DEVELOPMENT OF AN ACTIVE LOAD SHIFTING TECHNIQUE FOR DEMAND SIDE MANAGEMENT APPLICATIONS

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DEVELOPMENT OF AN ACTIVE LOAD SHIFTING TECHNIQUE FOR DEMAND SIDE MANAGEMENT APPLICATIONS

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By

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DECLARATION

I, Charles Chore Majani, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Majani
Signed

13th APRIL 2011
Date

ABSTRACT

Initiatives that are directed towards improving power management by a utility provider have to consider technical feasibility, socio-economic and the environment. Patterns of power consumption world over indicate that demand for electricity has over the years been on the rise due to increase in activities that demand usage of electricity. Such activities include construction and property development, development of industries and infrastructure. These activities have strained the power production, whose development does not match the increase in demand. ESKOM, a government authority mandated to generate, transmit and distribute power in South Africa has seen demand surpassing its generation capacity, hence resorting to load shedding actions. Load shedding imposes inconveniences to the consumers who are completely disconnected from the grid, translating to unpredictable periods of darkness. Utility providers have an option of constructing new peaker plants which lie idle most of the day, to take care of high demand during the peak periods, hence, avoid effecting load shedding actions.

Various ways of managing load have been presented in this research. In particular, the research investigated possible ways utilities use in managing their capacity with an aim of developing an alternative method and tool for Demand Side Management applications that can be used by energy utility to improve reliability, manage and control consumption of electrical energy through selective shedding of the load connected to the consumer when the demand surpasses the utility's safe capacity.

A characteristic feature of the research is the possibility of utility provider selectively switching OFF the customers' appliances in order to manage the energy consumption and regulate the load strain on the system. The benefits of active load shifting include conservation of energy, control of energy utilisation by the utility provider and at the same time reschedule construction of new power stations, customers not being affected adversely in case of load shedding. Effectively there will be a saving on the limited energy resources and deferment of construction of new plants avoids the emission of gasses which contributes toward minimisation of environmental degradation.

An overview of design and simulation results using ILC 150 ETH programmable controller have been presented. The various scenarios at the utility side were simulated in the LabVIEW program. The front panel control was published on the intranet to enable changes at different remote points.

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DEDICATION

Jane, Joy, Sally, Keith and Carol.

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ABBREVIATIONS/GLOSSARY

aka	also known as
ALST	Active Load Shifting Technique
CCN	Central Control Network
CPU	Central Processing Unit
CPP	Critical Peak Pricing
CVR	Conservation Voltage Regulation
DCN	Distributed Control Network
DLC	Direct Load Control
DR	Demand Response
DSM	Demand-Side Management
ETH	Ethernet
FBD	Function Block Diagram
FERC	Federal Energy Regulatory Commission
HMI	Human Machine Interface
IEC	International Electrotechnology Commission
IL	Instruction List
ILC	Inline Controller
ISO	Independent System Operator
LD	Ladder Diagram
LDC	Load Duration Curve
LED	Light Emitting Diode
PLC	Programmable Logic Controller
RTO	Regional Transmission Organisation
RTP	Real-time pricing
SFC	Sequential Function Charts
SSM	Supply side management
ST	Structured Text
TOU	Time-of-Use
US	United States of America

Actuator	A mechanism that causes a device to be adjusted, turned on or off, or moved.
Baseload demand	This is the minimum amount of power that a utility or distribution company must make available to its customers. It also refers to the amount of power required to meet minimum demands based on reasonable expectations of customer requirements.
Baseload plant	An energy plant dedicated to the production of baseload supply.

	These plants are the production facilities used to meet some or all of a given region's continuous energy demand, and produces energy at a constant rate, usually at a low cost relative to other production facilities available to the system. In most cases, the baseload plants are hydroelectric, nuclear and coal-fired.
Baseload supply	This is the actual available power used to meet minimum expected customer requirements (baseload demand) at a particular time.
Central Processing Unit (CPU)	is the nerve centre of a computer system that performs the central control functions and all computational, logical, and operational decisions. It contains the logic circuitry for performing the various computational activities. It has a memory where information or instructions are fetched, decoded to ensure operations called for by the instructions are executed properly
Coincident demand	Is the energy demand required by a given customer or class of customers during a particular time period.
Coincident peak	This is a situation when two or more systems or subsystems place demand on another system at the same time. The term is used to describe energy demand at any time when these parties' needs overlap with each other.
Coincident peak demand	Refers to demand among a group of customers that coincides with total demand on the system at that time. For example, residential demand at a time of peak industrial demand can be considered as coincident peak demand.
Demand response	Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised.
Demand side management:	These are deliberate actions that influence the quantity or patterns of use of energy consumed by end users. The actions target reduction of peak demand during periods when energy-supply systems are constrained. Peak demand management does not necessarily decrease total energy consumption but could be expected to reduce the need for investments in networks and/or power plants.
Electric utility	Any entity that generates, transmits, or distributes electricity and recovers the cost of its generation, transmission or distribution assets and operations, either directly or indirectly, through cost-based rates set by a separate regulatory authority (e.g., State Public Service Commission), or is owned by a governmental unit or the consumers that the entity serves. Examples of these entities include: investor owned entities, public power districts, public utility districts, municipalities, rural electric cooperatives.
Electricity demand	The rate at which energy is delivered to loads and scheduling points by generation, transmission, and distribution facilities.
Energy conservation	The act or process of reducing resource requirement for energy production and delivery or energy consumption.
Energy efficiency	Refers to programs aimed at reducing the energy used by specific end-use devices and systems, without affecting the services provided. Examples include high-efficiency appliances, efficient 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.

Energy savings A reduction in the amount of electricity used by end users as a result of participation in energy efficiency programs and load management programs.

Energy service provider (ESCo): An energy entity that provides service to a retail or end-use customer.

Federal Energy Regulatory Commission (FERC) This is an independent regulatory agency within the Department of Energy in the U.S with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification.

Fieldbus Is a generic-term that is used to describe a digital communications network which is used in industry to replace the 4 - 20mA analogue signal. The network is a digital, bi-directional, multi-drop, serial-bus, communications network used to connect isolated/remote field devices, such as controllers, transducers, actuators and sensors.

Grid Grid or electrical grid is an interconnected network or system used to deliver electricity from the generating stations to the consumer.

Interruptible load This Demand-Side Management category represents the consumer load that, in accordance with contractual arrangements, can be interrupted at the time of annual peak load by the action of the consumer at the direct request of the system operator. This type of control usually involves large-volume commercial and industrial consumers. Interruptible Load does not include Direct Load Control.

IP address An Internet Protocol (IP) address is a unique address used by certain electronic devices on a computer network utilising the Internet Protocol standard (IP) to communicate.

Load (electric) The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

Load control program A program in which the utility company offers a lower rate in return for having permission to turn off the air conditioner or water heater for short periods of time by remote control. This control allows the utility to reduce peak demand.

Load curve A chart that indicates amount of electrical energy the customers use over a period of time. The information is essential in planning the quantity of energy to make available at any given time by the power producers.

Load duration curve A diagram that illustrates the relationship between generating capacity requirements and capacity utilisation for each increment of load. The demand data of a load duration curve is arranged in descending order of magnitude, rather than chronologically.

Load shedding This is an act of denying a customer access to energy, usually due to temporary shortage of supply. This action is most commonly applied during times of emergency or severe shortage.

Load shifting The technique of altering the pattern of energy use so that on-peak

	energy use is moved to off-peak periods. Load shifting is an essential demand-side management objective.
Marginal cost	This is the cost of providing an additional kilowatt-hour of energy output over and above any energy currently being produced. It only includes immediate expenses required to produce more energy.
Off peak	Period of relatively low system demand. These periods often occur in daily, weekly, and seasonal patterns; these off-peak periods differ for each individual electric utility.
On peak	Periods of relatively high system demand. These periods often occur in daily, weekly, and seasonal patterns; these on-peak periods differ for each individual electric utility.
Peak demand or Peak load	The maximum load during a specified period of time.
Peaker plant	A plant usually housing old, low-efficiency steam units, gas turbines, diesels, or pumped-storage hydroelectric equipment normally used during the peak-load periods.
Programmable Controller	An electronic device that can be programmed to control a process or machine operation. It typically consists of a power supply, processor, memory, inputs and outputs.
Protocol	A set of rules that enables two or more devices to communicate.
Spinning reserve	Spinning reserve is any back-up energy production capacity which can be made available to a transmission system within short notice and can operate continuously for at least two hours once it is brought online. The term is derived from hydroelectric and combustion turbine terminology. Reserve generator turbines can literally be kept spinning without producing any energy as a way to reduce the length of time required to bring them online when needed.
Tariff	A published volume of rate schedules and general terms and conditions under which a product or service will be supplied.
Valley filling	This Is a program that encourages additional use of energy during periods of lowest system demand in order to maximise efficiency of energy production and delivery of the system. Valley filling programs are usually accompanied by load shifting programs, often with the aim of shifting peak demand usage to low demand periods, but the term can refer to any program or strategy aimed at filling the valley.
Weatherisation	An energy industry term that refers to energy efficiency measures aimed at improving a structure's insulation against heat gains or losses; synonymous with weatherproofing and, in colder climates, winterisation. Weatherisation measures can include weather-stripping, installation of double- or triple-glazed windows, addition of insulation to walls and ceilings, and the use of shutters or blinds among many others.

CHAPTER ONE

INTRODUCTION

1.1 Background

"***Prosperity is not just for us, but for the whole world. I think it is inextricably linked to energy. Without sufficient energy, everybody's standard of living starts to decline. Abundance of sustainable energy is probably the solution to a lot of our problems. With energy, all other problems can be solved, without it, everything begins to fall apart***." These words by Divan (2007) during the IEEE conference on smart grid indicate the important role that energy plays in the human life. It is an indication that the standard of living is, and will continue to be determined on the basis of the amount of energy resources available. This being the case, effort has to be made to ensure that there is sustainable energy for equally sustainable development.

Electric utilities play the role of providing a supply that is reliable, efficient and economical to the connected customer. There are challenges that the utilities have to face such as the fast changing technology, environmental concerns, political interests, world credit crunch as well as social limitations. In order to continue to be relevant, utilities have continued to seek ways that helps to improve reliability and efficiency of the existing systems.

A greater portion of generation and transmission energy capacity within the electricity industry is used for a small fraction of the time. According to PJM Market data in the US (2008), over the calendar year 2006, 15% of the generation capacity in the Pennsylvania-New Jersey-Maryland (PJM) territory ran less than 1.1 percent of the time, and 20 percent of capacity ran less than 2.3 percent of the time. This translates to billions of dollars being invested in peaking generation that has low capital cost, but high generation cost as well as life cycle social cost.

The excessive peaking capacity has two effects. The first one being technical, whereby enough system capacity is required in order to satisfy demand at all times otherwise there will be a blackout. The second is regulatory where a majority of the customers pay a constant flat-rate price for power instead of responding to the changing hourly price of the wholesale market.

The Flat-rate customers have no incentive to make them shift consumption away from peak-demand times. However, a number of electricity customers face "time of use" (TOU) pricing regime that is based on charging a higher price during on-peak hours compared to the off-peak rates. As observed by Barbose (2004), some utilities apply the "real time pricing" (RTP) policy to some of their connected customers. This policy entails retail price determination based on the hourly wholesale generation price. These strategies by the utilities are aimed at provision of both reliable and sustainable supply of electric energy.

In the past, electric utilities focused mainly on the supply side of their business to meet their power needs. This meant that as the customer demand for electric energy increased; the electric utilities reacted by building new generating plants to cater for the increase in demand. Opportunities for demand side management begun to be recognised in the seventies where utilities designed activities that were geared towards influencing the way customers used their energy. Among these programs by the utilities were: load management, customer generation and strategic conservation (Hyman and Peterson, 1988). Time has come when the role of energy management cannot be placed under a single entity only (utility or consumer), but both have to support each other.

Initiatives that are directed towards improving power management by an electric utility company have to consider technical feasibility, socio-economic and the impact of the improvement on the environment. Patterns of power consumption world over indicate that the demand for electric power has over the years been on the rise due to increase in activities that demand usage of electricity. Such activities include construction and property development, development of industries and infrastructure. These activities have placed a greater strain on the production of electric power.

The development of energy sector does not match the un-paralleled demand increase. Eskom, a South African government authority mandated to generate, transmit and in some cases, distribute power (Eskom[1], 2008) has seen the demand for power far surpassing its generation capacity, hence, resorting to controlling the usage of energy through actions of load shedding. The country is one of the most industrialised in Africa and is extremely energy-intensive due to lack of awareness of energy efficiency and demand side management. Also the low cost of electricity previously contributed to poor financial viability of energy reduction projects (Eskom[2]).

Load shedding imposes inconveniences to the affected consumers by completely denying them access to electrical energy, at times for unpredictable periods of darkness.

Introduction of electrical energy management in industrial sector is the effective method of minimising the energy consumed by industries as well as for improvement of reliability of power supply system of the Power Supply Industry. However, in this study, electrical energy management is to concentrate on selective (discriminative) shedding of the load in homes by the energy provider as a way of stabilising the demand. This will involve the energy provider sending signals to disengage certain appliances from the supply especially during peak energy demand times.

1.2 Problem Statement

During peak times when energy demand overstretches the production capacity, utilities resort to a blanket load shedding action in which case, the consumers are completely denied energy for duration of time. In some situations, governments in conjunction with utilities construct peaking plants that are only activated during the peak periods. It may not make economic sense for the peaking plants to remain idle for long durations, or else it may not be possible for the capital costs to be recovered. DSM programs can, to some extent, assist in reducing the energy consumption during peak times. However, the current topologies place the onus of implementation of these programs on the consumer. If the consumer opts not to act, the utility responds by shedding off the load in order to stabilise the system. The load shedding action disconnects all the loads connected, and hence a complete denial of energy.

1.3 Research Objectives

The primary objective of the research was to explore techniques and strategies that can be applied in order to effectively control the power consumption\purchased by domestic\commercial clients of a power utility and improve reliability of electrical supply by introducing an electrical energy management tool and strategies to the consumers. A characteristic of the research is possibility of the utility provider selectively switching OFF the customer's appliances in order to manage the energy consumption and regulate the load strain on the system especially during peak demand periods. The research object was to design an electronically controlled device that can be installed at the consumer's side, which selectively disconnects particular appliances upon receiving a signal from a control point within the utility provider so as to control the energy consumption during the high energy demand periods.

The research was carried out keeping in mind the following objectives:

- Analysis of the performance and implementation of Demand side management (DSM) options
- Technology survey, comparison and evaluation of the different techniques of DSM
- Develop an algorithm to implement selective load shifting technique
- Test the performance of the designed system

1.4 Thesis Statement

The overall study was to develop an alternative method and tool for Demand Side Management applications that can be used by energy utility to improve reliability, manage and control consumption of electrical energy, by selectively shedding the load connected to the consumer when the demand surpasses the safe capacity of the utility.

1.5 Delineation

The benefits of electrical energy management are significant to consumers, utilities and Governments. The research will much concentrate on the consumers in the residential sector. This research project will investigate and research possible way of actively shifting the load for demand side management applications. The magnitude of energy consumed will be detected and signals transmitted by the utility provider, to selectively turn OFF power to designated appliances in order to keep the demand within the acceptable limits. The research does not include the setting up of a communication link between the PC at the utility and the control device at the consumers' side.

1.6 Significance of the Research

The standard of living and degree of industrialisation of a country has a direct link to the electrical energy sector. Electrical energy is one of the commodities vastly generated and widely used in developed/industrialised world. However, with the customers consuming large amounts of energy, a high burden is felt by the utility industries since their declared capacity of energy is less than the demand. This scenario forces the utility to apply load shedding techniques that completely disconnect the consumers from the supply grid.

The proposed techniques will ensure that the consumers are not completely switched OFF from the power supply grid in cases of load shedding. This will be of advantage to both the consumer and the utility. For example in residential areas, certain appliances on the consumer's side such as geysers can be switched OFF while the lighting system is left intact. Industries with machines that have large lead-times will be spared the inconveniences. The power producers will have control over power consumption and at the same time reschedule construction of new power generating plants; effectively there will be a saving on the limited energy resources and contribution towards minimisation of environmental degradation.

1.7 Thesis Outline

The introduction to this thesis has been covered in chapter one. Chapter 2 considers the literature survey. In this chapter, various works on demand side management of electrical energy have been highlighted. Comparisons, features and merits of each topology have also been mentioned.

Chapter 3 discusses the aspect of load management. The chapter highlights the importance of load profile, ways in which maximum benefits can be realised through load management strategies and the scenario of load demand sectors of South Africa. The chapter rounds up with information on selected CPUT substations that mirror various demand sectors.

Chapter 4 introduces aspects of demand side management. In this chapter, various DSM program options intended to produce particular characteristics in customer behaviour toward energy consumption have been considered. In addition, load shape objectives and potential of smart technology in implementing DSM programmes have been discussed.

Chapter 5 discusses facets of programmable logic controller. Various PLC programming languages have also been outlined.

The results have been highlighted in chapters 6 and 7. In Chapter 6, details of ALST design, PC protocol, system realisation and the PLC protocol have been provided. Chapter 7 considers implementation of the ALST in LabVIEW environment. Conclusions and recommendations are presented in Chapter 8.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Any efforts intended to bring improvements of power management by a utility provider have to consider technical feasibility, socio-economic and the environment. The exponential rise in power consumption patterns world over has resulted to electric utilities to explore new choices for their future. Rather than sticking to their traditional role of being suppliers of electricity, many of them have repositioned themselves as marketers of energy services (Gellings and Smith, 1989), at the same time, are forging closer relationships with their connected customers. This mutual relationship is to assist in controlling the electricity costs as well as shaping the electricity demand patterns, thereby bringing benefits to both the utility and the consumer. In this chapter, a review of Demand side management is undertaken. Various Demand-Side Management techniques and their benefits are highlighted.

2.2 Demand side management

Demand-Side Management programs have been praised and proclaimed in recent times as a great advancement in provision of new options for utilities to assure efficient and reliable supply of energy and at the same time, assist the connected customers to manage their energy use and costs. Electric utilities started implementing programs which had been designed to alter both the level and timing of electricity demand among their customers in the early seventies. These programs referred to as demand-side management (DSM), arose due to escalating prices of oil and gas (Loughran and Kulick, 2004).

Ashok and Banerjee (2000) identified two goals of investing in Demand-side management (DSM) activities as energy efficiency and load management. The DSM programs contribute to improved performance of energy supply facilities, thereby reducing the requirements for new facilities. As they noted, the available energy resources have to be assigned efficiently in order to derive greater benefits for the national economy.

In a report prepared by the International Institute of Energy Conservation (IIEC, 2006), it was noted that the increase in fossil fuel costs made electricity production to be expensive. The trend created an avenue for power utilities to seek alternate strategies such as investment into renewable energy technologies and work towards optimising demand side consumption. One of the goals of DSM is to cut on the consumption of energy, an act that is bound to reduce the profits for utility. At the same time, it is a considered duty for the energy providers to make profit (Lee *et al,* 2007; Gellings, 1985). This calls for a balancing act by the utility company so as not to compromise the 'business oriented profit making goal' and implementation of energy reduction strategies. Pete (2006) correctly concluded that utilities and governments have to recognise DSM programmes as essential "tool-box" in making energy systems more suited to their purpose. Furthermore, there have been many changes in the organisation of the energy markets in the world and accordingly, the DSM programmes have been adjusted in order to cater for the actual and changing circumstances.

In most countries of the world, electric utilities have been seen in terms of providing electrical energy for use by the consumers. The electric utilities are therefore, always associated with the power plants including generators and transformers. Nevertheless, utility providers have diversified their operations by formulating policies and strategies that are geared towards reducing consumption of energy by their connected customers.

One of the major problems encountered by an electric utility is whether it is possible to determine the actual manner of energy consumption over a period of time. This information is vital since it results to more effective demand side management (DSM) (Ali and Islam, 2004).

The behaviour of the load significantly weighs on the utility planning and strategic corporate objectives of realising maximum earnings and cash flow, reduction of risks (Schaefer, 1985). Some of the ways in which these objectives are realised include peak clipping, load shifting, energy conservation, load growth and flexible reliability. This calls for investigation of energy consumption to be undertaken in conjunction with the general shape of its load and the variation of this shape during the year (Mitropoulos *et al*, 1995)

Energy conservation has become a major concern in many countries of the world and the policy makers are faced with the challenge of identifying the best way that promotes and/or supports efficient use of energy by consumers. In fact, some of the countries with high energy prices and taxes argue that the market forces are sufficient economic incentives for energy conservation, and therefore the intervention of governments or states needs to be restricted to areas of doing away with impediments of market mechanisms and/or providing consumers with information regarding benefits of conservation (Sioshansi, 1994).

Studies have been carried out to examine the reasons of running programmes that assist consumers in keeping in check their electricity bills. The oil embargo imposed by the Arab nations in the early eighties served as stimuli for utilities to seriously consider implementation of DSM programmes (Hirst *et al,* 1996). With the increase in the world population, energy demand in both developed and developing worlds has continued to rise. Marechal *et al* (2005) as well as Rankin and Rousseau (2008) are in agreement with the fact that the high electrical energy demand has put strains on the energy utility providers and at the same time, it has presented technological challenges that can lead to reduction of specific consumption.

Boyle (1996) identified two situations where DSM option is more attractive. The first situation is when the demand for electricity grows faster than the generation capacity. The second situation is the utility provider is faced with limited financing options. In case the utility provider was financially sound, then the obvious option would be to construct a new plant that will cater for the increase. However, in a situation where there is over-capacity, there are greater challenges of convincing customers to participate in the DSM programmes. Nevertheless, it has to be noted that the solution of yesterday may not be fit for tomorrow. For example, Boyle had also observed that by 1996, South Africa had over-capacity of energy and yet the current scenario demands aggressive promotion and implementation of DSM programmes and/or techniques to curb the spiraling energy demand.

As Sagar and Zwaan (2006) aver, "the development and deployment of new and improved energy technologies have been and will continue to be, central to the transition towards cleaner and more efficient forms of energy production and consumption". This means that new and improved technologies permit for changes in the trajectory of the energy sector in several ways; enabling it to deliver better services, to become more efficient, and to respond to environmental matters like local air pollution and global climate change.

2.3 DSM Categories

The major categories of Demand Side Management are shown in Figure 2.1. The topology or the DSM technique applied has an impact on the energy use, which effectively contributes to safeguarding of the environment, reducing greenhouse gas emissions, promoting sustainable use of energy resources and reducing energy costs. The other benefits derived from DSM (Saini, 2004) include:

- demand during peak periods is reduced
- rescheduling requirement for infrastructure capital investment.
- reduced costs in electricity
- customers can choose from a range of electricity efficient options to implement and benefit financially.
- supporting the macro-economic development of economies through improved productivity.

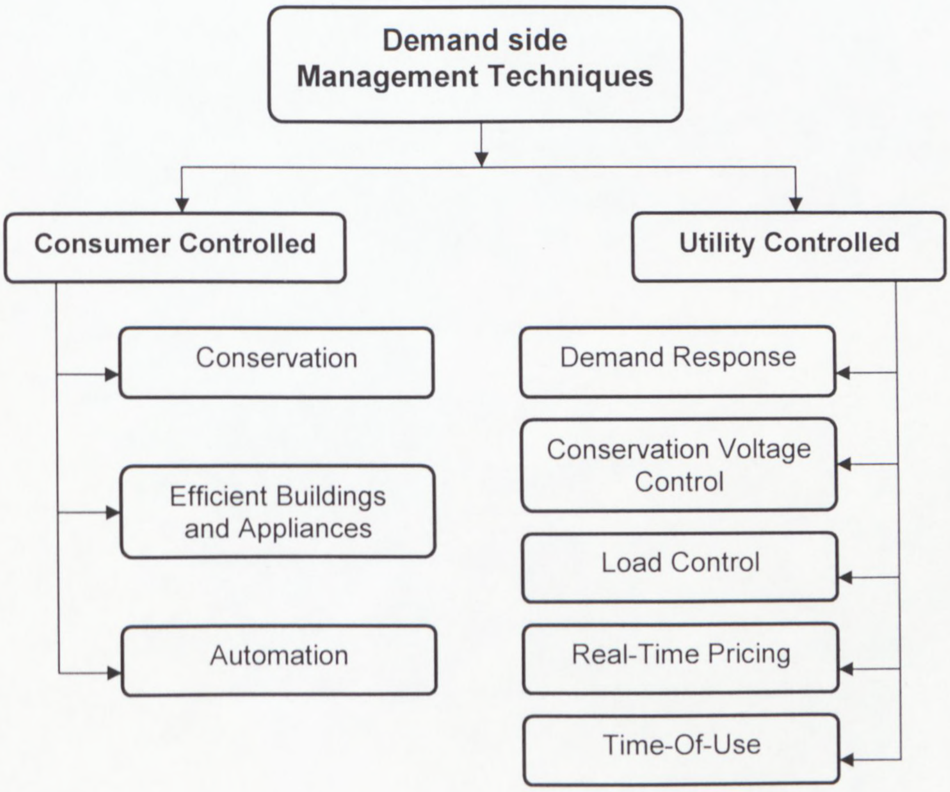


Figure 2.1: Categories of Demand Side Management Techniques.

2.3.1 Conservation

This method of DSM encompasses provision of education to the consumer on ways that will lead to either less energy utilisation or usage of energy in a less expensive manner. Conservation programs that include information programs like audits, media advertising, and school programs, provide important benefits to utilities. Information programs rely on information distributed to utility customers as the basis for achieving changes in customer energy use. Tactics include brochures, hand-bills, newspaper inserts, displays, information packets, advertising, direct mailings, workshops and other face-to-face contact (Hyman and Peterson, 1988).

These conservation programs are essential in building a positive image with customers. More importantly, they serve as effective relationship builders and marketing tools, providing a way for utility representatives to meet with and see the facilities of customers who might be candidates for other services or products (Gehring, 2002). In fact, Lombard *et al* (1999) indicate that promotion and education is one of the four actions that need to be emphasised and incorporated into the development plan of a utility. Other advantages of these information strategies include low cost, easy implementation and quick access to a large share of the potential market.

However, conservation strategy has been one of the least effective DSM techniques due to the readily available low-cost energy (Brian, 2005). In addition, the drawback of this method hinges on the difficulty in determining the success of the programme due to evaluation problems. In other words, there is no proper follow-up since the utility provider may not know the decision that the customer makes thereafter (once such education has been provided). The option of implementing the strategy lies squarely with the customer. Nevertheless, this attitude is fast changing as a result of increased prices of energy, effectively translating to higher electricity bills. The situation has been compounded with the global economic meltdown, making conservation to be one of the viable DSM programs.

2.3.2 Conservation Voltage Reduction

This option of DSM allows utility or energy provider to lower the voltage on the distribution circuits feeding homes and businesses to the lowest value that will not harm equipment or make it perform poorly. The aim of Conservation Voltage Reduction (CVR) is to have the customer's utilisation voltage at the lowest level, but consistent within proper operation of equipment (within ratings of utilisation equipment) and also within the regulatory settings as well as standards set by organisations (Wilson, 2002). The American National Standards Institute's (ANSI) standard C 84.1 requirement for the voltage variation at the distribution transformer secondary terminals is given as:

$$V_{TX} = V_N(1 \pm 0.05) \qquad (2.1)$$

Where: V_{TX} is the voltage at the secondary terminals of the transformer and V_N is the nominal value of voltage.

In case the nominal voltage were 240V, the transformer terminal voltage will vary between 240 x 0.95 and 240 x 1.05 (i.e. 228V and 252V)

The two strategies of implementing CVR according to DeSteese *et al* (1990) are Voltage Spread Reduction (VSR) and Line Drop Compensation (LDC). Implementation of CVR using the first strategy (VSR) is through compression of the feeder voltage range. With adequate voltage margin on the circuits, the regulator voltage level controls can be adjusted to a narrower range that does not compromise on the required minimum voltage value at far distant load. The second strategy (LDC) entails setting of the controls on the voltage regulators or load tap changing transformers to ensure that the voltage level at the far distant part of the circuit is within the acceptable minimum range; the rest of the circuit voltage is allowed to fluctuate depending on the load conditions.

The benefits derived as a result of implementing CVR include energy savings through reduced distribution system losses (since the voltage is lower), lower energy bills, and longer life for the consumer's electrical appliances due to use of reduced voltage stresses.

Although CVR would seem to be a better option since the connected consumers will still continue to receive a measure of power, however, the efficiency of the machines using lower voltages will be compromised, and at the same time, equipment(s) that is/are sensitive to voltage fluctuations may malfunction during the times that the power has been reduced.

According to Wilson (2002), several utilities in the US were apprehensive in the sense that consumer response to reduced voltage was not encouraging. It was feared that consumers having knowledge of voltage manipulation by the utility would raise complains irrespective of whether their supply has a problem or not. The other drawback of CVR is the differential reduction in energy usage. In other words, customers far away from the utility's substation may experience serious under voltage situations compared to those who are near.

2.3.3 Demand Response

This is DSM oriented toward and motivated by a need to reduce peak demand, which focuses on methods that the utility can control by request or operation, obtaining 'response' (reduction) when needed because it is running short of energy or equipment capacity on its system.

According to Sioshansi (2001), the success of Demand Response (DR) lies in the ability to encourage some customers to forego their electricity usage in capacity-constrained systems in order that others may continue to be served by the utility provider. This implies that the targeted customers have elastic or discretionary demand and have to be enticed to forego usage of energy during those periods that the capacity on the utility is constrained by the demand. The DR programs are best suited for networks that are "over-subscribed" during a significant number of hours.

In most load shedding applications, the utility calls or e-mails the customer with an energy reduction request and it is expected that the customer will take action. However, suggestions have been made with a view of automating the DR (Scott, 2007). Two conditions, economic and emergency are further suggested. In the economic condition, a signal is sent to the customer indicating that the cost of electricity has gone beyond a predetermined amount agreed upon by the utility and the customer. The response to this request is voluntary. On the other hand, a signal is sent to the customer in the emergency condition, indicating that the utility's reserve capacity is critically low. The response to this signal is mandatory.

There are some drawbacks with this option of DSM. First the customer has the discretion of choosing either to participate or not. This effectively defeats the purpose of lowering the strain on the system due to peak demand. The second drawback is due to 'the not at home' cases. In this situation, the information may be sent to a customer who is not available to respond to the request.

2.3.4 Load Control

There are two ways in which the control of load at the consumer's side can be achieved. One method involves the control of many appliances from a central location (the electric utility in consultation with the consumer) to manage their usage, dropping the demand at peak and allowing the electric system to serve more homes with less peak energy output. The other method is to send information to the consumer regarding the prevailing situation; the consumer is then expected to take action within a stipulated time (Saini, 2004).

Just like other techniques discussed, the utility provider has to liaise with the consumer, and only when the capacity can not support the demand is when the utility provider can decide to completely remove some of the customers from the grid through load shedding. To this customer it is no longer 'load control' but 'energy denied'.

2.3.5 Automation

Automation involves computerising control of all appliances and machinery in the home or business, to schedule electrical usage among them so that they smooth out demand, resulting in lower peak usage and improved voltage regulation in the power system. (Philipson *et al* e-book :143).

The use of computerisation control leads to a "smart home" or an environment enriched with ambient intelligence (Cook *et al*, 2009). A "smart home" is equipped with several artefacts and items in a house that are enriched with sensors to gather information about their use and in some cases even to act independently without human intervention (Peine, 2008).

Some examples of such devices include electro-domestics (e.g., cooker and fridge) and temperature handling devices (e.g., air conditioning and radiators). Some of the benefits derived from using this technology include: (a) increasing safety (e.g., by monitoring lifestyle patterns or the latest activities and providing assistance when a possibly harmful situation is developing), (b) comfort (e.g., by adjusting temperature automatically), and (c) economy (e.g., by controlling the use of lights). The use of computerisation control is proactive since it can contribute to energy savings and hence, a positive demand side management initiative.

2.3.6 Real-Time Pricing

These are energy prices that are set for a specific time period on an advance or forward basis and which may change according to price changes in the market. Prices paid for energy consumed during these periods are typically established and known to consumers a day ahead ("day-ahead pricing") or an hour ahead ("hour-ahead pricing") in advance of such consumption, allowing them to vary their demand

and usage in response to such prices. In this way, customer can manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall.

In Real-Time pricing (RTP) program, the utility installs a 'smart' meter on the home or business that communicates with the utility's control centre to obtain the current 'price' for power. The customer's computer checks when the price is higher; it shuts down the appliances until the price level drops to the set value. Real-time pricing programs have the potential to overcome some of the limitations of behaviour modification incentives present in other DSM techniques (Chapman and Tramutola, 1990)

As suggested by Corner (1990), when a customer's 'pocket' is affected, he is capable of changing his energy usage pattern, leading to implementation of new on-site controls. Additionally the customer will be motivated to replace the less efficient equipment and facilities in order to realise some savings.

Although this alternative DSM technique is proactive, it has the drawback of initial capital cost of installation of the equipment to monitor the pricing. Demanding constant monitoring of the system imposes an inconvenience to the customer, who may see the system as restrictive rather than a solution.

2.3.7 Efficient Buildings and Appliances

Efficient buildings category of DSM calls for design measures that keep buildings naturally warm during winter and summer seasons. Gellings *et al*, (2006) observed that significant impacts on annual energy savings in the US forecasted for the year 2010 are associated with energy efficiency programs in the residential, commercial, and industrial sectors. They also observed that the residential sector energy efficiency programs have to target high-efficiency air conditioners that exceed current federal standards, improved building shell measures, and efficient lighting and appliances. A greater fraction is expected to be obtained through improvements in end-use devices and enforcement of higher standards in new construction.

The design and implementation cost of this category may seem to be high. However, the long term benefits will be derived by both the utility provider (less energy use) and the customer (less electricity bill to pay). On the other hand, efficient appliances category requires that appliances such as motors, air conditioners, lights etc, be designed with characteristics of reducing the energy consumption and minimising energy wastage.

As Philipson et al (e-book 89), note that the cost of efficient appliances is moderately high, though the benefits realised in using these appliances far outweigh the effect of the initial cost. An innovative design of a ceiling fan by Schmidt, et al (2001) is an addition to other designs of energy efficient appliances that can be used in DSM programmes.

While discussing the future DSM in the US, Hirst et al (1996) observed that measuring the performance of DSM programmes presents a challenge of making comparison of energy behaviour shown by the programme participants with the non-existent behaviour that the participants would have exhibited if they did not participate in the programme. They identified three factors that would make future DSM programmes succeed as technical cost-effective energy efficiency improvements, changes in the regulatory practices under which utilities operate and incentives offered by the utility providers.

2.3.8 Time-Of-Use (TOU)

The time-of-use (TOU) program is intended to offer the consumers an opportunity to efficiently use or manage their energy. This is achieved by installing special power meters that are used by the utility company to bill the customers differently, depending on the time of day. With the Time-Of-Use pricing, the end consumer may pay up between 3 and 5 times per kilowatt-hour of energy consumed during "peak" periods as compared to the "off-peak" rates. This offers a discretional incentive for the customer to shift the power usage to times where the 'per kilowatt' cost of energy is minimal (in the off-peak period).

TOU program benefits the customers in many ways. First, customers will be able to track their electricity usage and adjust accordingly. Second, knowledge of electricity usage will enable them make decisions on the appropriate appliances to buy and when to use the different appliances. Furthermore, knowledge of energy consumption and the associated cost may enhance the tolerance span of the customers. In this way, some may decide to do their laundry after the on-peak or not to switch on the air conditioner during a hot summer day (*unless such action may lead to a loss of life*!). Third, customers who participate in the TOU program will have less electricity bills.

Although the TOU approach offers incentives and information that can motivate the customers relocate their energy consumption to possible off-peak hours (weekends and night times), the affluent consumers may not adjust their load usage.

Furthermore, TOU does not account for the times when wholesale prices increase due to high demand or there are problems with the equipment (Barbose et al, 2004).

2.4 Conclusion

Energy conservation has become a major global concern and the policy makers are faced with the challenge of identifying the best way that promotes and/or supports efficient use of energy by consumers. Utilities have had to reconsider their traditional role of being suppliers of electricity by engaging in DSM activities that are directed towards achieving energy efficiency and load management.

The purpose of the DSM activities is to improve the performance of energy supply facilities, thereby reducing the requirements for new facilities. Furthermore, the available energy resources will be more efficiently assigned in order to derive benefits for the national economy. There have been many changes in the organisation of the energy markets in the world and the DSM programmes have accordingly been adjusted in order to cater for the actual and changing circumstances.

From the aforementioned literature, it is evident that great efforts have been put in place to make the aspect of load management as inclusive as possible. This has resulted to a shift from the traditional goal of utilities being suppliers of electricity demanded by the customers. Many of them have repositioned themselves as marketers of energy services through controlling the electricity costs as well as shaping the electricity demand patterns.

It is imperative that the available load be managed effectively to realise greater benefits by customers, utilities and the society. The aspects of load management and highlights of South African energy scenario are considered in the next chapter.

CHAPTER THREE

LOAD MANAGEMENT

3.0 Introduction

Electricity provides a convenient form of energy for lighting, heating, cooling and motive power for driving different types of loads. The growth and development of a country is sometimes determined by the utilisation of electrical power. Most of the industries are dependant on electrical energy for most of their operations. However, the sources for electrical energy are getting depleted leading to a widening of the gap between the supplied and the demanded load. Furthermore, it is not economically viable (at present), to store electricity on a large scale; hence, it is utilised in the same quantity that it is produced.

