy efficiency. The program had a sufficient impact in Indonesia within the five years 1995-200 as shown in Table 2.1.

Table 2.1

Industrial Motor Programs Impacts by Year in Indonesia

Year	1995/1996	1997/1998	1999/2000
Energy Saved (GWh)	7	26	138
Peak Reduction (MW)	1	3	17

2.4.1.1.2 Power Factor Correction

Power factor reductions result from reactive loads which in effect use up generation, transmission and distribution capacity. Inductive loads, such as motors, often reduce power factor to the range 0.8 to 0.9. Some inductive loads, such as certain types of electric furnaces, may have power factors as low as 0.3. The most commonly used means of correcting low power factor are:

(a) On-site capacitor banks. Capacitors can be installed at any point in the electrical system and will improve the power factor between the point of application and the power source. However, the power factor between the load and the capacitors will remain unchanged. Capacitors are usually added at each piece of offending equipment, ahead of groups of motors or at main services.

(b) On-site switched capacitors. Plants equipped with very large intermittent inductive loads, such as large motors, may require switched capacitors which are utilized only when the motor load is on. Such capacitors may be controlled from the substation depending on the measured power factor. The switching feature is only required if the capacitors needed are so large that they cause an undesirable leading power factor during times when inductive loads are off.

(c) Utility distribution line capacitors. Utilities can install capacitors on their own lines where it is not practical to measure power factor or to assess charges to owners. For instance, capacitor banks are often installed on utility poles in residential neighbourhoods [9].

2.4.1.2 Residential and Commercial

2.4.1.2.1 High Efficiency Lighting

The following measures are suggested for consideration into high efficiency lighting: (a) Replacing incandescent bulbs with Compact Fluorescent Lamps (CFL); (b) Replacing standard fluorescent tube lamps with energy-saving fluorescent tube lamps; (c) Replacing standard fluorescent ballasts with high-efficiency magnetic or electronic ballasts; (d) Installing optical reflectors and removing lamps that are no longer required; (e) Installing occupancy sensors; and (f) Replacing mercury vapour High Intensity Discharge (HID) lamps with sodium HID lamps.

The program had excellent impacts in the utilities. For example Indonesia achieved both energy save and peak reduction as shown in Table 2.2.

Table 2.2

High Efficiency Lighting Programs Impacts by year in Indonesia

Year	1995/1996	1997/1998	1999/2000
Energy Saved (GWh)	7	29	74
Peak Reduction (MW)	1	4	10

2.4.1.2.2 Improved Air Conditioning

This program is assumed to target building Heating, Ventilating and Air Conditioning (HVAC) systems rather than window air conditioning units. The proposed program entails the implementation of the following measures: (a) Proper sizing of cooling tower pump; (d) Reducing air leakage and infiltration; (e) Operating fans according to loads; and (f) Using more efficient compressors, pumps, and motors. As case study the effect has been taking in Indonesia considering air conditioning improvement will show in Table 2.3.

Table 2.3

HVAC Programs Impacts by Year in Indonesia

Year	1995/1996	1997/1998	1999/2000
Energy Saved (GWh)	2	11	62
Peak Reduction (MW)	0.3	1.1	6.6

2.4.1.2.3 Improved Refrigerators

The program would entail three components to encourage the use of the more efficient domestic refrigerators: testing and labelling of all refrigerators to be sold, so consumers would be aware of the energy costs associated with that particular model, both in absolute terms and relative to other models in that class; rebates to trade allies, e.g. appliance retailers, to help encourage the sale of these improved models; and incentives to manufacturers and assemblers in Indonesia to incorporate more efficient designs in their production. Potential Impacts in Indonesia for 5 years is illustrated in following table.

Table 2.4

Refrigerators Improvements Programs Impacts by Year in Indonesia

Year	1995/1996	1997/1998	1999/2000
Energy Saved (GWh)	2	11	62
Peak Reduction (MW)	0.3	1.1	6.6

2.4.2 Load Management

Demand response programs, also known as load management programs can be broadly categorized along two dimensions:

-Trigger criteria: system reliability or economic trigger

-Notification method: load response or price response [11].

2.4.2.1 Load Response

Utilities offer customers payments for reducing their demand electricity for specified periods of time. Program participants can be considered “sellers,” since they provide load reductions in exchange for various prices offered by the utility. However implementing these technologies and techniques is not always so cheap. However there are many opportunities where we can apply these without any additional cost or investment. But to apply them at large scale for the whole market there are various factors to be considered as:

- Cost to the customer to shed and reschedule the load
- Time it takes to activate the load response
- The variation in wholesale price
- Losses to occur in case of reliability problems due to acute shortage
- Any losses in production by implementing these programs [22]

2.4.2.2 Price Response

Demand response programs in which customers voluntarily reduce their demand in response to economic signals. This program has different sub programs which are TOU, CCP and RTP as described below.

•Time-of-Use (TOU) is typically 3 time blocks published in advance for entire season

•Critical Peak Pricing (CPP) is a high price imposed on a few days a year when energy is expensive or system conditions are critical or near critical as shown in Figure 2.3. In general non-CPP hours are less expensive as a result; customer pays the critical price when invoked by the utility and day-ahead forecast of CPP offers added time for response.

•Real-Time Pricing (RTP) charges the hourly marginal energy cost with the following concepts:-

- Reflects hot weather, scarcity, or equipment failure
- Notification can be day-ahead or hour ahead

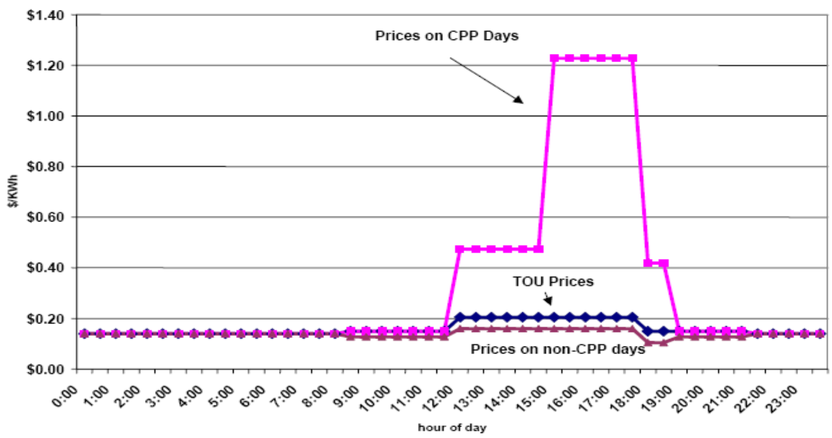


Fig. 2.3 Example of a Utility CPP Summer Tariff [11]

Demand Response technologies most often target HVAC and lighting for load reductions, but frequently target additional end uses (Residential programs target A/C, water heater, pool pumps) Customers have a variety of technologies available to them to enable load flexing for demand response as shown in Figure 2.4.

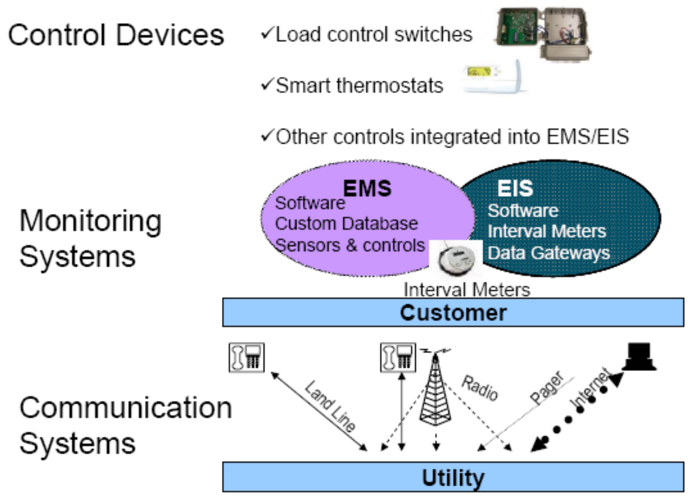


Fig. 2.4 Technologies used in monitoring [11]

2.5 DSM Cost-Effectiveness

When doing a long-term asset management strategy the objective is to find the right balance between costs, condition and reliability. If too much resources are allocated for maintenance the lifecycle costs will be too high, and on the other hand, too little maintenance will inevitable lead to a slow deterioration that will result in a high risk of unacceptable outage and restoration cost [22].

Since the implementation of a DSM program reduces the system peak load and increases the operating efficiency, an opportunity cost to the utility, such as the avoided cost, is induced by the implementation of an appropriate DSM program. In other words, the cost reduction results from savings in both the capital carrying and operating expenses.

To maximize effectiveness and cost-effectiveness it is necessary to design and implement specific activities to desired areas and sectors as the following:

1. General information to inform customers about generic energy efficiency options.

2. Site -specific information to provide information about specific DM measures appropriate for a particular enterprise or home.

3. Financing to assist customers with paying for DSM measures, including loan, rebate, and shared-savings programs.

4. Direct installation to provide complete services to design, finance, and install a package of efficiency measures.

5. Market transformation to seek to change the market for a particular technology or service so that the efficient technology is in widespread use without continued utility intervention.

6. Alternative rate design including time-of-use rates, interruptible rates, and load shifting rates [7].

CHAPTER 3

3 ADDC AS A UTILITY COMPANY

3.1 Introduction

The Abu Dhabi water and electricity sector comprises the production, transmission, distribution and supply of electricity and potable water to customers. Electricity is generated in predominantly power stations located throughout the Emirate. Transmission lines at voltages of 400, 220 and 132 kilovolts connect the major centres of generation and demand. Electricity is distributed to customers at 33 KV and 11 KV. The Emirate experiences high temperatures, reaching nearly 50 degree Celsius during summer months that extend from May to September, as well as high relative humidity especially during August, while the weather becomes fine in winter. Since major power consumption is for domestic use, the power loads peak during the summer months due to intensive use of air conditioning, raising loads to more than double those in winter.

3.2 Structure of Power System

The organised Electricity Supply Industry comprises the following principal organisations:

- The Abu Dhabi Transmission and Despatch Co. (TRANSCO)
- Electricity and Water Distributors (ADDC & AADC)
- Generators (GENCOS), comprising four main companies derived from ADWEA, and certain independent Generators
- Customers who have Generating Plant for supplying part or all of their own needs and who may sell limited amounts of electricity without a licence.
- The Abu Dhabi Water and Electricity Company which is the single of buyer of water and electricity capacity and output and is responsible for the matching of capacity and demand [1].

As one of the two distribution companies' subsidiary of ADWEA, ADDC involves providing services distributing Water and Electricity to the consumers in the district of Abu Dhabi and the Western Region with a secure and efficiency power supply. Figure 3.1 shows how the power network flow starting from the generation and reach to the customers as end use.

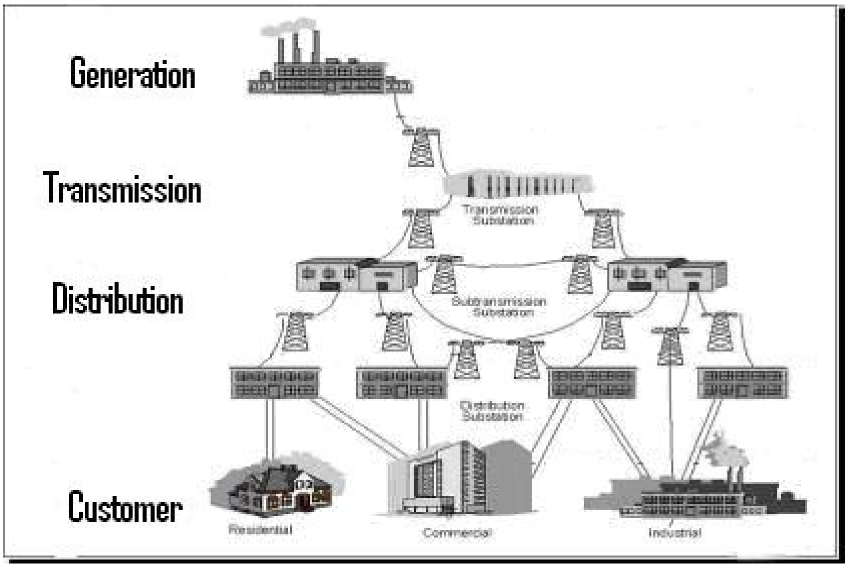


Fig. 3.1 Structure of power system

3.3 Abu Dhabi Emirate Regions

The ADDC system is organised as three regional systems:

- Abu Dhabi Island (i.e. Abu Dhabi City)
- Eastern Region;
- Western Region.

The regions differ significantly in three main respects:

1- The available transmission voltage

In Abu Dhabi City the principal transmission voltage is 132 kV with the only 220 kV installations at E48. In the Eastern Region both 220 kV and 132 kV are available to supply bulk power to ADDC, whilst in the Western Region only 220 kV exists. A 400 kV transmission network overlays the 220 kV and 132 kV systems to interconnect the principle generating stations with Abu Dhabi City (via Shahama in the Eastern Region) and with Al-Ain.

2- The range of load densities

The highest load densities in the emirate are found in the main commercial district of Abu Dhabi City. However western region is considered to be the lowest load density.

3- The nature of power distribution

In Abu Dhabi City the distribution system is exclusively based on underground power cables, whereas in the Eastern and Western regions the distribution system is mainly reliant on overhead lines, see Fig. 3.2. The distribution system in Abu Dhabi City has developed principally as a two tier system based on an 11 kV primary voltage and a 415 V secondary voltage, with direct transformation from 132 kV to 11 kV at all but a handful of primary substations. On the mainland, the distribution system has mainly developed as a three tier system, i.e. 33/11/0.415 kV. In the towns and industrial areas of the network in Eastern Region, the 11kV network is based on underground cable circuits. There are fewer areas in the West region designated for specific development other than for farming, but Madinat Zayed and Liwa are still experiencing considerable growth [23].

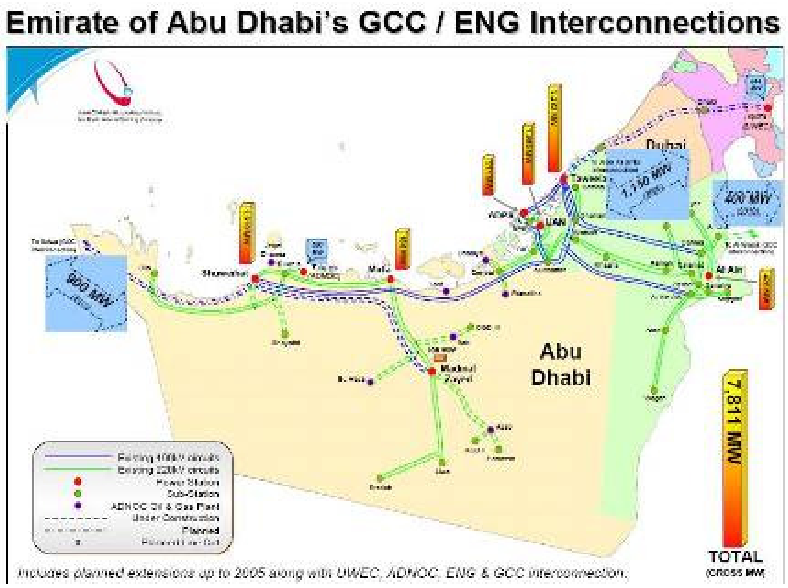


Fig.3.2 The power network in Emirate of Abu-Dhabi [17]

3.4 Power demand growth

3.4.1 Abu Dhabi Island Load Growth

In year 2005, the peak load for Abu Dhabi Island was 1457 MW based on ADDC Regional Control Centre data. However, the Island peak load for Year 2004 was 1441 MW based on the same source of data, which implies 1.1 % peak load growth in 2004. This figure of low growth rate may due to the fact that high load density areas of the island (North East) are becoming saturated, which means a drop in the rate growth in these areas. Also, loads of commercial buildings commissioned lately in 2004 will actually be reflected in 2005 peak. This is in addition to the delay in the construction of some development projects in the island. About 76 MW of additional load is expected to be added to the island peak this year, which means 5.2% growth rate. Similarly, about 82 MW of additional load is expected to be added to the island peak in Year 2006, which means 5.3% growth rate. Accordingly the expected coming projects will perform high growth rate.

3.4.2 Eastern Region Load Growth

The peak load for Eastern Region was 855 MW in year 2005 based on ADDC Regional Control Centre data. However, East Region peak load for year 2004 was 789.49 MW based on the same source of data, which implies 8% peak load growth in year 2004. This figure of considerable growth rate may due to the fact that newly developed houses in the area are in the stage of becoming occupied by their owners. Another reason would be the increasing number of industrial and commercial businesses especially in Mussafah area. This is in addition to large residential projects that are being developed in this area following the recent boom in real estate industry in the Emirate of Abu Dhabi.

3.5 Existing Distribution Networks

3.5.1 Electrical Distribution Network at ADDC

ADDC has three regions, Abu Dhabi Island, Eastern and Western. The existing distribution at ADDC consists of 132-11 kV and 33-11 kV primary substations. The 132-11 kV substations are located in the higher load density areas of Abu Dhabi Island, while the 33-11 kV substations are predominately located in the Eastern Region and Western Region. The 33 kV network is also used to serve distribution load, normally for loads of large demand levels.

Abu Dhabi Island has the highest concentration of load. The 11 kV distribution network includes switching substations that are used to provide load relief for overloaded 11 kV feeders and to provide a source of power for large consumers. The 11 kV network consists of direct buried underground cable fed from the 132-11 kV primary substations. These primary substations have up to four 40 MVA transformers. The Abu Dhabi 11 kV distribution network is interconnected and is operated as an open ring network. It is possible to transfer load between primary substations using the 11 kV feeders. The Eastern Region is located on the mainland to the north and east of Abu Dhabi City. This area is experiencing large growth due to housing and industrial developments. The 11 kV distribution network is supplied from 33-11 kV primary substations. The 33 kV network is supplied from 220-33 kV grid substations. The Western Region is a large area with a lower load density than the other regions. There is a significant amount of overhead lines located in this region.

3.5.2 Existing Distribution Design Practices

The design practices involve the installation of new facilities to serve new loads and the upgrading or reinforcement of existing facilities due to load growth on the existing network. Planning engineers develop schemes for 33 kV feeders, 33-11 kV primary substations, 11 kV feeders, and 11-0.415 kV distribution substations. The low voltage (LV) design is accomplished by planning engineers and others in the field services area. The planning engineers work with TRANSCO when requesting facilities from the 132-11 kV primary substations or 220-33 kV grid substations. The design practices are based on meeting the security standards, providing electric facilities with adequate capacity to serve the load and installing electric facilities to provide proper utilization voltage. The following provides a brief description of activities required in the existing design practice [23].

1- Load Data Acquisition and Load Forecasting Begins the Process

The load forecasts were developed by evaluating planning data from towns and by using linear regression analysis for medium-term and long-term forecasts. These load forecasts are used to develop plans for additional facilities to meet the proposed growth. The distribution planning engineers also obtain information on load growth of existing substations and feeders from their respective Regional Control Centre (RCC) on an annual basis. This information provides planning engineers with an indication of load being added by existing customers. This is done on the primaries and grid district but not apply yet for the load categories.

2-Design Options are created and provided for Approval

The planning engineers design the network expansion and reinforcement projects on a localized basis, rather than consider large area studies. Load demand diversity factors to be applied to new load additions based upon the type of load being served. However, they do not appear to be universally applied in day-to-day designing of the distribution network. There are instances of distribution transformers and service conductors sized to serve 100% of connected load, not the specified diversified load. The diversified load could be 40% of the connected load. Therefore, this could be a systemic element to overbuilding of the distribution network. The current engineering design process does not provide for consideration of alternative engineering designs and economic analyses.

Table 3.1 is an example for designing a new load (housing project) that is requested by Shamkha town planning authorities to provide the area with a suitable feeding arrangement and power requirement. For example we have a new 400 low cost house in Shamkha which is one of the newest cities in Abu-Dhabi, Eastern region. The bill of electrical equipments quantities to feed this city will be described as shown in Table 3.1. The results show that the total cost is approximately 24,000,000 Dhs in order to serve this city based on the current market prices.

Table 3.1

Bill of Quantity for 400 houses in Shamkha

S/N	Description	Unit	Rate (Dhs.)		Quantity	Total (Dhs)
			Supply	Installation		
1	11 kV, 3/cx240 mm^2 Land cable work with joint & Installation.	M	184.00	27.00	28,000	5,908,000
2	11 kV Ring Main Substation (4 Panels) (Building cost in the Instl.)	No.	250,000.00	150,000.00	13	5,200,000
3	11 kV TRM/QRM	No.	30,000.00	5,000.00	1	35,000
4	4/C x 240 sq.mm cable work	M	167.00	25.00	60,000	11,520,000
5	4/C x 120/70 sq.mm cable work	M	93.00	24.00	2,000	234,000
6	4/C x 25/16 sq.mm cable work	M	17.00	25.00	16,000	672,000
7	LV FP	No.	2,850.00	400.00	100	325,000
8	LV ST	No.	1,300.00	300.00	5	8,000
9	Energy meters	No.	1,000.00		400	400,000
	TOTAL (Dhs)					24,302,000

3.6 Security of Supply

Electric distribution companies design, construct and operate their networks to meet their security standards at the least cost. Although individual consumers have their own particular needs, supply reliability tends to be of varying importance to different "types" of consumer. Life cycle maintenance plans are prepared for all network assets including transformers and switchgear, as well as the lines themselves. Interruptions to the electricity supply can be planned or unplanned. Planned interruptions generally arise from the need to carry out maintenance, refurbishment or upgrading on the network. Unplanned interruptions can arise within all segments of the electricity supply chain. They are caused by a wide variety of factors - including trees or animals interfering with lines, cars hitting poles, cables being accidentally excavated, faulty equipment, and adverse weather – including high winds, lightning strikes and heavy rain giving rise to land subsidence [24].

Security standards reflect a trade off between service quality and service cost, or utilization of assets. These standards therefore have a direct bearing on the capital investment and type of network design to be employed for various load demands and load densities in the various service areas. The security standards are often characterized as "N-1" criteria, which means that they call for a design in which one component can fail without causing a sustained outage. The extent to which the companies are meeting the security standards can be measured using the service quality metrics, the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). In general two service elements are addressed in the security of supply standards:

(1) Capacity of the system to supply sufficient energy to the customer

(2) Transfer capability of the distribution system to transfer customers to alternative sources of supply in the event of an outage in their primary service.

The security of supply standards addresses capacity of the system by requiring the network to be capable of meeting the peak demand. Network equipment must be sized such that it does not incur thermal damage at peak load and that it provides adequate voltage to consumers at all times including during peak demand periods. The security of supply standards address transfer capability by requiring network equipment such as cables and transformers to be able to accept additional load transferred to them during outages of other network components. The performance of security indices (SAIFI) and (SAIDI) in ADDC display a very good results as shown in appendix A, this is due following the N-1 criteria as security of supply.

3.7 Performance Utilization in ADDC

TCA consultant had prepared a study to evaluate the performance of the network and they built software in order to show how far ADDC is from the target benchmark they develop. The recorded data and analysis of this data has several metrics for power system, cost and quality but what concerned here is to show the utilization of the network assets and the security of supply which is high in AbuDhabi network due to the n-1 criteria applied. The system utilization metrics address key components of the physical network that have a major direct impact on both service cost and service quality. The metrics are prepared for the most important assets which are primary transformers, distribution transformers and feeder capacity. The benchmarking targets used for these three metrics are 66% for primary transformers, 55% for distribution transformers and 63% for the feeders. The utilization of these assets can be classified by the region (AD Island, ER and WR) and also we can figure out the system utilization

3.7.1 System Utilization Metrics

3.7.1.1 Primary Transformer Utilization

Transformers are very expensive, so from a cost control and asset management perspective it is important that they be used at an optimal level. Optimal in this context means the highest level of loading consistent with the relevant reliability criterion, e.g., N-1, which can be maintained without causing equipment failure or premature wear. Primary transformer utilization metric measures the extent to which the capacity of primary transformers is loaded, or utilized, at the time of peak power delivery into an electric distribution company. Primary transformers are located at the point of interconnection between the distribution company and its sources of electricity, i.e., a transmission system and/or generating units. Primary Transformer Utilization is calculated on a system-wide basis by dividing the annual peak load, or demand, by the corresponding system-wide power factor at the primary transformers and then dividing that result by the total capacity of the primary transformers. The total capacity of the primary transformers used in this calculation should be the sum of their nameplate ratings [28]. Through two years the utilization of the primaries transformers for all regions had been less than target benchmark especially in Eastern and western (see appendix A) region and that force the utilization as a system wide to be also low as shown in Figure 3.3.This Figure shows that the year of 2005 has less utilization than 2004, this case has been investigated and obtained suitable options to integrate a new technique (DSM) in the planning for better assets utilization.

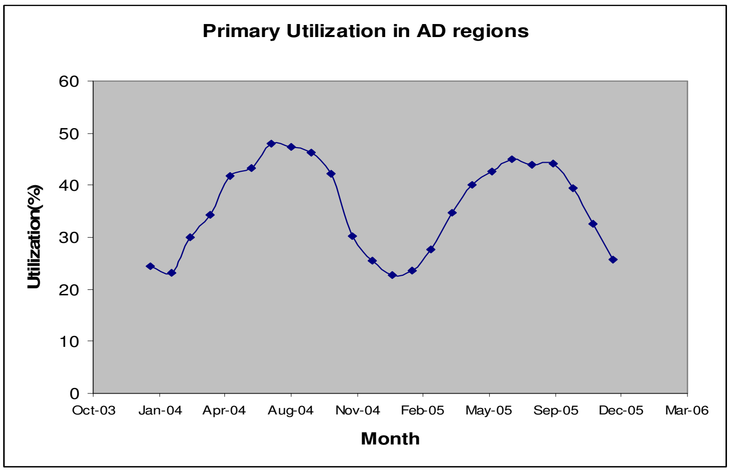


Fig. 3.3 Primary Transformers Utilization in AD Regions

3.7.1.2 Distribution Transformer Utilization

Distribution transformers are among the most expensive assets in the network, so from a cost control and asset management perspective it is important that they be used at an optimal level. This metric measures the extent to which the capacity of distribution transformers are loaded, or utilized, at the time of peak-power delivery. Distribution Transformer Utilization is calculated on a system-wide basis by dividing the annual peak demand, by the corresponding system wide power factor and then dividing that result by the total capacity of the distribution transformers. The annual peak demand served by the distribution transformers is the system-wide coincident peak demand. A reasonable estimate of the corresponding system wide power factor is the average of the power factor of each primary transformer measured at the hour of the system-wide coincident peak demand. The total capacity of the distribution transformers used in this calculation should be the sum of their nameplate ratings [28]. Through two years the utilization of the distribution transformers (see appendix A), which they are much more than the primary transformers had been less than target benchmark especially in Eastern and western region as shown in Figure 3.4. This Figure shows that the utilization of year 2005 is less than that of the year 2004.

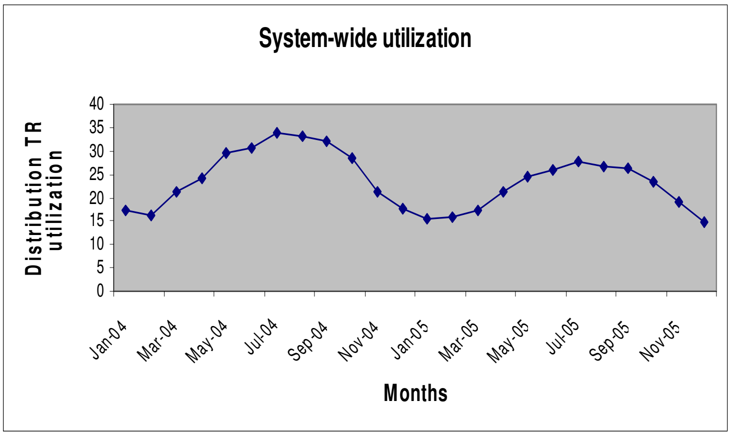


Fig. 3.4 Distribution Transformers Utilization in AD Regions

3.7.1.3 Feeder Utilization

As with primary and distribution transformers, optimizing the use of feeder capacity helps minimize service cost without reducing service quality. Optimal utilization in this context again means the highest level of loading consistent with the relevant reliability criterion, e.g., N-1, which can be maintained without causing equipment failure or premature wear. This metric measures the utilization of 11 kV feeder capacities. Feeder utilization is calculated on a system-wide basis by dividing the annual peak demand served by 11 kV feeders by the total capacity of 11 kV feeders. The annual peak demand served by the feeders should be the sum of the metered peak load on each feeder at the hour of the system-wide coincident peak demand. The total capacity of the feeders used in this calculation should be the sum of their nameplate ratings [28]. Through two years the utilization of the feeders (see Appendix A) loading in all regions had been less than target benchmark as shown in Figure 3.5. As ADWEA rules state that all consumers who have load more than 5 MW will install, supply and maintain all the electrical equipments while ADDC will charge less connection charge. This rule also ties with a right to provide the bulk customer with a no. of dedicated feeders depend on their load. This feeding arrangement is the most sources of feeders under utilization since we can't force the consumers to utilize their own feeders and also as 'n-1' criteria for security of supply they have an express feeders or backup feeder which are not utilize unless there is a failure on other feeders.

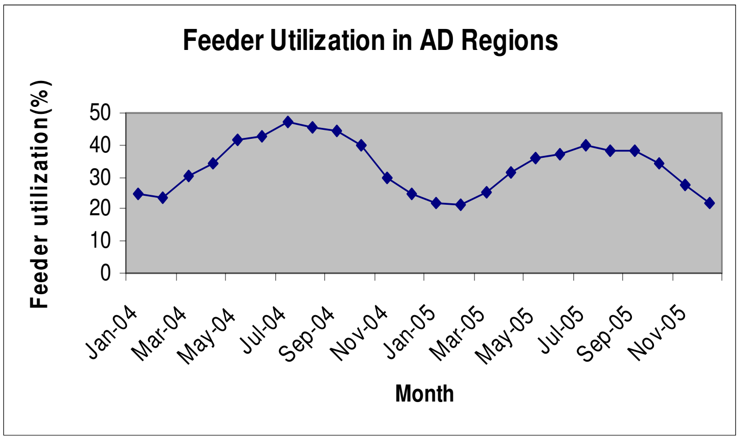


Fig. 3.5 11kV Feeders Utilization in AD Regions

So as it shown the utilization of network assets is below and comparing with the last two years, the utilization is going down instead of the improvement. This may due to the unbalanced ratio between adding the assets in the network and utilizing them. Action should be done in order to utilize these assets where it's increasing in monthly basis (Distribution transformers and feeders) and the most non utilize feeders are the dedicated feeders given to bulk consumers where their load is above 5000KW as the rule of ADWEA.

One of the solutions in order to utilize the existing capacity is to control the demand peak which is in proportional relationship with the network capacity. Whenever the peak is increased, the need of additional source capacity is increased and thus under utilizing the existing capacity constrained with the security of supply. Demand peak can be controlled and therefore reduced through introducing a new technique such as Demand Side Management.

CHAPTER 4

4 LOAD FORECAST

4.1 Introduction

Demand and energy forecasts form the basis for power system expansion planning, and affect system security and reliability. The increasing desire to obtain reliable forecasts is the objective of all electric utilities. The reliability and the confidence levels associated with these forecasts are more crucial in fast growing areas experiencing a phenomenal growth in demand and energy requirements. The confidence levels associated with classical forecasting techniques, when applied to forecasting problems in mature and stable utilities, are unlikely to be similar to those of dynamic and fast growing utilities. This is attributed to the differences in the nature of growth, socio-economic conditions, occurrence of special events, extreme climatic conditions, and subsidized energy tariffs [10]. A common forecasting problem in most fast growing utilities is the short and insufficient database, unparalleled experience of fast growth and unavailability of forecasting techniques capable of addressing adequately this particular problem [3].

The trend growth in demand is attributed mainly to the huge investment in the electric power sector and the availability of advanced technology right from the start of the system development. Other factors that have contributed to this rate of growth include high Gross Domestic Product per capita, low energy tariff in comparison with production cost, prevailing severe climatic conditions and different social traditions. The system demand is dominated by air conditioning load, thus the ambient temperature exhibits a unique pattern every year and characterized by a hot-spell temperature period during July, August and September. The system peak demand is partially influenced by the temperature, both its magnitude and time of its occurrence. In addition to the maximum temperatures, there are other cyclic and dynamic events that contribute significantly to the system peak demand. The loads of these events vary in magnitude and time every Gregorian year and, hence, their contribution to the annual system peak demand is dynamic in nature.

4.2 Forecast Methods

The peak demand forecasts for a fast developing system is obtained by three different classical methods of qualitative, quantitative, and causal methods. For the sake of comparison, long-term peak demand forecast is also obtained by direct application of the classical method to a normal developing system. The results of both systems are compared with their corresponding actual demands using standard statistical measures Depending on the time span and the degree of mathematical analysis involved in the forecasting model [14].

4.2.1 Qualitative method

In this category, the forecasting method is not actually reliant on a load model in the mathematical sense, for example: (a) collecting the opinion of several experts and deriving some ‘weighted forecast’; (b) aggregating the forecasts of individual customers or groups of customers; (c) analogy with similar countries that recently went through the same stages of development; (d) graphical extrapolation of load evolution curves, etc. These methods are still widely in use. Based on human judgments, they often produce load forecasts that are nothing more than expression of expectation or fear rather than a neutral estimation. These methods can take advantage of the human intuition and can incorporate non quantifiable information [14].

4.2.2 Quantitative method

This category contains forecasting models, which are based only on the extrapolation of past observations of the load. The technique used consists of analyzing the load evolution in order to detect the dynamic characteristics of the load and to extrapolate them into the future by a mathematical procedure. It is often useful to decompose the load into components and to treat these components separately. In this category, one finds two classes of models: time series models and stochastic models.

4.2.2.1 Time-series models

These models rely on the fitting of a time series to the original data. The load, PD (t), is expressed as a function of time t plus some random disturbance εt, as:

$$PD(t) = F(t) + \varepsilon t \qquad (4.1)$$

The subjective aspect of these methods appears in the specification of the F function. When a, b, c, K and m are fitting parameters, few possible relationships of typical functions are:

Straight line $PD\ (t) = a + b * t$ (4.2)

Time polynomial $PD\ (t) = \sum_i b_i * t_i$ (4.3)

Exponential $PD\ (t) = a * e^{bt}$ (4.4)

Logistic $PD(t) = K/(1 + m * e^{at})$ (4.5)

Gompertz $PD\ (t) = e^{be^t}$ (4.6)

4.2.2.2 Stochastic models

Stochastic models describe the time series by different equations applied to the past observations of the load data (auto-regressive models), the successive realizations of an uncorrected random variable (moving average models), or a combination of both (Box–Jenkins models). Exponential smoothing and the decomposition methods are the most flexible models that can be applied to fast growing system for producing long-term forecasting [14].

- Exponential smoothing

When the system load contains a horizontal pattern, it is useful to smooth some of this variation in order to obtain the underlying trend. In order to forecast the peak, *PD*(*t*+1), a weight α and (1−α) is chosen between 0 and 1 to give the latest observed load data, *Xt*, and the latest forecasted value at period *t*, *PD*(*t*). This can be written as

$PD(t+1) = \alpha * Xt + (1-\alpha)\ PD\ (t)$ $\qquad 0<\alpha<1$ (4.7)

However, this model is not sufficient to reflect the seasonal and cyclic pattern of the system. Therefore, linear exponential smoothing may be applied to recognize this fact and drive the adjusted peak demand [14].

- Decomposition model

The decomposition method aims to identify three separate components of the basic underlying pattern that tend to characterize the load pattern during the considered period. The general mathematical representation of this model is:-

$PD\ (t) = St * Tt * Ct * Et$ (4.8)

Where *St*, *Tt*, *Ct*, and *Et* are the seasonal, trend, cyclical, and random (or error) component, respectively, at period *t*. The more appropriate trend model is selected on the basis of iterative solution to minimize the error [14].

4.2.3 Causal Method

The aim of the causal or econometric method is to build models, which relate the demand and energy to economic and demographic variables such as population growth, electricity rates, climatic weather variables, sectarian investments, disposable income, and gross national product. The selection of the independent variables depends on the availability of data and on their strong relationship with the electric energy and load demand. The construction of energy and load models involves the use of trial and error. Explanatory variables, which would logically influence demand requirements, are selected, a regression is performed, and statistical tests are made. During model development, alternative forms of equations are tested to determine which best fits the historical data and/or satisfy some statistical standards and scenarios.

The different types of load forecasting can be classified according to the forecast period as follows:

- ✓ Short-term forecast
- ✓ Medium-term forecast
- ✓ Long-term forecast

Short-term power system load is mainly dependent on nonlinear combinations of variables that can be classified according to their dependence on weather, social, and seasonal factors. Temperature and humidity are the most independent weather factors. Social variables that affect the system load include the human duty activities such as work, school, and entertainment. Seasonal variations result from load growth and seasonal weather changes [2].

4.3 Load Forecast in ADDC

4.3.1 Background

In year 2005, the peak load for the system was 4456 MW based on ADDC Regional Control Centre data. However, the system peak load for Year 2004 was 4320 MW based on the same source of data, which implies 3.1 % peak load growth in 2005. This figure will be increased due to the new developments strategy and management decision to bring AbuDhabi city into the ship of the attraction and tourism pointers.

The total actual recorded connected load for each year in the system is recoded by hard copies before 2000 and since that year, dedicated database has been creative to record the new connected load.

This Load Demand Notification (LDN) database contains the connected load obtained by the application of the power request from various government agencies as well as from prospective customers.

4.3.2 Load Forecast Model

The model based on exponential smoothing method. What has been used on this method is to give a weight level (alpha) between 0-1, the closest no. of 1 will give the more weight to the load forecast. In this study a new weight level has been developed based on three factors affect the load forecast which is growth rate, demand factor and the diversity factor. The model is depending on the available actual connected load in all regions and all categories from 1981 to 2005. Also it depends basically on the actual connected load from 2002 to 2005 distinguished by the load categories which are: (1) Residential include villas, houses and flats ;(2) Commercial include office, retail, malls and services occur typically in mixed-use buildings ;(3) Industrial include the factories ;(4) Agricultural include farms and green house farms; (5) other loads include all Federal, Local Government and other Authorities buildings inside the Emirate. Also this category includes fire fighting, police, schools, Higher Colleges and Universities buildings beside the mosques, clubs and stadiums. From the classified load categories and the connected load from each in the years 2002-2005, the average of the distributed load for each category can be extracted. Moreover, the percentage for each load type also can be gathered from the average connected load for each category.

Since no full load is utilize all the hours of the day and in all seasons equally, there is a need to have a factor which quantify this inequity. This factor is called the demand factor. The demand factor which is the figure that represents the average portion of connected load expected to be energized during the peak period of the day for individual consumers as the following equation can be obtained from the history load data. The estimated connected load is given upon the application submittal for the power requirement and the demand peak is the measured and actual reading from the meter. The demand load for each category is calculated by multiplying the connected load by the demand factor for each type.

$$Demand\ Factor = \frac{Peak\ Demand}{Connected\ Load} \quad (4.9)$$

The Average load demand factor will be the total demand factor for each category divided by their number and this demand factor will be the approximate factor used for any connected load whatever the type of project where most of the new developments and coming projects is a combination of mainly residential, commercial and others load like clinics, schools and mosques.

