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Demand-Supply Interacting System Towards a Dynamic Electrical Energy Management- The Smart Grid

A dissertation submitted by
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ABSTRACT

High peak demands are common occurrences in Australian electricity market increasing the volatility of electricity whole sale prices. Recently, reducing electricity demand has been one of the most common objectives for all electricity suppliers, environmental organizations and others at the national and international level. Peak demands make it difficult to meet the increased demand of electricity, to lower prices, to increase quality and to avoid negative impacts on the environment. A scheme that allows consumers to moderate own demand will reduce the electricity peak demands.

This project describes and delineates the scheme of averting peak demands. The main premise up on which this study is designed is to enable electricity users to effectively manage and control own demand based on information, publicly available from the Australian Energy Market Operator (AEMO). Adequately managing and controlling energy demands shall lead to enhanced system performance. The scheme is contributing towards achieving a Smart Grid environment.

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CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

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Date

DEDICATION

To my parents, my wife, my children, brothers, sisters and friends

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I would like to express my warm appreciation to the advisory committee: Dr. Fouad Kamel, Dr. Wei Xiang and Dr. Tony Ahfock for their help and positive attitudes. I would like to express my deepest gratefulness to my project supervisor, Dr. Fouad Kamel, for his precious time, continuous assistance, consultation, encouragement, valuable feedback and patience during the entire period of the preparation of the project.

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Abdullah AlMahrouqi

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Chapter 1 INTRODUCTION

1.1 Problem Description

Reaching high electricity demands for a few hours a day is one of the most significant problems at the national and international level. The current increase in demand peaks in Australia is unprecedented particularly at the level of the residential sector. The reason for electricity demand peaks includes the simultaneous high consumption of electricity. Not only does the wasted energy resulting from the unconscious consumption like over cooling or over heating or in lighting contribute to the electricity demand peaks, but the rapidly increase in miscellaneous Information Technology (I T) and entertainment equipments has also contributed to the increase in the simultaneous electricity consumption (Williams et al., 2006; GEF, 2008). Other reasons contributing to increase in demand peaks include the lack of residential consumers' awareness of the dramatic increases occurring due to simultaneous high consumption.

The residential electricity usage in the National Electricity Market (NEM) represents 27.8% of the total electricity demand in 2009 (AEMO, 2009). This estimated ratio is expected to considerably increase in the coming years due to the growing of the population and other factors such as increase in Heating, Ventilation and Air Conditioning (HVAC) system usage due to increase in population and residential households. The number of the occupied residential households is expected to rise from six millions to about ten millions in the period from 1990 to 2020, or approximately 61% increase (EES, 2008). The study also estimated that the energy consumption of the residential sector (electricity, gas, LPG and wood) will increase by about 56% over the same period by about 20 % increase per person (EES, 2008). Although the peak demand time is normally about 0.2 % of the whole day, such short period of time requires establishing more than 5 % of the entire specified electricity network infrastructure in order to assure electricity supply (Fraser, 2005; Kamel, 2009).

The relationship between electricity users and suppliers in the electricity market has been usually based on that whenever and whatever loads are required by users, they are expected to be met by suppliers at the expected time with the maximal quality. The above electricity consumption increase in the residential sector and other sectors is leading to the overcrowding electricity demands. However, to meet the current continuous growing electricity demands, there should be a constantly growing electricity supply; this would lead to assist the existing network with more electricity generators and improve transmission and distribution infrastructure. More noticeable negative impacts could occur including increase in energy generating cost, increased electricity prices, compromised quality e.g. voltage fluctuations, technical and economic deficiencies and even undesirable environmental impacts e.g. greenhouse gas emissions. Technical and economic difficulties are presented mainly in congestions at peak demands associated with compromises in quality and high-priced energy. At low-demands, a resulting low energy cost could drive power stations to operate at the limits of economic viability (Kamel, 2009).

1.2 Proposed solution

With the problematic issue of the increased electricity demand and excessive peak demands, there is a need to design a system that enables electricity consumers to decrease and defer their usage as required. The users are receiving information from the Australian Energy Market Operator (AEMO) which would help effectively manage own electricity demand. The system enables users to rationally decide the quantity of energy usage based on information publicly received on the internet. With such effective engagement, the users could contribute and control electricity demand paving the way towards achieving improved electrical supply services.

The main premise of this research is based on information made public through AEMO to the electricity users through the internet about the state of electricity market (electricity demand or load profile). The load curve will show a peak point where electricity consumption reaches critical points causing undesired consequences. Providing consumers with such a load curve will enable users to switch off certain load when the state of electricity demands reaches certain limit. More details about this technique will be elaborated in the followings chapters.

1.3 Disposition

This report is divided into eight chapters and three appendices.

The first chapter presents the introduction of the report and the significance of the project, provides discussion of the problem for the increased peak demand and describes the proposed solution and the abbreviations used in the report.

In the second chapter, the report focuses on describing the goals, objectives, project description and focus region and sector of the project.

In the third chapter entitled background, the report presents review of the literature about the most significantly related topics to the project including electricity market in Australia, analysis of the current electricity demand costs and the critical market situations which occurred because of peak demands. The third chapter provides the related studies which have been conducted on the impacts of the electricity peak demand. Additionally, it analyses the electricity market management and the main companies or authorities that are responsible for the management process and extends to discuss the national electricity market providing description of the development of Australian Energy Market Operator.

Chapter four discusses analysis of the Queensland electricity market providing discussion of the stages of electricity delivery and electricity selling contractors.

The fifth chapter involves discussion of the proposed design for reducing the electricity demand, description of the apparatus used and the connection and operation of the system.

The sixth chapter provides discussion of the results which have been achieved through the project and the benefits which have resulted. Besides, it continues to provide the implementation procedures of the proposed design and the hindrances that could be confronted by its implementation.

The seventh chapter explains the implications of implementing the proposed scheme, which could be applied in Queensland and in other markets. Besides, different types of returns obtained by implementing this scheme have been provided in chapter seven.

Finally, the eighth chapter lists suggestions for possible future studies based on the scheme and provides a conclusion.

Three appendices are providing project specifications, software codes, and software descriptions are enclosed with the report.

1.4 Abbreviation

AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AMI	Advanced Metering Infrastructure
BMS	Building Management System
DSR	Demand Side Response
GOC	Government Owned Corporations
HVAC	Heating, Ventilation and Air Conditioning
I T	Internet Protocol
IMO	Independent Market Operator
kWh	kilowatt hour
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
MWh	Megawatt hour
NEM	National Electricity Market
PCF	plant capacity factor
RRP	Regional Reference Price
SCC	Standard Connection Contract
SRC	Standard Retail Contract

SSR	Solid State Relay
STEM	Short Term Energy Market
SWIS	South West Interconnected System
WEM	Wholesale Electricity Market

Chapter 2 RESEARCH GOALS & OBJECTIVES

2.1 Objectives

On a long term, applying the system could lead to the followings benefits:

- Decreasing Peak Demand.
- Raising users' awareness.
- Reducing Environmental impacts.
- Improved system reliability.
- Reducing electricity Price.
- Reducing price volatility.
- Improved efficiency.
- Improved economics.

2.2 Goals

The project goals which are to be accomplished during the offered period are as follow:

1. Problem identification.
2. Identification of solutions.
3. Define project components.
4. Components selection.
5. Coordination with concerned utilities and suppliers.
6. Choosing and writing software.
7. Familiarise with the components and software.

8. Conducting experiment.
9. Work evaluation.
10. Writing the dissertation.

2.3 Project description

With the use of the publicly published information, customers will be alarmed about the need for reduction in their demand at particular times. Upon getting the signal containing this information about electricity rates or peak demand, the customer (computer) scrutinizes the condition to immediately take the appropriate action. This action should be carried out according to the consumer management plan.

Reduction in demand peaks are expected to reflect economic/social/environmental benefits to consumers, suppliers, generators and the whole economy. No doubt that the utility is the direct beneficial from implementation of the system, so it ought to be offering incentives to the consumers to encourage them implementing the scheme. Such encouragement can be bill credit, direct payments or any other inducement which will not only satisfy the consumers but let them express about their willingness to participate in such mutually beneficial plan, even if not called by the utility.

2.4 Towards Smart Grid

Given that the project design is one part of the entire smart grid, it would be beneficial for this project to provide some information about the smart grid. Smart grid, or Dynamic Energy Management framework, is an intelligent connected communication and control system which is involving the entire electricity generation, transmission and delivery infrastructure

(Brown, 2008). Drifting from manual connection between all components of the entire electricity community, the smart grid allows automatic and intelligent multisided flow of energy and information between electricity generators and end users. Its main role is to provide the right information to the right entity at the right time to take the right action. Smart grid reduces power losses, enhances power supply and delivery, enables self-healing, and paves the way to the next-generation energy efficiency and demand response applications (Gellings, 2008). Smart grid main features include the two sided communication within the grid community; therefore, electricity consumers can, whenever they want, move from passive to active participation in the marketplace (LSC, 2007; Albadi & El-Saadany, 2007).

Smart grid comprises computerized multi-sided standard intelligent devices which allow communication among the participants of the entire electricity system including transmission, distribution and end use devices(Brown, 2008). Other functions performed by smart grid include smart interconnections to distributed energy resources and advanced metering infrastructure (AMI) (Bennett & Highfill, 2008). Smart grid automatically delivers power in response to end users' varied demand and gathers power from those end users whether they are residential, businesses who produce their own power by solar, wind or geothermal power when they have more than they need (Gunther et al., 2009).

2.5 Project focused sector and area

Although the project is compatible to be implemented in any electricity using sector, the main focus of the project, for significant reasons, is on the residential sector in Queensland. The residential sector is considered one of the largest electricity consumers in Australia next to the industrial sector (APC, 2005; AEMO, 2009). Moreover, given that the commercial sector is provided electricity on a negotiated electricity contract; this means that the commercial sector is able to afford the prices offered by suppliers. This makes the commercial sectors less attracted than the residential sector for implementing the project. It is estimated that the number of households in Australia will be growing by approximately 39% to 47% in 2026, or from 7.4 million in 2001 to between 10.2 and 10.8 million in 2026 (ABS, 2006). The increase in households is expected to be faster and higher than the growth of Australia's population growth of 25% for the same period. Other reasons include that most individuals' electricity related activities are based at homes with the availability of domestic appliances which provide users with the lifestyle needed such as cooling, heating, lighting internet, entertainment and etc. For example, the operation of split-cycle air-conditioning into hundreds of thousands of Australian houses has had a dramatic impact on the daily electricity load and on seasonal variations in demand for electricity (Frew, 2006a).

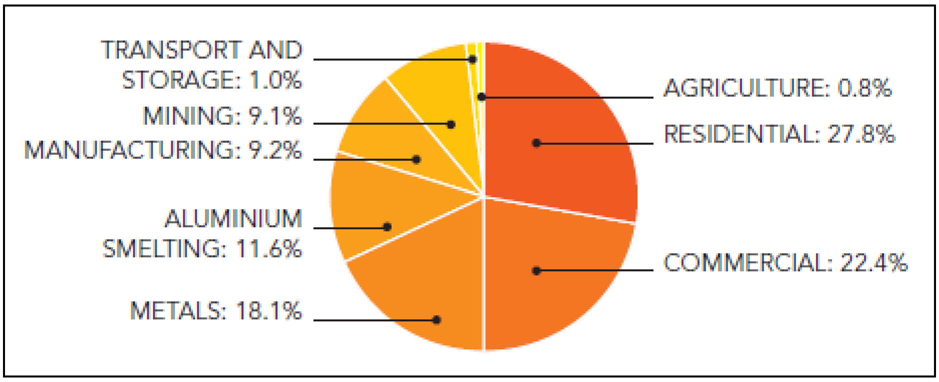

Figure 2.1 Electricity consumption by sector, (AEMO 2009)

Figure 2.1 indicates the electricity usage for every sector in Australia including residential, industry, transport, agriculture and storage. It indicates that the residential sector includes the largest electricity consumers and comes in the second rank at 27.8 % while the industrial sector which involves metals, aluminum smelting, manufacturing and mining comes in the first rank at 48 %. Even the commercial sector comes in the third rank at 22.4 %. This makes the residential sector one of the most significant sectors in electricity consumption which if managed properly would affect the reduction in the electricity peak demand.

From the five states in Australia, the project focuses on Queensland for different significant objectives. For example, the fastest household growth in Australia is expected to occur in Queensland in the period from 2001 and 2026. The households in Queensland are expected to increase by approximately 63% to 76%, from 1.4 million in 2001 to between 2.3 million and 2.4 million in 2026 which is considered to be faster than the expected national growth of 39% to 47% (ABS, 2006).

Figure 2.2 below indicates the number of electricity consumers in every state in all Australia including Queensland. The chart indicates that although New South Wales comes in the first rank in terms of the number of electricity users because of its large population, electricity consumers in Queensland represents around 28 percent of all electricity consumers in Australia making Queensland second largest electricity consumer in all Australia.

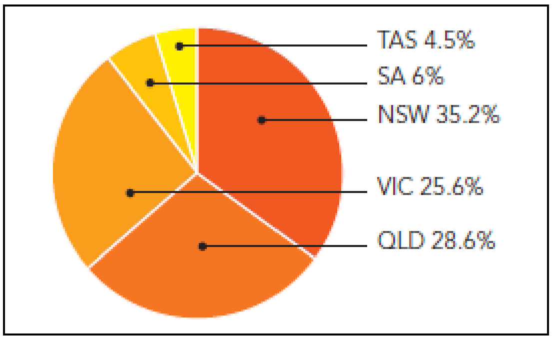

Figure 2.2 Total energy sent out (2007-2008), (AEMO 2009)

Figure 2.3 illustrates that the main three states which are considered large electricity consumers on a daily basis in Australia are QLD, NSW and VIC. In terms of the average daily demand, Queensland State has the second largest electricity demand which reached an average of 5846 MW in 2007-2008. Reducing the electricity demand in Queensland shall have significant impacts on the total electricity demand in Australia.

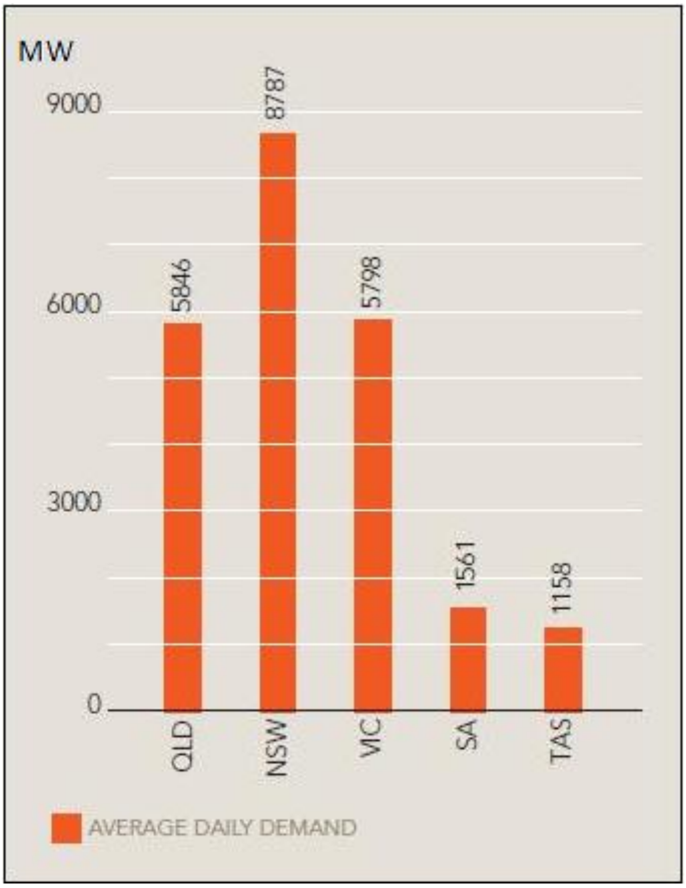

Figure 2.3 Average daily 2007-2008 demand (MW), (AEMO 2009)

In the period from 1999-2000 to 2007-08, the annual growth of electricity consumption in Queensland has increased by more than 29 percent or approximately 10,500 Giga Watt hours (GWh) making Queensland the second highest consumer of electricity in Australia. In February 2009, for example, Queensland's record electricity power demand reached 8699 MW (DEEDI, 2009).

Chapter 3 BACKGROUND

3.1 Australian electricity market

The Australian electricity market involves three main regions; Western Australia, Northern territories and the NEM which involves six interconnected states. Due to the geographical distance among the three regions, it is not possible to interconnect them into one network (Karri et al., 2007). The following part provides a brief explanation about the electricity market in the three regions. Figure 3.1 illustrates the electricity network i.e. transmission lines and generators in the three regions.

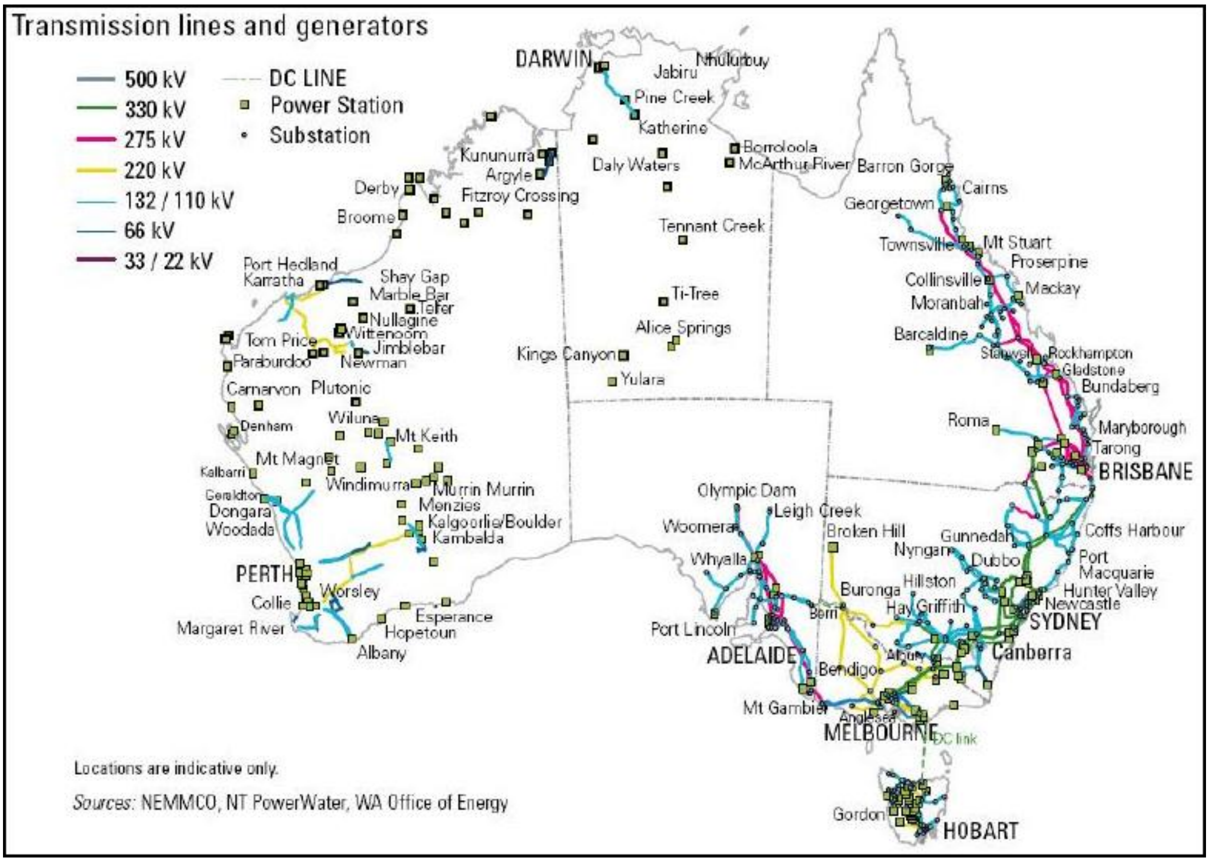

Figure 3.1 Transmission lines and generators in Australia (Cuevas-Cubria et al., 2009, pp.31)

3.1.1 National Electricity Market

Establishing the National Electricity Market (NEM) has been one of the most significant reforms that occurred to electricity and gas supply industry in Queensland (Phunnarungsi & Dixon, G 2003). Instead of owning and operating Australia's electricity suppliers and gas companies by the states and territories governments, National Energy Market (NEM) which allows businesses to manage electricity and gas supply was established on 13 December 1998 (Higgs, 2009).

The NEM, geographically the largest interconnected power system in the world, involves 270 registered generators, transmission networks for six states and 13 major distribution networks which collectively supply electricity to end use customers. The main regions involved in the market include New South Wales, Queensland, Victoria, South Australia and Tasmania. The customers supplied by electricity by the NEM are almost nine million residential and business customers. The market generated around 208 terawatt hours (TWh) of electricity in 2008-2009 with a turnover of $9.4 billion (AER, 2009; table 3.1).

Participating jurisdictions	Qld, NSW, Vic, SA, Tas, ACT
NEM regions	Qld, NSW, Vic, SA, Tas
Registered capacity	47 418 MW
Number of registered generators	268
Number of customers	8.8 million
NEM turnover 2008–09	$9.4 billion
Total energy generated 2008–09	208 TWh
National maximum winter demand 2008–09 (11 June 2009)	32 094 MW[1]
National maximum summer demand 2008–09 (29 January 2009)	35 551 MW

TWh, terrawatt hour; MW, megawatt; NEM, National Electricity Market.
1. The maximum historical winter demand of 34 422 MW occurred in 2008.

Table 3.1 National Electricity Market at a glance (AER, 2009)

In the NEM, businesses and retailers have been enabled to supply electricity; therefore, consumers could compare the electricity prices available from different suppliers with the aim that competition would deliver cost efficiencies to the market. The main functions of the NEM include administering the trade between the generators of electricity and the wholesale consumers of electricity. The activities of administering the electricity trade include setting electricity demand levels, receiving offers to supply electricity from generators, scheduling generators, dispatching generators into production, calculating the spot price of electricity, measuring electricity use and financially settling the electricity market (DME, 2009b; AEMO, 2009).

The NEM which is the umbrella under which electricity generators, distributors and retailers trade electricity 24-hours-a-day and seven-days-a-week is operated and administered by the National Electricity Market Management Company Limited (NEMMCO) which is made up of directors from the state governments of Queensland, New South Wales, the Australian

Capital Territory, Victoria, South Australia and Tasmania (Anderson et al., 2007). However, the roles of NEMMCO has been recently operated and administered by Australian Energy Market Operator (AEMO), which was established on first of July 2009 (AEMO, 2009). Figure 3.2 illustrates the electricity market structure.

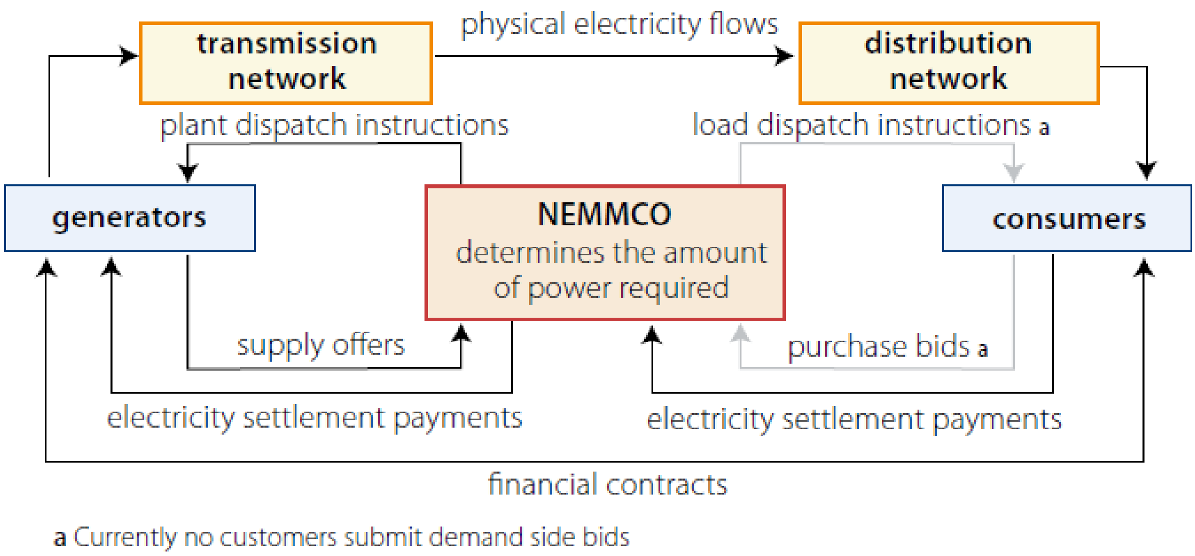

Figure 3.2 Electricity market structure, (Cuevas-Cubria et al., A 2009)

Australian Energy Market Operator

Australian Energy Market Operator (AEMO) operates the electricity trade by aggregating electricity produced by generators into an electricity pool to be bought by market retailers or suppliers. The other key roles of AEMO include the National Transmission Planning function for electricity, production of a National Transmission Network Development Plan, ensuring the supply of electricity by measuring the power system's capacity to continue operating, managing a Supply Reserve to cater for shortage in electricity supply compared to the demand (AEMO, 2009c). Establishing the AEMO has resulted into ongoing improvements to efficiency and competitiveness in gas and electricity markets and warranting that Australians retain is secure and effectively managing energy markets and electricity for the lowest possible prices (AEMO, 2009c).