Due to fluctuations in electricity demand at different times on utility, it is necessary to effect load management so as to avoid or minimise on shutdowns or load shedding. Effective load management can reduce costs and therefore price of electricity and this means the producer can defer building of new plants, and a saving on energy bills for the end user. The work presented in this chapter highlights the need to have control of usage of the available electric energy through effective load management techniques.

3.1 Electricity Load Management

An electrical power network is made of three major components of generation, transmission and distribution. In order for the electricity to reach the consumer, these three components have to be integrated and operated efficiently. Figure 3.1 illustrates the way an electrical power network is integrated so as to deliver power to the consumer.

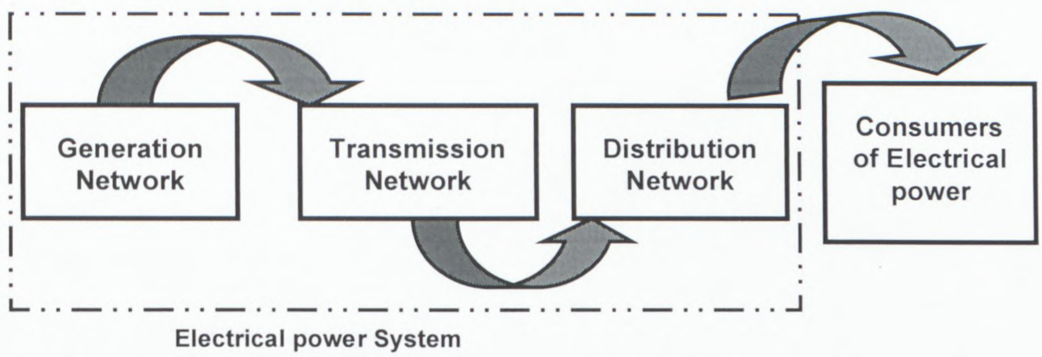


Figure 3.1: Integrated components of an electrical power network

Load management is essential in optimising operation of an electrical power system through best use of available capacity. It is imperative to formulate objectives and/or strategies that are aimed at controlling and modifying the patterns of demand of various consumers (Paracha and Doulai, n.d). Load management can be applied to all the loads experienced by a power utility including industrial loads, cooling loads, heating loads and lighting loads. Since these loads continuously vary by hour, day, month or year/season, it is important for power utilities to monitor the average load as well as maximum load on the system. The strain on the system can be determined by considering the demand factor which is given by the following expression:

$$D_F = \frac{M_D}{C_L} \tag{3.1}$$

Where D_F is demand factor, M_D is the maximum demand and C_L is the connected load. The strain on the system increases as the demand factor approaches unity, and the system will be operating on the *rated demand* or network capacity.

Peaker plants with short duration of production of electrical energy to meet peak demand is expensive since it requires a plant which can react rapidly to changing demand patterns. In addition, peaker plants that are sometimes older are expensive to operate – requiring fuel to be bought on the market with volatile price regime (see Figure 3.2). Furthermore peaker plants generate additional greenhouse gases, degrading the air quality. Compounding the inefficiency of this scenario is the fact that peaker plants are generation assets that typically sit idle for most of the year without generating revenue but must be paid for nevertheless. Therefore, a plant that is specifically operated to meet peak demand contributes to a high marginal cost of power consumed at peak periods. This cost is usually passed on to the customer in form of increased tariff rates. Effectively, customers whose demand coincides with system peak demand will have to contend with increased electricity bill.

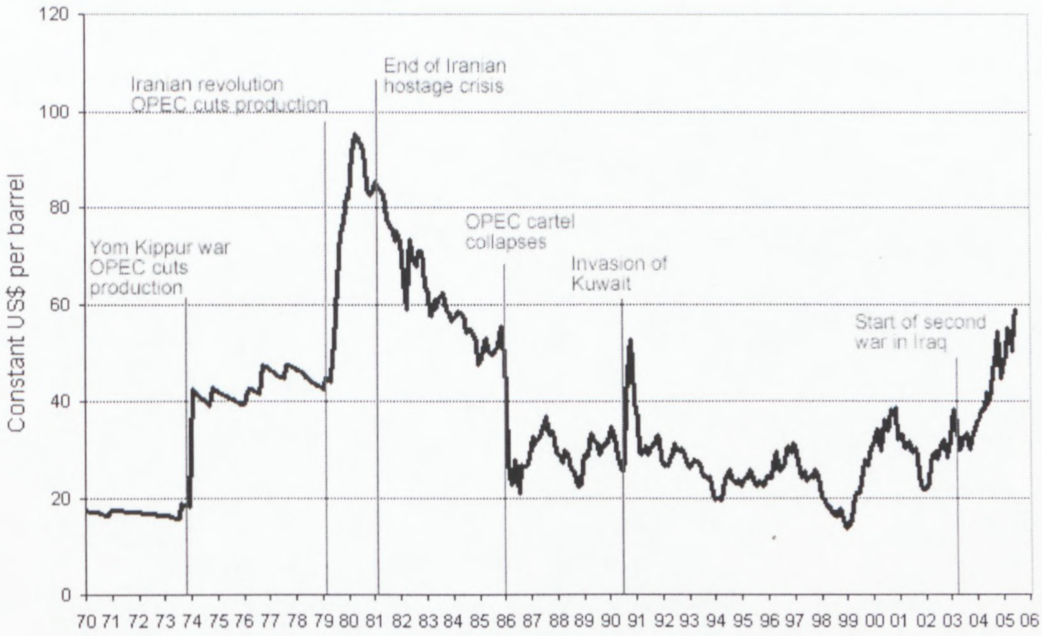


Figure 3.2: Crude oil prices from January 1970 to July 2005[1].

Source: ***The Oil Price Mirage*** **by Pierre, L (2005)**

The demand patterns at various levels within the network are realised by considering the demand of each customer together with others' demand. In the long run, the customer's demand contributes towards the total system demand seen by the producers. In case customers can reduce their demand during system peak demand, requirement for network capacity (rated demand) will reduce.

Control of demand that coincides with the peak demand at various levels in the electricity supply chain can yield savings to the supplier and the customer. Customers will be attracted to participating in load control programmes if there are tangible savings achieved to compensate for the cost of achieving load control, such as production scheduling, advanced control and use of energy storage mediums. The important components of the bill where a customer is able to realise savings include:

- Production costs reflected in the maximum demand (kW) or the energy (kWh) cost element of the bill, i.e. the contribution that the customers' demand makes towards the generating capacity at various times of the day.

[1] During the Arab embargo period beginning 1979, the prices of crude oil tremendously increased.

• Transmission costs (high voltage, system-wide network costs) reflected in the Transmission Use of System (TUS) element of the bill, often expressed in terms of maximum demand coincident with system peak demand, i.e. the contribution that the customers' demand makes towards the required capacity of the Transmission System.

• Distribution costs (lower voltage, local network costs) reflected in the Distribution Use of System (DUS) element of the bill, either as a kWh rate or as maximum demand charge expressed in kVA or kW i.e. the contribution that the customers' demand makes towards the required capacity of the local distribution network.

In addition to the above costs, customers who demand a new connection or an expansion of existing capacity may be asked to contribute towards the direct costs of the distribution system reinforcement at the local level.

It is important to note that whereas costs associated with energy demand are charged at the time-of-use (contribution towards demand at a particular time of day), maximum demand and demand coincident with transmission peak demand relates to fixed electricity distribution assets which must be sized to meet that demand.

Costs are always minimised by seeking the greatest utilisation of fixed assets, by spreading the total demand as evenly as possible to reduce the peak capacity requirement. In some cases, electricity producers and suppliers generate cost messages for their customers in the form of tariffs or contracts for energy supply which reflect their desire to maximise the utilisation of assets. Most tariffs contain incentives and/or penalties to persuade the customer to use energy in a way that optimises the use of the electrical power network (generation, transmission and distribution assets).

The system aggregated demand mostly conforms to the patterns of life. For instance, industrial and commercial demand tends to occur at different times to that resulting from domestic customers due to the fact that the domestic customers will either be out at work or shopping. Similarly, demand varies with the time of day due to lifestyles, working days and weekends & holidays. It may also vary with time of year, particularly in northern and southern climates where heating is required during winter while during summer, cooling will be required.

Demand for electricity during the night is understandably low; therefore, most of the electricity companies promote off-peak sales of electricity through advantageous tariffs with the aim of optimising the utilisation of network and generation assets. A major element of load control is the utilisation of energy storage devices to take advantage of off-peak supplies and reduce on-peak demand. Depending on the climate and work patterns of the country concerned, other off-peak periods (mid-day, for example) may also be promoted through these advantageous tariffs.

3.2 Customer Load Profile versus Total System Demand

In order to identify load management possibilities at the customers' installations so as to reduce the peak load in the electric system, the total system demand has to be weighed against the customers' load profile. A load profile will show the variation in the electrical load versus time and this variation is dependant on temperature, seasons and customer type such as residential, commercial or industrial.

Examination of the daily load curves is an essential step towards the implementation of Load Management. Such investigation can include defining load curve objectives, observing monthly electricity bills with a view of identifying opportunities for load management, recording of the total load curves on days when the facility is to be controlled and technical analysis of the likelihood of Load Management.

As illustrated in Figure 3.3, the total system has two peak loads at times t1 and t3. In this illustration, both peaks can be met by using peaker plant production. The customers' demand profile is assumed to be flat during the daytime period to simplify the comparison between the two demand profiles.

The target is to reduce the need for gas turbine production or other peak-time expensive production capacity by decreasing the demand at the customers' installations during t_1 and t_3. One way of doing so is to increase the load during t_2 or postpone the energy use until the low period in the evening. This scenario calls for changes to be instituted at the customer's installation without sacrificing the comfort or performance of the customer. Some of the most common techniques include:

- Energy storage units that are charged during off-peak periods and used during peak hours
- Load priority systems to avoid large loads interacting simultaneously
- Scheduling of processes to a later time after the peak period.
- Use of own power production during the peak period.

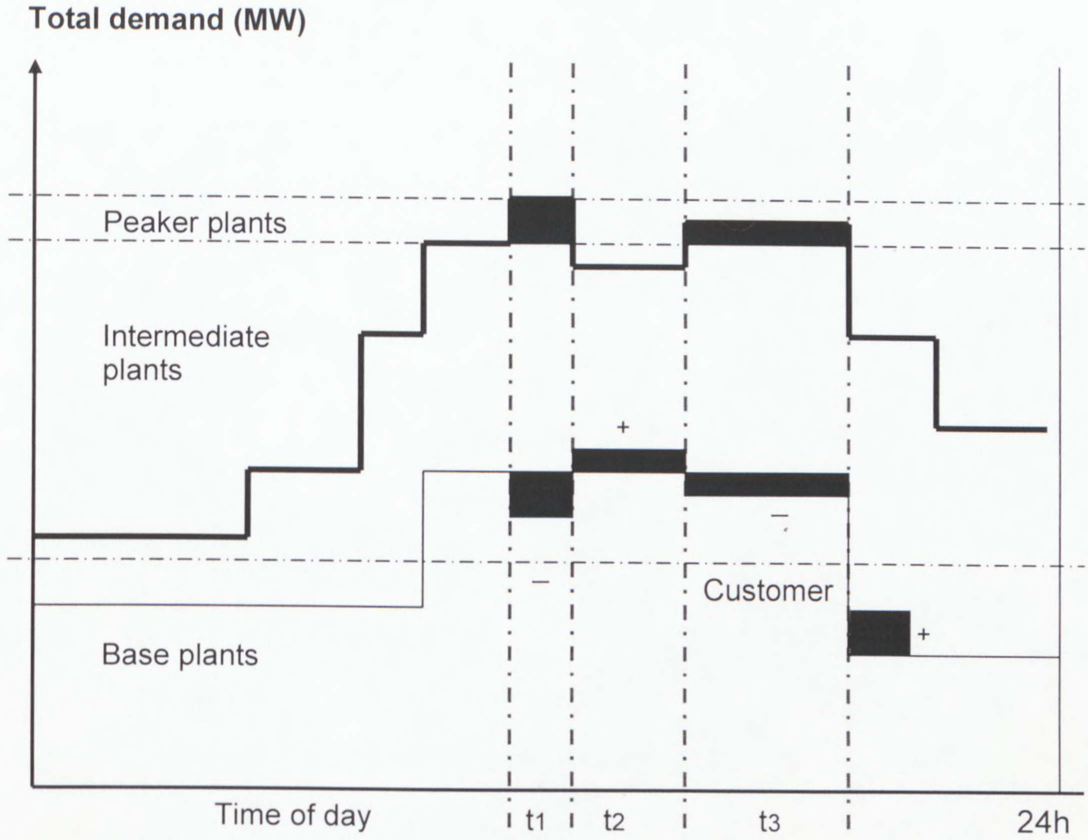


Figure 3.3: Total system demand compared with customer's load profile

The illustration in Figure 3.3 indicates a load profile that is varying. As suggested by Paracha and Doulai (n.d), utilities can improve their load profile by taking into account the annual load factor. The load factor is given by the following:

$$L_F = \frac{L_A}{M_L} \tag{3.2}$$

Where L_A is the average load and M_L is the maximum load on the utility.

In case the load factor L_F is unity, it implies that a constant load curve is experienced the whole day. As observed earlier, this situation is not practically possible since the load keeps on changing either hourly, daily or seasonally. At the same time, a lower load factor is an indication that the production facilities are underutilised. Practicing Load management would therefore identify programmes that can lead to optimal use of the facilities, bringing benefits to both the customer and the power producer.

3.3 Load Duration Curve

A load duration curve (LDC) is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilisation. An LDC is similar to a load curve except that the demand data is ordered in descending order of magnitude, rather than chronologically. In other words, a load duration curve considers a set of time series data such as hour-to-hour electric usage that is sorted in order to determine the usage rate or frequency and the magnitudes. The LDC curve is a reflection of the capacity utilisation requirements for each increment of load. The height of each slice on the LDC is a measure of capacity, and the width of each slice is a measure of the utilisation rate or capacity factor. The system LDC can provide useful information regarding the DSM topology to be applied.

As Rahman and Rinaldy (1993) observed, LDC makes it possible for the impacts of DSM to be incorporated into power system planning and operation. A model of the LDC is one of the most important tools in the analysis of electric power systems. It has been utilised for purposes such as estimating the operating cost of a power system, predicting the amount of energy delivered by each unit, and calculating reliability measures.

In case the duration curve is relatively flat, the values tend to fall within a small range and this implies that the utilisation efficiency of the generated power is higher. However, a steep curve indicates that usage varies widely over a time period. This scenario implies that the on-peak to off-peak ratio will be higher and there would be a need to consider either load growth or valley filling objective. Figure 3.4 shows a typical duration curve with data values arranged in a descending order of magnitude. Of particular interest is the "tail", which gives an indication of how frequently the data is very high in comparison to the typical times.

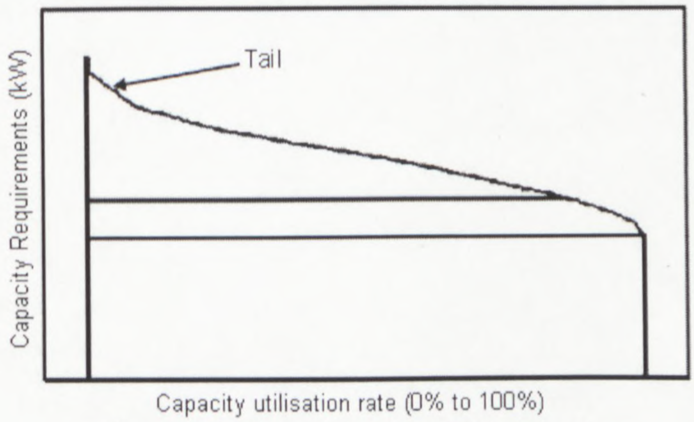


Figure 3.4: Typical Load Duration Curve.

It is generally observed that the LDC has final and continuous function over the range between 0 and number of time units in the period concerned (for example 8760 hours in a year). The area under the curve does represent the total amount of electrical energy required by the customers for all uses during the period. Simply stated, the product of the width and height of LDC is a measure of electrical energy.

3.4 Deriving Maximum Benefit through Load Management

The benefits of load management are numerous. It serves the efficient use of investments related to production and distribution of electricity. These benefits can be achieved by the producer and distributor as well as by the customer. The focus of the action taken and the reasons for load management may not be uniform among the participants.

Through co-ordinated load management of activities made with respect to the total system, it is possible to avoid the start of unnecessary production plant and at the same time, gives rise to environmental benefits. If load control is not co-ordinated between the producer, distributor and customer, action taken by the customer in order to reduce the cost for power demand may not be optimal for the total system. This is the case when the customers reduce their energy consumption during hours that capacity is available at the production plant and in the distribution network. In this case, the revenue for the customer who has taken this action could be higher though the reduced costs for the distributor and the producer may not be significant.

If load control among customers increases widely without co-ordinating with the producer and distributor (that is in the presence of incorrect price signals or unsuited incentives), the small or non-existent systems' effect that results may unbalance the supplier's cost/revenue equilibrium. This may lead to an adjustment (increase) in the present tariffs by the energy provider to compensate for the lost margin, thus raising a problem of equity, as customers without load management will be cross-subsidising those who have inappropriately modulated their load curve.

It is therefore vital that any efforts directed towards load control be co-ordinated centrally by the utility in order to reap maximum benefits.

3.5 Advantages of Practicing Load Management

The producer, distributor and customer are presented with many advantages in case they practice load management. These advantages are summarised as follows:

I. Load management avoids the requirement to increase transformer, cable sizes and generator capacity

II. Load profile is generally more efficient, controlling peaks

III. As peaks are likely to coincide with periods of most expensive electricity prices, either individual industries will become more competitive or prices will be forced downwards

IV. It is environmentally more acceptable due to an effective use of resources.

3.6 Example of Industrial Load Management

A typical example of load profile is shown in Figure 3.5. In this example, the aggregate demand for one large industrial customer and two classes of domestic customer are considered. The domestic demand consists of two major classes of customers; those with off-peak storage heating, and those without storage heating.

As can be seen in Figure 3.5, the total demand curve at the primary substation shows three peak demands; an early morning peak relating to domestic storage heating, and two later peaks relating to coincident domestic and industrial demand during the transition from home to work in the morning and from work back to home in the evening. In this particular example, the distributor has reached the maximum available safe capacity of the primary substation and is faced with reinforcement if the early evening peak cannot be reduced. Failure to take account of the reinforcement requirements would have implications for the security of supply to all of the customers connected to the primary substation.

In practice, various combinations of load management and conservation measures may be possible, including targeted energy efficiency, power factor correction, partial rescheduling and combinations of energy storage.

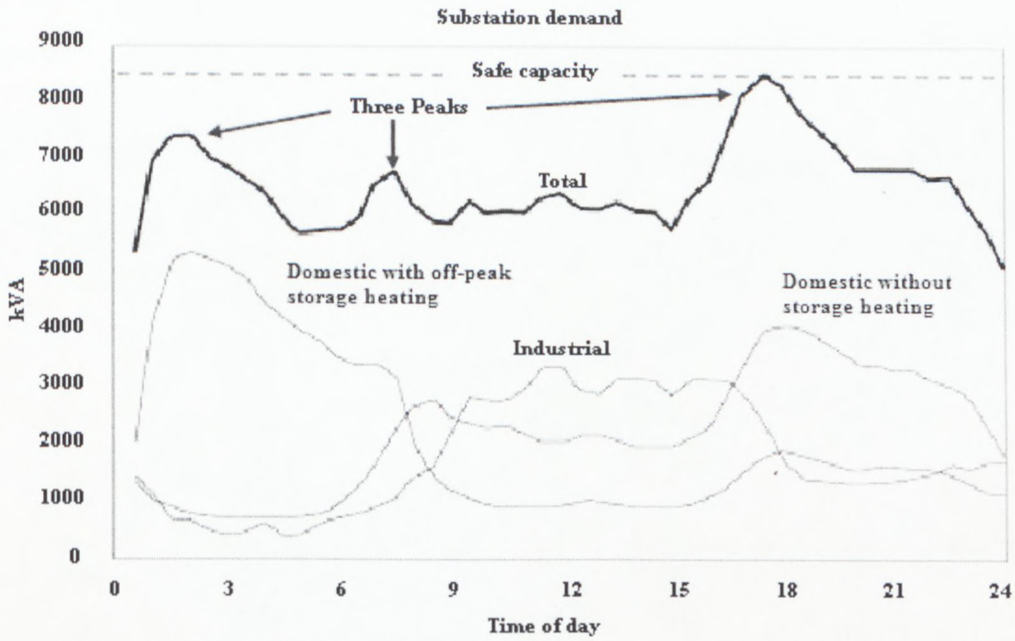


Figure 3.5: Total demand curve at a primary substation

3.7 Scenario of South Africa in Load Management

DSM activities are very minimal in the African context due to low electricity tariffs, political instability and management inefficiencies among the many reasons. However, donor countries have provided financial assistance towards activities that support industrial efficiencies (Boyle, 1996)

The various energy production resources in South Africa are shown in Figure 3.6. This figure indicates that a large portion of electricity generated in South Africa comes from coal-fired power stations. Despite efforts made to minimise emissions into the atmosphere, greenhouse and other gases are still released into the air. If the electrical energy that is produced is well utilised, the emissions will be reduced and effectively give support to sustainable use of energy resources. Furthermore the customers connected will benefit as a result of lower electricity tariffs.

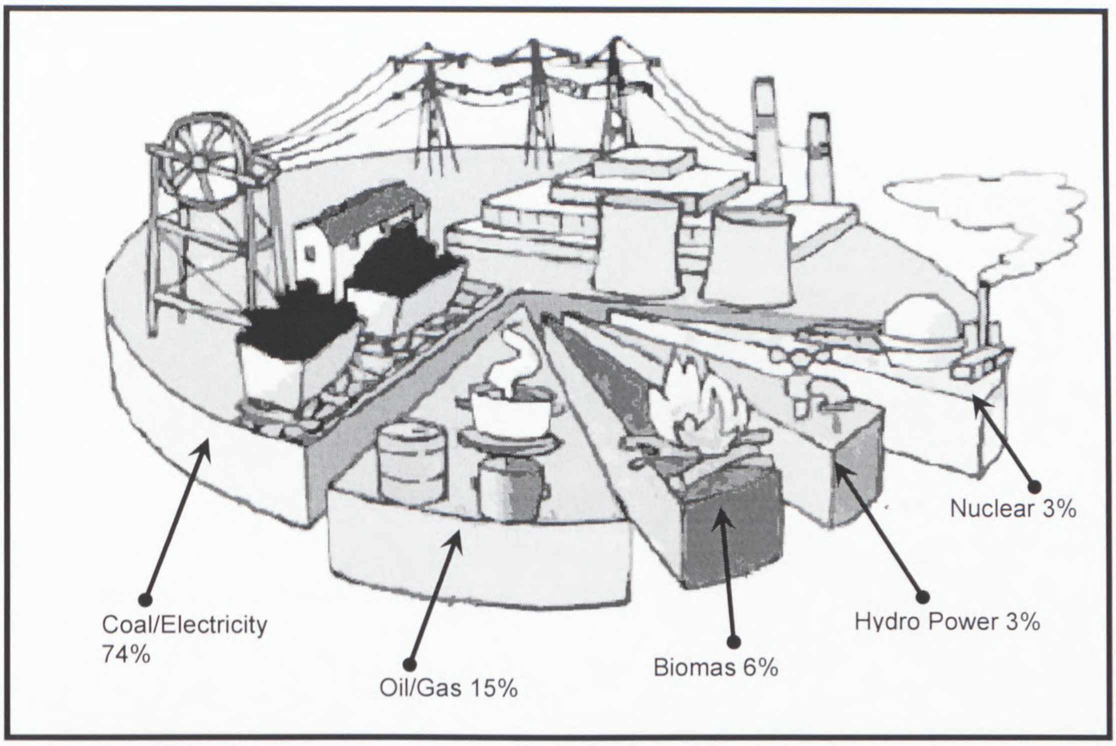


Figure 3.6: South Africa's Energy Resources. (*Source: Eskom*[2])

Electricity usage by consumers in the domestic sector of South Africa does reflect a particular pattern. Most of electrical energy is used during early mornings between 06:00 and 09:30; consumption then reduces, but picks up again in late afternoons from 18:30 to 21:30 (see Figure 3.7). The increased energy consumption has resulted from the added customer base under the Reconstruction and Development Programme – RDP (ANC, n.d). This imposes a strain on national electricity resources that require Eskom to generate significantly more electricity to meet the high demand for short durations of time.

This pattern of energy usage has considerable implications for achieving energy efficiency in South Africa. Levelling the demand so that electricity usage does not have distinct peaks during the day will ensure efficient use of power stations. This would imply that some customer transfer there energy use to periods falling under low energy demand on the utility.

Creating energy efficient society requires all South Africans to embrace the policy of saving on power utilisation. The tripartite cooperation between Eskom, the government (through the Department of Mines and Energy) and the consumers can create an environment conducive for energy efficient society to thrive.

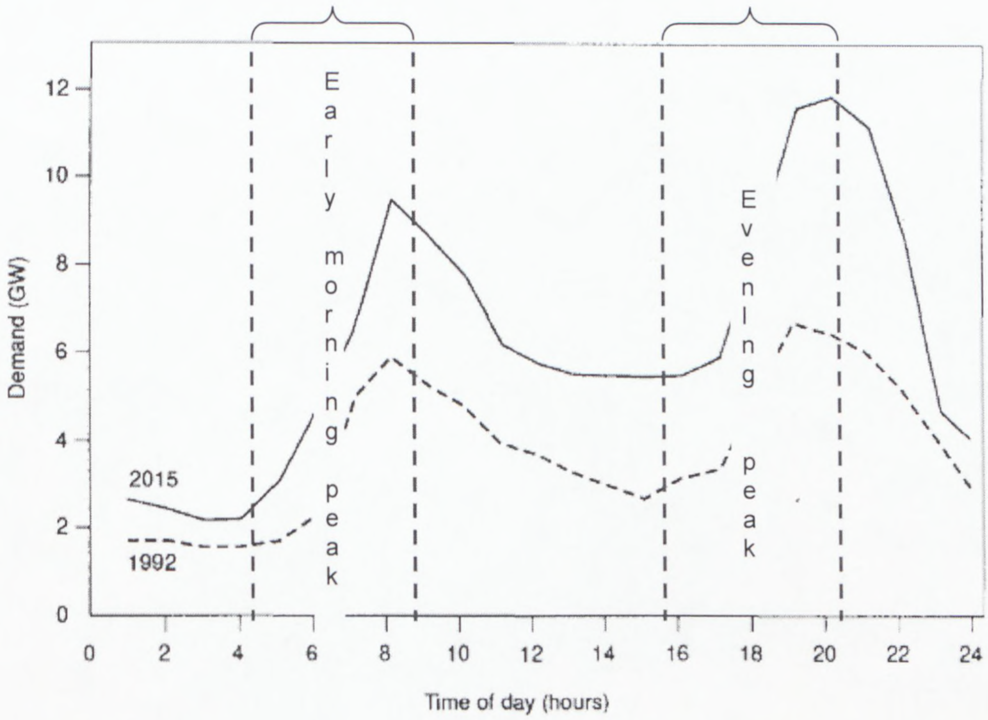


Figure 3.7: Typical domestic load profile for South Africa. (Boyle, 1996)

3.7.1 Accelerated Energy Efficiency Plan by Eskom

The efficient use of electricity has become a national priority, a necessity for the future development of the South African economy and effective provision of electricity. Eskom through its Accelerated Energy Efficiency Plan has focused on reducing electricity demand by 3000MW by the year 2012 and a further 5000MW by the year 2025. The plan encompasses twelve elements of energy efficiency strategy covering short, medium and long term goals (Eskom[3]). Particular projects have been identified where most of the focus will be in order to achieve the set objectives.

The Eskom plan of action targets various sectors of energy use and already some programmes have so far been implemented in the residential sector. Examples include the rolling out efficient compact fluorescent lighting, solar water heating, installation of aerated shower heads and geyser blankets, thereby reducing residential consumption of electricity. The plan suggested concentrating efforts on street lighting projects and the conversion of lighting, heating, ventilation and air conditioning systems in the commercial sector. In industrial sector, it was envisaged that participation would be through encouragement of the players to use energy efficient electrical motors.

The medium and long term objectives are of greater concern and relevant. Among these objectives is the element of concentrating on the delivery of new technologies to assist with power delivery between 2012 and 2025. As envisaged, Eskom will play the coordinating role among researchers and inventors so as to come up with innovations that will not only support the efficient use of energy, but also enhance sustainable activities in the energy sector (Eskom[3]).

It was observed by Maura (1993) that there was a surge in acquisition of demand side management resources by electric utilities. These efforts need to be revitalised considering the ever increasing global demand for electricity.

3.7.2 Energy consumption

The major end users of electrical energy in South Africa are the Industrial (49%) as well as the mining (18%) sectors. The two sectors had a combined total of 67% of energy consumption as at 2003. The commercial (10%) and residential (17%) sectors had a combined energy use of 27%. Figure 3.8 illustrates the energy consumption in the sectors of Mining, Residential, Agriculture, Industry, Commercial and Transport. The proposed technique is intended for use in the residential (domestic) and the commercial sectors. However, industries can also use the technique to spread their energy consumption by shifting from the on-peak to the off-peak times.

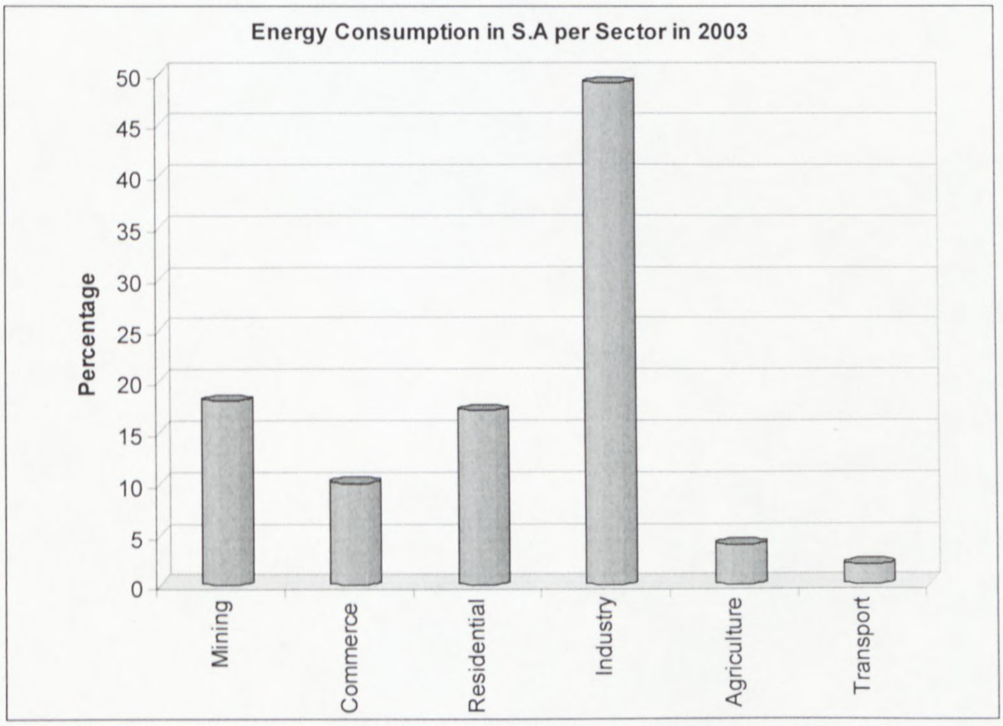


Figure 3.8: S.A Energy consumption per sector in 2003 (Eskom[2])

3.7.3 Demand distribution in the Residential sector

A report by Eskom (Eskom[2]) indicated that by the year 2003, the energy consumption in the residential sector accounted for 17% of the total demand. The breakdown of each end use applications in the sector shown in Figure 3.9 further indicate that water heating and space heating accounted for more than 30% of the sector's energy consumption. These appliances can be ranked higher in terms of switching off priority since they comparatively cause minimal discomfort. Incandescent lighting is another area where reduction in energy consumption can be implemented. The scenario in the residential sector compares well with that of the US (indicated in Figure 3.10).

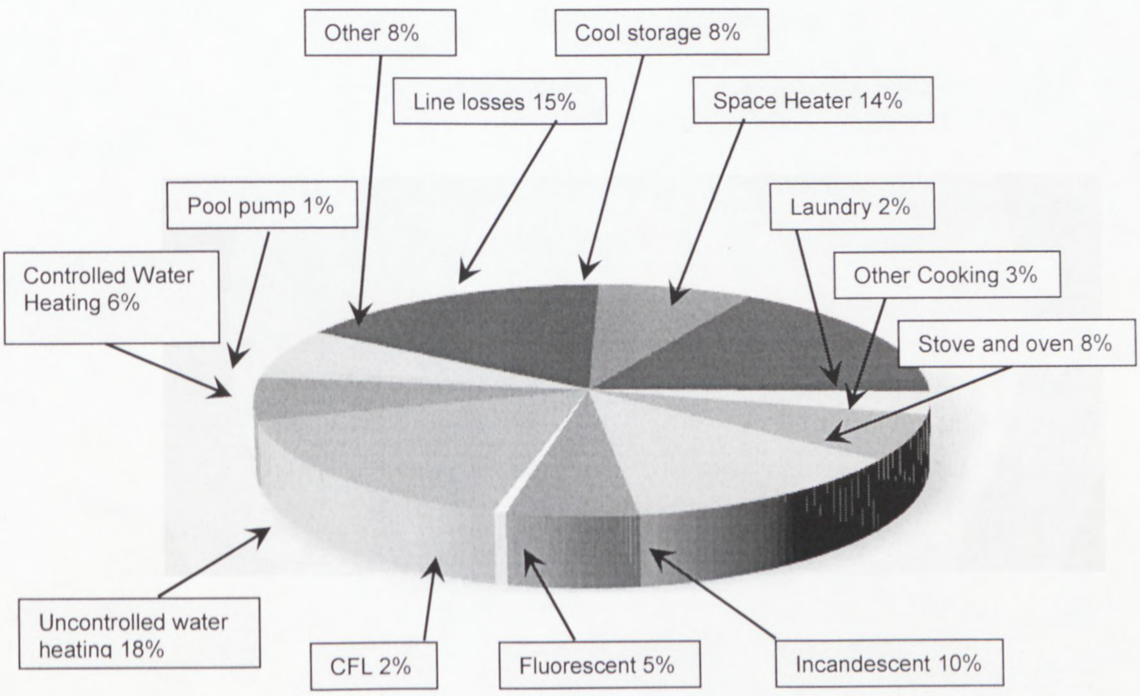


Figure 3.9: Maximum demand in the residential sector (*Eskom*[2])

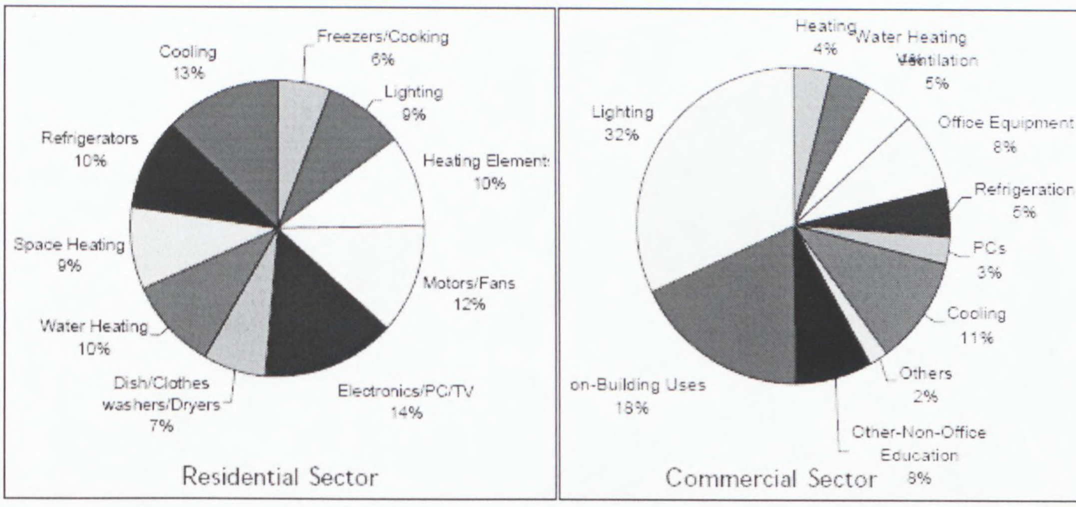


Figure 3.10: Breakdown of Electricity End-Use Load Consumption in Residential and Commercial Sectors in U.S. (**Source**: Annual Energy Outlook, 2001, Department of Energy. Adapted from EPRI Power Quality Commentary No. 4 Dec. 2001)

3.7.4 Demand distribution in the Commercial sector

Lighting and Heating, Ventilation and Air Conditioning (HVAC) are the major end use applications for energy in the commercial sector. The two account for a total of 62% of the total consumption in the commercial sector. The two areas had been identified as having the potential of reducing loads during peak times. However, this has to be coordinated and the industry has to be consulted in order to properly identify areas that can participate in management of the load. For example, in one industry, HVAC may be critical due to the installed plants or machinery (that requires a certain environmental temperature). The energy audits of each industry would have to be conducted.