The growth rate is show how is the rapidly increase in the load where it's in proportional relationship with the population rate increment and the projects developments. In the model it will be the average for the last six years difference connected load , as the different between two following years, and multiply by a utilization factor(α) as not all the load connected is utilized within the day or the year in parallel with it may be a non occupancy of the utility for long time.

$$\%Growth\_rate = ((Ln - L_{n-1})/Ln) * \alpha * 100 \quad (4.10)$$

Where: Ln is the connected load for the year n

L_{n-1} is the connected year for the year n-1

The utilization factor, α

As it's approved huge developments coming within 3 years the growth rate will be increased by the appropriate value through taking the average of the growth rate for the coming six years where a confirmed commissioning date of the projects available.

Since the peak for all the categories and regions will not happen on the same day and same time then the model will need a factor to resolve this problem and this factor will be the diversity factor. The Diversity Factor represents the portion of the summation of peak demand by multiple consumers that contributes to the system peak.

$$Diversity\ Factor = \frac{Peak\ Demand\ of\ a\ Group\ of\ Consumers}{Summation\ of\ Peak\ Demand\ for\ a\ Group\ of\ Consumers} \quad (4.11)$$

The model which bases on the exponential smoothing method contains all the three weighting factors to show the peak load forecast for the next years.

So, the load for the next year will be the load for the previous year multiplied by the growth rate, multiplied by the demand factor for each category multiplied by the average diversity factor.

$$F_{n+1} = (diversity\_factor * demand\_factor * growth\_rate)F_n + F_n \qquad (4.12)$$

Where: F_n is the load for the current year

F_{n+1} is the load forecast for the next year

4.3.3 Sensitivity Analysis

In order to test the robustness of the forecasts separate electricity high and low forecasts have been prepared that take account of as many uncertainties as possible. Two alternative scenarios have been developed for the electricity demand forecast that encompass variation factors affect the system peak which are; temperature, regional peaks occurring time , delays in commercial and government projects and changes in government policies. Scenario 1 is assumed that the system peak load will vary by 25% taking into account low variation of the factors affecting the system peak load. Scenario 2 is assumed to vary by 50%, with the assumption to have high variation with the logical limitation limit.

4.3.4 Results and Findings

The connected load before the availability of LDN system (year 2002) was depend on the hard copies of the coming projects from government agencies and customers. Approximate assumptions of the connected load before 1982 was defined by the experts' engineers was 300 MW, and since the recorded connected load for 1983 was 200 MW, the total connected load in the system then was 500 MW. The connected load for each year has been translated from the hard copy chart into the actual reading and depends on the previous measure the result was the accommodation for each year.

The percentage of each load category (residential, commercial, agricultural, industrial and other) can be obtained from the recorded connected load for each category on the years from 2002 to 2005 in line with the recorded total connected load, see appendix B. From these records the average percentage load contribution was calculated from the total connected load for each category and the results obtained are shown Table 4.1 and Figure 4.1.

Table 4.1

Percentage load distribution by load category

Category	Average percentage
Residential	41.94%
Commercial	25.47%
Agricultural	2.57%
Industrial	9.60%
Other load	20.41%
Total Load	100.00%

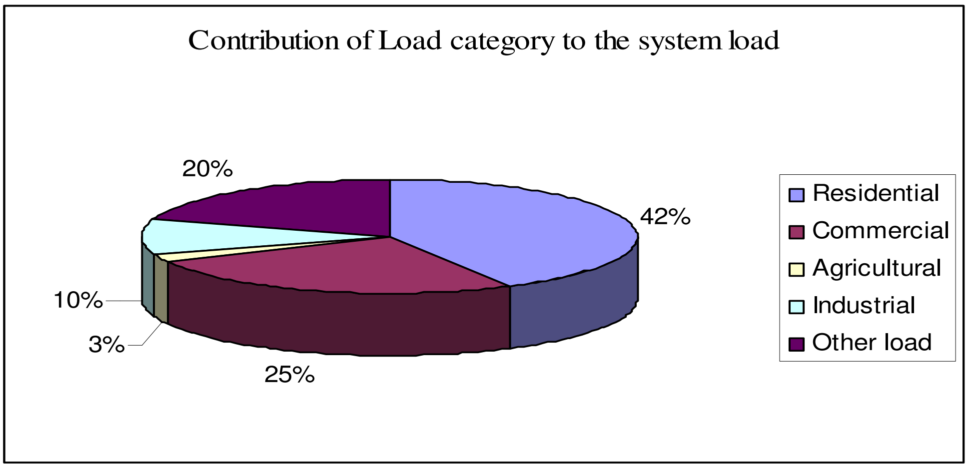


Fig.4.1 Percentage of load category contribution to the System load

The results demonstrate that most of the load contributes in AbuDhabi is the residential following with the commercial which is true for all others in the world. In order to show how much load contributed for each category, each percentage for its respective category will be multiplied by the total connected load for each year. For example in the year 1990, the total connected load is 1548.48 MW, the distribution for each category will be:

Residential load = 0.4194*1548.48= 649.48 MW

Commercial load =0.2547*1548.48=394.4 MW

Industrial load=0.096*1548.48=148.68 MW

Agricultural load=0.0257*1548.48=39.8 MW

Other loads=0.2041*1548.48=316.05 MW

The demand factor for each category is obtained from the history load data where the estimated connected load is given upon the application submittal for the power requirement and the demand peak is the reading from the meter. Five samples have been taken of each category to get the average demand factor. Table 4.1 shows the demand factor for each category in all regions.

Table 4.2

Demand factor for load categories

Load category	Demand Factor
Residential	0.45
Commercial	0.65
Industrial	0.8
Agricultural	0.3
Others	0.4
Total Average	0.52

The Average load demand (0.52) will be the approximate demand factor used for any connected load whatever the type of project.

The growth rate is assumed to be 4% approximately, see appendix B, as refer to the comparison of the total connected load for the previous six years as shown in Table 4.3. The utilization factor as per the field engineers can reach to 0.05 where it depends on the utility occupation upon the load connected and the utilization of that connected load.

Table 4.3

Growth rate for years (2000-2005)

Year	Growth rate (%)
2000	3.77
2001	3.72
2002	3.46
2003	2.82
2004	3.61
2005	3.57
Average	3.49

In the next coming years, from year 2008 this growth rate will change due to the huge developments coming in all area especially Eastern Region, see Appendix B. Table 4.4 shows the booming developments that starts from 2007 until 2010 where it will slow down unless there are upcoming projects that are not announced yet.

Table 4.4

Connected load (MW) for the major projects

Abu Dhabi Island and Mainland connected load (MW)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Raha Beach Development			97	125	101	65	89	96		
Raha Gardens	29	68	70							
10 Towers		10								
Al Falah			98	98	98	98				
Airports Side			289	289	289	289	289	289		
Project X			1445	1445	1445					
ICAD		100	100	100	200					
Central Market			20	40						
Airport Extension				50	50	50	50			
Mohd Bin Zayed City (297 Towers)				250						
Plot C1 in Z9				43						
Mina Zayed Development			175	175	175	175				
Total (MW)	29	178	2099	2057	2133	452	378	385		
Abu Dhabi Islands Connected load (MW)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Al Reem Island	100	100	100	100	100	100	100			
Al Sadiat Island	50	50	50	50	50	85	85	85	85	85
Saada Island Development			30							
Total (MW)	150	150	180	150	150	185	185	85	85	85
Grand Total (MW)	179	328	2279	2207	2283	637	563	470	85	85

The growth rate is assumed to be 6% up to year 2012 based on the announced projects that will be accomplished as shown in Table 4.5. The same rate will be used until 2020 unless there is a change in the development plan or additional announced major projects that will be introduced in the future.

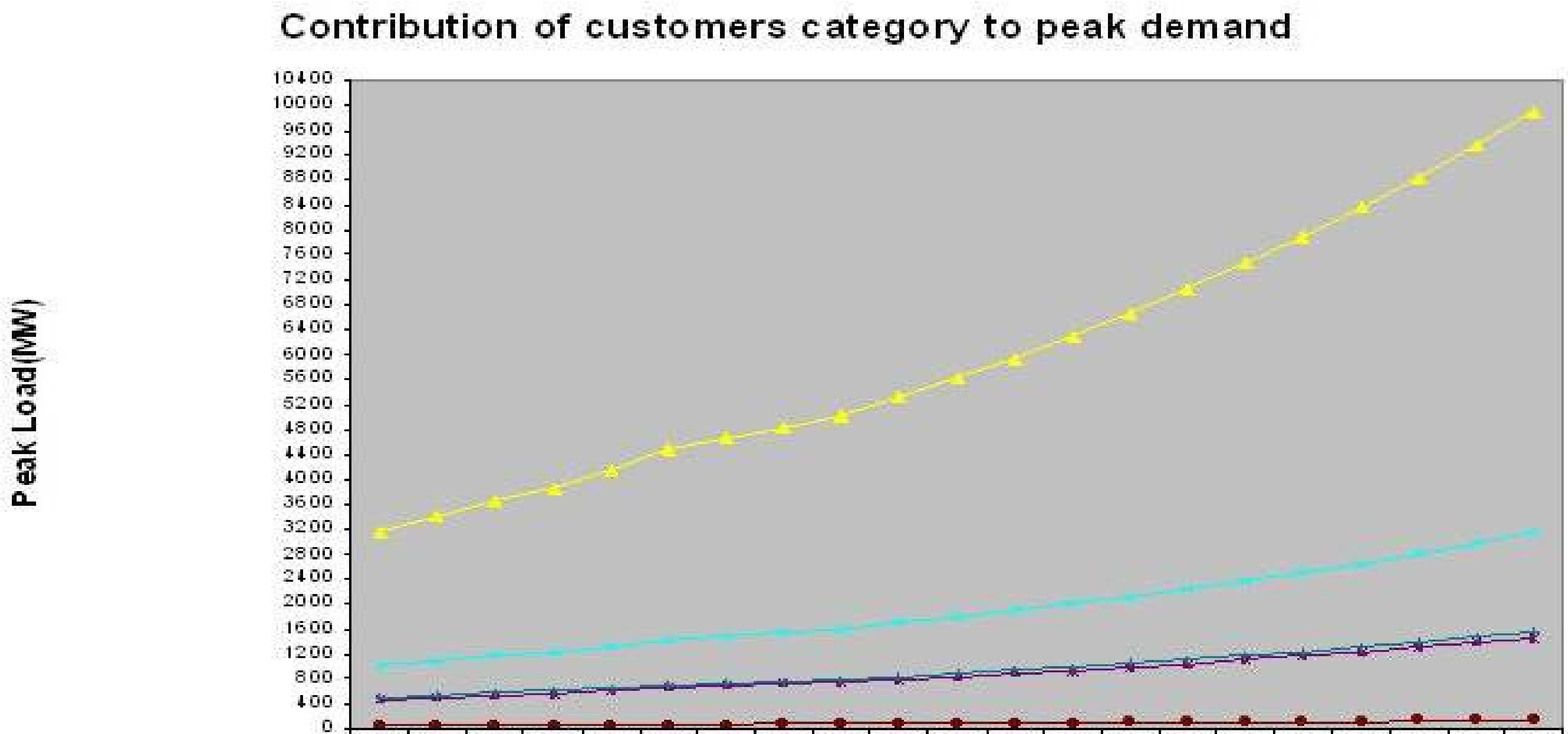
Table 4.5

Growth rate for years (2006-2012)

Year	Growth rate (%)
2006	2.9
2007	3.5
2008	10.6
2009	8.9
2010	8.0
2011	3.5
2012	3.2
Average	5.8

The Diversity Factor represents the portion of the summation of peak demand by multiple consumers that contributes to the system peak. Taking the demand load for each category for years 2002-2005 with the respective load distribution percentage and demand factor and compare the summation for them all with the total demand load for each year, will result out the diversity factor for all the years from 2002-2005. The average diversity factor will be 97% which indicate the difference of peak load for each category relative to the total peak load.

Finally the factors affect the load forecast are the growth rate, diversity factor and the demand factor. These factors combined together in equation 4.12 in order to calculate the load forecast. Figure 4.2 shows the load forecast result for all considered categories.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential demand load	3137	3389	3642	3859	4159	4479	4653	4834	5021	5313	5623	5950	6296	6663	7050	7461	7895	8354	8841	9355	9900
Commercial demand load	999	1079	1159	1229	1324	1426	1481	1539	1599	1692	1790	1894	2005	2121	2245	2375	2514	2660	2815	2978	3152
Industrial demand load	463	501	538	570	614	662	687	714	742	785	830	879	930	984	1041	1102	1166	1234	1306	1382	1462
Agricultural demand load	47	50	54	57	62	66	69	72	74	79	83	88	93	99	105	111	117	124	131	139	147
Other demand load	493	532	572	606	653	703	731	759	788	834	883	934	989	1046	1107	1171	1240	1312	1388	1469	1554

Year

Fig. 4.2 Load Forecast by category

The sensitivity test results show in details the two assumptions scenarios with variation based on the growth rate by 25% and 50%. The details and results of these scenarios as compared to the base load forecast load are investigated as follows.

Scenario 1: The growth rate is varying by 25%

	2006-2008	2009-2020
Low	3%	5%
Base	4%	6%
High	5%	8%

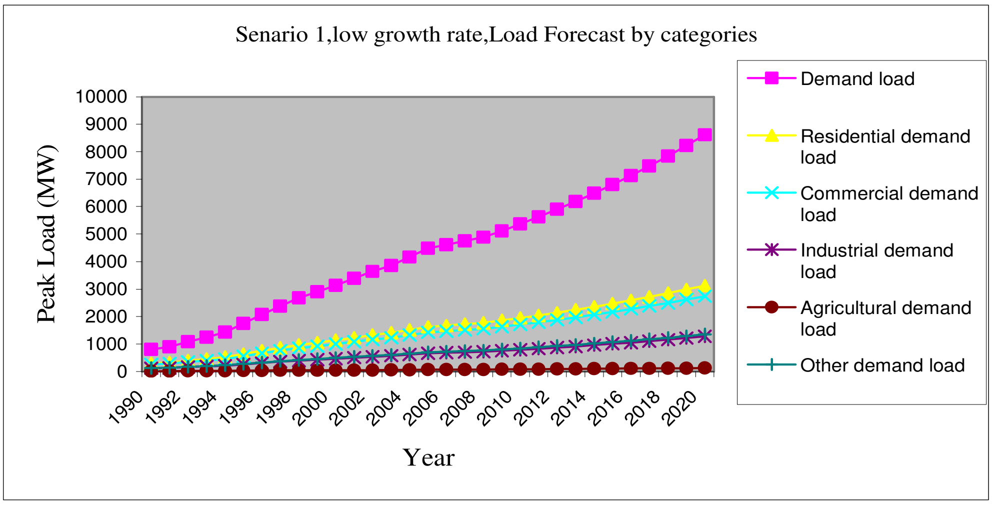


Fig. 4.3 Low growth Load forecast for Scenario 1

Figure 4.3 shows that the low growth rate variation of 25% has a minor impact on the total load changes comparing with the base rate.

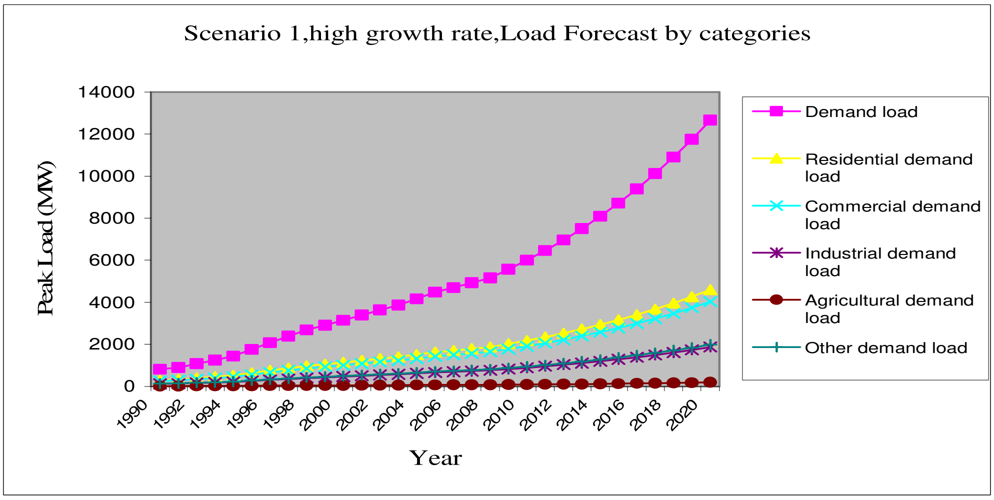


Fig. 4.4 High growth Load forecast for Scenario 1

The variation of 25% incremental to the base load indicates high but acceptable incremental in the load forecast due to the major development and limited to the factors of utilities utilization and government polices.

The base, low and high growths load peak forecasts in scenario 1 combined together in order to show the relation and the impact are shown in Table 4.6, and Figure 4.5.

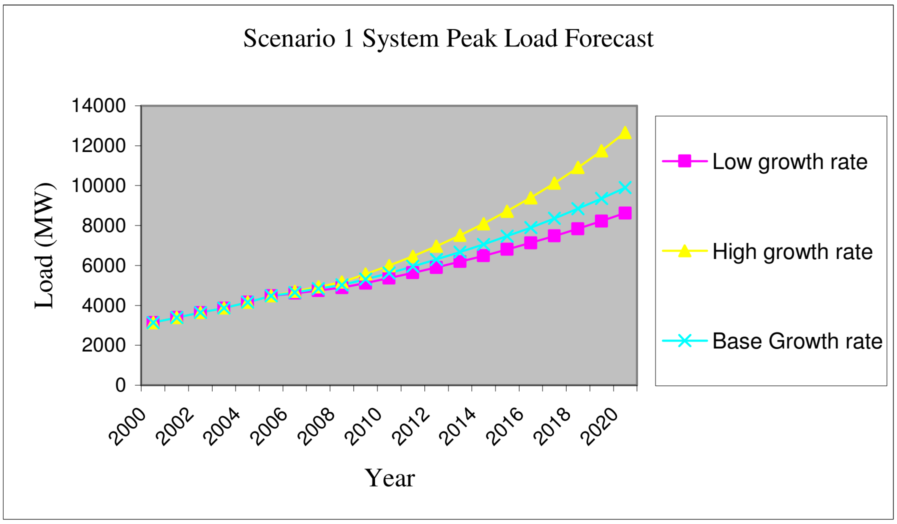


Fig. 4.5 System Peak load forecast for base, low and high growth rate in scenario 1

Table 4.6

Demand load forecast for base, low and high growth rate for scenario 1

Year	Demand load (Base growth) (MW)	Demand load (Low growth Rate) (MW)	Demand load (High growth rate) (MW)
2000	3137	3137	3137
2001	3389	3389	3389
2002	3642	3642	3642
2003	3859	3859	3859
2004	4159	4159	4159
2005	4479	4479	4479
2006	4653	4610	4697
2007	4834	4744	4924
2008	5021	4882	5163
2009	5313	5119	5564
2010	5623	5367	5996
2011	5950	5627	6461
2012	6296	5900	6962

(table continues)

2013	6663	6186	7503
2014	7050	6486	8085
2015	7461	6801	8712
2016	7895	7131	9388
2017	8354	7477	10117
2018	8841	7839	10902
2019	9355	8219	11748
2020	9900	8618	12659

The comparison shows that the low and high growth rate for the years 2006-2008 has not t have a big impact and a major change; however the situation is not the same moving to the years 2009-2020. Any small variation has visible impact to the total peak load as indicated in details in Appendix B.

Scenario 2: The growth rate is varying by 50%

	2006-2009	2009-2020
Low	2%	3%
Base	4%	6%
High	6%	9%

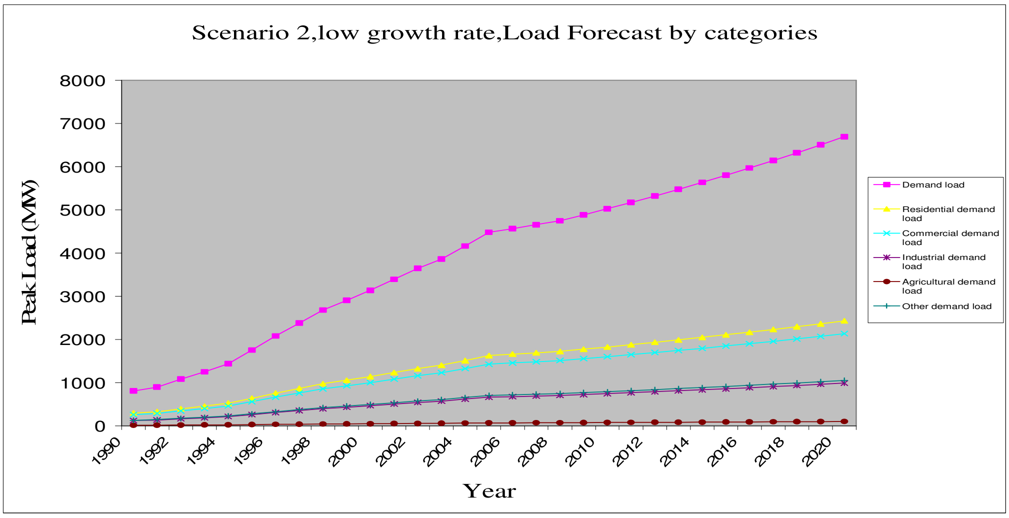


Fig. 4.6 Low growth Load forecast for Scenario 2

The variation of 50% decrement will result of an obvious low load forecast especially in the years above 2009 as indicated in Figure 4.6. This does not indicate any engineering sense until the year of 2020 since the peak load approaches 7000 MW and as the projects accomplishments data provided by the investors and municipality that in year 2015, the peak load will be approximately 9000 MW, see Appendix B.

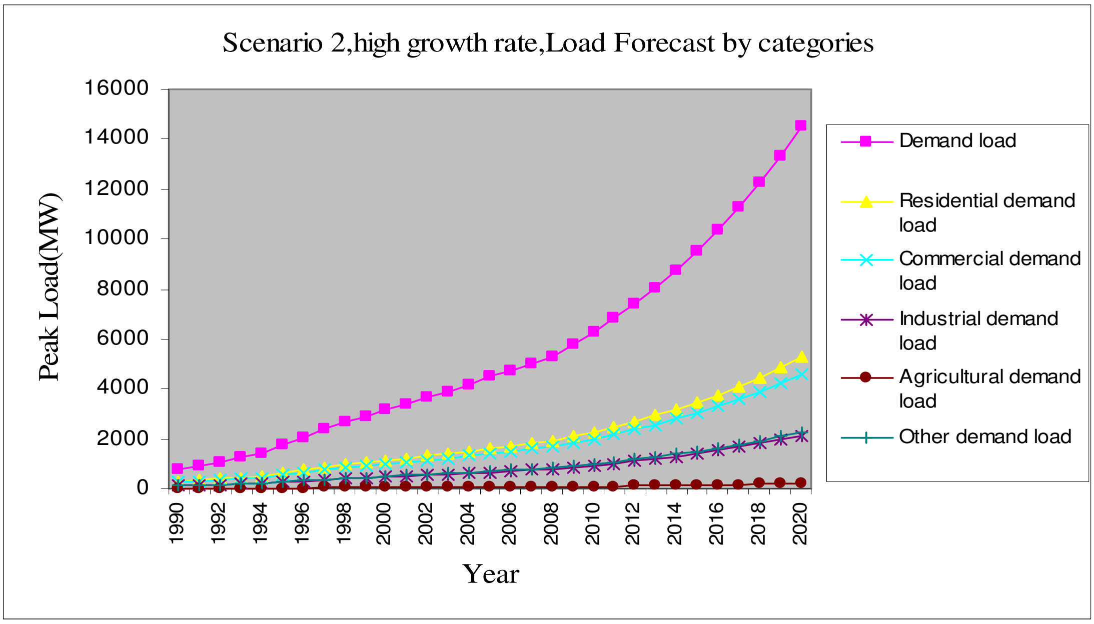


Fig. 4.7 High growth Load forecast for Scenario 2

Accordingly the high growth rate variation of 50% will also has a major impact, as the peak load reaches 15000 MW in year 2020 while its base load is 10000 MW as shown in Figure 4.7.

The base, low and high growths load peak forecasts in scenario 1 combined together in order to show the relation and the impact are shown in Table 4.7, and Figure 4.8.

Table 4.7

Demand load forecast for base, low and high growth rate for scenario 2

Year	Demand load (Base growth) (MW)	Demand load (Low growth Rate) (MW)	Demand load (High growth rate) (MW)
2000	3137	3137	3137
2001	3389	3389	3389
2002	3642	3642	3642
2003	3859	3859	3859
2004	4159	4159	4159
2005	4479	4479	4479
2006	4653	4566	4740
2007	4834	4655	5016
2008	5021	4745	5308
2009	5313	4883	5771

(table continues)

2010	5623	5025	6275
2011	5950	5172	6823
2012	6296	5322	7418
2013	6663	5477	8066
2014	7050	5636	8770
2015	7461	5800	9536
2016	7895	5969	10368
2017	8354	6143	11274
2018	8841	6322	12258
2019	9355	6505	13328
2020	9900	6695	14491

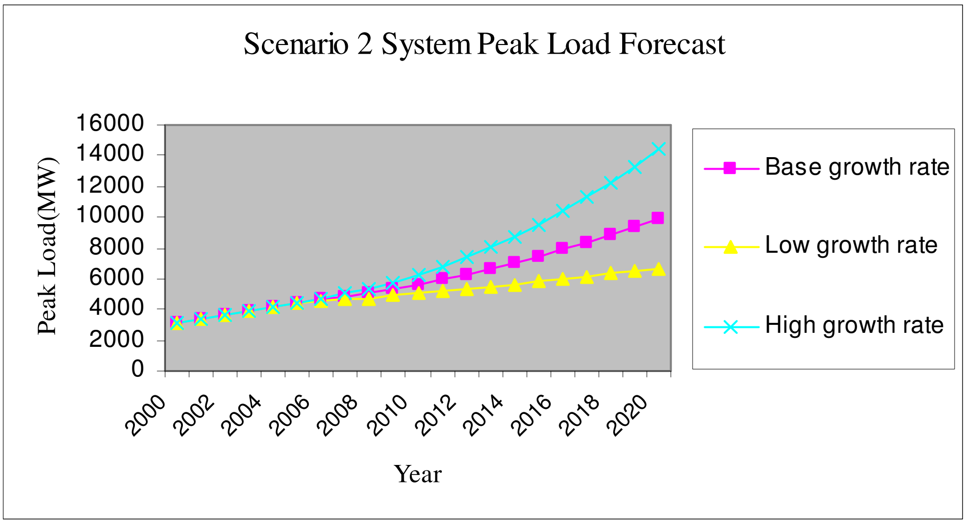


Fig. 4.8 System Peak load forecast for base, low and high growth rate in scenario 2

The high and low scenarios graphs have the same trend and characteristics as the base case for the two scenarios. Also it shows that the base case scenario is almost equal to the average of the high and low scenarios with slight inclination towards the lower side especially in scenario 1 and years above 2008. The high scenario of growth rate as in scenario 2 has a major impact in incremental the system peak load, while in the same scenario the low growth rate has the same impact in triggering the peak load down. As a conclusion the scenario 1 with a variation of 25% is acceptable more than the second scenario for leveling and stabling the load fluctuation.

CHAPTER 5

5 LOAD CHARACTERIZATION

5.1 Introduction

In a perfect world, every customer would use a constant amount of power at all times of the day, every day of the year. This would make it easy for the companies saddled with the responsibility of maintaining and operating the electricity generation and distribution systems to keep everything running smoothly, and at an economical price. Unfortunately for everybody, the world doesn't work that way. People use more power at peak hours during the day when they are operating power-hungry machines under bright fluorescent lights in air-conditioned offices, than they use at night when they are home in bed. This means that utility companies must change their strategy to make allowances for mid-day peaks in power consumption as they provide for the generation, transportation and distribution of power to customers in all cities.

New and developing technologies provide a better understanding of the usage of electric power, and promise to strengthen the link between electric utility companies and their customers. The new technique of smart meters can analyze electrical load signatures to monitor usage and relay this information to the utility. Knowledge of electric load signatures is the foundation of practical technologies for load monitoring, load diagnostics, power quality control and power circuit design. Such knowledge can provide benefits to utilities, customers, regulators, appliance manufacturers and others. A utility can improve planning and operations and develop new products and services, such as enhanced building audits, optimized operation and other energy services. Customers benefit from reduced costs and improvements in power quality and reliability. Regulators can improve the precision and relevance of policies and rules. Manufacturers of appliances and equipment can improve quality and compliance, while anticipating market demands and providing more effective and efficient products [12].

In order to manage energy use, the most important asset is information. Nobody can control what can not be measured. The first information needed is hour-by-hour load profile is the basic information about the facility. Secondly, the planner should obtain hourly load profile data at the largest electrical loads, such as chillers, refrigeration compressors, or large air compressors. Once the information is there, the planning engineer could begin to investigate strategies to "shave the peak", or "shift the load" to lower cost off-peak periods. This trend is called load levelizing technique. The lower a customer's load profile is, the more the coincidence factor could contribute to exceptionally high costs for the delivery of power from the generator to the consumer, especially during peak seasons. Most of the customers can make changes to their operating methods or their facilities' systems to improve their load profiles. In general, better load profiles leads to stable service and better prices for consumers.

5.2 Load Characterization in ADDC

The demand profiles at the time of system maximum demand form a convenient basis for determining the power supply requirements for prospective consumers in the distribution planning. The shape of the load pattern indicates the peak demand that must be meet and the duration time for that demand. Along with indicating the peak, it also shows when and how long is the off peak. All this can be integrated in order to help the distribution planner to investigate the most efficient techniques for utility low cost and customer high satisfaction.

A previous study in ADDC recorded the load profiles for some substations using a tool measurement and the result was obtaining 14 load categories for AbuDhabi emirates. The measurement survey was undertaken in mid-summer, in July and August 2001, in order to record consumer demands during the period of system maximum demand. Recordings were made of active and reactive power demands for fourteen consumer categories agreed with ADDC.

Six identical Dranetz Power Platform Model 4300 measuring instruments were used for the measurement survey. The instruments were connected to measure current, voltage and power factor for each channel and were set to record the measured values at time intervals of 10 minutes for the period for which the instruments were connected and in service. After completing the measurements, the recorded values of voltage, current and power factor were downloaded into a computer in the form of an Excel spreadsheet and the records were then subjected to the following calculation routine [23].

Using the following equations the three-phase active power flow, P (kW), and reactive power flow, Q (kVAr), in the respective feeders were calculated at 10-minute intervals from each record:

$$P = 3 * \frac{V * I * PF}{1000} \qquad kilowatts$$

$In\ which:$

$V = Single - phase\ voltage\ record,\ in\ Volts.$

$I = Phase\ current\ record,\ in\ Amps.$

$PF = Power\ factor\ from\ measuring\ instrument,\ in\ p.u.$

$$Q = \sqrt{\left(\left(\frac{3 * V * I}{1000}\right)^2 - P^2\right)} \qquad kilovolt - amperes\ reactive$$

$In\ which:$

$V = Single - phase\ voltage\ record,\ in\ volts.$

$I = Phase\ current\ record,\ in\ Amps.$

$P = Three - phase\ active\ power\ flow,\ in\ kW.$

The previous study classifies the load categories into 14 categories.

Table 5.1

Load Categories Based on Previous Study

Category No.	Category Name
1	Villas for local
2	Villas for non local
3	Old Shabia
4	New Shabia
5	Water wells farms
6	Water network farms
7	Green house Farms
8	Gr. Floor + 5 residential floors(Commercial building)
9	Gr. floor + 10 residential floors (Commercial building)
10	Gr. floor + 10 office floors (Commercial building)
11	Above gr. floor + 10 residential floors (Commercial building)
12	Above gr. Floor + 10 residential /office floors (Commercial building)
13	Shopping Mall
14	Light industrial

From this classification, the present work investigates actual load characterization. This in turn highlights the general used load category in power network division which are residential, commercial, agricultural, and industrial. These measurements are the only hourly peak load measures on the LV side which is the distribution side until the Digital Management System (DMS) tool for load measurement and short load forecast activate for all primaries, see Appendix C. One substation has been chosen for the study for each load category from PB study to show the load pattern, and the selected ones has the most visible load pattern fluctuation within the 24 hours day for each category.

5.3 Results and Findings

From the study done for ADDC in load profile measurements, the customer category no.1 is selected to represent the residential load category, category no.6 for agricultural activity where the water feeding is from the water network. The commercial category was also represented by category no. 13 while industrial load was represented by category no. 14. The active power has been calculated and the obtained results show how much the real power used within the 24 hours of a day.

The load pattern in the residential load category indicates that between 12:00 to 15:00, the peak is occurring due to the loading of A/C in the summer season as shown in the Figure 5.1.

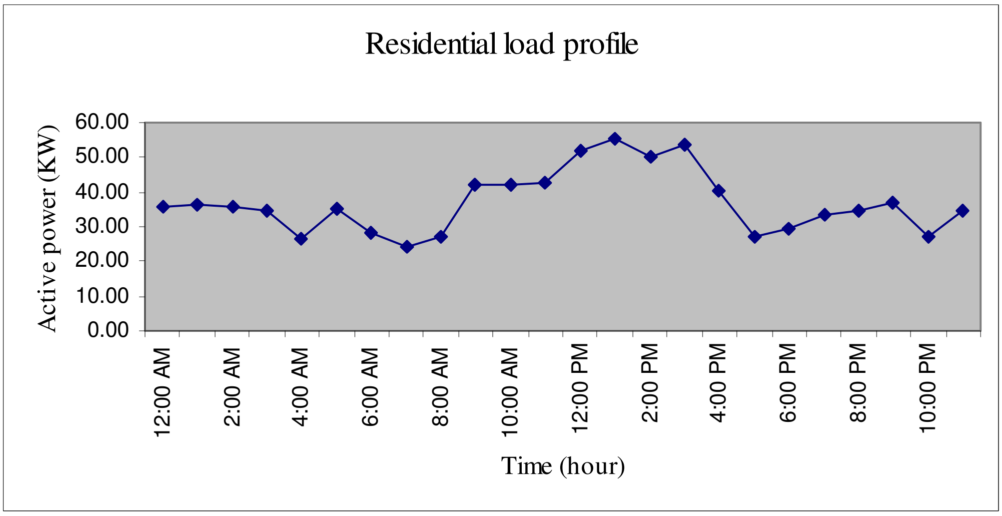


Fig.5.1 Residential load profile

The load pattern for the commercial load type indicates that between 10:00 to 22:00, the peak is occurring. This is due the working day hours from 10:00 to midnight continuously especially for this kind of commercial load (Hypermarket).These load patterns is shown in Figure 5.2.

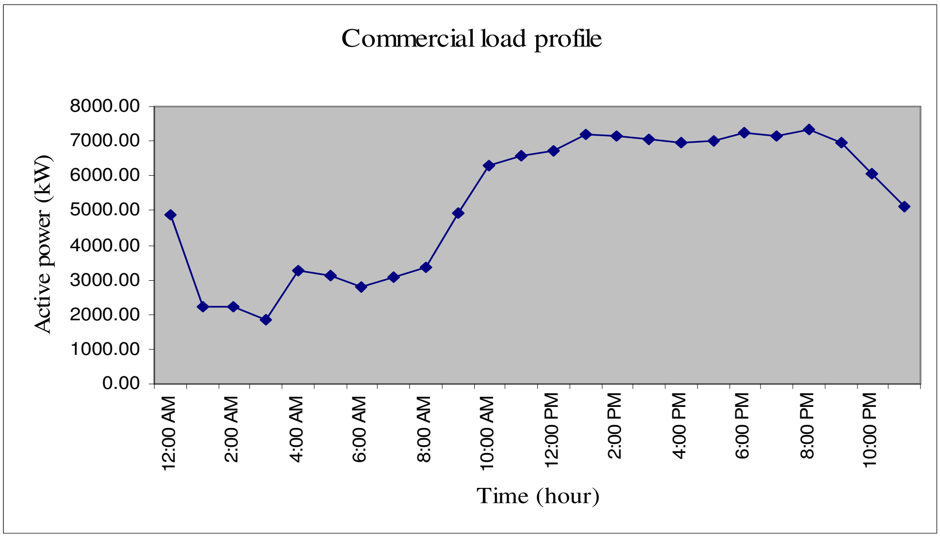


Fig. 5.2 Commercial load profile

The load pattern in the industrial load is somehow differ from other categories since it contains motors in which most of them are in continuous operation and the shedding for some chosen load has lower power consumption as shown in Figure 5.3.

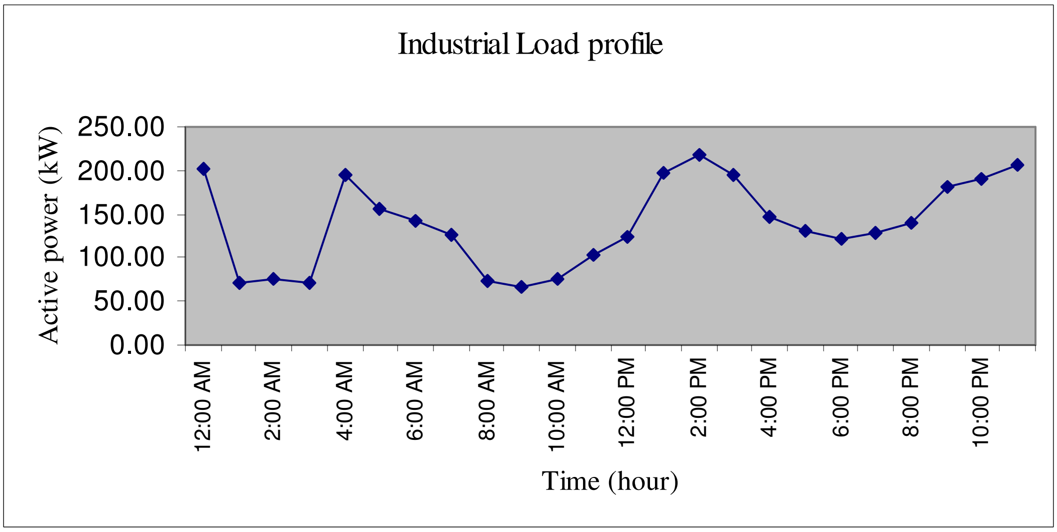


Fig. 5.3 Industrial load profile

The load pattern in the agricultural load indicates two peak periods, in the afternoon during using pumps for irrigation between 20:00 to 2:00 as shown Figure 5.4.