3.1.2 Western Australia's electricity System

Western Australia, owing to its geographical distance, could not be physically interconnected with the other states under NEM (AER, 2009). However, western power, a State Government owned corporation dominated the energy industry in WA. The Wholesale Electricity Market (WEM) was established in 2006 in the South West Interconnected System (SWIS) of Western Australia (Karri et al., 2007). Three mechanisms for energy trading exist within the WEM; Bilateral Trade of Energy (Bilateral Contracts), Short Term Energy Market (STEM) and the Balancing Mechanism. The Independent Market Operator (IMO), a government body, was established in order to operate and oversee the WEM in accordance with the Market Rules (Stewart, 2005).

Independent Market Operator (IMO)

Pursuant to the Electricity Industry Act 2004, the IMO was established to be a corporate body responsible for the management and operation of the Western Australian Wholesale Electricity Market. Furthermore, the IMO assures efficient capacity to meet Western Australian consumers' demand within the South West Interconnected System which is the biggest interconnected network in WA. 88,000 km of power lines that cover about 322,000 sq km which connects about 840,000 properties e.g. homes, offices and factories to the network (Karri et al., 2007; AER, 2009). Energy resources used for power generation in the SWIS is mainly coal and natural gas, with some liquid-fuelled plants used for peaking duty. However, there are still renewable energy sources such as wind farms and a number of small landfill gas projects responsible for a small amount of generation (Stewart, 2005). SWIS, despite the large area it services, has an installed capacity of just over 4200 MW and a summer peak demand of about 3500 MW (Karri et al., 2007). The State's Western Power Corporation has been, in a reform process, divided into four separate publicly owned utilities managing four areas; Generation (Verve Energy), Retail (Synergy), Networks and System Management (Western Power) and Regional Power (Horizon Power) (Stewart, 2004; Stewart, 2005).

3.1.3 Northern Territory's electricity industry

Around 82,500 only of the 220,000 population of the Northern Territory (NT) are connected to a network making the electricity industry in NT small. In NT, three relatively small regulated systems exist; the largest is the Darwin-Katherine system, with a 320 MW capacity. After the commissioning of the first generator at the Weddell Power Station, the Territory's regulated systems had 444 MW of total capacity at 30 June 2008 (AER, 2009). In 2007-08 the Territory consumed around 1795 GWh of electricity. Main generators are Gas fired plants which generate public electricity in NT, sourcing gas from the Amadeus Basinin Central Australia. However, increasing demand in NT cannot be met by the Amadeus fields and many contracts for gas supply are due to end in 2009 (AER, 2009).

3.2 Current Electricity Demand and cost

The electricity demand-cost relationship presents a challenge for generators, suppliers and consumers. The main reason for the increased costs for the increased demand is that generating lower loads of electricity does not require the same equipments and preparations as producing higher electricity loads does. However, the other end of the formula (consumers) is not aware of the electricity demand-cost relationship because they are charged a fixed price whether demand increased or not (Fraser, 2005).

In analyzing the electricity demand-costs relationship, the following chart supplied by the AEMO publicly on the internet, will be analyzed.

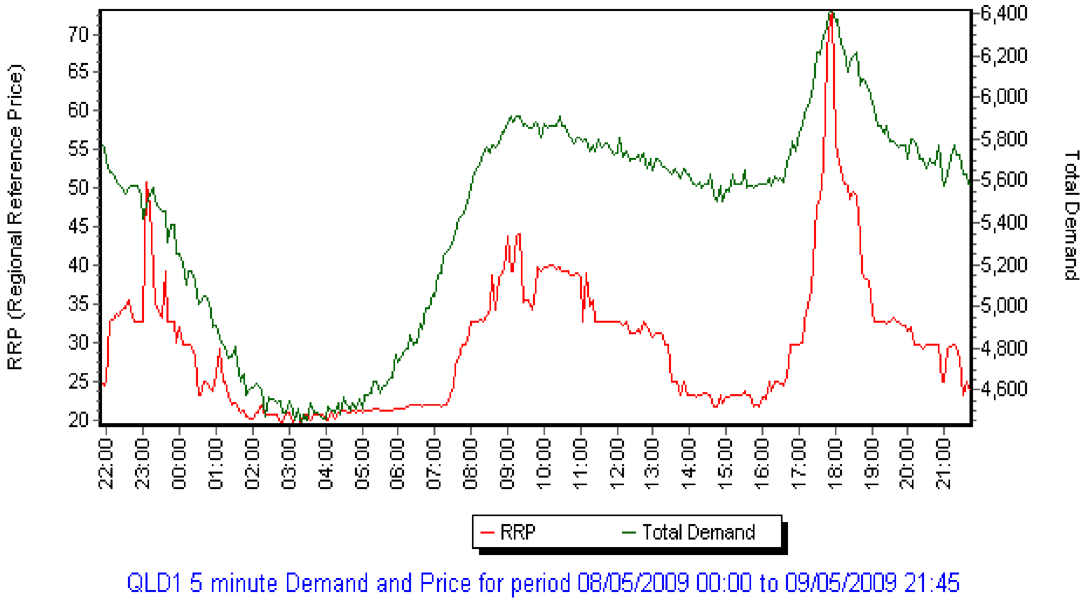

Figure 3.3: Electricity Demand and Cost, Queensland, (AEMO, 2009b)

Figure 3.3 shows the demand and costs of electricity in Queensland recorded by AEMO (was known as NEMCO) during the period (8/5/2009 12 am to 9/5/2009 21:45 pm). The figure illustrates clearly how electricity demands changes. Although the price curve follows the demand curve closely, power generators used to provide base load power which are used twenty-four hours per day are far cheaper than the most expensive plant such as gas turbines which are used only to supply peak load power, usually three to four hours a day. There are two major peak demands at day time from 9 AM to 14 PM and evenings from 17 to 20 PM when prices usually rise. However, residential electricity customers are not affected by varied electricity pricing because they usually pay a fixed price regardless of the time of day (Kamel, 2009b).

Figure 3.4 extracted from data of the AEMO (2009), illustrates the curve of electricity demand supplied in Queensland during 2008. The figure indicates mainly the fact that when the load is above the base load of about 4100 MW, the extent of their duration will be less (Kamel & Kist, 2009). Power stations which generate **Base load** are those operated twenty four hours per day throughout the year providing the most economic operation and the least possible energy price. Other power plants operated for shorter periods i.e. less than 10% a year providing thus higher energy prices will cover higher loads. This implies that the higher the peak demand is, the higher the energy price will be. Although peak demands occur for short periods per year, significant high energy generation cost due to a reduced plant capacity factor (PCF) occur (Kamel, 2009).

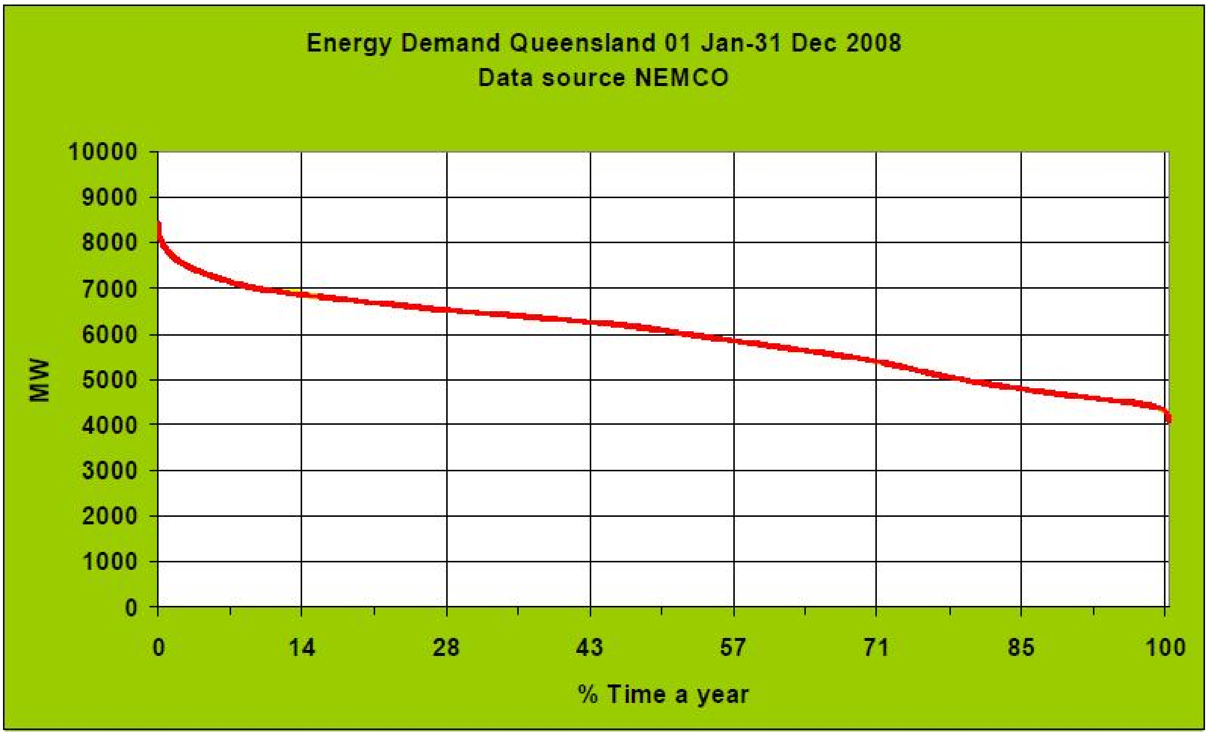

Figure 3.4 Electricity demand in Queensland in 2008, data extracted from the Australian Energy Market Operator AEMO (2009) (Kamel & Kist, 2009).

Figure 3.5 extracted from data of the AEMO (2009), illustrates the regional reference wholesale price RRP in Queensland during the year 2008. The figure illustrates that at more than 80% a year low-priced supplies are taking place, while high prices happen at lower occurrences. For example, prices of around AUD $20/MWh are occurring at about 80 % of the year, while prices of over $50/MWh have occurred at less than 10 % (Kamel & Kist, 2009). The presented scheme in this study focuses on avoiding peak prices.

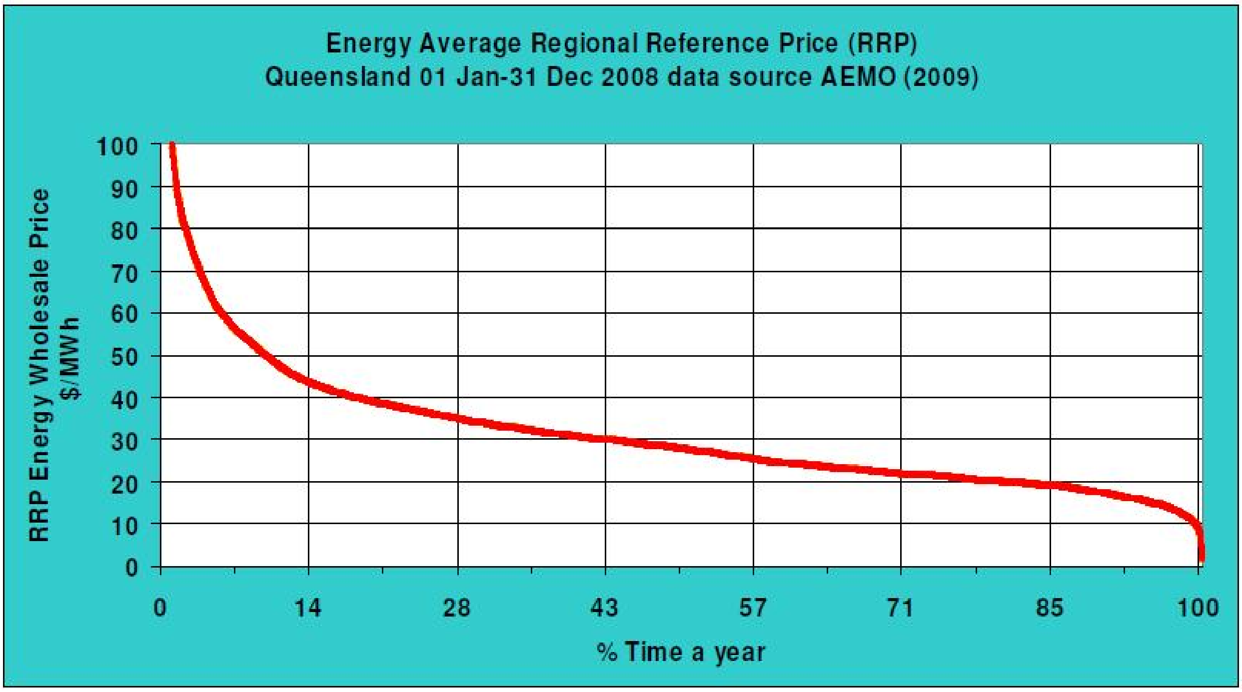

Figure 3.5 Frequency of occurrence of electricity wholesale price RRP in Queensland year 2008, data extracted from the Australian Energy Market Operator AEMO (2009) (Kamel & Kist, 2009).

Table 3.2 illustrates the annual electricity consumption across the NEM since 1999-2000.

	QLD	NSW	VIC	SA	TAS[1]	SNOWY[2]	NATIONAL
2008–09	52.6	79.5	52.0	13.4	10.1		207.9
2007–08	51.5	78.8	52.3	13.3	10.3	1.6	208.0
2006–07	51.4	78.6	51.5	13.4	10.2	1.3	206.4
2005–06	51.3	77.3	50.8	12.9	10.0	0.5	202.8
2004–05	50.3	74.8	49.8	12.9		0.6	189.7
2003–04	48.9	74.0	49.4	13.0		0.7	185.3
2002–03	46.3	71.6	48.2	13.0		0.2	179.3
2001–02	45.2	70.2	46.8	12.5		0.3	175.0
2000–01	43.0	69.4	46.9	13.0		0.3	172.5
1999–2000	41.0	67.6	45.8	12.4		0.2	167.1

1. Tasmania entered the market on 29 May 2005.
2. The Snowy region was abolished on 1 July 2008.
Electricity consumption formerly attributed to Snowy is now reflected in the New South Wales and Victorian data.

Source: AEMO.

Table 3.2 Annual electricity consumption (terawatt hours) in the National Electricity Market (AER, 2009)

Table 3.2 shows thatbNew South Wales, due to its high population base, has the highest electricity consumption then Queensland and Victoria. In the less populated regions of South Australia and Tasmania, demand is considerably lower.

An increase from 170 TWh in 1999-2000 to 208 TWh in 2008-09 occurred in the annual consumption of electricity of the NEM (figure 3.6). The entry of Tasmania in 2005 in the NEM accounted for 10 TWh. Demand levels fluctuate throughout the year, with peaks occurring in summer (for air conditioning) and winter (for heating) due to temperature. Figure 3.7 illustrates the national increase in seasonal peaks from around 26 gigawatts (GW) in 1999 to over 35 GW in 2009 (AER, 2009). Due to variations in weather conditions from year to year, there is volatility in the summer peak's prices.

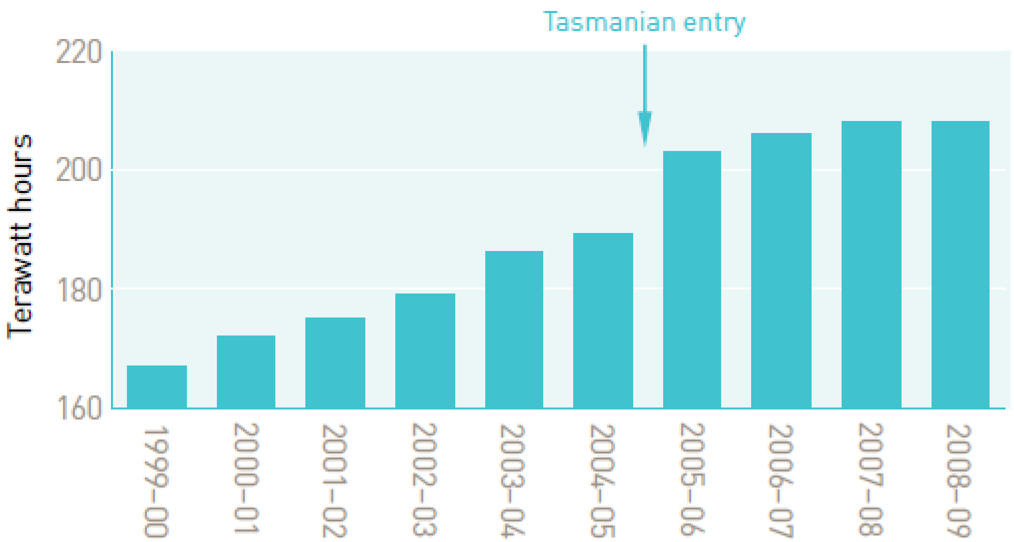

Figure 3.6 National Electricity Market electricity consumption (AER, 2009)

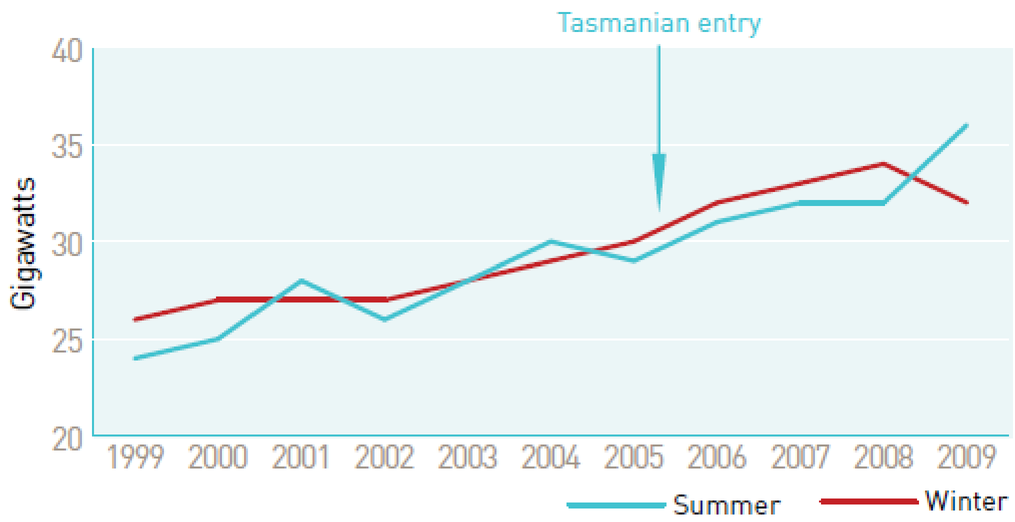

Figure 3.7 National Electricity Market peak demand (AER, 2009)

In order to meet the demand at lowest possible cost, AEMO list the offer bids of all generators in ascending price order for each 5 minute dispatch period. That is, the cheapest generator bids are dispatched first, then progressively more expensive offers are dispatched till meeting the required demand. A 5 minute interval dispatch price is the highest priced megawatt (MW) of generation dispatched to meet demand. For example, figure 3.8 illustrates that to meet the level of the demand for electricity at 4.15 with 350 MW, generators 1, 2 and 3 are fully dispatched and generator 4 is partly dispatched. $37 per MWh is the dispatch price. When the demand reaches 4.20, a higher cost generator is required to be dispatched; therefore, a higher offer price of $38 per MWh is reached. Therefore, increase in demand between the times 4.15 to 4.20 raise prices to $38 per MWh.

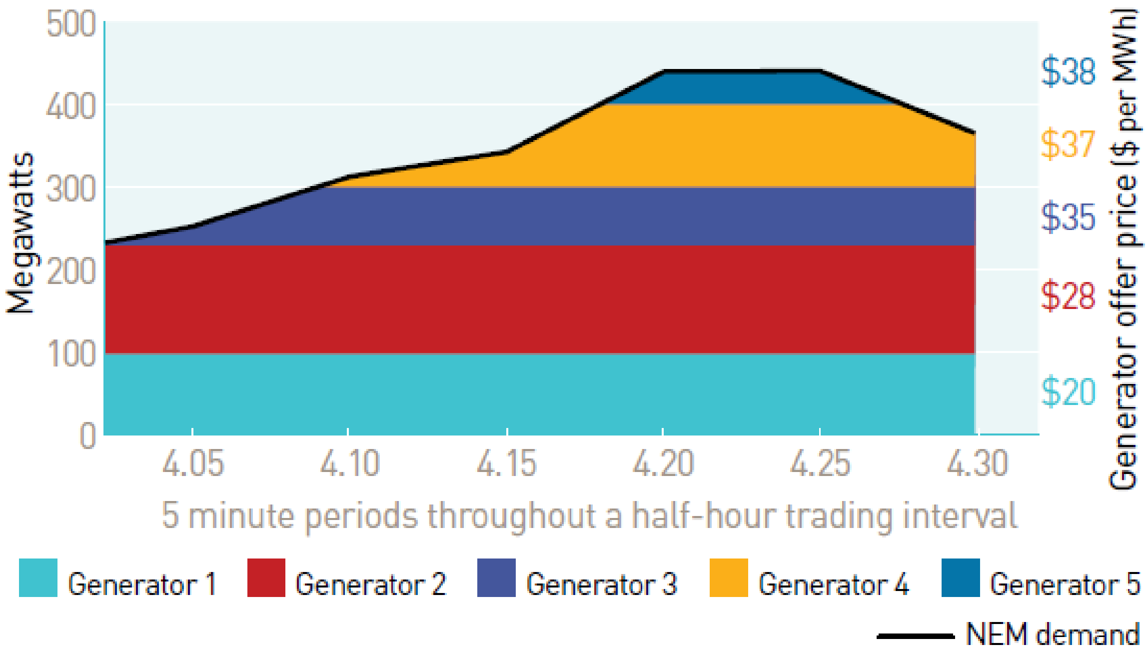

Figure 3.8 Illustrative generator offers (megawatts) at various prices, (AER, 2009)

Average of the 5 minute dispatch prices is the wholesale spot price for each half hour period (trading interval). Figure 3.8 illustrates that $37 per MWh is the spot price in the 4.00-4.30 interval. All generators receive this price for their supply during this 30 minute period, and market customers pay this price for the electricity they use in this period. However, due to the physical losses in the transport of electricity over distances and transmission congestion, a separate spot price is determined for each region.

The Daily Load Curves for South Australia and New South Wales for Tuesday, December 9, 2008, in a normal working day, are shown in Figure 3.9. The scales for New South Wales and South Australia differ; the maximum demand for South Australia is just over 1800 megawatts (MW) at about 4.30 p.m., while for New South Wales the maximum demand is 11,000 MW at about 4 p.m., six times that of South Australia (Evans & Quirk, 2009).