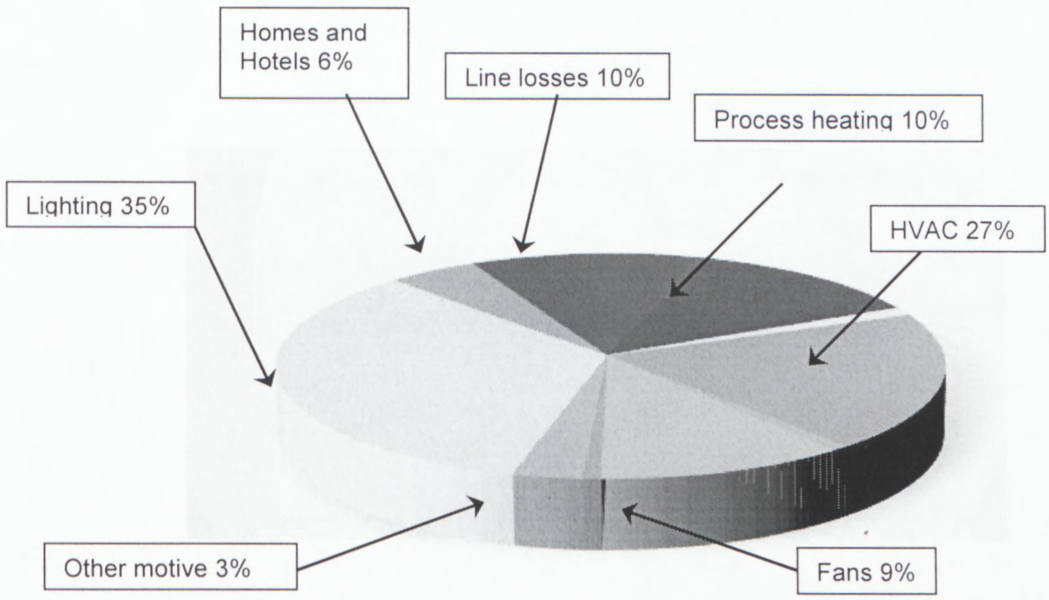


Figure 3.11: Maximum demand in the commercial sector

3.8 Load at selected CPUT substations

Data was obtained at various substations within the Bellville campus of CPUT. The campus is supplied by 11 kV ring network consisting a number of substations spread within the campus. The substations are located at the residential blocks, educational blocks and the sports field. Within the reticulation network, there are distribution transformers; 6 are rated 1000kVA, 11/0.4 kV while 8 of them are rated as 500 kVA, 11/0.4kV. The loads that were sampled for this research were obtained at the residential and educational blocks. This was chosen considering the parallel activities tied to domestic, commercial and industrial sectors of energy use. The recording interval was 30 minutes, but the sample values were different for the substations selected. The selected substations together with the duration that data were obtained are given in Table 3.1. Most of the data were collected during week days since it was assumed that the load during weekends and holidays does not require much of control.

Table 3.1 Substations on CPUT Bellville campus where data was recorded.

Substation	Recording Interval (mins)	Duration
Electrical Engineering Building	30	3 days
ABC Building	30	2 days
Anglo and Freedom Square Residences	30	1 day
Heroes and Postgraduate Residences	30	4 days

The results are shown in Figures 3.12 – 3.15. The plotted results agree with the assumptions that during the day, most of the energy consumed is in the commercial and industrial sectors. However, during the evening, most of the power is consumed within the residential sector. The laboratories and administration block represent the commercial sector while student residences represent the domestic (residential) load consumption

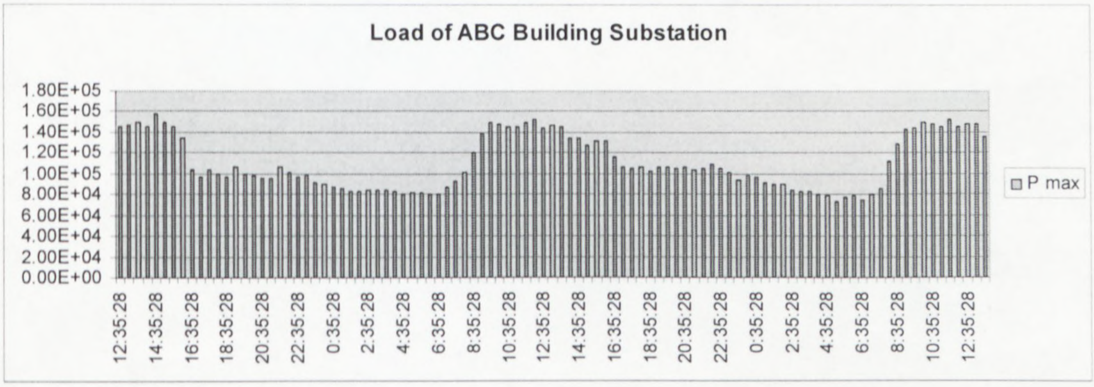


Figure 3.12: ABC Building substation (12h35 of first day to 12h35 of third day).

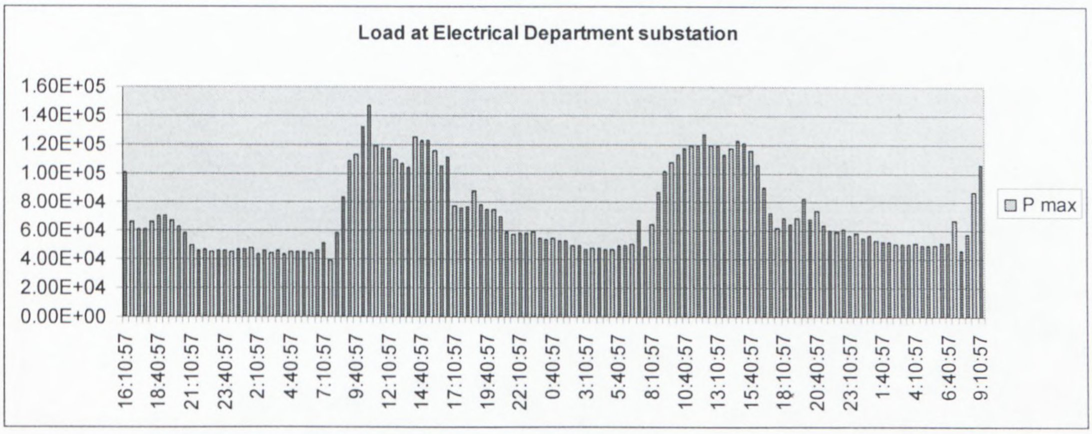


Figure 3.13: Electrical Engineering Building (16h10 of first day to 09h10 of third day).

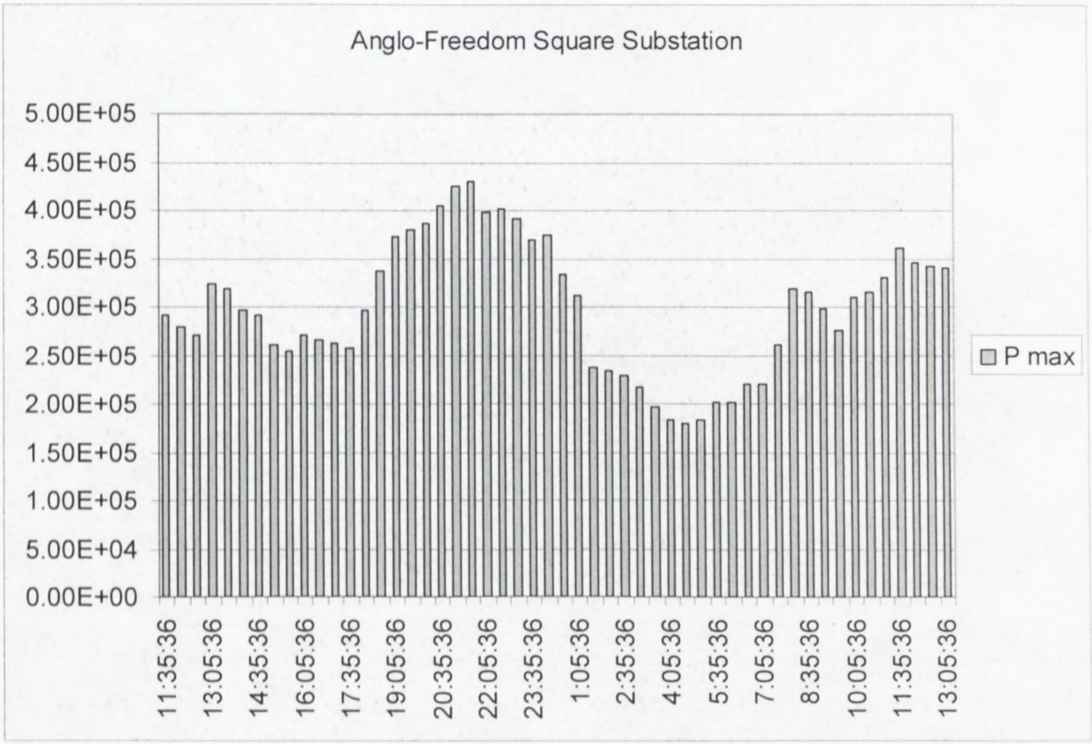


Figure 3.14: Anglo and Freedom Square Substation (11h35 of first day to 13h05 of second day)

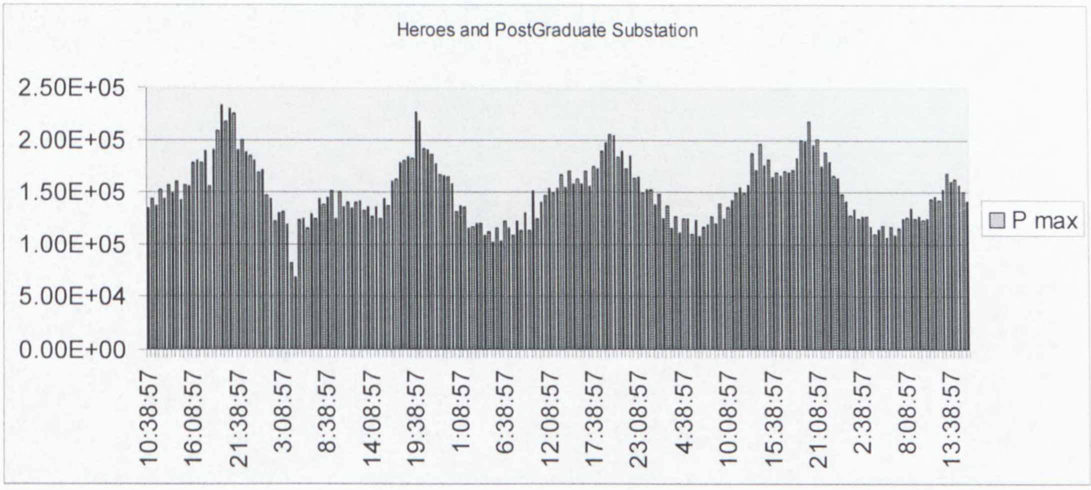


Figure 3.15: Heroes and Postgraduate Substation (10h38 of first day to 13h38 of fifth day)

3.9 Conclusion

Electricity is an essential commodity in spurring the growth and development of a country. Unfortunately, this sort after commodity at present can not economically be stored in large quantities. In order to contribute to a balance in the demand for energy and the diminishing resources for the production of energy, load management exercises have to be instituted by both the utilities and the consumers in a coordinated manner. The main purpose of implementing DSM in power systems is to modify the utility's load shape. Changing the load shape due to demand side activities could lead to changes in the peak load, base load and/or energy demand. The load duration curve technique assists in accurately characterising the effects of demand side management.

The different DSM program options, implementation techniques and smart technology as a potential 'option choice' are discussed in Chapter 4.

CHAPTER FOUR

DEMAND SIDE MANAGEMENT

4.1 Introduction

Traditionally, electric utilities focused on the supply side of their business so as to meet their power needs. For example, in order to cater for increase in customer demand for electricity, electric utilities reacted by building more and typically larger generating plant facilities. Starting in the 1970s, utilities began to recognise the opportunities available on the customer side, leading to formulation of demand side management (DSM) programs.

In the electricity industry, DSM refers to actions that are directed towards changing the electrical demand on the system. Among the wide range of activities encompassed by this term include:

- Actions which are taken on the customer side of the electricity meter (the *demand side*). For example, energy efficiency measures and power factor correction;
- Arrangements for reducing loads on request, such as interruptible contracts, direct load control and demand response;
- Fuel switching, such as changing from electricity to gas as a means of heating water;
- Distributed generation, such as stand by generators in office buildings or solar power generation; and
- Pricing regime, such as time of use and demand-based tariffs.

Smart technology is taking position in influencing the direction of utility load management. For example, suggestions have been made for the development and deployment of automated metering infrastructure (AMI) that allows two way communications between utility and customer (Ratcliffe, 2007). Also suggested is the need for development of a smart grid system that will allow the utilities to effect disconnects and reconnects of the connected customers.

Some of the envisaged benefits to customers through deployment of smart technology include close monitoring and control of electricity usage. Furthermore, as smart grid systems are developed and refined, AMI will no doubt play a key role in a fully automated grid; and greater benefits such as planning, customer service and marketing will be realised in organisations.

In this chapter, various DSM program options that are designed to produce predictable and desired changes in customer energy consumption have been considered. In addition, load shape objectives, their merits and demerits as well as benefits have been highlighted. Further, smart technology which has the potential of being the 'option choice' of implementing DSM has been discussed.

4.2 Demand-Side Management Program Options

Demand-Side Management (DSM) consists of electric utilities' planning, implementing, and monitoring of activities designed to encourage consumers to modify their levels and patterns of electricity consumption. The aim of these activities is to obtain benefits for the utilities, consumers, and society. As shown in Figure 4.1, Demand-side management seeks the common ground that maximises the mutual benefits of the utility and the customers (Limaye, 1985).

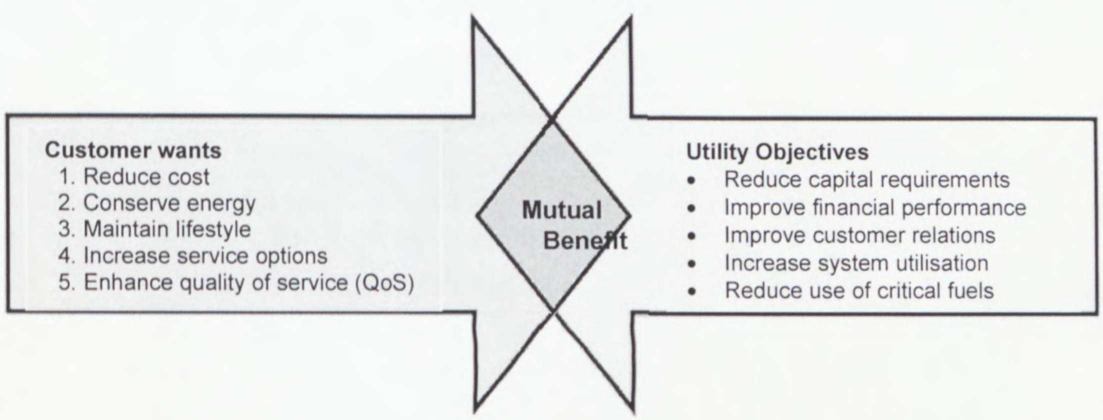


Figure 4.1: Demand Side Management: Seeking common ground to maximise mutual benefits. **Adopted from** *Implementation of Demand-Side Management Programs by Limaye D.R (1985).*

The two important goals that motivate the utilities to implement DSM programs are energy efficiency and load management. Energy efficiency is anchored in programs that promote overall reduction in energy consumption of specific end-use devices and systems by endorsing high-efficiency equipment and building designs. On the other hand, load management programs, are purposed to achieve load reductions; primarily implemented at the time when the demand on the utility is at the peak. It is vital to note that the load reduction programs are not aimed at reducing the total energy consumption as is the case for energy efficient programs.

Electric utilities have steadily increased DSM programs in promoting energy efficiency, and achieving cost effectiveness for both utilities and consumers, mainly by deferring the need to construct new power plants. Energy efficiency programs also conserve fossil-fuel energy sources and reduce gas emissions; essentially the program has a derivative benefit on environmental conservation.

DSM programs are categorised variously depending on the change desired. Among the categories are direct control, energy efficiency, interruptible load, and load building. Another way to examine DSM programs is according to whether they are information-based, marketing-based, or regulatory-based.

There are differences in the planning, financing, implementation and delivery techniques of these programs. For example, marketing-based programs are almost always expensive than informational programs; similarly, regulatory-based programs almost always achieve better market penetration than marketing programs. These various types of programs, their features, effects and benefits have been considered in the next sections.

4.2.1 Direct Load Control

This program category represents the consumer load that can be interrupted during periods of peak demand by the utility system operator, directly interrupting power supply to individual appliances or equipment (Ericson,). As electricity demand rises above the base-load (lowest level of generation required to meet electrical demand over a twenty-four hour period), utilities produce more electricity in active generation facilities, and also switch on the reserve additional generation from the peaker plants – if available.

Peaker plants are activated to cater for peak demand periods whereby the electrical load the utility must supply is at its highest point. The gap between the utility's electrical demand and its maximum generation capacity gets narrower as peak demand increases, with a possibility of brownouts increasing and at the same time, the distribution grid's backup reliability being compromised.

Utilities are now looking into demand side management and direct load control (DLC) to actively shift load from peak periods to non peak periods, and add a level of grid security with the ability to reduce the distribution grid's load in case of equipment failures or excessive electrical usage (Ericson,). DLC ensures a proper balance of supply and demand, specifically through the use of direct measures designed to decrease demand.

DLC actions involve rolling blackouts and brownouts, mandatory service interruptions during peak demand periods, and at the most drastic stage, manual disconnection of customer equipment by the utility. As expected, these actions bring discomfort to the customer and can lead to restoration problems. Furthermore, customer participation in DLC may be limited once the contract has been signed. Nevertheless, DLC can effectively be applied to residential consumers so as to periodically interrupt service to non essential appliances such as air conditioning units or the water heating system (geysers) during the hours of peak load.

4.2.2 Energy Efficiency

The energy efficiency programs are aimed at reducing the energy consumed by specific end-use devices and systems, without jeopardising the quality of energy services provided. These programs reduce overall electricity consumption over many hours during the year, although the greatest impacts of cost-effective programs often coincide with periods of peak usage.

Achievement of savings is realised mostly by use of technologically more advanced equipment to produce same levels of energy services (e.g., lighting, heating, motor drive) with less electricity. Examples include energy saving appliances and lighting, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modification, efficient building designs, advanced electric motors and drive systems, and heat recovery systems.

Financing or financial incentive is a regular feature for participants in energy efficiency programs. This means that replacement of the traditional electric appliances with energy efficient ones has to be seen as cost-effective to the consumers in order to win their participation.

4.2.3 Interruptible Load

This program encompasses contractual arrangements between the customer and utility, allowing interruption of supply to the customer during periods of peak load, either by direct control of the utility system operator or by action of the consumer, at the direct request of the system operator.

In most cases, certain benefits are passed on to the customers willing to forego electricity for a time. For example, large commercial and industrial consumers may obtain discounted interruptible rates for agreeing to reduce electrical loads upon request from the utility, usually as a strategy to reduce peak load.

The success of this program is dependant on the willingness of the customer to participate. There are those customers who may prefer to use electricity in whatever amount since the means to pay for the higher price is within their comfortable reach. It therefore calls for concerted efforts by the utility provider and the governments to come up with legislation that would give opportunities to the utilities to enforce certain minimum restrictions on consumptions of energy for the benefit of the nation.

4.2.4 Other Load Management

There are programs apart from direct load control and interruptible load, whose purpose is to limit peak loads, shift peak load from on-peak to off-peak hours, or encourage consumers to respond to changes in the utility's cost of providing power. Included are technologies that primarily shift all or part of a load from one time of day to another and also may affect overall energy consumption. Examples include space heating and water heating storage systems, cool storage systems, and load limiting devices in energy management systems. This category also includes programs that aggressively promote time-of-use (TOU) rates and other innovative rates such as real-time pricing (RTP). These rates are intended to reduce consumer bills and shift hours of operation of equipment from on-peak to off-peak or high-cost to low-cost periods through the application of time-differentiated rates.

4.3 Load Shape Objectives

Load shape is a method used to describe peak load demand and the relationship of power supplied to the time of occurrence. 'Load shape objectives' is one of the three key steps of selecting the appropriate DSM to implement in addition to strategic and operational objectives (Gellings *et al*, 1985; Malik, 2001). Each utility therefore has to decide which DSM programs to pursue based on careful evaluation of its broad utility objectives and specific operational objectives. This evaluation will determine load shape objectives for the utility.

The six load shape objectives shown in Figure 4.2 are commonly used in reviewing DSM alternatives and their impacts on the system (Yau *et al*, 1990). These objectives (which may be applicable on a daily, weekly or seasonal basis) are: peak clipping, valley filling, load shifting, conservation, load building and flexible load shape. Peak clipping and load shifting are programs that focus on load management, or changes in demand when sections of a transmission or distribution system reach capacity or where it is otherwise desirable to delay system expansion.

4.3.1 Peak Clipping

Peak clipping is a way in which the utility uses to control the load profile to a desired shape in order to take care of the high demand for energy it experiences during peak times (Qureshi and Saleem n.d). Peak clipping leads to load reduction on the part of consumers especially when usage of electric appliance is a maximum; which effectively the utility's or system's peak load is reduced by direct load control of customer appliances. The typical target is the forecasted days of system peak, such as hottest or coldest days. An example is the management of air conditioning systems by radio control where customers volunteer to have their air conditioners turned off for short intervals during system peak periods. Usually an incentive or bill credit is passed on to the participating customers. Peak clipping results to coordinated load management since load control is determined centrally by the utility or energy producer.

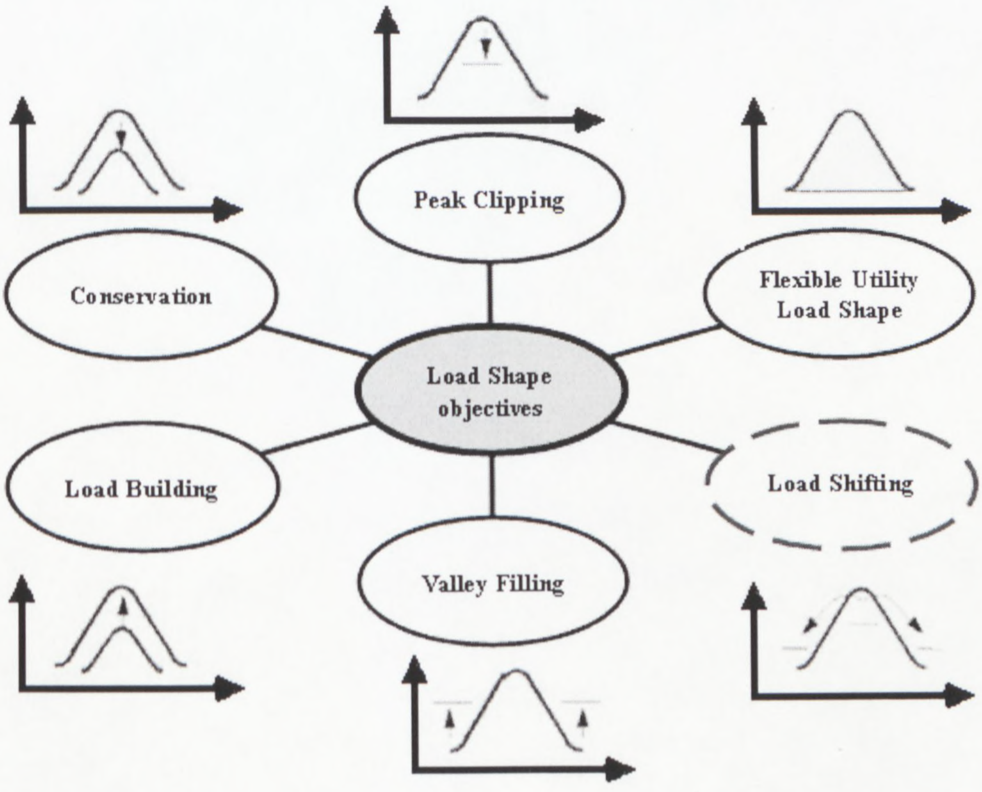


Figure 4.2: Load shape objectives embraced in Demand-side management

4.3.2 Valley Filling

Valley filling is intended to achieve the building of off-peak loads and produce better or more efficient use of system capacity (Grover and Pretorius, 2008). The method is also intended to increase revenue base of the utility. Through provision of incentives, customers are encouraged to increase their energy consumption when utility load is low (Bellarmine, 2000). Valley filling has been modelled by Malik (2001). In achieving the model, he shows that valley filling is akin to charging or pumping operation of a pumped storage unit. The model shows that with a possibility of adding pumping load or additional stimulated demand to the base-load thermal unit at the knee of the effective load duration curve (LDC) at position *j* then:

$$F'j(x) = p_s^c Fj(x - C_s^c) + q_s^c Fj(x) \tag{4.1}$$

Where p_s^c, C_s^c and q_s^c are respectively availability, capacity charging side of storage unit and forced outage rate of generating units.

Addition of load at the right price has the potential of reducing the average cost of electricity to all consumers, at the same time, improve system load factors. One probable method of valley filling is off-peak industrial production, which displaces loads served by fossil fuels with electricity. Alternatively, customers can be encouraged to install technologies that use electricity throughout the year. A fine example of such technologies is a heat pump used for heating and cooling. All the same, this option requires the utility to offer a corresponding incentive that will attract customer participation. Valley filling program best suits utility and customers when incremental cost of electricity is less than the average cost of electricity.

4.3.3 Load Shifting

Load shifting is a form of load management that focuses on transferring some load from on-peak to off-peak. As Malik (1998) observes, the purpose of shifting the load is not to affect the energy use pattern, instead, it is to balance the system load as much as possible throughout the production time. This is usually done through direct control by the customer or the utility shifting the electric usage to times before or after the peak periods; in order to reduce consumption during the anticipated peak-price periods (Ning Lu Chassin and Widergren, 2005). This topology can have little effect on the comfort of the customer by shifting the loads in conformity with the energy usage patterns (Ilic *et al*, 2002). Storage of water heating and storage of space heating or space cooling is an example of this technique (Rupanagunta *et al*, 1995).

The proposed technique will consider the various appliances and prioritise them according to the utilisation pattern so as not to cause severe discomfort to the customer.

4.3.4 Conservation

Conservation (aka strategic conservation) is aimed at reducing energy use which subsequently results in reduction in peak loads. Conservation affects end-use consumption so that overall electricity sales are reduced by altering specific patterns options as what reduction would occur or if the price increases then what degree of additional stimulation is needed from utility programs. Appliance efficiency improvement and insulation programs are some examples of strategic conservation. For example, construction of new energy-efficient houses can reduce the load by several kilowatts due to the smaller-size heating system.

4.3.5 Load Building

Load building (strategic load building) or load growth produces a general increase in sales and increased peak load (Kwon, 1994). This is usually accomplished through increased market share of loads that currently are, or could be served by another fuel e.g. space heating or water heating. This situation exists when there is a greater surplus of power produced. Incentives have to be offered to the consumers to motivate them into participating in this program.

4.3.6 Flexible Load Shape

This relates to reliability and can be achieved if customers are given options about the variations in quality of service that they are willing to receive. In return, the customer receives various incentives. Examples could include certain kinds of interruptible load, integrated energy management systems or individual customer load control devices which include service constraints.

4.4 DSM Technology Options

Mapping out an appropriate DSM option to users requires the knowledge about the user and the applications of electricity by the user. This process involves a clear understanding of end-uses of electricity, which then helps identify end-use options that offer maximum DSM potential (IEEC, 2006).

The study of users and end uses of electricity offers to identify generalised DSM option i.e. which end-use and/or which customer sector and/or segment to be targeted. However, the need for more specific option for the purpose of DSM implementation would require identification of alternatives. This implies that a list of all available options that can replace existing conditions in order to achieve DSM objectives has to be provided.

The alternative technology refers to efficient technology intended to replace the base technology (standard or most commonly used technology within the geographical boundaries of a utility).

Table 4.1 indicates some of the alternative DSM technologies and Table 4.2 highlights the key features of the alternatives. It has to be noted that the main goal of the technologies highlighted is energy efficiency.

Table 4.1: Alternate DSM Technologies

DOMESTIC	COMMERCIAL	INDUSTRIAL
CFLs	CFLs	CFLs
High efficiency fluorescents	High efficiency fluorescents	High efficiency fluorescents
Low Loss Ballasts	Low Loss Ballasts	Low Loss Ballasts
High efficiency Air-Conditioners	High efficiency Air-Conditioners	High efficiency Air-Conditioners
High efficiency Refrigerators	High efficiency Refrigerators	High efficiency Refrigerators
Efficient Rice cookers	Air Conditioner Timers	Air Conditioner Timers
Solar Hot Water Systems	Solar Hot Water Systems	Cogeneration
Orientation of New homes	Efficient Security Lighting	Efficient Security Lighting
	High efficiency Motors	High efficiency Motors
	Interruptible Tariffs	Interruptible Tariffs
		Power Factor Correction
		Variable Speed Drives

Source: Demand Side Management Best Practices Guidebook. *International Institute for Energy Conservation (IIEC)* 2006.

Table 4.2: Key Features of Selected DSM Programs

PROGRAMME	KEY FEATURES
Compact Fluorescent Lamp	Purchase CFLs in bulk from lamp manufacturer and sell to customers, allowing them to pay in instalments through their electricity bills.
High Efficiency Fluorescent Lighting	Use lighting suppliers and trade allies to promote high efficiency fluorescent lamps and ballasts.
Refrigerator Labelling and Standards	Introduce energy labelling of fridges and freezers to enable customers to identify more energy efficient units. Establish minimum efficiency standard, and prohibit sale of fridges below this standard.
Air Conditioner Labelling and Standards	Introduce energy labelling of air conditioners to enable customers to identify more energy efficient units. Establish Standards minimum efficiency standard, and prohibit sale of air conditioners below this standard.
Commercial Refrigeration Equipment Maintenance	Provide information and advice to customers through brochures and on-site visits on methods to ensure refrigeration equipment is running as efficiently as possible.
Air Conditioner Equipment Maintenance	Provide information and advice to customers through brochures and on-site visits on methods to ensure air conditioning and ventilation equipment is running as efficiently as possible.
Interruptible Rates	Provide financial incentive for customers with Interruptible loads to switch these loads off, during times of system peak.
Energy Audits	Conduct energy audits to identify cost-effective energy efficiency opportunities for large customers. Assist in financing and implementing the opportunities identified.
Air Conditioner Timer Controls Programme	Purchase Programmable Timer Controls in bulk and sell to customers with air conditioners, (perhaps through trade allies) allowing customers to pay for the timer in installments.
Municipal Water Pumping	Use of High efficiency motors and pumps and Variable Speed Drives (VSDs) for water pumping
Street Lighting	Use of High Pressure Sodium Vapour Lamps in place of Mercury Vapour Lamps
Solar Hot Water Systems	Use of Solar hot water systems in place of electrical systems
TOU tariffs	Having differential tariffs for system peak and off-peak periods to encourage load

Source: Demand Side Management Best Practices Guidebook. International Institute for Energy Conservation (IIEC) 2006.

4.5 Implementation of DSM options

Demand side management (DSM) programs were initiated in 1980's and by late 1990's; electric utilities began subjecting these programs to a careful review. Most of them were opting to discontinue or reduce the emphasis on the programs (Chambers, 1998). In fact a report by the Energy Information Agency (EIA) indicated that by 1996, 10 large and 40 small electric utility companies either discontinued the programs or the tracking of the programs (EIA:1997). In that report, EIA found that 1,003 of the 3,199 electric utilities in the United States reported having DSM programs in 1996, compared with 1,053 in 1995. Of these 1,003 electric utilities, 573 were classified as large and 430 as small (see Figure 4.2).

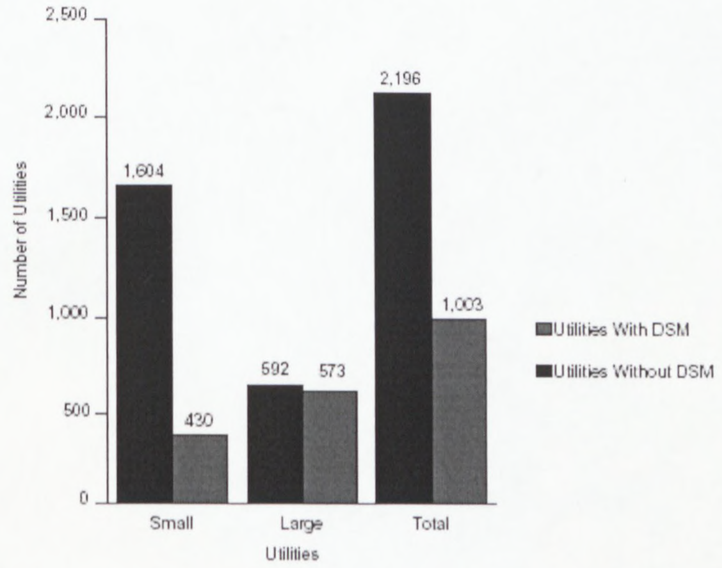


Figure 4.3: Number of U.S. Electric Utilities with and without DSM Programs, 1996

Source: Energy Information Administration, Form EIA-861," Annual Electric Utility Report." (EIA: 1997)

Due to the need of conserving, managing as well as reducing the carbon footprint and subsequent environmental conservation, an increasing number of utilities as well as industries positively began embracing the DSM techniques, with greater benefits being realised.

Successful implementation of DSM has partly been attributed to information, technical assistance, financial assistance and direct intervention programme designs (energy conservation techniques) and also the load management techniques such as peak load clipping, valley filling, load shifting, load building(Yang, 2006).

The effort levels of implementation of these programme designs is shown in Figure 4.3. There is a greater improvement in energy efficiency as one moves up on the rungs of the pyramid; which requires an equally greater design effort and higher expenditure on the programme.

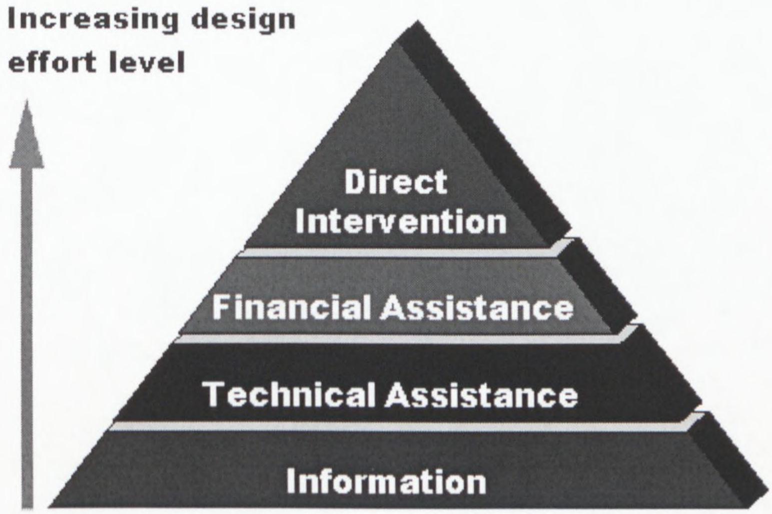


Figure 4.4: Design effort level of programme implementation

4.5.1 Information Programs

Information programs focus on dissemination of information to the customers regarding energy efficiency by way of brochures, hand-bills, booklets and seminars among others. They are often used in the early stages of a utility's involvement in a particular DSM program.

The advantages of information strategies include low cost, easy implementation and quick access to a large share of the potential market. Disadvantages include low response rates and difficulty achieving long-lasting changes in behaviour and energy use (Hayman and Peterson, 1988).

4.5.2 Technical Assistance Programs

These programs provide customers with energy audits of their facilities or design services. These programs address the technical barriers encountered by customers who may understand the benefits of implementing energy efficiency but do not have the technical skills to do so.

The utility staff will then provide guidance on selecting or implementing specified technologies by consumers and/or users. This in itself is like offering free consultancy services to the consumers.

Qualities that pertain to technical assistance programs include sophisticated or new technologies, information not easily explained through the media, and a relatively smaller number of customers. New residential construction programs also provide technical assistance to individual home builders. Technical assistance programs are also commonly found in the commercial and industrial sector.

4.5.3 Financial Assistance

Most energy efficiency measures require additional expenditure to obtain the financial benefits. However, many customers do not have the capital to invest; or find the financial returns of energy efficiency less attractive. The purpose of financial assistance is to reduce the cost to the customer while implementing energy efficiency measures.

Some of the ways in which energy conservation financial assistance can be offered to the consumers include Indirect financial participation, where the utility has an arrangement with a bank or other lending institutions; Direct loans to consumers; Incentives such as rebates, grants, or full financing by the utility and Energy purchase contracts or buy-backs.

It is important to note that financial programs are used when utilities face consumer reluctance or difficulties in purchasing conservation products. In most of the cases, the customer either does not have the money or will spend it elsewhere if attractive financing for conservation measures is not available.

4.5.4 Direct Intervention

These are actions which “intercede” in the market by either requiring customers to purchase energy efficient equipment or installing/providing the energy efficient equipment for free or at a reduced cost. Minimum efficiency performance standards which are introduced through regulation by governments are examples of direct intervention.