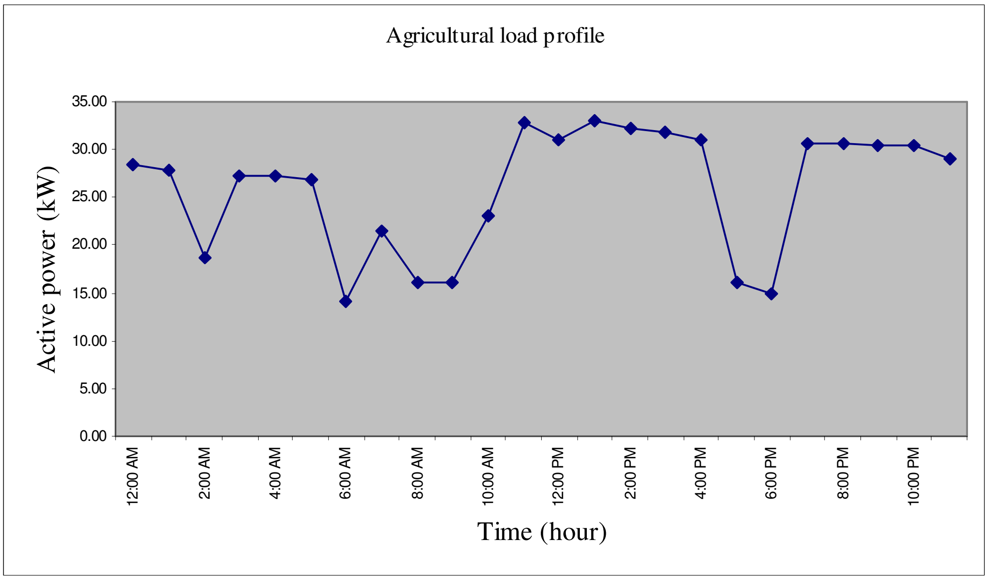


Fig.5.4 Agricultural load profile

General observations form all categories of load profile are summarized as follows:

- The major portion of the load, particularly during the summer months, is mainly due to continuous operation of air conditioning systems. This is apparent due to the poor power factor (i.e. between 0.72 and 0.79). This is assured by many load records in relating to multi-storey buildings in Abu Dhabi city and represents an indicative factor of the significant motor-based load in this area.
- A typical power factor value for motor driven equipment is about 0.85 at rated output, and for the more modern power-electronic drives the power factor should be much closer to unity (i.e. 1.0). When operating systems exist below rated output, the power factor would be expected to be reduced to a level depending on the operating characteristics of the motor and the magnitude of the load. This is an applicable scenario in the residential load.
- It is evident from the load measurements that even though ADDC has set a minimum level of acceptable power factor for its consumers, there are many buildings in Abu Dhabi city with electrical systems operating at a poor and inefficient power factor. This in turn reduces the capacity of ADDC's distribution network and increases the power losses on the system.

- For buildings with significant proportion of commercial and residential occupants, the load profiles show a distinct pattern of high loading during the respective periods of occupancy.
- It is noted from the records (which were taken every 10 minutes) that there are significant and rapid changes in demand occurring at any time in a 24hour period. These changes are representative of the combination of the normal modulation of air conditioning system output and the static load fluctuations due to switching of lights, water heater, and electric cooking equipment. While in the larger high-rise buildings, these changes are mainly due to the operation of passenger lifts (elevators) and escalators.
- The maximum demand of farms is very dependent upon water supply arrangements, with farms supplied from a water network only drawing about 7 kW each, whilst those having to produce their own pumped water drawing between 15 kW and 60 kW depending on the size of individual farms. In general the agricultural load is considered to be the less occupancy from the entire connected load.

5.4 Load Distribution for different load category

5.4.1 Load Distribution Method (LDM)

This section investigates how much is the appliances load is contributing in each customer total load. The study starts by referring to the LV schedule for some of the load submittals and calculating the total of each load type in different rooms, floors, etc (See Appendix D). This can be done by multiplying the number of load type by the unit load in KW. The A/C load if it is a split unit or window type as in the villas will have exact value in the schedule. The flats, stores and medical utilities have a central A/C type based on chillers supplying required cold water to air handling units of A/C for each building. As refer to carrier standard and the usage in Abu Dhabi Emirate, the approximate A/C load for each room is about 2 kW. Therefore the average A/C load for each flat is about 10KW including the load for fan coiling unit (FCU). Table 5.2 presents the respective load per unit of each load type.

Table 5.2

Load (KW)/unit for different load type

Load Type	Load(KW)/Unit
Lighting	0.1
Sockets	0.2
Washing machine	1
cooker	3
Water heater	1

Data were collected from different total connected load for each category. Residential flats in medium and high rise buildings in line with villas in different area have been chosen as samples for the residential load type. For commercial buildings, the samples include shops, exhibitions in commercial buildings in addition to some shops in Abu Dhabi Mall. Detailed analysis was performed for one factory as an example of the industrial load. The other load contains different types of business such as medical centers. Detailed analysis was carried for a new medical centre as an example of other load as indicated in Appendix E.

The results from this study show how is the load is distributed within the residential. Additionally the main load of appliances is A/C, lighting, water heater, Cooker, washing machines and the sockets. The main contribution load belongs to the A/C with 49% contribution to the total connected load. The load distribution in residential type based on the most appliances used is shown in Figure 5.5.

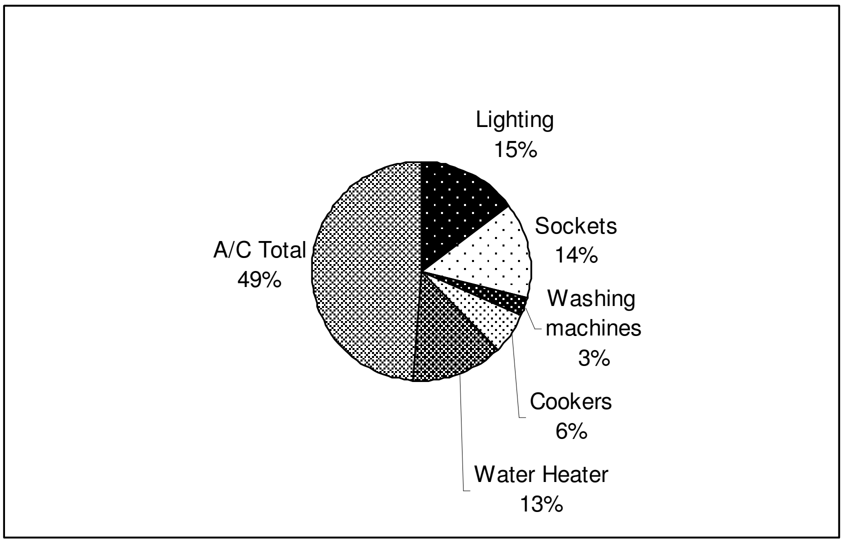


Fig.5.5 Load distribution in residential load type

The distribution has another direction in the commercial load; the main load of appliances is A/C, lighting and sockets as shown in the Figure 5.6. The results indicate that not only the A/C load represents most of the load contribution to the connected load but also the lighting systems share a high weight. This is a logic sense since the main concept in the shops decoration is to concentrate in the lighting type and distribution in such a way the goods can be visible very clearly to the customers.

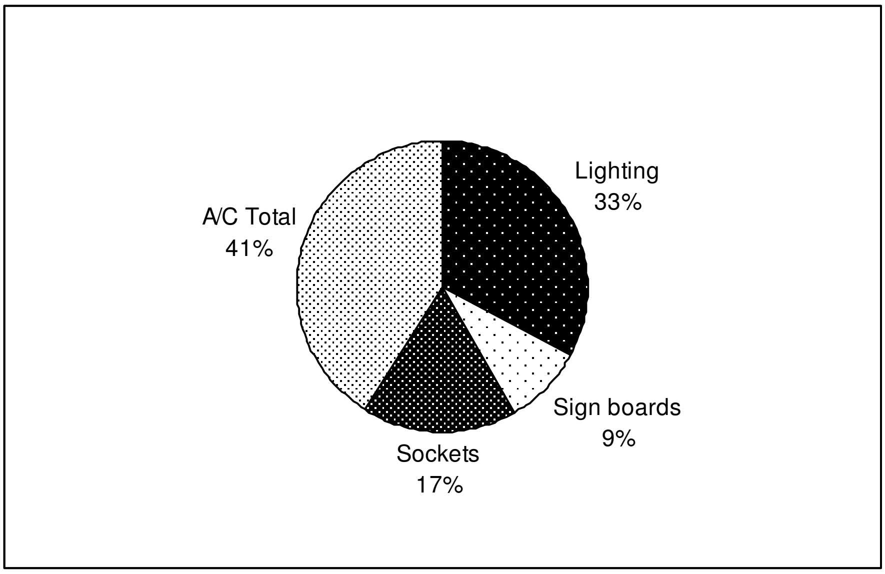


Fig.5.6 Load distribution in commercial load type

For the industrial load, the situation is much different. The effect of A/C, lighting and sockets will not be seen as in the case of residential and commercial loads. Machine isolators are the major load in the industrial load and it contributes with more than 60% of the load as indicated in the Figure 5.7.

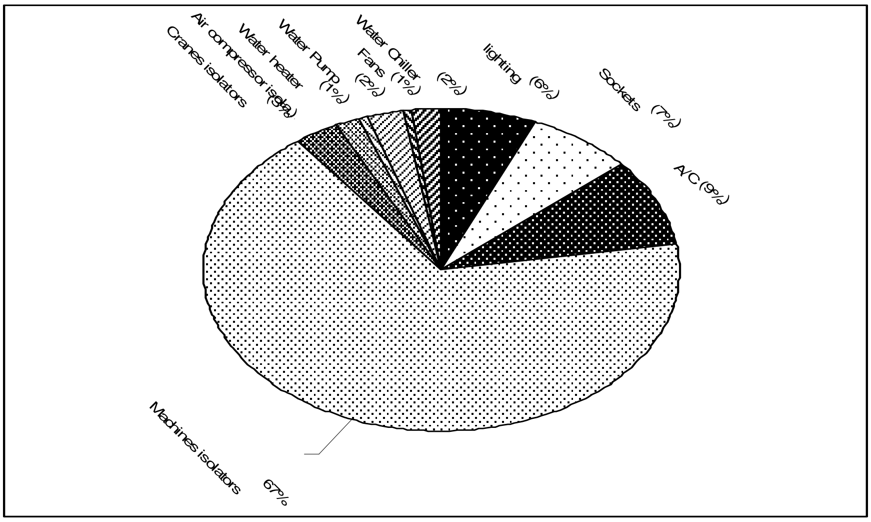


Fig.5.7 Load distribution in industrial load type

Other loads in ADDC include different type such as schools, mosques, clinics, hospitals, civil defence and universities. Only the new medical centre in AD Island as example of medical load (clinic, hospitals, and centres) has been selected for complete analysis. Most of the load (see Figure 5.8) which is 44% is sockets' load. This is mainly because most of medical utilities need the sockets for their medical equipments.

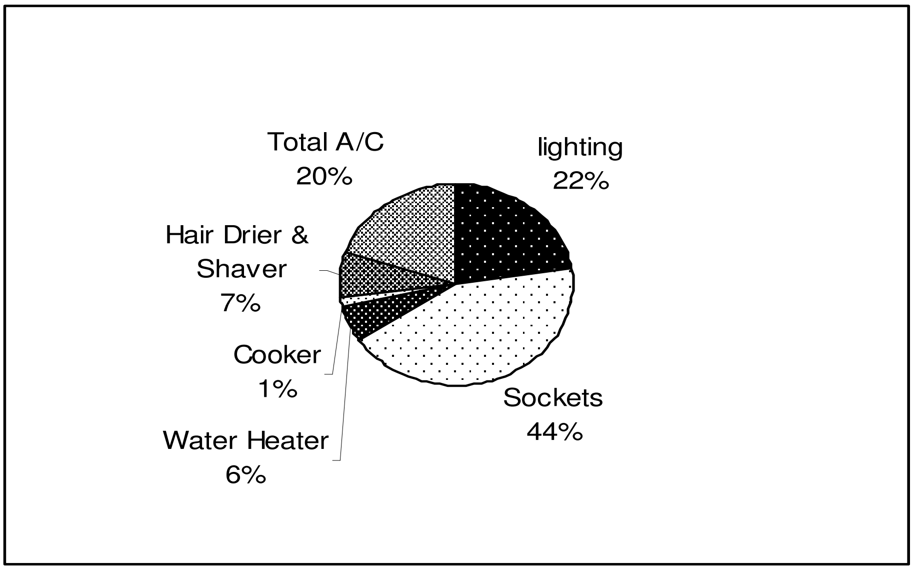


Fig.5.8 Load distribution in medical centre as other load type

5.4.2 Effect of load distribution on load characterization

The load profile for each category was first determined. By adding the type of load appliance percentages, clear visible indications on how much close or far of each load unit related to the total connected load. For example, the A/C load is the closest load to the total load as compared with other loads like lighting, sockets and water heaters in residential category as indicated in Figure 5.9.

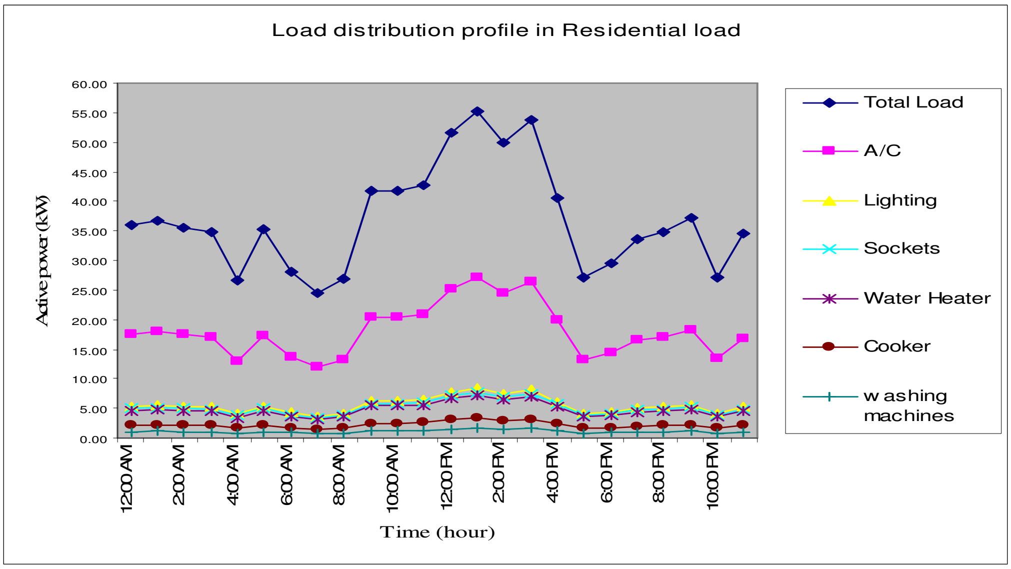


Fig.5.9 Load distribution profile in Residential load

In the commercial category, the load distribution profiles for sockets, lighting, and A/C are approximately close to each other specially the A/C and lightings as Figure 5.10.

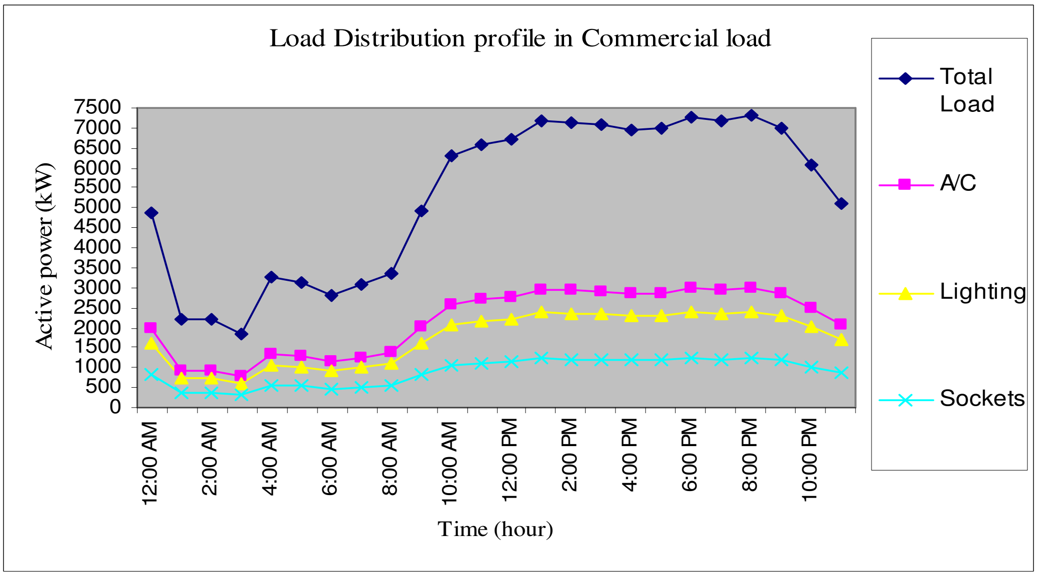


Fig.5.10 Load distribution profile in Commercial load

The machines isolators in the industrial load have the most contribution to the total load as compared to A/C, Sockets, and lighting loads as shown in Figure 5.11. It is observed that the appliance load profile is the minimum load that is contributed to the total demand load.

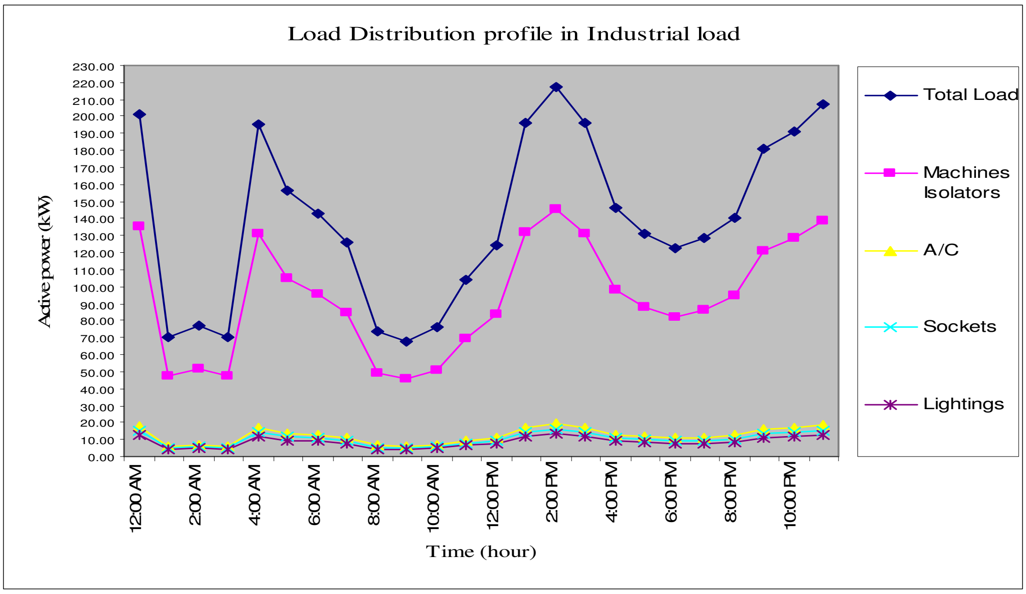


Fig.5.11 Load distribution profile in Industrial load

5.5 Future Load Profile Measurement in ADDC

By using the Spectrum which is the DMS Short Term Load Forecast tool, the Short Term Load Forecast function (STLF) can be used in calculating the global load (power system load) for the future hours and days (two weeks). This is based on the actual measurement for the load profile where at the end the user display screen contains both the actual readings and the forecast.

Power system load is the sum of all individual demands distribution network global load. Each demand or usage pattern is random in nature from the point of view of the computer system. Due to the unpredictability and the diversity of the individual demands, power system load can not be calculated exactly by extrapolating the estimated individual demand usage patterns. This is mainly due to different expansion strategies that differ from one year to another depending on the developers and investors plan. While the totality of the individual loads results in a distinct consumption pattern which is predicted with statistical methods [27].

The system load behavior is general influenced by the following factors:

- Economic factors

  Long time trending

- Time factors

  Seasonal trending

  Day type (Monday,..., Sunday)

  State and religious holidays

- Weather effects

  Temperature (the most significant single factor)

  Light intensity, number of daylight hours

  Humidity

- Special events

  Strikes

  Shutdown of facilities

  TV programs

- Unexpected events

  Load reduction due to failure of network part

To display, modify and enter the process in line with the calculation data connected with the short term load forecast function, the following interactive STLF-Displays are used:

- Historical Days for Data Analysis
- Weather Data
- Load Forecast/Similar Days
- Multiple Similar Days

- Pattern Matching
- Error Analysis

CHAPTER 6

6 DEMAND SIDE MANAGEMENT IN A UTILITY COMPANY

6.1 Introduction

With the huge growth of electricity demand supply, planning and operation methods must be integrated in such a way influencing this demand. Through the implementation of demand side management (DSM) activities, the utilities looking for influence consumer demand directly for electricity in predetermined ways. This influence decreases electricity use, or simply shifts and levelized the load in use from peak on hours to off-peak hours.

Many DSM alternatives have been adopted by utilities world wide. These alternatives can be categorized into two major options: load management and strategic conservation. Within each of these options, the concept of using load shape objectives as part of an overall demand side planning framework is utilized. The basic goal of any utility load shape objective is to influence the pattern and or amount of electricity consumption in some useful trends. In precise DSM program aims at influencing the amount, or timing, of customers' energy use so that efficiency of generation plants can be sustain and capital expenditure on new generating equipment can be saved or postponed. The objectives of a DSM program may include peak clipping, valley filling and load shifting. Peak clipping refers to reducing the peak electricity demand by reducing the overall consumption or simply cutting back demand during on peak periods Whereas valley filling encourages electricity users to operate required systems during off-peak periods. Load shifting attempts to shift consumption from the peak periods to off peak periods. Since valley filling and load shifting may not lead to overall energy use reduction, many DSM programs focus on peak clipping [30]. Rebates are often offered in DSM programs to provide incentives to the adoption of energy saving measures.

Price/demand relationship between consumer and company providing electricity should be taken in account whenever trying to put pricing policies. This leads to the need to ascertain the price elasticity of demand for electrical energy. One way to quantify this elasticity is to form an economic model for the demand for electricity to estimate the total load demand.

These models are used to observe the growth of electrical load in general due to the effect of price and demand relationships. This feature is the most interesting and effective tool for load management. The price and demand can be coupled by elasticity factor to achieve a strategy for load shifting from the on-peak hours of the day for different categories of consumers. In other words, while prices could be reduced by the effects of lower peak period electricity usage, lower prices during off-peak periods could increase off-peak usage, and off-peak electricity prices could be higher than they would have been with a lower level of consumer price responsiveness.

Strategic conservation is load shape strategy change that results from utility-sponsored programs directed at end-use consumption. These programs seek to reduce energy sales as well as change usage patterns. The present work investigates the TOD Tariff tool in the residential load for all regions; AD island, ER and WR. The results are shown primarily in the two seasons, summer and winter. Additionally energy efficiency technique is introduced through changing the customer's consumption behavior through Energy Efficiency Culture (EEC). Incentives scenarios are presented in order to show how the consumption behavior changes relating to the operating systems. This could be covered all categories specially the residential and commercial buildings.

6.2 Time of Day Tariff Model

This model is based on changing the tariff rate within 24 hours day into three classification; on-peak, off-peak, and flat rate. In the initiation, based on the load profile for each load category, the load pattern with one day is analyzed to define where the period of the peak is. Also examination the minimum load consumption will aid to define the off-peak time. The flat rate will be on the other time not classified on either the on and off peaks hours. Two scenarios are recommended to investigate the effect of varying the Time of day Tariff for the residential load category on the actual variations of load consumption. This analysis in turn identifies the incremental and decrement values in the periods of on-peak and off-peak respectively as indicated in Tables 6.1 and 6.2.

Table 6.1

Scenario 1 TOD tariff

On Peak: peak consumption period	30% increment from base tariff (Fils/KWh)
Off Peak: Minimum consumption period	15% decrement from base tariff (Fils/KWh)
Flat rate : Others time consumption	Base Tariff (Fils/KWh)

Table 6.2

Scenario 2 TOD tariff

On Peak: peak consumption period	50% increment from base tariff (Fils/KWh)
Off Peak: Minimum consumption period	25% decrement from base tariff (Fils/KWh)
Flat rate : Others time consumption	Base Tariff (Fils/KWh)

The effect of these changes result some changes of load pattern for each consumer within the 24 hours a day. Taking into consideration the bottom up view, the model is started by assessment the usage percentage of the different appliances and systems that have major contributions to the load pattern.

This information is mainly provided from the survey result indicated in Appendix E. Load consumption survey is very important in this stage to show how the power consumption is varying throughout a day, both in summer and winter seasons. This survey also includes changes of the customer load-consumption pattern as the tariff changes with incremental tariff of the two scenarios 30% and 50% in on-peak hours and decrement tariff of 15% and 23% in off-peak hours while the other hours of the day is considered to have the base tariff rate.

The same distribution of the usage percentage from each appliance in the current status for different time of usage is compared to the appliances percentage usage after TOU tariff. Since there are two different fixed tariff rates for residential local and non local, each will be analyzed separately as indicated in Appendix F. The percentage reduction for each appliance is then calculated based on the following equation:-

$$\%reduction = [E_{nb}\% + E_{ob}\% + E_{fb}\%] - [E_{na}\% + E_{oa}\% + E_{fa}\%] \qquad (6.1)$$

Where E_{nb} is the on peak consumption before TOU implementation;

E_{ob} is the off peak consumption before TOU implementation;

E_{fb} is the other period consumption before TOU implementation;

E_{na} is the on peak consumption after TOU implementation;

E_{oa} is the off peak consumption after TOU implementation;

E_{fa} is the other period consumption after TOU implementation.

The summer reduction percentage is different from the winter based on the appliances usage pattern for each season. Then the load reduction is then calculated in summer and in winter by multiplying the percentage of load reduction in each season by the peak load. Finally the total load reduction is considered to be the average load reduction of summer and winter seasons.

Summer load reduction = summer percentage reduction x peak load (6.2)

Winter load reduction = winter percentage reduction x peak load (6.3)

In this analysis, the number of housing units is provided by ADWEC Company where this reference includes the actual number of the housing units up to 2005 and the forecast starting from 2006 to 2015. Additionally the connected load for each housing units differentiating by flats, villas, and houses are obtained from ADWEC. Finally, the housing-units peak load is calculated by multiplying the total number of housing units by peak load for each unit as indicated in Appendix E.

Housing Peak Load = Number of Housing Units x Peak Load for Each Unit (6.4)

Based on the number of operating units, the load forecast starting from 2006 will be the load forecasted before TOU implementation, equation 6.5, minus the load reduction for that year. From 2007 and above, the load forecast can be calculated as indicated in equation 6.6.

The Load forecast equation from the chapter four is:-

$$F_{n+1} = (diversity\_factor * demand\_factor * growth\_rate)F_n + F_n \quad (6.5)$$

The modified load forecast after TOD Tariff technique apply:-

$$F_{n+1(new)} = (diversity\_factor * demand\_factor * growth\_rate)F_{n(new)} + F_{n(new)} \quad (6.6)$$

6.3 Results and Findings

6.3.1 General Results

The load profile for each customer in the residential load as discussed in chapter 5 is summarized in Figure.6.1.

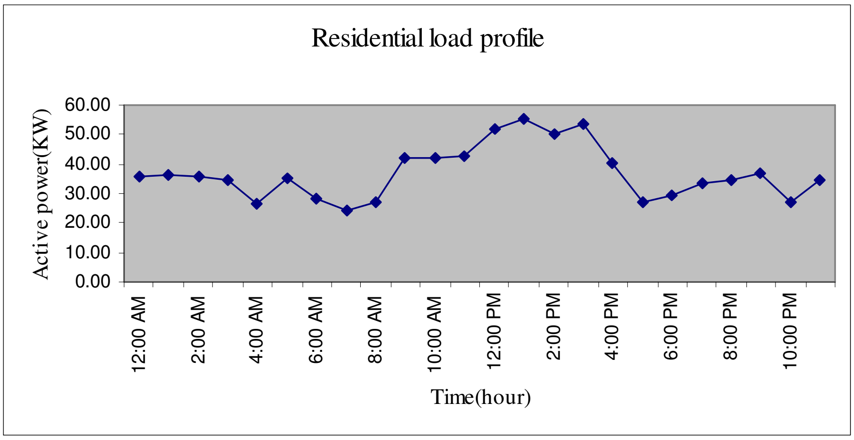


Fig. 6.1 Residential load profile

From Figure 6.1 it is clear that the on-peak hours occur approximately between 2:00 PM to 05:00 PM where most of the students and employees return back to their houses. The off-peak is happen with two periods one is between 06:00PM to 08:00 PM while the other is in the early morning between 04:00AM to 06:00AM. The load distribution for the major operating systems in the residential load category is depicted from load characterization as shown in Figure 6.2.

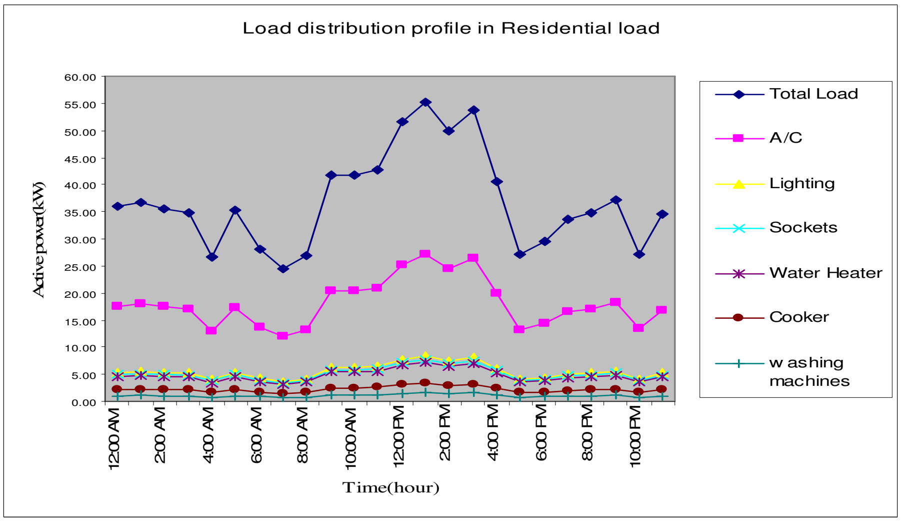
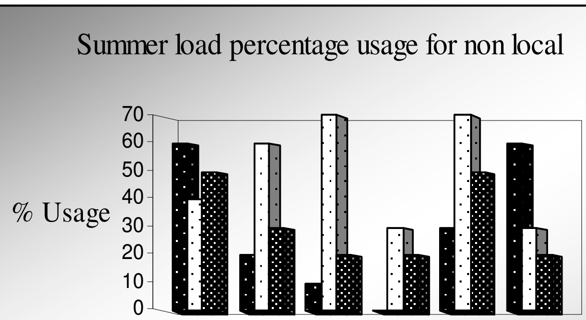


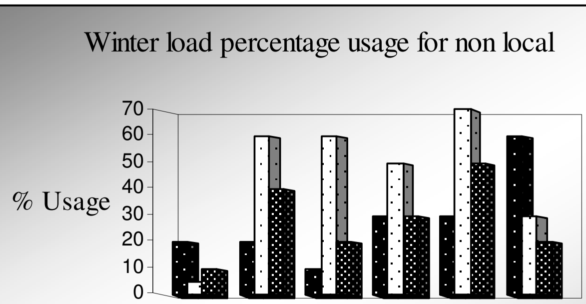
Fig. 6.2 Load distribution profile in residential load category

From the survey and the questioner results, the percentage usages of the appliances are calculated as an average value from all responses as indicated in Appendix E. This percentage usage is calculated for the two seasons in non local category as shown in Figures 6.3 and 6.4.



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	60	20	10	0	30	60
Off-Peak	40	60	70	30	70	30
Other	50	30	20	20	50	20

Fig.6.3 Non local appliances percentage usage in current status for summer season

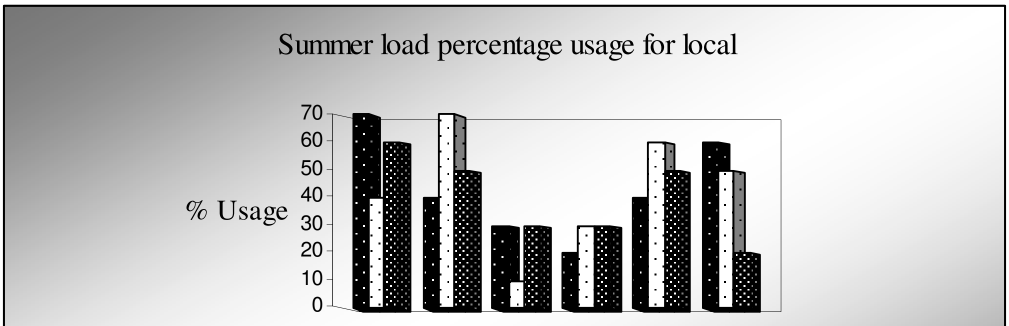


	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	20	20	10	30	30	60
Off-Peak	5	60	60	50	70	30
Other	10	40	20	30	50	20

Fig.6.4 Non local appliances percentage usage in current status for winter season

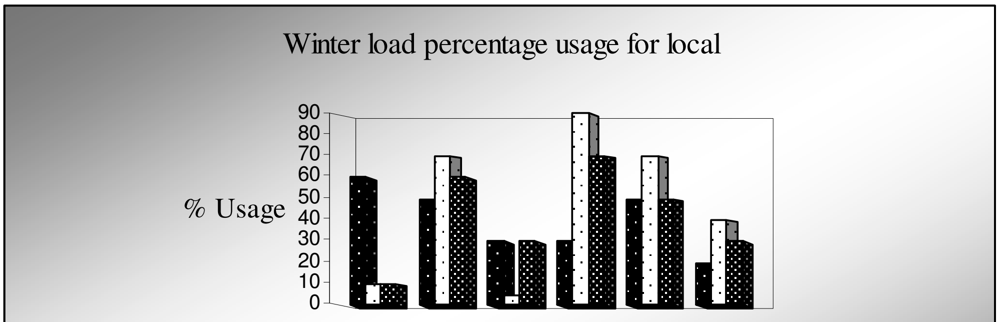
The results demonstrate that the A/C load, the most load contribution to the total load, has a visible fluctuation percentage between summer and winter. This is true especially in the on-peak time when the ambient temperature is in its highest rate. On the other hand water heaters have an opposite trend, where the percentage usage in the summer is so less than the winter. People usually need to have warm water in the winter season especially during the off-peak hours and others rather than the on- peak hours since the ambient temperature is low.

The same analysis was carried out for local categories and the results are shown in Figures 6.5 and 6.6.



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	70	40	30	20	40	60
Off-Peak	40	70	10	30	60	50
Other	60	50	30	30	50	20

Fig.6.5 Local appliances percentage usage in current status for summer season



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	60	50	30	30	50	20
Off-Peak	10	70	5	90	70	40
Other	10	60	30	70	50	30

Fig.6.6 Local appliances percentage usage in current status for winter season

Additionally the percentage usage results were estimated for the local load outputs specially the A/C systems and water heaters.

The two proposed scenarios of TOD tariff are different based on the percentage usage of the operating systems. These scenarios are proposed to have incremental of 30% in scenario #1 and 50% in scenario # 2. The decrement percentages for the two scenarios are 15% and 25%, respectively.

6.3.2 Scenario #1Analysis

Based on the load pattern for the residential load category, the on-peak, off-peak and other times can be determined based on the maximum and minimum consumptions.

The three different timing with the respective tariff rate are shown in Tables 6.3 and 6.4. In order to side with the market price incremental for the electrical equipments, 10% escalation of the tariff incremental every five years has been proposed as indicated in Tables 6.5 and 6.6.

Table 6.3

Scenario #1:Non-Local TOD Tariff Rates (2006-2010)

On Peak: 1pm-5pm	20 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	15 Fils/KWh
Off Peak: 9pm-6am	13 Fils/KWh

Table 6.4

Scenario #1: Local TOD Tariff Rates (2006-2010)

On Peak: 1pm-5pm	6.5 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	5 Fils/KWh
Off Peak: 9pm-6am	4.5 Fils/KWh

Table 6.5

Scenario #1:Non-Local TOD Tariff Rates (2011-2015)

On Peak: 1pm-5pm	21 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	15 Fils/KWh
Off Peak: 9pm-6am	13 Fils/KWh

Table 6.6

Scenario #1: Local TOD Tariff Rates(2011-2015)

On Peak: 1pm-5pm	7 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	5 Fils/KWh
Off Peak: 9pm-6am	4.5 Fils/KWh

The total peak load for all housing units was calculated based on the peak load per unit in kW and the total number housing units. Tables 6.7 and 6.8 depict the results for the actual peak load and the peak load forecast.

Table 6.7

Actual load peak in housing units

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total housing Units (No.)	92291	102332	108170	114775	117466	120179	123504	125490	125949	128620	131754
Peak Load Per Housing Unit (KW)	7.8	15.1	15.1	15.1	15.1	15.1	15.1	15.1	14.5	14.5	14.5
Peak Load (MW)	633	1362	1439	1527	1563	1599	1643	1670	1609	1643	1684

Table 6.8

Forecast load peak in housing units

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total housing Units (No.)	134044	136929	140150	143422	146658	149941	153230	156584	159984	163404
Peak Load Per Housing Unit (KW)	14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	16.5
Peak Load (MW)	1677	1737	1801	1868	1935	2004	2074	2146	2219	2295

Based on the result of the survey from some of the customers, the new distribution load percentage used in summer and winter for the proposed three different rates and the type of operating systems is calculated as an average consumption from all participants. This is achieved for non local consumers as well as the local consumers' categories. It is from Figure 6.7 that the reduction in non-local load mostly comes from A/C systems, lighting systems, and sockets.

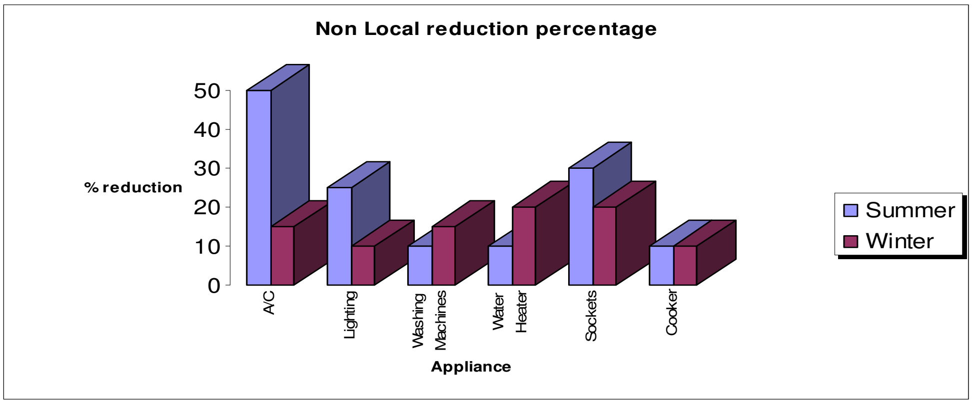


Fig. 6.7 Non local load reduction percentage in scenario 1

While the local load will not differ from the non local load since most of the reduction is the result in reduction of A/C, lightings and sockets consumptions as shown in Figure 6.8.