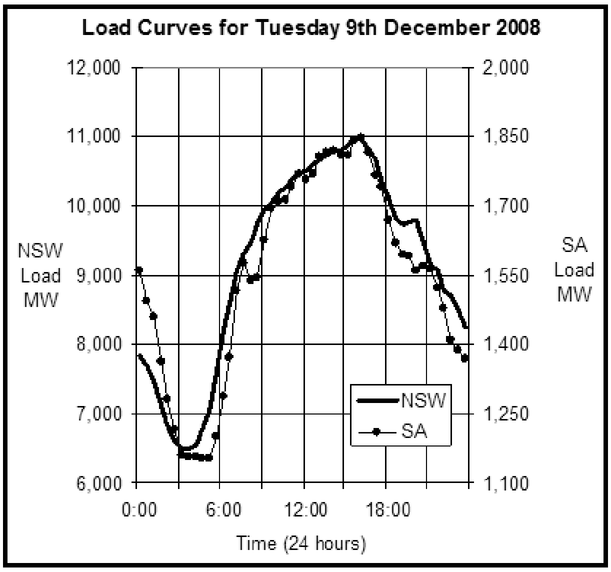

Figure 3.9 Daily Load Curves for South Australia and New South Wales for Tuesday, December 9, 2008, (Evans & Quirk, 2009)

The minimum demand for South Australia was 1150 MW between 3 a.m. and 6 a.m., 64 per cent of the maximum demand. For New South Wales, minimum demand was 6500 MW between 3 a.m. and 4 a.m., 59 per cent of maximum demand.

The regional reference price (whole-sale) curve is shown in Figure 3.10. As it is explained by the Daily Load Curve, the generating station system has to cope with consumers' electricity demand changes. The elevated electricity demand during the day reaching a critical demand peak requires electricity suppliers to run the cheapest generators to provide the base load power during the whole day while the critical increase in demand which takes about three to four hours during the day requires the most expensive generators such as gas turbines. Although the variation in price during the day was between $14 and $42 per MWh, peak hour prices can become much higher than the based load price, often over $100 per MWh Evans & Quirk, 2009).

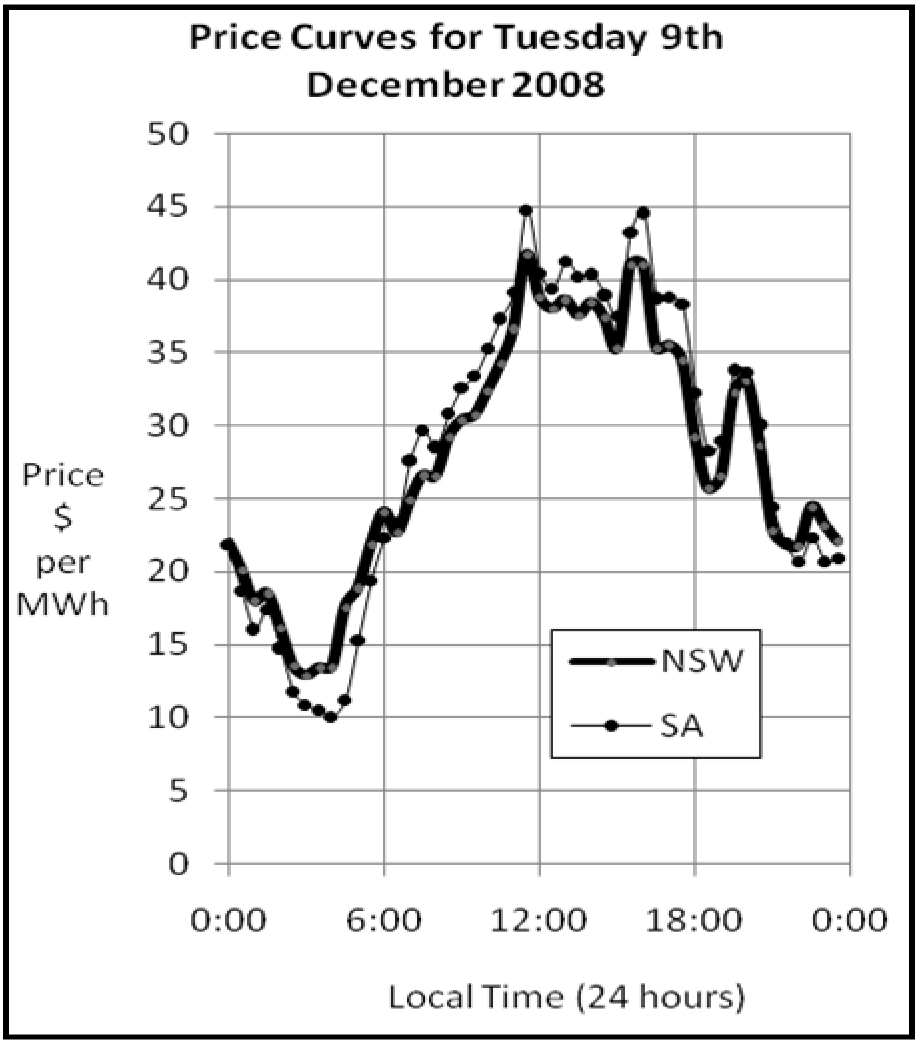

Figure 3.10 Electricity wholesale Price Curves for South Australia and New South Wales for Tuesday, December 9, 2008, (Evans & Quirk, 2009)

The analysis of the above charts illustrates that increased electricity demands is causing increase in energy production costs. Furthermore, the operation of more generating capacity is associated with more environmental impacts.

In order to understand the impacts of electricity demand-costs and their impacts on the markets, the market situation should be analyzed as well. The following section presents analysis of the market situation.

3.3 Critical market situations

There have been critical incidences which occurred in the electricity demand-supply market leading to severe adverse impacts on the stability and quality of electricity supply. For example, increased energy generating cost, increased prices and inability to meet electricity demand are consequences of increased electricity demand. Figure 3.11 shows an example of the daily spot in electricity prices for Queensland market in the period from 13th of December 1998 till the 30th of June 2001(Worthington et al., 2005). The graph shows that there are numerous fluctuation of prices reaching the highest recorded value which exceeds 1000 $/MWh.

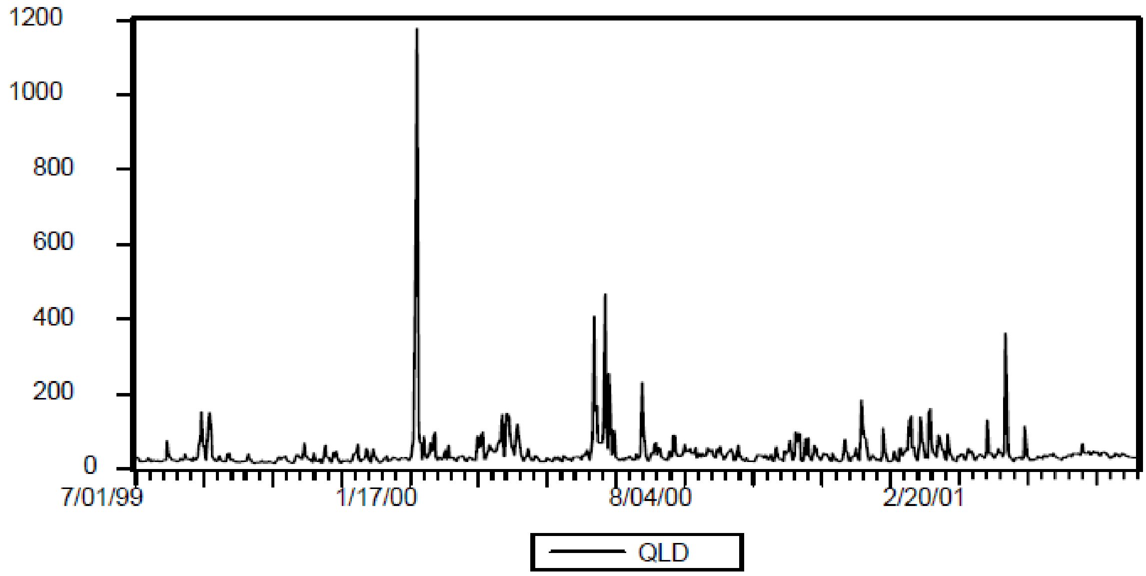

Figure 3.11 Daily spot electricity prices for QLD market, 13/12/1998 – 30/6/2001 (Worthington et al., 2005)

Figure 3.12 also continue to show the daily spot in electricity prices for Queensland market in the period from first of January 1998 till 31 of December 2004.

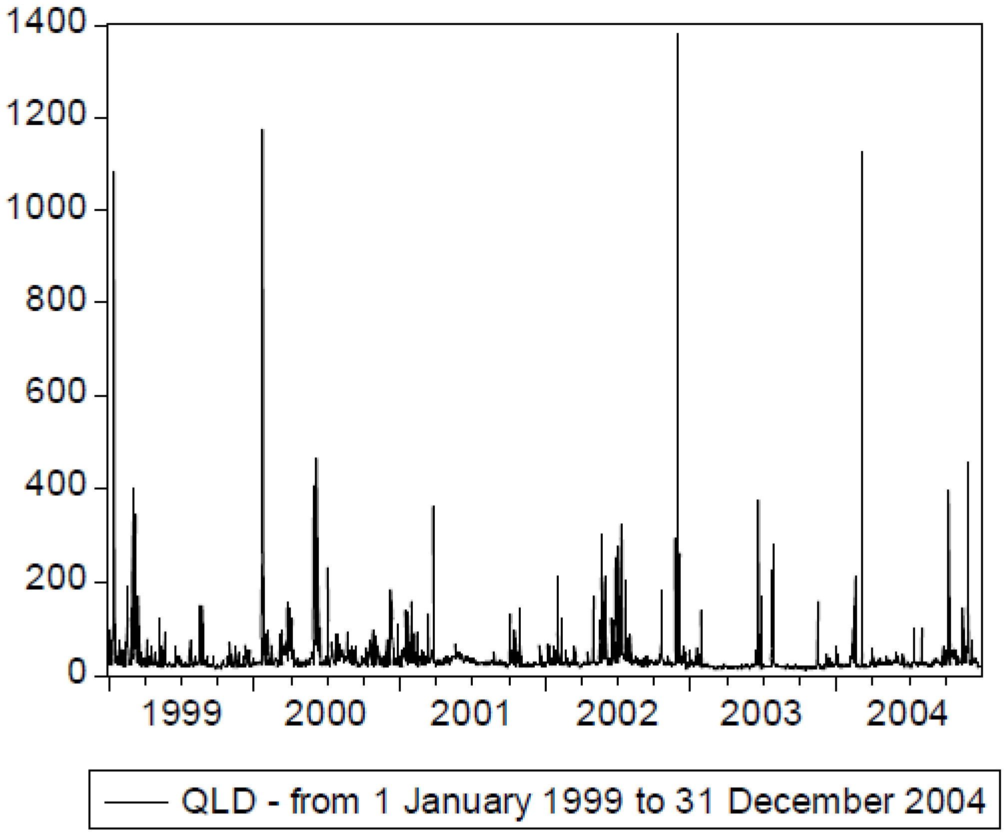

Figure 3.12 Daily spot electricity prices for QLD market ($/MWh), 1/1/1999 – 31/12/2004 (Higgs, 2006)

Figure 3.13 illustrates electricity prices, during the year 2008, exceeding at times $500/MWh while the average acceptable price is in the range of $50/MWh (Kamel & kist, 2009).

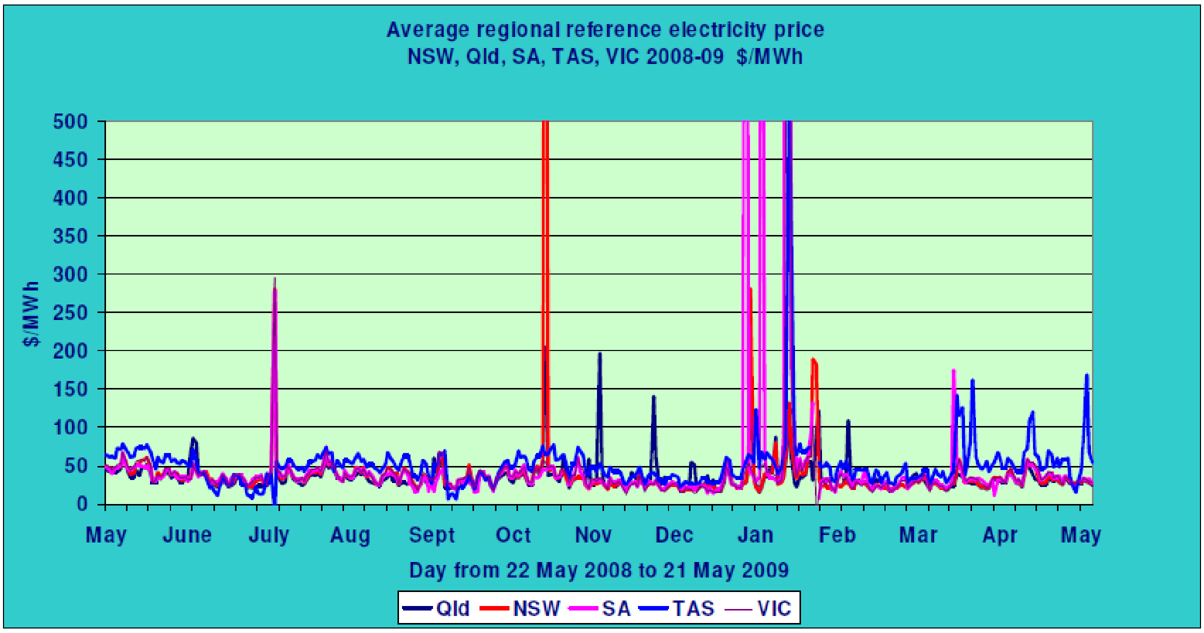

Figure 3.13 Fluctuation of electricity prices in Queensland, data extracted from the Australian Energy Market Operator AEMO (Kamel & kist, 2009)

The weekly average whole-sale prices of electricity in Queensland in the period (1998 to July 2007) are shown in figure 3.14 (DME, 2007b).

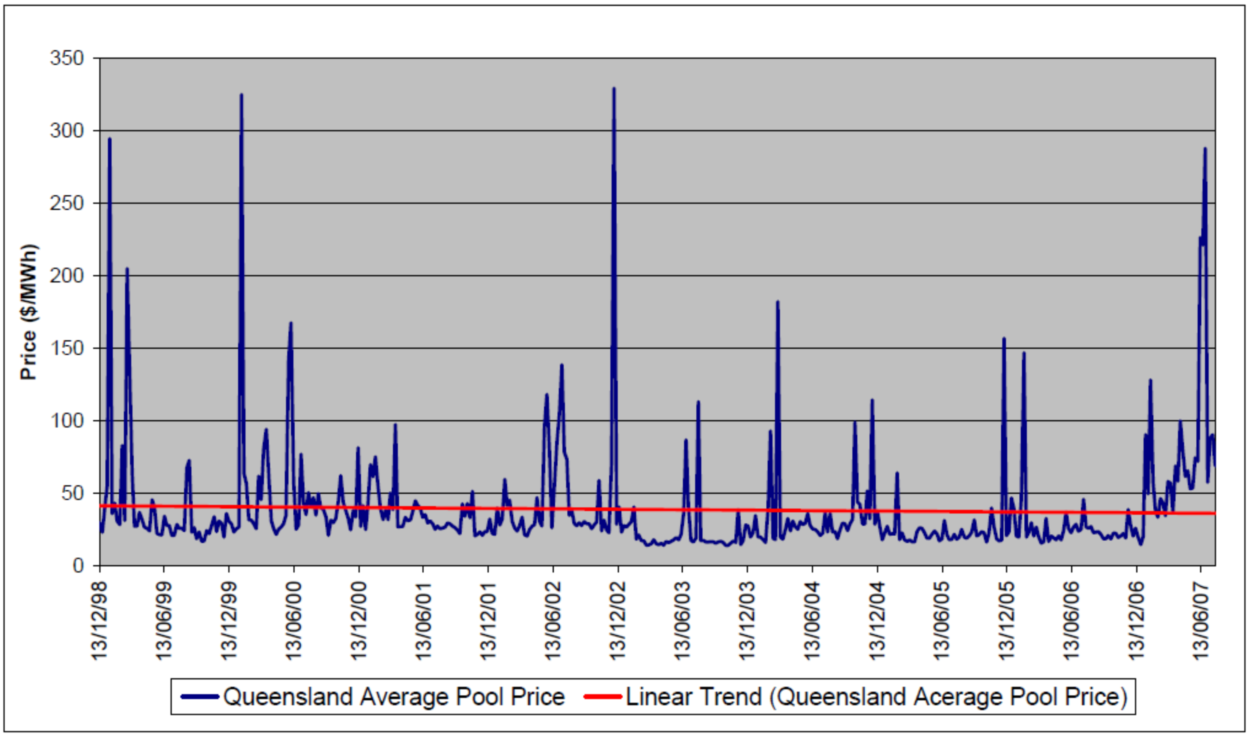

Figure 3.14 Queensland Average Weekly Pool Prices (1998-2007) (DME, 2007b)

The volatility of wholesale electricity prices are experienced in the same way in both Queensland and across eastern Australia. This could be further explained in figure 3.15 which indicates the weekly average whole-sale prices in Queensland in 2007 (to July) and the long run average price. Prices in 2007 tended to be higher than the long-run average price (DME, 2007b).

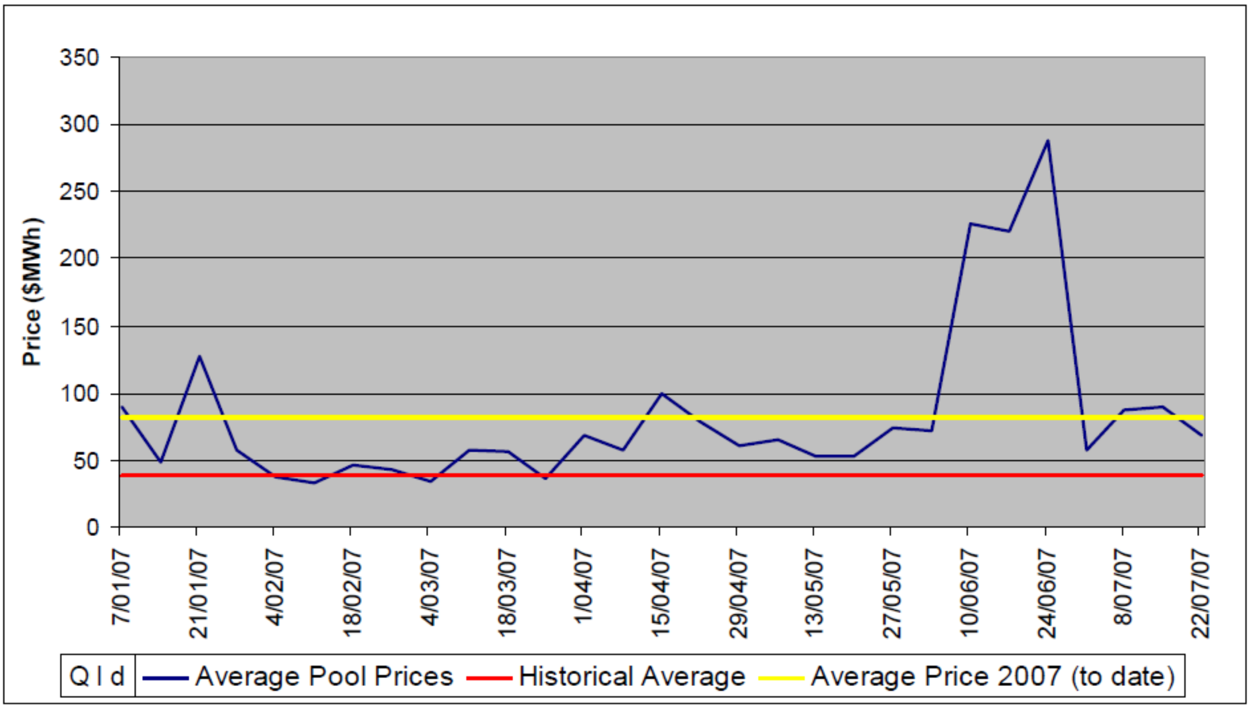

Figure 3.15 Queensland Average Weekly Pool Prices (January to July, 2007) (DME, 2007b)

The increase in average whole-sale prices is mainly caused by the impact of the prolonged drought on generation capacity across the National Electricity Market. Droughts which occurred in areas such as the Snowy region of New South Wales and Victoria, and in south-east Queensland made some of the largest generators in the market to be operating at reduced capacity levels in the first half of 2007 (DME, 2007b). Because of the increased level of water in south-east Queensland due to the rainfall in January and February, water is no longer a critical issue for electricity supply. Therefore, the pool price for 2008 (to date) is less than that experienced in 2007 (figure 3.16).

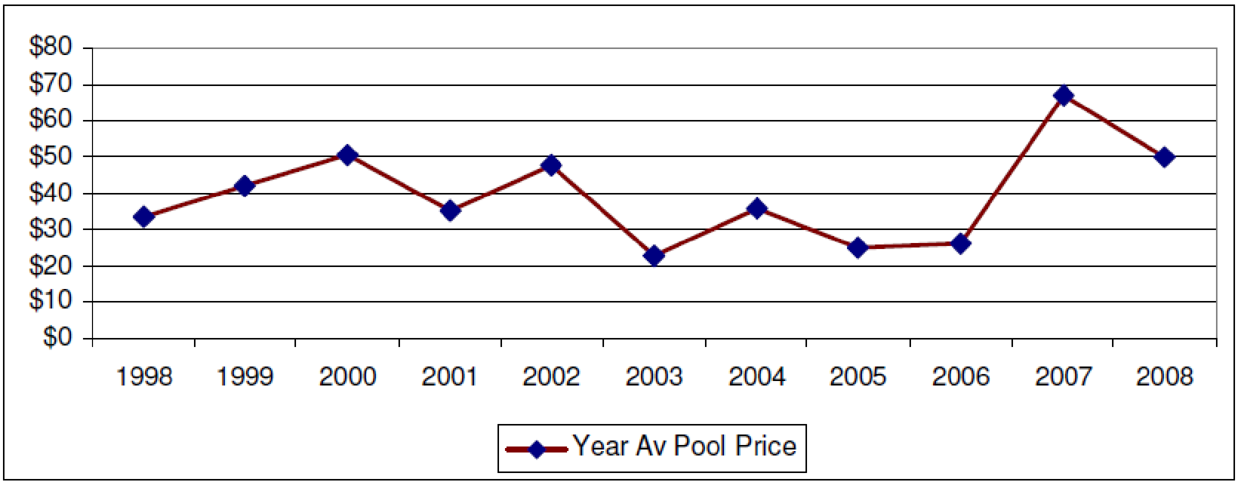

Figure 3.16 Queensland Yearly Average Pool Price 1998-2008

In the following figure 3.17, a recent incident of high energy cost was experienced by Queensland region on 7 February 2008 due to an error in scheduling while managing a double circuit line reclassification which also caused an inappropriate constraint equation.

The following figure 3.17 shows the dispatch interval and trading interval energy prices.

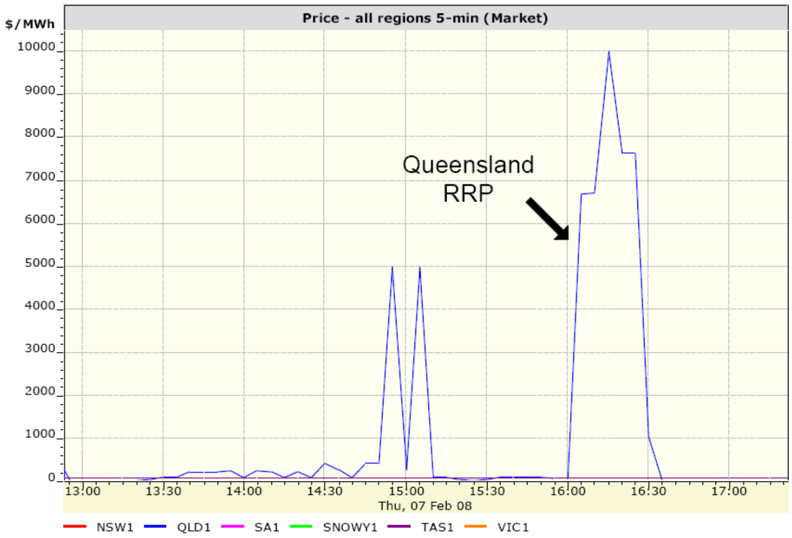

Figure 3.17 Energy Dispatch Prices in the NEM ($/MWh) (NEMMCO 2008b)

More details also shown in table 3.3 below;

Trading Interval		Trading Price ($/MWh)
Date	**Time**	
7/02/2008	14:30	232.84
7/02/2008	15:00	1094.11
7/02/2008	15:30	896.88
7/02/2008	16:00	98.39
7/02/2008	16:30	6622.24
7/02/2008	17:00	32.76

Table 3.3 Trading Interval Energy Prices (NEMMCO 2008b)

From the graph and the above table, it can be clearly noticed that the maximum significant energy prices is $6622.24/MWh for the trading interval ending 16:30hrs and the average price for the day was $215.98/MWh.