Table 4.3 shows ways in which DSM programs are capable of being marketed to customers using information, technical assistance and financial assistance methods.

Table 4.3: Marketing strategies for DSM Programs

MARKET IMPLEMENTATION METHOD	ILLUSTRATIVE OBJECTIVE	EXAMPLES
Customer Education	• Increase customer awareness of utility programs. • Increase perceived value of service	• Bill inserts • Brochures • Information packets • Displays • Clearing house • Direct mailing
Direct Customer Contact	• Through face-to-face communication, encourage greater customer acceptance and response to utility programs	• Energy audits • Direct installation • Store fronts • Workshops/energy clinics • Exhibits/displays • Inspection service
Trade Ally Cooperation (i.e. architects, engineers, appliance dealers, heating/cooling contractors)	• Increase utility capability in marketing and implementing programs • Obtain support and technical advice on customers' adoption of demand side technologies.	• Cooperative advertising and marketing • Training • Certification • Selected product sales/service
Advertising and Promotion	• Increase public awareness of new programs • Influence customer response	• Mass media (radio, TV and newspaper) • Point of purchase advertising
Alternative Pricing	• Provide customers with pricing signals that reflect real economic costs and encourage the desired market response	• Demand rates • Time-of-use rates • Off-peak rates • Seasonal rates • Variable levels of service • Promotional rates • Conservation rates
Direct Incentives	• Reduce up-front purchase price and risk of demand technologies to the customer • Increase short term market penetration • Provide incentives to employees to promote demand side programs	• Low/no interest loan • Cash grants • Subsidised installation/modification • Rebates • Buy-back programs • Rewards to employees for successful marketing of demand side programs

Source: Electric Power Research Institute, 1984 Vol. 3

4.6 Demand Response

In the 2006 Federal Energy Regulatory Commission (FERC) De mand Response Assessment, Commission staff noted that demand response refers to actions by customers that change their consumption (demand) of electric power in response to price signals, incentives, or directions from grid operators, and adopted the definition of "demand response" that was used by the U.S. Department of Energy (DOE) in its February 2006 report to Congress:

Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised. (U.S DoE, 2005)

In the definition above, the 2006 FERC Demand Response Assessment does not include energy efficiency and instead, relies on the idea that the changes in electricity use are designed to be short-term in nature, with focus on critical hours during a day or year when demand is high or when reserve margins are low.

In addition to actions at the state level since the 2006 report, there has been a flurry of recent utility announcements of programs and tariffs that include demand response, time-based rates, energy efficiency, and advanced metering.

4.6.1 Demand Response Characteristics

Demand response in a wider sense requires active participation by retail customers in electricity markets, seeing and responding to prices as they change over time. In most cases, customers see only flat average-cost based electric rates that give them no indication that electricity values change over time, nor any incentive to vary their electric use in response to prices. However in a well functioning competitive market, both supply and demand respond to price changes. Cases where the prices are high offer incentive to suppliers who tend to produce more while at the same time, consumers' demand will preferably reduce (Sioshansi and Vojdani, 2001).

The effects of demand response on a quantity under two conditions of elastic and inelastic are shown in Figure 4.5. It can be observed that extremely high price shown as P1, may result on a strained electricity market under inelastic demand (D1) scenario. Electricity consumption therefore is not sensitive to the cost of production because the "real" price of production is not taken into consideration.

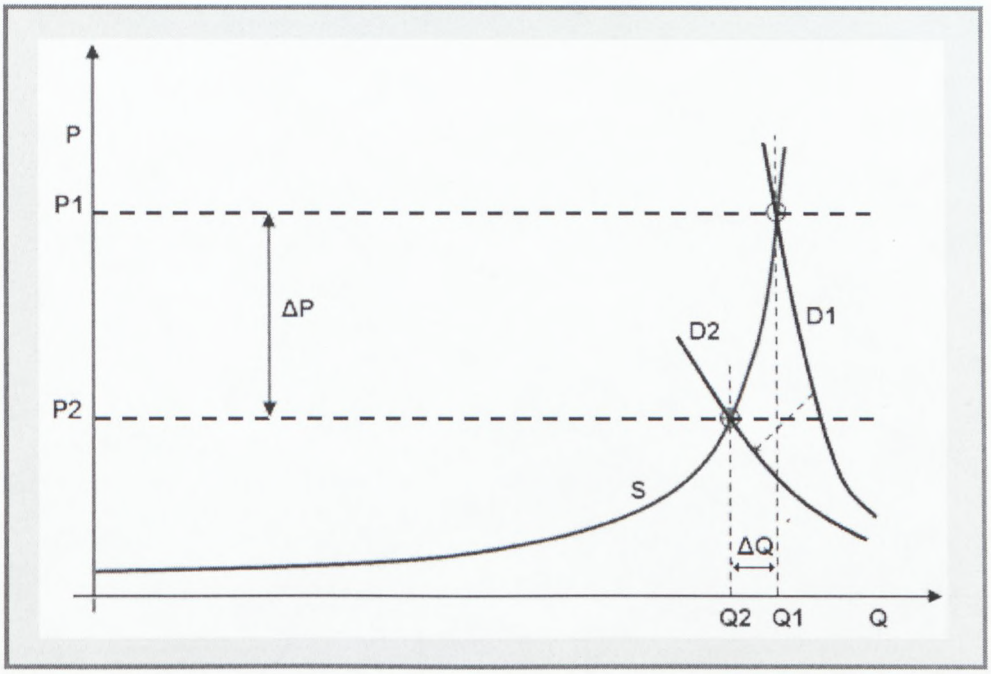


Figure 4.5: Effects of Demand Response on a quantity.

In case demand response measures are employed, then the demand becomes more elastic as indicated by D2. Subjecting consumers to meeting the real prices of production is bound to make them react by either increasing or reducing their usage of electricity. Effectively, it is possible to realise a much lower price in the market as depicted by P2.

Lower electricity use in peak periods creates benefits by reducing the amount of generation and transmission assets required to provide electric service. Lower demand in response to high prices reduces the costs of electricity production and holds down prices in electricity spot markets. Reduced demand in response to system reliability problems enhances operators' ability to manage the electric grid or network that transmits electricity from generators to consumers, and reduces the potential for forced outages or full-scale blackouts.

4.6.2 Categories of Demand Response

Demand response can be classified according to the way changes in the load are brought about.

• *Price-based demand response* occurs when customers change the utilisation of energy in response to changes in the prices they pay for energy consumed. Examples include real-time pricing, critical-peak pricing, and time-of-use rates. In case the price differentials between hours or time periods are significant, customers can respond to the price structure with significant changes in energy use. Effectively this results to a reduction in electricity bills if the customers adjust the timing of their electricity usage to take advantage of lower-priced periods and/or avoid consuming when prices are higher. Customers' load use modifications are entirely voluntary.

• *Incentive-based demand response* programs are established by utilities, load serving entities, or a regional grid operator. These programs give customers load reduction incentives that are separate from, or in additional to their retail electricity rate, which may be fixed (based on average costs) or time-varying. The load reductions are needed and requested either when the grid operator thinks reliability conditions are compromised or when prices are too high. Most demand response programs specify a method for establishing customers' baseline energy consumption level, so observers can measure and verify the magnitude of their load response. Some demand response programs penalise customers that enrol but fail to respond or fulfil their contractual commitments when events are declared.

Table 4.4 is a summary of the major price-based and incentive-based demand response programs that are currently in use in the U.S.

Table 4.4: Price-based and incentive-based demand response programs

DEMAND RESPONSE OPTIONS	
Price-Based Options	Incentive-Based Programs
• ***Time-of-use (TOU):*** a rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods. • ***Real-time pricing (RTP)***: a rate in which the price for electricity typically fluctuate hourly reflecting changes in the wholesale price of electricity. Customers are typically notified of RTP prices on a day-ahead or hour-ahead basis. • ***Critical Peak Pricing (CPP):*** CPP rates are a hybrid of the TOU and RTP design. The basic rate structure is TOU. However, provision is made for replacing the normal peak price with a much higher CPP event price under specified trigger conditions (e.g., when system reliability is compromised or supply prices are very high).	• ***Direct load control:*** a program by which the program operator remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner, water heater) on short notice. Direct load control programs are primarily offered to residential or small commercial customers. • ***Interruptible/curtailable (I/C) service:*** curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties maybe assessed for failure to curtail. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers. • ***Demand Bidding/Buyback Programs:*** customers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one megawatt [MW] and over). • ***Emergency Demand Response Programs:*** programs that provide incentive payments to customers for load reductions during periods when reserve shortfalls arise. • ***Capacity Market Programs:*** customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-of notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so. • ***Ancillary Services Market Programs:*** customers bid load curtailments in ISO/RTO markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. If their load curtailments are needed, they are called by the ISO/RTO, and may be paid the spot market energy price.

Source: US Department of Energy (US DoE: 2005)

4.7 Smart Technology

Technological changes and innovations have led to a flood of terminologies in equal measures. Terms such as smart metering, automation, smart home, smart grid and many others are finding comfortable places in the written works of many researchers and authors. These terminologies deliver the simple message that man is yearning for systems that can perform certain activities with little or no human supervision or control. In effect, it requires application of systems that have intelligence embedded in them. These systems or technologies involved differ in terms of the industrial and market structures they serve.

In discussing the technological paradigms and complex technical systems, Peine (2008) underscores the idea of smart homes in utilising the Information & Communication Technology (ICT) to enable interoperability of household appliances and services in a built entity. He further mentions that the idea of smartness in the built environment had the intention of having central control and monitoring functions that would provide a cutting edge to managers of facilities.

Smart technology is anchored on the same principle of central control of several interrelated and interoperable systems or devices to enhance reliability and efficiency in a cost-effective manner. Smart technology varies in three aspects of topology, protocol and medium of transmission. Topology shows the relationship between linked elements in a system, either centrally or in a decentralised manner. The type of transmission media determines important parameters such as speed, capacity and interference. The different types of media include optical fiber, twisted pair copper cables, coaxial cables, electricity power lines and a myriad of wireless media. It has to be noted that there are particular virtues and vices associated with each of the media; hence, it is essential to make a wise choice that fit the specific function(s). Protocol establishes a set of technical rules necessary for transmission and reception between interrelated components of a system.

Smart technology in electricity industry ranges from smart metering to smart grid. Smart meters became popular when there was a need to introduce prices for electricity used depending on the time of day and/or season. Unlike the traditional meters that would only measure the total consumption, the smart meters are able to give information of when the energy was consumed. This allows for utility providers of electricity to bill their customers according to how much they consume and at what time of day. Examples of such billing programs include Real-Time pricing and Time-Of-Use

A smart meter happens to be one of the enabling technologies that make it possible to extract value from two-way communication in support of distributed technologies and consumer participation. Advanced Metering Infrastructure (AMI) is an approach to integrating consumers based upon the development of open standards. It provides consumers with the ability to use electricity more efficiently and provides utilities with the ability to detect problems on their systems and operate them more efficiently.

In an article by Therese Shakra of New Mexico State University titled "EYE ON RESEARCH: NMSU faculty work to improve electrical grid technology", U.S. Secretary of Energy Dr. Steven Chu quoted a popular comparison that says:

If Alexander Graham Bell were somehow transported to the 21st century, he would not begin to recognise the components of modern telephony – cell phones, texting, cell towers, PDAs, etc. – while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid.

The comment refers to the pace of change – or lack thereof – regarding state of US national electricity grid.

4.8 Smart Distribution Board

4.8.1 Rational of Smart Distribution Board.

Electricity markets in both developing and developed countries are influenced by the uncertainties in the load growth, costly investments needed to augment capacity as well as the ever diminishing fuel sources and its associated environmental impact. Development of Demand Side Management concept was in response to the potential problems of global warming and the need for sustainable development; and also the realisation that improved energy efficiency represents the most cost-effective option to reduce the impacts associated with these problems.

Successful implementation of DSM is dependant on cooperation between the utility and its customers. In some cases the assistance of third parties where Electricity Service Companies (ESCo) exist is vital; especially in areas of increasing efficiency of energy utilisation that translates to benefits to utility, the customer and the society at large.

Despite these efforts, the demand for energy may far surpass the generating capacity of the utility during peak periods whence the utility is not able to service the customer base; necessitating actions of load shedding in order to reduce the load strain on the utility.

During these intervals of load shedding, the customer is completely disconnected until such a time that the utility load has stabilised. The smart distribution board (SDB) will allow the utility to selectively disconnect certain appliances on the customer side whenever the demand increases beyond the safe capacity. This translates to graceful load shedding as opposed to complete disconnects.

Smart Distribution Board (SDB) has to function in similar manner as traditional distribution board; dividing the electrical mains feed into various circuits and providing a fuse or circuit breaker for each circuit. However the SDB has electronic actuators connected to the switches of the various circuits on the distribution board to control the on and off conditions of the appliances. These actuators are based on a programmable logic controller (PLC) that obtains control signals transmitted from the utility provider. Figure 4.6 illustrates the way signals are sent from a central point (utility company).

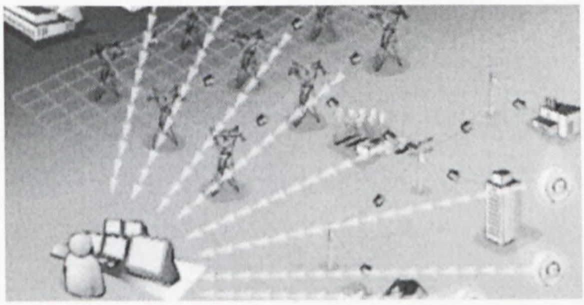


Figure 4.6: Signals transmitted from a central point to the smart SDB

4.8.2 Benefits of the Technique

The utility provider will benefit by having control and efficient management of the energy produced through active shifting of the load. In order to take care of the peak periods without effecting load shedding actions, the utility provider has to construct new standby plants. These standby plants lie idle for long periods of the day, only being put into action during peak demand. The utility provider can defer the need for construction of standby plants and instead, use signals to selectively apply load shedding that takes care of the peak periods.

The consumer will benefit through graceful load shifting in case the demand requires load shedding action. This will be achieved through selective load shifting technique. The nation and the world will benefit through conservation of environment. Figure 4.8 shows the emissions that come from electric power stations. These emissions have far reaching effects on the environment. Deferment of construction of new plants avoids or minimises such emission of gasses that can lead to global warm ing effect.

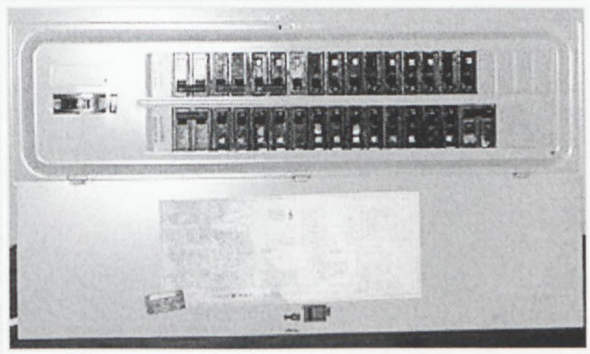


Figure 4.7: Traditional distribution board

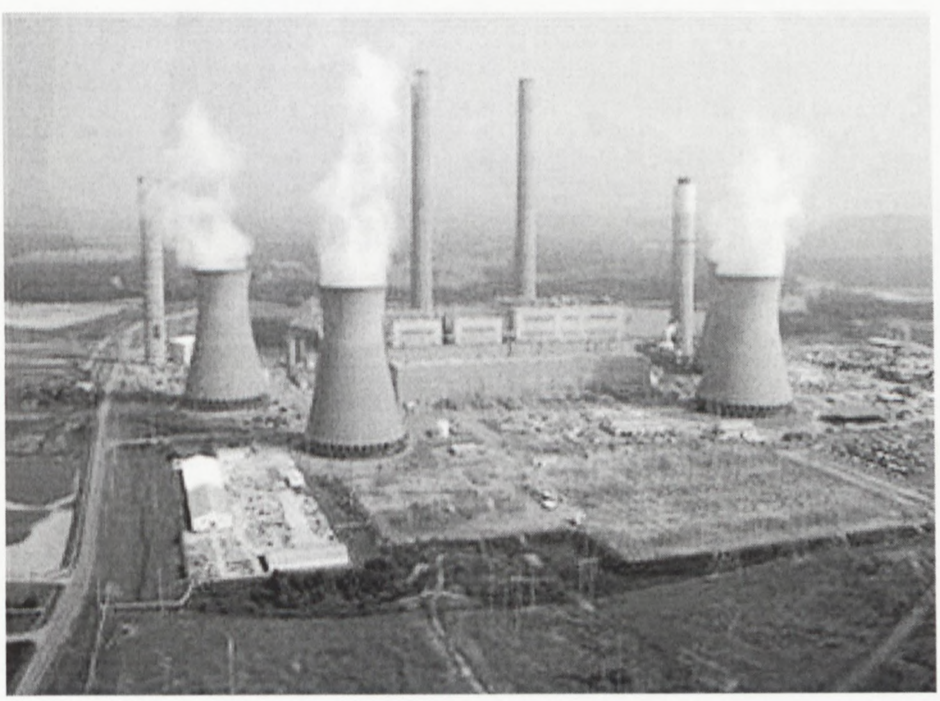


Figure 4.8: Carbon emissions by electricity generating plants

4.9 Conclusion

Electricity has made a substantial impact on the way we do business, the plant and factory environment, as well as our living standards. In the industries, homes and commercial fronts, electricity has continued to play a vital role in the development of these sectors. Furthermore, electricity has become a major commodity that drives the economies of countries world over. It is therefore crucial to manage well the usage of this sort after commodity. At times this would imply that the consumers have to forgo usage of some appliances as the utility providers seek ways of stabilising the system when demand is high. Shedding loads during peak demand is crucial in reducing the costs that would result in case "spinning reserve" assets that lie idle most of the time were to be built. The chapter covered techniques and strategies that can be employed or implemented so as to effectively control and manage energy consumption. The next chapter considers programmable logic controller.

CHAPTER FIVE

PROGRAMMABLE LOGIC CONTROLLER

5.0 Introduction

This chapter gives an overview of Programmable Logic Controller device. The various programming languages and one particular device, the ILC 150 ETH have been highlighted.

A programmable logic controller (PLC) is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines or lighting fixtures (Hugh, 2005). PLCs find major applications in industries and machines, such as packaging and semiconductor machines. They differ from the general-purpose computers since they are designed for multiple inputs and output arrangements with extended operating temperature ranges. The other inherent features of PLCs include immunity to electrical noise and resistance to vibration and impact.

The input/output (I/O) arrangements connect the PLC to sensors and actuators. On the sensor side, PLCs are capable of reading limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. Similarly, on the actuator side, the PLCs can operate electric motors, pneumatic or hydraulic cylinders, magnetic relays, solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or external I/O module attached to a computer network that plugs into the PLC.

The PLCs are controlled by programs that are written and stored in non-volatile memories that have a back-up battery to safeguard loss of data. A PLC exemplifies a real-time system that is capable of producing an output that is dependant on the input variables within a bounded time, otherwise unintended operation will result

The features that are embedded in modern control systems include reliability, cost-effectiveness, accessibility and proper functionality. These characteristics are resolved by use of programmable logic controller (PLC).

5.1 PLC Connections

When a process is controlled by a PLC it uses inputs from sensors to make decisions and update outputs to drive actuators, as shown in Figure 5.1. The process is a real process that will change over time.

Actuators will drive the system to new states (or modes of operation). This means that the controller is limited by the sensors available, if an input is not available, the controller will have no way to detect a condition.

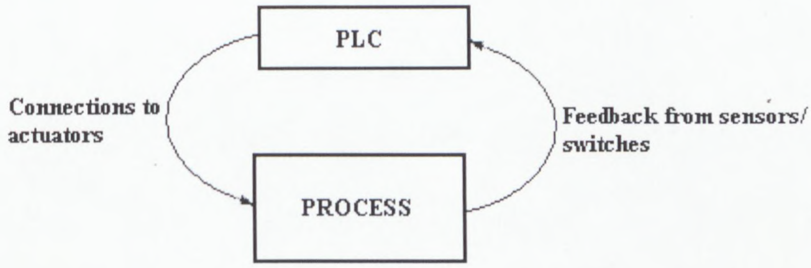


Figure 5.1: Separation of Controller and Process

The control loop is a continuous cycle of the PLC reading inputs, solving the ladder logic, and then changing the outputs. Like any computer this does not happen instantly.

Figure 5.2 shows the basic operation cycle of a PLC. When power is turned on, initially the PLC does a quick sanity check to ensure that the hardware is working properly. Malfunctioning of the PLC could be as a result of power loss in the back-up battery, which effectively corrupts the memory. In case a problem is detected, the PLC will halt and give the error indication. Once the PLC successfully goes through the sanity check, it begins to scan (read) all the inputs.

After the inputs' values are stored in memory, the ladder logic will be scanned (solved) using the stored values - not the current values. This is done to prevent logic problems that might occur in circumstances where the inputs change during the ladder logic scan. At completion of the ladder logic scan, the outputs will be scanned (the output values will be changed). After this the system goes back to do a sanity check, and the loop continues indefinitely. Unlike normal computers, the entire program will be run for every scan. The typical time for each of the stages is in the order of milliseconds.

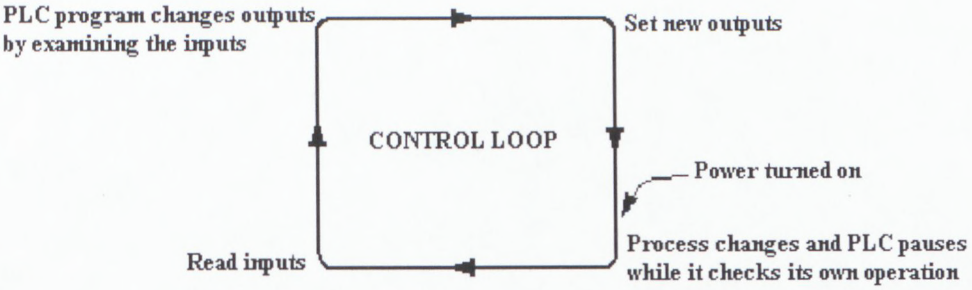


Figure 5.2: Scan cycle of PLC

5.2 PLC Configuration

Many PLC configurations are available, even from a single vendor. But in each of these there are common components and concepts. PLC configuration refers to the packaging of the components. Figure 5.3 is a block diagram illustrating the units of a Programmable Logic Controller.

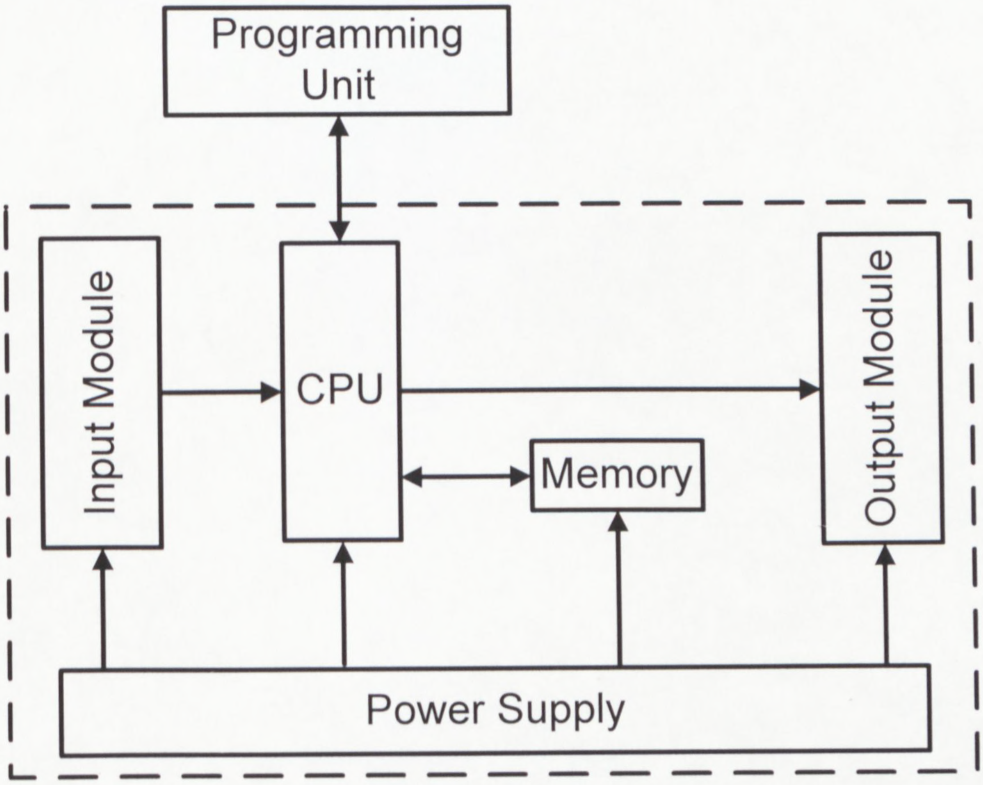


Figure 5.3: Block diagram of a PLC

The most essential components of a PLC are highlighted.

Power Supply - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC are 24Vdc, 20Vac, 220Vac.

Central Processing Unit (CPU) – As shown in Figure 5.3, the CPU is the nerve centre of a computer system that performs the central control functions and all computational, logical, and operational decisions. It contains the logic circuitry for performing the various computational activities. In addition, it has a memory where information or instructions are fetched, decoded to ensure that the operations called for by the instructions are executed properly. In order to do all this, the CPU communicates or interfaces with the input and output units and the memory.

Input/Output (I/O) *module* - A number of input/output terminals are essential in facilitating the PLC to monitor the process and initiate actions. These modules make possible communication between the PLC and the outside world. The terminals on the input module enables the user enter external process (electrical) signals. Similarly the output module has a set of terminals that deliver the signals to the process. The process operating under control of the PLC may be located at a remote place far from the I/O modules and the CPU. The internal voltage levels in a PLC are of lower magnitude compared to higher power electrical sensor and actuator circuits. Opto-isolators are used to buffer the PLC from the high power rated circuits. An example of an isolation circuit is shown in Figure 5.4

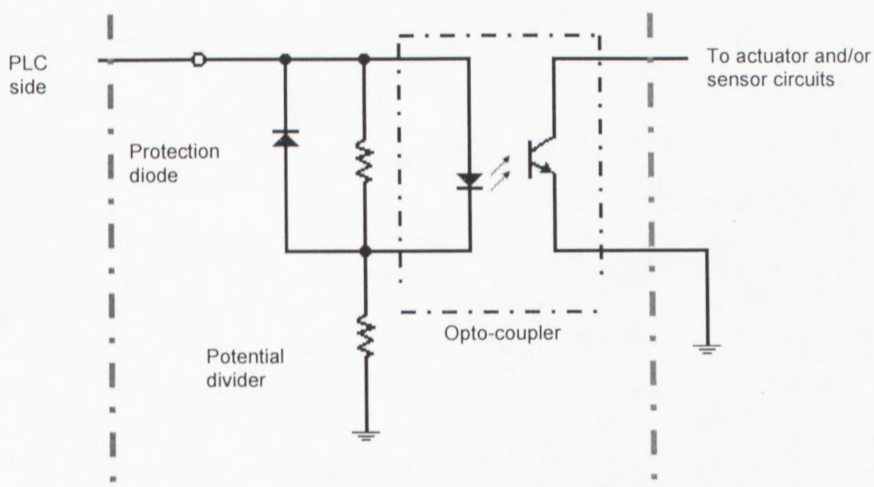


Figure 5.4: opto-isolator circuit

Human machine interface (HMI): These are interface devices that facilitate interaction with a process. The devices are known variously either as touch screens, displays, man machine interface (MMI) or human machine interface (HMI). The purpose of the HMI is to assist the operator through use of easy displays that determine the condition of machines in order to make simple settings. Common among the settings to be made are display of machine faults, display of machine status, allow for start and stop cycles and also monitor particular counts in the system (Hugh, 2005).

The advantages of HMI include use of colour codes for easier identification, the pictures/icons provide faster recognition and sorting of illiteracy issues. In addition, the screen can be altered to allow different levels of information and access.

In making a design of an HMI interface, it is crucial to evaluate the needs of the user and the operator. The probing questions that require to be addressed include:

I. Who needs what kind of information?
II. How do they expect the information to be presented?
III. When is the information to be presented?
IV. What are the needs of the operators if any?
V. Will sound be required?
VI. Are there options or choices for the operator?

Answers to the above questions will lead to a design that is appropriate and at the same time, improve the working environment for the operators.

Indicator lights - These are used to symbolise the status of the PLC including power on, program running, and/or a fault. They are also essential in providing hints to location of a fault in diagnosing problems.

Software - A PLC that is software based requires a computer with an interface card, which allows it to be connected to sensors and other PLCs across a network. The program that controls the operation of the PLC resides in the computer.

Relays - Although relays are rarely used for control logic, they are still essential for switching large power loads. Some important terminologies and functions performed by relays include:

4) *Contactor* - Special relays for switching large current loads.
5) *Motor Starter* - Basically a contactor in series with an overload relay to cut off when too much current is drawn.

6) *Arc Suppression* - when any relay is opened or closed an arc will jump. This becomes a major problem with large relays. On relays switching AC this problem can be overcome by opening the relay when the voltage goes to zero (while crossing between negative and positive). When switching DC loads this problem can be minimised by blowing pressurised gas across during opening to suppress the arc formation.
7) *AC coils* - If a normal relay coil is driven by AC power the contacts will vibrate (open and close) at the frequency of the AC power. This problem is overcome by adding a shading pole to the relay.

Selection of relays or relay outputs to be used by the PLC is carefully done to avoid damage or premature contact wear. To ensure safety to the equipment, plant and staff, it is important not to exceed the rated current and voltage values; the rated current being the maximum current before contact damage(welding or melting) occurs while rated voltage being safe operating voltage, with levels below causing failure in operation and levels above resulting to shorter life.

In most cases, the rated values are given for both AC and DC, although DC ratings are lower than AC. Ideally the relays should work well indefinitely as long as the actual loads used are below the rated values of the relays. If the values are exceeded by a small amount, the life of the relay will be shortened accordingly. Exceeding the values significantly may lead to immediate failure and/or permanent damage. Conversely, operating these devices with lower levels of voltage can result to system malfunction.

Rail mounting. The modules are snapped on grounded mounting rails with clamp angles and spring clamps. Rail mounting is possible for modules including: Remote Terminals (RT), Smart Terminals (ST) and Configurable Terminals (CT). Mounting can also be direct whereby the modules are fastened with screws to grounded mounting angles or mounting plates. Direct mounting is possible for the following modules: Motor starter, sensor/actuator boxes (SAB) and Remote Terminals (RT).

5.3 PLC Programming Languages

The software program is an essential component of a PLC. The programmer uses elements, functions and instructions to design the system that the PLC is to control or monitor. The function of all programming languages is to enable the user to communicate with the programmable controller (PC) via a programming device. Desirable features of programming tools include the following:

a) Simultaneous use of several PLC programming languages
b) 'online' modification of programs in the PLC
c) Reverse documentation of the programs from the PLC
d) Reusability of PLC program blocks
e) 'offline' testing and simulation of user programs
f) Integrated configuring and commissioning tools
g) Quality assurance, project documentation
h) Use of systems with open interfaces (Erickson, 2005).

There are five languages that can be used to program a PLC as: Ladder Diagram (LD), Instruction List (IL), Sequential Function Charts (SFC), Structured Text (ST) and Function Block Diagram (FBD). These languages are defined by the International Electrotechnology Commission (IEC) which has the mandate of preparing and publishing International Standards for all electrical and electronic technologies. IEC standards encompass a wide range of technologies from power generation to nanotechnologies. The IEC61131 is one of the international automation standards. IEC61131-3 is in reality the programming language for industrial controllers. Benefits of using an IEC61131-3 standard language include:

- code re-use
- universal code can be purchased
- less development time
- reduced costs
- larger pool of available engineering resources
- data exchange between PC-based and embedded controllers
- interoperability

The IEC 61131-3 standard defines the syntax of the five programming languages and describes their representation and language elements. Two of these languages, IL and ST are textual while three languages, FBD, LD and SFC are graphical languages.

The PLC programmer has the option of programming in one of the five languages or mixing the elements of one or more languages in the program. This results to a wide choice of format to use when writing control programs. Standardisation of has the advantage of allowing use of different programming languages within a program.

The IL code consists of a sequence of instructions with each instruction starting on a new line. Each line is indicated by a line number and an operator is written at the beginning of the line followed by an operand. Operands in IL can be variables, literals or instance names of function blocks. Operands are used together with operators or functions in the instructions.

Jumps and labels in the IL code are used where subroutines exist in a program. In case a jump instruction (JMP) is encountered while executing the code, the program is directed from the line with the jump instruction to the line having the label.

The ST code is made of statements and expressions consisting of operators and operands in lines, each line being terminated by a semicolon. The operators have to be applied to the operands in the way that the operator with the highest precedence is followed by the operators with the next lower precedence.

The code body worksheets in ST are edited using the text editor by typing the statements and expressions or inserting them using the Edit Wizard. The Edit Wizard in ST contains several standard keywords (for example IF, WHILE, FOR), functions and function blocks which can be inserted. A good program orientation is achieved by use of indents for statements and loops as well as starting each statement on a new line.

The syntax highlighting represents the different elements by colors whereby, keywords are displayed in blue, variables and instance names are in black and comments are in green.

Operands in ST can be literals, variables or names of functions. Operands are used together with operators in expressions. When editing the ST code body, variables that have already been declared can be used or undeclared variables can be inserted and be declared while editing the code body. It has to be noted that a variable which is to be accessed throughout the program has to be declared as global while local variable declaration applies to the variables that are only accessible to the function or block in which it is declared.

The FBD is a code body programmed in the graphical language. FBD is composed of functions and function blocks which are connected with each other or with variables using lines. These lines can also be connected with each other. In FBD networks it is not possible to connect outputs with outputs. The set of connected objects is called FBD network.

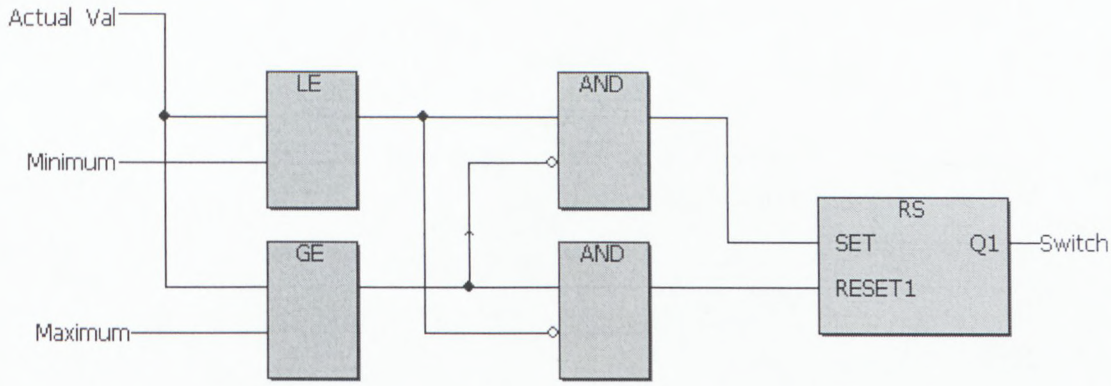


Figure 5.5: Arrangement of Function Block Diagram (FBD)

SFC is a code body programmed in the graphic language. SFC is composed of steps and transitions which are connected with directed links. One or several action blocks can be associated to a step.

An action block consists of an action and the corresponding action qualifier. Action qualifiers specify how an action is affected by the step it is associated to. While a step is active, the associated action is executed according to its action qualifier. The action can either be a Boolean variable or an IL/ST/LD/FBD code body (called 'detail').

Ladder diagram is one of the frequently selected software formats. It includes contacts, coils, timers, counters, registers, digital comparison blocks and other types of special data handling functions that conform to the IEC 61131-3 standard. The aim of ladder diagram program is to control outputs based on input conditions. A basic structure of the ladder rung is shown in Figure 5.6. The contacts are indicated by A and B while C is the coil. Contacts and coils are connected via lines and they are bounded on the left and on the right with power rails L_1 and L_2. The state of the left power rail is considered ON all the time. Both, contacts and coils, are assigned to Boolean variables. The Boolean equation representing the conditions in Figure 5.5 is given as:

$$C = \overline{A}\,\overline{B} + AB \qquad (5.1\}$$

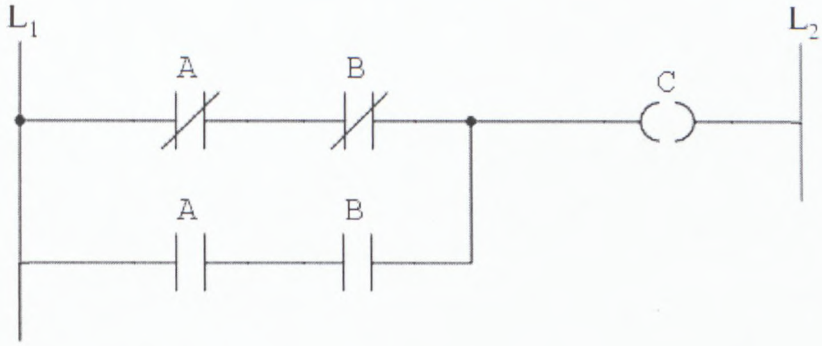


Figure 5.6: Ladder diagram arrangement

Coils and contacts are the basic symbols of the ladder diagram instruction set. The coil symbols represent all the outputs, while contacts represent conditions to be evaluated in order to determine the control of the output. Each coil and contact is referenced with an address number that is used to identify the operating conditions (what is being evaluated and what is being controlled).