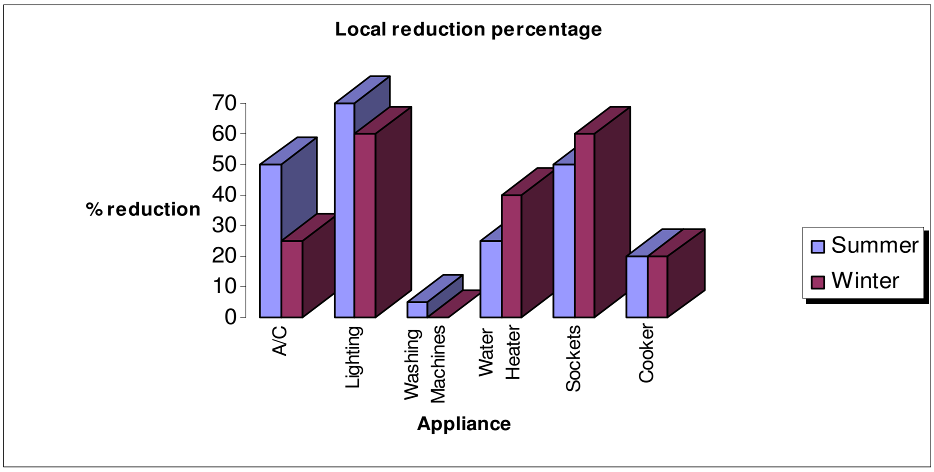


Fig. 6.8 Local load reduction percentage in scenario 1

The combination load percentage reduction for local and non local can be determined as indicated in Figure 6.9.

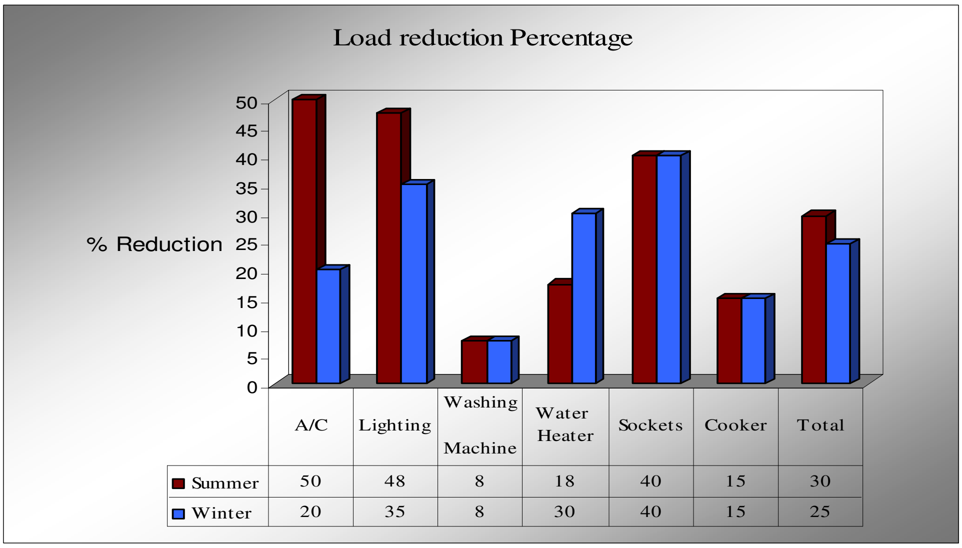


Fig. 6.9 Load reduction percentage in scenario 1

It is clear from Figure 6.9 that changing the tariff in on-peak period incremental by 30% and decrement by 15% on the off-peak period will result of 30% reduction in the summer load and 25% reduction in winter load, respectively in years from 2006-2010. On the other hand the summer reduction in years from 2011-2015 is 32% and 28% in winter season. The major reduction in summer that triggers the total reduction is the A/C systems and lighting loads. On the other hand these reductions will not be the same since the sockets besides the lighting are triggering the total load reduction.

The summer load reduction can be calculated from the peak and the summer reduction percentage. In addition the winter load reduction can be determined based on the total load and the winter reduction percentage. The total load reduction that will affect the system network is the average of the summer peak reduction and winter peak reduction. Figure 6.10 depicts the forecast of the load reduction for the two seasons in addition of the overall yearly reduction. Comparing the reduction results, it is visible from Figure 6.10 that the summer reduction is triggering the total load reduction

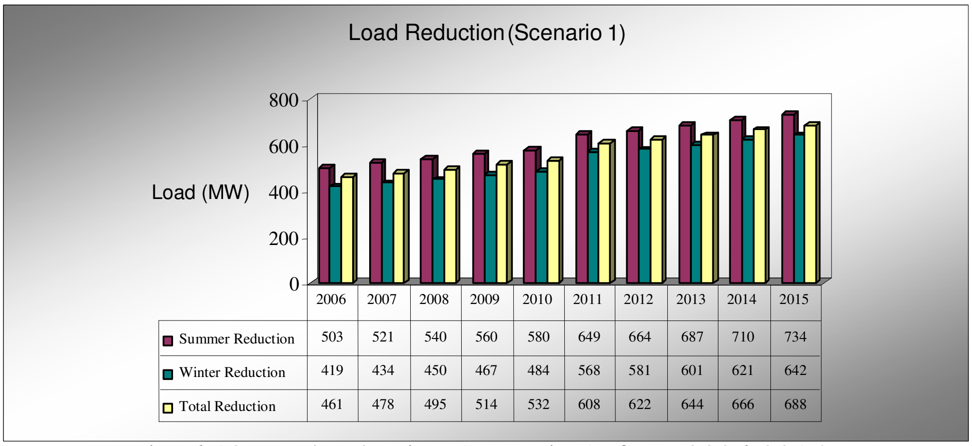


Fig. 6.10 Load reduction (scenario 1) from 2006-2015

Retrieving the load forecast for residential load, the new load forecast after considering the total load reduction is estimated based on peak load 2006 while the load forecast for years 2007-2020 is estimated based on Equation 6.6.

Figure 6.11 display the difference in the load forecast e after implementing the TOD scheme.

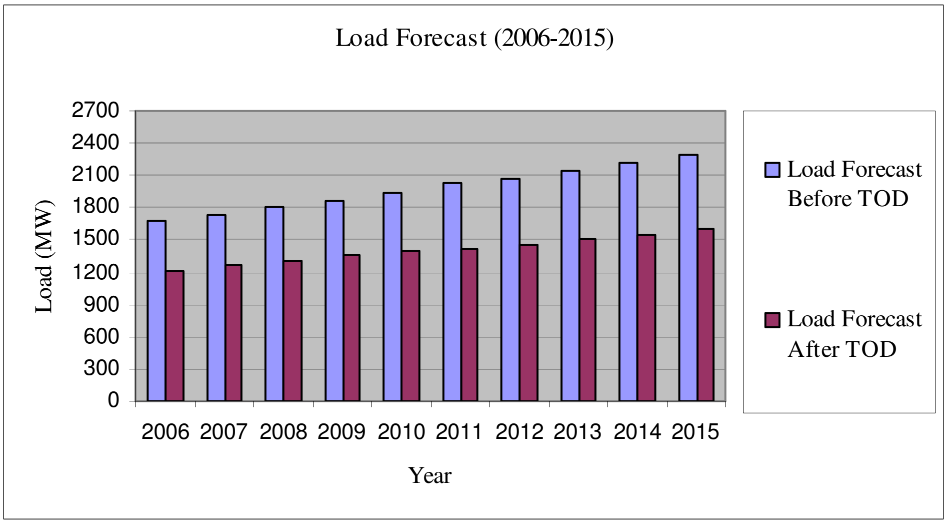


Fig. 6.11 Load forecast before and after applying TOD for scenario#1

6.3.3 Scenario #2 Analysis

The same procedure is followed in this scenario where the tariff is changed as indicated in Tables 6.11 and 6.12 with 50% incremental during on-peak hours and 25% reduction during off-peak hours in years from (2006-2010). Like scenario 1, tables 6.13 and 6.14 demonstrate the escalation of 10% for the next five years.

Table 6.9

Scenario #2:Non-Local TOD Tariff Rates (2006-2010)

On Peak: 1pm-5pm	23 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	15 Fils/KWh
Off Peak: 9pm-6am	11.5 Fils/KWh

Table 6.10

Scenario #2: Local TOD Tariff Rates (2006-2010)

On Peak: 1pm-5pm	7.5 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	5 Fils/KWh
Off Peak: 9pm-6am	4 Fils/KWh

Table 6.11

Scenario #2:Non-Local TOD Tariff Rates (2011-2015)

On Peak: 1pm-5pm	24 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	15 Fils/KWh
Off Peak: 9pm-6am	11.5 Fils/KWh

Table 6.12

Scenario #2: Local TOD Tariff Rates (2011-2015)

On Peak: 1pm-5pm	8 Fils/KWh
Flat rate: 5pm-9pm,6am-1pm	5 Fils/KWh
Off Peak: 9pm-6am	4 Fils/KWh

Based on the result of the survey from the customers, the new distribution load percentage in summer and winter based on three different rates and the operating appliances is calculated as an average consumption from all participants. This is estimated for non-local consumers as well as the local consumer's category as shown in Figures 6.12 and 6.13. The results illustrate that most of the reduction belongs to A/C, water heaters, sockets and lighting systems.

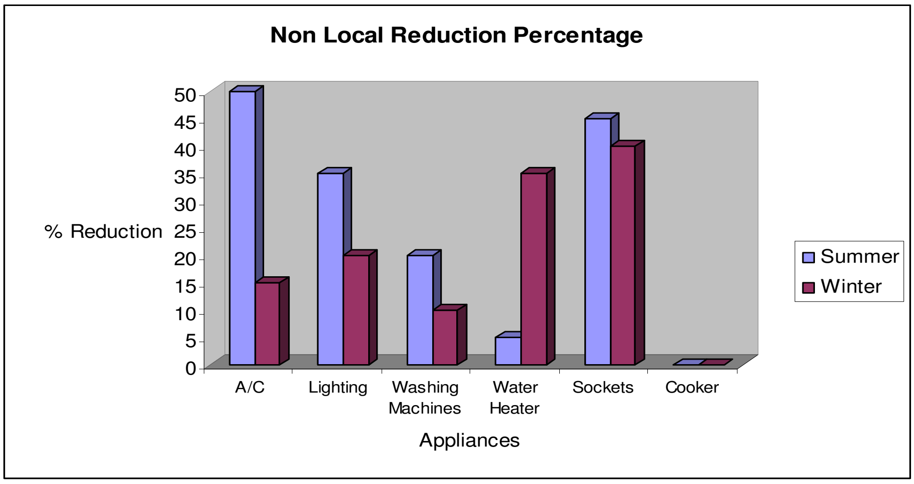


Fig. 6.12 Non local load reduction percentage in scenario 2

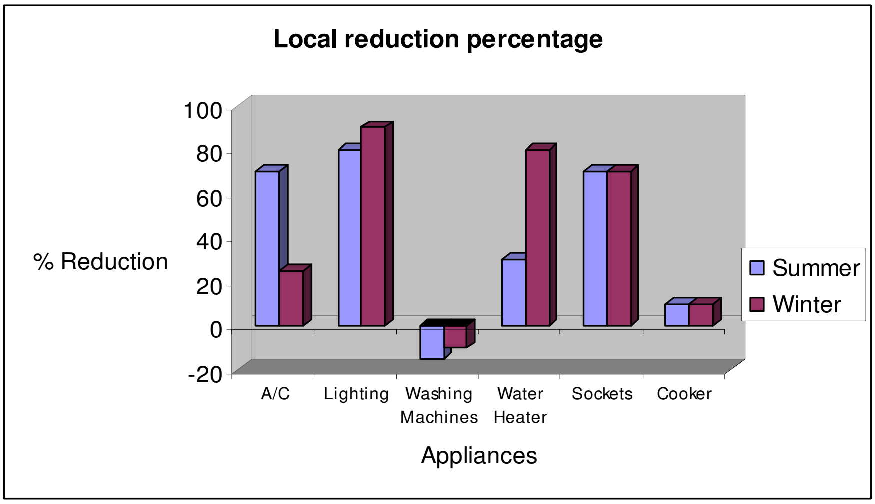
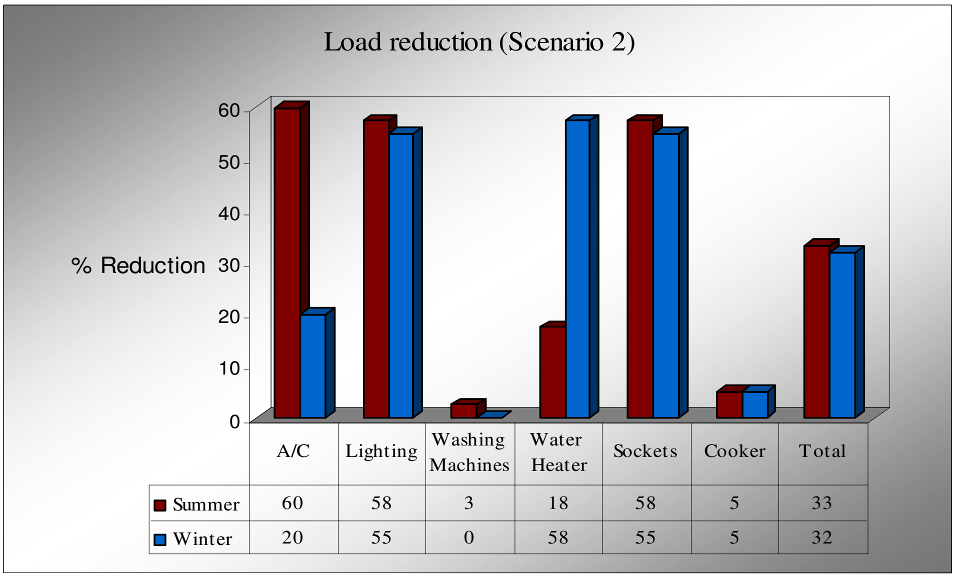


Fig. 6.13 local load reduction percentage in scenario 2

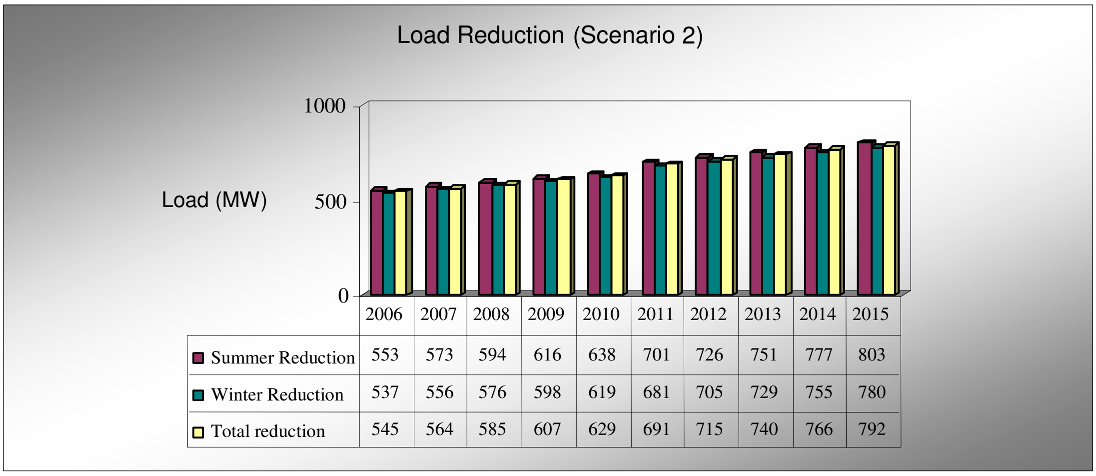
The combination load percentage reduction for local as well as non-local is shown in the Figure 6.14. The results indicates that any change in the tariff for on-peak period by 50% and decrement by 25% on the off-peak period will result of 33% reduction in the summer load and 32% reduction in winter load which are close to each other.



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker	Total
Summer	60	58	3	18	58	5	33
Winter	20	55	0	58	55	5	32

Fig. 6.14 Load reduction percentage in scenario 2

The summer load reduction then is estimated based on the peak loads and the summer reduction percentage which is 33% from 2006-2010. Moreover the winter load reduction is calculated by multiplying the total load by the winter reduction percentage which is 32%. However the percentage load reduction in 2011-2015 for summer and winter are 35% and 34% respectively. The total load reduction that will affect the system network is the average of the summer peak and winter peak reductions. Figures 6.15 and 6.16 show the forecast of load reduction for summer and winter seasons in addition of the total reduction. The reductions for the two seasons are so close to each other and equal to the distribution of appliances within 24 hours period.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Summer Reduction	553	573	594	616	638	701	726	751	777	803
Winter Reduction	537	556	576	598	619	681	705	729	755	780
Total reduction	545	564	585	607	629	691	715	740	766	792

Fig. 6.15 Load reduction (scenario 2) from 2006-2015

Retrieving the load forecast for residential load, the new load forecast after the load reduction is estimated by calculating the load peak for 2006 after the reduction and the load forecast for years 2007-2020 is calculated based on equation 6.6. The figure below will show how is the difference in the load forecast will be after applying TOD for scenario 2.

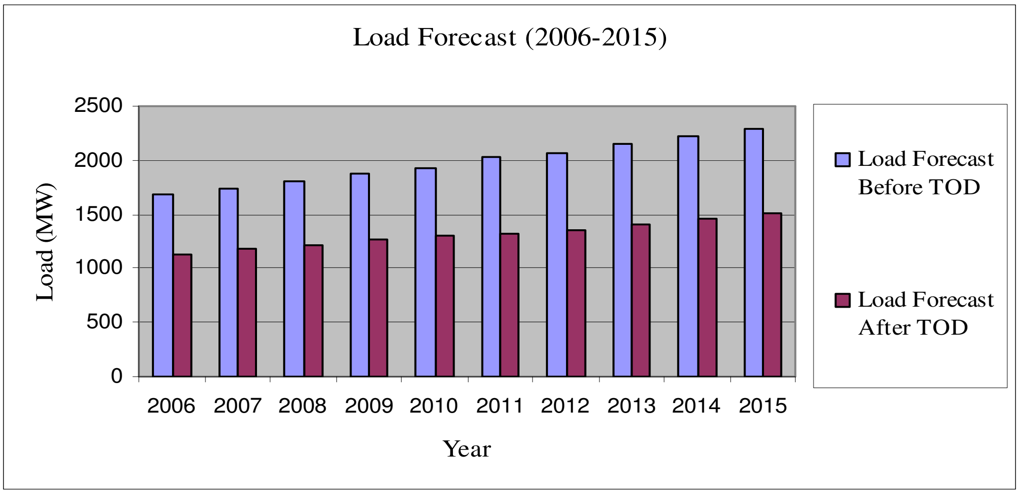


Fig 6.16 Load forecast before and after applying TOD for scenario#2

The two scenarios explain how the incremental of tariff value in the on-peak time affect the load reduction. This is mainly due to the high rate tariff. This give a significance on how the TOD tariff tool affect the load consumption if it is applied and integrated during the power planning stage. This will affect the overall load forecast especially in the years with high development connected load and high required capacity. The improvement in the load usage is triggering the reduction in peak load reduction which therefore will avoid installing some of new primaries. The planning engineer usually plans based on the load forecast searching for two objectives, the least cost plan to ADDC and with high efficiency power to the customers. Introducing the integration of DSM in the network planning can help to achieve these objectives.

6.4 Energy Efficiency Culture

People today are using energy like never before. Such items as dishwashers, microwaves, washers and dryers, personal computers, fax machines, and modems have allowed us to save valuable time, but it doesn't come without a cost. It is increasingly important to manage the amount of electricity the people use, not only to save money, but also to keep meet the demand growth and the future of power requirements.

ADDC system has been designed to meet normal customer demand for electricity. However in summer there is a much higher use of electricity and more possibilities of outages.

One of the Energy Efficiency methods is to encourage changing the customer's behavior and Energy Efficiency culture. What can be done is too much and if it really applied by most of the customers that will gain benefits for the customers along with ADDC. It can predicted that the results will be as twice as the TOU tool since the consumption usage will be as the TOU considering the distribution of appliance load within the 24 day hours. This strategy will assist in avoiding switching the un-used appliances or in the time of un-occupancy. Beside that controlling of the appliances and the awareness of the energy efficiency equipments will also keep the load maintain in a suitable range avoiding the sharp peak.

The followings are some ways that businesses in different areas can reduce energy consumption while continuing to provide a comfortable environment for employees and customers.

6.4.1 Home Cooling

Cutting cooling costs is easy when everyone know what to do. A poorly maintained air conditioner uses 10 to 20 percent more energy than necessary as it prove in some international cities. But following these simple steps, the customer will be on the way to cutting their energy bills.

- ✓ Have a yearly safety check and tune-up. Each spring, a licensed heating and air conditioning technician should service your system. It's a small investment considering that the customer could spend as much as checking expense on cooling the home in just one season. Performing regular maintenance keep the air conditioning systems running more efficiently.
- ✓ Clear away weeds and debris. If air can't circulate freely around your outside unit, this leads to have higher bills and more service calls. Shading the unit can help, as long as air flow is not blocked.
- ✓ Replace or clean dirty filters. Dirty air filters are the No. 1 cause of air conditioning service calls. But filters are easy to replace or putting in a new one every month during the summer.

- ✓ Repair crushed disconnected or leaky ducts. If a supply duct has worked loose from a vent or connecting duct, the air from your cooling system never reaches the rooms.
- ✓ Paying attention to the thermostat settings. Air conditioning thermostats should be set no lower than 20° C reference to our climate and temperature; each degree be raised for temperature setting can save on air conditioning costs.
- ✓ Setting the thermostat down or off when there is nobody in the house. Also using ceiling or room fans allows setting the thermostat higher because the air movement will cool the room.
- ✓ Consider a whole-house fan. Because some nights are cool, but have no light wind, the one may benefit from using a whole-house fan to force cool air through the home. A whole-house fan is permanently installed in the attic and draws cooler air into the home and forces warmed air out through the attic vents. Also using a portable or ceiling fan to circulate air whenever possible.
- ✓ Shading the home's exterior with landscaping, awnings or overhangs. Shading with trees can make a surprising difference in the cooling bills.
- ✓ When replacing cooling equipment, the air conditioning contractor can help in calculating the right size for your home. Also it's recommended to have energy Efficiency one.
- ✓ Installing programmable thermostats or timers to give better control when the air conditioning is on. Programmable thermostats also will help control the temperature it's desirable to maintain.
- ✓ Keeping the sun and heat out by closing the door and draw the curtains and/or shades to on hot days.
- ✓ Weatherizing the building by installing awnings, solar window shade screens or sun-control window film, and applying a heat-blocking coating to the roof.

6.4.2 Lightings

The lighting energy cost may represent as much as 30 percent or maybe more of the energy bill. Fortunately, there are ways to reduce this cost:

- ✓ Installing occupancy sensors or turn off lights when not needed. Occupancy sensors have been shown to save up to 30 percent on lighting costs during normal working hours. Lights in storage areas, conference rooms, restrooms, or near windows can be left off when space is unoccupied or daylight is sufficient.
- ✓ Reducing lighting where possible and take advantage of natural daylight. Turning lights off or dimming them during the day allows for lower energy costs and a more comfortable environment. Also, removing excess lighting, and turn off signage and other lights not necessary for security and safety.
- ✓ Installing timers, time clocks or photocells to ensure that interior and exterior lights are turned off at the appropriate time.
- ✓ Buying efficient replacement lamps. Forty-watt fluorescent lamps can be replaced with 34-watt compact fluorescent lamps that produce just as much light. Incandescent lamps can often be replaced with compact fluorescent lamps that can reduce lighting costs by up to 75% and last up to ten times as long as incandescent bulbs.

6.4.3 Office Equipment

These days, every business has computers, printers, copiers and faxes. Starting an energy-savings program for the office machines can result in savings for years to come by following the below tips:-

- ✓ Choose energy efficiency products when upgrading or adding new equipment. And since most energy efficiency equipment powers down during periods of inactivity, you'll also save on air conditioning costs.
- ✓ Reducing the hours where equipment is left running unnecessarily. PCs, monitors, printers, copiers and scanners should be turned off at night and over weekends if they aren't needed.

6.4.4 Refrigeration

If the business involves selling or serving food like restaurants and hotels, a significant portion of the energy bill goes towards keeping the food refrigerated. Here are some things you can be done to reduce refrigeration costs either in the houses, hotels or restaurants:

- ✓ Adding strip curtains to walk-in coolers to reduce the amount of energy lost to the surrounding air. Strip curtains used in busy kitchens can cut down on compressor run time significantly and that could save you money. As an added bonus, these curtains repel windborne contaminants like dust and pollutants.
- ✓ Keeping the temperature at the right setting. Considering install variable speed drives which automatically adjust the level of refrigeration and are being used on the motors of all kinds of refrigeration units.
- ✓ Looking at the door gaskets on all of the refrigerators and replace any that are torn, cracked or missing. A refrigerator must seal completely to be effective; the concept is not trying to keep the cold air in but trying to keep the hot, humid kitchen air out.
- ✓ Airflow is an important part of refrigeration. When the coils are clogged and dirty the compressor works harder and will fail sooner. Each month, it should be clean the evaporator and condenser coils and check for the proper amount of refrigerant.
- ✓ Keeping those fridge and freezer doors closed as much as possible.

6.4.5 Others

- ✓ Running the dishwasher, washer and dryer early in morning or late at night.
- ✓ Drying clothes outdoors
- ✓ Avoid using heat-producing small appliances (toasters, hairdryers) at peak times.
- ✓ To have Energy Efficiency appliances when upgrading or adding new equipment
- ✓ Avoid heating the swimming pool at night and letting hot daytime temperatures warm it during the day.
- ✓ Using manual skimmers rather than pool vacuums daily and vacuum twice a week.
- ✓ Turning off lights, computers, stereos and TVs when they are not in use.
- ✓ Decreasing the thermostat on the water heater and this can help to reduce the water heating costs.

- ✓ Avoiding standby power waste: No-load power waste is the energy used by a device - such as, for example, a cell phone charger - which is plugged in even if it is performing no function (the cell phone is not attached).

CHAPTER 7

7 ECONOMIC ANALYSIS FOR TOD TECHNIQUE

7.1 Capacity Reduction

Depending on the load reduction, the load forecast is found to be dynamically changed after the TOD is introduced. Moreover, the power system planning is found to be changed accordingly. Consequently, the number of electrical equipment to be installed is reduced as an effect of capacity reduction which reduces the utility cost.

Table 7.1

Total Reduction per Year in MW (2006-2010) Scenario 1

Year	2006	2007	2008	2009	2010
Peak reduction (MW)	461	478	495	514	532

Table 7.2

Total Reduction per Year in MW (2011-2015) Scenario 1

Year	2011	2012	2013	2014	2015
Peak reduction (MW)	608	622	644	666	688

For any projects development, the network planning is based on the 33kV and 11 kV network in order to provide such a project with the electricity needed. It starts by assumptions of 2,000,000 Dhs CAPEX per (MW) demand load, see appendix J. Also to side with the yearly increment of the market price of electrical equipment triggered by the copper increment cost, a10% escalation percentage is added yearly to the CAPEX. Depend on the demand reduction; the CAPEX/Demand (MW) will be affected depending on the value of the yearly reduction. Tables 7.3 and 7.4 illustrate such results and the obvious summary denoted in Figure 7.1 for scenario 1 when the Tariff is increment by 30% in on-peak time and decrement by 15% in off-peak time.

Table 7.3

CAPEX reduction per year (2006-2010) Scenario 1

Year	2006	2007	2008	2009	2010
Peak Reduction (MW)	461	478	495	514	532
CAPEX (Million Dhs)	932	965	1001	1038	1075

Table 7.4

CAPEX reduction per year (2011-2015) Scenario 1

Year	2011	2012	2013	2014	2015
Peak Reduction (MW)	608	622	644	666	688
CAPEX (Million Dhs)	1229	1257	1301	1346	1391

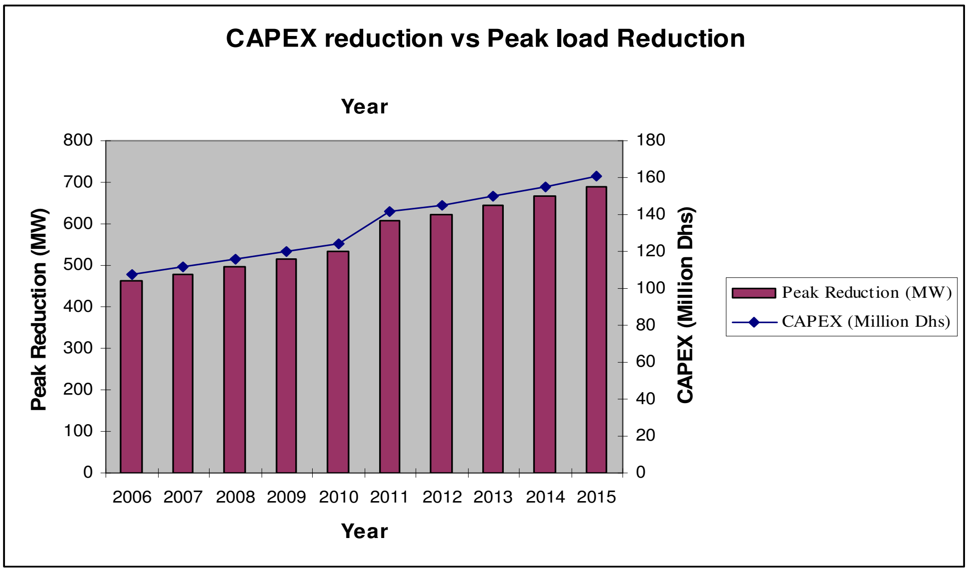


Fig. 7.1 CAPEX Reduction vs. Peak load Reduction Scenario 1

The same analysis is applied for scenario 2, when the tariff are vary with 50% increment in on-peak and 25% decrement in off-peak The results obtained are shown in tables 7.5, 7.6.

Table 7.5

Total Reduction per Year in MW (2006-2010) Scenario 2

Year	2006	2007	2008	2009	2010
Peak Reduction (MW)	545	564	585	607	629

Table 7.6

Total Reduction per Year in MW (2011-2015) Scenario 2

Year	2011	2012	2013	2014	2015
Peak Reduction (MW)	691	715	740	766	792

Considering the demand reduction, the CAPEX/Demand (MW) will be affected depend on the value of the demand reduction yearly as in scenario 1. Tables 7.7 and 7.8 display the findings for each year and the observable summary is indicated in Figure 7.2.

Table 7.7

CAPEX reduction per year (2006-2010) Scenario 2

Year	2006	2007	2008	2009	2010
Peak Reduction (MW)	545	564	585	607	629
CAPEX (Million Dhs)	1102	1141	1183	1227	1271

Table 7.8

CAPEX reduction per year (2011-2015) Scenario 2

Year	2011	2012	2013	2014	2015
Peak Reduction (MW)	691	715	740	766	792
CAPEX (Million Dhs)	1397	1446	1496	1548	1600

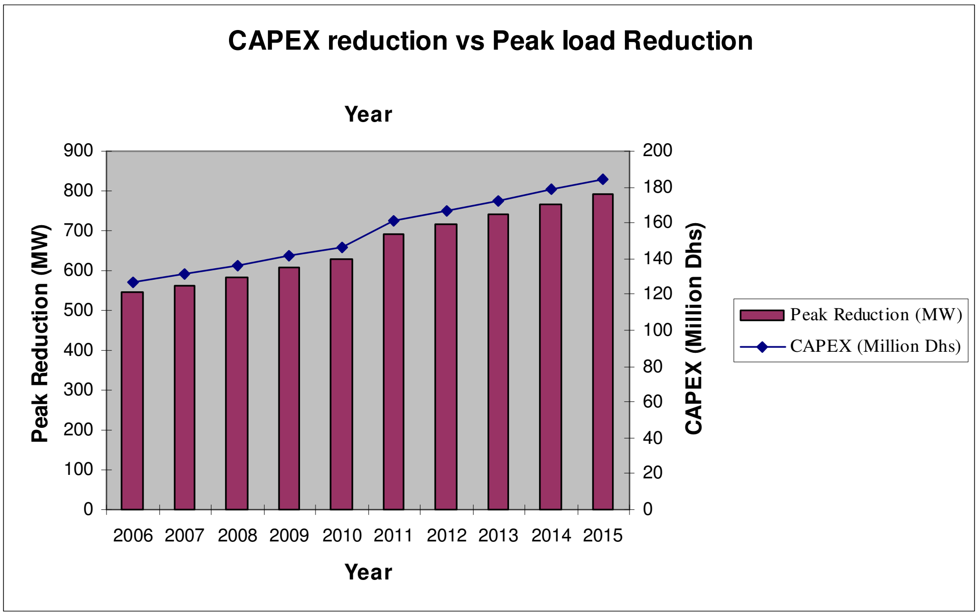


Fig. 7.2 CAPEX Reduction vs. Peak load Reduction Scenario 2

7.2 Demand Charge Reduction

ADDC is purchasing the electricity from the generation plants, based on yearly agreement between the generation, transmission and ADWEC as the buyer and seller company under the organization of RSB. These demand charge payments are based on the forecast peak load yearly. From another point of view and as additional cost saving for ADDC, the yearly payment for purchasing the electricity from the generation will be reduced depending on the yearly peak demand reduction, when introducing TOD into the system network.

Demand Charge (Dhs) = Forecast Demand Peak (KW) x Demand charge rate (Dhs/KW)

The demand charge rate = 460 Dhs/KWh in year 2006 and since this rate changes yearly depending on some factors such as the fuel cost and O&M cost, the demand charge rate will change accordingly. The estimated percentage of increment is 2% yearly based on the fuel cost increment. Thus the demand charges payments will vary as indicated in tables 7.8 and 7.9 and summarized in Figure 7.3.

Table 7.9

Demand Charge before TOD in Scenario 1

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Peak Load (MW)	1677	1737	1801	1868	1935	2004	2074	2146	2219	2295
Demand Charge (Million Dhs)	771	815	845	877	908	940	973	1007	1042	1077

Table 7.10

Demand Charge after TOD in Scenario 1

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Peak Load (MW)	1216	1259	1306	1354	1403	1419	1451	1502	1554	1606
Demand Charge (Million Dhs)	559	591	613	636	658	666	681	705	729	754

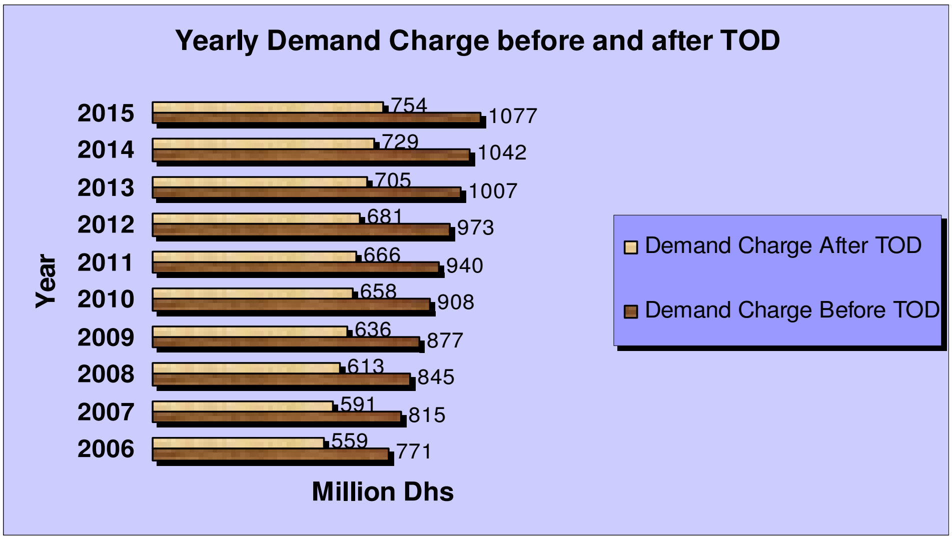


Fig. 7.3 Demand Charge before and after TOD in Scenario 1

The same results obtained for scenario 2 as indicated in the Tables 7.10, 7.11 and Figure 7.4.

Table 7.11

Demand Charge before TOD in Scenario 2

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Peak Load (MW)	1677	1737	1801	1868	1935	2004	2074	2146	2219	2295
Demand Charge (Million Dhs)	771	815	845	877	908	940	973	1007	1042	1077

Table 7.12

Demand Charge after TOD in Scenario 2

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Peak Load (MW)	1132	1172	1216	1261	1306	1312	1358	1405	1454	1503
Demand Charge (Million Dhs)	521	550	571	592	613	616	638	660	682	705

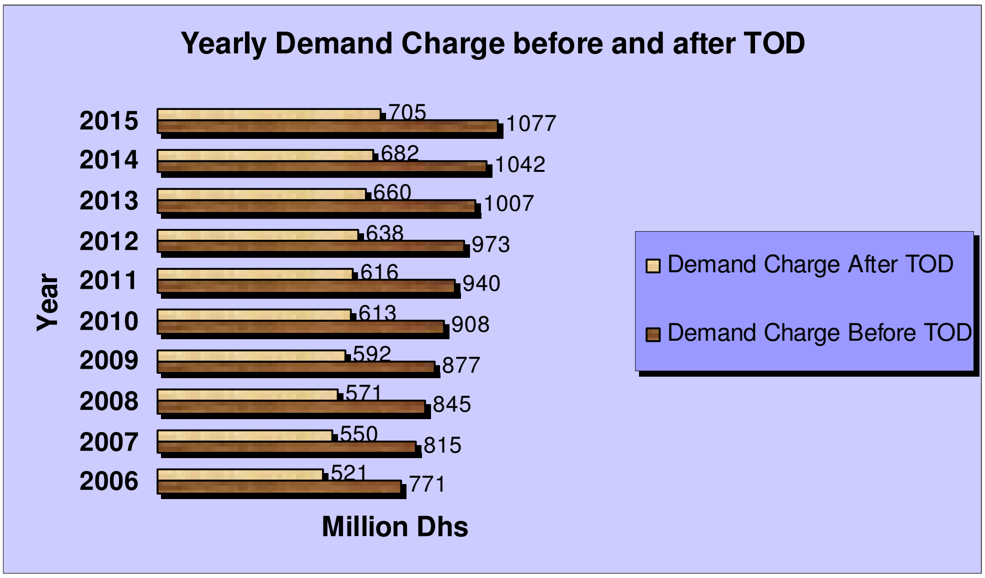


Fig. 7.4 Demand Charge before and after TOD in scenario 2

7.3 Electricity Bill Reduction

Similarly the customers will be benefited from introducing this new technique into the network system through reducing their monthly bill. The reduction in the customer bill can is calculated through multiplying each season reduction with the hours of four months season duration. The tariff rate is estimated to be the flat rate for local and non local multiply by the KWh from the reduction. Therefore the bill reduction for each customer can be calculated by dividing the local or non local customer by their respective tariff value as indicated in equation 7.1 and 7.2

$$bill\_reduction/customer(non\_local)/season = \frac{No.\_non\_local\_customers}{(load\_reduction * 2880000 * 0.15)} \quad (7.1)$$

$$bill\_reduction/customer(local)/season = \frac{No.\_local\_customers}{(load\_reduction * 2880000 * 0.05)} \quad (7.2)$$

The number of customers at the end of 2005 was 2366398 based on ADDC database and 2310178 in year 2004. The approximate growth rate for the customers based on these values is 2.4% but based on the expectations of the incremental growth, it will be assumed to be more by 25%,. Thus the 3% will be reasonable and sufficient for population growth up to year 2008. However since the load growth rate will have a high trend from year 2009 due to the mega projects accomplishments, the customers will also be affected by the increment of 5% accordingly. Moreover the residential customers are 42% from the total customers triggered by the relationship of residential load and the system load as shown in Table 7.13 and for more details it is indicated in Appendix G.