The conditions which resulted in the significant increase in Queensland energy prices can be summarized according to NEMMCO (2008b) as following:

- Tight supply/demand situation in Queensland;
- Shift of Queensland generation capacity to the higher priced bands; and

- Invocation of a shoulder season constraint equation to manage a line reclassification which bound and constrained off most Queensland generators.

3.4 Peak Demand Impacts

Electricity peak demand has serious negative impacts on both electricity aspects and other consumers' life. Those negative impacts lead to other deficiencies in electricity generation, transmission and distribution. The negative impacts of the sudden severe variable change in electricity demand include inconsistency in the electric power system and instability of the grid. The main three areas which are affected by electricity peak demand include technical impacts, environmental impacts and economical impacts. One of the main goals of the project is to adequately manage electricity peak demands to reduce the negative impacts including the uncertainties of the system, increase grid reliability, reduce energy cost, and optimize energy consumption.

3.4.1 Technical impacts

Reliability

Electricity reliability involves the capacity of the electricity generation to supply the required total electricity demand to consumers at any given time (adequacy) and to withstand sudden disturbances (security). That is, reliability is the ability to avoid power outrages. In order to maintain reliability of electricity system, adequate electricity generation, transmission infrastructure and effective management of the power system are essential (Berrie & IEE, 1992).

The main reasons that maximize the performance of the electricity infrastructure at the three stages of electricity delivery include a reasonable and moderate demand of electricity. That is, while the increased electricity demand leads to deficiencies in power generators at the long term period, it affects the capacity and efficiency of the electricity supply making the reliability of electricity delivery weaker and slower.

Efficiency

Efficiency of power generating stations at all levels of generators, connecting system, transmission, distribution, protection and maintenance is highly impacted by the increased electricity demand. Increased electricity demand oblige power generating station to run the generators on overloaded mode which in turn increases its maintenance, reduces efficiency and decrease life expectancy range of equipments. However, it becomes worse when the increased electricity demand occurs during the increasing summer heat which has more negative impacts on the entire electricity system (Berrie & IEE, 1992).

3.4.2 Economical and Social impacts

While the least expensive power plants (such as coal at the moment) are used to cover the continuous (8760 h/year) base load (Gilau & Small, 2008), the most expensive-to-run power plants will be used to cover peak demand. Although electricity consumers do not have direct correlation with the use of most expensive-to-run power plants, generators add the increased generation costs to the whole sale prices of electricity, which increase consumers bills. Because of the electricity peak demand, electricity consumers pay a significant (and largely unseen) price for the suppliers' costs for building sufficient electricity generation and networks to meet the short peaks in physical electricity demand, which can occur for only a relatively small number of hours each day (Fraser, 2005). While the electricity consumers are insulated from price volatility by 'flat' electricity prices, they are also paying a significant and undisclosed (hard to evaluate) premium in their retail electricity prices to cover the retail supplier's costs of managing the risks of the extreme price volatility (Fraser, 2005).

The negative impacts of the electricity peak demand extend to affect the entire infrastructure of the electricity system including transmission and distribution and delivery. For example, more than 5% of the network infrastructure is only used for 0.2% of the time and this under-utilised capital investment in the network is paid for by all consumers, whether they ever use it or not, due to the nature of retail energy contracts and network charges (Fraser, 2005; Kamel, 2009).

3.4.3 Environmental impacts

Many detrimental environmental impacts are experienced because of the fossil fuel fired power stations. There are many greenhouses gas emissions taking place because of using fossil fuel for generating electricity. The main cause of such emissions are caused e.g. by coal whether in the stage of mining, transportation or burning involves its poor efficiency which causes the waste of energy and the need to dispose of the wastes (Healey, 2009). That is, for every unit of energy produced as electricity, about two units of energy are produced as heat and must be dispersed in some way. So, huge amounts of waste heat are emitted either into the atmosphere or into water; however, in the case of Callide B, evaporative cooling towers are used with the water vapour heating the atmosphere (IPPC, 2001). According to (Keating, 2001), one of the dirtiest fuels in the world which is used to operate power stations is coal.

With the increasing demand for electricity in Australia, electricity industry was required to increase electricity supply to meet the increasing needs. Different and numerous toxic pollutants are released by coal into air, waters and lands in all stages from mining to coal cleaning, from transportation to electricity generation to disposal (FSCETF, 1994; Lyster & Bradbrook, 2006). Callide B power station in Queensland, for example, which is operated by coal, burns about 2.2 million tons of coal a year. The negative impacts of coal use in power station include health problems such as cancer, impairing reproduction and the normal development of children, and damaging the nervous and immune systems and damaging the environmental ecosystem (Fanchi et al., 2005).

3.5 Related researches and applications

The majority of the previous studies investigated how to reduce peak demands focused on reducing the consumers load without considering the actual state load profile. That is, this was normally achieved either by attempting to encourage the end users to achieve general energy conservation or through the implementation of different tariffs.

There were also great efforts in producing electrical equipment with high energy saving techniques in the manufacturing sectors. For instance, high energy saving lamps, air-conditioning temperature thermostats, timer controlled-machines and etc have been introduced and used in the manufacturing sectors. However, that is not all, other studies moved towards building management system (BMS) in which the whole energy consumption is automatically observed and controlled (APC, 2005).

In the industrial sector, some agreements have been established between the utilities and users which benefits both parties. For instance, when the factory is working on limiting its load to certain kilowatt per hours a day for agreed rewards or bill reduction from the utility, both parties will benefit. In order to accomplish such conditions and agreements, the development of smart switches and smart meters are required (Adilov et al., 2004). The main functions of smart meters include automatic adjustment for high energy consuming machines, during periods of peak demand and higher electricity prices, allow consumers to pre-pay for electricity and giving another dimension of control for consumers (Rassenti et al., 2008).

In the residential sector, reducing and controlling electricity demand is achieved through implementing real time pricing strategies. Smart meters provide consumers with options of lower prices during off-peak periods and higher prices during peak periods making electricity prices impacting purchase decisions (Frew, 2006a). With real-time pricing and time-of-use tariffs where the electricity prices vary with time, the users tend to reduce their usage at times when electricity prices are relatively high (Adilov et al., 2004). Communication between utilities and consumers would enable consumers to be alerted of the different demand prices. Consumers will receive from suppliers an alert on any day the real-time price that day reaches or exceeds. Consumers are given the option to run their appliances such as air conditioners, laundry machines and dishwashers in those low-priced hours like evenings, nights and weekends which would save them money on their electricity bills. Therefore, when consumers use electricity when the demand and prices are low, they will save on their electricity bills with real time pricing (Wilson, 2006).

One of the previous studies which have a similar objective to reduce the overall demand of an entire state aiming to achieve cheaper electricity was conducted in the USA (Huber, 2008). The main premises of the study is based on that the price of electricity sold in wholesale markets tracks the rising and falling demand in the area in consideration. According to (Huber, 2008; figure 3.18), in the USA, demand moves from east to west with the sun because it tracks human activity and afternoon peaks in air-conditioning loads because weather and seasons raise and lower the temperature. Somewhere in America, some community is always paying significantly more for power -20 to 50 percent- more than the market is selling it for elsewhere. The project uses time zone as a platform for all the factors that determine where costs are high and where they're low. In order to achieve almost a fixed daily supply without the fluctuations and shifts in daily demand and supply, the whole suppliers in the USA got to be solidly connected by one network.

Figure 3.18 peak and off-peak wholesale spot prices in different time zones of USA (2007), (Huber, 2008)

Queensland Solar City project in magnetic island, for example, is one of the significant projects which integrates energy conservation and demand management and offer customers a choice of power sources and tariffs options. Queensland government designated 5 million dollars to support the delivery of the Ergon Energy ltd (Foulger, 2008). Involved in the project is the installation of about 500 solar photovoltaic (PV) systems, 2500 smart meters and around 1700 energy audits. It is predicted to conserve energy and minimize greenhouse gas emissions by approximately 50,000 tonnes CO2 annually by 2013 (OCE, 2009).

Constructing the solar energy project in magnetic island will transform the island into a Solar Suburb demonstrating an integrated approach to conserving energy to achieve a localized reduction in electricity demand. The other significant objectives of the project is increasing the awareness of Queenslanders to work together, embrace solar energy and become more energy efficient to achieve positive energy and environmental outcomes for their community (OCE, 2009). Moreover, the findings of the program and other pilots will inform future wider-scale initiatives in Queensland and across Australia.

Another project called solar schools project will achieve reduction in the electricity demand, particularly electricity generated using coal by installing solar panels and energy efficient light bulbs at 1251 Queensland state schools more over three years (OCE, 2009). A part of a sixty million USD package has been designated for installing circuit-timers to turn off night non-essential power and installation of ‘smart meters’ that control energy use. Therefore, every year, each school system will minimize greenhouse gas emissions such as CO2 by more than 3.2 tones, which is the equivalent of 64 000 black balloons each of which weigh 50 grams of greenhouse gas (Foulger, 2008). Besides expanding the solar system industry and usage, this project will increase the awareness of young people about energy conservation and their role in tackling the combat against climate change.

Chapter 4 ELECTRICTY MARKET IN QUEENSLAND

The scheme devised by the project is intrinsically interrelated with the numerous variables of electricity market including electricity pricing, supply, demand, investment and consumption. Therefore, analysis and investigating the electricity market variables are crucial element for the implementation of this project. Given that the project is designed to be implemented in Queensland, variables of Queensland electricity market are analyzed. The market variables are also interrelated with the different electricity marketing stages starting from electricity generation at the power station to the end user's consumption and demand. For example, setting electricity pricing takes into consideration four types of costs incurred at the stage of generating electricity, establishing and maintaining the state's extensive high voltage power line infrastructure, building and maintaining the state's network of poles and lines that deliver electricity to customers, billing customers and managing accounts (Docwra et al., 1991; DME, 2007b). In other words, those costs could be categorized into four types; generation, transmission, distribution and retailing costs.

Therefore, in the following sections, analysis of the Queensland electricity market in terms of electricity generation, transmission, distribution and management and their relation to demand and consumption which are highly beneficial for implementing the project scheme will be discussed.

4.1 Stages of electricity delivery in QLD

Electricity generation, transmission and distribution are the three main stages performed to deliver electricity to all types of customers. Generation is performed at a power station then passed through a transformer to increase the voltage, which minimizes losses during transportation. Transportation is carried out through a transmission networks. Then the voltage is reduced in several steps as it passes through a series of transformers until it reaches 240 volts for household use. The medium and lower voltage networks are called distribution networks. At every stage, different amount of costs which are affected by demand and consumption are incurred and considered in setting electricity market pricing. For example, Queensland investment in generation, transmission has increased with its rapid economic and population growth which leads to increased consumption of electricity (DEEDI, 2009; DME, 2009c).

In Queensland, the companies owning and operating the different stages of electricity delivery are illustrated in figure 4.1. For example, companies such as CS Energy, Stanwell Corporation and Tarong Energy own and operate the power stations. Powerlink is the only transmission company, which owns and operates high-voltage power lines from power stations to distribution companies and other large electricity users. Distribution companies include Ergon Energy and ENERGEX. Retail companies which are responsible for purchase of the electricity from generators, receiving electricity from distributors and selling it to consumers include Sun Retail and Ergon Energy Retail (Phunnarungsi & Dixon, 2003). In the following part, analysis of the three stages carried out to deliver electricity in QLD will be provided.

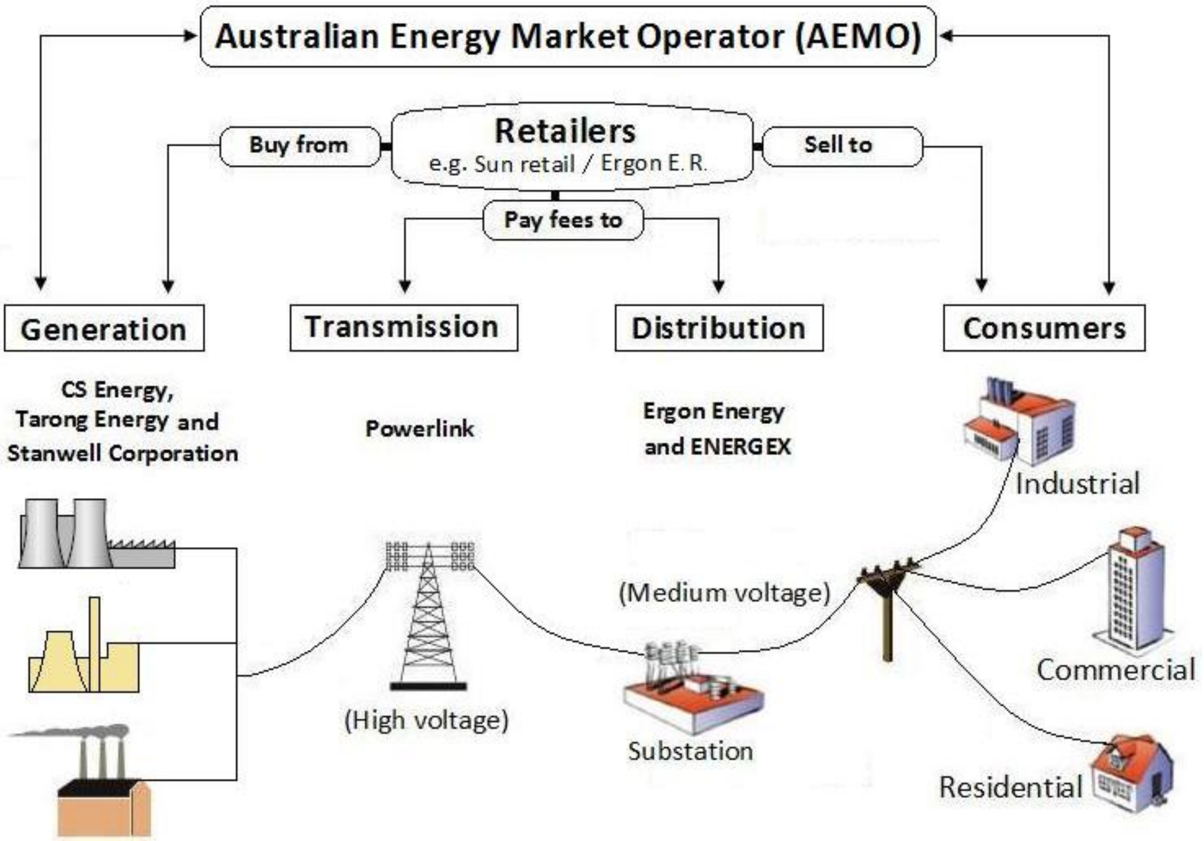

Figure 4.1 Electricity delivery chain in QLD.

4.1.1 Generation

Coal-fired power stations which are located in central and northern parts of Queensland and are owned by Government Owned Corporations (GOC) are the main power stations used for electricity generation in the state (DME, 2009c).

While the number of gas-fired power stations is increasing, Queensland is being developing also renewable energy, such as hydro, wind and biomass which are currently being used to generate electricity in the state. The electricity generation capacity of Queensland is more than 10,000 megawatts (MW) (DME, 2009c; QG, 2008). This investment in Queensland is because of the high quality and low cost of Queensland fuel sources, and their proximity to load growth.

While most of power stations in Queensland are owned and operated by Government Owned Corporations (GOC), private corporations operate and own a few numbers of power stations. Some details about these generators are as follow:

CS Energy

One of the Queensland Government-owned electricity generators is CS Energy which is operated using a diverse mix of fuels to operate more than **3,000 megawatts** of electricity generating plant to supply the national electricity market (ESQ, 2009; DME, 2008). There are a large number of power stations which are operated by the CS Energy such as:

- Swanbank Power Station (south east Queensland)
- Callide Power Station (central Queensland)
- Mica Creek Power Station (north west Queensland)
- Kogan Creek Power Station (south west Queensland)

Stanwell Corporation

Queensland Government owns and operates Stanwell electricity generator which generates more than **1,500 megawatts** of electricity from thermal and hydro fired facilities located throughout Queensland. Stanwell Power Station is the largest Stanwell's operating sites which generates around of 1,400 megawatts (ESQ, 2009; DME, 2008). However, there are other sites by Stanwell such as:

- Stanwell Power Station (22 kilometres west of Rockhampton)
- Barron Gorge Hydro, Kareeya Hydro and Koombooloomba Hydro - (far north Queensland)
- Wivenhoe Hydro (south east Queensland)
- Mackay Gas Turbine

Tarong Energy Corporation

There are a number of generating assets operated and owned by Tarong Energy Corporation. For example, Tarong Power Station generates capacity of **1400 megawatts** which is considered one of Queensland's largest power stations. Next to Tarong station is a single 445 megawatt advanced cycle coal-fired unit (ESQ, 2009). Wivenhoe Power Station generates 500 megawatt and is considered Tarong Energy's pumped storage hydroelectric plant. Moreover, Tarong energy owns the Meandu Mine and Kunioon coal resource which will fuel the power stations into the future (DME, 2008).

NRG Gladstone Operating Services (NRGGOS)

One of the largest power stations in Queensland is Gladstone Power Station which contributes **1,680 megawatts** capacity to the State grid. The power station is located five kilometres north-west of Gladstone, and sells around 60% of the station's output to Boyne Smelters under a long term contract. NRG Gladstone Operating Services has been operating the station since 1994 on behalf of Joint Venture participants Rio Tinto Ltd (42.125%), NRG Energy Inc (37.5%), SLMA GPS Pty Ltd (8.50%), Ryowa II GPS Pty Ltd (7.125%) and YKK GPS (Queensland) Pty Ltd (4.75%) (ESQ, 2009; DME, 2008).

Fueling Queensland's electricity supply

Despite developing Queensland state's energy mix towards a greater use of renewables and gas, approximately 88 percent of Queensland's electricity generation is still carried out by Queensland's high-quality, low-priced black coal. For example, renewable sources fired stations in Queensland include **12 megawatt** (MW) Windy Hill (wind) project and the hydro-electric facilities Barron Goroge (**60 MW**) and Kareeya (**84 MW**) (DME, 2009c). Both gas fired generation and electricity generated from renewable sources accounted for approximately 12 per cent of Queensland's electricity generation. Moreover, QLD has had the greatest level of investment in committed generation of about 3,500 megawatts of generation capacity, since the creation of the National Electricity Market in 1998 (ESQ, 2009; DME, 2008c).

In Queensland the Gas-fired power generation capacity is over 2000 megawatts. Increased private investment for gas-fired generation electricity retailers and other large electricity users in Queensland must source at least 13 percent of their electricity from gas-fired generation (DME, 2009c).

4.1.2 Transmission

Transmission of electricity in Queensland is mainly managed by a Government Owned Corporation called Powerlink Queensland. The main roles of Powerlink include managing more than 12,000 kilometres of Queensland's high voltage transmission network, transporting electricity from the generators to the distribution networks and directly to large customers such as aluminium smelters. Most of the power stations in the east coast network are directly connected to the Queensland transmission system (DME 2009b).

Queensland Electricity Transmission Corporation Limited was established in 1995 through a process of functional separation and corporatization of the electricity industry in Queensland. The main responsibilities of the company include the delivery of a secure and reliable transmission service to electricity market participants, providing services to the Australian Energy Market Operator (AEMO) and providing metering at generation and customer/distribution connection points. Other responsibilities of Powerlink include jurisdictionally coordinating the sensitive loads and planning the transmission network in

Queensland according to Queensland government. Moreover, around 98 substations and 8,400km of transmission lines of Queensland's high-voltage electricity transmission network are owned and operated by Powerlink (MONSTER, 2009).

4.1.3 Distribution

In order to supply customers with electricity, an electricity distribution system is used connecting the high voltage transmission system to individual premises. The main two distribution system retailers include ENERGEX and Ergon Energy which carry out the main distribution functions for around 1.8 million industrial, commercial and domestic consumers of electricity. ENERGEX and Ergon Energy must meet certain standards which will ensure that they put the people who matter and their customers, first and are more accountable to the public in terms of service performance. ENERGEX has 50,000 kilometers of powerlines and half a million power poles. Ergon Energy's network consists of more than 150,000 kilometres of powerlines and one million power poles and covers an area six times the size of Victoria (DME 2009b).

Ergon Energy

Ergon Energy Queensland Pty Ltd is the branch retailer of Ergon Energy which sells electricity to household customers in regional Queensland. Supplying electricity to regional and remote parts of Queensland would incur much higher costs than the regulated prices that Ergon Energy is allowed to charge its customers. Thus, the electricity provided for regional customers are subsidized by the Queensland Government pooling into community service obligation payments, to Ergon Energy to meet the difference between the cost of supply and the prices Ergon Energy can charge. For example, the Queensland government paid Ergon Energy around $636 million in 2006/07 payments (DME, 2007). Because Ergon Energy is the only retailer operating in Queensland that is owned and subsidized by the Queensland Government, it is not allowed to compete with other retailers. Moreover, it is not permitted for Ergon Energy to provide for any Queensland customers negotiated retail contracts and is obliged to supply its customers on standard retail contracts.

Because of the subsidy provided by the government, Ergon Energy customers who switch to another retailer will not be able to return to Ergon Energy as a customer at that premises in the future. This goes back to that a retailer offering a negotiated retail contract to a customer indicates that the customer at that premises is a commercially attractive customer and in turn no longer requires the benefit of the subsidy paid to Ergon Energy (DME, 2007a).

Customers returning to Ergon energy could only be provided services on exactly the same terms and conditions, including price, that Ergon Energy unsubsidized customers receive. Moreover, all small customers are entitled to return to Ergon energy and pay the regulated prices set annually by the Queensland Government on a standard retail contract which is set by the Queensland Government and forms part of the *Electricity Industry Code* when their negotiated contract ends. Except the name of company sending the bill, the standard retail contract with Ergon Energy have the same terms, conditions, rights and protections as any other retailer (DME, 2007a).

ENERGEX

One of the largest electricity companies in Australia owned by the government is ENERGEX Limited. Energex delivers electricity to approximately about 25,000 km2 in area of South East Queensland in which demand has increased because of increase of its population (ENERGEX, 2009). Therefore, ENERGEX increasingly improves and builds on the electricity network in order to meet the increased demand of the community. In South East

Queensland, Energex has now over 50,000 km of underground and overhead electricity lines and cables serving over 1.3 million homes and businesses (DME, 2009b).

However, electricity customers cannot choose an alternate supplier, given that Energex and Ergon are the only distributors of electricity. The prices for these services are ensured to be fair and reasonable by the Queensland Competition Authority and the quality of service provided is monitored.

4.2 Electricity selling contracts

Electricity partial retailing system was first introduced in Queensland in 1998 (DME 2009b). In the partial retailing system, large electricity users have been given a small opportunity to choose their electricity retailer for some time on negotiated contracts with their retailer of choice. However, in 2007, all household electricity consumers and business electricity consumers have been fully enabled to choose their electricity retailer with the provision of the Full Retail Competition (Defeuilley, 2009). Depending on types of customers, the type and terms of electricity selling contracts are determined. Two main types of customers include contestable customers who can negotiate their contract and electricity supply contract with the retailers or suppliers and non-contestable customers who will not be able to negotiate their electricity supply contract. For every category of electricity consumers, different types of negotiations, dealing and contracting were established (DME 2009e).

Standard Customer Contracts

For the contracting purpose of electricity supply, standard connection contract (SCC) has been established under the *Electricity Act 1994* which states that distribution entities are responsible for the connection and supply and transmission of electricity to customers' premises. Only those few large business entities have negotiated connection contracts with their distribution entity. However, small non-market customers are taken to have entered into a standard retail contract (SRC) with their existing retailer when receiving a supply of electricity (DME 2009e). However, there are still some large customers who do not have a current negotiated retail contract; therefore, they are on a standard large customer retail contract which is already designed by cooperation between retailers and government. However, the standard contracts are not the copy signed by the parties; their function is only to establish the terms and conditions which apply to the provision of customer connection services by the distribution entities and customer retail services by retail entities (DME 2009e).