The arrangement of the rung contacts depends on the requirements of the control logic. Contacts may be placed in any formation such as series, parallel, or a hybrid of series/parallel that is necessary to control a particular output. The programmer designs a control system by placing the elements (contacts, coils, counters, timers) on individually numbered rungs. The external devices and components are then wired into the system identical to that of the programmer's software ladder logic. For an output to be activated or energised, at least one left-to-right path of contacts must be closed. In this case, the condition of the rung is TRUE. The rung condition will be FALSE if none of the path has continuity.

The action of the contacts placed in the rungs depends on the type used. The two types are Normally Closed (NC) and Normally Open (NO). In the ladder diagram of Figure 5.6, contacts A and B in the upper branch are NC type while in the lower branch, the contacts are NO type. Coil C represents the output.The NO contact represents any input to the control logic. An input can be a connected switch closure or sensor, a contact from a connected output, or a contact from an internal output. When interpreted, the referenced input or output is examined for an ON condition. If its status is 1, the contact will close and allow current to flow through the contact. If the status of the referenced input/output is 0, the contact will remain open, barring current from flowing through the contact. Similarly, a Normally closed contact represents any input to the control logic and when interpreted, the referenced input/output is examined for an OFF condition. If its status is 0, the contact will remain closed, thus allowing current to flow through the contact. If the status of the referenced input/output is 1, the contact will open, prohibiting current from flowing through the contact.

Output represents any output that is driven by some combination of input logic. An output can be a connected device or an internal output. If any left-to-right path of input conditions is TRUE (all contacts closed), the referenced output is energized (turned ON). NOT output represents any output that is driven by some combination of input logic such that if any left-to-right path of input combination results to TRUE conditions (all contacts closed), the referenced output will be de-energized (turned OFF).

The execution of the ladder diagram program is achieved by the CPU (of the PLC) scanning (top-down) through the software program rung-by-rung. The hard-wired device that the software is emulating then becomes active. The software which happens to be the controlling device, provides the programmer with the flexibility to either "force a state" or "block a device" from the system operation. For example, a coil or contact can be made to operate directly from the software (independent of the control cabinet's hard-wiring to source or field input devices). Or, a device can be masked to appear invisible even though it's electrically hard-wired and physically in place.

When developing large networks, connectors can be used to improve the layout of the element's structure in the worksheet. Connectors replace the connection lines. Additionally, jumps can be used. A jump instruction requires two objects a jump and label (which is the target for the jump) to be inserted in the same worksheet. Returns can be inserted to go back to a calling program organisation unit (POU).

In each of the programming language, comments can be inserted to make the program reader-friendly. The comments are intended to improve the understanding of the function or tasks performed by the program.

With the several programming languages available, it's essential to consider certain factors before deciding which one to use. There is a tendency of sticking to an already familiar language; however the high-level benefits of each language have to be taken into consideration in selection of language. Some of the benefits include:

- Ease of maintenance by the final user
- Universal acceptance of language
- Execution speed of by the PLC
- Applications mainly using digital I/O and basic processing
- Ease of changing code later

- Ease of use by newer engineers
- Ease of implementing complex mathematical operations and
- Applications with repeating processes or processes requiring interlocks and concurrent operations.

5.4 I/O Bus System

A bus is a collection of lines that transmit data and/or power. The PLC has an I/O bus networks or fieldbus whose function is to communicate information with, as well as supply power to the field devices. Fieldbus is a generic-term that is used to describe a digital communications network which is used in industry to replace the 4 - 20mA analogue signal. The network is a digital, bi-directional, multidrop, serial-bus, communications network used to connect remote field devices, such as controllers, transducers, actuators and sensors. Each field device has low cost computing power installed in it, making each device a 'smart' device. Each device is capable of executing simple functions on its own such as diagnostic, control, and maintenance functions as well as providing bi-directional communication capabilities. The fieldbus technology not only allows access to the field devices, but the devices can communicate with other field devices. In essence, use of fieldbus replaces centralised control networks (CCN) with distributed-control networks (DCN).

Fieldbus makes it possible for devices to communicate fast and reliably. The devices can be networked and configured according to the needs of the end user. However, different types and hence, different definitions of fieldbuses have come as a result of various objectives of the designers. For example, Thomesse (1990) mentions two objectives as simplifying the wiring between devices and distributed real-time system.

Fieldbuses have to satisfy certain requirements from the end user point of view. Among these requirements include:

- Safety and availability
- Modular – whereby addition of new components and modification of the existing is made easier.
- Openness, interoperability and interchangeability. This requirement implies that the fieldbus needs to provide a global system that allows compatibility of products from different vendors.
- Better maintainability – in which case, maintenance of the global system is simplified through easier detection of faults, repairing the fault and configuring the components.

- Dependability – whereby the fieldbus can detect errors in transmission of data, be able to meet time constraints and also electromagnetic compatibility (EMC) requirements.

The points above indicate that the end user may not be interested in the fieldbus itself, but the system in which it is used. The end user will not need to see the fieldbus, its protocol or its technical choices. If the system functionality is as expected, it may not matter who the vendor or type of fieldbus is. The IEC therefore sets the standard requirements that the vendors have to observe.

In an I/O bus network, the PLC drives the field devices directly, without the use of I/O modules; therefore, the PLC connects to and communicates with each field I/O device according to the bus's protocol. Fundamentally, PLCs connect with I/O bus networks in a manner similar to the way they connect with remote I/O, except that PLCs in an I/O bus use an I/O bus network scanner. An I/O bus network scanner reads and writes to each field device address, as well as decodes the information contained in the network information packet.

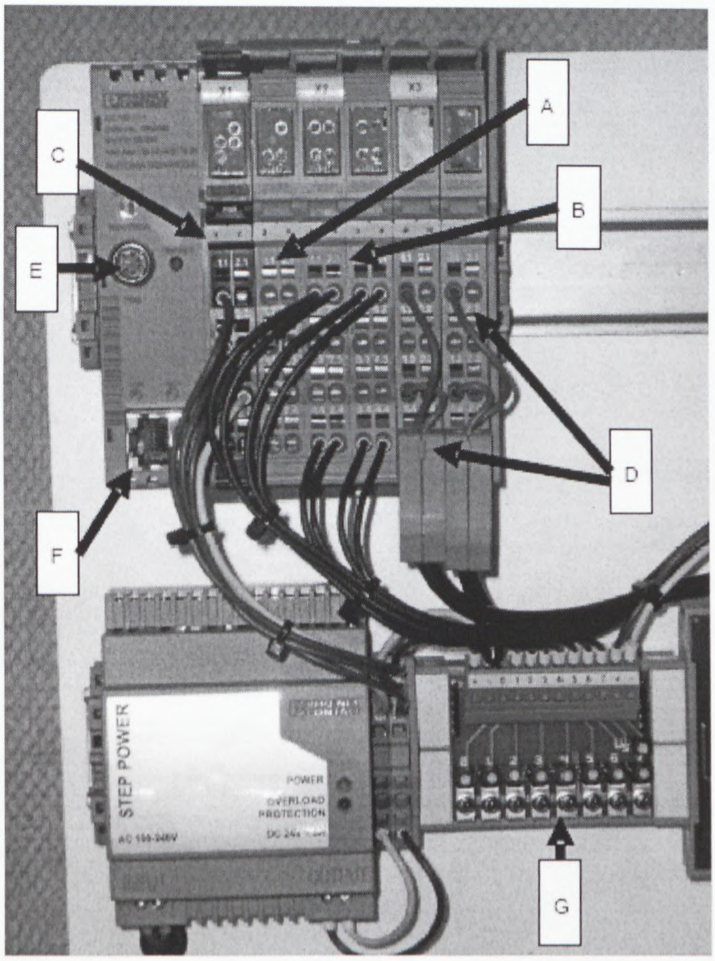
The field devices that connect to I/O bus networks contain intelligence in the form of microprocessors or other circuits. In addition to communicating the ON/OFF state of input and output controls, the field devices also provide diagnostic information about their operating states. For example, a photoelectric sensor (switch) can report when its internal gain starts to decrease because of a dirty lens, or a limit switch can report the number of motions it has performed. This type of information can prevent I/O device malfunction and can indicate when a sensor has reached the end of its operating life, thus requiring replacement.

5.5 ILC 150 ETH

5.5.1 Introduction

The inline controller ILC 150 ETH is highly modular and can be easily expanded with terminal blocks, which makes it ideal for efficient control of distributed applications. "ILC" is an acronym that indicates the type of controller, namely an inline controller. The number "150" signifies the performance class (in this case, the mid range section of 100 performance class) while "ETH" indicates that it is an Ethernet device. A PROFINET device can be identified by a "PN" in its device number, for example ILC370PN. Similarly, the ILC370PN belongs to the upper mid range section of the 300 performance class.

The program code can be downloaded from a PC to the ILC 150 ETH controller using either the serial or Ethernet port. The Ethernet port can also be used to connect up to three operator terminal or touch screen (OT/TP) devices with Ethernet through a switch. Figure 5.7 shows the compact inline ILC 150 ETH controller. The controller has 8 digital inputs, 4 digital outputs and it has both Ethernet and RS 232 (PS/2) ports for connection to the PC.



A 4 digital outputs

B 8 digital inputs

C power supply connector block

D separate analogue I/O channels

E RS-232 (PS/2) port

F Ethernet port

G 8 way simulator buttons

Figure 5.7: ILC 150 ETH controller from phoenix contact.

The practical area of application of Inline controllers is extended to smaller applications using the ILC 150 ETH controller. The compact controller can be adapted to the relevant requirements in a highly modular manner by integrating it directly in the Inline automation system. Table 5.1 shows an abridged technical data for ILC 150 ETH (*see Appendix B for complete technical data of* ILC 150 ETH).

Table 5.1 Technical data of ILC 150 ETH controller.

PROGRAMMING TOOL	PC WORX 5
Diagnostics tool	DIAG+ from version 1.14
Interface	INTERBUS local bus (master)
Type of connection	Inline data jumper
Interface	Parameterisation/operation/diagnostics
Type of connection	RS-232-C, 6-pos. MINI-DIN female connector (PS/2), Ethernet 10/100 (RJ45)
Interface	Ethernet 10Base-T/100Base-TX
Type of connection	RJ45 female connector
Transmission speed	10/100 MBit/s
Typical current consumption	210 mA (no local bus device connected during idling, bus inactive)
Max. current consumption	870 mA (370 mA Logikversorgung + 500 mA Analog-Spannungsversorgung)
Supply voltage	24 V DC
Range of supply voltages	19.2 V DC ... 30 V DC
Residual ripple	± 5 %

5.5.2 The ILC 150 ETH interface

The ILC150ETH inline controller utilises Ethernet interface for coupling to other controllers or systems, according to IEC61131-3 programming. Using its integrated Ethernet interface, the ILC150ETH can be parameterised and programmed as per IEC 61131 using the PC WorX automation software. It can also exchange data with OPC servers simultaneously and communicate with TCP/IP-compatible devices. The Technical specification of the control system is as follows:

- Data memory: 256 kByte
- Retentive data memory: 8 kByte (NVRAM)
- Onboard Realtime clock
- Supply for main circuit UM 24 V DC ±20%
- Communications voltage UL 7.5 V DC ±5% (Fritz, 2008).

The ILC150ETH has onboard I/O for eight 24V digital inputs to be evaluated and four 24V digital outputs to be controlled. The supply and I/O wiring colour codes of the controller are listed in Table5.2

Table 5.2 Wire colour coding

Function	Wiring colour
Supply +	Red
Supply -	White
Inputs	Black/Grey
Earth	Yellow/Green

The two types of cables that the ILC 150 ETH controller may use for data interface are serial RS-232(PS/2) and Ethernet 10/100 (RJ45). In order to download a code from the PC to the controller, it is important to choose the correct type of Ethernet cable to connect to the controller's Ethernet port. A straight Ethernet cable can be used between the PC and controller, if a network switch or hub is installed between the two devices. Each pin of the connector on one end is linked to the corresponding pin on the other connector (pin1 to pin 1, pin 2 to pin 2 *etcetera*). In this circumstance, the crossover connection has to be done internally in the switch or hub. In Figure 5.8, an arrangement of the pin position for 8 pin 8 connector plug is illustrated.

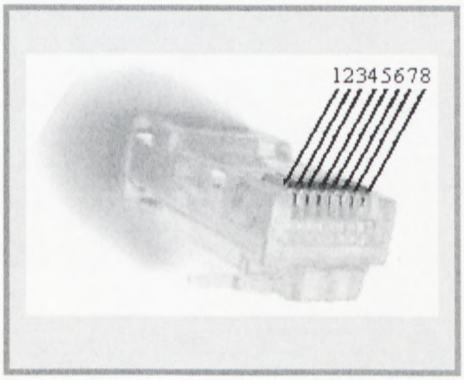


Figure 5.8: 8P8C modular plug pin positions

In case a direct link is made between the PC and controller without a switch or hub, a crossover connection (receive to transmit and transmit to receive) needs to be used. The crossover is done externally in the cable connector. The 10BASE-T and 100BASE-TX Ethernet cable use pairs 2 and 3 for transmission. The number (10 or 100) refers to the theoretical maximum transmission speed in Megabits per second (Mbit/s). **BASE** is short for baseband, meaning that there is no frequency division multiplexing (FDM) or other frequency shifting modulation in use; each signal has full control of wire, on a single frequency. The **T** shows that the cable is twisted pair type, where the pair of wires for each signal is twisted together to reduce radio frequency (RF) interference and crosstalk.

These two pairs are swapped in one of the connectors of the cable connection between two similar devices such as DTE/DTE or DCE/DCE by using a crossover cable. The arrangement of the two communication pairs (pins 1 & 3 and pins 2 & 6) determines whether one is crossover or straight. For the crossover, the arrangement is such that the two pairs are swapped. Swapping is done in accordance to the IEEE 802.3 standards for local area network (LAN) technology, which defines the wired Ethernet physical layer and the media access control (MAC) sub-layer of the data link layer.

5.5.3 PC WorX

The ILC 150 ETH is programmed using PC WorX software. The vender of the software is phoenix contact. The PC WorX consists of four workspaces as:

- IEC programming
- Bus configuration
- Process data assignment
- Project comparison

The "View" menu or the corresponding icon in the toolbar can be used to switch between the workspaces. The windows to be displayed can be defined at any time for each workspace.

5.5.4 Creating a project

A programme to be run in the ILC 150 ETH is created in PC WorX software. This programme is referred to as project. The sequences of creating a project are shown in Figure 5.9.

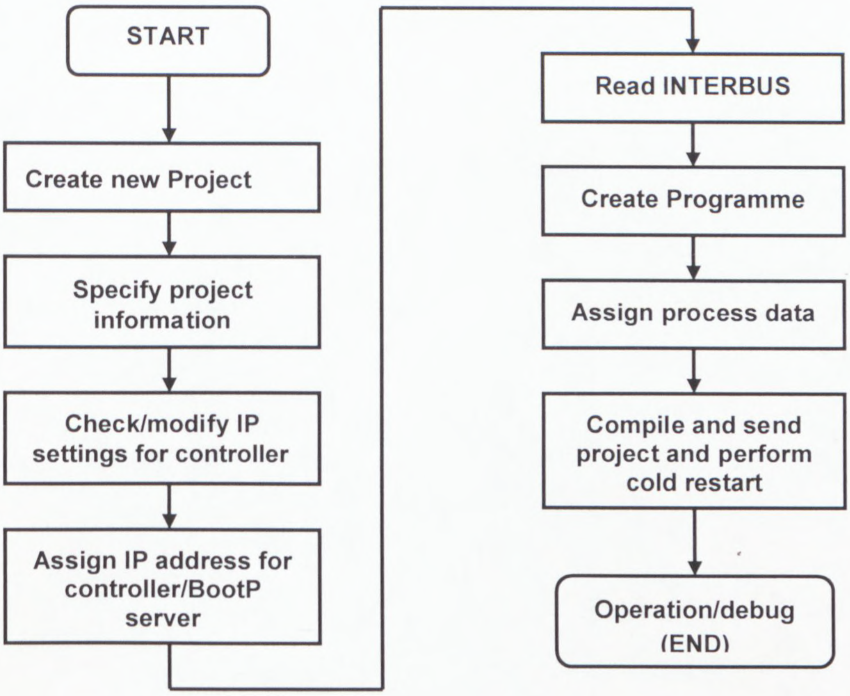


Figure 5.9: sequences followed in creating a project with PC WorX software.

There are several steps that are done in order to realise a project. Creation of a new project begins by selecting "New Project" from the File menu and choosing a controller template. This is followed by defining the project structure in the project tree; which is achieved by inserting Program Organisation Units (POUs) in the project. The POUs are programs, function blocks or functions. POUs are then edited by declaring parameters and variables, and editing code bodies using graphic editor, text editor and edit wizard facilities. The next step is to associate each program to the task needed to be performed on the PLC. Once editing of the program is complete, the compilation process has to be done so as to generate the specific PLC code. The next step is to download the compiled program to the PLC. The downloaded project goes through a debugging process to test its functionality. Good practice is to document the project by having a printout copy. PC WorX has customised page layouts with a choice of ranges to be printed in case the whole document may not be required.

5.6 Conclusion

Programmable logic controllers are essential devices that are robust for industrial process control purposes. However, the application of these devices can be extended to controlling and managing energy consumption. The next chapter considers the PLC for the purpose of controlling and managing electrical energy use in the domestic as well as industrial sectors.

CHAPTER SIX

ACTIVE LOAD SHIFTING TECHNIQUE (ALST)

6.0 Introduction

This chapter deals with the development of the active load shifting technique (ALST) that allows the utility to disconnect and reconnect the consumers depending on the status of the demand and the capacity. The design takes into consideration the distribution board used to separate circuits that provide supply to various electrical appliances such as water heaters (geysers), air conditioners, lighting and socket outlets. Effectively, the load is shifted to a later time by selectively switching off certain appliances during peak periods. The ALST is based on programmable logic controller (PLC).

In commercial buildings, 30 percent of total electrical energy consumption is contributed by lighting. As a result, lighting has increasingly become a candidate for energy-efficient initiatives that focus particularly in ensuring that the lights are OFF when they are not needed. Automated systems with sensors, actuators and timers can be used to achieve control and energy management.

The proposed active load shifting technique (ALST) is discussed in this chapter. A description of the technique is given in section 6.1. The ALST design and system realisation are discussed in sections 6.2 and 6.3 respectively.

6.1 Description of ALST

6.1.1 System Organisation

The proposed ALST system is PLC based consisting of three major components as personal computer (PC), interface devices and the PLC itself. The PC, which is at the utility side is responsible for the program(s) and signals that control operation of the PLC. The PLC device is installed at the customer's premises and determines which appliances are to be switched off when such action is required. The switching sequence is dependant on the program resident on the PLC, but upon receiving a command from the utility side. The interface circuits link the control device to the PC. The PLC receives signals that are transmitted from the PC and executes program instructions accordingly.

A block diagram of the load control layout is shown in Figure 6.1. The PLC is used to control the loads at the customer location. The PLC will provide the timing, counting and latching relay functions that are necessary to control individual loads. The number of loads can be extended by using multiple paralleled PLCs.

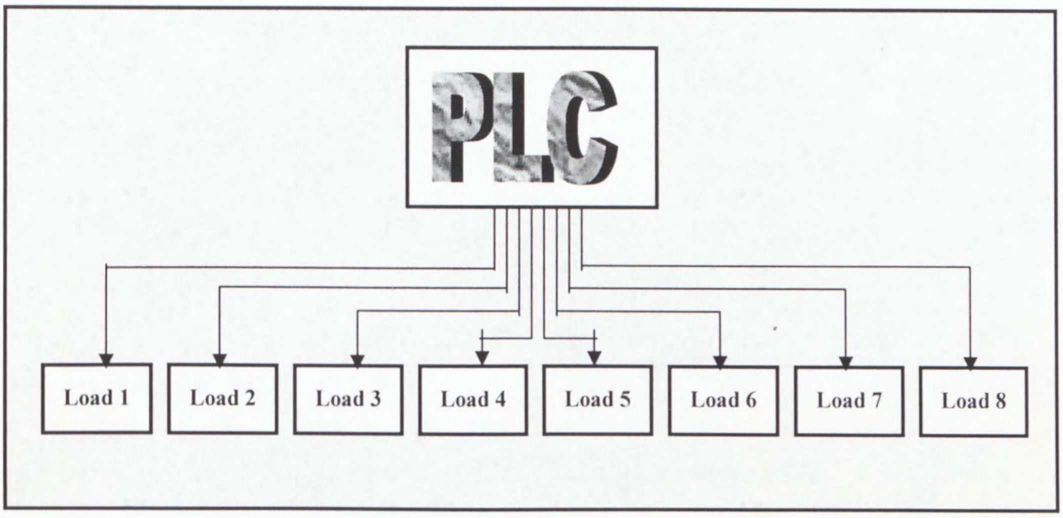


Figure 6.1: Block diagram of ALST with 8 different load circuits.

The design of ALST requires implementation of:

- a PLC hardware and software design to control loads installed at the side of the customer.
- a user interface with the utility company.
- development of the communication protocol to link the users with the utility via a PC. The PC is located at the utility.

This research considered a model based on the inline controller (ILC 150 ETH) PLC, onto which the program to control customer loads was loaded. The programming software used was PC WorX from phoenix contact. As earlier discussed in chapter 5, the ILC 150 ETH has 8 onboard digital inputs, 4 onboard digital outputs. Each of the outputs and inputs has an LED provided for the diagnostic purposes. Other LEDs are provide to indicate the power supply, condition of the PLC

The communication protocol linking the PC located at the utility to the PLC at the consumers side is not part of this research. However, communication between the PLC and the PC was established via an Ethernet cable. Figure 6.2 shows the ALST system with three customers connected via a wireless link to the computer at the utility.

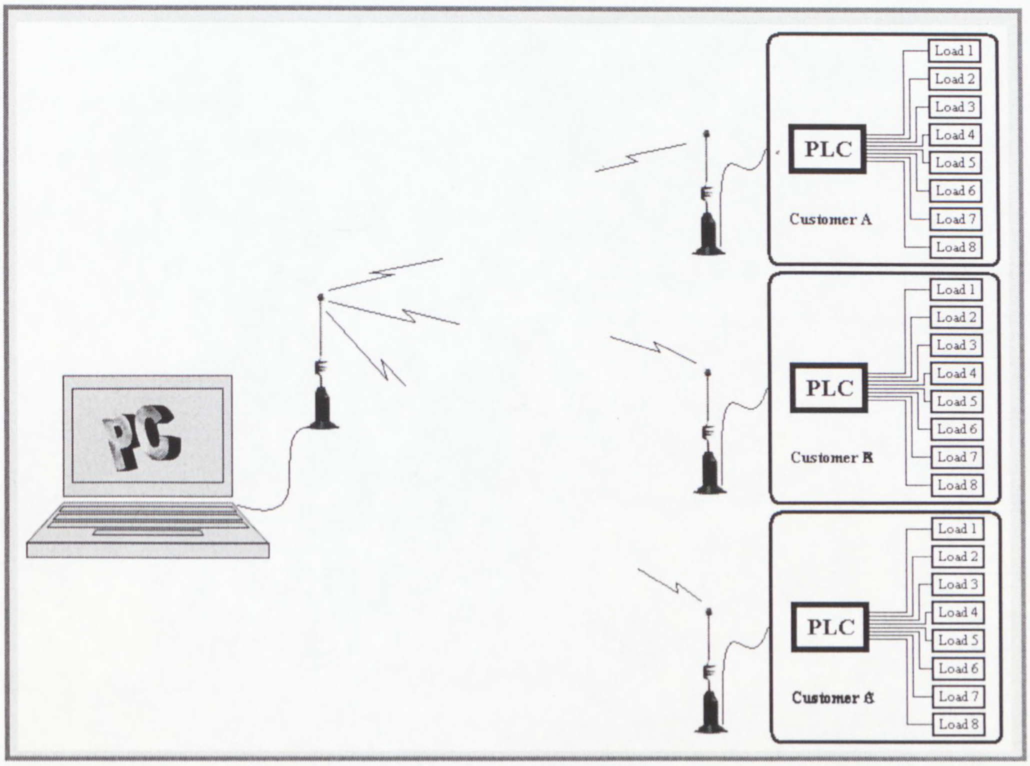


Figure 6.2: The ALST system with the computer on the utility side that transmits control signals to the PLCs on the consumers' side

6.1.2 Operation Procedure

The actuators can be activated remotely from the utility provider's side or by the consumer to disengage their respective switches. However, activation from the utility provider's side overrides any attempt or effort by the consumer to change this state. This precaution is necessary to avoid the consumer switching on the appliances after they have been disconnected by the utility provider, and thereby defeating the main objective of this DSM programme.

The available capacity (aka available safe capacity) of the utility is compared with the present demand. In case the demand is greater than the capacity, the load with higher switch-off priority is disengaged from the supply network; otherwise all loads will be switched ON. If the loads with higher priority are already switched off and yet there is a need for further reduction of load to stabilise the system, then the loads with the next lower priority will be switched OFF. This comparison and switch off action continues until all the prioritised loads have been turned off. In case the system is not yet stable after all priority loads are off, complete load shedding will be implemented to safeguard the network system.

6.2 Active Load Shedding Technique Design

A flow chart showing the sequence of events that the PLC goes through while executing a program is given in Figure 6.3. The loads at the top on the chart have a highest switching priority while those at the bottom have lowest priority of switching off. It has to be noted that the loads with higher switching off priority are those that will cause minimal discomfort to the customer when they have been switched off. The high priority indicates that these loads will be the first targets when selective load shedding commences.

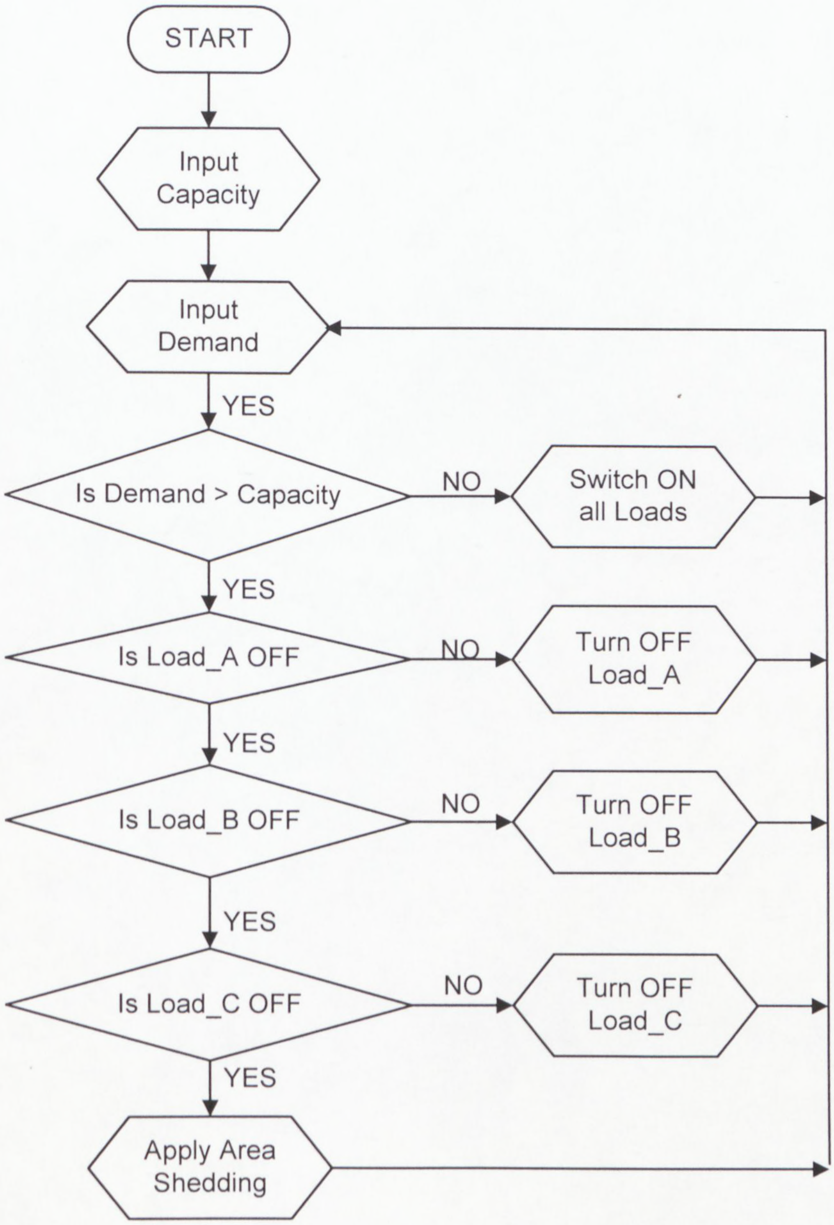


Figure 6.3: Flow chart diagram of ALST

6.3 System Realisation

The system was realised through modular development. The first module to be developed and programmed was the block to achieve selection of one of the loads depending on a code received by the PLC. This formed the decoding function of the control part of the PLC. The truth table of a 3-input decoder is show in Table 6.1. E is the enable input which either allows or disables the activation of the selected load switch.

Table 6.1: Truth table of a 3-input decoder with enable

INPUTS				OUTPUTS							
E	A	B	C	L1	L2	L3	L4	L5	L6	L7	L8
1	0	0	0	**1**	0	0	0	0	0	0	0
1	0	0	1	0	**1**	0	0	0	0	0	0
1	0	1	0	0	0	**1**	0	0	0	0	0
1	0	1	1	0	0	0	**1**	0	0	0	0
1	1	0	0	0	0	0	0	**1**	0	0	0
1	1	0	1	0	0	0	0	0	**1**	0	0
1	1	1	0	0	0	0	0	0	0	**1**	0
1	1	1	1	0	0	0	0	0	0	0	**1**
0	*	*	*	**No action on the outputs irrespective of input changes when E = 0**							

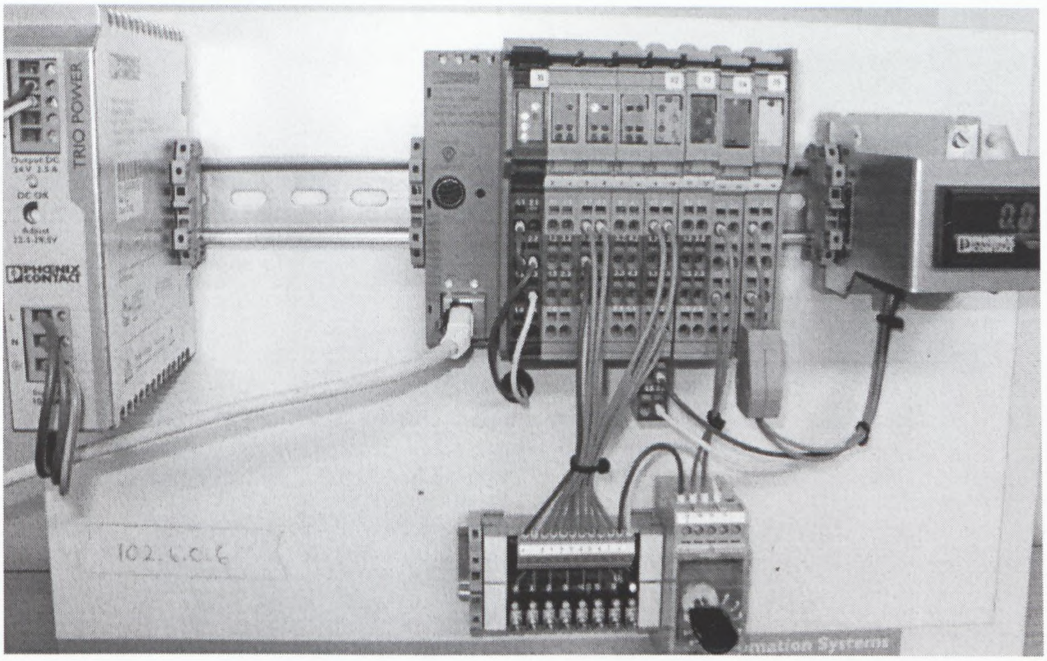
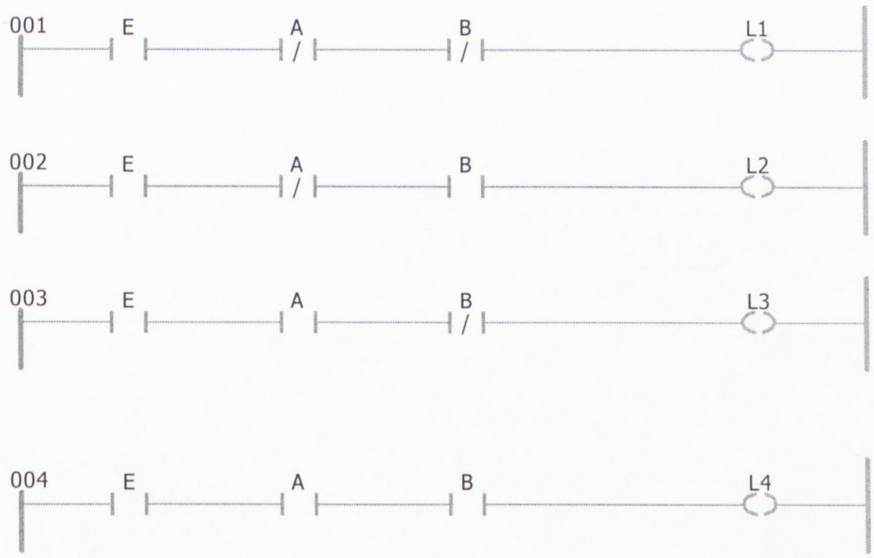


Figure 6.4: ILC 150 ETH with power supply on the left and digital inputs selection.

The ladder diagram used to realise the decoding function for two inputs is shown in Figure 6.5. As it can be noted, input E is placed in each rung of the ladder diagram and serves as the enable input. The running and stop mode simulated information results are respectively shown in Figure 6.6 and Figure 6.7. The decoder has FOUR outputs that are activated depending on the conditions at each of the two contacts.

The information dialog of Figure 6.6 includes the type of PLC (that is ILC 150 ETH) represented by A, the project name and date built highlighted by B and the status of the PLC as indicated by C. Similarly, A and B respectively in Figure 6.7 highlights the project name and status of the PLC in the stop mode.



(*2 input decoder used to generate different signals depending on the level of demand. E is used as the the enable input. This input disables transmission of a control signal on the utility when '0' and allows the signal when '1'. *)

)NBOARD_INPUT_BIT0——E

)NBOARD_INPUT_BIT1——A

)NBOARD_INPUT_BIT2——B

L1—ONBOARD_OUTPUT_BIT

L2—ONBOARD_OUTPUT_BIT

L3—ONBOARD_OUTPUT_BIT

L4—ONBOARD_OUTPUT_BIT

Figure 6.5: Ladder diagram of 2-input decoder.