Table 7.13

Number of residential customers yearly

Year	No. of customers	Residential customers	Local customers	Non local customers
2004	2310178	970275	323425	646850
2005	2366398	993887	331296	662591
2006	2437390	1023704	341235	682469
2007	2510512	1054415	351472	702943
2008	2585827	1086047	362016	724032
2009	2663402	1118629	372876	745753
2010	2743304	1152188	384063	768125
2011	2825603	1186753	395584	791169
2012	2910371	1222356	407452	814904
2013	2997682	1259027	419676	839351
2014	3087613	1296797	432266	864532
2015	3180241	1335701	445234	890467
2016	3275648	1375772	458591	917182
2017	3373918	1417045	472348	944697
2018	3475135	1459557	486519	973038
2019	3579389	1503344	501115	1002229
2020	3686771	1548444	516148	1032296

The Energy consumption is calculated by multiplying the hours in each season by the season reduction load in kW. Furthermore the bill reduction will be the amount of the tariff multiplied by the energy consumption. In order to get the yearly amount of bill reduction per customer, it's considered to be the no. of customers divided by the total bill reduction for each year as indicated in Table 7.14, 7.15, 7.16 and 7.17 for local and non local customers in summer and winter seasons.

Table 7.14

Local and Non Local Bill Reduction, Summer in Scenario 1 (2006-2010)

Year	2006	2007	2008	2009	2010
Summer Reduction (MW)	503	521	540	560	580
Energy (KWh)	1449068011	1500363948	1556240300	1613645726	1671593433
Total Local bill reduction (Dhs/KWh)	72453400.5	75018197.4	77812015	80682286.3	83579671.7
Total Non Local bill reduction (Dhs/KWh)	217360202	217360202	217360202	217360202	217360202
Local bill reduction/customer (Dhs/KWh)	0.00470971	0.00468515	0.00465244	0.00462154	0.00459517
Non Local bill reduction/customer (Dhs/KWh)	0.00313981	0.003234	0.00333102	0.00343095	0.00353388

Table 7.15

Local and Non Local Bill Reduction, Summer in Scenario 1 (2011-2015)

Year	2011	2012	2013	2014	2015
Summer Reduction (MW)	649	664	687	710	734
Energy (KWh)	1868162280	1910951102	1977311821	2045303928	2114632281
Total Local bill reduction (Dhs/KWh)	93408114	95547555.1	98865591.1	102265196	105731614
Total Non Local bill reduction (Dhs/KWh)	217360202	217360202	217360202	217360202	217360202
Local bill reduction/customer (Dhs/KWh)	0.00461594	0.00478334	0.00490018	0.00502152	0.0051483
Non Local bill reduction/customer (Dhs/KWh)	0.0039673	0.00420534	0.00445766	0.00472512	0.00500863

Table 7.16

Local and Non Local Bill Reduction, Winter in Scenario 1 (2006-2010)

Year	2006	2007	2008	2009	2010
Winter Reduction (MW)	419	434	450	467	484
Energy (KWh)	1207556676	1250303290	1296866917	1344704772	1392994528
Total Local bill reduction (Dhs/KWh)	60377834	62515164	64843346	67235239	69649726
Total Non Local bill reduction (Dhs/KWh)	181133501	187545493	194530038	201705716	208949179
Local bill reduction/customer (Dhs/KWh)	0.005652	0.005622	0.005583	0.005546	0.005514
Non Local bill reduction/customer (Dhs/KWh)	0.00377	0.00375	0.00372	0.00370	0.00368

Table 7.17

Local and Non Local Bill Reduction, Winter in Scenario 1 (2011-2015)

Year	2011	2012	2013	2014	2015
Winter Reduction (MW)	568	581	601	621	642
Energy (KWh)	1634641995	1672082215	1730147843	1789640937	1850303246
Total Local bill reduction (Dhs/KWh)	81732100	83604111	86507392	89482047	92515162
Total Non Local bill reduction (Dhs/KWh)	245196299	250812332	259522177	268446141	277545487
Local bill reduction/customer (Dhs/KWh)	0.005275	0.005467	0.005600	0.005739	0.005884
Non Local bill reduction/customer (Dhs/KWh)	0.00352	0.00364	0.00373	0.00383	0.00392

Figures 7.5 and 7.6 will illustrate the yearly bill reduction per customer per season in local and non local customers and the yearly variation basically depends on the number of customers and how they are related to the no. of load reduction.

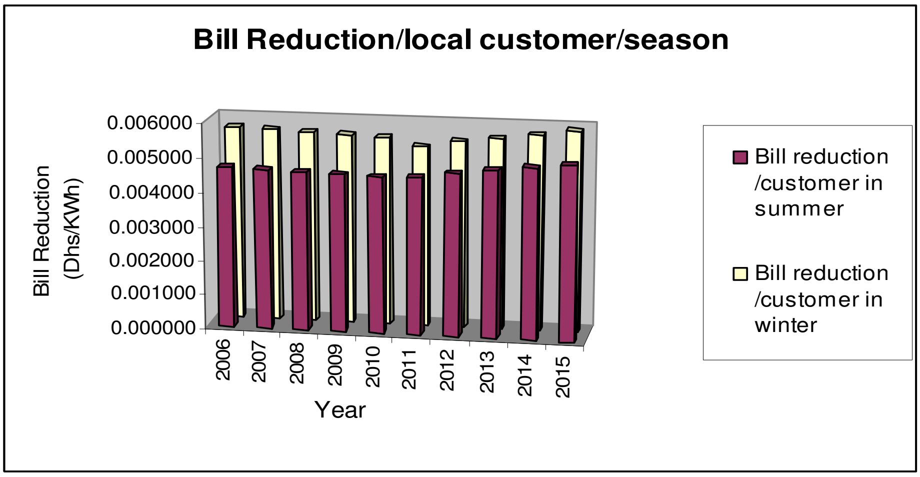


Fig. 7.5 Bill reduction for local customer in summer and winter (Scenario 1)

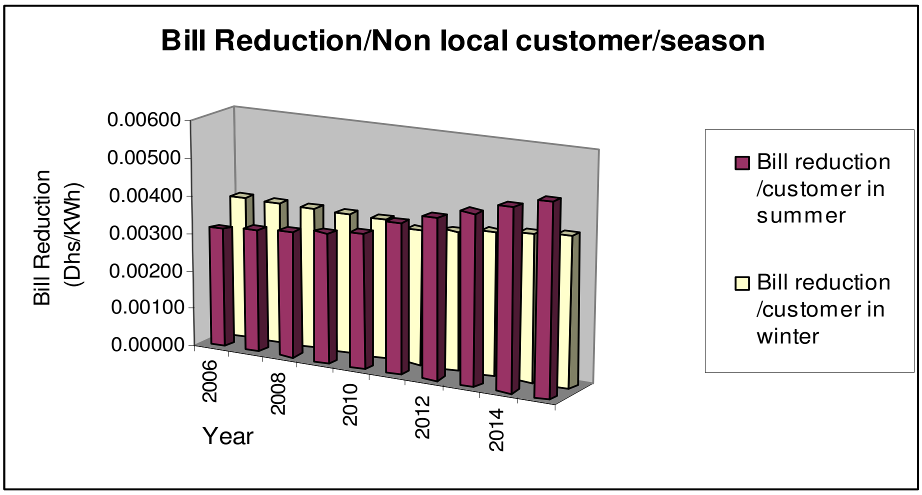


Fig. 7.6 Bill reduction for non local customer in summer and winter (Scenario 1)

The same analysis was applied for Scenario 2 and the obtained results are denoted in Tables 7.18, 7.19, 7.20, 7.21 and Figures 7.7 and 7.8. Since the yearly peak reduction in scenario 2 have high trend than scenario 1, the bill reduction will be affected accordingly. Since the no. of customers are the same for the two scenarios, scenario 2 results show different approach than scenario 1.

Table 7.18

Local and Non Local Bill Reduction, Summer in Scenario 2 (2006-2010)

Year	2006	2007	2008	2009	2010
Summer Reduction (MW)	553	573	594	616	638
Energy (KWh)	1593974812	1650400343	1711864330	1775010299	1838752776
Total Local bill reduction (Dhs/KWh)	79698741	82520017	85593217	88750515	91937639
Total Non Local bill reduction (Dhs/KWh)	239096222	239096222	239096222	239096222	239096222
Local bill reduction/customer (Dhs/KWh)	0.004282	0.004259	0.004229	0.004201	0.004177
Non Local bill reduction/customer (Dhs/KWh)	0.00285	0.00294	0.00303	0.00312	0.00321

Table 7.19

Local and Non Local Bill Reduction, Summer in Scenario 2 (2011-2015)

Year	2011	2012	2013	2014	2015
Summer Reduction (MW)	701	726	751	777	803
Energy (KWh)	2019543162	2090102768	2162684804	2237051171	2312879057
Total Local bill reduction (Dhs/KWh)	100977158	104505138	108134240	111852559	115643953
Total Non Local bill reduction (Dhs/KWh)	239096222	239096222	239096222	239096222	239096222
Local bill reduction/customer (Dhs/KWh)	0.004270	0.004373	0.004480	0.004591	0.004707
Non Local bill reduction/customer (Dhs/KWh)	0.00361	0.00382	0.00405	0.00430	0.00455

Table 7.20

Local and Non Local Bill Reduction, Winter in Scenario 2 (2011-2015)

Year	2006	2007	2008	2009	2010
Winter Reduction (MW)	537	556	576	598	619
Energy (KWh)	1545672545	1600388211	1659989654	1721222108	1783032995
Total Local bill reduction (Dhs/KWh)	77283627	80019411	82999483	86061105	89151650
Total Non Local bill reduction (Dhs/KWh)	231850882	240058232	248998448	258183316	267454949
Local bill reduction/customer (Dhs/KWh)	0.004415	0.004392	0.004362	0.004333	0.004308
Non Local bill reduction/customer (Dhs/KWh)	0.00294	0.00293	0.00291	0.00289	0.00287

Table 7.21

Local and Non Local Bill Reduction, Winter in Scenario 2 (2011-2015)

Year	2011	2012	2013	2014	2015
Winter Reduction (MW)	681	705	729	755	780
Energy (KWh)	1961841929	2030385546	2100893810	2173135423	2246796799
Total Local bill reduction (Dhs/KWh)	98092096	101519277	105044690	108656771	112339840
Total Non Local bill reduction (Dhs/KWh)	294276289	304557832	315134071	325970313	337019520
Local bill reduction/customer (Dhs/KWh)	0.004396	0.004502	0.004612	0.004726	0.004845
Non Local bill reduction/customer (Dhs/KWh)	0.00293	0.00300	0.00307	0.00315	0.00323

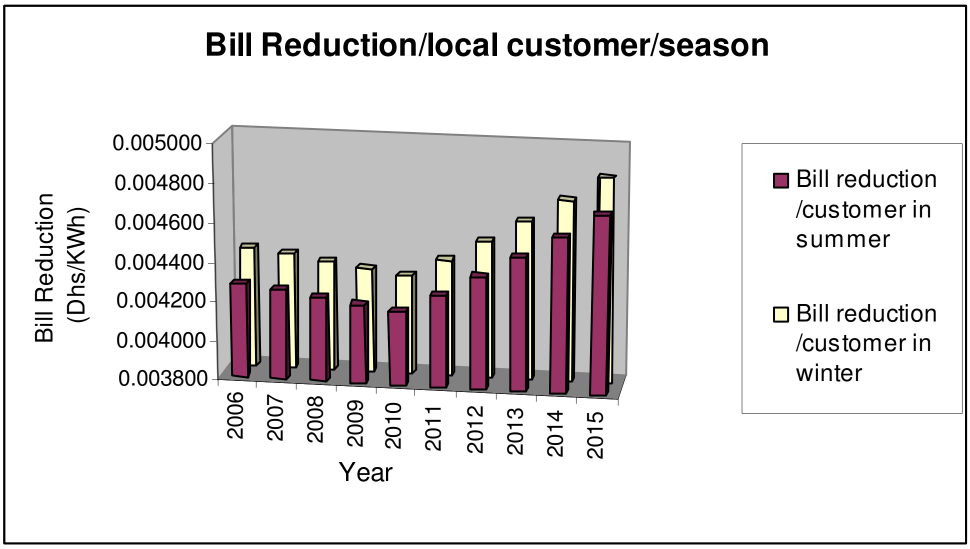


Fig. 7.7 Bill reduction for local customer in summer and winter (Scenario 2)

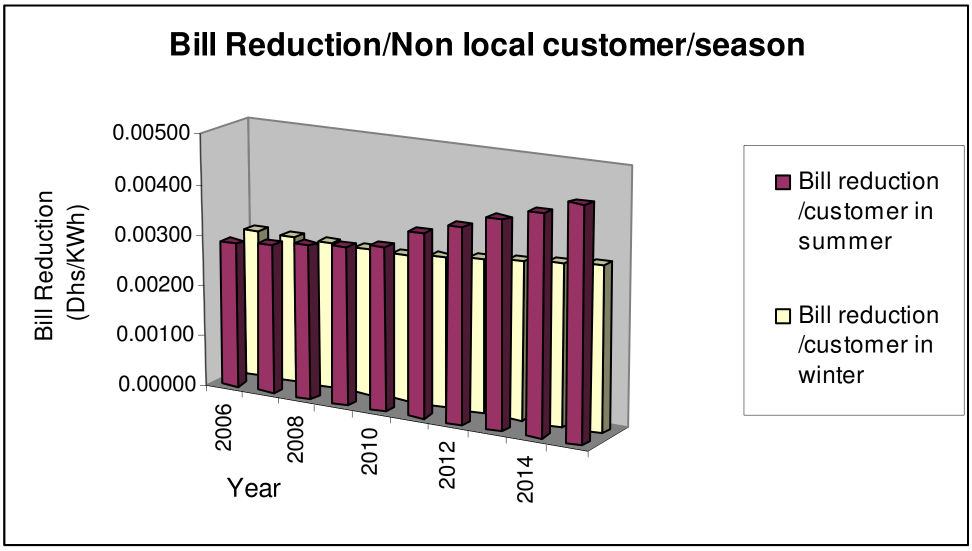


Fig. 7.8 Bill reduction for non local customer in summer and winter (Scenario 2)

CHAPTER 8

8 CONCLUSUON AND RECOMMENDATIONS

8.1 Conclusion

DSM can be thought as a management tool for energy utilities that is capable to find resources on the demand side, instead of on the supply side, or as a more general managerial tool for society to better use and distribute scarce resources. In both cases the objective is to choose the best option to have services that energy can provide at the lowest cost.

Although there are hundreds of innovative DSM programs, all of these programs achieve their real two economic benefits. First benefit could be achieved by improving utilization of the fixed infrastructure. Since the fixed infrastructure investment is determined by peak load requirements, DSM programs that reduce the peak load in relation to total usage enable more electricity to be delivered with the same infrastructure investment reducing the cost per kilowatt hour (KWh) of providing electricity. Second benefit could be targeted by improving energy efficiency of existing energy systems. Energy efficiency programs focus on reducing an energy user's overall energy requirements, without affecting the level of energy services they receive. An energy efficiency improvement typically results from installing an energy efficiency technology or adopting a more energy efficient practice. It can mean changing equipment use, building design, and management practices in different ways that reduce the total cost of energy services over time. Measures that can increase energy efficiency include adding insulation in building walls and roofs, installing high-efficiency lighting, using high-efficiency industrial motors. The research in the global implementation of DSM show limited effort in integrating the DSM into the power network planning

In this thesis, the concentration was on DSM as a utility tool that reduces the peak load and changes the load pattern by introducing Time of Day Tariff technique. Moreover this study overview the energy efficiency culture which will be the energy efficiency roadmap for the customers in all load categories if it implemented properly.

In order to evaluate the effectiveness of DSM technique, it required dependent load forecast which does not exist till now in ADDC. The planning engineer usually depends on the load forecast based or the primary and grid district loading regardless of the load type category whether it's residential, commercial, industrial or agricultural. On that base, there is no consideration for demand factor required for each category and the diversity factor. The only factor that was actually considered is the growth rate. In this thesis a new load forecast model has been developed depending on the exponential smoothing forecast method. The weight level was obtained from the study determined by three factors of growth rate, demand factor, and diversity factor.

In addition this study investigated the load profile for each category, the load distribution of appliances, and the percentage effect of each appliance on the load profile. This study will help utility companies and specially ADDC planning and operation engineers whenever they are planning for future new LV power. Investigation for the most contribution load for each customers and the respective demand factor affect the planning study for the feeding arrangements and therefore the capacity rating. Also the operation engineer can be easily investigate the main reasons for any failure substation, feeder pillar and service cabinet when related to the load profile served by those feeders.

The results from adopting TOD tariff in the residential load category illustrate the unexpected value of peak reduction for summer as well as the winter seasons. This decremented value is increased on the ongoing years. The economic benefit based on the implementation is the deferred of some primaries, while others have been cancelled. The customers who are welling to change their load pattern and distribute it well between the three periods; on-peak, off-peak and others, will like the incentives by reducing their monthly bill.

The Energy Efficiency culture illustrates the same effect or more when state the load reduction that trigger the deferred or avoidance the incremental capacity added. Moreover the customers will enjoy the reduced monthly bill caused by low consumption. The improvement load consumption is mainly derived from better utilization of the existing equipment in line with better controlling for the sensitive load like A/C and water heater.

Finally the overall results will add new dimensions to utility companies and specially ADDC to integrate the DSM into the network planning where this method can be used to restrain the incremental growth rate in the power demand.

8.2 Recommendations

8.2.1 Demand Side Management Programs in different Load Categories

ADDC can implement separate load category programs for demand side management including residential, commercial and industrial DSM programs.

8.2.1.1 Residential Programs

The program directed primarily at three areas cover the improving energy efficiency of customer appliances; improving efficiency of new and existing construction, and managing residential load.

Improving energy efficiency of customer appliances like:-

- Replacing old inefficient air conditioners with high-efficiency units
- Replacing incandescent lighting with compact fluorescent lighting
- Replacing old refrigerators and freezers with new, high-efficiency units.

Improving energy efficiency of new and existing construction like:-

- For existing construction, weatherization measures (insulation, air sealing, window treatments, etc.)
- For new construction, promoting whole house energy performance improvements (increased insulation, better windows, superior air sealing, improved heating and air conditioning distribution systems, mechanical ventilation and passive solar design and construction).

Managing Residential Load

- Home automation systems where one can determine which load can be off/dimming and at what level and when can be implemented.
- Direct control by ADDC control centre of customer air conditioners and water heaters by controlling the demand controller of the thermostats.
- Rate structures that encourage off-peak electricity consumption like Time of Day Tariff. As the results from proposal implementation of this technique, of some benefits to the utility as well as the customers as shown below.
    - Changes in load patterns where it will move to somehow flat pattern and that will reduce the energy consumptions for the customers.

- Reduce the peak load and therefore utilize the existing electrical capacity.
- Avoiding or Deferred the investment of the supplying capacity for ADDC.

8.2.1.2 Commercial Programs

There are four general categories of technology options for commercial customers can be implemented separately or both which are:

- Building envelopes like the residential energy efficiency constructions (increased insulation, better windows, superior air sealing, improved heating and air conditioning distribution systems, mechanical ventilation and passive solar design and construction). Where thermal insulation of Buildings can reduce the amount of AC Energy Consumption and consequently helps in reducing the Demand Load of any building. Its recommend that ADDC encourage the authorities, buildings owners and developers to the usage of thermal insulations as a prerequisite to reduce future investments and to meet huge growth in Buildings and Towers in Abu Dhabi for the coming years.
- Efficient equipment (e.g., lighting, motors, variable speed drives, HVAC equipment)
- Load Shedding like elevators (shutting down one out of a bank of several) or shutting down one A/C chillers out of four for a specific time and preferably to be in on-peak period.
- Load management by Time of Day Tariff for three different rates within the day as it’s discussed previously in residential program. Also there is direct load control through An Integrated Building Management System which is a single, cohesive building management system controlling lighting, HVAC, fire, security, and other facilities. Integrated Building Management Systems bring many benefits when trying to squeeze the best performance from the building. This tool can be used to reduce the load on certain times of the peak or whenever no occupation in the unit of the building. The control is through dimming or switch off the main appliances such as A/C and lights. In advance ADDC can control it by its control center by either a certain specific time or as a customer request.

8.2.1.3 Industrial Programs

Primary end use applications for industrial electricity can be grouped under four major headings:

- Motor drives and controls where high efficiency motors can be introduced to the factories.
- Process applications
- Lighting like residential and commercial programs through energy efficiency (substitute by more efficient lighting) or by load management (control on the light usage automatically)
- Electric cooling (by reducing outside air, slightly raising room temperatures, controlling the thermostat automatically.

The results of industrial DSM technology options may include:

- ✓ Reduced capital requirements
- ✓ Reduced energy consumption
- ✓ Greater control over production
- ✓ Improved product quality
- ✓ Increased production at less energy per unit produced

8.2.2 General Recommendations

- ➢ Power factor charges can be implemented to discourage commercial and industrial utility customers from partially loading their electrical equipment, also when they are not using the capacitor banks as a power factor improvement. This requires ADDC to generate extra current to cover the resulting system losses.
- ➢ Changing the timing from the summer and winter season, this mean that the working hours will shift one hour behind/ahead as the season move to either winter/summer will changed. Since in winter season, the working hours will start before the sunrise and that mean the people will switch most of their lights in the house. Shifting the time will give a chance to start the working hours on the winter after the sunrise and therefore that will reduce the energy consumption as a total and practically for the lighting loads.
- ➢ ADDC in the beginning can imply general information programmes to inform customers about DSM and energy service options through advertising media

such as brochures, bill attachments, TV and radio advertisement, and workshops.

- ADDC can offer multi scenarios to the consumers regarding the energy efficiency program and installing Automatic Meters.
  - Scenario A: Promotion only where it combines wide scale public promotion to increase energy efficiency awareness with advertising for improved insulation, an energy awareness booklet, and free auditing and advice on request. This is not including supplying and installing the Automatic Meters
  - Scenario B: Promotion plus Loan adds to scenario A, an interest free loan will be for supplying, installing and maintaining Automatic Meters.
  - Scenario C: Promotion, Loan and interest adds to scenario B, where the interest can be collected and divided in the monthly bill.

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APPENDIX A

POWER SYSTEM AND QUALITY METRICS

Table A.1
SAIFI Results for 2004&2005

Month	System-wide Service Interruptions Frequency Index (SAIFI) Monthly Interruptions/Customer	Abu Dhabi Island Service Interruptions Frequency Index (SAIFI) Monthly Interruptions/Customer	Eastern Service Interruptions Frequency Index (SAIFI) Monthly Interruptions/Customer	Western Service Interruptions Frequency Index (SAIFI) Monthly Interruptions/Customer
Jan-04	1.26	0.45	3.05	2.67
Feb-04	1.24	0.44	2.97	2.7
Mar-04	1.23	0.45	2.91	2.64
Apr-04	1.16	0.43	2.81	2.23
May-04	1.14	0.42	2.74	2.24
Jun-04	1.08	0.41	2.52	2.23
Jul-04	1.01	0.4	2.28	2.22
Aug-04	0.97	0.39	2.08	2.24
Sep-04	0.98	0.41	2.07	2.25
Oct-04	1.02	0.42	2.12	2.4
Nov-04	1.01	0.4	2.06	2.65
Dec-04	1.07	0.4	2.13	3.05
Jan-05	1.09	0.39	2.09	3.41
Feb-05	1.08	0.37	2.07	3.52
Mar-05	1.07	0.34	1.99	3.8
Apr-05	1.1	0.33	1.98	4.16
May-05	1.13	0.35	1.91	4.43
Jun-05	1.18	0.39	1.99	4.45
Jul-05	1.2	0.41	2.1	4.34
Aug-05	1.22	0.41	2.17	4.25
Sep-05	1.21	0.39	2.17	4.24
Oct-05	1.19	0.4	2.1	4.18
Nov-05	1.19	0.43	2.1	3.94
Dec-05	1.18	0.44	2.15	3.66

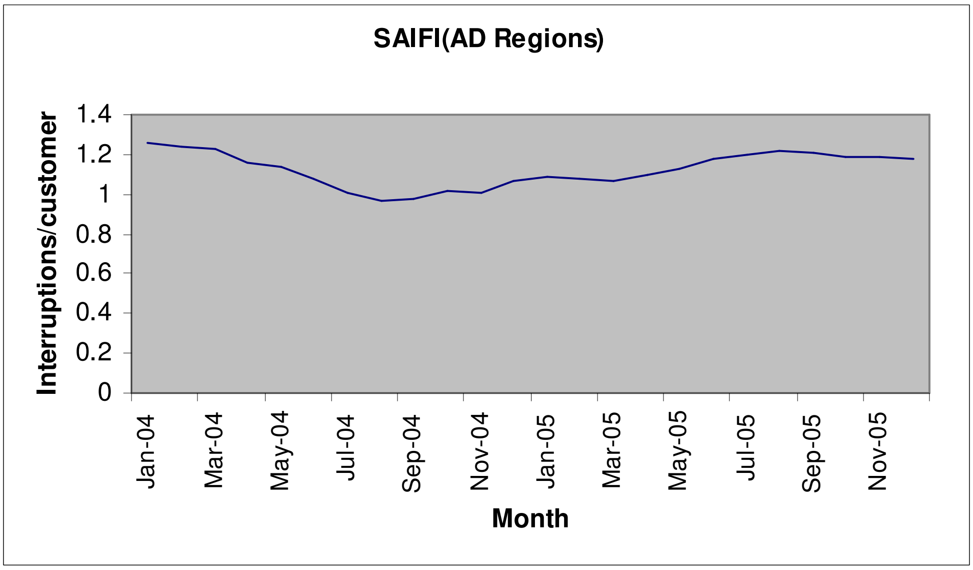


Fig. A.1 SAIFI in AD

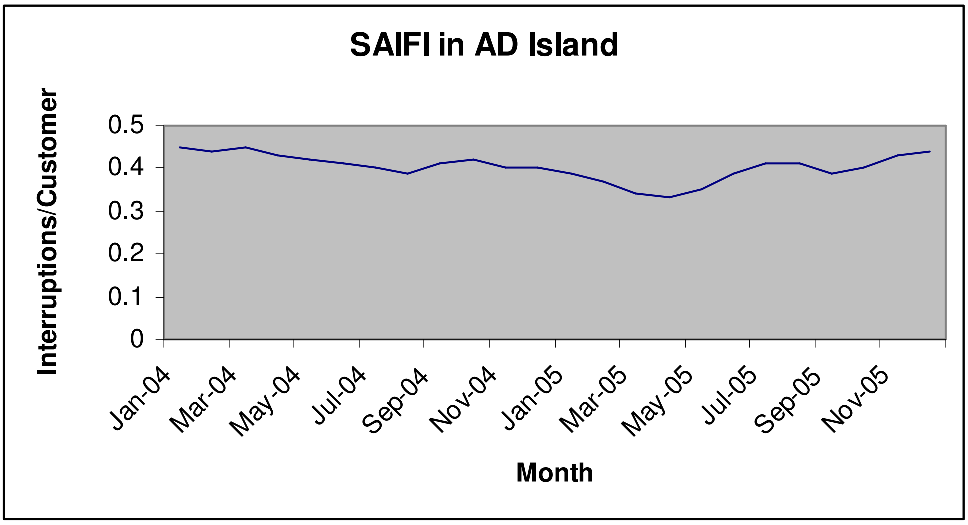


Fig. A.2 SAIFI in AD Island

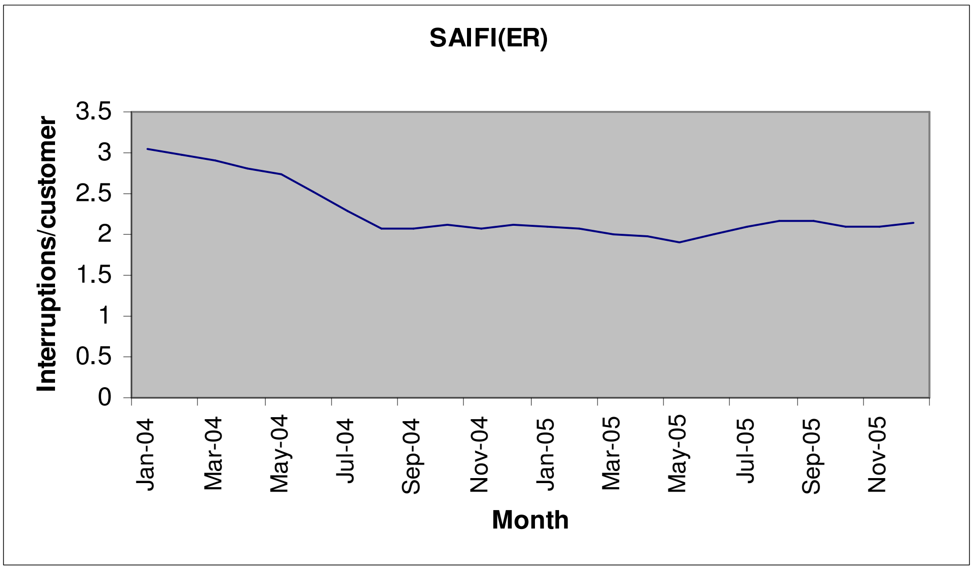


Fig. A.3 SAIFI in ER

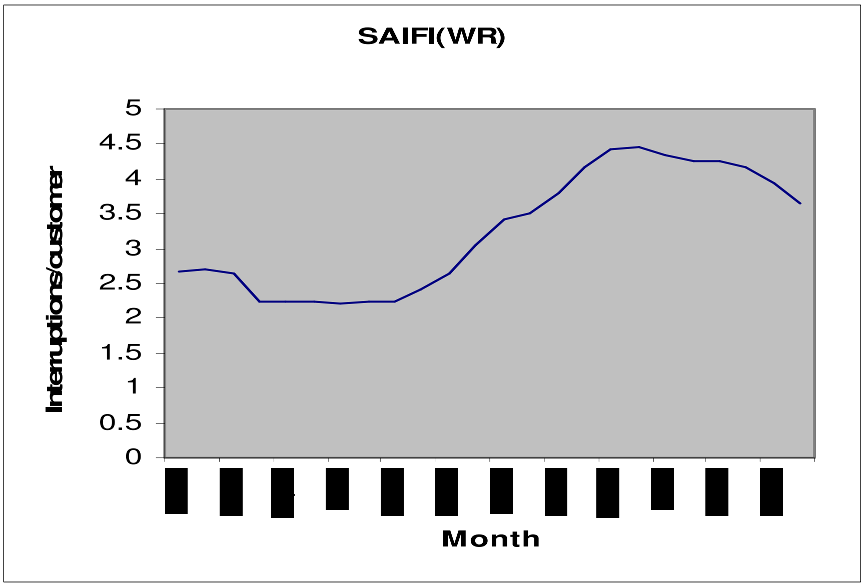


Fig. A.4 SAIFI in WR

Table A.2
SAIDI Results for 2004&2005

Month	Abu Dhabi Island Service Interruptions Duration Index (SAIDI) Monthly Minutes/Customer	Eastern Service Interruptions Duration Index (SAIDI) Monthly Minutes/Customer	Western Service Interruptions Duration Index (SAIDI) Monthly Minutes/Customer	System-wide Service Interruptions Duration Index (SAIDI) Monthly Minutes/Customer
Jan-04	26.2	290	347.6	117.91
Feb-04	30	280.2	347.8	118.4
Mar-04	37.1	268.4	330.9	119
Apr-04	40.2	256.4	246.9	110.38
May-04	43.1	263.1	244.1	113.8
Jun-04	45.6	253.8	243.9	113.41
Jul-04	45.8	232.6	241.8	108.58
Aug-04	46	225.7	233.6	106.46
Sep-04	47.8	235.4	233.8	110.15
Oct-04	53.4	250.9	246.6	118.93
Nov-04	53.9	248.5	263.7	120.47
Dec-04	55.4	244.6	325.5	126.65
Jan-05	51.5	235.6	395.1	128.88
Feb-05	47.8	236	409.3	128.08
Mar-05	41.5	230.3	448	126.49
Apr-05	39.4	224	481.6	127.08
May-05	37.7	209.8	490.1	123.59
Jun-05	37.8	202.9	492.1	122.37
Jul-05	38.4	206.5	479.4	122.65
Aug-05	37.8	210	465.9	122.02
Sep-05	37.4	203.3	463.5	120.04
Oct-05	36.1	184.2	453.1	113.59
Nov-05	39.5	180.1	432.8	112.99
Dec-05	42.2	175.7	374.8	108.16

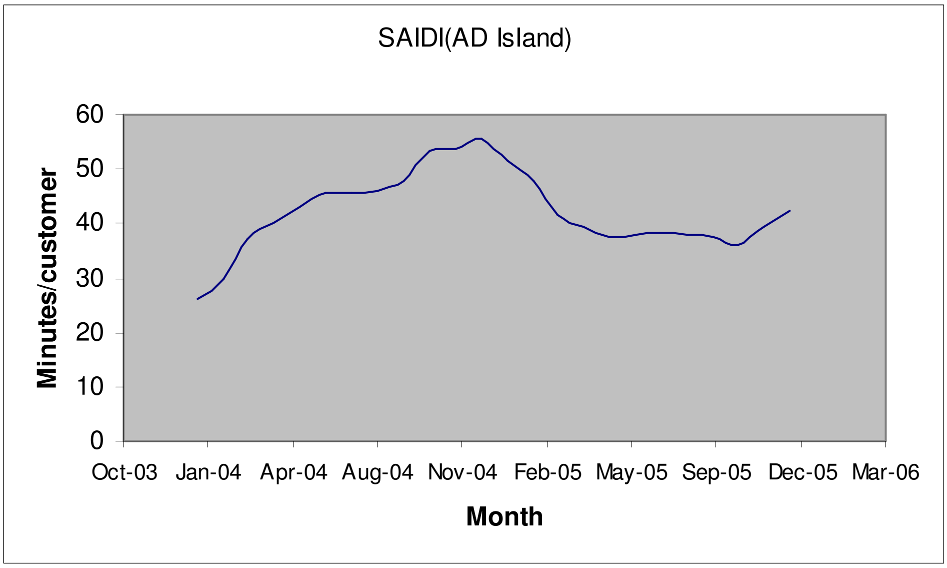


Fig. A.5 SAIDI in AD Island

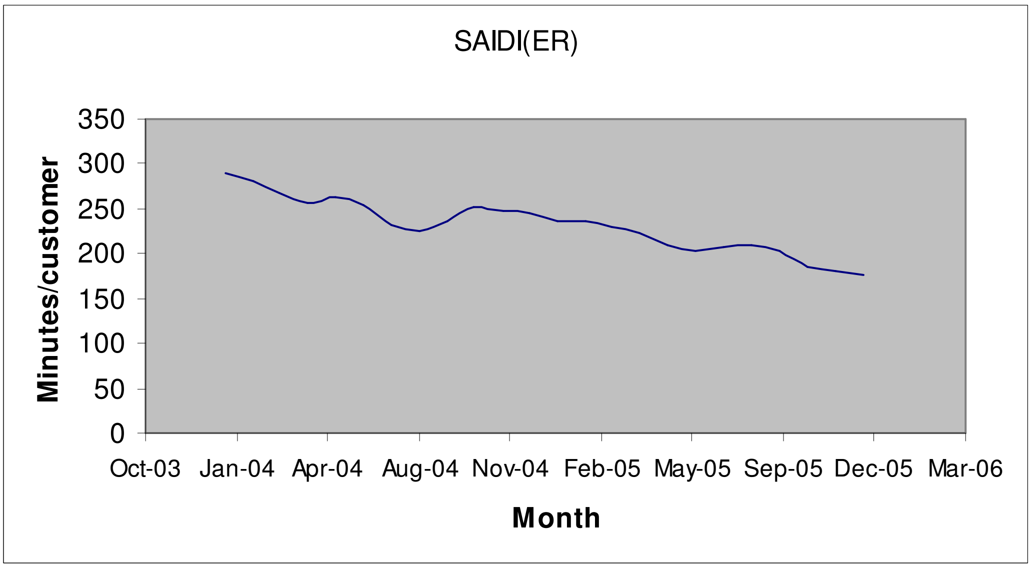


Fig. A.6 SAIDI in ER

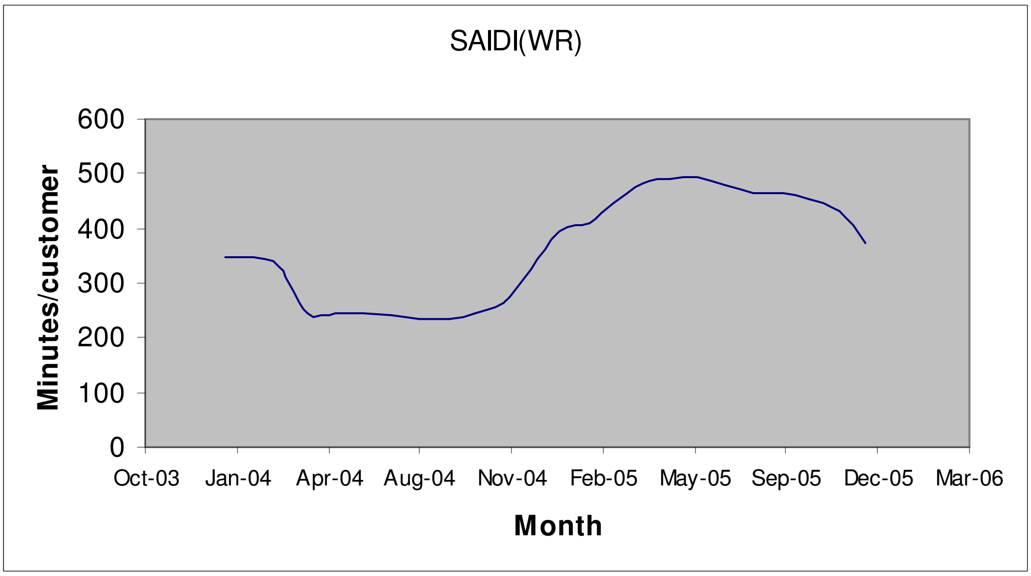


Fig. A.7 SAIDI in WR

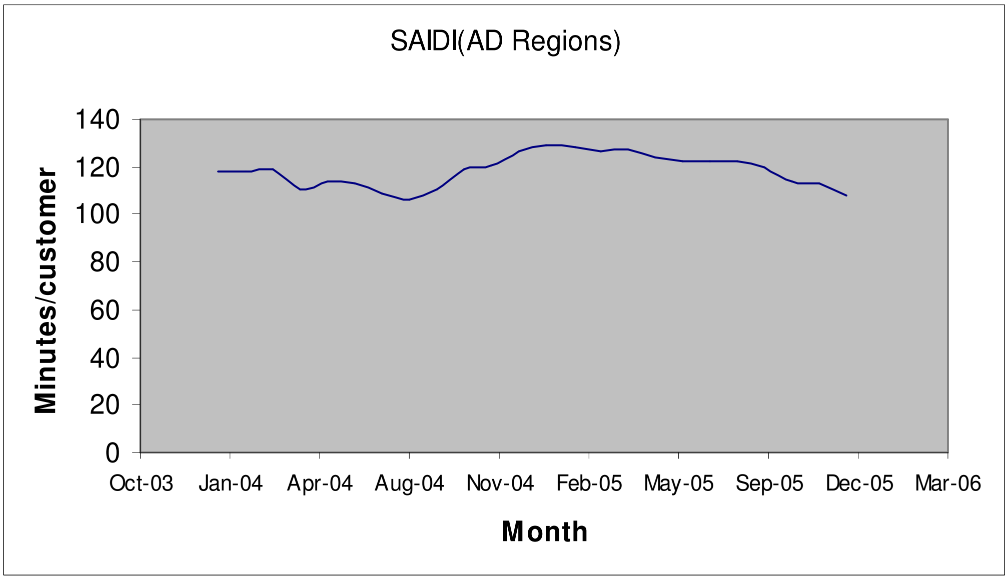


Fig. A.8 SAIDI in AD

Table A.3
Primary Utilization Report

Month	Abu Dhabi Island Primary Transformer Utilization Monthly	Eastern Primary Transformer Utilization Monthly	Western Primary Transformer Utilization Monthly	System-wide Primary Transformer Utilization Monthly
Jan-04	28.09	18.91	27.93	24.47
Feb-04	26.98	16.69	28.6	23.16
Mar-04	34.5	23.62	32.75	30
Apr-04	39.8	28.98	30.71	34.33
May-04	49.13	36.2	32.01	41.74
Jun-04	50.95	37.52	33.85	43.37
Jul-04	55.55	41.77	39.14	47.92
Aug-04	55.89	40.58	36.49	47.26
Sep-04	54.48	39.2	38.34	46.3
Oct-04	49.24	37.12	31.69	42.11
Nov-04	37.57	22.34	30.27	30.12
Dec-04	31.95	19.41	23.12	25.46
Jan-05	26.65	17.47	25.75	22.61
Feb-05	29.08	18.19	22.09	23.53
Mar-05	33.53	21.91	26.52	27.67
Apr-05	41.71	28.56	30.73	34.68
May-05	49.11	32.47	34.62	40.14
Jun-05	52.71	34.26	35.7	42.64
Jul-05	53.61	36.75	42.13	45.08
Aug-05	53.18	36.3	36.35	43.93
Sep-05	53.73	36.4	35.77	44.14
Oct-05	48.13	32.59	31.88	39.51
Nov-05	40.11	25.41	28.88	32.5
Dec-05	30.93	20.55	24.26	25.72

