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Demand Side Response to Mitigate Electrical Peak Demand in Eastern and Southern Australia

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Abstract

The aim of this work is to develop a Demand-Side-Response (DSR) model, which assists electricity end-users to be engaged in mitigating peak demands on the electricity network in Eastern and Southern Australia. The proposed innovative model will comprise a technical set-up of a programmable internet relay, a router, solid state switches in addition to the suitable software to control electricity demand at user's premises. The software on appropriate multimedia tool (CD Rom) will be curtailing/shifting electric loads to the most appropriate time of the day following the implemented economic model, which is designed to be maximizing financial benefits to electricity consumers. Additionally the model is targeting a national electrical load be spread-out evenly throughout the year in order to satisfy best economic performance for electricity generation, transmission and distribution. The model is applicable in region managed by the Australian Energy Management Operator (AEMO) covering states of Eastern-, Southern-Australia and Tasmania.

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Keywords: Demand side response, electrical energy consumption, electricity network, mitigate peak demand

1. Introduction

The traditional user-supplier rapport in the electrical energy market has historically evolved following a strategy implying whenever a load is switched on it is expected to be fulfilled by the supplier at the expected time and quality. Growing electrical demands followed by constantly growing supply led to troubled electrical services manifested mainly by daily and seasonal excessive peak and low demands. Those chronic peaks on electrical networks are usually associated with compromised quality, risk of

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forced outages and high-priced energy supply; while low-demands on the other side may be driving power plants to be operating at critical economic viability. Demand-side-response (DSR) techniques are helping electricity users to become proactively participating in averting detrimental conditions presently prevailing on the electricity network [1].

2. Background

Fig 1 depicts an example of actual energy demand and price conditions regularly released on the internet by the AEMO [2]. The price pattern is closely following that of the demand. Electricity price is typically at its lowest level during times of low demand (off-peak) e.g. at night. Traditionally, price is soaring twice daily following morning and evening peak demands. For most residential consumers, electricity pricing doesn't vary; consumers typically pay a flat-rate regardless of day time.

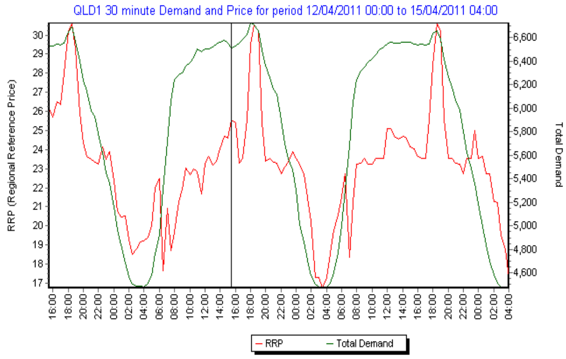

Fig. 1. Wholesale electricity prise in Queensland on 12th April 2011 [2] .

Fig 2 illustrates the occurrence of electrical demand in Queensland during the year 2010. Peak demand 8890.66 MW, base-load 4055 MW and total supplied electrical energy 52.324 TWh. The figure indicates mainly the fact, the higher the load above the base load the lesser likely the extent of its duration. Base load power stations are those operated at full rated capacity twenty four hours a day throughout the year corresponding to a plant capacity factor (PCF) of 1 providing thus the most economic operation and the least possible energy cost [3].

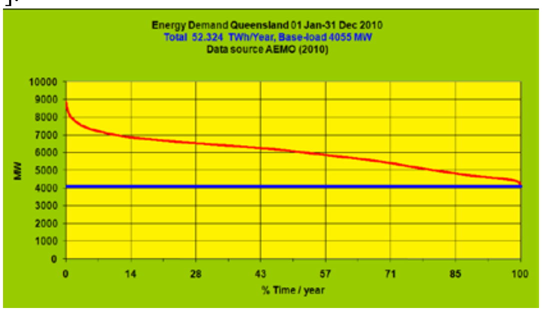

Fig. 2. Occurrence of electrical energy demand in Queensland during 2010 .

3. Electricity Industry Development in Australia

Generally, the electricity supply system has three interconnected main components: generation, transmission and distribution. Each of these components contributes to provide electricity to consumers.

Queensland total electricity generating capacity was 12487 MW in 2008. This power generation is used for residential, commercial and industrial consumers in Queensland [4]. However, the amount of energy produced from various generators depends on market demand, price and availability of sources. In 2008, 81% of electricity came from coal-fired power stations, while 15% from gas and 4% from renewable energy [4].

Most of the power stations are directly connected to the transmission system. The Queensland electricity transmission system is provided by Powerlink, licensed to operate more than 12,000 kilometres of Queensland high voltage transmission network, transporting electricity from the generators to the distribution networks [5]. The distribution network is carrying electricity from the transmission system to consumers. In Queensland, ENERGEX and ERGON energy are purchasing electrical energy from the Energy Spot Market and distributing it to the consumer. ERGON e.g. provides energy at several tariff options to end users. For example, Tariff 11 for all domestic consumption 18.84 ¢/kWh, while the night rate Tariff 31 for all consumption 7.7 ¢/kWh and the economy Tariff 33 for all consumption 11.32 ¢/kWh [6].