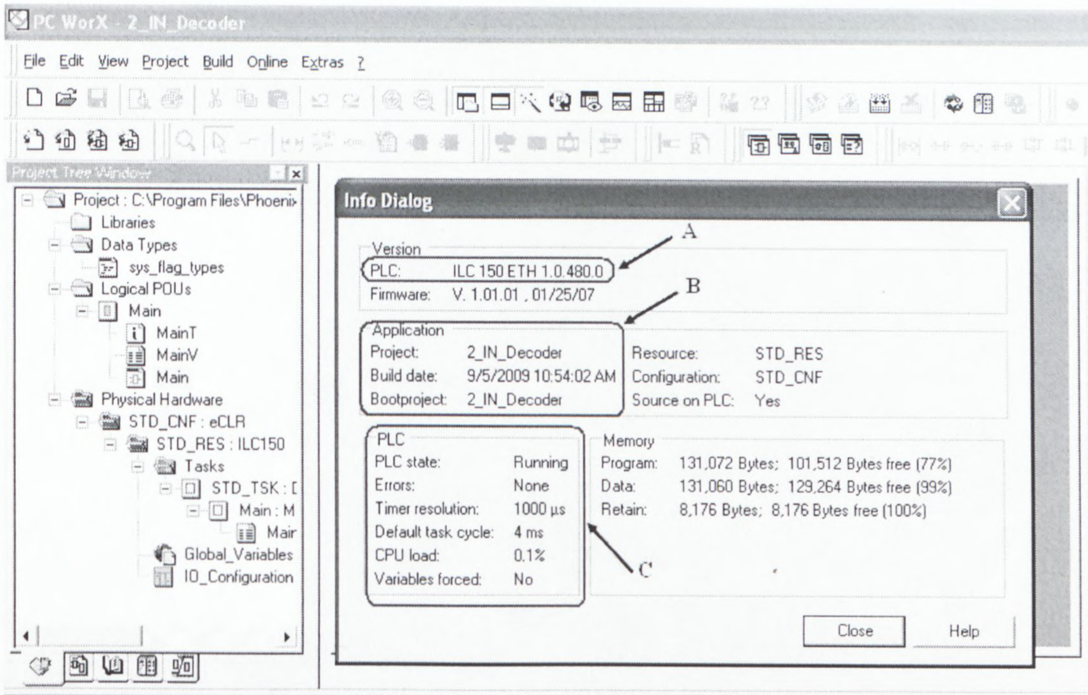


Figure 6.6: 2_IN_Decoder simulated information - running mode

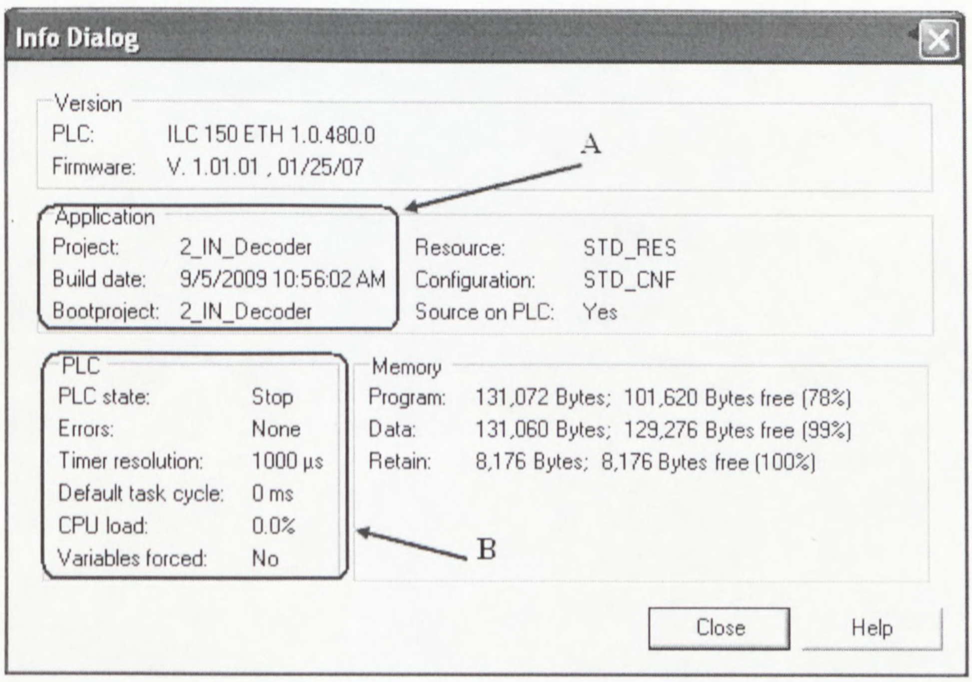


Figure 6.7: 2_IN_Decoder simulated information – stop mode

The second module block is one that determines the delay or time that the loads will be off. This module consists of timer pulse blocks with a preset time. The time is preset during the programming cycle of the PLC. Figure 6.8 shows the operational waveforms of the timer pulse. The timer operation is such that in case the input IN changes from Low (0) to High (1), i.e. t0, t2 and t4 in Figure 6.8, a pulse is created at the output Q for a time interval specified by the value on PT. The time which has already elapsed is indicated at the output ET. For the input signal IN to have an effect on the output Q, then;

$$ET < PT \tag{6.1}$$

If IN becomes High (1) before PT has elapsed, i.e. t3, it will have no impact on the duration of the pulse created at output Q.

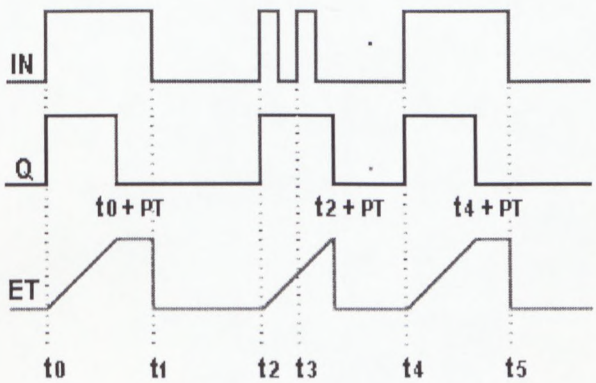


Figure 6.8: Operation of pulse timer

The description and type of data at the various input and output parameters of the timer are summarised in table 6.2.

Table 6.2 Pulse timer parameters

PARAMETER	DATA TYPE	DESCRIPTION
IN	BOOLEAN	A pulse is created at the output in case a rising edge is detected at this input
PT	TIME	Is a preset time interval for the pulse at the output
ET	TIME	Indicates the elapsed time.
Q	BOOLEAN	FALSE if IN = FALSE and ET => PT TRUE if IN = TRUE and ET<PT.

6.3.1 Load shifting control options

The design considered two options of controlling the switching off operation as independent and sequence. In the independent option, the loads are switched off for a whole shifting control duration. However, in the sequence option, different loads are switched off in turns for a short period within the load shifting control period. In both options, the off period for each set of loads can be varied.

6.3.1.1 Independent control option

In this control option the loads are switched off for the whole shedding period depending on the demand status and switching off priority. Loads with lower switch off priority can only be turned off upon receiving a signal and at the same time the immediate higher switch off priority loads are in the off state. This condition ensures that loads with higher priority are off before the lower prioritised ones can go off. The project to realise this conditions was created using the PCWorX software. Figure 6.9 shows the device details of the controller used for independent load control. Included among the details is the software PC WorX 5.10.22 and the first IP address 102.006.000.006 (which is shortened as 102.6.0.6).

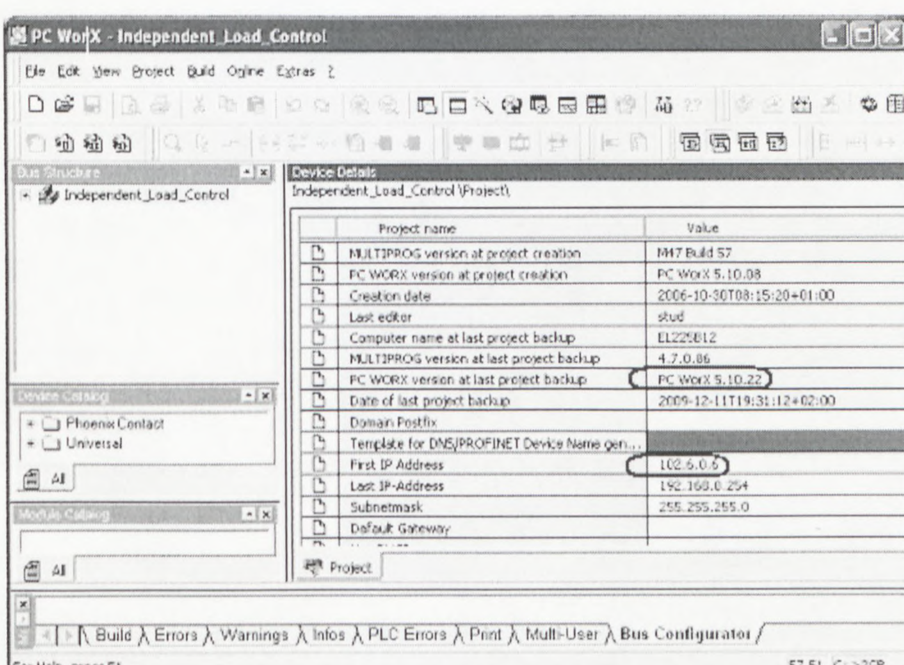


Figure 6.9: Device details of controller used for independent load control.

Figure 6.10 shows the displayed results when communication between the PC and the device is successfully established. The project name and device number are highlighted by A, the green colour in B indicates successful establishment of communication link between the controller and PC, C shows that the device uses the Ethernet cable and D highlights the first IP address. In the event that communication was not established between the device and the PC, then the bar in B will be red.

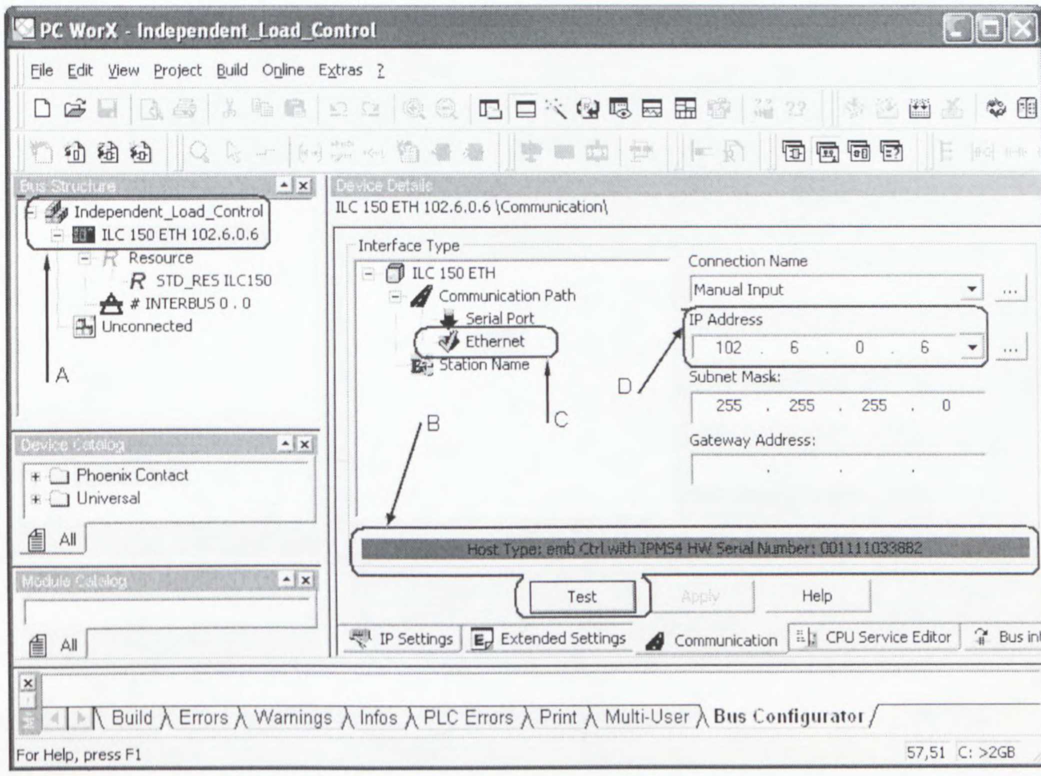


Figure 6.10: Testing for establishment of communication between the PC and the controller

The arrangement that realises independent control option is shown in Figure 6.11. Two programming languages ladder diagram and function block diagram are used. In this arrangement, Loads_1 have been set to be off for 30 seconds, Loads_2 for 25 seconds and Loads_3 and Loads_4 for 20 seconds each. The timer operational principle (Figure 6.8) is applied to the timer block such that once the block is operated (activated), it turns OFF the corresponding set of loads for a specified time. Any other activation pulses received at the input of the block within the switch off period have no effect on the end time of the pulse. This ensures that a set of loads is turned off for a constant but predetermined period.

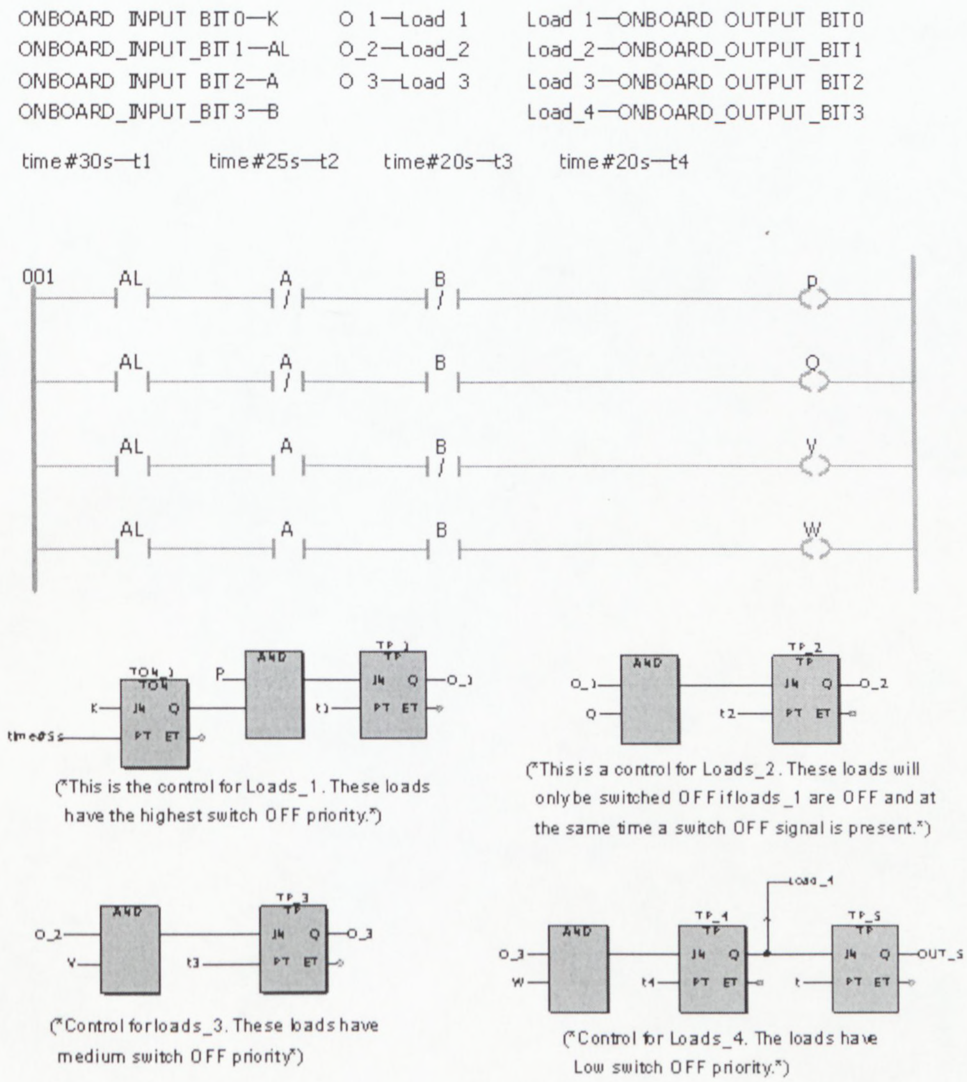


Figure 6.11: Independent switch off control diagram

6.3.1.2 Sequence control option

The sequence control option operates in asynchronous form whereby one or more sets of loads are switched off for a short interval within the shifting control period. This is similar to the cycling option. The number of loads to be shifted or cycled is dependant on the demand status. Higher prioritised loads are the first to join the cycling operation. The timer operational principle is also applied to the delay block in order to turn OFF the corresponding set of loads for a predetermined time.

The sequence control FBD is shown in Figure 6.12 whereby t determines the duration when the load is OFF. Figure 6.13 shows the information dialogue in the running mode. In this figure, 'A' gives information regarding the project name and the date it was built. As highlighted by B, the status in the running condition gave no errors; there were no forced variables, and the timer resolution was 1000 µS.

(*The timer pulse is used to generate a Load switching sequence.
The sequence depends on the signal waveform at the input K.
The duration of this signal should not be less than the PT
value, otherwise there will be no effect on the output of the
respective timer block.*)

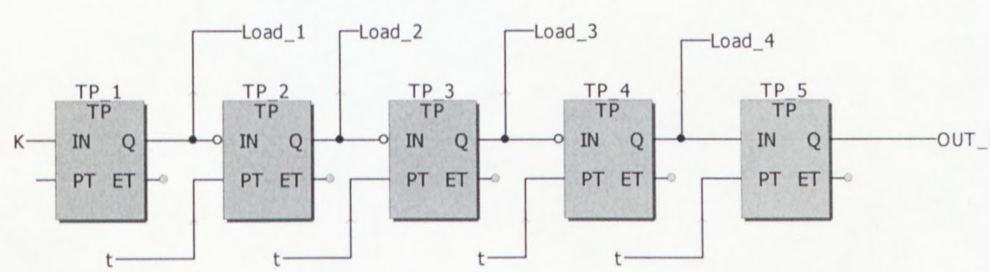


Figure 6.12: The FBD program for the sequence control option.

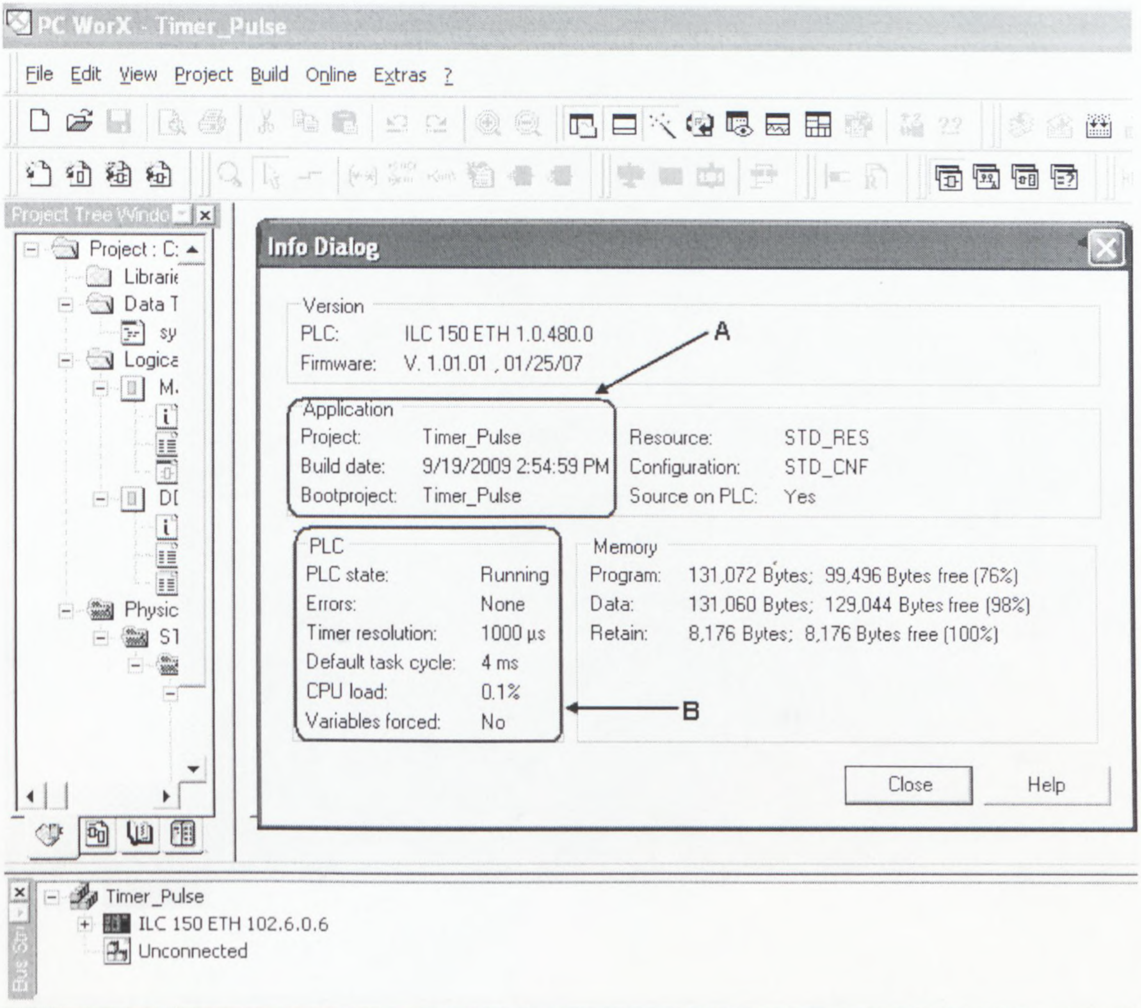


Figure 6.13: Sequence control option information after the program had been loaded onto the PLC.

The PLC shifting routine commences upon receiving a signal from the utility indicating the presence of a shifting control period. The PLC will generate an alert signal to indicate the impending shifting control action. However, the control action can be terminated in case the demand status improves. The load shifting control action will depend on the option chosen, and is determined by the demand status. The four possible shifting control options are:

1 **One load OFF sequence option**.

In this option, one load will be OFF for a predetermined or preset time (PT) within a cycle of operation. The operation cycle will depend on the number of loads to be switched OFF within that cycle. Figure 6.14 is a waveform representation of the operation cycle for this option. After the expiry of a cycle operation, the switching OFF sequence is repeated until the end of the shifting control period.

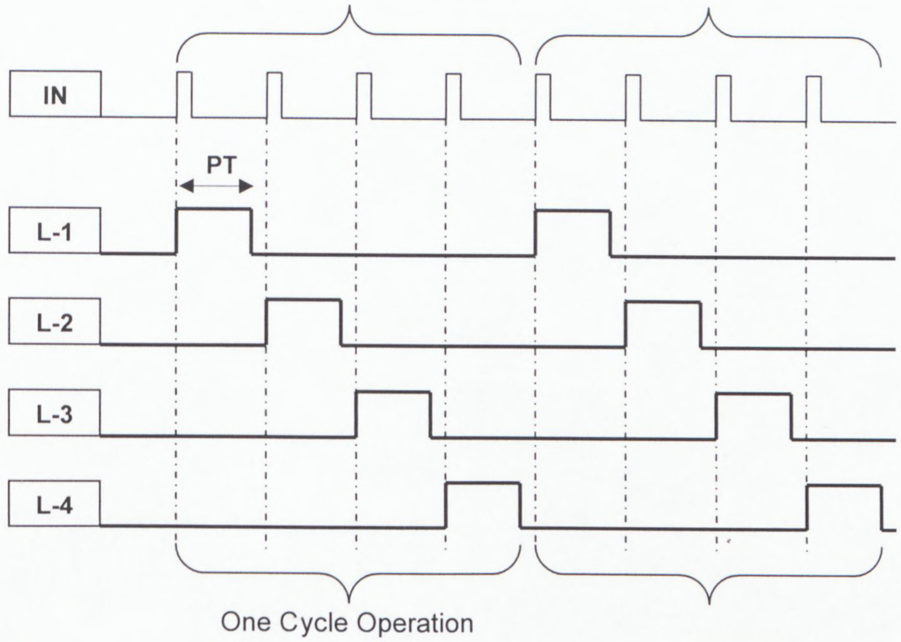


Figure 6.14: One load OFF sequence operation

2 Two loads OFF sequence option

In this option, two loads will simultaneously be OFF, each for a predetermined time within the cycle of control. The sequence is repeated during the shifting control period. The switching signals will have to be applied independently to each of the timer blocks from the switching controller. Figure 6.15 illustrates the operation of two loads OFF cycling. The on and off duration of each cycling load is about 50 percent of one cycle operation.

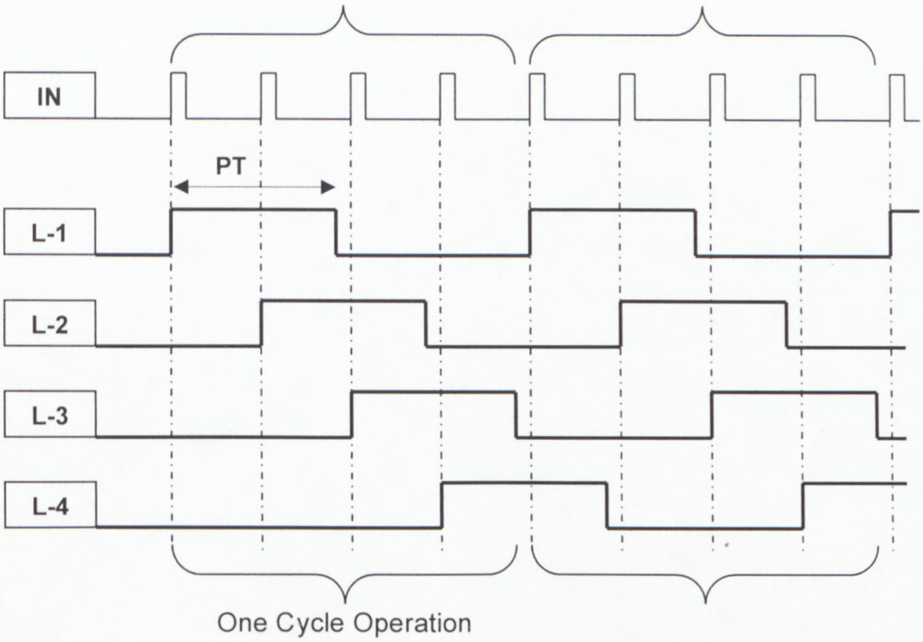


Figure 6.15: Two loads OFF sequence operation

3 **Three Loads OFF sequence option**.

This option allows three loads to be OFF simultaneously for a predetermined time within a cycle operation. The OFF period for each load is approximately three quarters of the whole cycle operation. The three loads off sequence is illustrated by Figure 6.16.

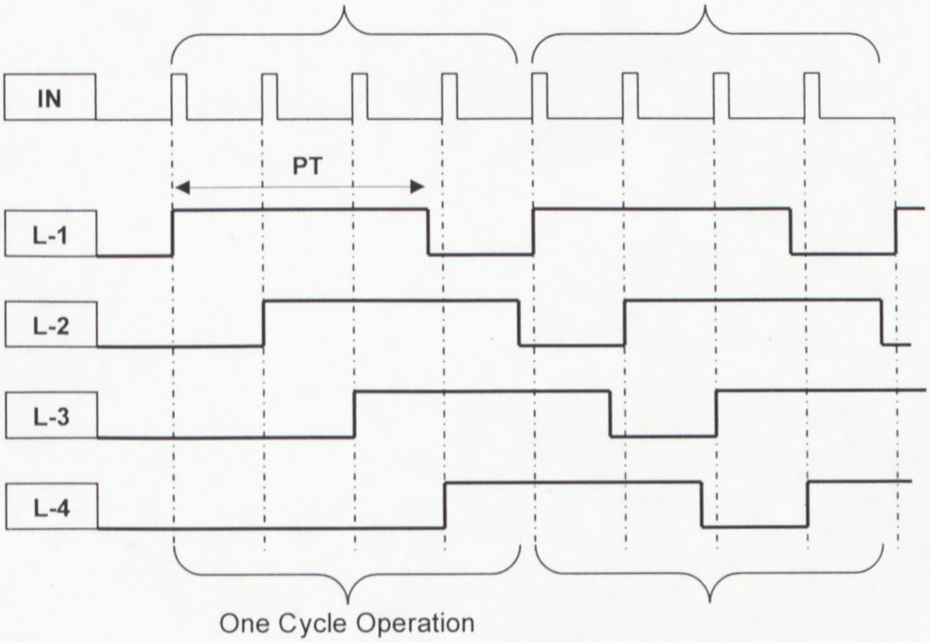


Figure 6.16: Three loads OFF sequence operation

4 Four Loads OFF sequence option.

This option switches OFF four loads for a predetermined period within the cycling control duration. The action is repeated for a number of operation cycles until the end of the shedding period. In case there were only four sets of priorities, the next action would be complete load shedding by a utility.

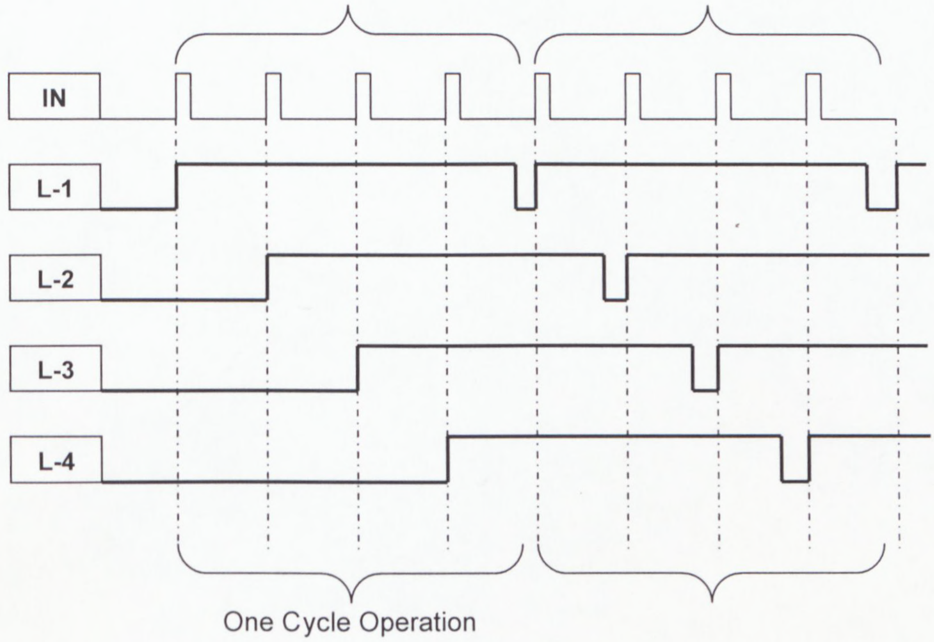


Figure 6.17: Four loads OFF sequence operation

CHAPTER SEVEN

LabVIEW MODEL OF ALST

7.1 Introduction

LabVIEW is a graphical programming environment that is widely used by engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. It was introduced in 1986 and has become an industry leader by offering unrivalled integration with thousands of hardware devices and provides hundreds of built-in libraries for advancéd analysis and data visualisation.

The supremacy of LabVIEW lies in the hierarchical nature of the virtual instrument (VI). It is possible to create a VI and use it in block diagrams of other VIs. A subVI is a VI within another VI, which is similar to a subroutine in text-based programming languages. In case double-clicking action is done on a subVI, its front panel and block diagram appear instead of a dialog box. The front panel includes controls and indicators that might look familiar while the block diagram includes wires, front panel icons, functions, possibly subVIs, and other LabVIEW objects. There is no limit on the number of layers in the hierarchy and due to the modular programming feature, managing changes and debugging the block diagram can be achieved faster.

In this chapter, a model of the active load shifting technique (ALST) is realised using LabVIEW software. The design takes into consideration the different scenarios that the utility provider uses to manage the connected load. A block diagram of the ALST is developed in section 7.3. Section 7.4 covers the realisation of the front panel appearance for the different scenarios. Section 7.5 provides the results of the simulation

7.2 Development of ALST Model

The development of the ALST in LabVIEW considered different scenarios that the utility is subjected to by the loading conditions. There were assumptions and conditions that were made in order to realise and depict the actual scenarios at the utility. Among these scenarios were: the demand being within the safe capacity range and the demand having surpassed the safe capacity limits. Various indicators are used to portray the status of the control room of the utility.

The loads for simulation purposes have been estimated for a typical residential installation. The connected load considered power-consuming equipment connected in the installation and any equipment that could be connected to the installation (such as iron box, radio, television *etcetera*) as per the SANS 10142:2003 (SANS[1]) standard. The assumptions made in the calculation of the total connected load include:

- Each lamp consumes 60 W
- Socket outlets under cover of 100m^2
- Water heater rating of 5.5 kW

The diversity factors applied were according to SANS 10142-1:2003 standard. The total connected load was estimated for a single household with appliances as indicated in table 7.1.

Table 7.1 Single customer estimated load

Appliance	No.	Power	Diversity factor	Estimated power
Water heater	1	5.5 kW	1	5.5 kW
Socket outlets	>100 m^2 cover	6.0 kW	0.5	3.0 kW
Lighting (Fluorescent)	4 each 40 W	160 W	0.5	80 W
Lighting bulbs	6 each 60 W	360 W	0.5	180 W
Total load estimated				8.76 kW

The total load was approximated to 10 kW.

7.3 LabVIEW block diagram of the ALST

The ALST was developed and simulated in the LabVIEW environment using the various VIs and at the same time, creating sub VIs so as to accommodate them on a smaller sized block diagram.

7.3.1 Dynamic load

The dynamic load is the aggregation of various load contributions on the system. In the model, the load contributions include the baseloads, loads_1, loads_2, loads_3 and loads_4. Figure 7.1 shows a block diagram of a subVI that was created to aggregate the load contributions.

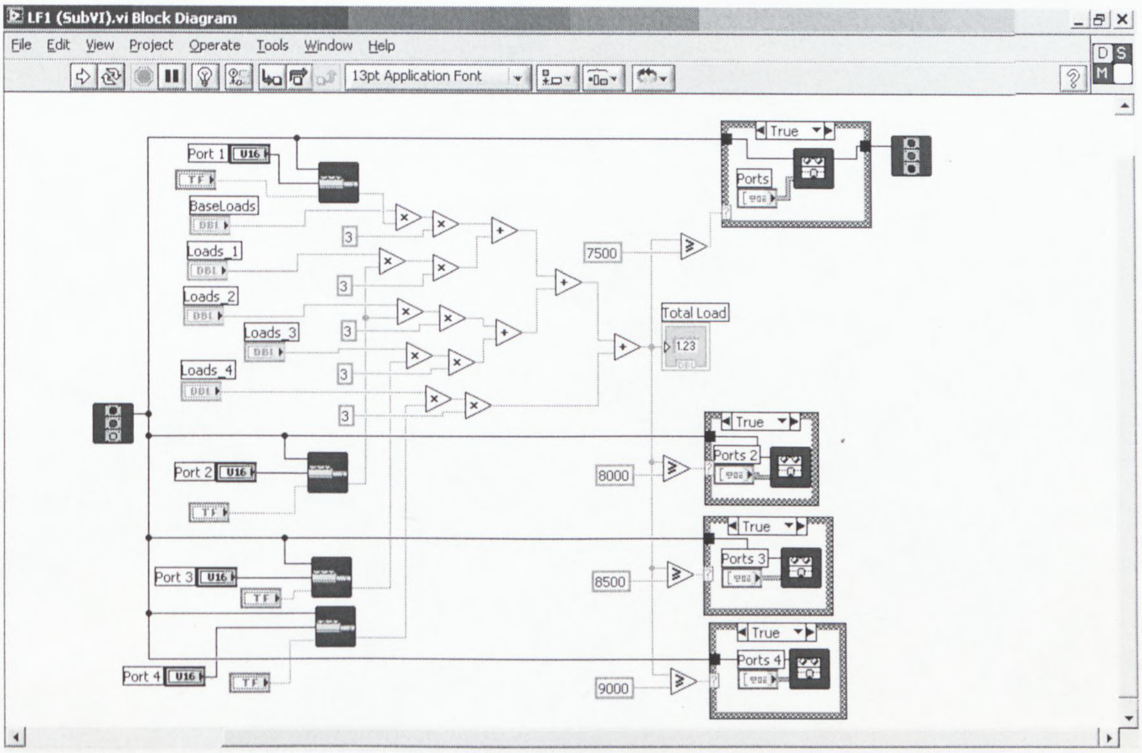


Figure 7.1: Block diagram of loads aggregation and indicator sub VIs.

7.3.2 Sensing

The sensing portion consists of a formula node VI with a set of conditions programmed to satisfy the various scenarios. At the output of the formula node are VIs that detect the separate system conditions and send signals to the corresponding actuators and indicators. Figure 7.2 shows the sub VI block diagram of the sensing portion of ALST.

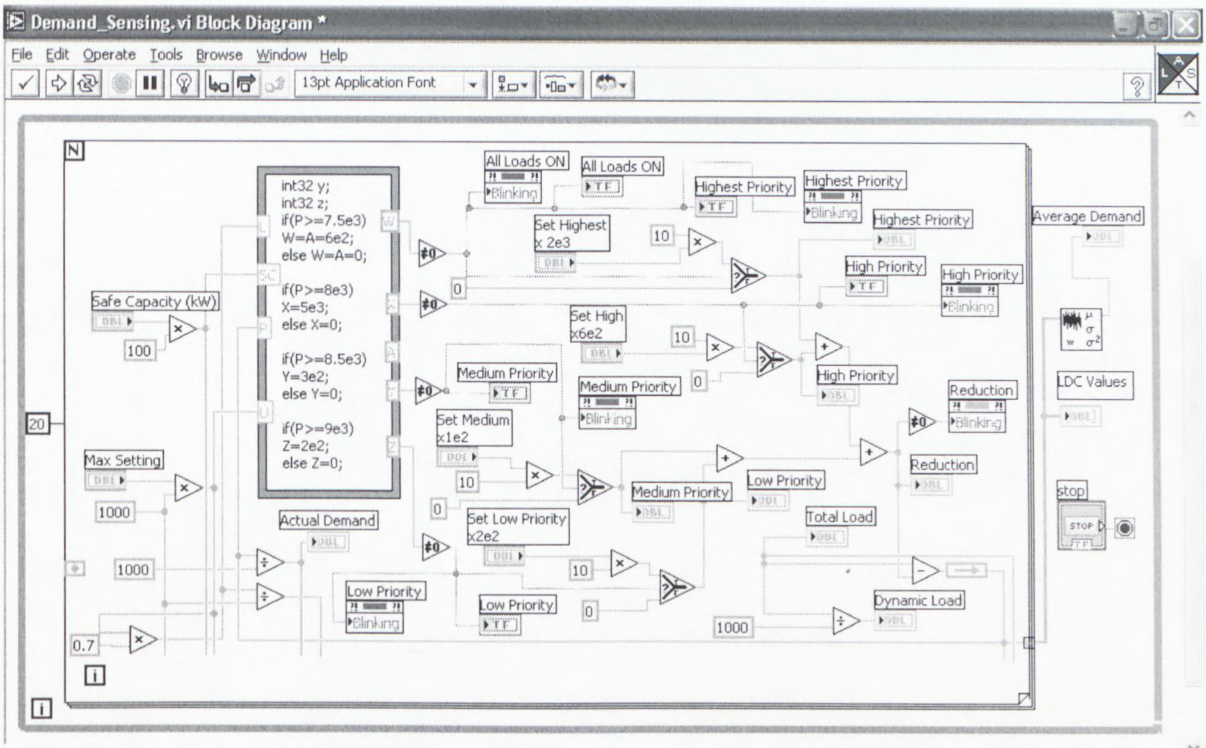


Figure 7.2: ALST block diagram of sensing sub VI.