Large customers being supplied under a Standard Large Customer Retail Contract may have experienced significant increases in their electricity accounts in 2007 due to increased volatility of the whole sale prices (DME, 2007b). This may be the case even if the customer's negotiated contract ended some time ago and they have been facing the pass-through of pool prices for some time. Although large customers can escape the high wholesale prices by entering into a new negotiated contract with a retailer of their choice, they will be still affected by the impact of the drought on electricity prices. That is, retailers are unlikely to offer the same, lower prices that may have been available to large customers entering into negotiated retail contracts in the past.

Chapter 5 METHODOLOGY

5.1 Project concept

Although wholesale electricity prices vary along the day, retail customers are not usually affected by the price variations. Rates paid by most consumers are calculated based on the average cost of electricity over a certain period of a week or more (Gabaldon et al., 2008). With no clear indication of real prices or peak demand, customers will **not be** encouraged to decrease their electricity consumption during peak periods.

The purpose of this project is to provide customers with the appropriate automated switching technology and price or peak demand signals in order to benefit all those involved in electricity market by responding to those signals. The customers would select to switch off some loads in response to those signals when the demand exceeds the threshold value. Therefore, it would be beneficial to demonstrate the main mechanism of Demand Side Response practice which is aligned to the operation of project scheme. The following part will provide explanation of the mechanism of DSR.

5.2 Demand Side Response

Demand side response (DSR) refers to the changes by customers in their electric consumption patterns to reduce or shift electric load over time. These changes are made in response to load reduction signals sent by utility during the peak demand or when the wholesale price becomes higher.

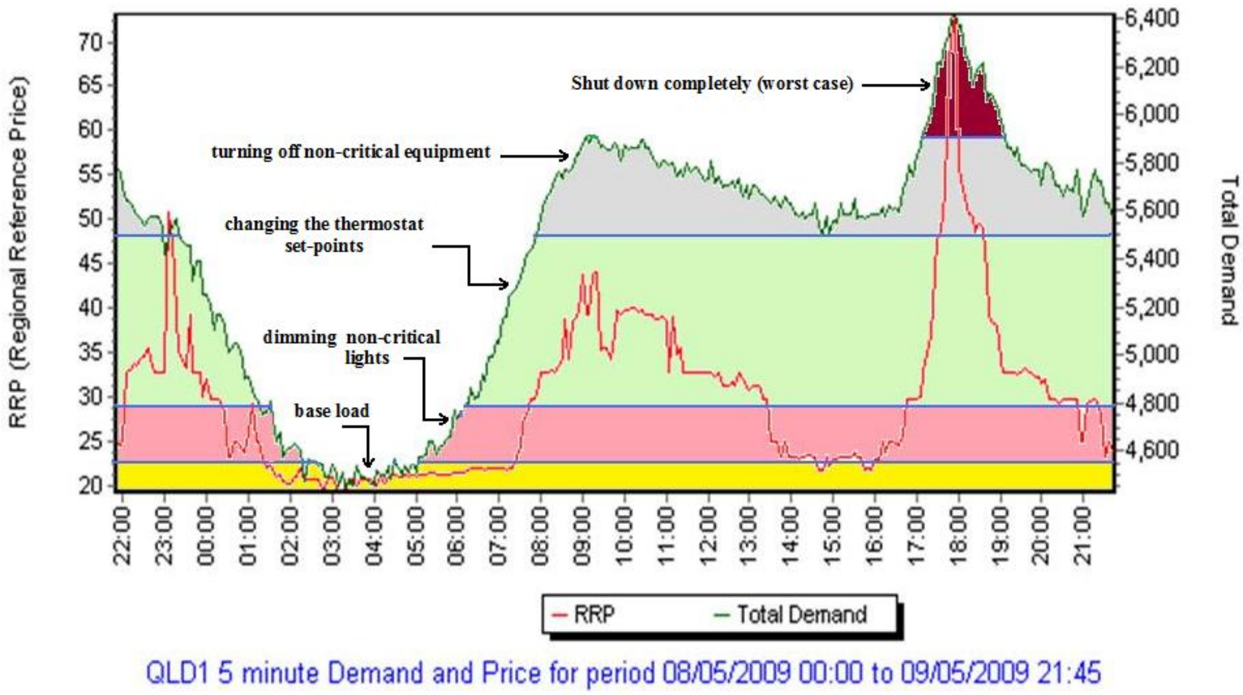

Figure 5.1 **Areas of possible demand response**

Figure 5.1 indicates the areas where the user can manage and control their loads by taking the right actions such as dimming or turning off unessential lights, changing the thermostat set-points of air-conditioning or turning off unnecessary equipments. Customer's contribution can be classified into:

1. Shifting the loads from peak hours to non-peak hours.
2. Switch off unessential services in which the load is curtailed.
3. Shut down completely (worst case).

While the classical principle obliges suppliers to supply all the required electricity demand whenever occurs, the current principle, induced from the above graph, states that the system will be most efficient if fluctuations in demand is kept as small as possible (Albadi & El-Saadany, 2007).

DSR provides means for utilities to reduce energy demand, save energy, maximize utilizing the current capacity of the distribution system infrastructure, reducing or eliminating the need for building new lines and expanding the system. Customers would perform those changes in response to their agreement with the utility, various price based or incentive based plans designed to induce lower electricity use, or in response to load reduction request signals sent by utilities when the wholesale price becomes high or when system reliability is jeopardized (Dam et al., 2008). Applying the demand response signal would require residential customers to perform one of the several possible actions such as dimming or turning off non-critical lights, changing the thermostat set-points of air-conditioning, or turning off non-critical equipment.

Engaging users in a demand-side-response approach is the most efficient method to avert adverse impact of peak demands on the electricity market (DOE, 2006). Figure 5.2 illustrates that, for example, the highest 10% of the maximum electrical demand of south Australian electricity consumers occurs in less than 0.5% of the time per year, i.e., for about 40 hours per year (Fraser, 2005, pp20). However, DSR could be implemented to reduce the installed network capacity serving less than 5% of the time per year. Capital expenditures associated with the last 5 to 10% of the peak demand could be deferred using DSR. Due to peak demands, consumers are paying significant premium to cover the retail supplier’s costs of managing the risks of the extreme price volatility.

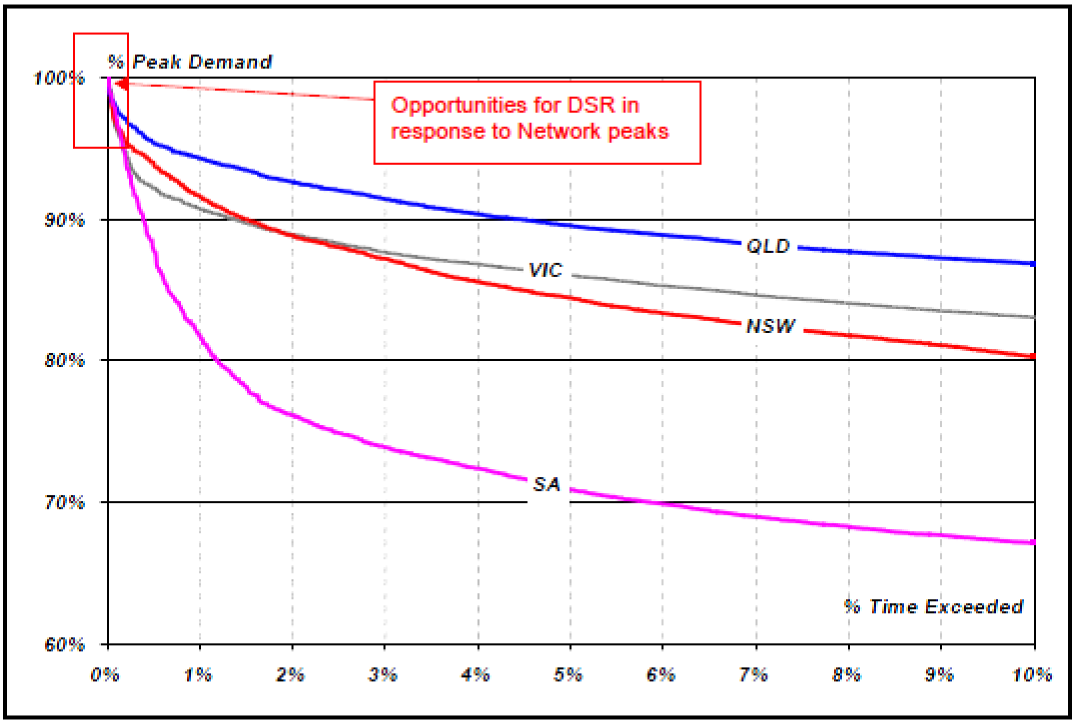

Figure 5.2 Illustration of the peakiness of the network demand and opportunities for DSR applications (Diagram provided by EUAA/Pareto from the EUAA Report on the DSR)

The presented scheme would enable electricity consumers to make a choice, hence provide an effective DSR without even the need for a signal from the supplier. However, the present tariffs are not providing incentives for implementing this scheme. Moreover, there has been critical reforsm at the national market level in order to allow the DMS into the whole sale price. Such critical reforms which have been made in wholesale electricity markets at the electricity national level include allowing demand response providers to bid demand response on behalf of retail customers, and amending the rules of the market to permit market-clearing prices which keep reliability up through the supply and demand mechanism (Reid, Gerber & Adib 2009).

5.3 Proposed Design

The scheme is based on the AEMO managing the electricity market and deploying operational information; demand and reference regional price (RRP) and other information on the internet. Electricity users (user's computer), on their end, are receiving this information and controlling accordingly own electricity demand on the premises. Figure 5.3 illustrates the circuit diagram of the proposed design which reflects the idea of the project.

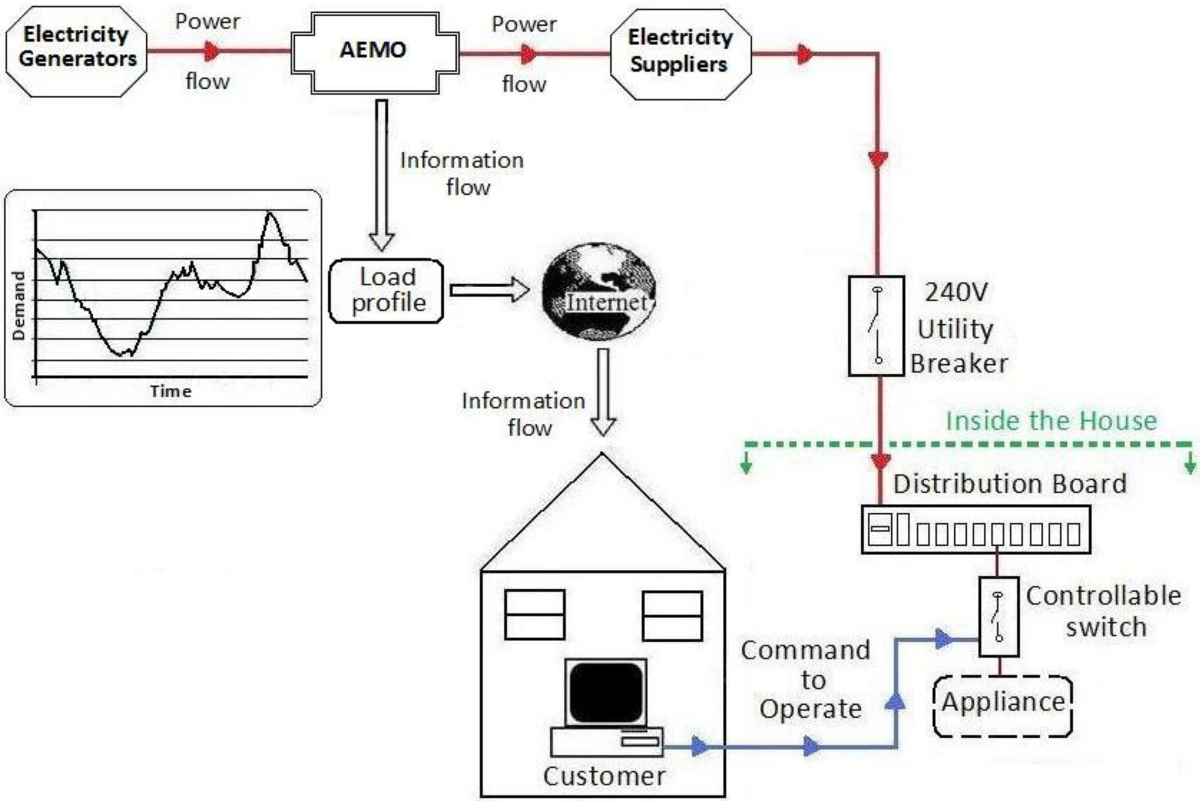

Figure 5.3 Project concept design, Note: the dotted line located inside the house.

The main components of the design include a specially written software, internet modem, computer, interface device and controllable smart switch. Internet functions as the medium or channel through which information are transferred from AEMO websites to electricity users computers. The especially written software imports the electricity load profile issued by the AEMO through the internet then analyzes its data. Based on threshold load limits set by customers, the software sends commands to the customer load switches to turn OFF or ON.

5.4 Apparatus

Figure 5.3 below illustrates the main devices and accessories required to operate the system.

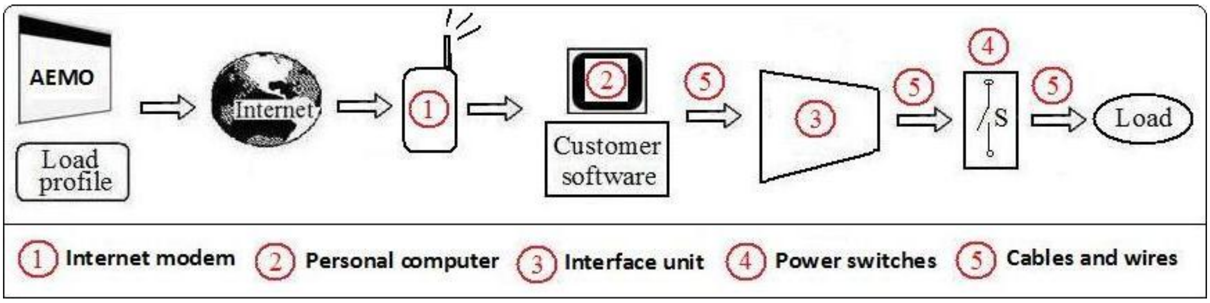

Figure 5.4 Project apparatus

5.4.1 Internet modem

Modem is an electronic device which converts a computer's digital signals into other specific frequencies to be transmitted across telephone lines. The main function of modems is to connect computers with the internet across telephone lines. This occurs by converting the digital signals sent from a certain computers to analog signals transmitted through telephone lines. The modem main function in this project is to connect the computer with the World Wide Web.

5.4.2 Personal computer

The main function of the computer is to receive information from the AEMO websites and to analyze this information. The computer then will send the commands to control the switches through the web relay (Interface unit). The specifications of the computer operational system required for operating the software and the system are of the average standard.

5.4.3 Interface unit

Web Relay is a smart device which has many features and many applications and can be used for monitoring and controlling a network. It can be used to control house lights, pumps and motors in factories and whatever in between. The input installed in the Web Relay can be used to control the relay, monitor the state of devices or control a remote relay somewhere else on the network. For the purpose of this project, Web Relay is used as an interface unit between the consumer computer and the controlled switches. It receives the command signals from the software then translating the signals into ON or OFF commands sent to the controlled switch to operate accordingly. The Web Relay used is shown in figure 5.5.

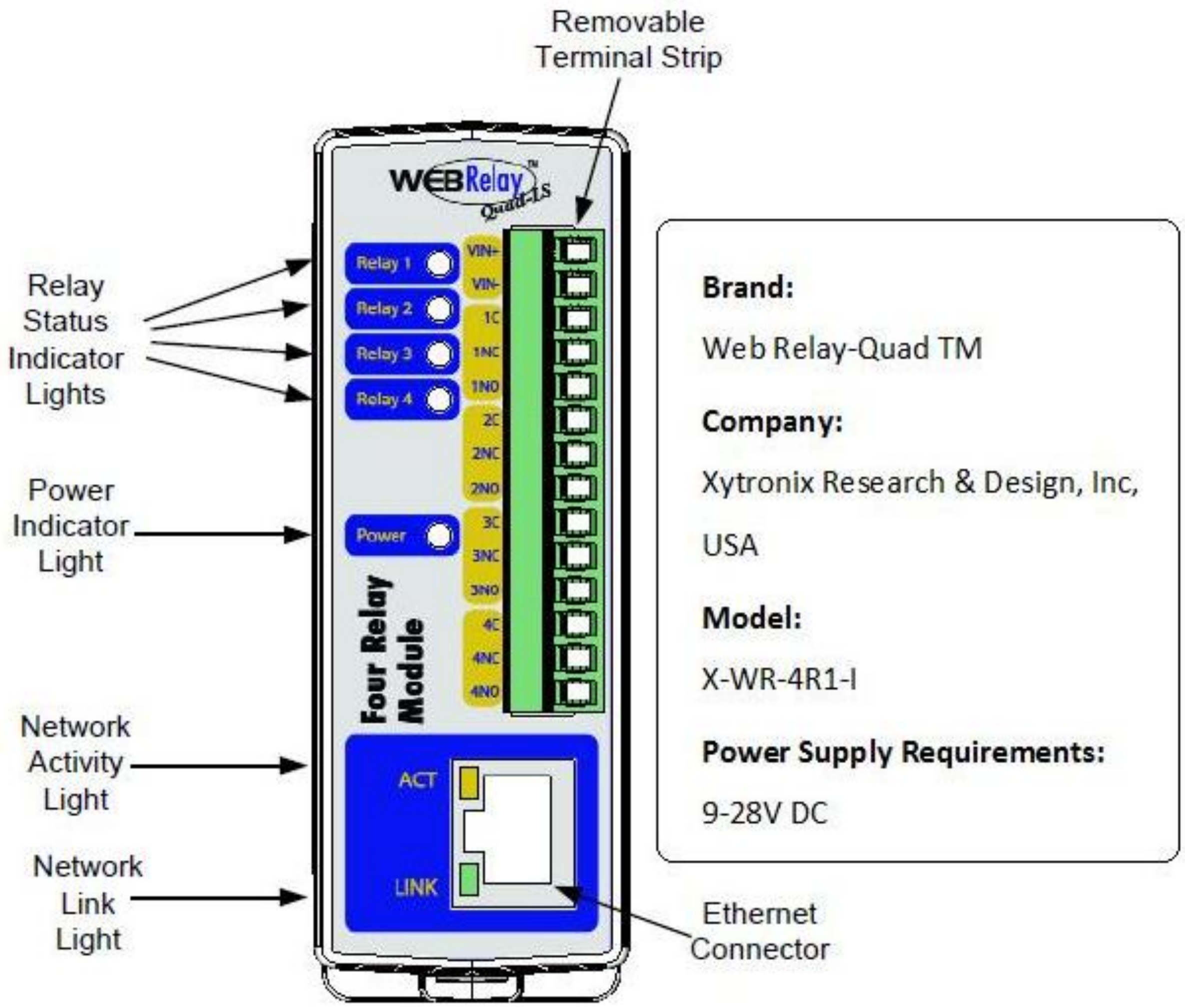

Figure 5.5 Web Relay components and features (XRDI, 2007)

Web Relay-Quad TM is a compact, four-relay module with a built in web server. Any internet protocol (IP) network such as private networks or IP-based industrial control networks can control or monitor the web relay. Therefore, computers, PLCs, or automation controllers may control and monitor Web Relay-Quad TM without user intervention. This works by sending text commands over the network and reading XML status pages from Web Relay-Quad TM, or by using Modbus/TCP protocol (XRDI, 2007).

As it is shown in figure 5.5, Web Relay has two types of connectors; a removable terminal connector and an Ethernet connector. While the Ethernet connector is the input used to connect the device to the computer using Ethernet cable, the terminal connector has two functions; to provide power to the internal web server and to connect external electrical loads to the relay contacts.

Web Relay-Quad TM has Light Emitting Diode (LED) indicators including the Power LED which turns green when the unit is powered and other four LEDs labeled Relay 1-4 which turn green when the corresponding relay coil is energized switching ON/OFF loads. Moreover, the web relay has four outputs each of which has Common (C), Normally Closed (NC) and Normally Open (NO) contacts (XRDI, 2007). When the relay coils are energized, the NO contacts are closed and the NC contacts are open. Depending on whether the load device is connected to the NO or NC contacts of the relay, it may be ON or OFF when the coil is energized.

5.4.4 Power switches

In this project, Solid state relays are used as a power switches for turning ON and OFF the set devices. A solid state relay (SSR), unlike an electromechanical relay, is an electronic switch without moving parts. There are three types of SSR; photo-coupled SSR, transformer-coupled SSR, and hybrid SSR.

Figure 5.6*: *Solid state relay

Solid state relay is used as an external relay which has the capability to operate when it receives a signal from Web relay. As it can be seen in figure 5.6, SSR has two sides; the low voltage (12V DC) and the high voltage (240V AC). The low voltage side represents the input of the device which receives the control signal whereas the high voltage side represents the output of the device which is applicable to pass 240V feeding the load (Kuphaldt, 2007).

When low voltage signal is sent to the control line of SSR, the Light-Emitting Diode (LED) shines on the photo-sensitive diode. As a result, a voltage is produced between the metal-oxide-semiconductor field-effect transistor (MOSFET) source and gate, which causes the MOSFET to turn on. Depending on the application, the MOSFET can be back-to-back thyristor, or silicon controlled rectifier (Jenneson, 1990).

Figure 5.7 illustrates the operation of the Solid State Relay.

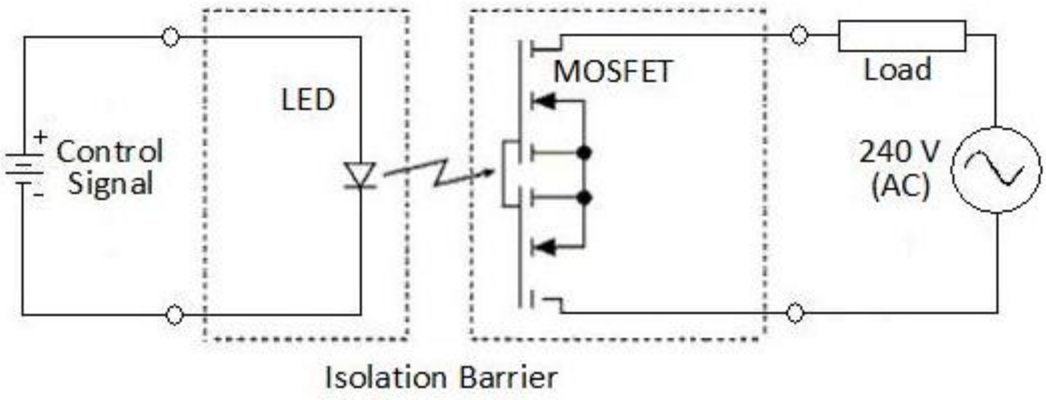

Figure 5.7 SSR basic circuit diagram (NI, 2008)

Solid state relay is selected for this study as it is a faster alternative to electromechanical relays. Switching SSR takes the time required to power the LED ON or OFF which is of microseconds to milliseconds. Because of its non-mechanical parts and its purely electronic nature, life expectancy of SSR is higher than an electromechanical relay and it is completely silent (Scherz, 2000).

Given the fact that the LED actuation provides a galvanic isolation between the control circuitry and the MOSFET, SSRs are useful for 240V applications. The MOSFET is accomplishing the switching; however, there is no galvanic barrier between its contacts. The drain-source channel on the MOSFET has a very high resistance when there is no gate signal on the MOSFET. Although SSRs fail short more easily than electro-mechanical relays and have higher impedance when closed, they are generally preferred for this particular application (Jenneson, 1990).

5.4.5 Cables and wires

Two types of cables and wires are used; communication cables and power wires. The communication cable is used to connect the computer to the interface unit and the internet modem to the computer, in case that modem used does not have a wireless feature. The specification of the network cable could be as follow:

Network Ethernet cables, UTP Cat5e at least, stranded copper core, patch cord, sufficient length , gray/blue color, pre-terminated (568B standard), and pre-tested.