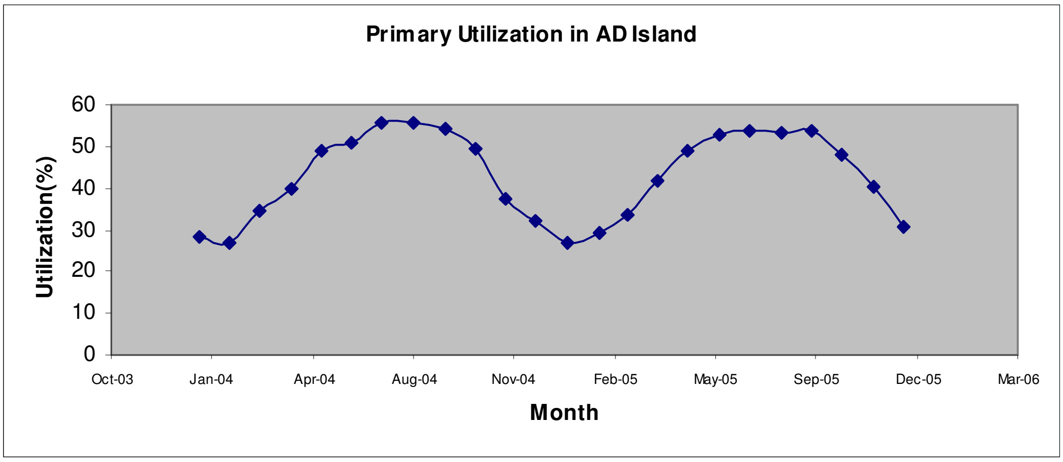


Fig. A.9 Primary utilization in AD Island

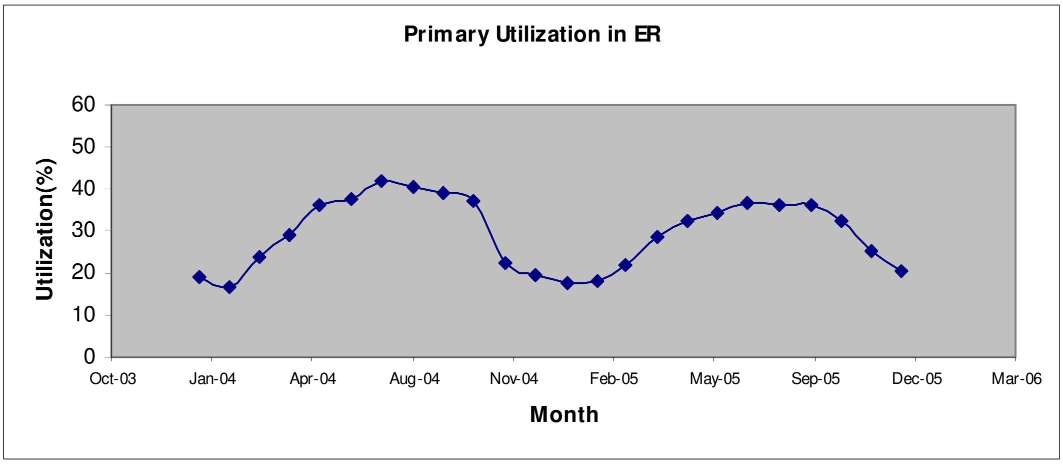


Fig. A10 Primary utilization in ER

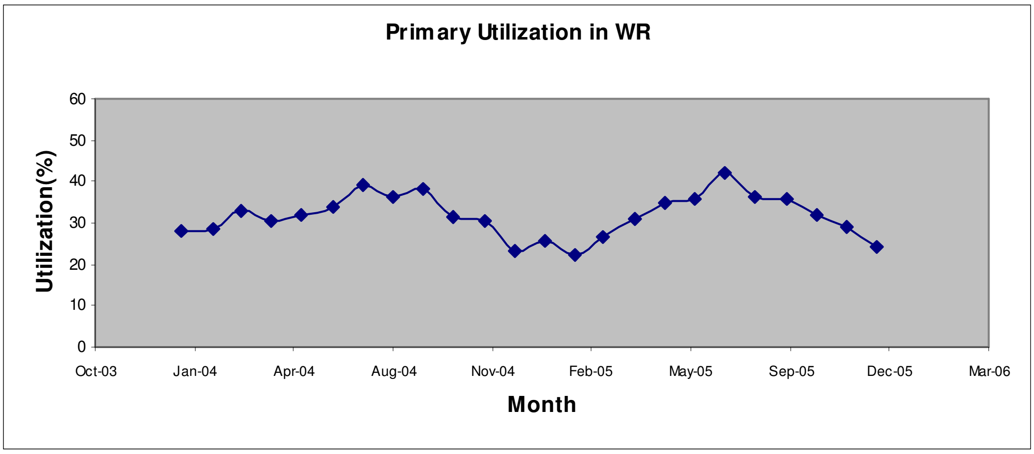


Fig. A.11 Primary utilization in WR

Table A.4
Distribution Transformer Utilization

Month	ADDC System-wide Distribution Transformer Utilization Monthly %	ADDC Abu Dhabi Island Distribution Transformer Utilization Monthly %	ADDC Eastern Distribution Transformer Utilization Monthly %	ADDC Western Distribution Transformer Utilization Monthly %
Jan-04	17.25	18.37	13.91	23.25
Feb-04	16.33	17.64	12.28	23.81
Mar-04	21.15	22.56	17.38	27.26
Apr-04	24.21	26.03	21.32	25.56
May-04	29.43	32.13	26.63	26.65
Jun-04	30.58	33.32	27.6	28.18
Jul-04	33.7	36.14	30.73	32.58
Aug-04	33.14	36.16	29.85	30.37
Sep-04	31.9	35.06	28.36	29.57
Oct-04	28.58	31.69	26.43	22.76
Nov-04	21.42	24.07	18.28	20.35
Dec-04	17.83	20.37	15.7	14.61
Jan-05	15.45	16.82	13.74	15.3
Feb-05	15.77	17.72	14.29	12.95
Mar-05	17.21	20.35	14.84	13.91
Apr-05	21.37	25.23	19.25	15.48
May-05	24.62	29.64	21.7	17.43
Jun-05	25.89	31.63	22.53	17.78
Jul-05	27.7	33.41	23.94	20.83
Aug-05	26.74	33.03	23.48	17.61
Sep-05	26.41	33.19	22.68	17.33
Oct-05	23.48	29.56	20.26	15.1
Nov-05	18.93	24.52	15.11	13.68
Dec-05	14.87	18.89	12.17	11.12
Max	**33.7**	**36.16**	**30.73**	**32.58**
Min	**14.87**	**16.82**	**12.17**	**11.12**
Avg	**23.5**	**26.98**	**20.52**	**20.56**

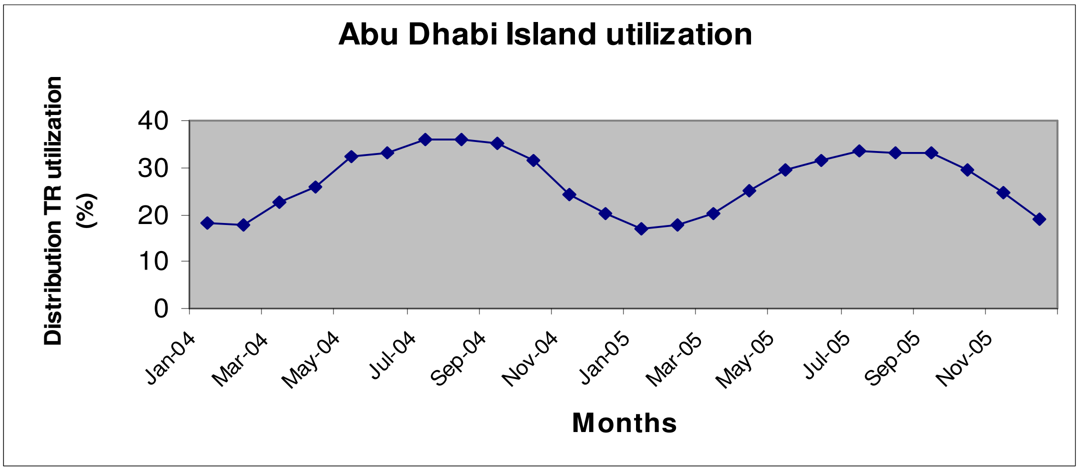


Fig. A12 Distribution TR utilization in AD Island

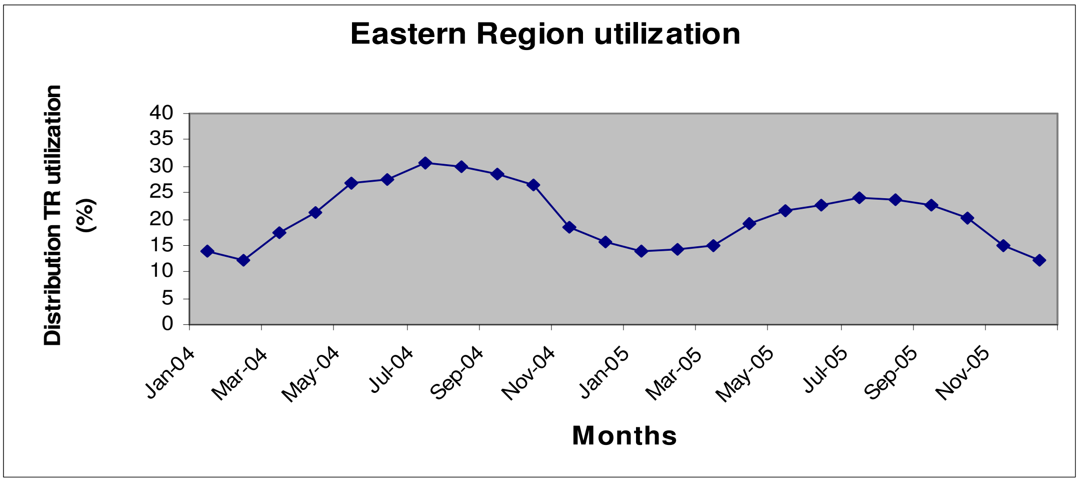


Fig. A13 Distribution TR utilization in ER

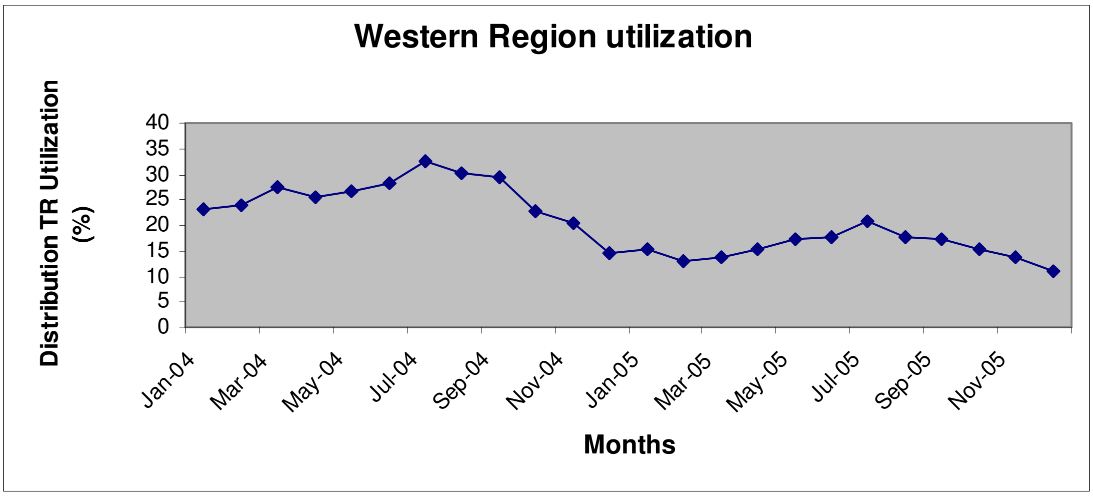


Fig. A14 Distribution TR utilization in WR

Table A.5
Feeder Utilization

Month	ADDC System-wide 11 kV Feeders Utilization Monthly %	ADDC Abu Dhabi Island 11 kV Feeders Utilization Monthly %	ADDC Eastern 11 kV Feeders Utilization Monthly %	ADDC Western 11 kV Feeders Utilization Monthly %
Jan-04	24.91	25.5	20	41.3
Feb-04	23.58	24.5	17.6	42.3
Mar-04	30.11	31.4	25	42
Apr-04	34.45	36.2	30.6	39.4
May-04	41.31	44.6	38.3	36.2
Jun-04	42.92	46.3	39.7	38.3
Jul-04	47.43	50.5	44.2	44.3
Aug-04	45.51	50.8	42.9	33.5
Sep-04	44.58	49.5	41.4	35.2
Oct-04	39.91	43.9	38.6	29.1
Nov-04	29.87	32.9	26.5	27.8
Dec-04	24.87	27.4	22.6	21.2
Jan-05	21.68	22.5	20.1	22.8
Feb-05	21.38	24.6	19	17.1
Mar-05	25.11	28.3	22.8	20.5
Apr-05	31.4	35.2	29.6	23.8
May-05	36.12	40.9	33.7	26.7
Jun-05	37.02	42	34.4	27.1
Jul-05	39.73	44.4	36.9	31.4
Aug-05	38.44	43.8	35.5	28.4
Sep-05	38.27	44.2	34.9	27.8
Oct-05	34.01	39.3	31.2	24.2
Nov-05	27.72	32.7	23.7	21.9
Dec-05	21.87	25.1	19.2	18.3
Count	**24**	**24**	**24**	**24**
Maximum	**47.43**	**50.8**	**44.2**	**44.3**
Minimum	**21.38**	**22.5**	**17.6**	**17.1**
Average	**33.43**	**36.9**	**30.4**	**30**
Total	**802.2**	**886.5**	**728.4**	**720.6**

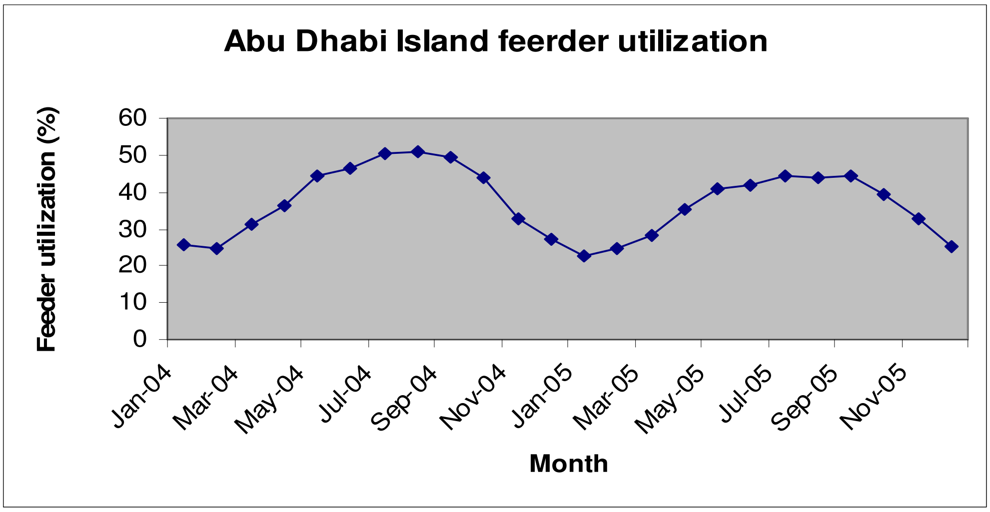


Fig. A15 Feeder Utilization in AD Island

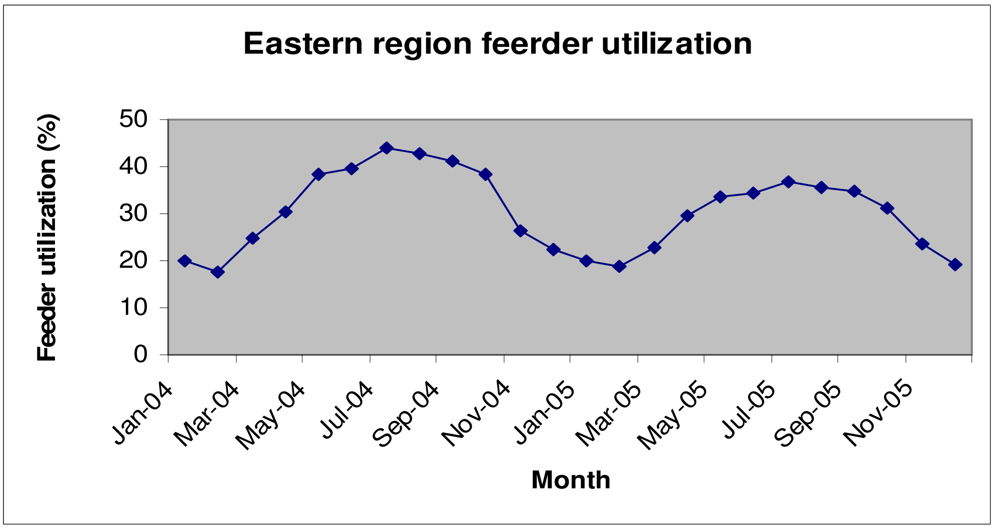


Fig. A16 Feeder Utilization in ER

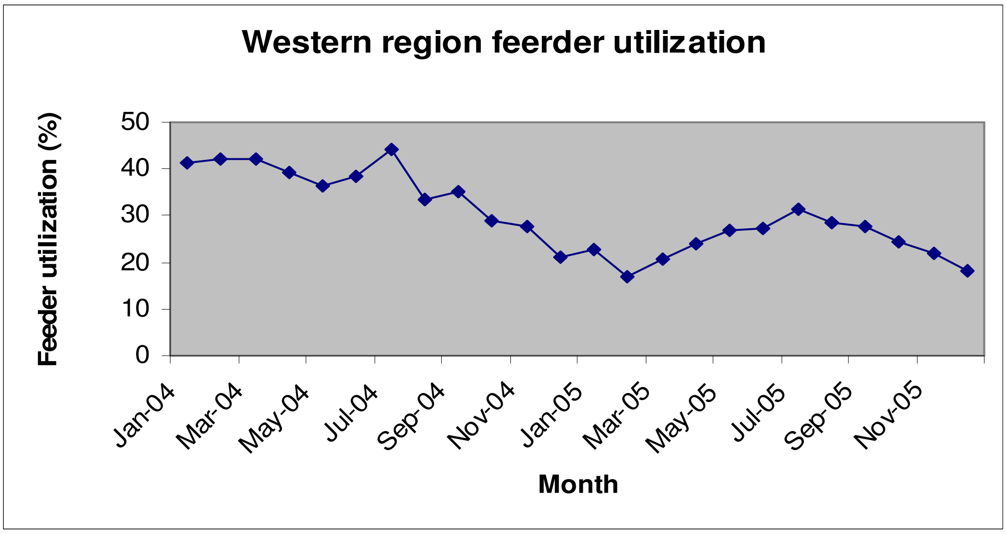


Fig. A17 Feeder Utilization in WR

APPENDIX B

LOAD FORECAST DATA

Table B.1
Connected load by category (2002-2005)

Category	2002	Percentage	2003	Percentage	2004	Percentage	2005	Percentage	Average load	Average Percentage
Residential	144	29.71%	156.83	37.49%	313.3	54.25%	284.87	46.31%	224.75	41.94%
Commercial	139.048	28.69%	138.63	33.14%	115.88	20.06%	123.05	20.00%	129.152	25.47%
Agricultural	9.77	2.02%	15.87	3.79%	11.96	2.07%	14.81	2.41%	13.1025	2.57%
Industrial	42.982	8.87%	41.58	9.94%	56.36	9.76%	60.54	9.84%	50.3655	9.60%
Other load	148.81	30.71%	65.46	15.65%	80.04	13.86%	131.89	21.44%	106.55	20.41%
Connected load (MW)	**484.61**	100.00%	**418.37**	100.00%	**577.54**	100.00%	**615.16**	100.00%	**523.92**	100.00%

Table B.2
Load Forecast by categories

Year	Total Connected load (MW)	Total Demand load(MW)	Residential connected load(MW)	Residential demand load(MW)	Commercial Connected load(MW)	Commercial demand load(MW)	Industrial Connected load(MW)	Industrial demand load(MW)	Agricultural Connected load(MW)	Agricultural demand load(MW)	Others Connected load(MW)	Other demand load(MW)
1983	500	260	210	94	127	83	48	38	13	4	102	41
1984	712	370	299	134	181	118	68	55	18	5	145	58
1985	858	446	360	162	218	142	82	66	22	7	175	70
1986	979	509	411	185	249	162	94	75	25	8	200	80
1987	1076	559	451	203	274	178	103	83	28	8	220	88
1988	1179	613	494	222	300	195	113	91	30	9	241	96
1989	1288	670	540	243	328	213	124	99	33	10	263	105
1990	1548	805	649	292	394	256	149	119	40	12	316	126
1991	1724	897	723	325	439	285	166	132	44	13	352	141
1992	2076	1079	871	392	529	344	199	159	53	16	424	169
1993	2397	1246	1005	452	611	397	230	184	62	18	489	196
1994	2761	1436	1158	521	703	457	265	212	71	21	563	225
1995	3367	1751	1412	635	857	557	323	259	87	26	687	275
1996	3997	2078	1676	754	1018	662	384	307	103	31	816	326
1997	4573	2378	1918	863	1165	757	439	351	118	35	933	373
1998	5148	2677	2159	972	1311	852	494	395	132	40	1051	420
1999	5579	2901	2340	1053	1421	924	536	428	143	43	1139	455
2000	6033	3137	2530	1139	1537	999	579	463	155	47	1231	493
2001	6518	3389	2734	1230	1660	1079	626	501	168	50	1330	532
2002	7003	3642	2937	1322	1784	1159	672	538	180	54	1429	572
2003	7421	3859	3113	1401	1890	1229	712	570	191	57	1515	606
2004	7999	4159	3355	1510	2037	1324	768	614	206	62	1633	653
2005	8614	4479	3613	1626	2194	1426	827	662	221	66	1758	703
2006	9115	4740	3823	1720	2322	1509	875	700	234	70	1860	744

(table continues)

Year	Total Connected load(MW)	Total Demand load(MW)	Residential connected load(MW)	Residential demand load(MW)	Commercial Connected load(MW)	Commercial demand load(MW)	Industrial Connected load(MW)	Industrial demand load(MW)	Agricultural Connected load(MW)	Agricultural demand load(MW)	Others Connected load(MW)	Other demand load(MW)
2007	9646	5016	4046	1820	2457	1597	926	741	248	74	1969	787
2008	10207	5308	4281	1926	2600	1690	980	784	262	79	2083	833
2009	11098	5771	4655	2095	2827	1837	1065	852	285	86	2265	906
2010	12067	6275	5061	2277	3074	1998	1158	927	310	93	2463	985
2011	13121	6823	5503	2476	3342	2172	1260	1008	337	101	2678	1071
2012	14266	7418	5983	2692	3634	2362	1370	1096	367	110	2912	1165
2013	15512	8066	6506	2928	3951	2568	1489	1191	399	120	3166	1266
2014	16866	8770	7074	3183	4296	2792	1619	1295	433	130	3442	1377
2015	18338	9536	7691	3461	4671	3036	1760	1408	471	141	3743	1497
2016	19939	10368	8363	3763	5079	3301	1914	1531	512	154	4070	1628
2017	21680	11274	9093	4092	5522	3589	2081	1665	557	167	4425	1770
2018	23573	12258	9886	4449	6004	3903	2263	1810	606	182	4811	1924
2019	25630	13328	10749	4837	6528	4243	2461	1968	659	198	5231	2092
2020	27868	14491	11688	5260	7098	4614	2675	2140	716	215	5688	2275

Sensitivity Analysis

The sensitivity analysis, assumed to have low growth rate (25% less from the base) and high growth rate (25% from the base)

Scenario 1	(2006-2008)	(2009-2020)
Low	3%	5%
Base	4%	6%
High	5%	8%

Table B.3
Demand load for the base load growth

Year	Total Demand load(MW)	Residential demand load(MW)	Commercial demand load (MW)	Industrial demand load (MW)	Agricultural demand load (MW)	Other demand load (MW)
1983	260	94	83	38	4	41
1984	370	134	118	55	5	58
1985	446	162	142	66	7	70
1986	509	185	162	75	8	80
1987	559	203	178	83	8	88
1988	613	222	195	91	9	96
1989	670	243	213	99	10	105
1990	805	292	256	119	12	126
1991	897	325	285	132	13	141
1992	1079	392	344	159	16	169
1993	1246	452	397	184	18	196
1994	1436	521	457	212	21	225
1995	1751	635	557	259	26	275
1996	2078	754	662	307	31	326
1997	2378	863	757	351	35	373
1998	2677	972	852	395	40	420
1999	2901	1053	924	428	43	455
2000	3137	1139	999	463	47	493
2001	3389	1230	1079	501	50	532
2002	3642	1322	1159	538	54	572
2003	3859	1401	1229	570	57	606
2004	4159	1510	1324	614	62	653
2005	4479	1626	1426	662	66	703
2006	4653	1689	1481	687	69	731
2007	4834	1754	1539	714	72	759
2008	5021	1822	1599	742	74	788
2009	5313	1928	1692	785	79	834
2010	5623	2041	1790	830	83	883
2011	5950	2159	1894	879	88	934
2012	6296	2285	2005	930	93	989
2013	6663	2418	2121	984	99	1046
2014	7050	2559	2245	1041	105	1107
2015	7461	2708	2375	1102	111	1171
2016	7895	2865	2514	1166	117	1240
2017	8354	3032	2660	1234	124	1312
2018	8841	3209	2815	1306	131	1388
2019	9355	3395	2978	1382	139	1469
2020	9900	3593	3152	1462	147	1554

Table B.4
Demand load for low growth rate in scenario 1

Year	Demand load (MW)	Residential demand load (MW)	Commercial demand load (MW)	Industrial demand load (MW)	Agricultural demand load (MW)	Other demand load (MW)
1983	260	94	83	38	4	41
1984	370	134	118	55	5	58
1985	446	162	142	66	7	70
1986	509	185	162	75	8	80
1987	559	203	178	83	8	88
1988	613	222	195	91	9	96
1989	670	243	213	99	10	105
1990	805	292	256	119	12	126
1991	897	325	285	132	13	141
1992	1079	392	344	159	16	169
1993	1246	452	397	184	18	196
1994	1436	521	457	212	21	225
1995	1751	635	557	259	26	275
1996	2078	754	662	307	31	326
1997	2378	863	757	351	35	373
1998	2677	972	852	395	40	420
1999	2901	1053	924	428	43	455
2000	3137	1139	999	463	47	493
2001	3389	1230	1079	501	50	532
2002	3642	1322	1159	538	54	572
2003	3859	1401	1229	570	57	606
2004	4159	1510	1324	614	62	653
2005	4479	1626	1426	662	66	703
2006	4610	1673	1468	681	68	724
2007	4744	1722	1510	701	70	745
2008	4882	1772	1554	721	72	766
2009	5119	1858	1630	756	76	804
2010	5367	1948	1709	793	80	843
2011	5627	2042	1792	831	83	883
2012	5900	2141	1878	871	87	926
2013	6186	2245	1970	914	92	971
2014	6486	2354	2065	958	96	1018
2015	6801	2468	2165	1004	101	1068
2016	7131	2588	2270	1053	106	1120
2017	7477	2714	2380	1104	111	1174
2018	7839	2845	2496	1158	116	1231
2019	8219	2983	2617	1214	122	1290
2020	8618	3128	2744	1273	128	1353

Table B.5
Demand load for high growth rate in scenario1

Year	Demand load (MW)	Residential demand load(MW)	Commercial demand load(MW)	Industrial demand load(MW)	Agricultural demand load(MW)	Other demand load(MW)
1983	260	94	83	38	4	41
1984	370	134	118	55	5	58
1985	446	162	142	66	7	70
1986	509	185	162	75	8	80
1987	559	203	178	83	8	88
1988	613	222	195	91	9	96
1989	670	243	213	99	10	105
1990	805	292	256	119	12	126
1991	897	325	285	132	13	141
1992	1079	392	344	159	16	169
1993	1246	452	397	184	18	196
1994	1436	521	457	212	21	225
1995	1751	635	557	259	26	275
1996	2078	754	662	307	31	326
1997	2378	863	757	351	35	373
1998	2677	972	852	395	40	420
1999	2901	1053	924	428	43	455
2000	3137	1139	999	463	47	493
2001	3389	1230	1079	501	50	532
2002	3642	1322	1159	538	54	572
2003	3859	1401	1229	570	57	606
2004	4159	1510	1324	614	62	653
2005	4479	1626	1426	662	66	703
2006	4697	1705	1495	694	70	737
2007	4924	1787	1568	727	73	773
2008	5163	1874	1644	763	77	811
2009	5564	2019	1771	822	82	874
2010	5996	2176	1909	886	89	941
2011	6461	2345	2057	954	96	1014
2012	6962	2527	2217	1028	103	1093
2013	7503	2723	2389	1108	111	1178
2014	8085	2934	2574	1194	120	1269
2015	8712	3162	2774	1287	129	1368
2016	9388	3407	2989	1387	139	1474
2017	10117	3672	3221	1494	150	1588
2018	10902	3957	3471	1610	162	1712
2019	11748	4264	3740	1735	174	1844
2020	12659	4595	4030	1870	188	1988

Scenario 2 (2006-2008)		2009-2020
Low	2%	3%
Base	4%	6%
High	6%	9%

Table B.6
Demand load for low growth rate in scenario 2

Year	Demand load (MW)	Residential demand load(MW)	Commercial demand load(MW)	Industrial demand load(MW)	Agricultural demand load(MW)	Other demand load(MW)
1983	260	94	83	38	4	41
1984	370	134	118	55	5	58
1985	446	162	142	66	7	70
1986	509	185	162	75	8	80
1987	559	203	178	83	8	88
1988	613	222	195	91	9	96
1989	670	243	213	99	10	105
1990	805	292	256	119	12	126
1991	897	325	285	132	13	141
1992	1079	392	344	159	16	169
1993	1246	452	397	184	18	196
1994	1436	521	457	212	21	225
1995	1751	635	557	259	26	275
1996	2078	754	662	307	31	326
1997	2378	863	757	351	35	373
1998	2677	972	852	395	40	420
1999	2901	1053	924	428	43	455
2000	3137	1139	999	463	47	493
2001	3389	1230	1079	501	50	532
2002	3642	1322	1159	538	54	572
2003	3859	1401	1229	570	57	606
2004	4159	1510	1324	614	62	653
2005	4479	1626	1426	662	66	703
2006	4566	1657	1454	674	68	717
2007	4655	1689	1482	687	69	731
2008	4745	1722	1511	701	70	745
2009	4883	1772	1555	721	72	767
2010	5025	1824	1600	742	75	789
2011	5172	1877	1646	764	77	812
2012	5322	1932	1694	786	79	836
2013	5477	1988	1744	809	81	860
2014	5636	2046	1794	832	84	885
2015	5800	2105	1847	857	86	911
2016	5969	2166	1900	882	89	937
2017	6143	2229	1956	907	91	964
2018	6322	2294	2013	934	94	992
2019	6505	2361	2071	961	96	1021
2020	6695	2430	2131	989	99	1051

Table B.7
Demand load for high growth rate in Scenario 2

Year	Total Demand load(MW)	Residential demand load(MW)	Commercial demand load(MW)	Industrial demand load(MW)	Agricultural demand load(MW)	Other demand load(MW)
1983	260	94	83	38	4	41
1984	370	134	118	55	5	58
1985	446	162	142	66	7	70
1986	509	185	162	75	8	80
1987	559	203	178	83	8	88
1988	613	222	195	91	9	96
1989	670	243	213	99	10	105
1990	805	292	256	119	12	126
1991	897	325	285	132	13	141
1992	1079	392	344	159	16	169
1993	1246	452	397	184	18	196
1994	1436	521	457	212	21	225
1995	1751	635	557	259	26	275
1996	2078	754	662	307	31	326
1997	2378	863	757	351	35	373
1998	2677	972	852	395	40	420
1999	2901	1053	924	428	43	455
2000	3137	1139	999	463	47	493
2001	3389	1230	1079	501	50	532
2002	3642	1322	1159	538	54	572
2003	3859	1401	1229	570	57	606
2004	4159	1510	1324	614	62	653
2005	4479	1626	1426	662	66	703
2006	4740	1720	1509	700	70	744
2007	5016	1820	1597	741	74	787
2008	5308	1926	1690	784	79	833
2009	5771	2095	1837	852	86	906
2010	6275	2277	1998	927	93	985
2011	6823	2476	2172	1008	101	1071
2012	7418	2692	2362	1096	110	1165
2013	8066	2928	2568	1191	120	1266
2014	8770	3183	2792	1295	130	1377
2015	9536	3461	3036	1408	141	1497
2016	10368	3763	3301	1531	154	1628
2017	11274	4092	3589	1665	167	1770
2018	12258	4449	3903	1810	182	1924
2019	13328	4837	4243	1968	198	2092
2020	14491	5260	4614	2140	215	2275

APPENDIX C

HOURLY LOAD DATA FROM DMS (STLF)

CORICH HOSPITAL PRIMARY FEEDER (B13)

Date: 23/12/2005

Time	Name	P (MW)	
12:00 AM	CHPPRY	0.89	act
1:00 AM	CHPPRY	0.89	act
2:00 AM	CHPPRY	0.87	act
3:00 AM	CHPPRY	0.83	act
4:00 AM	CHPPRY	0.83	act
5:00 AM	CHPPRY	0.78	act
6:00 AM	CHPPRY	0.71	act
7:00 AM	CHPPRY	0.7	act
8:00 AM	CHPPRY	0.68	act
9:00 AM	CHPPRY	0.74	act
10:00 AM	CHPPRY	0.75	act
11:00 AM	CHPPRY	0.75	act
12:00 PM	CHPPRY	0.82	act
1:00 PM	CHPPRY	0.82	act
2:00 PM	CHPPRY	0.86	act
3:00 PM	CHPPRY	0.92	act
4:00 PM	CHPPRY	0.87	act
5:00 PM	CHPPRY	0.85	act
6:00 PM	CHPPRY	0.82	act
7:00 PM	CHPPRY	0.85	act
8:00 PM	CHPPRY	0.85	act
9:00 PM	CHPPRY	0.84	act
10:00 PM	CHPPRY	0.86	act
11:00 PM	CHPPRY	0.92	act

Date: 24/12/2005

Time	Name	P(MW)	
12:00 AM	CHPPRY	0.9	act
1:00 AM	CHPPRY	0.88	act
2:00 AM	CHPPRY	0.87	act
3:00 AM	CHPPRY	0.8	act
4:00 AM	CHPPRY	0.78	act
5:00 AM	CHPPRY	0.75	act
6:00 AM	CHPPRY	0.69	act
7:00 AM	CHPPRY	0.72	act
8:00 AM	CHPPRY	0.71	act
9:00 AM	CHPPRY	0.68	act
10:00 AM	CHPPRY	0.7	act
11:00 AM	CHPPRY	0.68	act
12:00 PM	CHPPRY	0.77	act
1:00 PM	CHPPRY	0.77	act
2:00 PM	CHPPRY	0.75	act
3:00 PM	CHPPRY	0.82	act
4:00 PM	CHPPRY	0.81	act
5:00 PM	CHPPRY	0.81	act
6:00 PM	CHPPRY	0.85	act
7:00 PM	CHPPRY	0.9	act
8:00 PM	CHPPRY	0.91	act
9:00 PM	CHPPRY	0.91	act
10:00 PM	CHPPRY	0.94	act
11:00 PM	CHPPRY	0.94	act

Date: 25/12/2005

Time	Name	P(MW)	
12:00 AM	CHPPRY	0.91	act
1:00 AM	CHPPRY	0.86	act
2:00 AM	CHPPRY	0.83	act
3:00 AM	CHPPRY	0.8	act
4:00 AM	CHPPRY	0.8	act
5:00 AM	CHPPRY	0.81	act
6:00 AM	CHPPRY	0.74	act
7:00 AM	CHPPRY	0.74	act
8:00 AM	CHPPRY	0.68	act
9:00 AM	CHPPRY	0	no
10:00 AM	CHPPRY	0.62	act
11:00 AM	CHPPRY	0.75	act
12:00 PM	CHPPRY	0.75	act
1:00 PM	CHPPRY	0.76	act
2:00 PM	CHPPRY	0.77	act
3:00 PM	CHPPRY	0.84	act
4:00 PM	CHPPRY	0.8	act
5:00 PM	CHPPRY	0.8	act
6:00 PM	CHPPRY	0.84	act
7:00 PM	CHPPRY	0.85	act
8:00 PM	CHPPRY	0.9	act
9:00 PM	CHPPRY	0.91	act
10:00 PM	CHPPRY	0.9	act
11:00 PM	CHPPRY	0.92	act