7.3.3 Data storage

The storage of data is important for the determination of energy consumption. The information assists in obtaining the load curve as well as the load duration curve for the customers. It also shows when a peak load was experienced and the result of action taken during the peak period. This implies that the recorded data has to be time and date stamped. In order to achieve this, the following four function blocks were used:

a. Number To Fractional String – This converts a number to its fractional notation format (F-Format)

b. Get Date/Time – that converts a time stamp value or a numeric value to a date and time string in the time zone configured for the computer.

c. Concatenate Strings – that concatenates input strings and one dimension (1D) arrays of strings into a single output string. For array inputs, this function concatenates each element of the array. The function block was resized in order to have additional inputs to the function.

d. Write To File – which was used to store data in an excel file. This sub VI opens the file before writing commences and once the program is terminated, it closes the file. The 'Append to File' input is set to TRUE to avoid erasure of the previous data.

Additionally, the Tab Constant and the Carriage Return Constant were used to separate the data and record them in different columns of the spreadsheet. Figure 7.3 shows the block diagram of the data storage sub VI.

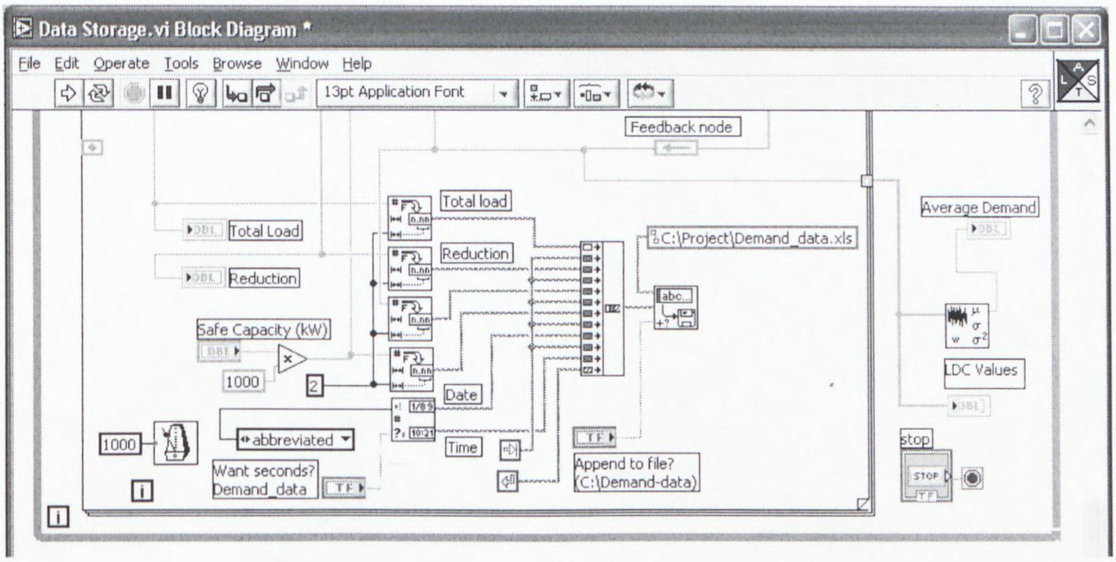


Figure 7.3: Block diagram of data storage section of ALST.

The Standard Deviation and Variance block was included in the data storage sub VI to calculate the average demand load.

7.3.3 Complete block diagram of ALST

In addition to the blocks considered in sections 7.3.1 to 7.3.3, the ALST block diagram has VIs for presetting values, meters, indicators and graphical displays. A complete block diagram of ALST is shown in Figure 7.4.

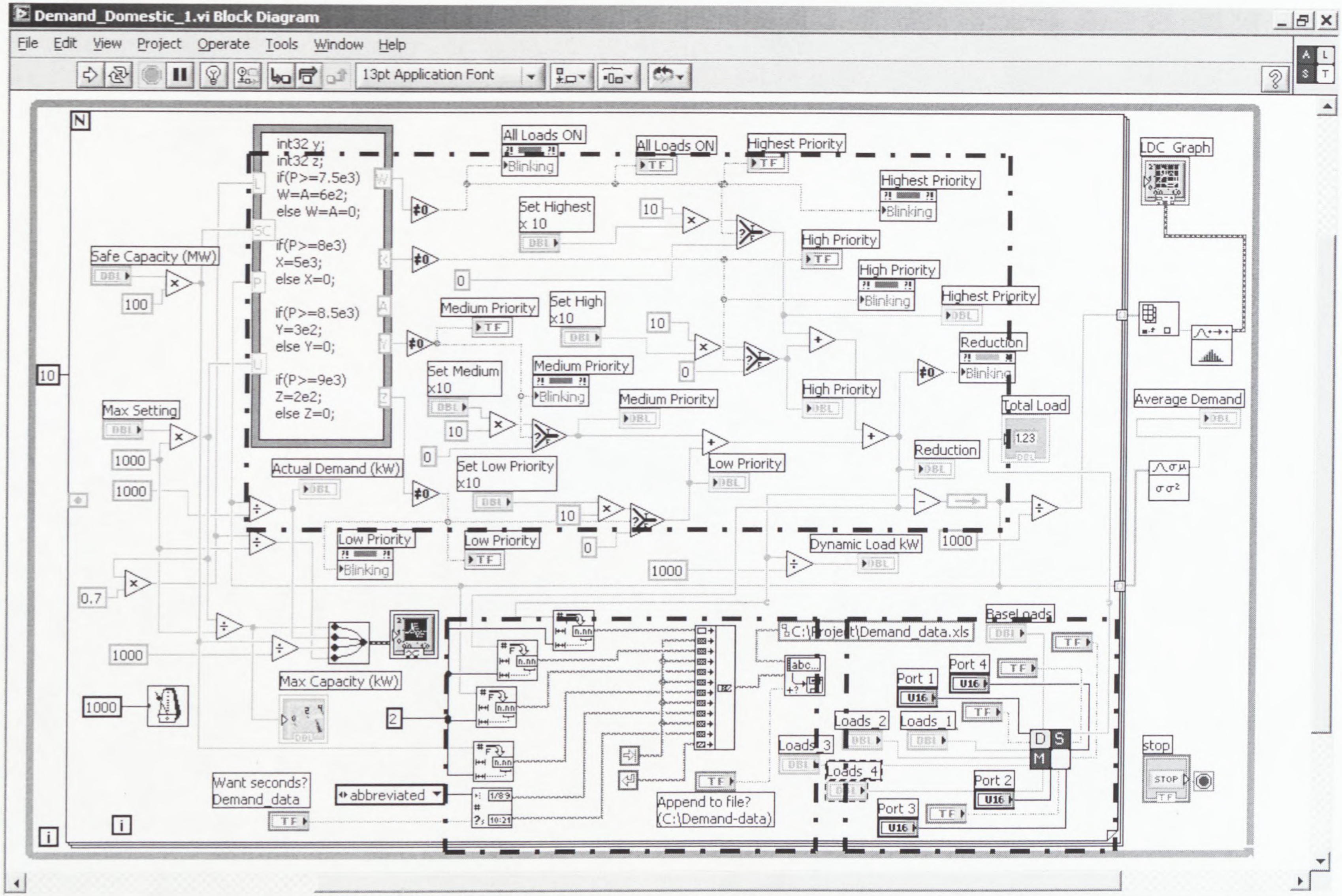


Figure 7.4: Block diagram of the ALST in LabVIEW.

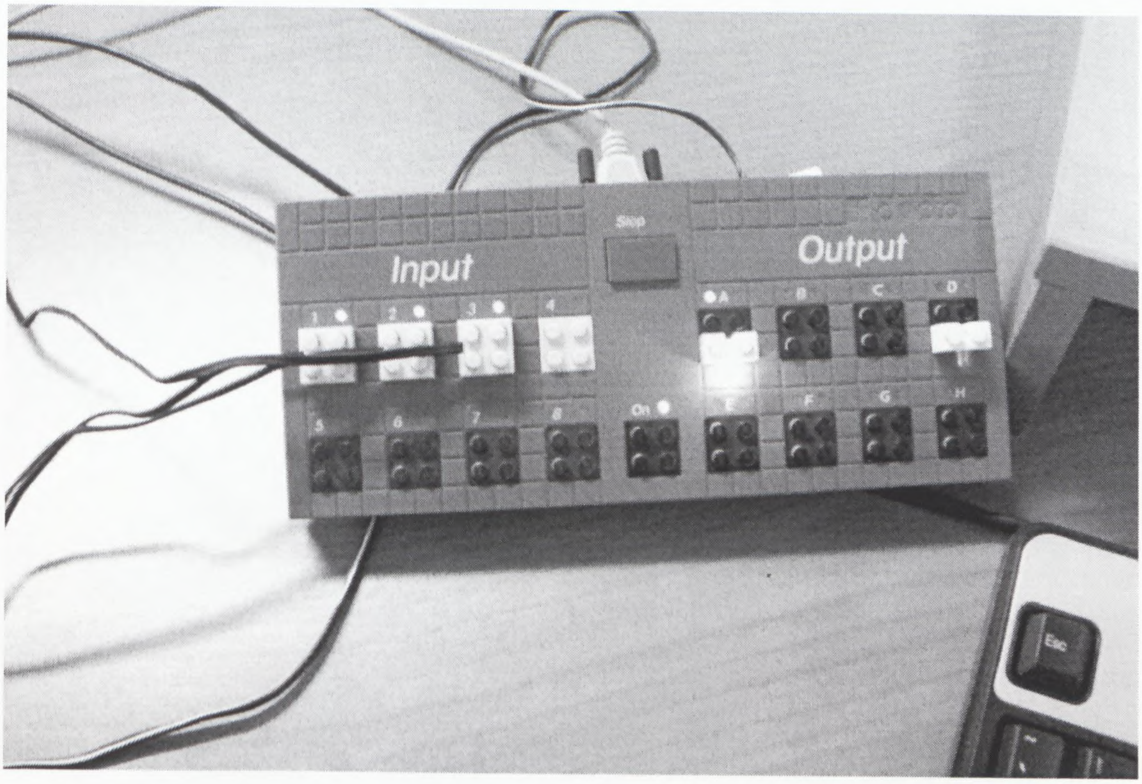


Figure 7.5: Lego kit for interfacing with the PC.

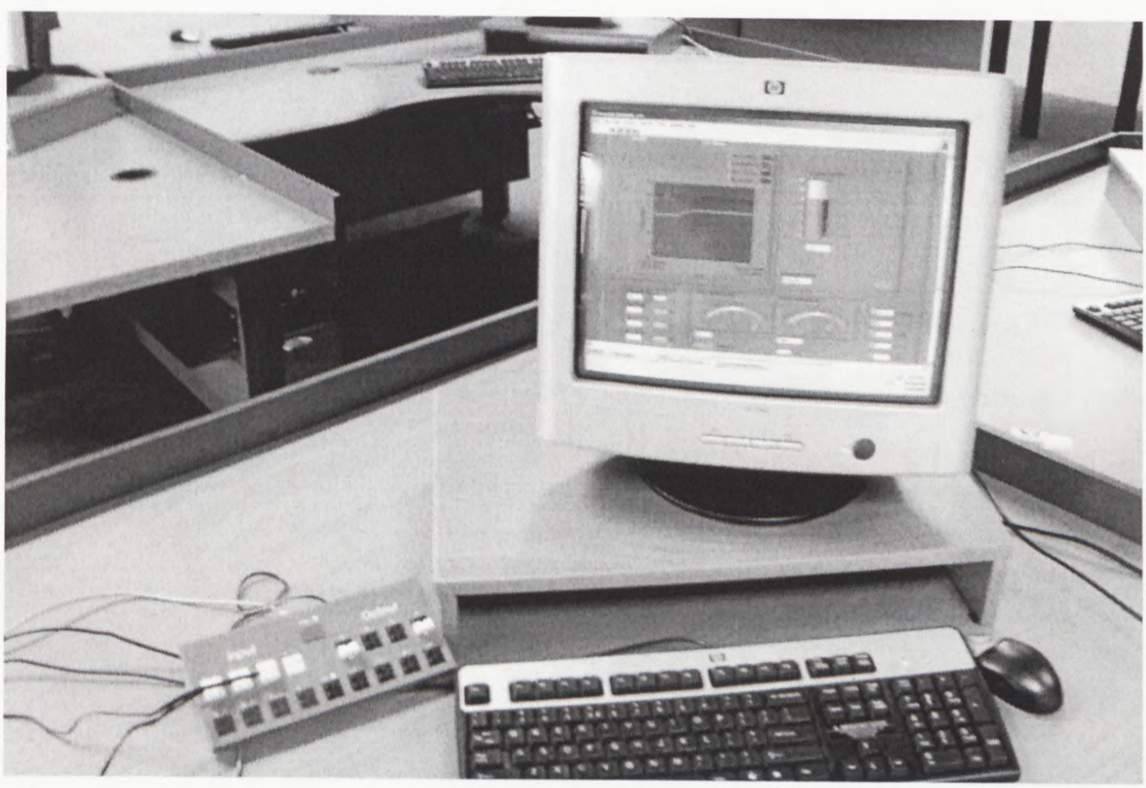


Figure 7.6: Lego interfacing box connected to the PC via serial communication cable.

7.4 Front panel of ALST in LabVIEW

The front panel is the user interface of a VI that displays various parameters of the system. The front panel consists of controls and indicators, which are respectively interactive input and output terminals of the VI. Controls of the panel include knobs, push buttons, and dials. They function by simulating instrument input devices and supply data to the block diagram of the VI.

Indicators on the front panel consist of graphs, light emitting diodes (LEDs) and other visual displays. They simulate instrument output devices and display the data acquired or generated by the block diagram. The displayed information on the designed front panel includes the maximum capacity, the actual demand, the average load and the dynamic load. The front panel also has LED indications of the priority conditions. A feature of the front panel is the tab control that allows the two graphical displays for demand and LDC to be overlapped. The demand chart indicates the maximum setting and safe capacity values with the actual demand graph superimposed on them. Figures 7.7 – 7.11 show the front panel displays for different scenarios. These include no load shedding and various priorities.

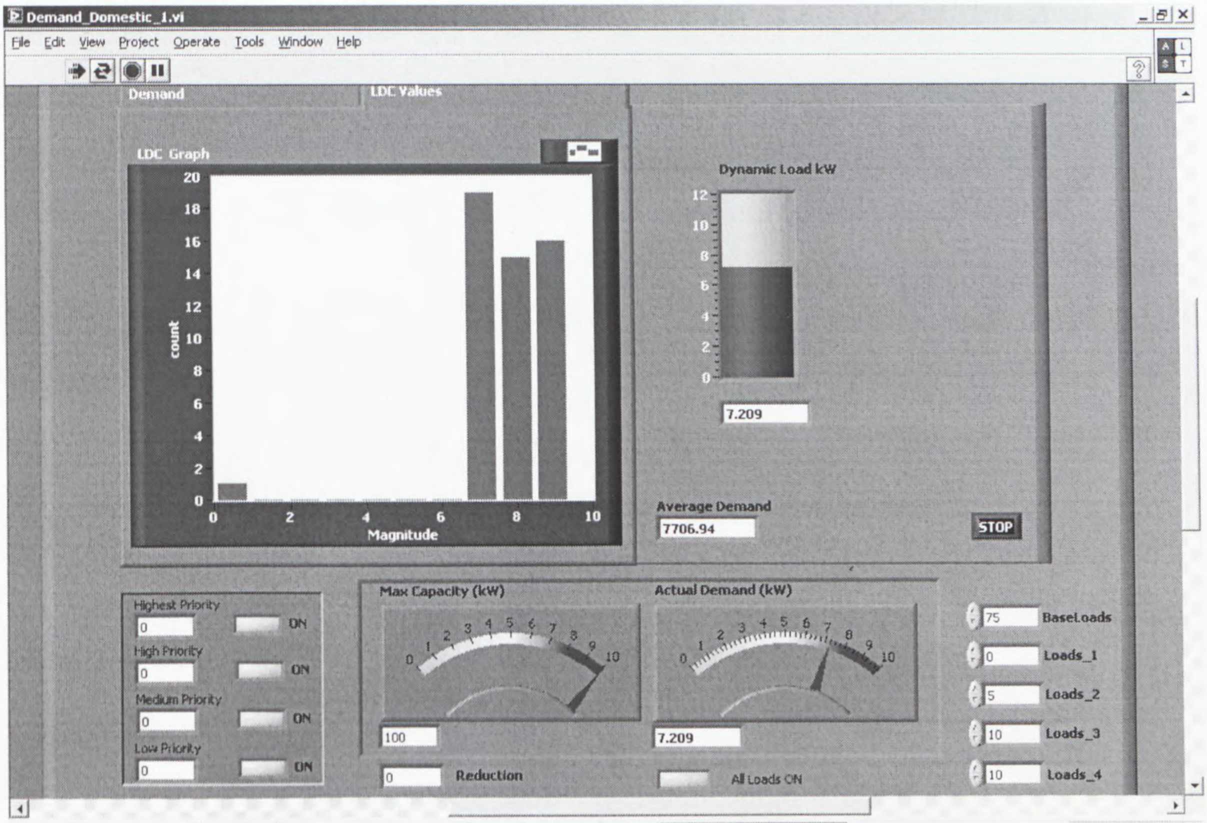


Figure 7.7: Front panel when there is no load shedding.

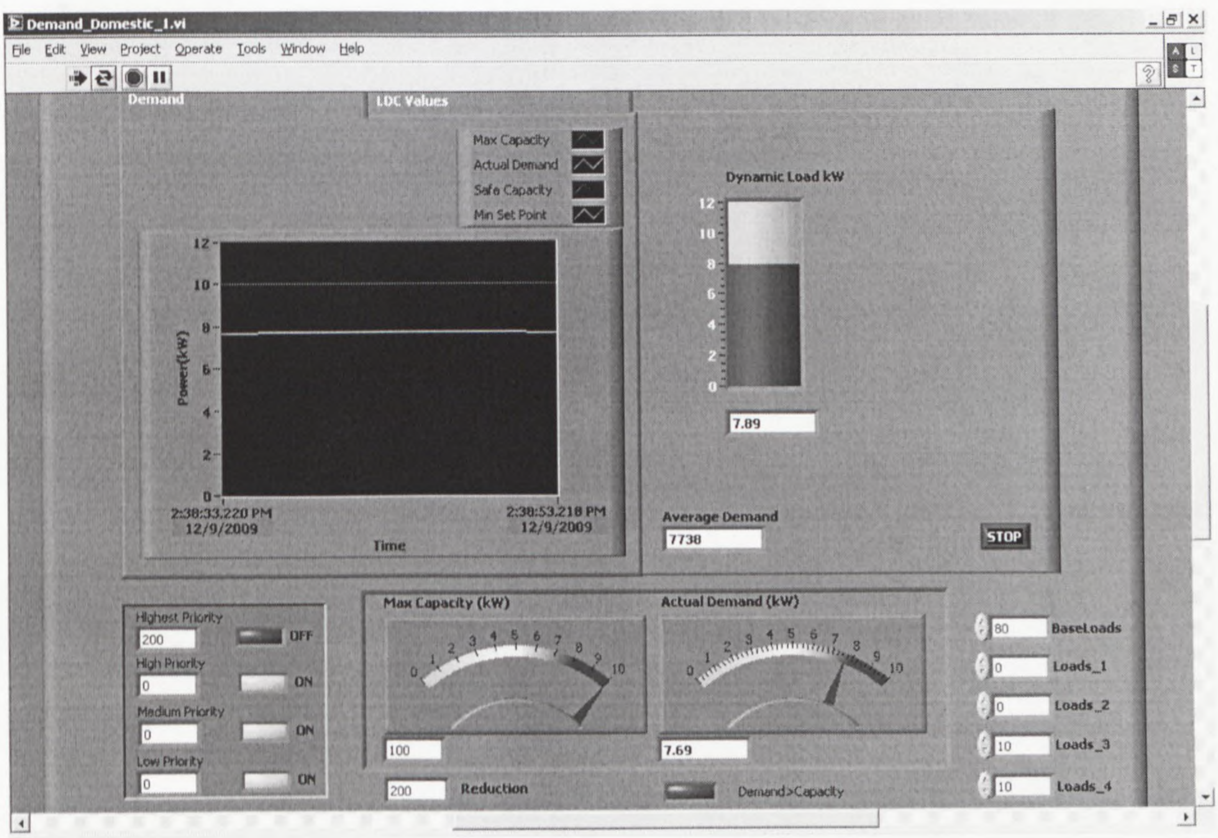


Figure 7.8: Front panel when Highest priority loads have been turned off.

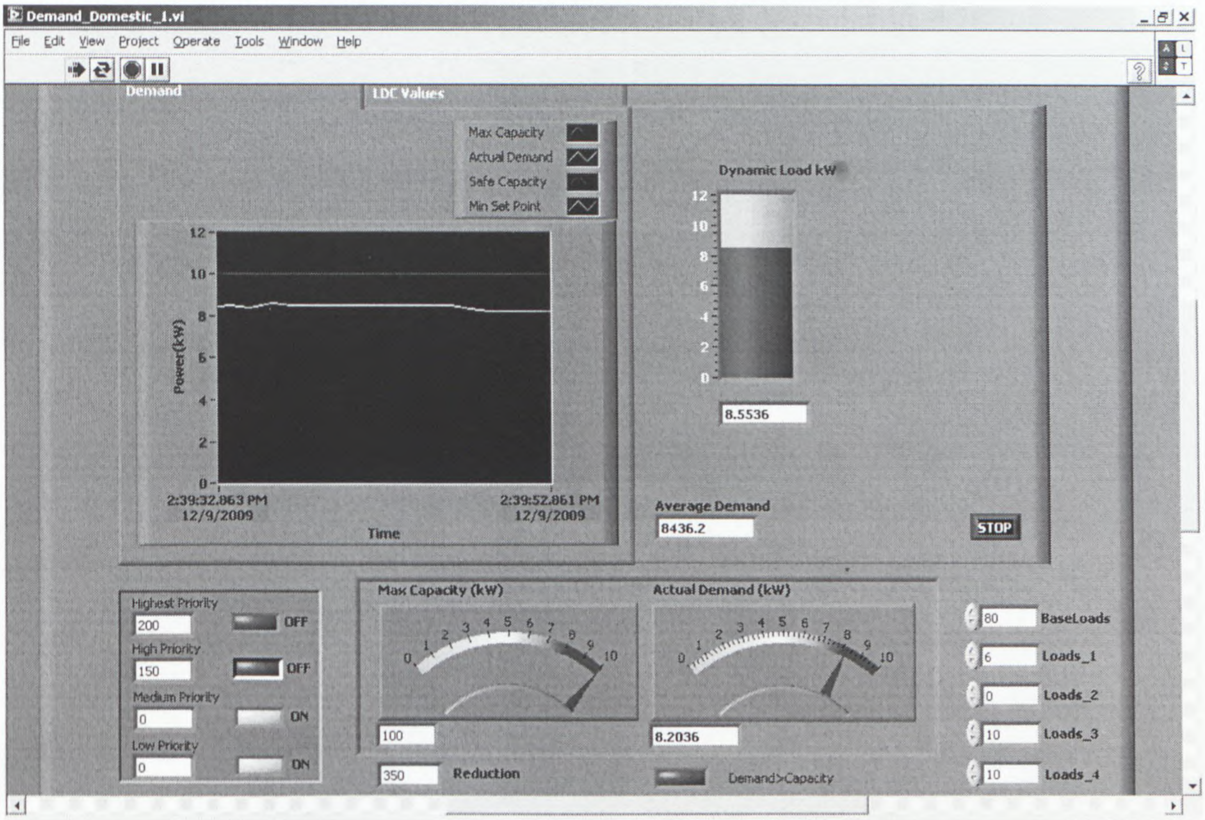


Figure 7.9: Front panel when both Highest and High priority loads have been turned off.

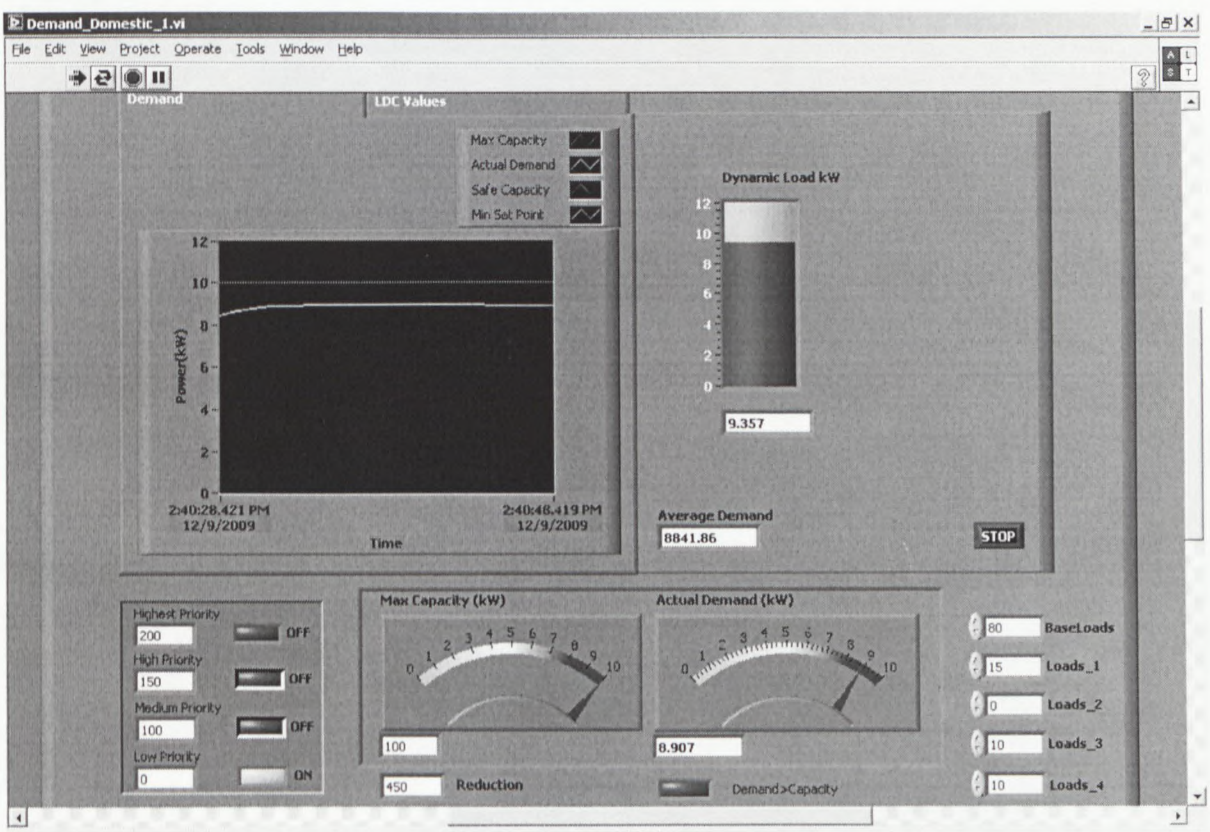


Figure 7.10: Front panel when Highest, High and Medium priority loads have been turned off.

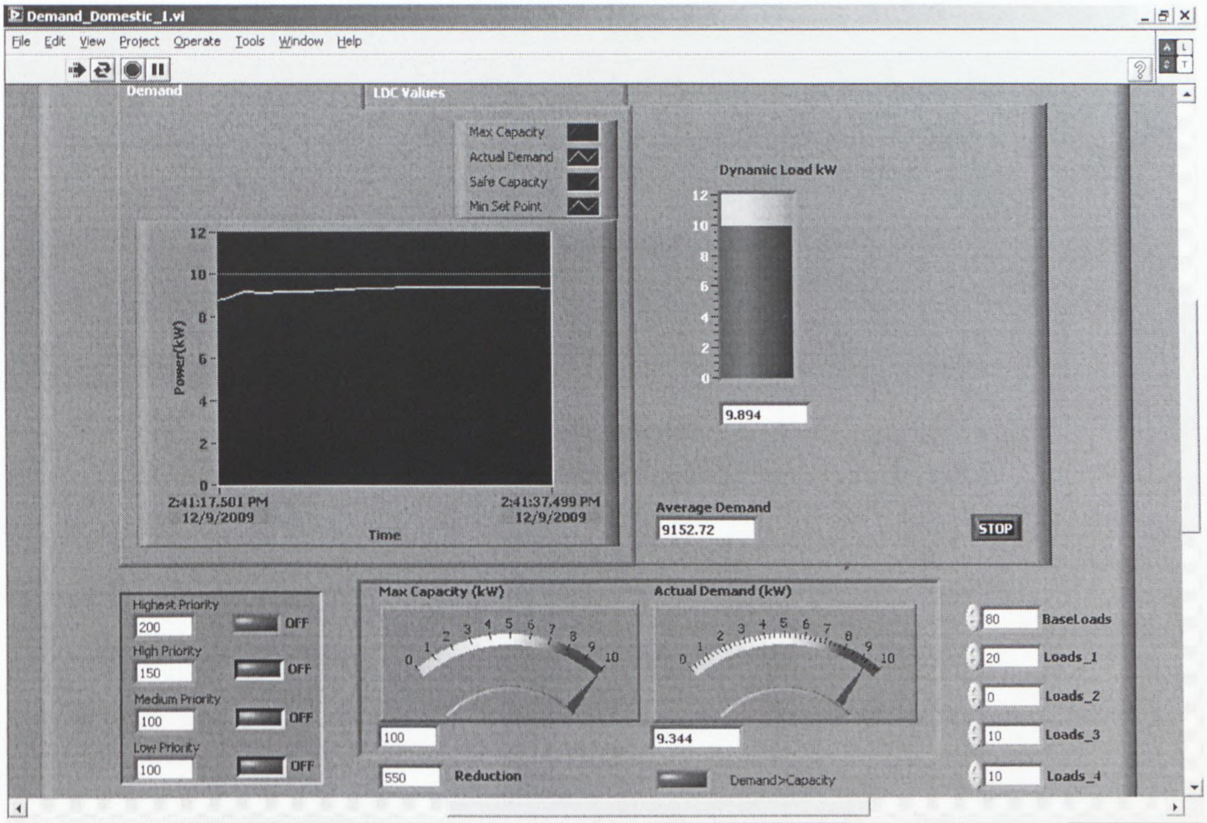


Figure 7.11: Front panel when Highest, High, Medium and Low priority loads have been turned off

7.5 Simulation results

The simulation results were obtained by varying the approximated values of the base loads, Loads_1, Loads_2, Loads_3 and Loads_4. The priority settings were as follows:

Highest priority	2000
High priority	1500
Medium priority	1000
Low priority	1000

Figure 7.12 are the plots of the system demand, net demand (demand after reduction) and the reduction using the obtained data.

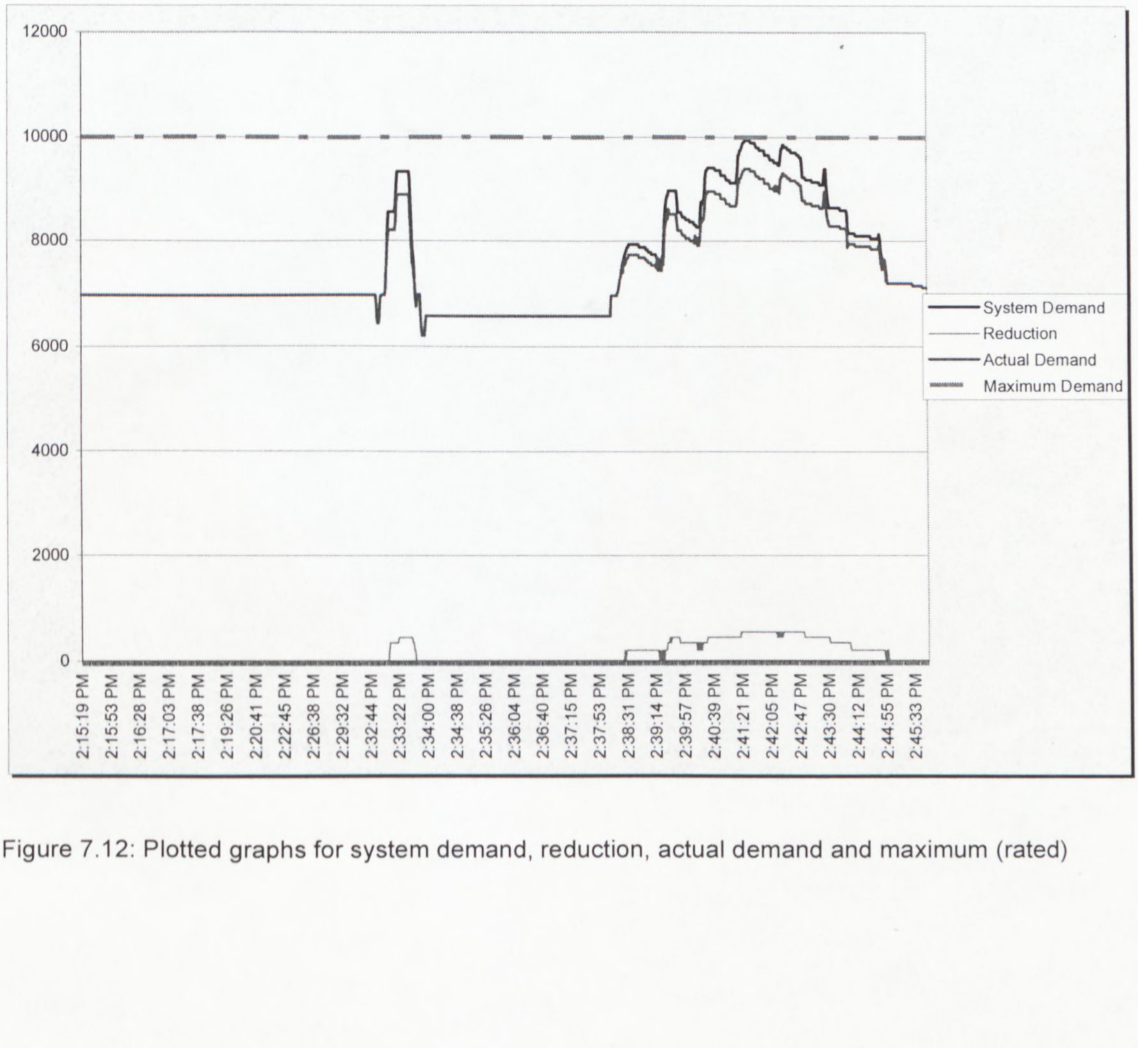


Figure 7.12: Plotted graphs for system demand, reduction, actual demand and maximum (rated)

7.6 Publishing on web

The front panel was published on the web to allow control to be effected at a remote PC other than the server. The control from a remote PC is possible by requesting from the server at the utility. The relationship between the remote PC is that of slave/ master. If the demand is within safe capacity, the utility can transfer control to the remote PC. However, in case the demand is more than the safe capacity value, the server can regain control from the remote PC. Figure 7.13 is a display of the dialogue box for information required when publishing the project on the web. The request control box is checked to allow a remote PC to 'seek permission' from the server. Figures 7.14 – 7.17 shows the messages at the remote PC and the server when a request for control is initiated.

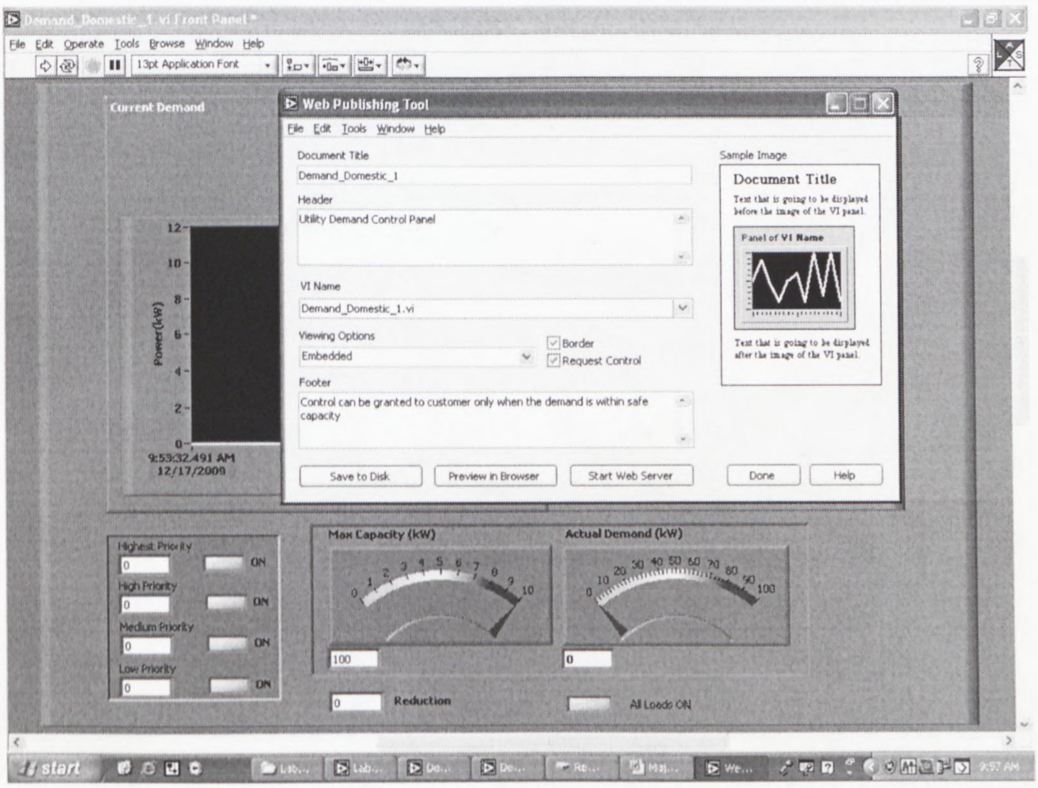


Figure 7.13: Publishing the front panel on the web.