The power wires are also two types; wires for DC and AC connections. The DC wires are used to connect the interface unit with the input of SSR. The second function is to connect the interface unit to the power plug. The AC power wires are used to connect the output of the SSR with different selected loads. The size of these wires should be compatible with each load power rating.

5.5 Software

To achieve the objectives of the project, three main functions should be performed by the software. The software uploads the electricity load profile from the AEMO websites to the customer personal computer, performs the analysis of the data and finally sends a command to the control switch to turn ON or OFF the devices under control.

MATLAB has been selected for this project because of its large applications for electric power systems, control systems, and power electronics circuits, being handy tool and its easiness of use. Moreover, MATLAB could communicate effectively with multiple different software.

There are many advantages for MATLAB software which made it better than other software to be used in this project. The acronym MATLAB stands for Matrix Laboratory which provides a good tool to deal with complex number and matrix computations. In addition to the widely used applications, MATLAB could be used for doing analysis, data acquisition, signal processing, control design and simulation. That is, MATLAB has numerous Toolboxes which can be used to replace or enhance the usage of traditional simulation tools for advanced engineering applications.

The following flow chart summarizes these processes and illustrates its sequence.

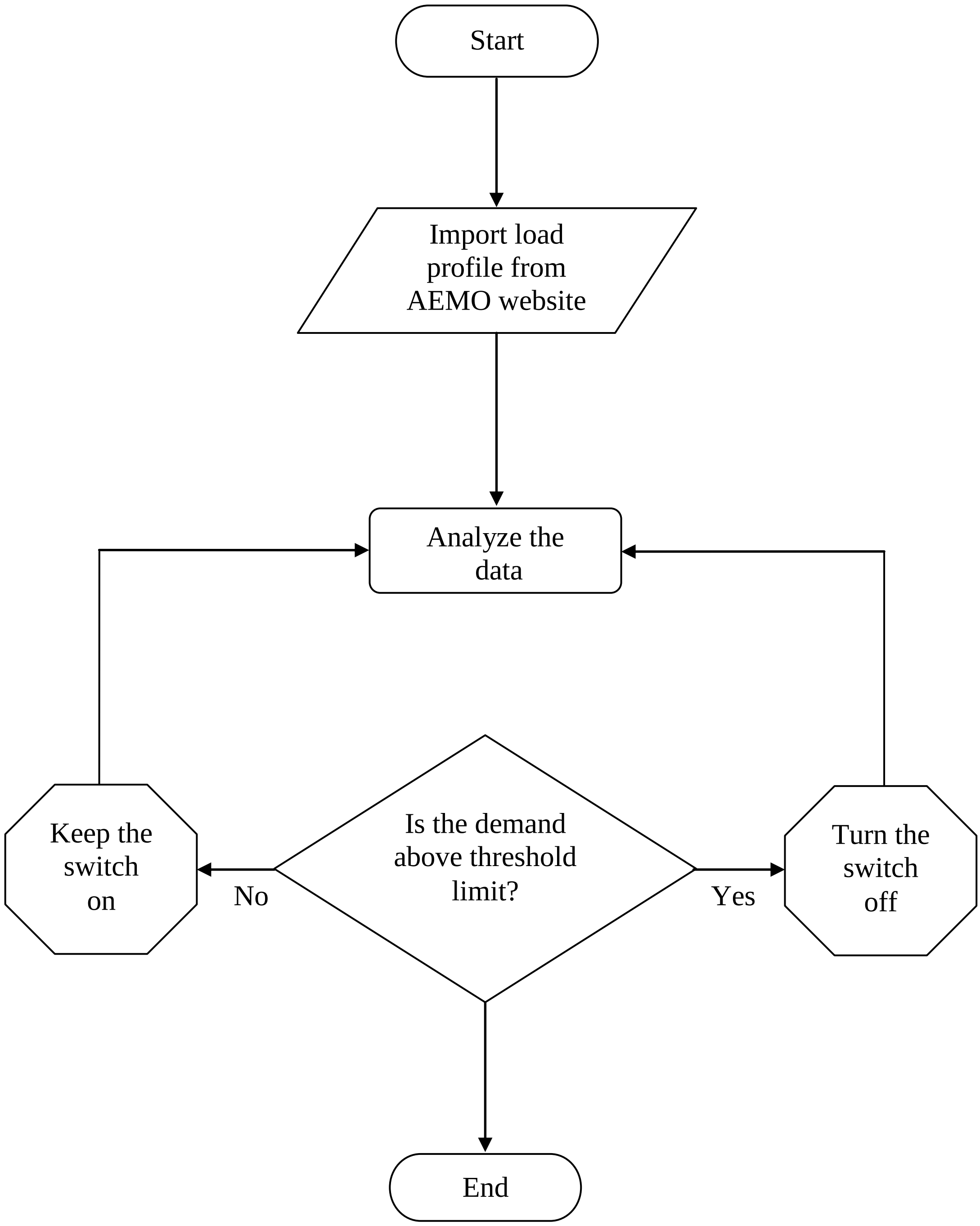

Figure 5.8 Flow chart of software sequence for one switch

Two different types of software have been designed for two different purposes. The function of the first software is to respond to total demand, while the second software responds to the price variation. In appendix 2 are the codes of both software.

The designed software has particular operation approach which connects it to the internet and the switches. First of all, the software is granted an access to the public website of AEMO which is considered the main link for recent peak demand related information. The format of the information available in this website is CSV file. Before the software commences reading this information or analyzing it, the software transforms the writing format of the information in order to be compatible with the software. After reading and analyzing the information, the software identifies the peak demand threshold limits according to which the software sends commands to the switch to turn the devices ON and OFF.

Moreover, multi tasked scripts that recognize the WebRelay and the four outputs connected to the devices have been written into the software in order to control the WebRelay on time. The software re-analyzes the information every half an hour according to the available information on websites of AEMO. The software is capable of plotting demand curves and store the information related to every device selected.

5.6 System installation requirements

The presented scheme is essentially based on enabling the electricity users to act proactively in a demand-side-response to control own electrical demand. In the scheme, electricity customers are receiving information about electrical network demand and energy prices from Australian Energy Market Operator (AEMO) on the internet. At times when the electricity network is experiencing peak-loads, customers are reducing own electrical demand at their discretion. Alternatively, when the network is at low-demand condition e.g. at night, customers are also enabled to switch on loads at their prioritization. The scheme is based on computer-controlled switches activated automatically by preprogrammed software able to recognize users set thresholds on energy demand or prices.

Figure 5.9 illustrates the proposed system.

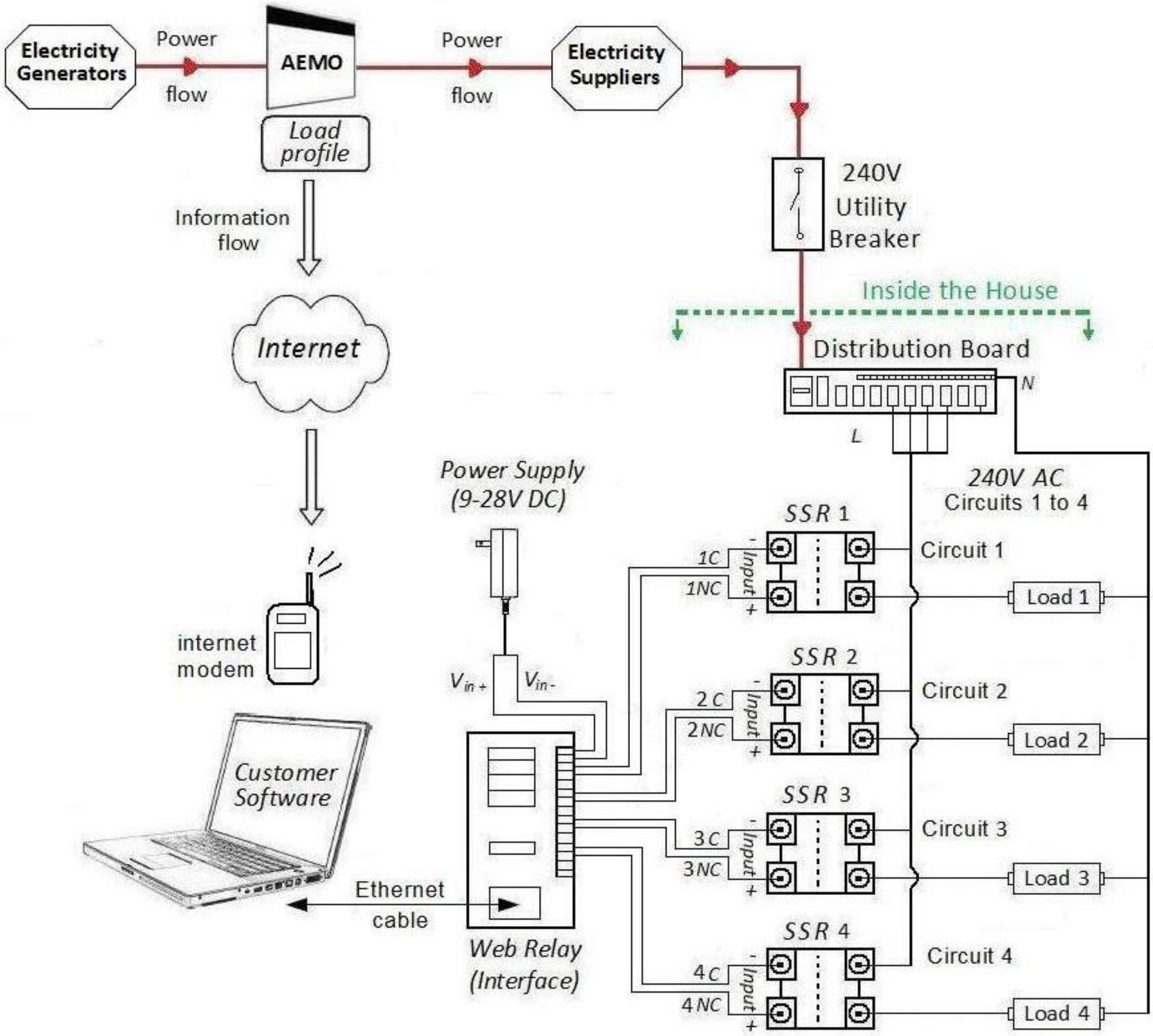

Figure 5.9 Entire system circuit diagram

The user computer and the Web Relay are located at safe and cool place (at least room temperature). Solid state relays (SSRs), switches, are placed close to the devices to be controlled, but they could be also located above the ceiling on the top of each load. However, the most important requirement is that SSR should be easily accessible for maintenance. The control wires from the Web Relay to each SSR could be passed through suitable conduit according to the normally followed electrical procedures in Queensland. The same procedures should be followed in passing power wires which connect every SSR to its device.

Figure 5.10 illustrates the system connection.

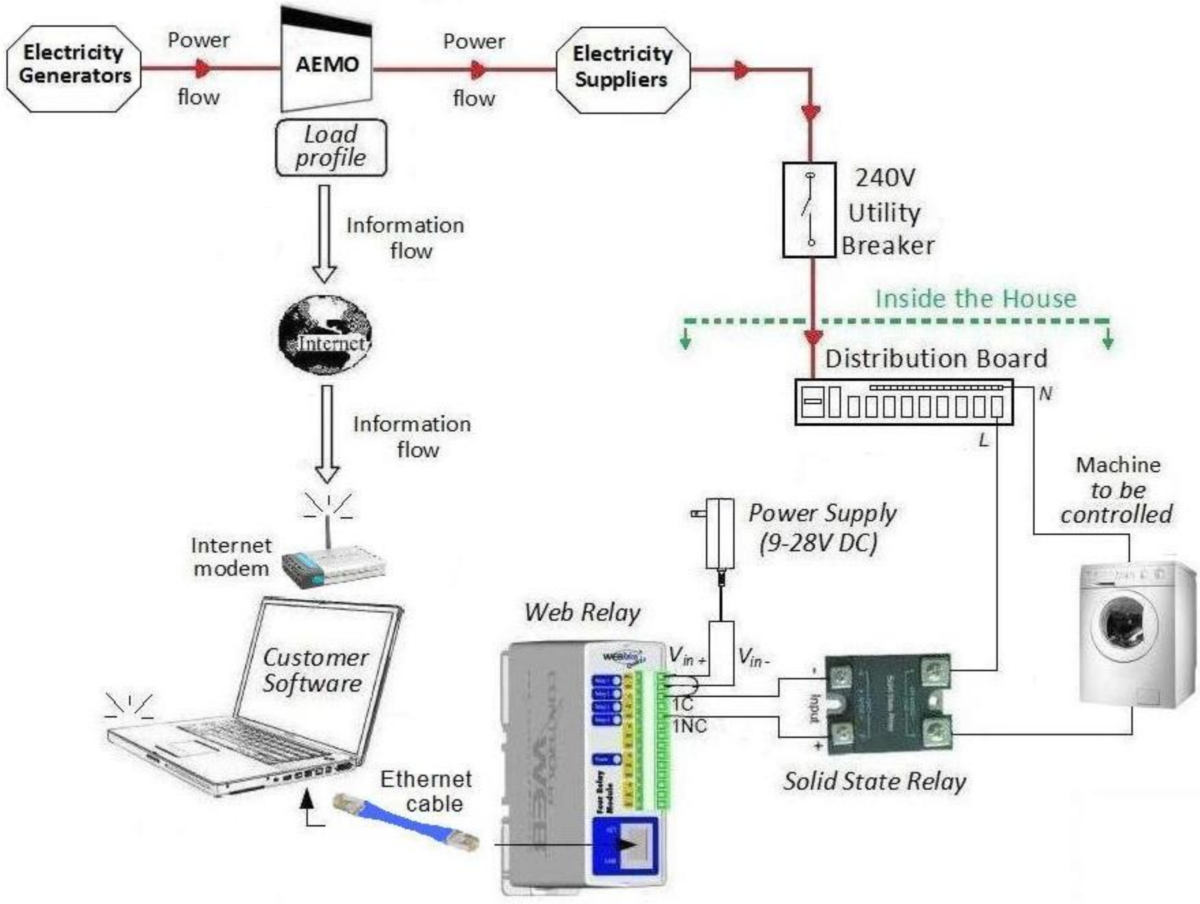

Figure 5.10 System connection

5.7 System operation

WebRelay fed with power supply is first connected to the computer. Then, the computer is configured –according to the WebRelay manual- in order to recognize the web relay. The interface unit (Web relay) used for the experimental part of this project contains four output signals. The four signals are designed for four different loads or devices which can be simultaneously controlled. Therefore, the written software is designed to send four commands based on four threshold limits. The first, second, third and fourth device will be turned off when the network demand exceeds 5000, 6000, 7000 and 8000 MW respectively. Moreover, when the electricity load exceeds the highest threshold limit (8000 MW), the four devices will be turned off. However, on exceeding the 5000 MW the first device only will be turned off. During off peak periods, when the demand starts declining gradually below the threshold limits, each switch returns to its normal position turning the connected device on. The main idea of that scenario is to allow the consumer to reduce as much load as possible when the electrical network demand is high.

Selection of the appliances to be controlled should be made according to consumers' preferences; however, priority is to be maintained while ranking the switches. Therefore, the first switch to be turned off should be the one connected to the least important device and so on. In addition, in some cases, instead of connecting a single device, the customer may prefer to connect a circuit which feeds a room with least usage.

5.8 Safety precautions

During the actual installation of system devices, there are number of safety precautions to be followed.

1. Follow the original regular installation procedures during installation, wiring, testing and commissioning.
2. Insert protection device to protect the appliance from any unexpected erroneous operation of the switch which could happen due to many reasons such as SSR failure.
3. Place all electronic devices in a suitable environment.

Chapter 6 ACHIEVED RESULTS, REQUIREMENTS FOR WIDE DEPLOYEMENT AND SCHEME LIMITATIONS

6.1 Achieved results

The scheme has been physically implemented as described in chapter four, where computer controlled switches are operated following signals received from the AEMO on the internet. The required software has been written to perform the analysis of the received information and send commands to the switches to turn the devices ON and OFF according to predetermined thresholds. The computerized circuit of the designed communication system including main components has been identified and procured. The experiment has examined the efficiency of the scheme to control loads.

The experiment has been conducted by connecting the computer to the web-relay. Indicators on the Web-relay have been observed operational according to commands sent by the software. The indicators of the web-relay responded to the commands correctly and appropriately. Extension of this trail involves the solid state relay and the load in order to assure the efficiency of the design.

In order to fulfill the study, a number of consultations and meetings have been accomplished with different electricity suppliers, manufacturers and companies who are related to either the devices used in the project or the electricity market such as Ergon Energy, Schneider Electric, and NHP.

6.2 Implementation requirements

The actual implementation of the project in the daily life is primarily based on the customer receiving information about electricity market conditions on the internet and acting upon controlling own demand. Challenges could be represented in suppliers which have financial and business interests, once the project is implemented, could be affected to some extent. That is, reducing demand will reduce the sales and profits that electricity suppliers are usually targeting with increased demand. This cannot deny the valuable results the project is able to achieve for both consumers and suppliers on long term. Suppliers would need to arrange new tariffs to encourage users to adopt the scheme.

Present electricity consumers' lack of awareness about electricity market condition and the impacts of peak demand would hinder implementation of the scheme. Residential customers would find it cumbersome to stop using any of the house appliances for a short time or to be limited in their electricity usage. Although the scheme has valuable advantages on the environment, the economy, the efficiency of electricity infrastructure and on human wellbeing, both suppliers and consumers need to be introduced to the benefits behind.

Therefore, it is necessary to perform the following measures to achieve the implementation of the project;

- Provide those who are involved in the electricity business and consumers with the valuable benefits that the scheme could have for the entire nation.
- Those in charge managing the electricity market need to cooperate to achieve an agreement that satisfies all parties.
- Provide consumers who join the scheme with financial incentives in order to encourage them to join.

- All those interested in the project such as environment organizations need to be involved in deploying the scheme in order to achieve reducing demand.
- A long term deployment of the scheme should be evaluated.
- The project should be partially tried in residential areas for a certain period to examine long term impacts.

6.3 Limitations

The information on which the implementation plan has been designed is extracted from the website of the Australian Energy Market Operator (AEMO). This causes two limitations;

Firstly this information reflects the demand curve of Queensland addressed to the generators not the suppliers. Despite of that, this information has in fact direct impact on suppliers (line losses, protections and control caused by peak-demand); however, the scheme in fact is using this information. For example, at low demand, suppliers are buying electricity at cheaper prices and selling them to consumers also at low prices and vice versa. Therefore, when the information provided to the users is achieving a moderate demand, suppliers will then operate a better manageable system featured by predictable and controllable demand.

The **second** limitations exist in the information released by AEMO about electricity demand/prices based on 30 minutes information. To switch the devices ON or OFF needs to be according to instantaneous information. However, the AEMO provides information of the electricity consumption half an hour later which does not reflect the real present demand situation.

Refining the information provided in this study was achieved by paying a visit to the websites of the suppliers and even meeting some large suppliers such as Ergon Energy in Queensland which explained that no suppliers, at the time being, are providing real day demand information.

Chapter 7 SCHEME APPLICATIONS AND RETURNS

7.1 Scheme implications

The main objective of the scheme is to reduce the peak demand, which will be achieved by consumers' contribution to postpone the use of the household loads to times with lower demand out of the peak periods. This would require electricity consumers to prioritize their household electricity loads according to their need and usage. This could be achieved by the proposed design and the prepared program which enable all consumers to select the devices which would be controlled and prioritized as shown in figure 7.1.

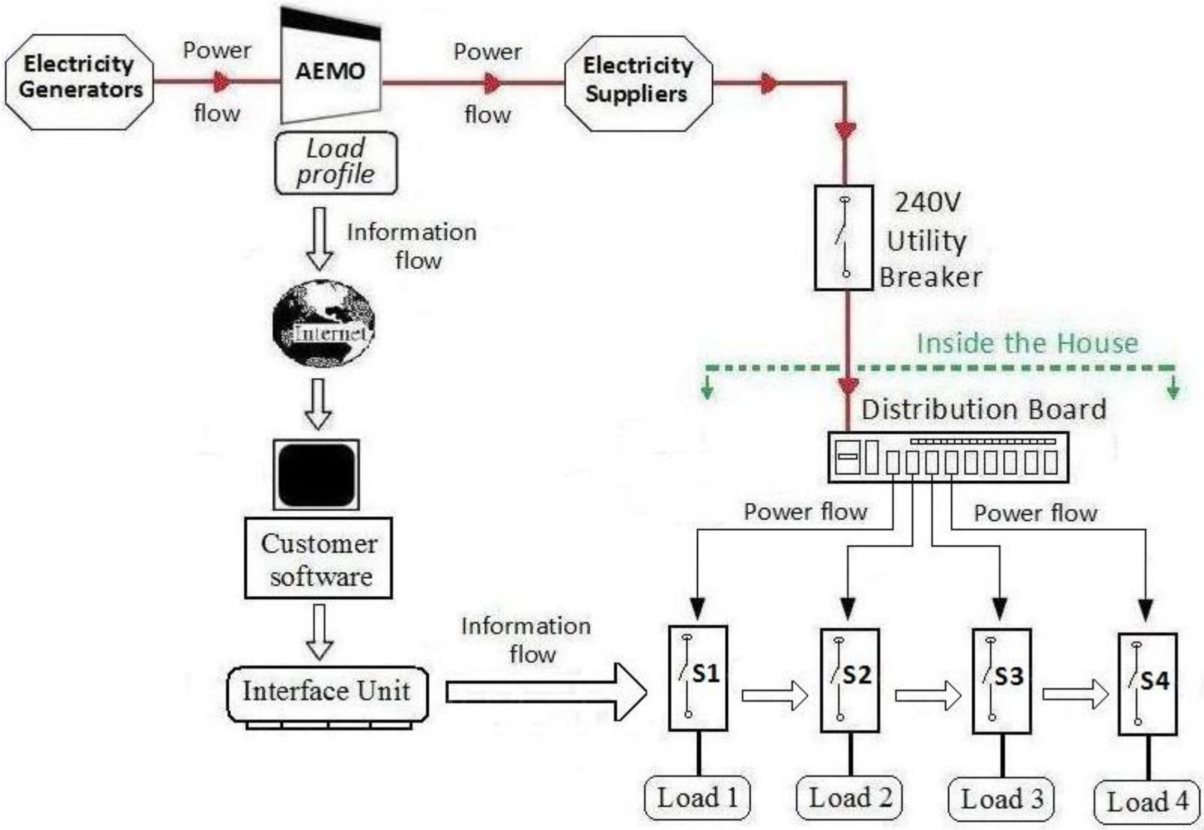

Figure 7.1 **loads selection and *prioritize by consumers through the project scheme.***

Figure 7.2 shows Energy demand and prices in Queensland as broadcasted by the Australian Energy Market Operator AEMO (2009). It illustrates customers e.g. fully curtailing energy withdrawals at any point above $55/MWh (Kamel, 2009).