SADYAT PRIMARY FEEDER (B09) LOAD PROFILE

Date: 23/12/2005

Time	Name	P(MW)	
12:00 AM	SDTPRY	0.16	act
1:00 AM	SDTPRY	0.15	act
2:00 AM	SDTPRY	0.15	act
3:00 AM	SDTPRY	0.15	act
4:00 AM	SDTPRY	0.15	act
5:00 AM	SDTPRY	0.15	act
6:00 AM	SDTPRY	0.16	act
7:00 AM	SDTPRY	0.16	act
8:00 AM	SDTPRY	0.15	act
9:00 AM	SDTPRY	0.15	act
10:00 AM	SDTPRY	0.15	act
11:00 AM	SDTPRY	0.15	act
12:00 PM	SDTPRY	0.15	act
1:00 PM	SDTPRY	0.15	act
2:00 PM	SDTPRY	0.15	act
3:00 PM	SDTPRY	0.15	act
4:00 PM	SDTPRY	0.15	act
5:00 PM	SDTPRY	0.15	act
6:00 PM	SDTPRY	0.15	act
7:00 PM	SDTPRY	0.15	act
8:00 PM	SDTPRY	0.15	act
9:00 PM	SDTPRY	0.16	act
10:00 PM	SDTPRY	0.15	act
11:00 PM	SDTPRY	0.15	act

Date: 24/12/2005

Time	Name	P(MW)
12:00 AM	SDTPRY	0.15
1:00 AM	SDTPRY	0.16
2:00 AM	SDTPRY	0.15
3:00 AM	SDTPRY	0.15
4:00 AM	SDTPRY	0.15
5:00 AM	SDTPRY	0.15
6:00 AM	SDTPRY	0.15
7:00 AM	SDTPRY	0.15
8:00 AM	SDTPRY	0.15
9:00 AM	SDTPRY	0.15
10:00 AM	SDTPRY	0.15
11:00 AM	SDTPRY	0.15
12:00 PM	SDTPRY	0.15
1:00 PM	SDTPRY	0.16
2:00 PM	SDTPRY	0.16
3:00 PM	SDTPRY	0.16
4:00 PM	SDTPRY	0.16
5:00 PM	SDTPRY	0.15
6:00 PM	SDTPRY	0.15
7:00 PM	SDTPRY	0.16
8:00 PM	SDTPRY	0.16
9:00 PM	SDTPRY	0.16
10:00 PM	SDTPRY	0.15
11:00 PM	SDTPRY	0.15

Date: 25/12/2005

Time	Name	P(MW)
12:00 AM	SDTPRY	0.15
1:00 AM	SDTPRY	0.15
2:00 AM	SDTPRY	0.09
3:00 AM	SDTPRY	0.09
4:00 AM	SDTPRY	0.09
5:00 AM	SDTPRY	0.09
6:00 AM	SDTPRY	0.09
7:00 AM	SDTPRY	0.09
8:00 AM	SDTPRY	0.09
9:00 AM	SDTPRY	0
10:00 AM	SDTPRY	0.08
11:00 AM	SDTPRY	0.08
12:00 PM	SDTPRY	0.09
1:00 PM	SDTPRY	0.1
2:00 PM	SDTPRY	0.09
3:00 PM	SDTPRY	0.09
4:00 PM	SDTPRY	0.09
5:00 PM	SDTPRY	0.09
6:00 PM	SDTPRY	0.09
7:00 PM	SDTPRY	0.09
8:00 PM	SDTPRY	0.09
9:00 PM	SDTPRY	0.09
10:00 PM	SDTPRY	0.09
11:00 PM	SDTPRY	0.09

APPENDIX D

LV SCHEDULE FOR ALL CATEGORIES

Sample of LV Schedule for Residential Load (Flat)

DB REF : DB-17	FED FROM : SMDB-R	INCOMING BREAKER SIZE: 60A 4P ELCB
LOCATION : ELEC. ROOM 17TH FLOOR	DB SIZE : 14 WAYS TPN RCBO DB	INCOMING CABLE SIZE : 4x25mm2 XLPE/SWA/PVC

CIRCUIT NO.	MCB RATING (A)	WIRE SIZE (mm2)	LOAD DESCRIPTION	LOAD/ POINT (KW)	TOTAL NO OF POINTS	LOAD (KW)		
						R	Y	B
R1	10	2.5	L1 – L9	0.1	9	0.9		
Y1	10	2.5	L10 – L15	0.1	6		0.6	
B1	10	2.5	L16 – L21	0.1	6			0.6
R2	10	2.5	L22 – L25	0.1	4	0.4		
Y2	15	2.5	L26 – L37	0.1	12		1.2	
B2	10	2.5	L38 – L41	0.1	4			0.4
R3	15	2.5	L61 – L66	0.1	7	0.7		
Y3	10	2.5	L42 – L48	0.1	7		0.7	
B3	10	2.5	L57 – L60	0.1	4			0.4
R4	10	2.5	L49 – L52	0.1	4	0.4		
Y4	10	2.5	L53 – L56	0.1	4		0.4	
B4	20	2.5	S29–S33	0.2	5			1.0
R5	30	4.0	S1 – S 4 (Ring)	0.2	4	0.8		
Y5	30	4.0	S14 – S18 (Ring)	0.2	5		1.0	
B5	20	4.0	S19 – S20 (Radial)	0.2	2			0.4
R6	20	4.0	S5 – S7 (Ring)	0.2	3	0.6		
Y6	30	4.0	S23 – S28 (Ring)	0.2	6		1.2	
B6	20	4.0	S21 – S22 (Radial)	0.2	2			0.4
R7	30	4.0	S8 – S11a (Ring)	0.2	5	1.0		
Y7	20	4.0	S12 – S13 (Radial)	0.2	2		0.4	
B7	20	4.0	FCU – 2	0.5	1			0.5
R8	20	4.0	FCU – 7	0.5	1	0.5		
Y8	20	–	SPARE					
B8	20	4.0	FCU – 4	0.5				0.5
R9	15	–	SPARE					
Y9	15	–	SPARE					
B9	20	4.0	FCU – 9	0.5	1			0.5
R10	15	–	SPARE					
Y10	15	–	SPARE					
B10	20	4.0	FCU – 8	0.5	1			0.5
R11						–		
Y11	30	–	Spare	–	–		–	
B11								–
R12						1.0		
Y12	20	4x6	B.P.C.P	3.0	1		1.0	
B12								1.0
R13						0.5		
Y13	20	4x10	F.P.C.P	1.5	1		0.5	
B13								0.5
R14	–	–	Space					
Y14	–	–	Space					
B14	–	–	Space					

Sample of LV Schedule for Residential Load (Villa)

EF : DB-G | FED FROM : MDB | LOC : GROUN

Y 100A TPN ELCB MAIN | CABLE SIZE : 4C,25mm2 XLPE

WIRE SIZE mm^2	POINT REFERANCE	NO. OF POINTS	WATT PER POINT	PHASE LOAD IN KW		
				R	Y	B
2.5	L1--L6+EX1+CH1-CH2	7+2	100/300	1.3		
2.5	L21-L22+CH6-CH7	2+2	100/300		0.8	
2.5	L37-L40+CH14	4+1	100/300			0.7
2.5	L7-L11+EX2+CH3-CH4	6+2	100/300	1.2		
2.5	L23--L27+EX4	6	100		0.6	
2.5	L41-L45+EX6+CH15-CH16	6+2	100/300			1.2
2.5	L12--L20+EX3+CH5	10+1	100/300	1.3		
2.5	L28--L34+EX5	8	100		0.8	
2.5	L46-L50+EX4+CH17-CH18	6+2	100/300			1.2
4.0	S1--S4 RING	4	200	0.8		
2.5	L36-L36a+CH8-CH9	2+2	100/300		0.8	
2.5	L51-L52+CH19-CH21	2+3	100/300			1.1
4.0	S5--S8 RING	4	200	0.8		
2.5	CH10--CH13	4	300		1.2	
4.0	S29--S35 RING	7	200			1.4
4.0	S9-S-11 RING	3	200	0.6		
4.0	S12--S15 RING	4	200		0.8	
4.0	S36--S39 RING	4	200			0.8
4.0	WH-1	1	1500	1.5		
4.0	S16--S19 RING	4	200		0.8	
4.0	WH-6	1	1500			1.5
4.0	WH-2	1	1500	1.5		
4.0	S20--S23 RING	4	200		0.8	
4.0	WH-7	1	1500			1.5
4.0	WH-3	1	1500	1.5		
4.0	S24--S28 RING	5	200		1.0	
6.0	CCU (COOKER UNIT)	1	3000			3.0
2.5	XL1--XL19	19	100	1.9		
4.0	WH-4	1	1500		1.5	
	SPARE					
	SPARE					
4.0	WH-5	1	1500		1.5	
	SPARE					
	SPARE					
4.0	B/PUMP	1	1000		1.0	
	SPACE					
			TOTAL PHASE LOAD	12.4	11.6	12.4

TOTAL LOAD 36.4 KW

Sample of LV Schedule for Industrial Load (Factory)

DB REF.: LH-1					FED FROM: SMDB-1	MAIN INCOMMER: 100A 4P, ELCB (100mA)					
LOCATION: OFFICE BLOCK(4) GROUND FLOOR					DB SIZE: - 14 WAY MCB TPN	MAIN FEEDER: 4C 50mm2 XLPE/SWA/PVC 1C 25mm2 CU/PVC Y/G					
PHASE REF.	MCB RATING AMPS	CCT WIRE mm2	ECC WIRE mm2	DESCRIPTION	No. OF PTS.	UNIT WATTS	LOAD/PHASE IN W.			TOTAL LOAD KW.	REMARKS
							R	Y	B		
R1	10	2.5	1.5	LIGHTS IN MEETING ROOM	8	100	0.8			0.8	
Y1	10	2.5	1.5	LIGHTS IN OFFICE 5 & 6	8	100		0.8		0.8	
B1	10	2.5	1.5	LIGHTS IN OFFICE 1 & 2	10	100			1.0	1.0	
R2	10	2.5	1.5	LIGHTS IN RECEPTION AND CORRIDOR	11	100	1.10			1.1	
Y2	10	2.5	1.5	LIGHTS AND EX FAN IN KITCHEN & TOILET	9	100		1.0		1.0	
B2	10	2.5	1.5	LIGHTS IN BATH 1	5	100			0.5	0.5	
R3	30	4.0	2.5	13A SOCKET IN MEETING ROOM (RING)	6	200	1.2			1.2	
Y3	30	4.0	2.5	13A SOCKET IN OFFICE 5 & 6	6	200		1.2		1.2	
B3	10	2.5	1.5	LIGHTS AND EXHAUST FAN IN BATH 2	10	100			1.0	1.0	
R4	30	4.0	2.5	13A SOCKET IN RECEPTION (RING)	3	200	0.6			0.6	
Y4	30	4.0	2.5	13A SOCKET IN KITCHEN	2	400		0.8		0.8	
B4	30	4.0	2.5	13A SOCKET IN OFFICE-1 (RING)	4	200			0.8	0.8	
R5	30	4.0	2.5	SPLIT A/C UNIT IN MEETING ROOM	1	2500	2.5			2.5	
Y5	20	4.0	2.5	15A POWER SOCKET IN KITCHEN	1	1000		1.0		1.0	
B5	30	4.0	2.5	13A SOCKET IN OFFICE 2 (RING)	4	200			0.8	0.8	
R6	30	6.0	4.0	SPLIT A/C UNIT IN MEETING ROOM	1	2500	2.5			2.5	
Y6	20	4.0	2.5	WATER HEATER IN KITCHEN	1	1500		1.5		1.5	
B6	20	4.0	2.5	WATER HEATER IN BATH-2	1	1000			1.0	1.0	
R7	30	6.0	4.0	SPLIT A/C UNIT IN RECEPTION	1	3000	3.0			3.0	
Y7	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 5	1	2500		2.5		2.5	
B7	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 1	1	2500			2.5	2.5	
R8	20	4.0	2.5	13A SOCKET IN CORRIDOR	2	200	0.4			0.4	
Y8	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 6	1	2500		2.5		2.5	
B8	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 2	1	2500			2.5	2.5	
R9	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 3	1	2500	2.5			2.5	
Y9	30	6.0	4.0	BOOSTER PUMP	1	2500		2.5		2.5	
B9	20	4.0	2.5	DUCT IN LINE FAN	1	200			0.2	0.2	
R10	10	2.5	1.5	LIGHT IN OFFICE 3	4	100	0.4			0.4	
Y10	20	-	-	SPARE	-	-		-		-	
B10	30	6.0	4.0	SPLIT A/C UNIT IN OFFICE 4	1	2500			2.5	2.5	
R11	30	4.0	2.5	13A SOCKET IN OFFICE 3	3	200	0.6			0.6	
Y11	20	-	-	SPARE	-	-		-		-	
B11	30	4.0	2.5	13A SOCKET IN OFFICE 4	3	200			0.6	0.6	
R12	20	4.0	2.5	F.A.C.P.	1	200	0.2			0.2	
Y12	20	-	-	SPARE	-	-		-		-	
B12	10	2.5	1.5	LIGHT IN OFFICE 4	4	100			0.4	0.4	
R13	20	-	-	SPARE	-	-	-			-	
Y13	20	-	-	SPARE	-	-		-		-	
B13	10	-	-	SPARE	-	-			-		
R14	20	-	-	SPARE	-	-	-			-	
Y14	10	-	-	SPARE	-	-		-		-	
B14	10	-	-	SPARE	-	-			-	-	
				TOTAL LOAD = 43.40 KW			15.80	13.80	13.80	43.40	

Sample of LV Schedule for Commercial Load (Paris Gallery Store)

DB - G - 13C | FED FROM: SMDB [illegible] | LOC. GROUND FLOOR

6WAY 40A 4POLE ELCB MAIN | WIRE SIZE: 4c,16mm2 XLPE/SWA/PVC

CKT NO.		MCB RAT. AMP.	WIRE SIZE mm2	ECC SIZE mm2	DESCRIPTION	NO. OF POINT	WATT PER POINT	LOAD IN KW			REMARKS
								R	Y	B	
1	R	10	2.5	1.5	LIGHT CONCH	10	100	1.0			
	Y	10	2.5	1.5	LIGHT CORNISH	10	100		1.0		
	B	10	2.5	1.5	LIGHT CORNISH	10	100			1.0	
2	R	10	2.5	1.5	LIGHT CONCH	10	100	1.0			
	Y	10	2.5	1.5	LIGHT CORNISH	10	100		1.0		
	B	10	2.5	1.5	LIGHT CORNISH	10	100			1.0	
3	R	10	2.5	1.5	LIGHT CONCH	10	100	1.0			
	Y	10	2.5	1.5	LIGHT CORNISH	10	100		1.0		
	B	10	2.5	1.5	LIGHT CORNISH	10	100			1.0	
4	R	10	2.5	1.5	LIGHT CONCH	10	100	1.0			
	Y	10	2.5	1.5	LIGHT CORNISH	10	100		1.0		
	B	10	2.5	1.5	LIGHT CORNISH	10	100			1.0	
5	R	10	2.5	1.5	LIGHT CONCH	10	100	1.0			
	Y	10	2.5	1.5	LIGHT CORNISH	10	100		1.0		
	B	10	2.5	1.5	LIGHT CORNISH	10	100			1.0	
6	R	10			SPARE						
	Y	10			SPARE						
	B	10			SPARE						
					TOTAL PHASE LOAD			5.0	5.0	5.0	
TOTAL LOAD 15.0 KW											

Sample of LV Schedule for Others Load (Medical Centre)

Location: Electrical Room

Fed From: SMP-1F
Feeder Size: $4C \times 25mm^2 + 1C \times 16mm^2$

Size	Description	No.of Points	Load Per Points	Load in Watts		
				R	Y	B
	13A S/S/O (Ring)(Stress)	6	200	1200		
	13A S/S/O (Ring)(EMG)	6	200		1200	
	13A S/S/O (Ring)(Treatement Room2)	8	200			1600
	Exam Light(Sress)	1	200	200		
	13A Switch Fuse With Cable Outlet (Laser)	1	200		200	
	13A Switch Fuse With Cable Outlet (TreatementRoom2)	1	200			200
	13A S/S/O (Ring)(Echo)	6	200	1200		
	13A S/S/O (Ring)(Laser-Equipement Store)	6	200		1200	
	13A S/S/O (Ring)(Treatement Room1)	6	200			1200
	13A S/S/O (Ring)(Hall-equipementStore)	5	200	1000		
	Hair Drier(Nurse interview office 26-27)	1	1000		1000	
	13A Switch Fuse With Cable Outlet (Treatement Room1)	1	200			200
	13A Switch Fuse With Cable Outlet(Hall)	1	200	200		
	13A S/S/O (Ring)(Diabetic Nurse Office20-21)	6	200		1200	
	Exam Light(Treatement2)	2	200			400
	Hand Drier(M patient WC)	1	2000	2000		
	13A S/S/O (Ring)Diabetic Nurse Office23)	6	200		1200	
	13A S/S/O (Ring)(NurseInterview office24-25)	6	200			1200
	Hand Drier(M Patient WC)	1	2000	2000		
	13A S/S/O (Ring)(Fandus Camera)	5	200		1000	
	13A S/S/O (Ring)(NurseInterview Office)	6	200			1200
	Exam Light(EMG)	1	200	200		
	13A Switch Fuse With Cable Outlet (Fandus Camera)	1	200		200	
	Water Heater(TreatementRoom1)	1	2000			2000
	Water Heater(M patient WC)	1	2000	2000		
	Switch Fuse(Fandus Camera)	1	200		200	
	13A S/S/O (Ring)(Public Foyer-Cleaner)	4	200			800
	Spare					
	13A S/S/O (Radial)(Cleaner)	1	200		200	
	13A S/S/O (Ring)(Staff Base)	4	200			800
	Spare					
	Water Heater(Diabetic NurseOffice20)	1	2000		2000	
	Spare					
	Spare					
	Spare					
	Spare					

APPENDIX E

LOAD PROFILE FOR DIFFERENT CATEGORIES

Residential Load Profile

SUBSTATION: W31C FEEDER PILLAR: FEEDER:

Peak demand (kW): 110.56 Minimum demand (kW): 40.82
Time of peak demand: 13:00:00 Time of minimum demand: 07:20:00

Table E.1
Residential readings from the load profile measurement tool

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
July	00:00	246.0	47.6	0.90	63.1	30.8	7.7
	00:10	245.9	52.2	0.85	65.7	40.3	8.0
	00:20	245.6	55.7	0.88	72.0	39.6	8.8
	00:30	246.3	44.7	0.87	57.6	32.2	7.0
	00:40	246.1	51.3	0.87	65.5	37.9	8.0
	00:50	246.0	48.7	0.87	62.7	35.1	7.6
	01:00	246.4	52.1	0.88	67.7	36.6	8.2
	01:10	246.2	53.7	0.86	68.3	40.3	8.3
	01:20	246.7	43.7	0.88	56.7	31.1	6.9
	01:30	246.7	56.3	0.88	73.2	39.7	8.9
	01:40	246.9	45.1	0.87	58.0	33.3	7.1
	01:50	247.0	51.0	0.90	68.0	33.1	8.3
	02:00	247.0	52.3	0.85	66.2	40.2	8.1
	02:10	247.0	55.8	0.86	71.3	42.0	8.7
	02:20	247.4	49.9	0.86	63.8	37.7	7.8
	02:30	247.3	50.5	0.87	65.5	36.5	8.0
	02:40	247.3	50.7	0.86	64.5	38.7	7.9
	02:50	247.4	50.0	0.88	65.5	34.9	8.0
	03:00	247.7	46.9	0.86	59.7	36.0	7.3
	03:10	247.4	53.3	0.88	69.7	37.6	8.5
	03:20	245.1	36.9	0.88	47.9	25.6	5.8
	03:30	244.9	40.8	0.87	52.3	29.4	6.4
	03:40	244.9	48.1	0.89	62.9	32.4	7.6
	03:50	245.2	41.2	0.85	51.4	32.1	6.3
	04:00	245.2	40.4	0.89	52.9	27.2	6.4
	04:10	245.2	40.6	0.87	52.1	29.3	6.3
	04:20	243.8	41.1	0.88	53.2	28.0	6.5
	04:30	244.2	37.4	0.87	47.5	27.3	5.8
	04:40	244.4	36.6	0.87	46.5	26.6	5.7
	04:50	244.4	42.1	0.86	53.2	31.2	6.5
	05:00	244.8	40.9	0.88	52.9	28.5	6.4
	05:10	244.8	40.2	0.90	53.1	25.9	6.5
	05:20	244.6	52.6	0.88	67.7	37.3	8.2
	05:30	244.9	53.6	0.90	70.6	34.9	8.6
	05:40	245.1	50.5	0.88	65.4	35.1	8.0
	05:50	245.4	43.7	0.90	57.9	28.3	7.0
	06:00	245.1	38.4	0.89	50.5	25.2	6.1
	06:10	244.4	43.3	0.87	55.3	31.3	6.7
	06:20	244.4	41.5	0.90	54.8	26.5	6.7

(table continues)

Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
06:30	244.5	43.0	0.86	54.2	32.4	6.6
06:40	244.7	42.7	0.89	56.1	28.0	6.8
06:50	244.9	38.5	0.89	50.4	25.8	6.1
07:00	244.6	38.5	0.87	49.0	28.2	6.0
07:10	244.7	35.5	0.86	45.1	26.2	5.5
07:20	244.6	32.7	0.85	40.8	25.3	5.0
07:30	244.3	34.5	0.92	46.3	20.3	5.6
07:40	244.1	37.0	0.85	46.2	28.3	5.6
07:50	243.8	38.3	0.84	47.0	30.5	5.7
08:00	243.3	38.1	0.85	47.2	29.3	5.7
08:10	243.2	41.9	0.88	54.0	28.8	6.6
08:20	243.4	40.5	0.87	51.5	29.2	6.3
08:30	243.8	38.3	0.84	47.0	30.5	5.7
08:40	243.3	38.1	0.85	47.2	29.3	5.7
08:50	243.2	41.9	0.88	54.0	28.8	6.6
09:00	243.4	40.5	0.87	51.5	29.2	6.3
09:10	243.8	59.5	0.87	75.9	42.5	9.2
09:20	243.8	57.1	0.89	74.2	38.3	9.0
09:30	244.1	49.2	0.89	63.7	33.5	7.8
09:40	243.7	64.7	0.88	83.7	44.2	10.2
09:50	243.8	59.5	0.87	75.9	42.5	9.2
10:00	243.8	57.1	0.89	74.2	38.3	9.0
10:10	244.1	49.2	0.89	63.7	33.5	7.8
10:20	243.7	64.7	0.88	83.7	44.2	10.2
10:30	243.5	49.4	0.85	61.4	38.0	7.5
10:40	243.6	56.7	0.87	72.0	41.1	8.8
10:50	243.5	51.4	0.87	65.5	36.8	8.0
11:00	246.6	35.7	0.84	44.3	28.8	5.4
11:10	245.7	59.6	0.84	74.2	47.1	9.0
11:20	245.7	56.9	0.87	72.8	41.7	8.9
11:30	245.5	56.5	0.88	73.5	39.1	8.9
11:40	245.0	64.8	0.90	85.6	41.9	10.4
11:50	244.7	64.8	0.90	85.3	42.4	10.4
12:00	244.7	63.6	0.89	83.1	42.7	10.1
12:10	245.2	55.1	0.91	73.7	33.9	9.0
12:20	245.3	55.1	0.89	72.3	36.6	8.8
12:30	244.2	79.0	0.89	103.3	52.3	12.6
12:40	244.1	67.9	0.89	88.3	45.8	10.7
12:50	244.3	61.5	0.88	79.8	42.1	9.7
13:00	243.9	83.1	0.91	110.6	50.8	13.4
13:10	243.5	74.5	0.89	96.4	50.4	11.7
13:20	243.4	75.8	0.89	98.9	49.9	12.0
13:30	243.3	69.8	0.88	89.2	49.1	10.9
13:40	243.8	56.4	0.87	72.0	40.1	8.8
13:50	243.5	65.4	0.88	84.4	44.7	10.3
14:00	243.8	53.4	0.88	68.9	36.7	8.4
14:10	243.7	79.1	0.86	100.0	58.2	12.2

(table continues)

Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
14:20	244.0	63.3	0.86	80.1	46.6	9.7
14:30	244.3	70.8	0.88	91.8	48.4	11.2
14:40	244.2	72.5	0.87	92.6	52.1	11.3
14:50	244.2	73.9	0.87	94.6	52.8	11.5
15:00	244.6	83.7	0.88	107.6	59.3	13.1
15:10	244.4	77.7	0.88	99.9	54.8	12.2
15:20	244.8	71.0	0.89	93.0	47.2	11.3
15:30	244.8	59.0	0.86	74.9	43.5	9.1
15:40	244.5	63.2	0.86	79.9	47.1	9.7
15:50	245.1	51.1	0.85	64.1	39.2	7.8
16:00	244.8	62.5	0.85	78.1	48.4	9.5
16:10	244.7	64.0	0.87	81.3	47.0	9.9
16:20	244.9	43.9	0.85	54.9	33.8	6.7
16:30	244.7	55.9	0.86	70.5	42.0	8.6
16:40	244.5	51.1	0.86	64.4	38.2	7.8
16:50	244.3	53.4	0.85	66.2	41.6	8.1
17:00	244.9	35.4	0.84	43.7	28.1	5.3
17:10	244.9	38.0	0.86	47.7	28.9	5.8
17:20	245.2	34.1	0.83	41.6	28.0	5.1
17:30	245.4	35.8	0.86	45.3	26.9	5.5
17:40	245.5	42.4	0.87	54.3	30.9	6.6
17:50	245.6	35.3	0.87	45.2	26.0	5.5
18:00	245.6	44.4	0.86	56.5	33.2	6.9
18:10	246.0	35.4	0.87	45.4	25.9	5.5
18:20	246.2	47.1	0.85	59.2	36.6	7.2
18:30	246.3	39.9	0.83	49.0	32.7	6.0
18:40	245.6	46.5	0.86	58.6	35.4	7.1
18:50	245.7	41.7	0.83	50.9	34.5	6.2
19:00	245.4	41.3	0.84	50.9	33.3	6.2
19:10	244.8	44.9	0.83	54.5	37.1	6.6
19:20	244.3	43.2	0.85	53.9	33.1	6.6
19:30	244.1	50.7	0.86	64.1	37.6	7.8
19:40	244.4	41.7	0.87	53.1	30.2	6.5
19:50	244.3	52.9	0.87	67.2	38.6	8.2
20:00	244.8	48.6	0.88	62.8	33.9	7.6
20:10	244.8	47.6	0.87	60.5	35.1	7.4
20:20	244.8	34.0	0.84	42.2	26.7	5.1
20:30	244.5	42.7	0.85	53.4	32.9	6.5
20:40	243.9	54.3	0.87	69.4	38.8	8.4
20:50	244.7	41.3	0.86	52.4	30.6	6.4
21:00	244.9	38.9	0.87	49.6	28.5	6.0
21:10	244.6	37.7	0.87	48.2	27.3	5.9

(table continues)

Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
21:20	244.6	57.7	0.87	73.6	41.9	9.0
21:30	244.3	57.8	0.88	74.2	40.8	9.0
21:40	244.7	52.7	0.87	67.0	38.8	8.2
21:50	244.7	46.2	0.86	58.1	35.1	7.1
22:00	244.7	36.6	0.86	46.3	27.4	5.6
22:10	244.7	42.7	0.84	52.4	34.3	6.4
22:20	245.2	37.5	0.87	47.9	27.5	5.8
22:30	245.5	33.5	0.84	41.2	27.0	5.0
22:40	245.3	41.8	0.89	54.5	28.5	6.6
22:50	245.2	41.9	0.84	51.6	33.6	6.3
23:00	245.2	50.2	0.86	63.8	37.3	7.8
23:10	245.4	51.8	0.85	64.9	40.0	7.9
23:20	245.5	54.3	0.86	69.0	40.5	8.4
23:30	245.6	50.3	0.85	63.0	39.1	7.7
23:40	245.7	50.8	0.84	63.0	40.5	7.7
23:50	245.8	44.9	0.84	55.4	36.4	6.7
00:00	246.0	47.6	0.90	63.1	30.8	7.7

Table E.2
Appliances load distribution in Residential load profile

Time	P (KW)	A/C (KW)	Lighting (KW)	Sockets (KW)	Water Heater (KW)	Cooker (KW)	washing machines (KW)
12:00 AM	71.98	35.27	10.80	10.08	9.36	4.32	2.16
1:00 AM	73.2	35.89	10.99	10.25	9.52	4.39	2.20
2:00 AM	71.3	34.91	10.69	9.98	9.26	4.28	2.14
3:00 AM	69.7	34.16	10.46	9.76	9.06	4.18	2.09
4:00 AM	53.2	26.08	7.99	7.45	6.92	3.19	1.60
5:00 AM	70.6	34.62	10.60	9.89	9.18	4.24	2.12
6:00 AM	56.1	27.48	8.41	7.85	7.29	3.36	1.68
7:00 AM	49.0	24.00	7.35	6.86	6.37	2.94	1.47
8:00 AM	54.0	26.44	8.09	7.55	7.01	3.24	1.62
9:00 AM	83.7	40.99	12.55	11.71	10.88	5.02	2.51
10:00 AM	83.7	40.99	12.55	11.71	10.88	5.02	2.51
11:00 AM	85.6	41.95	12.84	11.99	11.13	5.14	2.57
12:00 PM	103.3	50.63	15.50	14.46	13.43	6.20	3.10
1:00 PM	110.6	54.17	16.58	15.48	14.37	6.63	3.32
2:00 PM	100.0	48.99	15.00	14.00	13.00	6.00	3.00
3:00 PM	107.6	52.72	16.14	15.06	13.99	6.46	3.23
4:00 PM	81.3	39.83	12.19	11.38	10.57	4.88	2.44
5:00 PM	54.3	26.59	8.14	7.60	7.05	3.26	1.63
6:00 PM	59.2	29.00	8.88	8.29	7.69	3.55	1.78
7:00 PM	67.2	32.91	10.08	9.40	8.73	4.03	2.02
8:00 PM	69.4	34.00	10.41	9.71	9.02	4.16	2.08
9:00 PM	74.2	36.36	11.13	10.39	9.65	4.45	2.23
10:00 PM	54.5	26.68	8.17	7.62	7.08	3.27	1.63
11:00 PM	69.0	33.83	10.36	9.67	8.98	4.14	2.07

Commercial Load Profile

SUBSTATION: MM

Peak demand (kW):	7319.75	Minimum demand (kW):	2675.07
Time of peak demand:	20:00:00	Time of minimum demand:	04:50:00

Table E.3
Commercial readings from the load profile measurement tool

Date	Time	Active Power (kW)	Reactive power (kVAr)
Aug	00:00	4617.0	2551.8
	00:10	4870.5	2586.2
	00:20	4496.1	2533.0
	00:30	4124.2	2192.6
	00:40	4029.8	2182.5
	00:50	3698.6	2118.4
	01:00	3553.1	1973.9
	01:10	3581.5	2011.7
	01:20	3569.9	1982.2
	01:30	3634.0	2046.4
	01:40	3915.8	2098.5
	01:50	4170.5	2205.7
	02:00	4424.9	2221.9
	02:10	4154.3	2143.5
	02:20	3873.1	2045.9
	02:30	3733.8	1998.7
	02:40	3509.9	1948.9
	02:50	3509.9	1943.6
	03:00	3345.7	1858.4
	03:10	3213.3	1762.5
	03:20	2887.0	1698.5
	03:30	2723.4	1613.0
	03:40	2772.8	1676.5
	03:50	2869.4	1651.8
	04:00	3077.1	1723.9
	04:10	3227.8	1770.4
	04:20	3256.1	1789.4
	04:30	3177.2	1737.9
	04:40	2901.7	1664.2
	04:50	2675.1	1616.1
	05:00	2689.0	1663.6
	05:10	2715.9	1635.6
	05:20	3079.0	1732.4
	05:30	3113.5	1758.6
	05:40	3044.0	1713.5
	05:50	2885.4	1657.9

(table continues)

Date	Time	Active Power (kW)	Reactive power (kVAr)
	06:00	2742.8	1647.7
	06:10	2719.7	1623.4
	06:20	2799.1	1661.5
	06:30	2718.8	1648.6
	06:40	2711.9	1656.2
	06:50	2730.7	1611.7
	07:00	2721.4	1638.6
	07:10	2706.6	1642.9
	07:20	2734.5	1636.0
	07:30	2701.9	1610.6
	07:40	2819.7	1630.2
	07:50	3080.1	1680.9
	08:00	3209.4	1721.0
	08:10	2968.1	1613.6
	08:20	2764.6	1608.6
	08:30	2929.6	1619.5
	08:40	2992.7	1678.9
	08:50	3362.0	1878.6
	09:00	3093.6	1784.1
	09:10	3647.9	2048.3
	09:20	3980.9	1944.8
	09:30	4644.9	2193.8
	09:40	4886.3	2456.0
	09:50	4901.1	2630.5
	10:00	5563.9	2853.5
	10:10	5691.9	2882.3
	10:20	5655.5	3372.2
	10:30	5474.7	3424.4
	10:40	5719.7	3129.1
	10:50	6306.7	3337.2
	11:00	6260.1	3300.2
	11:10	6326.9	3332.5
	11:20	6290.6	3302.5
	11:30	6315.1	3278.4
	11:40	6378.2	3347.2
	11:50	6592.5	3442.7

(table continues)

Date	Time	Active Power (kW)	Reactive power (kVAr)
	12:00	6464.5	3478.9
	12:10	6656.8	3665.0
	12:20	6717.7	3656.2
	12:30	6709.2	3660.2
	12:40	6538.4	3575.4
	12:50	6449.3	3519.5
	13:00	6894.3	3725.4
	13:10	6918.5	3653.0
	13:20	7031.5	3748.8
	13:30	7031.9	3719.2
	13:40	7172.0	3840.2
	13:50	7184.7	3809.5
	14:00	7153.0	3808.2
	14:10	6988.3	3706.3
	14:20	6867.4	3648.8
	14:30	7062.1	3749.4
	14:40	7015.8	3671.1
	14:50	7025.2	3691.5
	15:00	7065.0	3735.6
	15:10	6971.3	3726.5
	15:20	6931.4	3678.3
	15:30	6955.3	3704.9
	15:40	7001.2	3709.6
	15:50	6718.2	3618.9
	16:00	6848.0	3642.3
	16:10	6844.0	3657.3
	16:20	6929.6	3689.4
	16:30	6806.1	3625.8
	16:40	6787.2	3621.5
	16:50	6941.7	3715.3
	17:00	6874.2	3677.1
	17:10	6859.4	3679.9
	17:20	6748.3	3608.8
	17:30	6558.5	3581.7
	17:40	6672.1	3642.7
	17:50	6983.0	3758.1
	18:00	7058.3	3744.2
	18:10	7154.6	3838.5
	18:20	7068.4	3774.8
	18:30	6994.7	3719.0
	18:40	7133.2	3899.0
	18:50	7250.4	3857.3

(table continues)

Date	Time	Active Power (kW)	Reactive power (kVAr)
	16:10	6844.0	3657.3
	19:00	7157.2	3866.5
	19:10	7152.8	3888.7
	19:20	6706.4	3658.2
	19:30	6625.1	3661.1
	19:40	6836.6	3746.4
	19:50	7066.8	3839.0
	20:00	7319.8	3979.7
	20:10	6894.5	3789.1
	20:20	6769.2	3761.5
	20:30	6780.8	3789.8
	20:40	6641.3	3643.4
	20:50	6938.4	3830.7
	21:00	6974.4	3796.9
	21:10	6755.0	3726.1
	21:20	6781.7	3739.9
	21:30	6084.0	3422.4
	21:40	6086.7	3354.8
	21:50	5756.7	3058.6
	22:00	5755.5	3167.1
	22:10	5941.3	3236.5
	22:20	6078.9	3233.6
	22:30	5848.7	3124.8
	22:40	5243.7	2880.6
	22:50	5314.5	2892.9
	23:00	5095.2	2825.3
	23:10	3756.3	2427.0
	23:20	3782.3	2291.4
	23:30	4084.3	2359.1
	23:40	4032.5	2306.5
	23:50	4238.9	2322.1
	00:00	4617.0	2551.8

Table E.4
Appliances load distribution in Commercial load profile

Time	Total Load(KW)	A/C(KW)	Lighting(KW)	Sockets(KW)
12:00 AM	4870.50	1996.90	1607.26	827.98
1:00 AM	2205.7	904.34	727.88	374.97
2:00 AM	2221.9	910.97	733.22	377.72
3:00 AM	1858.4	761.95	613.28	315.93
4:00 AM	3256.1	1335.00	1074.51	553.54
5:00 AM	3113.5	1276.54	1027.46	529.30
6:00 AM	2799.1	1147.65	923.72	475.85
7:00 AM	0.0	0.00	0.00	0.00
8:00 AM	3362.0	1378.44	1109.48	571.55
9:00 AM	4901.1	2009.45	1617.36	833.19
10:00 AM	6306.7	2585.74	2081.21	1072.14
11:00 AM	6592.5	2702.92	2175.52	1120.72
12:00 PM	6717.7	2754.25	2216.83	1142.01
1:00 PM	7184.7	2945.75	2370.97	1221.41
2:00 PM	7153.0	2932.74	2360.50	1216.01
3:00 PM	7065.0	2896.65	2331.45	1201.05
4:00 PM	0.0	0.00	0.00	0.00
5:00 PM	6983.0	2863.02	2304.38	1187.11
6:00 PM	7250.4	2972.68	2392.65	1232.58
7:00 PM	7157.2	2934.45	2361.87	1216.72
8:00 PM	7319.8	3001.10	2415.52	1244.36
9:00 PM	6974.4	2859.50	2301.55	1185.65
10:00 PM	6078.9	2492.33	2006.02	1033.41
11:00 PM	5095.2	2089.05	1681.43	866.19

Industrial Load Profile

SUBSTATION: Carr TR2 FEEDER PILLAR: FEEDER: Grand
Peak demand (kW): 217.3525 Minimum demand (kW): 53.63264
Time of peak demand: 14:50:00 Time of minimum demand: 09:00:00

Table E.5
Industrial readings from the load profile measurement tool

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
Aug	00:00	245.15	210.15	0.94	197.5	71.8	
	00:10	245.73	213.47	0.93	184.6	71.1	
	00:20	243.4	208.81	0.94	189.1	68.1	
	00:30	244.32	206.89	0.94	201.4	70.0	
	00:40	244.44	205.13	0.94	193.3	69.6	
	00:50	245.51	160.75	0.94	188.1	67.7	
	01:00	245.54	158.88	0.94	188.1	68.9	
	01:10	245.55	169.08	0.93	175.4	66.9	
	01:20	246.22	152.2	0.94	191.1	70.0	
	01:30	246.54	150.18	0.94	186.4	68.8	
	01:40	247	149.61	0.94	190.1	70.1	
	01:50	247.27	148.73	0.93	181.2	69.9	
	02:00	245.22	148.06	0.93	185.0	70.9	
	02:10	245.32	163.44	0.94	184.8	69.7	
	02:20	245.86	163.28	0.94	188.4	70.3	
	02:30	245.58	195.55	0.93	197.4	76.7	
	02:40	246.66	151.79	0.94	184.0	69.3	
	02:50	246.45	161.47	0.94	183.0	68.9	
	03:00	246.63	170.59	0.93	182.1	70.2	
	03:10	246.25	197.93	0.94	183.2	69.3	
	03:20	246.56	199.74	0.93	175.5	68.3	
	03:30	246.7	201.14	0.94	178.0	67.2	
	03:40	246.97	197.72	0.93	176.6	68.8	
	03:50	247.63	169.29	0.93	178.4	69.2	
	04:00	247.15	198.5	0.93	173.9	66.6	
	04:10	246.86	198.71	0.93	195.4	76.5	
	04:20	247.11	197.77	0.93	165.0	67.0	
	04:30	245.25	189.28	0.93	173.3	67.8	
	04:40	246.02	162.82	0.93	165.5	67.6	
	04:50	246.15	150.86	0.93	168.8	66.3	
	05:00	246.05	149.46	0.92	156.2	65.0	
	05:10	246.3	149.15	0.92	151.6	64.7	
	05:20	245.84	194.72	0.91	135.9	60.6	
	05:30	245.98	195.29	0.92	139.8	60.1	
	05:40	246.28	193.99	0.92	141.5	61.1	
	05:50	246.92	143.35	0.92	130.7	57.6	