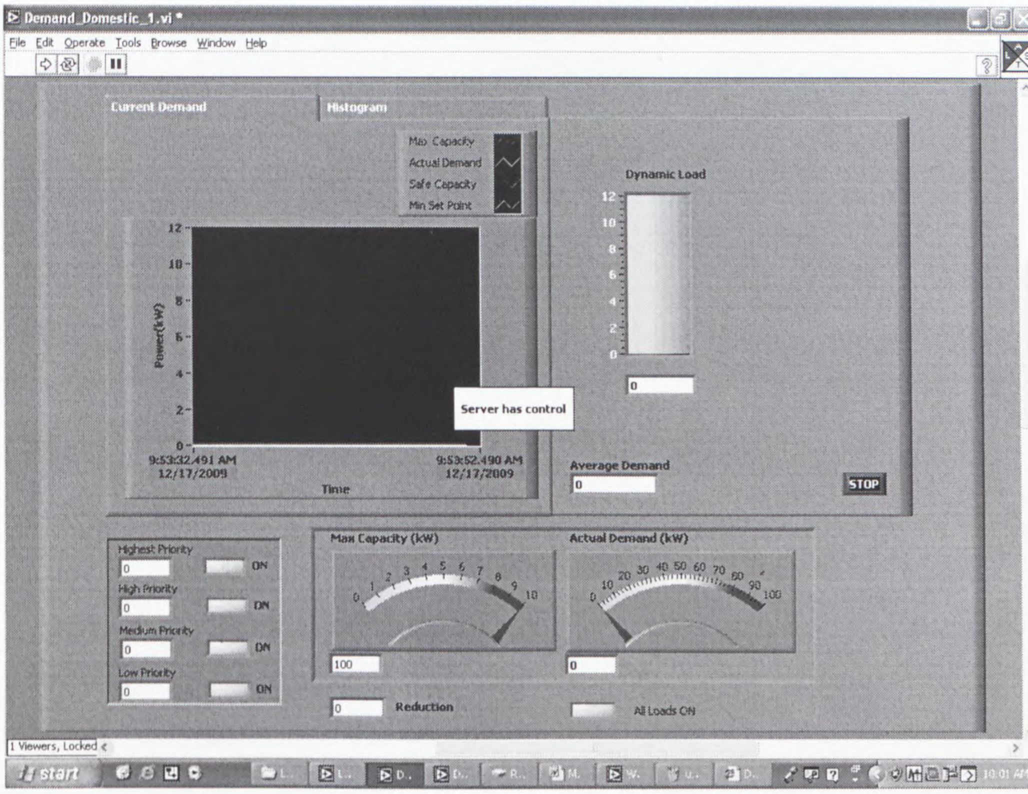


Figure 7.14 Display message indicating server has control.

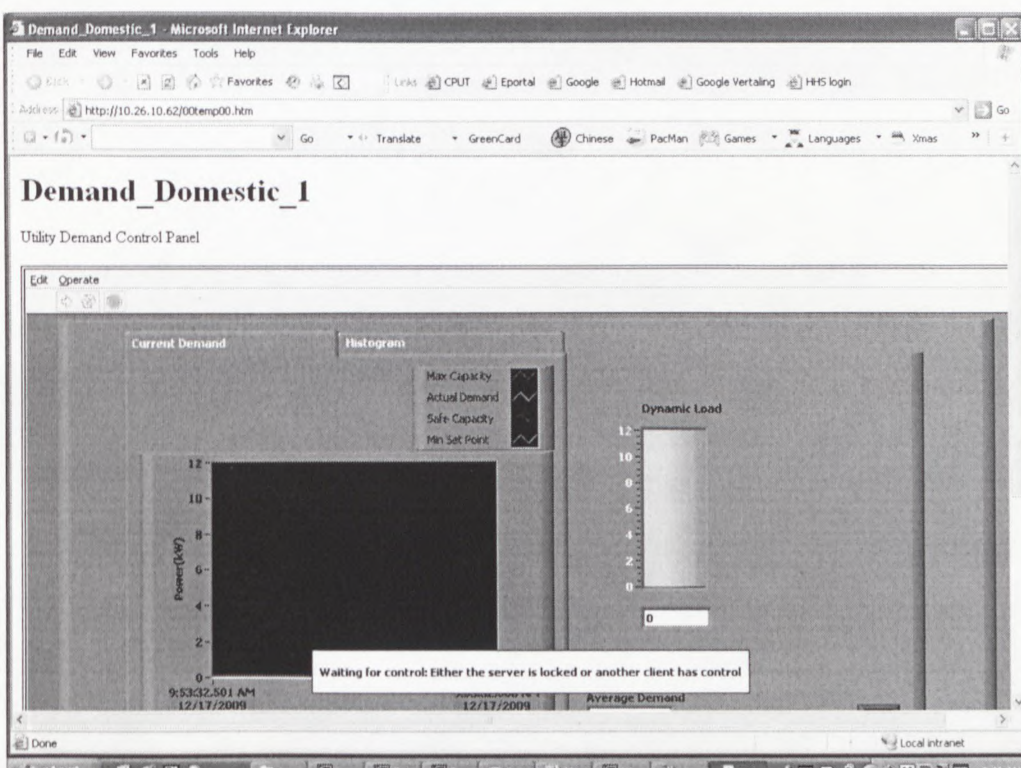


Figure 7.15 Remote PC waiting for server to release control.

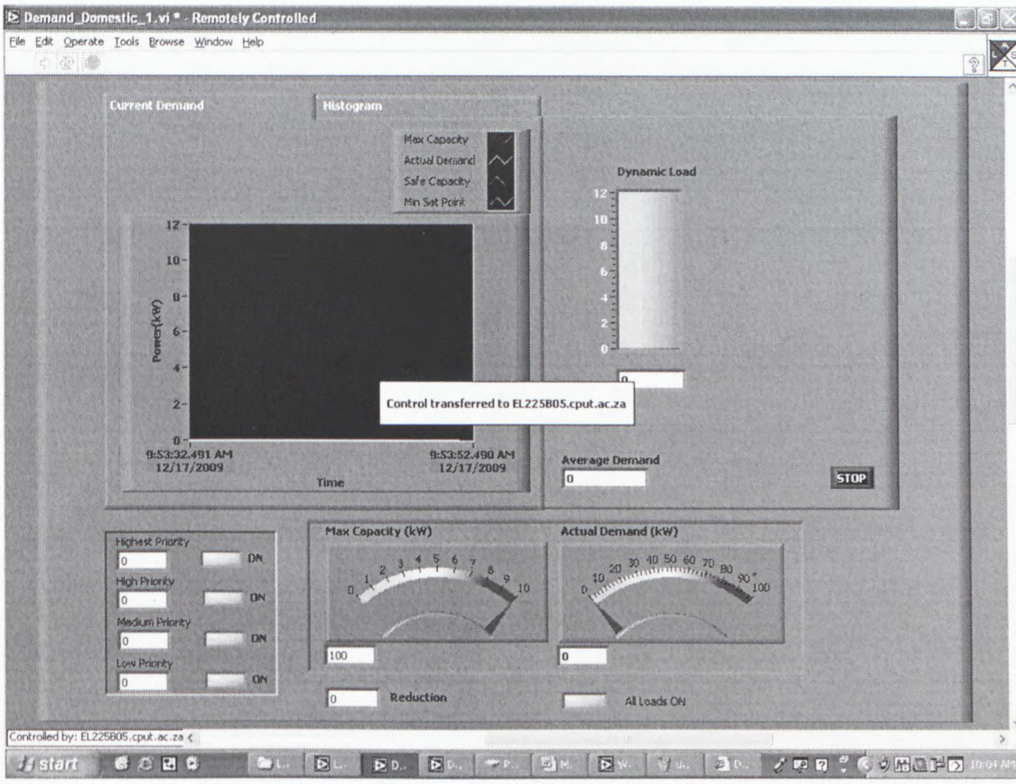


Figure 7.16 Message indicating server has released control to remote PC.

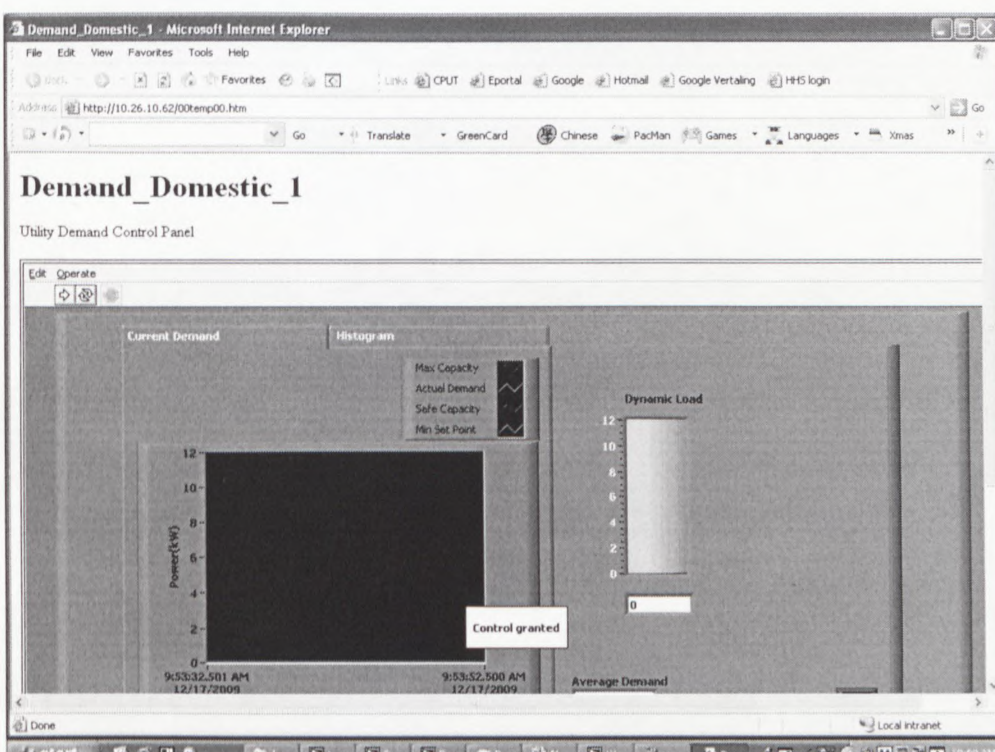


Figure 7.17 Message on remote PC request for control has been granted.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

The main object of this research was to develop a technique that would assist utility providers control and manage energy consumption by effecting selective load shedding in case the demand on the system surpasses the safe capacity. There are techniques that are being used to manage or control energy utilisation, but most of them rely heavily on the goodwill of the customers connected. With the continued increase in demand for electricity as opposed to diminishing energy resources and financial constraints, it is essential for the utility providers to have a way of controlling the energy consumption without compromising the comfort of the customers.

This thesis is in sections that have deliberately been arrangement to ensure continuous flow of information. The arrangement begins with a general introduction with particular emphasis on the requirements of the thesis. This is followed by a literature review and information on load curves, load management and the situation of South Africa in terms of energy consumption. Different aspects of demand side management have been highlighted.

The development of ALST was achieved using the inline controller (ILC 150 ETH) PLC to control the loads at the side of the customer. A program was written using the PC WorX software and downloaded on the controller. There were two options that were considered, the independent and the sequence options. The performance of the system on the side of utility was achieved using LabVIEW program. A block diagram and front panel were built using subVIs. Modules of subVIs were created in order to accommodate the system into a single small block diagram. The LabVIEW front panel was published on the intranet to facilitate remote control from a PC other than the server.

8.2 Future Research

The future improvements of the technique need to consider extending the use of PLCs in management of energy consumption in the industrial sector in order to capitalize on the possibility of substantial energy savings. Further research should consider integrating the PLC and the utility in real-time through establishment of a link between the PLC at the consumer's side and the utility.

8.3 Publications Related to the Thesis

Majani, C.C and Kahn M.T.E. Smart distribution board for active load shifting for demand side management applications. *Domestic Use of Energy International Conference, Cape Town, South Africa*, 14-15 April, 2009, pp 185 - 190

Majani, C.C and Kahn M.T.E. *Discussion paper in the South Africa Universities Power Engineering Conference (SAUPEC), Cape Town, South Africa*, 28-29 January 2009. Title appears at:

http://www.saupec.org.za/archive/2009/SAUPEC2009_Technical%20Sessions_Program_Final.pdf

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APPENDIX A: Technical data for ILC 150 ETH controller device

ILC 150 ETH Product description

The highly modular range of Inline controllers by Phoenix Contact has been supplemented with a powerful compact controller along with ILC 150 ETH. The practical area of application of Inline controllers is further extended to smaller applications using this controller. The compact controller can be adapted to the relevant requirements in a highly modular manner by integrating it directly in the Inline automation system. Using its integrated Ethernet interface, it can be parameterised and programmed as per IEC 61131 using the PC WorX automation software; it can also exchange data with OPC servers simultaneously and communicate with TCP/IP-compatible devices.

The range of Inline controllers covers a wide spectrum of services. Depending on the application, the user can find any desired controller, right from the starter version down to the high end controller. Users can choose from the portfolio between controllers with different computing capacities, with or without Profinet IO controllers and with or without GL approval.

Control system

Programming tool	PC WORX 5
Diagnostics tool	DIAG+ from version 1.14

Mechanical design

Height	119.8 mm
Width	80 mm
Weight	285 g
Ambient temperature (operation)	-25 °C ... 60 °C
Degree of protection	IP20

Data interfaces

Interface	INTERBUS local bus (master)
Type of connection	Inline data jumper
Interface	Parameterisation/operation/diagnostics
Type of connection	RS-232-C, 6-pos. MINI-DIN female connector (PS/2), Ethernet 10/100 (RJ45)
Interface	Ethernet 10Base-T/100Base-TX
Type of connection	RJ45 female connector
Transmission speed	10/100 MBit/s

Power supply

Typical current consumption	210 mA (no local bus device connected during idling, bus inactive)
Max. current consumption	870 mA (370 mA Logikversorgung + 500 mA Analog-Spannungsversorgung)
Supply voltage	24 V DC
Range of supply voltages	19.2 V DC ... 30 V DC
Residual ripple	± 5 %

INTERBUS data

Type	INTERBUS master
Number of Inline terminals which can be connected	63
Note on the number of Inline terminals which can be connected	observe current consumption
Number of devices with parameter channel (PCP)	Max. 16
Number of supported devices	Max. 128
Number of I/O nodes	Max. 4096
Battery	Integrated (rechargeable battery buffered)
Number of control tasks	8
Number of timers, counters	(depending on data memory)
Number of data blocks	(depending on data memory)
Data memory	256 kByte
Retentive data memory	8 kByte (NVRAM)

IEC 61131 runtime system

Programming tool	PC WORX 5
Data memory	256 kByte
Retentive data memory	8 kByte (NVRAM)
Number of data blocks	(depending on data memory)
Number of timers, counters	(depending on data memory)
Number of control tasks	8
Realtime clock	Yes

Inline potential routing

Communications voltage U_L	7.5 V DC ±5%
Power supply for U_L	0.8 A DC (observe derating)
Supply for main circuit U_M	24 V DC -15% / +20% (in acc. with EN 61131-2)
Power supply for U_M	8 A (maximum)
Segment power supply voltage U_S	24 V DC -15% / +20% (in acc. with EN 61131-2)
Power supply for U_S	8 A (maximum)
I/O supply voltage U_{ANA}	24 V DC -15% / +20%
Power supply for U_{ANA}	0.5 A DC (observe derating)

APPENDIX B: Ethernet connection between PC and ILC 150 ETH controller

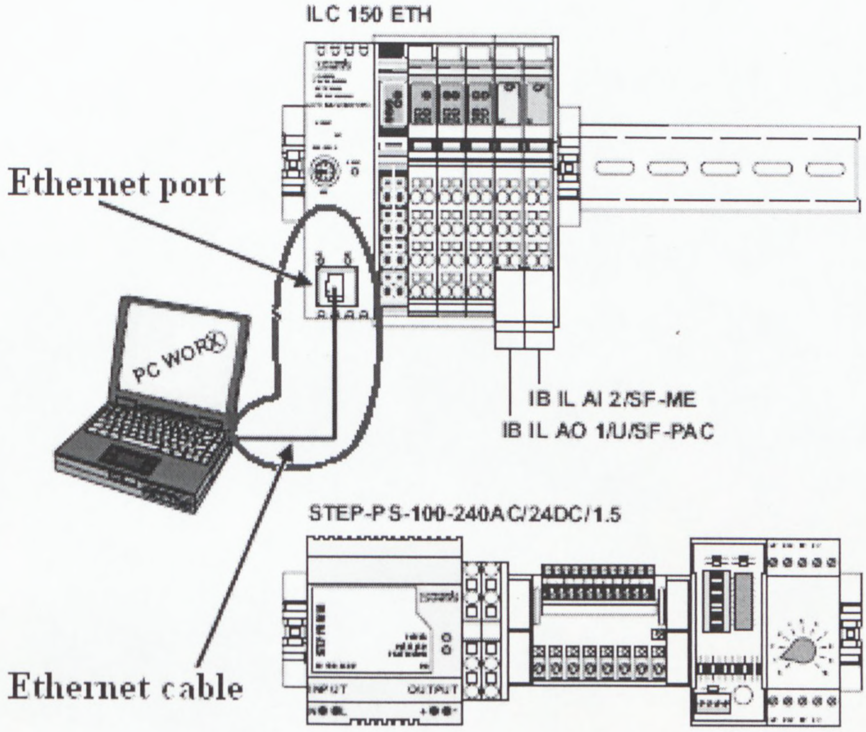

Figure A.B1: Ethernet connection between the PC and the ILC 150 ETH controller

APPENDIX C: Abstract of the paper submitted to the Domestic Use of Energy International Conference held on 14th and 15th April 2009.

Smart Distribution Board for Active Load Shifting for Demand Side Management Applications

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ABSTRACT

Initiatives that are directed towards improving power management by a utility provider have to consider technical feasibility, socio-economic and the environment. Power consumption patterns world over indicate continuous rise in demand for electric power leading utility provider resorting to controlling the usage through actions of load shedding. Load shedding imposes inconveniences to the consumers since they are completely disconnected from the grid. This study considers a technique of implementing Demand Side Management (DSM) program to benefit the utility provider, the customer, the nation and the world by installation of a smart distribution board (Smart DB) at the consumer's point to enable utility company to selectively turn on or off, the appliances connected. The Smart DB will consist of electronic actuators connected to the switches of the various circuits to the appliances and controlled by signals transmitted from the utility provider with limited option to the consumer. Implementation challenges include the integration of the Smart DB into the existing system as well as initial replacement cost.

Key words: load shedding, selective, active shifting, DSM, smart DB

APPENDIX D: LabVIEW simulation data

Date	Time	System Demand	Reduction	Actual Demand	Maximum Demand
Wed, Dec 09, 2009	2:15:19 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:20 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:21 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:21 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:22 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:23 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:24 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:25 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:26 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:27 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:28 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:15:29 PM	6978	0	6978	10000
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Wed, Dec 09, 2009	2:37:26 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:28 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:29 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:30 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:31 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:32 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:33 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:34 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:35 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:36 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:37 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:38 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:40 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:41 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:42 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:43 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:44 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:45 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:46 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:47 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:48 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:49 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:51 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:52 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:53 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:54 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:55 PM	6591	0	6591	10000

Wed, Dec 09, 2009	2:37:56 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:57 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:58 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:37:59 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:00 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:01 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:02 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:03 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:05 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:06 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:07 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:08 PM	6591	0	6591	10000
Wed, Dec 09, 2009	2:38:09 PM	6591	0	6591	10000
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Wed, Dec 09, 2009	2:38:11 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:12 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:13 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:14 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:15 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:16 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:17 PM	6978	0	6978	10000
Wed, Dec 09, 2009	2:38:18 PM	7026	0	7026	10000
Wed, Dec 09, 2009	2:38:19 PM	7074	0	7074	10000
Wed, Dec 09, 2009	2:38:20 PM	7170	0	7170	10000
Wed, Dec 09, 2009	2:38:22 PM	7266	0	7266	10000
Wed, Dec 09, 2009	2:38:23 PM	7314	0	7314	10000
Wed, Dec 09, 2009	2:38:24 PM	7458	0	7458	10000
Wed, Dec 09, 2009	2:38:25 PM	7506	0	7506	10000
Wed, Dec 09, 2009	2:38:26 PM	7602	200	7402	10000
Wed, Dec 09, 2009	2:38:27 PM	7650	0	7650	10000
Wed, Dec 09, 2009	2:38:29 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:38:30 PM	7794	200	7594	10000
Wed, Dec 09, 2009	2:38:31 PM	7842	200	7642	10000
Wed, Dec 09, 2009	2:38:32 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:34 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:35 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:36 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:37 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:38 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:40 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:41 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:42 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:43 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:45 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:46 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:47 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:48 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:50 PM	7938	200	7738	10000
Wed, Dec 09, 2009	2:38:51 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:52 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:53 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:54 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:56 PM	7890	200	7690	10000

Wed, Dec 09, 2009	2:38:57 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:58 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:38:59 PM	7890	200	7690	10000
Wed, Dec 09, 2009	2:39:01 PM	7842	200	7642	10000
Wed, Dec 09, 2009	2:39:02 PM	7842	200	7642	10000
Wed, Dec 09, 2009	2:39:03 PM	7842	200	7642	10000
Wed, Dec 09, 2009	2:39:04 PM	7794	200	7594	10000
Wed, Dec 09, 2009	2:39:06 PM	7794	200	7594	10000
Wed, Dec 09, 2009	2:39:07 PM	7794	200	7594	10000
Wed, Dec 09, 2009	2:39:08 PM	7794	200	7594	10000
Wed, Dec 09, 2009	2:39:09 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:39:11 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:39:12 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:39:13 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:39:14 PM	7746	200	7546	10000
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Wed, Dec 09, 2009	2:39:17 PM	7698	200	7498	10000
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Wed, Dec 09, 2009	2:39:22 PM	7650	200	7450	10000
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Wed, Dec 09, 2009	2:39:24 PM	7650	200	7450	10000
Wed, Dec 09, 2009	2:39:25 PM	7698	0	7698	10000
Wed, Dec 09, 2009	2:39:27 PM	7746	200	7546	10000
Wed, Dec 09, 2009	2:39:28 PM	8077.8	200	7877.8	10000
Wed, Dec 09, 2009	2:39:29 PM	8440.2	200	8240.2	10000
Wed, Dec 09, 2009	2:39:30 PM	8645.4	350	8295.4	10000
Wed, Dec 09, 2009	2:39:31 PM	8772	350	8422	10000
Wed, Dec 09, 2009	2:39:32 PM	8868	350	8518	10000
Wed, Dec 09, 2009	2:39:34 PM	8868	450	8418	10000
Wed, Dec 09, 2009	2:39:35 PM	8964	350	8614	10000
Wed, Dec 09, 2009	2:39:36 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:37 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:39 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:40 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:41 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:42 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:43 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:45 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:46 PM	8964	450	8514	10000
Wed, Dec 09, 2009	2:39:47 PM	8806.8	450	8356.8	10000
Wed, Dec 09, 2009	2:39:48 PM	8553.6	350	8203.6	10000
Wed, Dec 09, 2009	2:39:49 PM	8553.6	350	8203.6	10000
Wed, Dec 09, 2009	2:39:50 PM	8553.6	350	8203.6	10000
Wed, Dec 09, 2009	2:39:52 PM	8553.6	350	8203.6	10000
Wed, Dec 09, 2009	2:39:53 PM	8553.6	350	8203.6	10000
Wed, Dec 09, 2009	2:39:54 PM	8505.6	350	8155.6	10000
Wed, Dec 09, 2009	2:39:55 PM	8457.6	350	8107.6	10000
Wed, Dec 09, 2009	2:39:57 PM	8457.6	350	8107.6	10000
Wed, Dec 09, 2009	2:39:58 PM	8457.6	350	8107.6	10000
Wed, Dec 09, 2009	2:39:59 PM	8457.6	350	8107.6	10000
Wed, Dec 09, 2009	2:40:00 PM	8409.6	350	8059.6	10000

Wed, Dec 09, 2009	2:40:02 PM	8409.6	350	8059.6	10000
Wed, Dec 09, 2009	2:40:03 PM	8409.6	350	8059.6	10000
Wed, Dec 09, 2009	2:40:04 PM	8409.6	350	8059.6	10000
Wed, Dec 09, 2009	2:40:05 PM	8409.6	350	8059.6	10000
Wed, Dec 09, 2009	2:40:07 PM	8361.6	350	8011.6	10000
Wed, Dec 09, 2009	2:40:08 PM	8361.6	350	8011.6	10000
Wed, Dec 09, 2009	2:40:09 PM	8361.6	350	8011.6	10000
Wed, Dec 09, 2009	2:40:10 PM	8361.6	350	8011.6	10000
Wed, Dec 09, 2009	2:40:12 PM	8361.6	350	8011.6	10000
Wed, Dec 09, 2009	2:40:13 PM	8313.6	350	7963.6	10000
Wed, Dec 09, 2009	2:40:14 PM	8313.6	200	8113.6	10000
Wed, Dec 09, 2009	2:40:15 PM	8313.6	350	7963.6	10000
Wed, Dec 09, 2009	2:40:16 PM	8265.6	200	8065.6	10000
Wed, Dec 09, 2009	2:40:18 PM	8265.6	350	7915.6	10000
Wed, Dec 09, 2009	2:40:19 PM	8265.6	200	8065.6	10000
Wed, Dec 09, 2009	2:40:20 PM	8265.6	350	7915.6	10000
Wed, Dec 09, 2009	2:40:21 PM	8265.6	200	8065.6	10000
Wed, Dec 09, 2009	2:40:22 PM	8628	350	8278	10000
Wed, Dec 09, 2009	2:40:23 PM	8754.6	350	8404.6	10000
Wed, Dec 09, 2009	2:40:25 PM	8724	350	8374	10000
Wed, Dec 09, 2009	2:40:26 PM	8772	350	8422	10000
Wed, Dec 09, 2009	2:40:27 PM	8772	350	8422	10000
Wed, Dec 09, 2009	2:40:28 PM	8946.6	350	8596.6	10000
Wed, Dec 09, 2009	2:40:29 PM	9261	450	8811	10000
Wed, Dec 09, 2009	2:40:30 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:32 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:33 PM	9405	450	8955	10000
Wed, Dec 09, 2009	2:40:34 PM	9405	450	8955	10000
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Wed, Dec 09, 2009	2:40:36 PM	9405	450	8955	10000
Wed, Dec 09, 2009	2:40:38 PM	9405	450	8955	10000
Wed, Dec 09, 2009	2:40:39 PM	9405	450	8955	10000
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Wed, Dec 09, 2009	2:40:41 PM	9405	450	8955	10000
Wed, Dec 09, 2009	2:40:42 PM	9405	450	8955	10000
Wed, Dec 09, 2009	2:40:44 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:45 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:46 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:47 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:48 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:50 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:51 PM	9357	450	8907	10000
Wed, Dec 09, 2009	2:40:52 PM	9261	450	8811	10000
Wed, Dec 09, 2009	2:40:53 PM	9261	450	8811	10000
Wed, Dec 09, 2009	2:40:55 PM	9261	450	8811	10000
Wed, Dec 09, 2009	2:40:56 PM	9261	450	8811	10000
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Wed, Dec 09, 2009	2:40:58 PM	9261	450	8811	10000
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Wed, Dec 09, 2009	2:41:01 PM	9165	450	8715	10000
Wed, Dec 09, 2009	2:41:02 PM	9165	450	8715	10000
Wed, Dec 09, 2009	2:41:03 PM	9165	450	8715	10000
Wed, Dec 09, 2009	2:41:05 PM	9165	450	8715	10000

Wed, Dec 09, 2009	2:41:06 PM	9117	450	8667	10000
Wed, Dec 09, 2009	2:41:07 PM	9117	450	8667	10000
Wed, Dec 09, 2009	2:41:09 PM	9117	450	8667	10000
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Wed, Dec 09, 2009	2:41:11 PM	9117	450	8667	10000
Wed, Dec 09, 2009	2:41:12 PM	9117	450	8667	10000
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Wed, Dec 09, 2009	2:41:18 PM	9654	450	9204	10000
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Wed, Dec 09, 2009	2:41:20 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:21 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:23 PM	9798	550	9248	10000
Wed, Dec 09, 2009	2:41:24 PM	9846	550	9296	10000
Wed, Dec 09, 2009	2:41:25 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:26 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:28 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:29 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:30 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:31 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:32 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:34 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:35 PM	9942	550	9392	10000
Wed, Dec 09, 2009	2:41:36 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:37 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:39 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:40 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:41 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:42 PM	9894	550	9344	10000
Wed, Dec 09, 2009	2:41:44 PM	9846	550	9296	10000
Wed, Dec 09, 2009	2:41:45 PM	9798	550	9248	10000
Wed, Dec 09, 2009	2:41:46 PM	9798	550	9248	10000
Wed, Dec 09, 2009	2:41:47 PM	9798	550	9248	10000
Wed, Dec 09, 2009	2:41:49 PM	9798	550	9248	10000
Wed, Dec 09, 2009	2:41:50 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:51 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:52 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:54 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:55 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:56 PM	9750	550	9200	10000
Wed, Dec 09, 2009	2:41:57 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:41:59 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:42:00 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:42:01 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:42:02 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:42:04 PM	9654	550	9104	10000
Wed, Dec 09, 2009	2:42:05 PM	9606	550	9056	10000
Wed, Dec 09, 2009	2:42:06 PM	9558	550	9008	10000
Wed, Dec 09, 2009	2:42:07 PM	9558	550	9008	10000
Wed, Dec 09, 2009	2:42:08 PM	9558	550	9008	10000
Wed, Dec 09, 2009	2:42:10 PM	9558	550	9008	10000

Wed, Dec 09, 2009	2:42:11 PM	9558	550	9008	10000
Wed, Dec 09, 2009	2:42:12 PM	9510	550	8960	10000
Wed, Dec 09, 2009	2:42:13 PM	9510	450	9060	10000
Wed, Dec 09, 2009	2:42:14 PM	9510	550	8960	10000
Wed, Dec 09, 2009	2:42:16 PM	9510	450	9060	10000
Wed, Dec 09, 2009	2:42:17 PM	9510	550	8960	10000
Wed, Dec 09, 2009	2:42:18 PM	9462	450	9012	10000
Wed, Dec 09, 2009	2:42:19 PM	9462	550	8912	10000
Wed, Dec 09, 2009	2:42:21 PM	9619.2	450	9169.2	10000
Wed, Dec 09, 2009	2:42:22 PM	9776.4	550	9226.4	10000
Wed, Dec 09, 2009	2:42:23 PM	9776.4	550	9226.4	10000
Wed, Dec 09, 2009	2:42:24 PM	9855	550	9305	10000
Wed, Dec 09, 2009	2:42:25 PM	9855	550	9305	10000
Wed, Dec 09, 2009	2:42:26 PM	9807	550	9257	10000
Wed, Dec 09, 2009	2:42:28 PM	9807	550	9257	10000
Wed, Dec 09, 2009	2:42:29 PM	9807	550	9257	10000
Wed, Dec 09, 2009	2:42:30 PM	9807	550	9257	10000
Wed, Dec 09, 2009	2:42:31 PM	9759	550	9209	10000
Wed, Dec 09, 2009	2:42:33 PM	9759	550	9209	10000
Wed, Dec 09, 2009	2:42:34 PM	9759	550	9209	10000
Wed, Dec 09, 2009	2:42:35 PM	9759	550	9209	10000
Wed, Dec 09, 2009	2:42:36 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:37 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:39 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:40 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:41 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:43 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:44 PM	9711	550	9161	10000
Wed, Dec 09, 2009	2:42:45 PM	9663	550	9113	10000
Wed, Dec 09, 2009	2:42:46 PM	9663	550	9113	10000
Wed, Dec 09, 2009	2:42:47 PM	9663	550	9113	10000
Wed, Dec 09, 2009	2:42:49 PM	9615	550	9065	10000
Wed, Dec 09, 2009	2:42:50 PM	9615	550	9065	10000
Wed, Dec 09, 2009	2:42:51 PM	9615	550	9065	10000
Wed, Dec 09, 2009	2:42:52 PM	9457.8	550	8907.8	10000
Wed, Dec 09, 2009	2:42:53 PM	9222	450	8772	10000
Wed, Dec 09, 2009	2:42:55 PM	9222	450	8772	10000
Wed, Dec 09, 2009	2:42:56 PM	9222	450	8772	10000
Wed, Dec 09, 2009	2:42:57 PM	9222	450	8772	10000
Wed, Dec 09, 2009	2:42:58 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:00 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:01 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:02 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:03 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:04 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:06 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:07 PM	9174	450	8724	10000
Wed, Dec 09, 2009	2:43:08 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:09 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:11 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:12 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:13 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:14 PM	9126	450	8676	10000

Wed, Dec 09, 2009	2:43:15 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:17 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:18 PM	9126	450	8676	10000
Wed, Dec 09, 2009	2:43:19 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:20 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:22 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:23 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:24 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:25 PM	9235.2	450	8785.2	10000
Wed, Dec 09, 2009	2:43:26 PM	9392.4	450	8942.4	10000
Wed, Dec 09, 2009	2:43:27 PM	9392.4	450	8942.4	10000
Wed, Dec 09, 2009	2:43:28 PM	9078	450	8628	10000
Wed, Dec 09, 2009	2:43:30 PM	8920.8	450	8470.8	10000
Wed, Dec 09, 2009	2:43:31 PM	8763.6	350	8413.6	10000
Wed, Dec 09, 2009	2:43:32 PM	8685	350	8335	10000
Wed, Dec 09, 2009	2:43:33 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:34 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:36 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:37 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:38 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:39 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:41 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:42 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:43 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:44 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:46 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:47 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:48 PM	8637	350	8287	10000
Wed, Dec 09, 2009	2:43:49 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:51 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:52 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:53 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:54 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:56 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:57 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:58 PM	8589	350	8239	10000
Wed, Dec 09, 2009	2:43:59 PM	8541	350	8191	10000
Wed, Dec 09, 2009	2:44:00 PM	8226.6	350	7876.6	10000
Wed, Dec 09, 2009	2:44:01 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:02 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:04 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:05 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:06 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:07 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:09 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:10 PM	8148	200	7948	10000
Wed, Dec 09, 2009	2:44:11 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:12 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:13 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:15 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:16 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:17 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:18 PM	8100	200	7900	10000

Wed, Dec 09, 2009	2:44:20 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:21 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:22 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:23 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:25 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:26 PM	8100	200	7900	10000
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Wed, Dec 09, 2009	2:44:29 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:31 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:32 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:33 PM	8100	200	7900	10000
Wed, Dec 09, 2009	2:44:34 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:36 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:37 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:38 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:39 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:40 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:42 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:43 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:44 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:45 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:46 PM	8130.6	200	7930.6	10000
Wed, Dec 09, 2009	2:44:48 PM	8052	200	7852	10000
Wed, Dec 09, 2009	2:44:49 PM	7816.2	200	7616.2	10000
Wed, Dec 09, 2009	2:44:50 PM	7737.6	200	7537.6	10000
Wed, Dec 09, 2009	2:44:51 PM	7659	200	7459	10000
Wed, Dec 09, 2009	2:44:52 PM	7659	0	7659	10000
Wed, Dec 09, 2009	2:44:53 PM	7659	200	7459	10000
Wed, Dec 09, 2009	2:44:55 PM	7611	0	7611	10000
Wed, Dec 09, 2009	2:44:56 PM	7450.2	200	7250.2	10000
Wed, Dec 09, 2009	2:44:57 PM	7289.4	0	7289.4	10000
Wed, Dec 09, 2009	2:44:58 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:44:59 PM	7209	0	7209	10000
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Wed, Dec 09, 2009	2:45:02 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:03 PM	7209	0	7209	10000
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Wed, Dec 09, 2009	2:45:14 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:15 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:17 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:18 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:19 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:20 PM	7209	0	7209	10000

Wed, Dec 09, 2009	2:45:21 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:22 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:23 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:24 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:25 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:26 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:27 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:28 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:30 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:31 PM	7209	0	7209	10000
Wed, Dec 09, 2009	2:45:32 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:33 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:34 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:35 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:36 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:37 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:38 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:39 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:40 PM	7164	0	7164	10000
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Wed, Dec 09, 2009	2:45:44 PM	7164	0	7164	10000
Wed, Dec 09, 2009	2:45:45 PM	7119	0	7119	10000
Wed, Dec 09, 2009	2:45:46 PM	7119	0	7119	10000
Wed, Dec 09, 2009	2:45:47 PM	7119	0	7119	10000
Wed, Dec 09, 2009	2:45:48 PM	7119	0	7119	10000
Wed, Dec 09, 2009	2:45:49 PM	7119	0	7119	10000

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