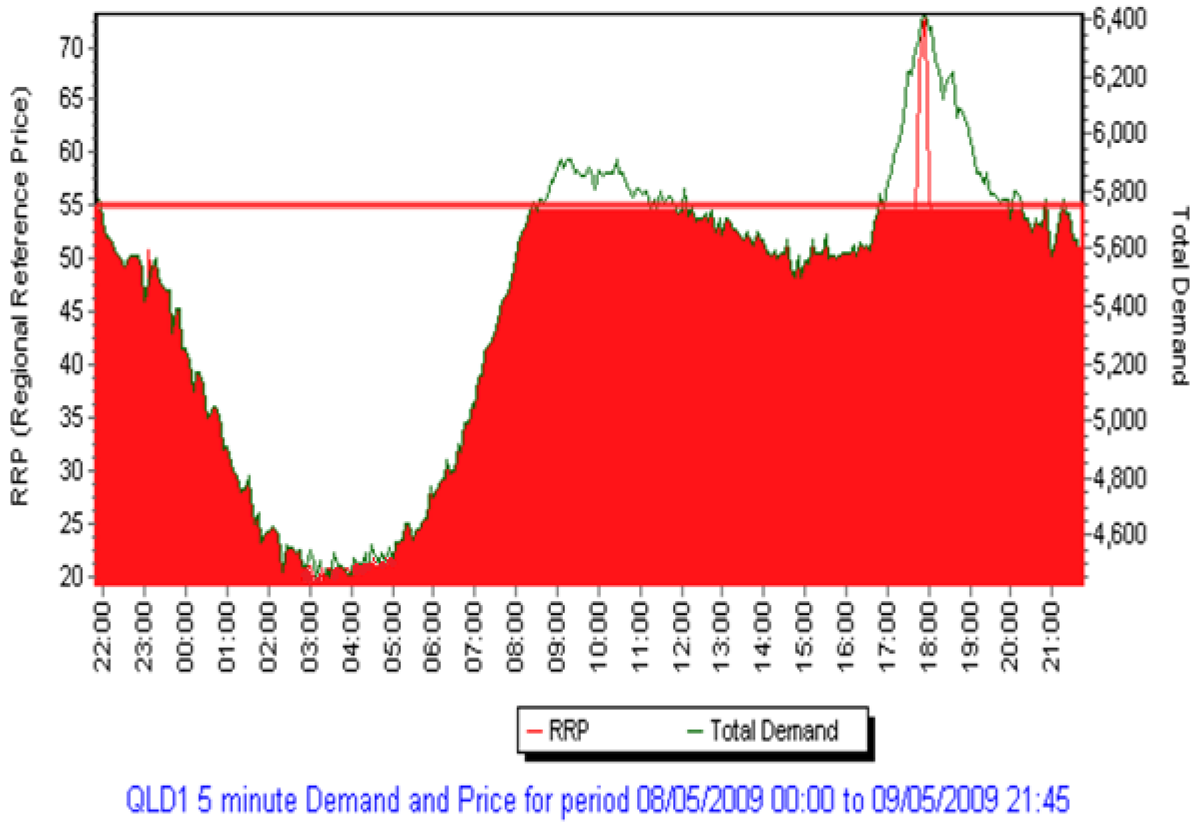

Figure 7.2 Day electricity demand curtailed for wholesale regional reference price not to exceed AUD $55/MWh in Queensland in 2008 (Kamel, 2009).

Implementing the scheme would reduce the electricity peak demand from 6.400 to around 5.800 kwh (Kamel, 2009). Customers would switch off their preset loads at the time of peak demands and move the work to times of base load demand. The consumption curve would be closer to being flat. Figure 7.3 illustrates the saving for Queensland as an example able to be achieved on the AEMO (Kamel, 2009).

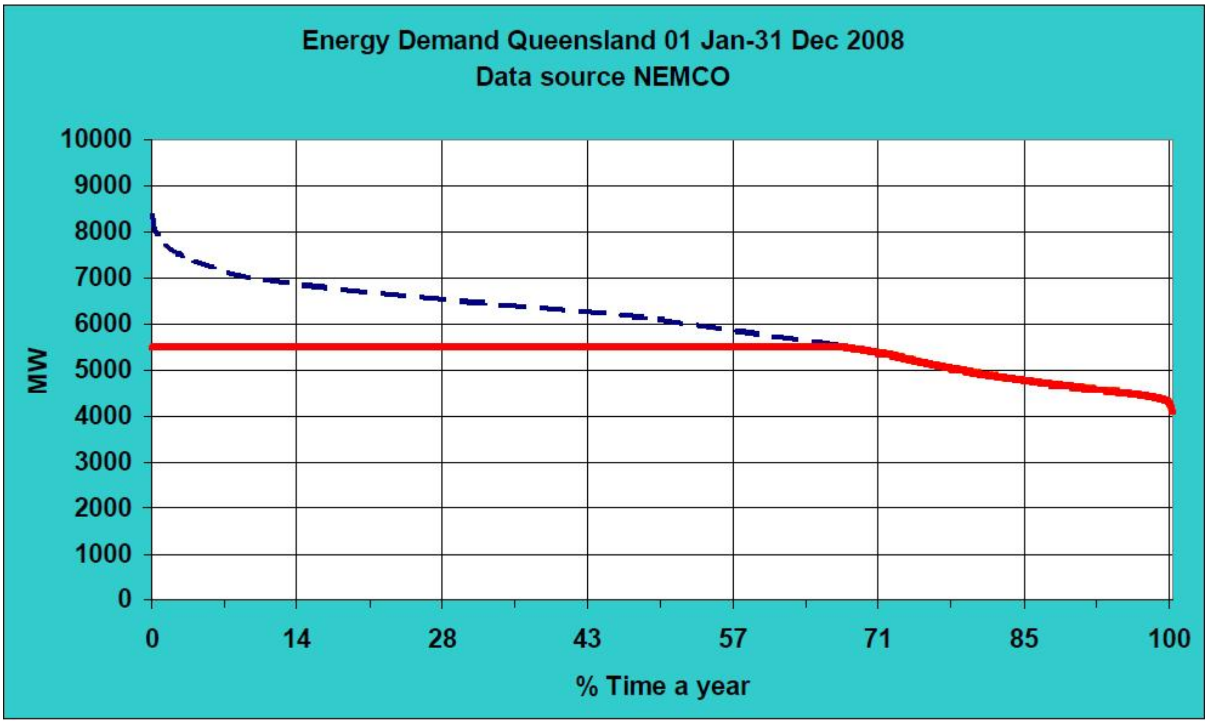

Figure 7.3 Electricity demand curtailed in Queensland not to exceed $55/MW (Kamel, 2009).

Figure 7.4 shows achievable energy savings by curtailing energy demand over a certain energy prices, Queensland 2008. It illustrates the reduction of about 6.1 TWh/year or a 11.7 % of a total of 52.2 TWh/year by implementing the scheme which make users set switches to curtail own loads at any RR prices above $50/MWh. The reduction in the total demand will be reached to 11.1 TWh/year or a percentage of 21.2%, when the users chose to curtail their loads at $40/MWh, and 24.8 TWh/year at a $30/MWh curtailment; a 47.5% (Kamel, 2009b). The requirements of installing the scheme in the market such as load-price curves publicly accessible on the AEMO website and computer-controlled switches are available; the scheme is today readily applicable.

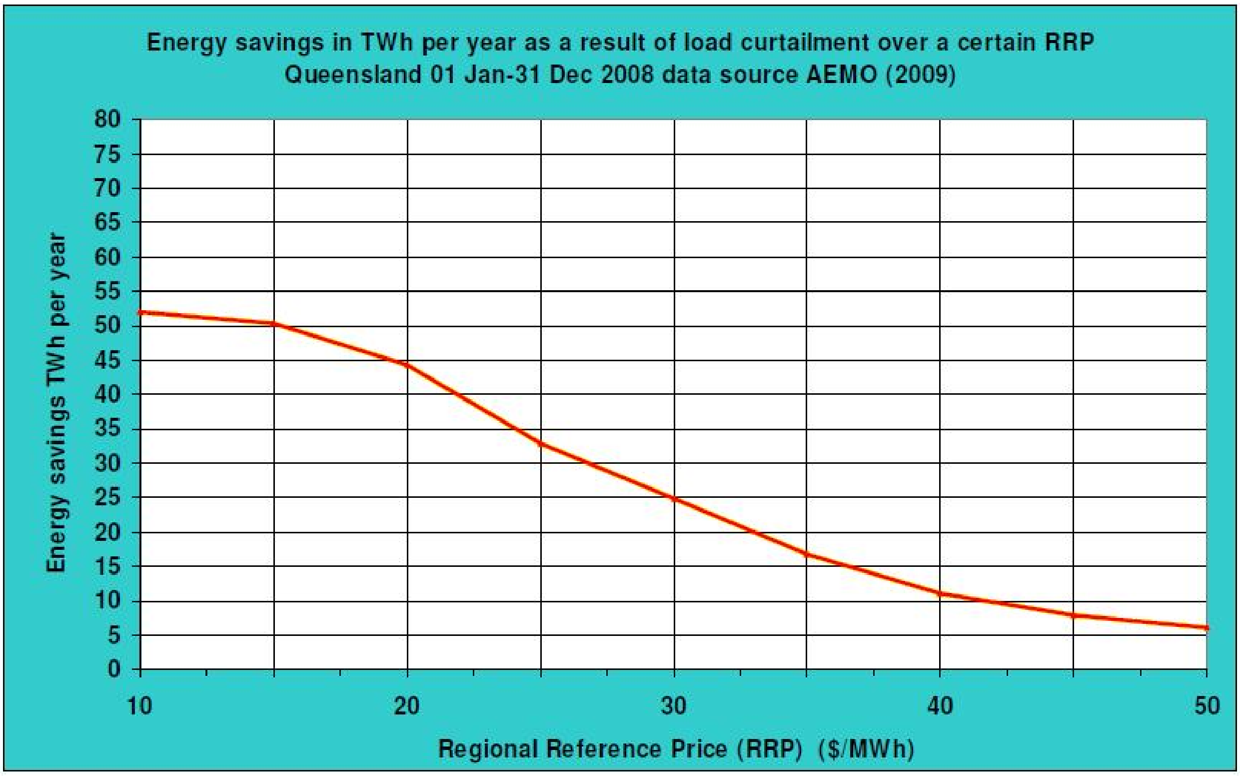

Figure 7.4 Achievable energy savings by curtailing energy demand over a certain energy prices, Queensland 2008, (Kamel, 2009b)

Number of assumptions have been created in order to give an in depth explanation of the efficacy and effectiveness of this project. Assuming that, with the encouragement and support by the government, one million consumers in Queensland would join the scheme, they would turn off their devices in equivalence to (3kWh); the total saved electricity will be 3 million kWh.

Furthermore, there are a number of applications would be achieved by implementing this scheme. In addition to specifying the peak demand, it allocates the areas whose electricity demand would be base load. Operating generators generate less than its main capacity would cause loss in its fuels and wasting the energy generated by the plant. This could be explained by the analogy of a 50 seated bus which is used for transporting 30 passengers; therefore 20 seats are wasted. The capacity of this design is to specify the areas with base loads would assist in exploiting the additional generated power in other beneficial purposes. This design has other applications which will be explained in the next part.

Figure 7.5 shows electricity demand curve during a period of time which fluctuates under and above the average load.

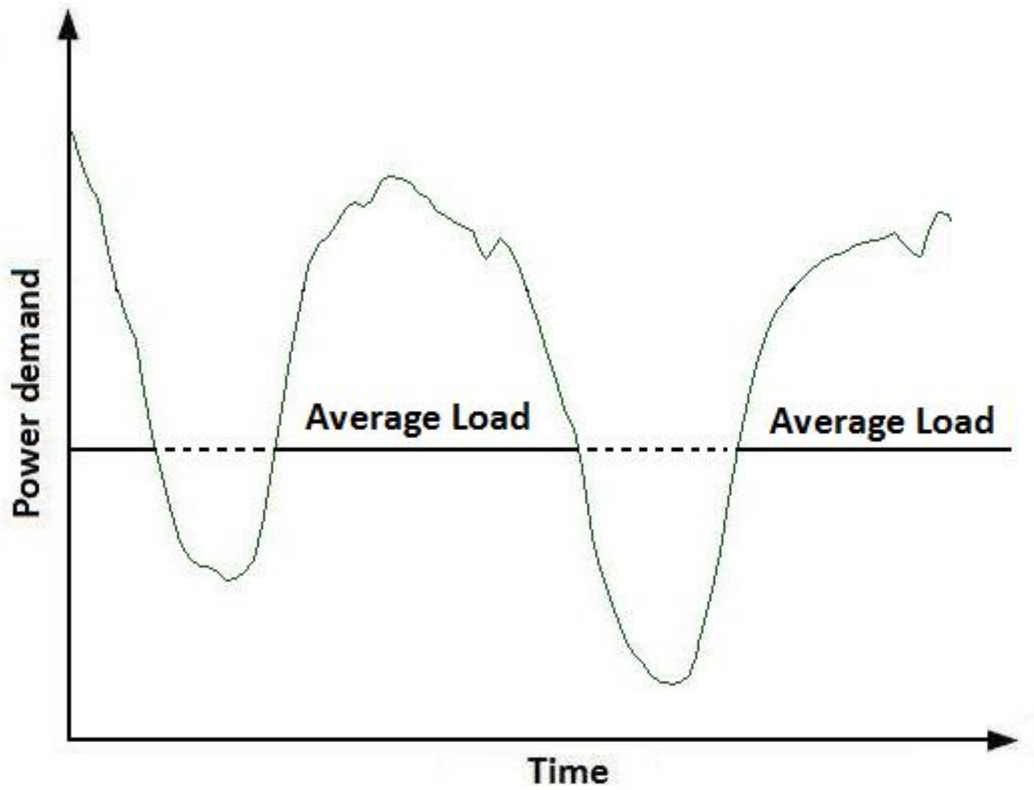

Figure 7.5 Electricity demand curve during a period of time

Turning the electricity demand curve into a near flat usage closer the average load line of electricity consumption would lead to closer to unity capacity factor, managing risk associated with high peak demands and improving operation of electricity generators.

The figure 7.6 turning the fluctuating demand curve into maximal usage near flat curve will provide energy for various purposes e.g. charging hybrid transport vehicles at night. The scheme's contribution to charging hybrid car storages at low-demand times shall improve the utilization of available peak-load power plants otherwise not used at those times.

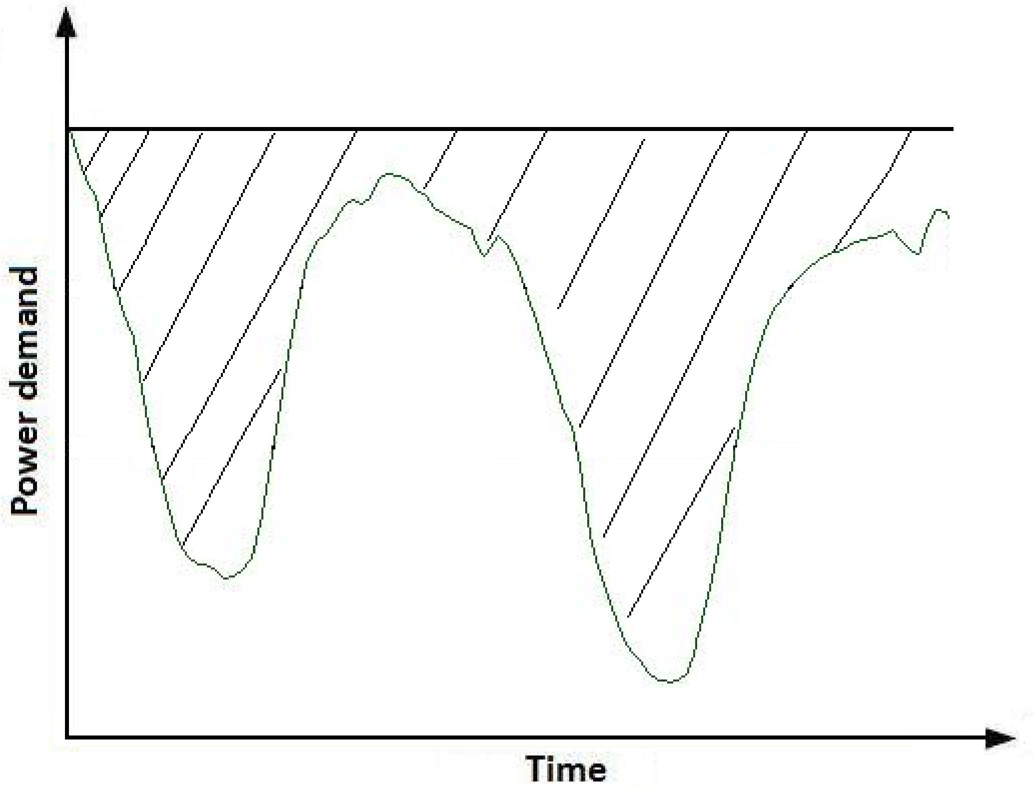

Figure 7.6 Opportunities for best utilization of electricity

Figure 7.7 illustrates the ideal flat electricity usage the scheme strives to achieve.

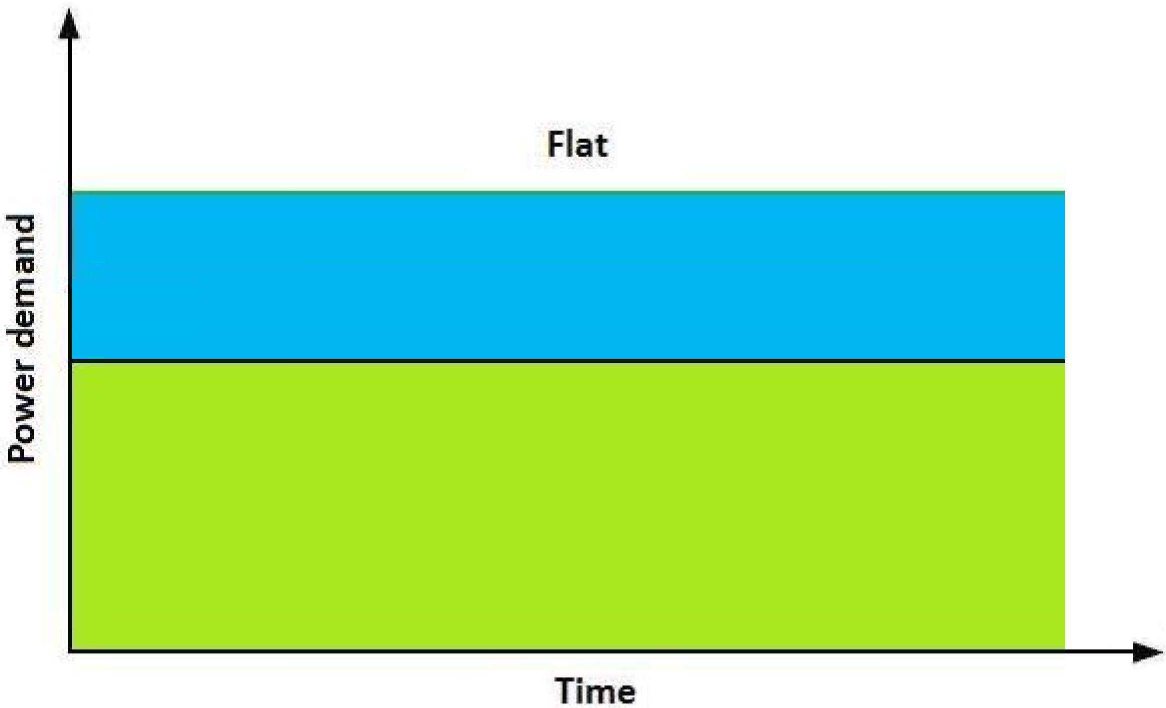

Figure 7.7 Flat consumption (ideally)

Other applications of scheme include avoiding power outages due to the low supply in response to the increased demand. Generators cannot meet the increased demand because they have lower capacities. In those cases, electricity suppliers have to schedule the city into areas in some of which power outage will occur in the period of peak demand in order to meet the increased demand in other areas.

7.2 Project returns

The direct correlation between electricity prices and electricity peak demand implies that reducing peak demand will lead to reducing the electricity prices. Therefore, reducing peak demand will lower customers' electricity bills by helping utilities avoid having to purchase extra power, for example, during the hottest summer days when its prices are higher (Sayers et al., 2001). Reduced electricity bills will encourage customers to reduce their electricity usage. The proposed scheme will lead to more efficient use of the electricity system because customers will alter behavior and reduce or shift on-peak usage and costs to off-peak periods when they receive price signals and incentives. For example, in California customers achieved a 2.5% reduction in electricity demand statewide which reduced wholesale spot prices in California by as much as 24% (Moore, 2001).

Other returns that would be gained by implementing the project scheme include enhancing and refreshing the local economic development. This would be achieved through reducing consumers' electricity bills which allow them to save more of their income and in turn spark economic growth. When the demand extremely increases, states would restore to importing electricity from neighbor states in order to meet the increased electricity demand. Therefore, with reducing demand, states with high demands would decrease its reliance on energy from sources primarily imported from other states. Thus, costs, prices, electricity bills, environmental impacts and better economy would result from implementing the project scheme which reduces electricity demand.

The findings of a large number of studies indicate that the costs and negative impacts associated with increased demand are higher and more expensive than reducing the demand of electricity especially with the recent increases for the price of electricity (Ruff, 2002). In other words, reduced electricity demand allows consumers to have lower bills with a more reliable electric system which minimize the costs at both the individual consumer level and the electricity generation level.

The increasing electricity peak demand will lead to higher maintenance expenditures and costs and negative environmental impacts. Therefore, reducing peak demand will reduce costs and environmental risks associated with generating electricity to meet high peak demands. For example, greenhouse gases such as carbon dioxide which are released by power plants particularly fossil fuels fired power plants will be reduced with reducing demand. Implementing the project scheme to reduce electricity demand would help the environment, the utilities and reduce consumers' electricity bills. One billion tons of coal consumed annually in power plants which causes significant portion of environmental negative impacts could be reduced by implementing the project scheme. It is essential for meeting the increased electricity demand to build new power plants which are considered to be highly expensive. However, by reducing the electricity demand, such costs spent for new power plant construction will be rechanneled. With preventing new power plants construction, the negative environmental impacts would be prevented and the increased prices resulting from the construction of new plants would be avoided.

Achieving reduction in electricity demand by implementing the project scheme would improve reliability of electricity system. That is, over strains could be burdened on an electric utility's system because of the unusual and extreme increases in electricity demand. Therefore, reducing electricity demands would minimize the strains and in turn delay expensive transmission and distribution upgrades and reduce certain congestion problems. The proposed scheme could enhance the electricity system reliability by providing reductions in electricity peak demand during emergency conditions. The increased peak demands cause power interruptions and inadequate power quality which lead to economic losses to the nation estimated at more than $100 billion a year (EPRI, 2001).

One of the most important benefits of the proposed scheme includes stabilizing the wholesale markets and avoiding the risk of the varying wholesale prices**.** Therefore, the scheme substantially reduces the suppliers' risk and their customers' risk in the market. Moreover, where retail markets are competitive, price guarantees provide substantial value to certain customers. Therefore, the scheme proposed provides efficient electricity markets which provide risk management products using all available economic tools. For example, retailers create callable quantity options (i.e., contracts for demand response) offering appropriate price for those customers who are willing to face varying prices. Therefore, retailers provide economically risk management products for those customers who most benefit from them. Thus, implementing the project scheme would manage risks through ready availability, high reliability, refined modularity, and rapid dispatch ability.

The project scheme could mitigate the power market by reducing electricity peak demand in real time with tight supplies and/or transmission constraints that might lead to an excess of market power. By avoiding tight supplies and/or transmission constraints, market power mitigation is achieved and lead to a better match between marginal supply costs and willingness to pay (Worthington et al., 2002).

Other benefits

The other benefits of the project scheme include:

1. To increase consumers' awareness of the commercial and broader economic benefits, which could result from effectively implementing the DSR.
2. To provide electricity consumers with significant benefits from relatively small and occasional responses to extreme NEM prices and demands, or peaks in network demand.
3. To achieve a more predictable, stable and efficient electricity market by facilitating implementing a demand side response.
4. To provide higher security to the interconnected power system.
5. To minimize costs of hedges and managing risk by market participants.
6. Improved asset utilization across the electricity system.
7. Energy saving due to a reduction in network losses.

Chapter 8 FUTURE WORK & CONCLUSION

8.1 Future work

Future applications of the scheme extend to impact different areas such as storage recharge, irrigation system and hybrid cars charge. The extra electricity saved by implementing the proposed scheme would be used to charge the hybrid cars batteries which are considered to be the recent trend in car manufacturing. Saving electricity by implementing the proposed scheme would contribute to encouraging the sale and the use of hybrid environmental friendly cars. Decreasing the peak demand would save electricity to provide electrical irrigation systems with the required energy without the increase in electricity prices. Moreover, with the increase usage of storages in many fields in life, charging those storages can be scheduled and enhanced by decreasing the peak demands. Therefore, this proposed scheme would have various implications in many fields in life.

The design of the project could be an initiative towards new developments and ideas in the area of achieving a moderate residential usage of electricity. However, much work and research are required to enhance and develop more intelligent designs. In the following part, some suggestions are provided for future studies with the same focus.

1. Replacing the computer with an intelligent device which could perform all the tasks such as operating the software, connecting to the internet and other devices of the design. However, the device should be in an appropriate size so that it could be connected to a screen and keyboard in order to be able to insert data into it manually or supervise its processes.