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
	06:00	247.24	122.63	0.89	128.0	64.3	
	06:10	246.74	127.29	0.90	143.2	70.2	
	06:20	246.7	177.22	0.90	137.4	67.5	
	06:30	246.89	128.02	0.90	132.0	64.6	
	06:40	246.18	157.02	0.89	128.6	64.5	
	06:50	246.56	130.35	0.90	130.6	64.2	
	07:00	246.08	130.76	0.89	125.9	66.2	
	07:10	244.8	174.57	0.88	111.2	59.3	
	07:20	244.27	175.56	0.88	99.1	54.7	
	07:30	243.34	173.18	0.86	100.7	59.6	
	07:40	243.06	174.42	0.84	86.0	55.1	
	07:50	242.33	172.35	0.83	73.2	49.6	
	08:00	244.64	176.44	0.77	59.0	49.6	
	08:10	244.96	175.4	0.75	73.4	64.8	
	08:20	244.18	180.17	0.76	61.9	53.4	
	08:30	243.34	173.18	0.66	56.3	64.4	
	08:40	243.06	174.42	0.67	67.3	75.2	
	08:50	242.33	172.35	0.64	67.6	81.3	
	09:00	244.64	176.44	0.62	53.6	68.8	
	09:10	244.96	175.4	0.67	67.3	75.2	
	09:20	244.18	180.17	0.64	67.6	81.3	
	09:30	243.14	211.91	0.62	53.6	68.8	
	09:40	243.42	216	0.64	64.8	77.0	
	09:50	243.35	219.27	0.58	57.1	80.0	
	10:00	243.35	204.56	0.69	76.2	78.9	
	10:10	242.7	215.59	0.64	64.8	77.0	
	10:20	242.33	216.37	0.58	57.1	80.0	
	10:30	243.14	211.91	0.69	76.2	78.9	
	10:40	243.42	216	0.66	69.0	78.3	
	10:50	243.35	219.27	0.66	72.0	82.3	
	11:00	243.35	204.56	0.68	75.2	81.9	
	11:10	242.7	215.59	0.68	82.8	88.6	
	11:20	242.33	216.37	0.70	82.4	83.2	
	11:30	242.79	218.85	0.71	83.6	83.0	
	11:40	242.38	218.02	0.77	103.9	87.3	
	11:50	242.52	218.18	0.74	96.3	87.7	
	12:00	242.13	218.28	0.76	103.9	89.6	
	12:10	242.9	169.97	0.73	100.1	94.2	
	12:20	241.42	217.51	0.70	92.7	94.0	
	12:30	241.77	216.73	0.78	98.8	80.5	
	12:40	241.84	221.44	0.79	124.7	96.4	
	12:50	242.18	220.46	0.82	119.3	83.2	

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
	13:00	241.74	219.68	0.84	110.5	71.2	
	13:10	242.07	221.23	0.85	113.5	70.0	
	13:20	241.45	220.61	0.86	142.2	86.0	
	13:30	241.69	219.16	0.94	179.4	66.9	
	13:40	241.71	213.57	0.94	186.5	67.1	
	13:50	241.83	213.47	0.94	196.3	71.1	
	14:00	242.41	213.21	0.95	206.9	70.3	
	14:10	241.97	215.12	0.95	212.4	71.2	
	14:20	242.41	217.35	0.95	206.3	71.2	
	14:30	242.41	217.56	0.94	213.7	74.1	
	14:40	241.94	214.61	0.95	207.7	68.5	
	14:50	241.71	216.42	0.95	217.4	75.1	
	15:00	241.39	215.28	0.94	196.1	70.6	
	15:10	241.84	223.2	0.94	182.3	67.3	
	15:20	241.8	218.18	0.92	161.6	70.0	
	15:30	242.29	220.98	0.88	169.4	92.9	
	15:40	242.91	174.57	0.85	171.8	104.9	
	15:50	242.19	216.83	0.85	154.0	93.6	
	16:00	241.6	223	0.88	141.4	75.1	
	16:10	241.46	217.25	0.83	146.5	98.8	
	16:20	241.34	218.75	0.86	134.9	81.0	
	16:30	240.78	214.92	0.81	133.0	95.6	
	16:40	243.69	217.56	0.83	134.7	90.7	
	16:50	243.35	219.32	0.84	129.0	84.4	
	17:00	243.69	217.76	0.85	131.4	82.2	
	17:10	243.66	216.68	0.85	125.9	79.6	
	17:20	244.57	195.29	0.83	121.4	82.2	
	17:30	243.49	246.14	0.80	111.1	83.3	
	17:40	244.01	238.84	0.79	106.7	82.0	
	17:50	244.54	238.84	0.79	95.8	74.9	
	18:00	244.61	238.74	0.77	110.9	91.3	
	18:10	244.77	237.7	0.78	101.3	80.6	
	18:20	245.67	196.27	0.81	98.2	70.0	
	18:30	244.64	242.67	0.81	116.4	83.5	
	18:40	244.3	243.97	0.83	122.5	82.4	
	18:50	244.24	242.99	0.78	109.2	87.7	
	19:00	243.96	246.35	0.77	108.0	90.0	
	19:10	242.94	255.57	0.79	103.8	79.2	
	19:20	242.77	243.97	0.79	119.0	92.0	
	19:30	242.47	245.89	0.78	105.4	83.2	
	19:40	242.3	241.12	0.81	125.8	89.5	
	19:50	242.36	241.38	0.82	128.7	89.6	

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (W/m2)
	20:00	241.84	255.88	0.83	134.0	89.9	
	20:10	241.9	262.09	0.82	130.9	90.7	
	20:20	241.83	258.11	0.86	131.8	76.7	
	20:30	242.15	244.85	0.88	138.1	75.4	
	20:40	242.27	245.47	0.88	132.9	70.4	
	20:50	242.09	246.51	0.87	140.8	81.3	
	21:00	241.95	242.73	0.89	153.8	79.3	
	21:10	242.26	249.92	0.88	149.1	79.2	
	21:20	242.04	247.13	0.89	158.7	83.0	
	21:30	242.42	248.47	0.91	168.5	76.3	
	21:40	242.41	251.63	0.91	180.5	84.7	
	21:50	242.67	244.23	0.91	163.9	73.5	
	22:00	242.77	249.3	0.91	157.5	70.3	
	22:10	243.2	228.95	0.92	167.4	72.2	
	22:20	244.38	182.45	0.92	161.5	71.2	
	22:30	243.37	245.99	0.91	174.2	77.7	
	22:40	244.19	227.45	0.93	191.5	78.2	
	22:50	245.63	184.05	0.94	179.4	67.8	
	23:00	242.62	226.98	0.94	190.8	71.1	
	23:10	243.55	228.23	0.94	198.0	69.9	
	23:20	243.46	223.88	0.94	196.2	68.5	
	23:30	244.18	221.08	0.94	195.8	69.2	
	23:40	244.12	223.46	0.95	206.8	69.5	
	23:50	244.54	217.51	0.94	199.8	71.0	
	00:00	245.15	210.15	0.94	205.7	73.4	

Agricultural load profile

SUBSTATION: ST FEEDER PILLAR: FEEDER:

Peak demand (kW):	33.09	Minimum demand (kW):	2.95
Time of peak demand:	13:20:00	Time of minimum demand:	08:10:00

Table E.7
Agricultural readings from the load profile measurement tool

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (kW/farm)
Aug	00:00	248.2	44.6	0.86	28.4	17.2	7.1
	00:10	248.3	44.7	0.85	28.3	17.4	7.1
	00:20	248.4	43.9	0.85	27.7	17.4	6.9
	00:30	247.7	42.9	0.85	27.0	16.9	6.7
	00:40	247.6	42.7	0.85	26.8	16.9	6.7
	00:50	247.9	30.7	0.82	18.8	12.9	4.7
	01:00	248.0	30.7	0.82	18.8	13.0	4.7
	01:10	248.5	30.8	0.82	18.8	13.1	4.7
	01:20	248.5	30.6	0.82	18.7	13.1	4.7
	01:30	248.2	43.9	0.85	27.9	17.0	7.0
	01:40	248.9	42.4	0.86	27.1	16.4	6.8
	01:50	249.3	30.8	0.81	18.7	13.4	4.7
	02:00	249.4	30.7	0.81	18.7	13.4	4.7
	02:10	249.2	30.6	0.81	18.6	13.4	4.6
	02:20	249.3	30.6	0.81	18.5	13.4	4.6
	02:30	249.6	30.7	0.81	18.6	13.5	4.7
	02:40	249.7	30.6	0.81	18.5	13.5	4.6
	02:50	249.2	43.3	0.84	27.2	17.5	6.8
	03:00	249.5	42.2	0.82	26.0	17.9	6.5
	03:10	249.9	30.7	0.81	18.5	13.6	4.6
	03:20	250.1	30.5	0.80	18.4	13.6	4.6
	03:30	250.2	30.6	0.82	18.9	13.1	4.7
	03:40	250.4	30.5	0.82	18.7	13.2	4.7
	03:50	250.3	30.1	0.81	18.2	13.3	4.6
	04:00	250.4	30.9	0.81	18.7	13.7	4.7
	04:10	250.3	43.5	0.83	27.3	18.0	6.8
	04:20	250.7	31.0	0.80	18.7	13.8	4.7
	04:30	250.8	30.4	0.79	18.1	13.9	4.5
	04:40	250.9	30.8	0.79	18.3	14.2	4.6
	04:50	251.6	18.3	0.77	10.6	8.9	2.6
	05:00	251.4	31.1	0.79	18.6	14.3	4.6
	05:10	251.8	29.1	0.74	16.4	14.7	4.1
	05:20	251.8	42.5	0.84	26.9	17.5	6.7
	05:30	251.4	42.6	0.81	26.1	18.7	6.5
	05:40	251.8	31.1	0.80	18.7	14.2	4.7
	05:50	252.5	21.0	0.73	11.6	10.9	2.9

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (kW/farm)
	06:10	252.6	8.1	0.50	3.1	5.3	0.8
	06:20	251.7	29.2	0.63	13.9	17.1	3.5
	06:30	253.2	29.7	0.63	14.2	17.5	3.6
	06:40	252.9	29.3	0.63	13.9	17.3	3.5
	06:50	254.3	29.7	0.62	14.1	17.8	3.5
	07:00	253.8	29.5	0.62	14.0	17.6	3.5
	07:10	252.5	42.5	0.66	21.4	24.0	5.3
	07:20	252.4	42.1	0.66	21.1	23.9	5.3
	07:30	252.2	42.3	0.67	21.3	23.8	5.3
	07:40	252.3	33.1	0.65	16.3	19.0	4.1
	07:50	252.3	32.7	0.64	15.8	19.0	4.0
	08:00	252.1	32.8	0.65	16.1	18.9	4.0
	08:10	252.7	7.8	0.50	2.9	5.1	0.7
	08:20	253.8	7.8	0.50	3.0	5.2	0.7
	08:30	253.7	7.8	0.50	3.0	5.2	0.7
	08:40	253.1	20.2	0.58	8.8	12.6	2.2
	08:50	253.2	20.1	0.57	8.7	12.5	2.2
	09:00	253.0	20.2	0.59	9.0	12.4	2.3
	09:10	252.4	29.5	0.72	16.1	15.5	4.0
	09:20	252.1	29.4	0.73	16.2	15.3	4.0
	09:30	252.8	17.5	0.79	10.4	8.2	2.6
	09:40	252.7	20.2	0.64	9.8	11.8	2.4
	09:50	252.9	20.1	0.64	9.7	11.7	2.4
	10:00	253.1	20.7	0.65	10.3	11.9	2.6
	10:10	253.6	20.1	0.63	9.7	11.9	2.4
	10:20	253.4	20.3	0.64	9.8	11.9	2.5
	10:30	254.0	8.4	0.51	3.3	5.5	0.8
	10:40	253.0	36.4	0.84	23.1	15.1	5.8
	10:50	252.9	46.6	0.86	30.3	18.2	7.6
	11:00	252.7	49.0	0.87	32.5	18.0	8.1
	11:10	252.7	33.3	0.84	21.2	13.7	5.3
	11:20	251.9	33.1	0.84	21.1	13.5	5.3
	11:30	251.1	49.2	0.88	32.7	17.3	8.2
	11:40	251.4	33.8	0.85	21.6	13.5	5.4
	11:50	251.6	34.0	0.85	21.7	13.6	5.4
	12:00	251.0	33.8	0.85	21.6	13.4	5.4
	12:10	250.3	33.9	0.85	21.7	13.2	5.4
	12:20	249.3	47.4	0.88	31.1	17.1	7.8
	12:30	249.3	33.0	0.86	21.2	12.7	5.3
	12:40	247.1	32.9	0.87	21.3	11.9	5.3
	12:50	247.3	48.3	0.90	32.2	15.7	8.0

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (kW/farm)
	13:00	249.3	33.5	0.87	21.7	12.5	5.4
	13:10	249.5	33.6	0.86	21.6	13.0	5.4
	13:20	249.0	49.7	0.89	33.1	16.8	8.3
	13:30	249.7	33.7	0.86	21.7	13.0	5.4
	13:40	249.5	34.2	0.86	22.1	12.9	5.5
	13:50	248.8	48.5	0.89	32.1	16.7	8.0
	14:00	249.1	32.3	0.87	21.1	11.8	5.3
	14:10	249.7	33.7	0.86	21.6	13.0	5.4
	14:20	249.1	47.6	0.88	31.3	16.9	7.8
	14:30	248.9	33.6	0.86	21.5	12.8	5.4
	14:40	248.9	33.5	0.86	21.5	12.8	5.4
	14:50	248.4	46.1	0.88	30.1	16.5	7.5
	15:00	248.9	33.0	0.86	21.2	12.6	5.3
	15:10	249.1	32.9	0.86	21.2	12.5	5.3
	15:20	248.8	32.9	0.86	21.0	12.6	5.3
	15:30	248.6	48.0	0.89	31.8	16.4	8.0
	15:40	248.6	47.3	0.89	31.2	16.4	7.8
	15:50	248.9	47.0	0.88	31.0	16.5	7.7
	16:00	249.4	31.6	0.85	20.1	12.5	5.0
	16:10	249.0	31.7	0.85	20.2	12.4	5.0
	16:20	249.5	17.5	0.81	10.7	7.6	2.7
	16:30	249.0	17.9	0.81	10.8	7.8	2.7
	16:40	248.4	27.2	0.80	16.1	12.3	4.0
	16:50	248.4	27.0	0.80	16.0	12.2	4.0
	17:00	248.6	16.8	0.67	8.4	9.3	2.1
	17:10	248.2	28.7	0.69	14.8	15.5	3.7
	17:20	248.3	28.5	0.69	14.6	15.4	3.6
	17:30	248.4	28.8	0.69	14.9	15.4	3.7
	17:40	248.6	28.4	0.68	14.5	15.4	3.6
	17:50	248.9	28.6	0.69	14.7	15.5	3.7
	18:00	249.7	19.9	0.66	9.9	11.2	2.5
	18:10	250.0	29.1	0.68	14.9	15.9	3.7
	18:20	250.7	20.1	0.66	9.9	11.4	2.5
	18:30	251.7	7.8	0.52	3.1	5.0	0.8
	18:40	250.7	7.7	0.53	3.1	4.9	0.8
	18:50	250.6	7.7	0.53	3.0	4.9	0.8
	19:00	249.5	8.0	0.53	3.2	5.1	0.8
	19:10	247.1	7.9	0.53	3.1	4.9	0.8
	19:20	245.1	32.6	0.83	19.8	13.4	5.0
	19:30	244.0	46.5	0.89	30.3	15.3	7.6
	19:40	244.0	46.8	0.89	30.5	15.5	7.6
	19:50	244.0	46.6	0.89	30.4	15.5	7.6

(table continues)

Date	Time	Voltage (V)	Current (A)	Power Factor (p.u)	Active Power (kW)	Reactive power (kVAr)	Load Density (kW/farm)
	20:00	243.7	46.7	0.89	30.5	15.4	7.6
	20:10	244.1	46.6	0.89	30.4	15.5	7.6
	20:20	244.2	47.0	0.89	30.6	15.7	7.7
	20:30	244.6	47.0	0.89	30.6	15.9	7.7
	20:40	244.4	46.6	0.89	30.3	15.9	7.6
	20:50	244.8	46.7	0.89	30.4	15.9	7.6
	21:00	245.1	46.4	0.88	30.1	16.1	7.5
	21:10	245.4	46.0	0.88	29.7	16.2	7.4
	21:20	245.9	46.0	0.87	29.7	16.5	7.4
	21:30	246.2	45.9	0.87	29.6	16.6	7.4
	21:40	246.2	45.9	0.87	29.6	16.5	7.4
	21:50	246.2	45.9	0.88	29.9	16.1	7.5
	22:00	246.3	46.5	0.88	30.4	16.0	7.6
	22:10	246.6	45.9	0.88	29.9	16.2	7.5
	22:20	247.1	46.0	0.87	29.7	16.9	7.4
	22:30	247.4	46.0	0.87	29.6	17.0	7.4
	22:40	247.4	45.5	0.87	29.3	16.8	7.3
	22:50	247.8	45.2	0.86	29.0	16.9	7.3
	23:00	247.9	44.8	0.86	28.8	16.8	7.2
	23:10	248.0	44.7	0.86	28.7	16.8	7.2
	23:20	247.3	44.5	0.87	28.6	16.5	7.2
	23:30	247.5	44.4	0.86	28.5	16.6	7.1
	23:40	247.5	44.7	0.86	28.6	16.9	7.1
	23:50	247.6	44.3	0.86	28.4	16.7	7.1
	00:00	247.6	44.1	0.86	28.1	16.7	7.0

APPENDIX F

TOU MODEL DATA

Appliance usage parentage (Non Local) Questionner

What is your current usage percentage in three different timing for the following appliances in summer and winter separately?

On-Peak : 1pm-5pm
Off-Peak : 9pm-6am
Other: 5pm-9pm,6am-1pm

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Appliance usage parentage (Non Local) Questionner

Scenario # 1

What will be the percentage usage of the same appliances if the tariff rate changes as the following in the three different timing?

On-Peak : 1pm-5pm *20 Fils/KWH*
Flat rate : 5pm-9pm,6am-1pm *15 Fils/KWH*
Off-Peak : 9pm-6am *13 Fils/KWH*

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Appliance usage parentage (Non Local) Questionner

Scenario # 2

What will be the percentage usage of the same appliances if the tariff rates change again as the following new rate in the three different timing?

On-Peak : 1pm-5pm *23 Fils/KWH*
Flat rate : 5pm-9pm,6am-1pm *15 Fils/KWH*
Off-Peak : 9pm-6am *11.5 Fils/KWH*

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Appliance usage percentage (Local) Questionner

What is your current usage percentage in three different timing for the following appliances in summer and winter separately?

On-Peak : 1pm-5pm
Off-Peak : 9pm-6am
Other: 5pm-9pm,6am-1pm

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Appliance usage percentage (Local) Questionner

Scenario # 1

What will be the percentage usage of the same appliances if the tariff rate changes as the following in the three different timing?

On-Peak : 1pm-5pm *6.5 Fils/KWH*
Flat rate : 5pm-9pm,6am-1pm *5 Fils/KWH*
Off-Peak : 9pm-6am *4.5 Fils/KWH*

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Appliance usage percentage (Local) Questionner

Scenario # 2

What will be the percentage usage of the same appliances if the tariff rates change again as the following new rate in the three different timing?

On-Peak : 1pm-5pm *7.5 Fils/KWH*
Flat rate : 5pm-9pm,6am-1pm *5 Fils/KWH*
Off-Peak : 9pm-6am *4 Fils/KWH*

Summer

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Winter

Percentage Usage	On-Peak	Off-Peak	Other
A/C			
Lighting			
Washing Machines			
Water Heater			
Sockets			
Cooker			

Examples of the survey results

Non Local Percentage Usage Of Appliances

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	70	50	50	20	0	5
Lighting	20	80	50	20	70	50
Washing Machines	40	50	30	20	50	30
Water Heater	10	10	10	40	50	50
Sockets	40	80	50	40	80	60
Cooker	40	40	30	40	40	30

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	50	30	50	10	0	0
Lighting	10	60	50	10	60	40
Washing Machines	20	80	10	20	80	10
Water Heater	0	10	5	30	70	40
Sockets	30	50	30	30	70	40
Cooker	30	50	40	40	50	40

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	50	50	50	20	0	20
Lighting	20	50	40	20	50	40
Washing Machines	30	50	30	20	50	30
Water Heater	10	30	10	40	80	40
Sockets	50	50	50	50	70	50
Cooker	20	50	50	30	70	30

Local Percentage Usage Of Appliances

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	80	40	70	30	0	20
Lighting	10	80	50	30	80	50
Washing Machines	50	10	20	50	10	30
Water Heater	10	40	30	50	80	60
Sockets	50	50	50	50	50	50
Cooker	70	50	30	70	60	30

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	70	30	50	20	10	20
Lighting	20	70	40	20	80	50
Washing Machines	70	20	20	70	20	20
Water Heater	20	50	30	60	80	60
Sockets	40	60	50	40	70	40
Cooker	60	50	50	60	50	50

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	90	50	50	30	5	10
Lighting	30	80	30	30	80	40
Washing Machines	80	30	30	80	30	30
Water Heater	10	30	30	50	90	60
Sockets	30	30	50	30	50	40
Cooker	70	60	20	70	60	40

Survey Analysis

Table F.1
Non local percentage usage in current status

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	60	40	50	20	5	10
Lighting	20	60	30	20	60	40
Washing Machines	10	70	20	10	60	20
Water Heater	0	30	20	30	50	30
Sockets	30	70	50	30	70	50
Cooker	60	30	20	60	30	20

Table F.2
Non local percentage usage in scenario 1

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	40	30	30	10	5	5
Lighting	10	45	30	20	60	30
Washing Machines	10	70	10	5	60	10
Water Heater	0	30	10	10	60	20
Sockets	10	70	40	20	80	30
Cooker	30	20	50	30	20	50

Table F.3
Non local percentage usage in scenario 2

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	30	40	30	10	5	5
Lighting	5	50	20	10	60	30
Washing Machines	0	70	10	0	70	10
Water Heater	0	40	5	5	60	10
Sockets	5	70	30	10	80	20
Cooker	20	30	60	20	30	60

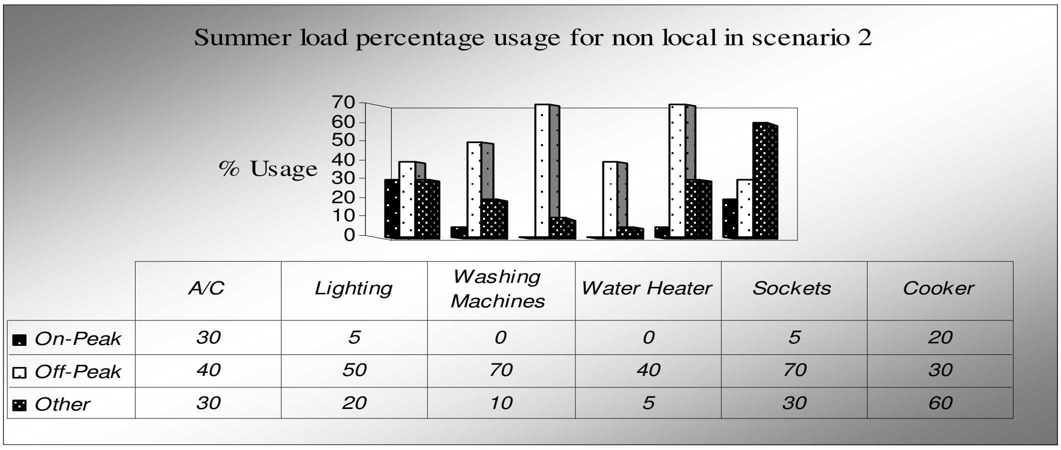


Fig. F.1 Summer load percentage usage for non local in scenario 2

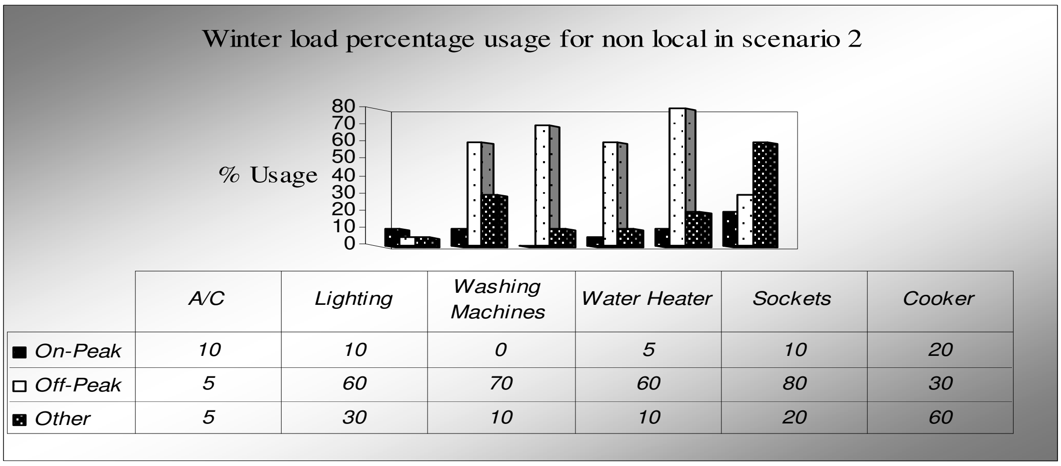


Fig. F.2 Winter load percentage usage for non local in Scenario 2

Table F.4
Local percentage usage in current status

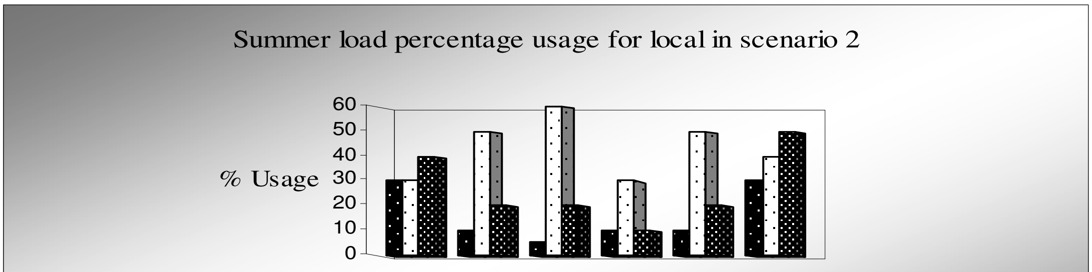
	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	70	40	60	20	10	10
Lighting	40	70	50	50	70	60
Washing Machines	30	10	30	30	5	30
Water Heater	20	30	30	50	90	70
Sockets	40	60	50	40	70	50
Cooker	60	50	20	60	40	30

Table F.5
local percentage usage in Scenario 1

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	40	30	50	10	0	5
Lighting	10	60	20	20	70	30
Washing Machines	5	40	20	5	40	20
Water Heater	20	30	5	40	70	60
Sockets	20	60	20	20	60	20
Cooker	50	40	20	50	40	20

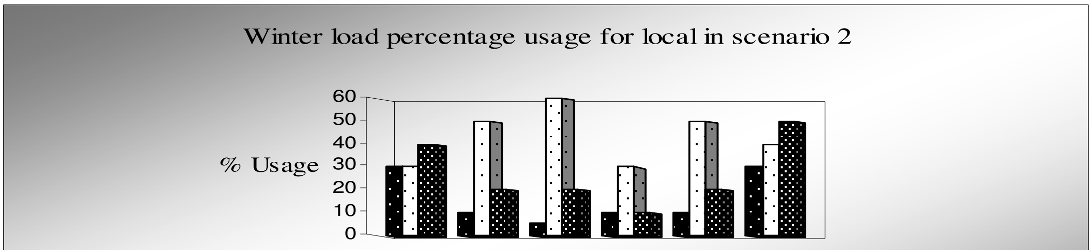
Table F.6
local percentage usage in Scenario 2

	Summer			Winter		
Percentage Usage	On-Peak	Off-Peak	Other	On-Peak	Off-Peak	Other
A/C	30	30	40	10	0	5
Lighting	10	50	20	10	50	30
Washing Machines	5	60	20	5	50	20
Water Heater	10	30	10	20	70	40
Sockets	10	50	20	10	60	20
Cooker	30	40	50	30	40	50



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	30	10	5	10	10	30
Off-Peak	30	50	60	30	50	40
Other	40	20	20	10	20	50

Fig.F.3 Summer load percentage usage for local in scenario 2



	A/C	Lighting	Washing Machines	Water Heater	Sockets	Cooker
On-Peak	30	10	5	10	10	30
Off-Peak	30	50	60	30	50	40
Other	40	20	20	10	20	50

Fig. F.4 Winter load percentage usage for local in scenario 2

Table F.7
Reduction in Scenario 1(Non Local)

Usage Reduction %	Summer %	Winter%
A/C	50	15
Lighting	25	10
Washing Machines	10	15
Water Heater	10	20
Sockets	30	20
Cooker	10	10
Total	22.5	15

Table F.8
Reduction in scenario 2(Non local)

Usage Reduction %	Summer(%)	Winter(%)
A/C	50	15
Lighting	35	20
Washing Machines	20	10
Water Heater	5	35
Sockets	45	40
Cooker	0	0
Total	26	20

Table F.9
Reduction in Scenario 1(Local)

Usage Reduction %	Summer(%)	Winter(%)
A/C	50	25
Lighting	70	60
Washing Machines	5	0
Water Heater	25	40
Sockets	50	60
Cooker	20	20
Total	37	34

Table F.10
Reduction in Scenario 2(local)

Usage Reduction %	Summer(%)	Winter(%)
A/C	70	25
Lighting	80	90
Washing Machines	-15	-10
Water Heater	30	80
Sockets	70	70
Cooker	10	10
Total	41	44

Table F.11
Reduction in Scenario 1

Usage Reduction %	Summer(%)	Winter(%)
A/C	50	20
Lighting	48	35
Washing Machines	8	8
Water Heater	18	30
Sockets	40	40
Cooker	15	15
Total	30	25

Table F.12
Reduction in Scenario 2

Usage Reduction %	Summer(%)	Winter(%)
A/C	60	20
Lighting	58	55
Washing Machines	3	0
Water Heater	18	58
Sockets	58	55
Cooker	5	5
Total	33	32

APPENDIX G

TARIFF RATES FOR ALL CATEGORY USED IN ADDC

Tariff Rate for all consumers

	PRICE_CODE	PRICE_DES	FIXED_TARRIF_W	FIXED_TARRIF_E
1	1	شيوخ كهرباء بعداد مياه	.01	.05
2	2	شيوخ كهرباء بدون عداد مياه	.01	.05
3	3	كبار الشخصيات بعداد مياه	.01	.05
4	4	كبار الشخصيات بدون عداد مياه	.01	.05
5	5	هيئات دبلوماسيه بعداد مياه	.01	.05
6	6	هيئات دبلوماسيه بدون عداد مياه	.01	.05
7	7	مساجد بعداد مياه	.01	.05
8	8	مساجد بدون عداد مياه	.01	.05
9	9	شئون اجتماعيه بعداد مياه	.01	.05
10	10	شئون اجتماعيه بدون عداد مياه	.01	.05
11	11	شئون اجتماعيه مناطق نائيه بعداد مياه	.01	.03
12	12	شئون اجتماعيه مناطق نائيه بدون عداد مياه	.01	.03
13	13	انديه وجمعيات النفع العام بعداد مياه	.01	.05
14	14	انديه وجمعيات النفع العام بدون عداد مياه	.01	.05
15	15	دبلوماسي بعداد مياه	.01	.05
16	16	شئون بعداد مياه رئيسي	.01	.05
17	17	مدارس خاصه بعداد مياه	.01	.1
18	18	مدارس خاصه بدون عداد مياه	.01	.1
19	19	وافد بعداد مياه مركزي	.01	.15
20	21	مواطن كهرباء بعداد مياه	.01	.05
21	22	مواطن كهرباء بدون عداد مياه	.01	.05
22	23	سكن / مزارع مواطن بعداد مياه	.01	.03
23	24	سكن / مزارع مواطن بدون عداد مياه	.01	.03
24	25	العزب بعداد مياه	.01	.05
25	26	العزب بدون عداد مياه	.01	.05
26	27	العزب مناطق نائيه بعداد مياه	.01	.03
27	28	العزب مناطق نائيه بدون عداد مياه	.01	.03
28	29	مواطن بعداد مياه رئيسي	.01	.05
29	30	سكن / مزارع مواطن تزود المياه بالصهاريج	.01	.03
30	31	حكومي ومدارس حكوميه بعداد مياه	.01	.1
31	32	حكومي ومدارس حكوميه بدون عداد مياه	.01	.1
32	33	مواطن من جهة حكومية بعداد مياه	.01	.05
33	34	مواطن من جهة حكومية بدون عداد	.01	.05
34	35	وافد من جهة حكومية بعداد مياه	.01	.15
35	36	وافد من جهة حكومية بدون عداد مياه	.01	.15
36	37	حكومي كهرباء فقط	.01	.1
37	38	حكومي بعداد مياه رئيسي	.01	.1
38	39	وافد بعداد مياه	.01	.15
39	40	وافد بدون عداد مياه	.01	.15
40	41	تجاري كهرباء بعداد مياه	.01	.15
41	42	تجاري كهرباء بدون عداد مياه	.01	.15
42	43	تجاري كهرباء فقط بدون مياه	.01	.15
43	45	خطوط مؤقتة بعداد مياه	.01	.15
44	46	خطوط مؤقتة كهرباء فقط	.01	.15
45	47	أشتراك كهرباء يتغذى من اخر	.01	.15
46	48	هـــــــدم كهرباء	.01	.15
47	50	قصور صاحب السمو رئيس الدولة وولي العهد	.01	.05
48	51	شيوخ مياه	.01	.05
49	53	كبار الشخصيات مياه	.01	.05
50	55	هيئات دبلوماسية مياه	.01	.05
51	57	مساجد مياه	.01	.05
52	59	شئون اجتماعيه مياه	.01	.05
53	61	شئون مناطق نائية مياه	.01	.03
54	63	اندية وجمعيات مياه	.01	.05
55	67	مدارس خاصة مياه	.01	.1

1

	PRICE_CODE	PRICE_DES	FIXED_TARRIF_W	FIXED_TARRIF_E
56	69	اشتراك رئيسي للبناية	.01	.15
57	71	مواطن مياه	.01	.05
58	73	سكن ومزارع للمواطنين	.01	.03
59	75	العزب مياه	.01	.05
60	77	العزب مناطق نائيه مياه	.01	.03
61	81	حكومي ومدارس حكومية مياه	.01	.1
62	83	مواطن من جهة حكومية مياه	.01	.05
63	85	وافد من جهة حكومية مياه	.01	.15
64	86	حكومي مياه فقط	.01	.1
65	88	معلقات لاتجلب لها قراءة مياه	.01	.1
66	89	وافد مياه	.01	.15
67	91	تجاري مياه	.01	.15
68	95	خطوط مؤقته مياه	.01	.15
69	96	ADDC Tanker Filling station	0	0
70	97	أشتراك مياه يتغذى من اخر	.01	.15
71	98	هدم مياه	.01	.15
72	99	مياه قيد الاجراء	.01	.15
73	100	خاص عقود	.01	.15

APPENDIX H

CUSTOMERS GROWTH RATE

Table H.1
No. of customer for years 2004 & 2005

Data Date	Operation Area	Location	Sample Loc	Parameter Type	Units
Jan-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Feb-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Mar-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Apr-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
May-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Jun-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Jul-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Aug-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Sep-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Oct-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Nov-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Dec-04	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Jan-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Feb-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Mar-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Apr-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
May-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Jun-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Jul-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Aug-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Sep-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Oct-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Nov-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number
Dec-05	ADDC	System-wide	Customer Count	12 Month Rolling Average	Number

Forecast No. of customer

$$Growth\_rate\% = \frac{(N05 - N04)}{N05} * 100 \quad = \quad 2.375762657$$

Where N04 is the no. of customers in 2004
N05 is the no. of customers in 2005

Since this growth rate cover for the two years history, sensitivity test of high scenario
25% will be added to predict the growth rate for the coming years
Growth rate = 2.37*0.25+2.37
= 2.969703321 = 3%

Table H.2
Total No. of customers

Year	No. of customers	Residential customers (No.)
2004	2310178	970275
2005	2366398	993887
2006	2437390	1023704
2007	2510512	1054415
2008	2585827	1086047
2009	2663402	1118629
2010	2743304	1152188

APPENDIX I

ECONOMIC ANALYSIS

Table I.1
Approximate Equipments Needed for Power Network in New Project

Equipments	Price/unit	Quantity	Total (Dhs)
33/11KV primary S/S 3x20MVA	24000000	1	24000000
33 kV cables with joints	360	20000	7200000
Pilot Cables with joints and installation	60	20000	1200000
11kV,3Cx240mm2 cables	248	46000	11408000
11kV ring main S/S (4 panels)	525890	46	24190940
4Cx 240mm2 LV cable	289	65000	18785000
FP	5065	185	937025
ST	3433	57	195681
Meters	500	700	350000
Total (Dhs)			88266646

Connected load (MVA)	112
Demand load (MVA)	49
Connected load (MW)	100.8
Demand load (MW)	44.1
CAPEX/MVA Connected	**788095**
CAPEX/MVA Demand	**1801360**
CAPEX/MW Connected	**875661**
CAPEX/MW Demand	**2001511**

Then For 11 KV Network

Load (MW)	CAPEX/load
Connected load	885,000
Demand load	2,000,000

VITA

Fatma Mohamed Khalfan was born on 1978 in AbuDhabi, UAE. She graduated with honours from Aysha Um Almuemeneen High School in AbuDhabi. She completed her undergraduate studies at UAE University College of Engineering in the field of Electrical Engineering in 2001. During that time she was trainee on ZADCO which is one of the oil companies, in the Mechanical and Electrical Repair Department.

After the graduation she worked for almost a year at Technip International Company, AbuDhabi branch, in the Power Department as Electrical Engineer. In year 2002 she was employed as Electrical Engineer in Abu Dhabi Distribution Company (ADDC) subsidiary of AbuDhabi Water and Electricity Authority (ADWEA) and presently working at a very important post as Strategic Planning Engineer in Asset Management Department of Power Network Division. She has attended various career development courses arranged by the company and has attended many conferences in country and abroad.

In September 2003, she enrolled in the Engineering System and Management Graduate Program at American University of Sharjah in the Department of Engineering and this Degree is going to make her excel further in her career.