2. Examining the capacity of using more effective software with more effective features than MATLAB such as LINUX or others.
3. Performing a real experiment on one of the neighborhoods for a sufficient duration to analyze the results after coordinating all the concerned authorities.

8.2 Conclusion

This project is an endeavor towards developing a technological means to achieve a demand-side-response scheme enabling electricity end users to avert peak demands and contribute minimizing volatility of electricity market prices. The developed scheme comprises developing software which extracts electricity demand/price information from publicly available Australian Energy Market Operator (AEMO) website, sourcing out and utilizing proper computer-controlled WebRelay and developing programs to switch ON or OFF electrical loads according to user preferences. The scheme engages electricity consumers to shift own demand from peak periods to periods of lower demand through a prioritization plan achieving thus immediate financial savings to users and economic benefits to the electricity sector and general benefits to the economy and environment.

Implementing the scheme is an efficient method to reduce peak demand periods avoiding negative impacts on electricity systems and markets. Although electricity system in Queensland has been the focus for implementing the scheme, the applications might be effectively implemented in other electricity markets. The scheme's contribution, for instance, to charging hybrid car storages at low-demand times shall improve the utilization of available peak-load power plants otherwise not used at those times. The scheme represents a form of end users' contribution to effectively improve electricity system economics and market performance. The present availability of electricity market information on the AEMO website and of on-the-shelf web-relays make the technology immediately available for wide-use applications.

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APPENDICES

Appendix 1 – Project specification (Initial and Updated)

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG8002 Project and Dissertation

Project Specifications (Initial)

Student Name	Mr. Abdullah Khalfan AlMahrouqi
Topic	Demand-Supply Interacting System Towards a Dynamic Electrical Energy Management-The Smart Grid
Supervisor	Dr. Fouad Kamel
Project Aim	To provide a guidance on key considerations and architectural guidelines for Intelligent Networking to support successful deployment of Smart Grid initiatives.

Program:

- Defining a Smart Grid and its elements
- Value of Smart Grid
- Challenges and opportunities
- Select all components needed for the project
- Recommendations
- Write the project dissertation

co-supervisor' Signature: Wei Xiang

Student's Signature.................. Supervisor's Signature..........................

Date: ...29/..03../ 2009 Date: 31..../03../ 2009

Examiner Signature ....

Date: 3......./....4../ 2009

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University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG8002 Project and Dissertation

Project Specifications (Updated)

Student Name	Mr. Abdullah Khalfan AlMahrouqi
Topic	Demand-Supply Interacting System Towards a Dynamic Electrical Energy Management-The Smart Grid
Supervisor	Dr. Fouad Kamel
Co-Supervisor	Dr. Wei Xiang
Project Aim	To design a communication and control system which enables electricity users to effectively manage and control own demand based on information, publicly available from the Australian Energy Market Operator (AEMO). The scheme is an architectural guideline for Intelligent Networking to support successful deployment of Smart Grid initiatives.

Program:

- Problem identification.
- Data Collection.
- Identification of solutions.
- Define the project components.
- Components selection.
- Coordination with concerned utilities and suppliers.
- Choosing or writing software.
- Familiarize with the components and software.
- Conducting the real experiment if time is allowed.
- Work evaluation.
- Writing the dissertation.

Student's Signature…………………………………

Date: ………/………/ 2009

Supervisor's Signature………………………………

Date: ………/………/ 2009

Co- Supervisor's Signature…………………………

Date: ………/………/ 2009

Examiner Signature …………………………………

Date: ………/………/ 2009

Appendix 2 – Software codes (Demand and Price controlled)

A) Demand controlled

```
clear all;close all
clc;

%%%%%%
%open all 4 switches when the demand is => 8000
DMax1=8000;
%open only 3 switches when the demand is => 7000
DMax2=7000;
%open only 2 switches when the demand is => 6000
DMax3=6000;
%open only 1 switches when the demand is => 5000
DMax4=5000;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
n=0;
while n~=1;
    c = clock;
    c=fix(c); disp(c)
    c=fix(c(1:5));
   if (c(5)==30) || (c(5)==0)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     WebPage =
'http://www.nemweb.com.au/mms.GRAPHS/GRAPHS/GRAPH_30QLD1.csv'; % to open
the webpage includes data

    RWebPage=urlread(WebPage); % to read data from website (url)and save
them as s workspace

    data = textscan(RWebPage,'%*s %q %n %n
%s','headerLines',1,'delimiter',',');
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     % store data into variables
    When=data{1};
    Demand=data{2};
    RPP=data{3};
    Periodtype=data{4};
    % % convert When? in to date "dd/mm/yyy" and time "hh:mm"

    Convtime=cell2mat(When);

   %%%%
   for nn=1:length(When)

       DateTime(nn,1)=str2num(Convtime(nn,1:4));       %Year
       DateTime(nn,2)=str2num(Convtime(nn,6:7));       %Month
       DateTime(nn,3)=str2num(Convtime(nn,9:10));       %Day
```

```
        DateTime(nn,4)=str2num(Convtime(nn,12:13));     %Hour
        DateTime(nn,5)=str2num(Convtime(nn,15:16));    %Minute
        %DateTime(nn,6)=str2num(Convtime(nn,18:19));   %Seconds

    end
    %%%
    %%%%%%%%%%%%%%%%%%%%%%
for nfind=1:length(DateTime(:,1))
    if DateTime(nfind,:)==c
        NF=nfind;
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%
    %  clear the textscan data
    clear data


    %%%%%%%%%%%%%%%%%%%%%%%

        if round(Demand(NF))>=DMax1

            page='http://192.168.1.2/state.xml?relay1State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);



        elseif round(Demand(NF))>=DMax2

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);

        elseif round(Demand(NF))>=DMax3

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
           s=urlread(page);
```

```
            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);

        elseif round(Demand(NF))>=DMax4

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=1 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);
        elseif round(Demand(NF))<DMax4

            page='http://192.168.1.2/state.xml?relay1State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay4State=1 HTTP/1.1\r\n';
            s=urlread(page);
        end


    % output to the switchs
     save -ascii Switch1.txt Switch1
     save -ascii Switch2.txt Switch2
     save -ascii Switch3.txt Switch3

 % graphs

    plot(Demand); hold on
    plot([1,length(Demand)],[DMax4,DMax4],'b--','LineWidth',2);
    plot([1,length(Demand)],[DMax3,DMax3],'y--','LineWidth',2);
    plot([1,length(Demand)],[DMax2,DMax2],'g--','LineWidth',2);
    plot([1,length(Demand)],[DMax1,DMax1],'r--','LineWidth',2);


   end
   end
```

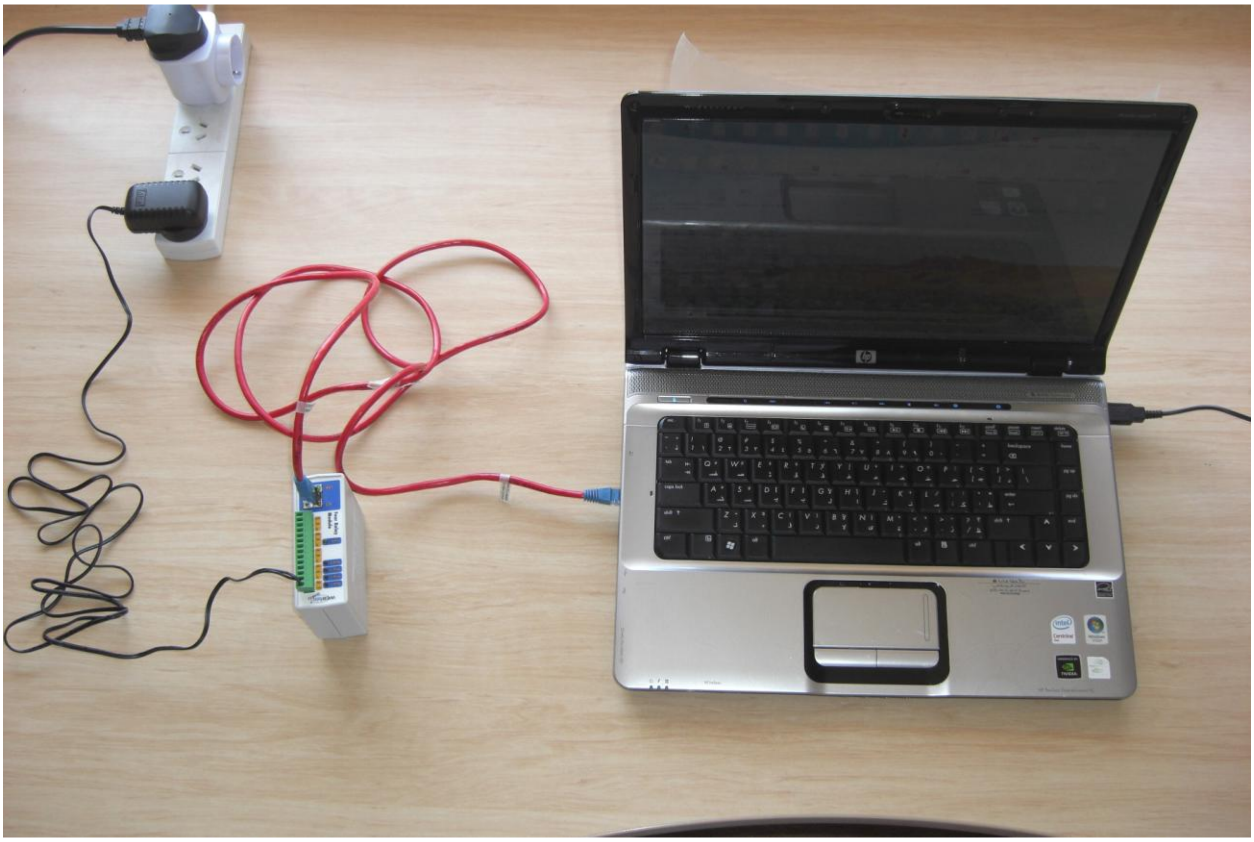
B) Price controlled

```
clear all;close all
clc;

%%%%%%
%open all 4 switches when the Price is => 28
PMax1=28;
%open only 3 switches when the Pricce is => 24
PMax2=24;
%open only 2 switches when the Price is => 20
PMax3=20;
%open only 1 switches when the Price is => 16
PMax4=16;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
n=0;
while n~=1;
    c = clock;
    c=fix(c); disp(c)
    c=fix(c(1:5));
   if (c(5)==30) || (c(5)==0)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     WebPage =
'http://www.nemweb.com.au/mms.GRAPHS/GRAPHS/GRAPH_30QLD1.csv'; % to open
the webpage includes data

    RWebPage=urlread(WebPage); % to read data from website (url)and save
them as s workspace

    data = textscan(RWebPage,'%*s %q %n %n
%s','headerLines',1,'delimiter',',');
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     % store data into variables
    When=data{1};
    Demand=data{2};
    RRP=data{3};
    Periodtype=data{4};
    % % convert When? in to date "dd/mm/yyy" and time "hh:mm"

    Convtime=cell2mat(When);

   %%%%
   for nn=1:length(When)

       DateTime(nn,1)=str2num(Convtime(nn,1:4));      %Year
       DateTime(nn,2)=str2num(Convtime(nn,6:7));      %Month
       DateTime(nn,3)=str2num(Convtime(nn,9:10));      %Day
       DateTime(nn,4)=str2num(Convtime(nn,12:13));     %Hour
       DateTime(nn,5)=str2num(Convtime(nn,15:16));    %Minute
       %DateTime(nn,6)=str2num(Convtime(nn,18:19));   %Seconds

   end
   %%%
```

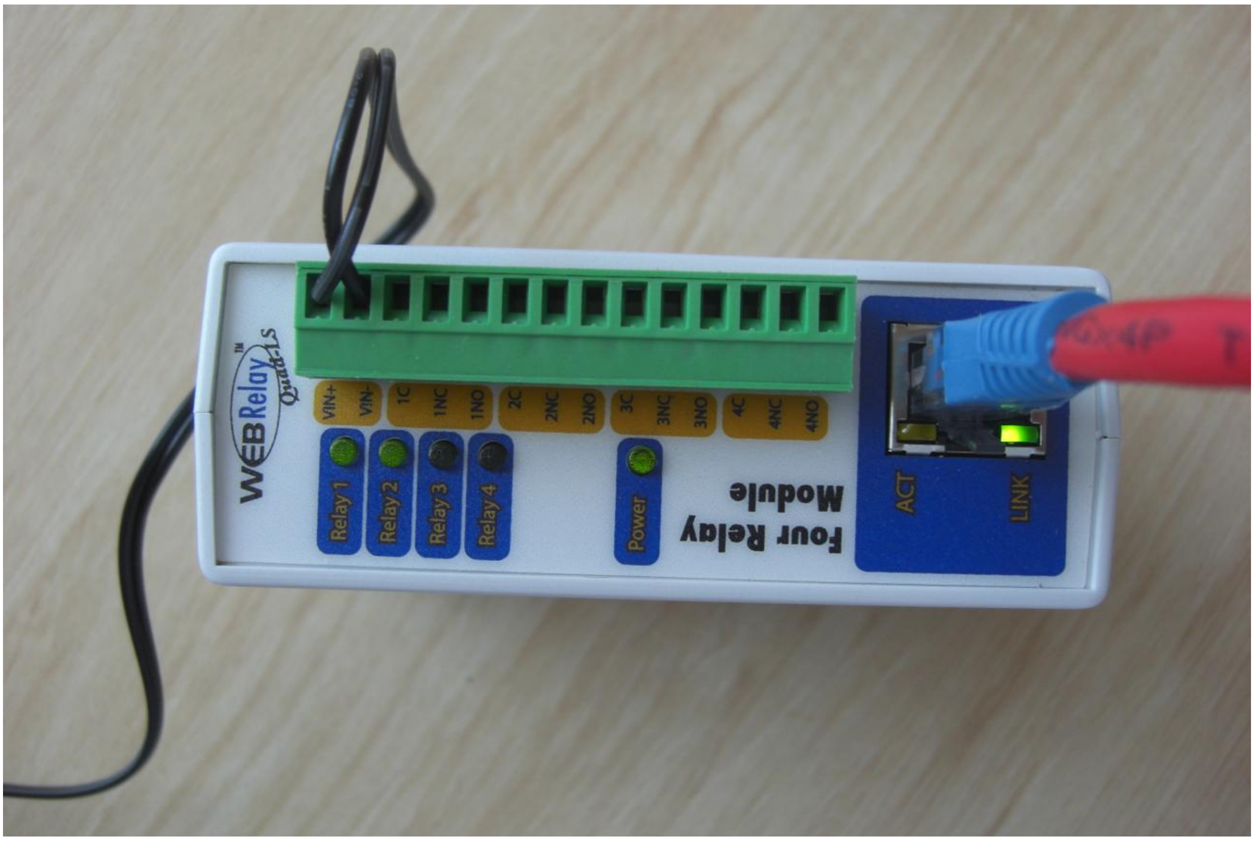
```
   %%%%%%%%%%%%%%%%%%%%%%
for nfind=1:length(DateTime(:,1))
    if DateTime(nfind,:)==c
        NF=nfind;
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%
    %  clear the textscan data
    clear data


    %%%%%%%%%%%%%%%%%%%%%%%

        if round(Demand(NF))>=PMax1

            page='http://192.168.1.2/state.xml?relay1State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);



        elseif round(Demand(NF))>=PMax2

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=0 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);

        elseif round(Demand(NF))>=PMax3

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=0 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
```

```
           s=urlread(page);

        elseif round(Demand(NF))>=PMax4

             page='http://192.168.1.2/state.xml?relay1State=1
HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
           s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=1 HTTP/1.1\r\n';
           s=urlread(page);

           page='http://192.168.1.2/state.xml?relay4State=0 HTTP/1.1\r\n';
           s=urlread(page);
        elseif round(Demand(NF))<PMax4

            page='http://192.168.1.2/state.xml?relay1State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay2State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay3State=1 HTTP/1.1\r\n';
            s=urlread(page);

            page='http://192.168.1.2/state.xml?relay4State=1 HTTP/1.1\r\n';
            s=urlread(page);
        end


    % output to the switchs

     save -ascii Switch1.txt Switch1
     save -ascii Switch2.txt Switch2
     save -ascii Switch3.txt Switch3

    % graphs

    plot(RRP); hold on
    plot([1,length(Demand)],[PMax4,PMax4],'b--','LineWidth',2);
    plot([1,length(Demand)],[PMax3,PMax3],'y--','LineWidth',2);
    plot([1,length(Demand)],[PMax2,PMax2],'g--','LineWidth',2);
    plot([1,length(Demand)],[PMax1,PMax1],'r--','LineWidth',2);


   end
end
```

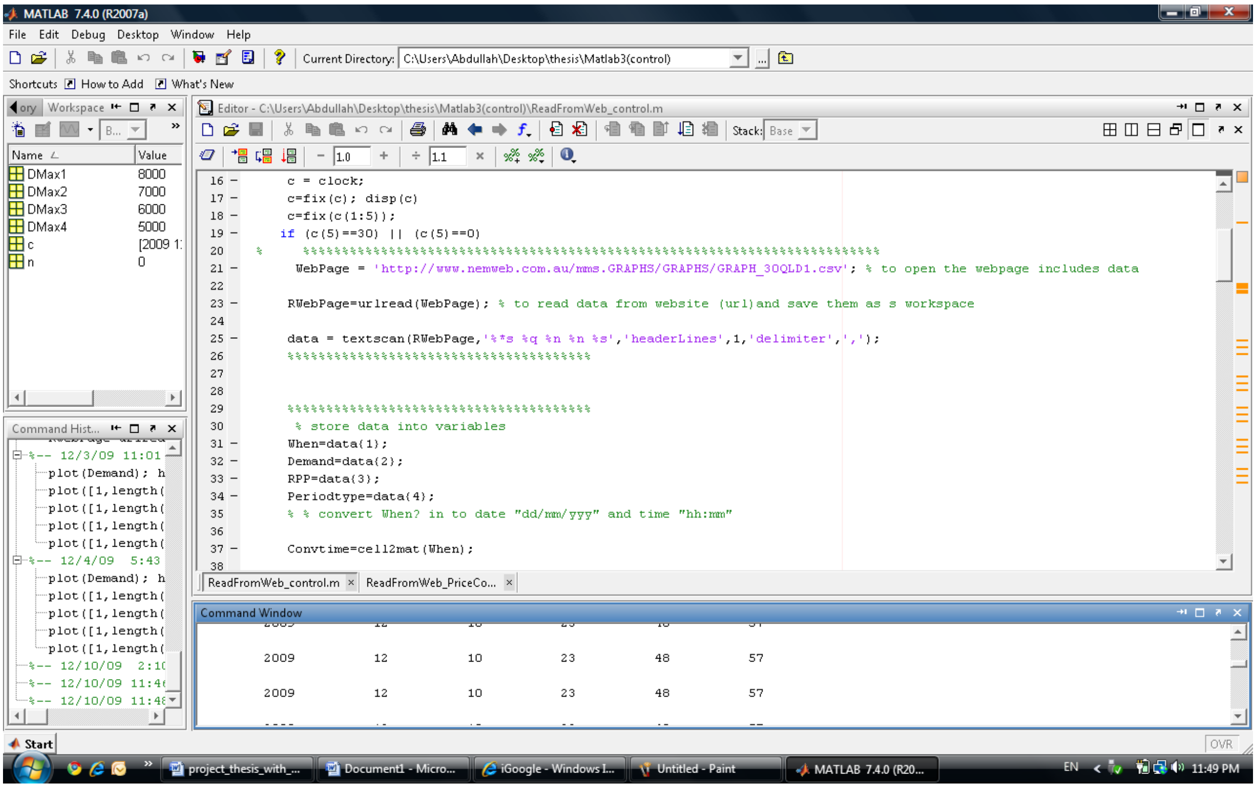
Appendix 3– Software results and photos



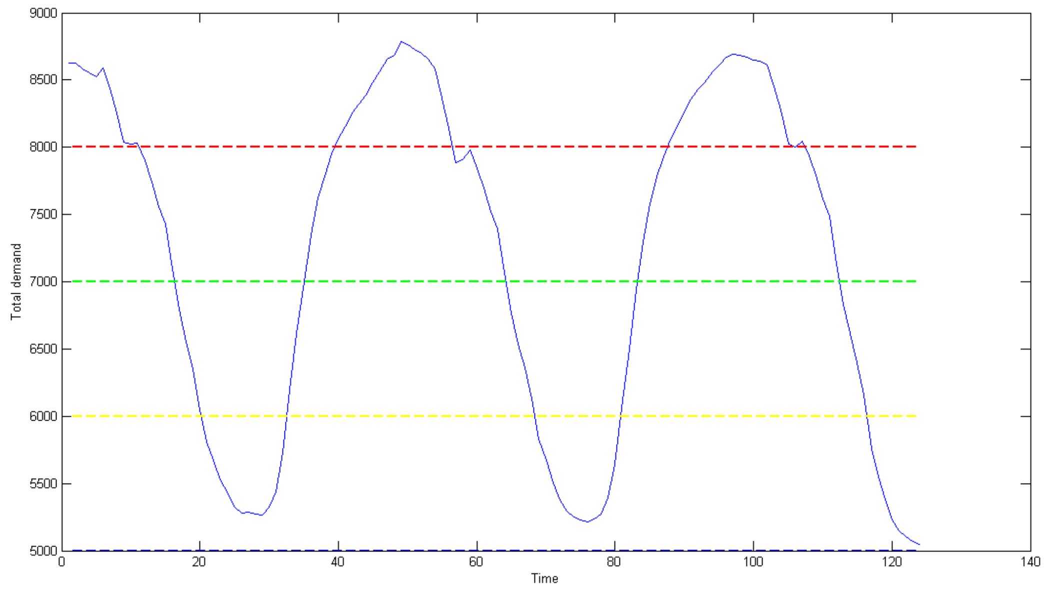
This photo shows the Web Relay connected to the computer for testing the performance of the software



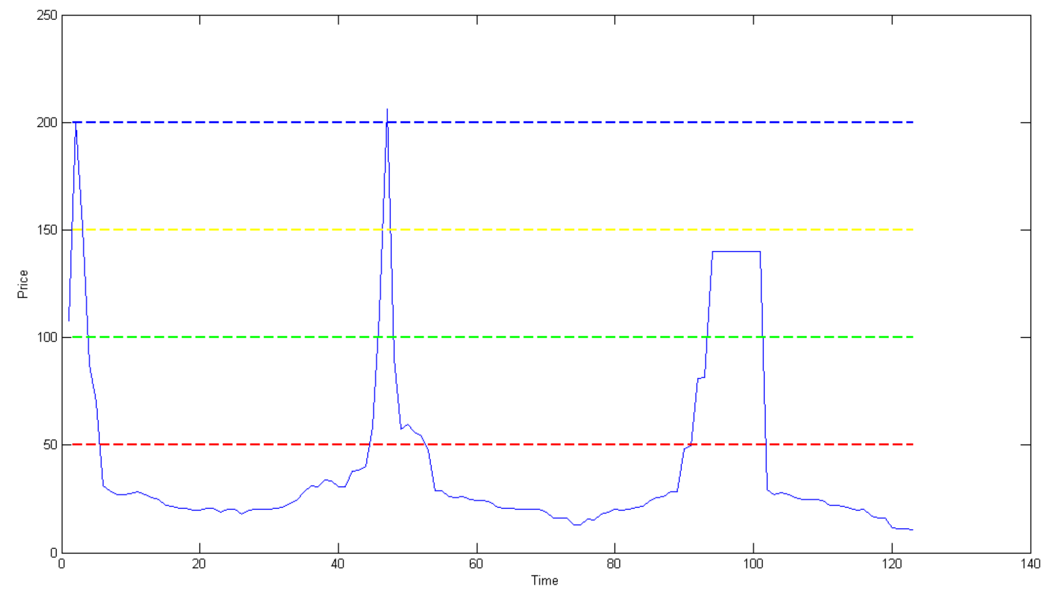
This photo shows the Web Relay LED indicators reaction according to the software commands. Relay 1 and 2 LEDs are turn ON While the other two (3&4) are off, indicating that two values are above the threshold limits.



This photo illustrates the written software usin MATLAB



Graph ploted by the software showing the demand curve and the set threshold limits



Graph ploted by the software showing the price curve and the set threshold limits