Since the beginning of the 1990s, Australia's electric power industry has undergone a series of structural reforms [7]. In Queensland, the electricity industry was restructured on 1 July 1998 to prepare the industry for participating in the competitive National Electricity Market (NEM), which is responsible for structure, rules and regulations in the delivery of energy to consumers [8]. The National Electricity Market Management Company Limited (NEMMCO) was the Wholesale Market and Power System Operator for the Australian NEM. NEMMCO was established in 1996 to administer and manage the NEM, develop the market and continually improve its efficiency and as of 1 July 2009 was replaced by the Australian Energy Market Operator (AEMO).

To improve governance, and enhance the reliability and sustainability of the state's electricity system, the Australian Government has created a collaborative electricity and gas industry in the AEMO [2], which commenced operation on 1 July 2009. The AEMO is managing power flows across the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Tasmania. Western Australia and the Northern Territory are not currently connected to this market primarily because of their geographic distance from the rest of the market. AEMO's responsibilities include wholesale and retail energy market operation, infrastructure and long term market planning demand forecasting data and scenario analysis [2]. The electricity market comprises of a wholesale sector and a competitive retail sector. All electricity dispatched in the market must be traded through the central spot market. The Market structure of NEMMCO / AEMO can be presented as in fig 3 [9].

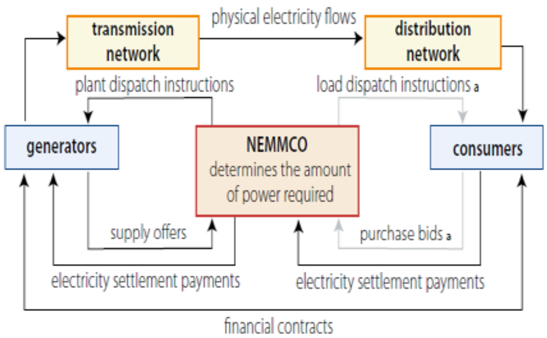

Fig. 3. The Market structure of NEMMCO/AEMO [9].

4. Smart Grid Technology and Demand Side Response in Australia

Demand side response (DSR), an integral part of the smart grid, is a cost effective, rapidly deployed resource that provides benefits to utilities and consumers [10]. Further on, demand response is a tariff or program established to motivate change in electricity consumption by end-users in response to change in the price of electricity over time [11].

The benefits of DSR programs apply to end-users and to electricity providers collectively. Some advantages are: increased economic efficiency of electricity infrastructure, enhanced reliability of the system, relief of power congestions and transmission constraints, reduced energy price and mitigated potential market power [12]. Based on a review of current utility programs, the Electric Power Research Institute (EPRI) estimates that DSR has the potential to reduce peak demand in U.S. by 45,000 MW [13]. Most importantly, by enabling end-users to observe electricity prices and congestions on the electrical network it allows consumers to be proactively sharing responsibility by reducing and optimizing energy consumption and experiencing electricity savings [14]. Therefore, the implementation of DSR programs is expected to improve economic efficiency on the wholesale electricity market.

In Australia, implementation of the DSR programs has been conducted several years ago. In late 2002, the Energy Users Association of Australia conducted a trial to demonstrate the benefits of a DSR aggregation process which would enable electricity consumers to respond to both the extreme prices and extreme peak demands [15]. This experiment was conducted by end-users to determine the value of an effective DSR for electricity consumers and its impact in terms of supporting an energy saving program. This trial was supported by the Victorian, New South Wales and Commonwealth Government, as well as the CSIRO, to implement a Demand Side Response Facility Trial [15].

In the experiment described above, the Australian Government through the EUAA involved consumers to participate in the DSR trial. This experiment was conducted in three regions that fall under the National Electricity Market operation, New South Wales, South Australia and Victoria [16]. These areas are regarded to represent the electricity load in Australia, and the results obtained show some significant benefits of using DSR for consumers and electricity providers. Hence, in December 2003 the Ministerial Council for Energy advised the Council of Australian Governments (COAG) on the need for further reform of the energy market to enhance active energy user participation [16].

5. DSR Popular Programs

Many different economic models are used to represent Demand Side Response programs (DSR). DSR is divided into two basic categories, namely: the time based program and the incentives based program [17]. The specific types of time based program are: time of use (TOU), real time pricing (RTP) and critical peak pricing [18]; while the specific types of incentive based program consist of direct load control (DLC), interruptible/curtailable (I/C), demand bidding (DB), emergency demand response program (EDRP), capacity market (CAP) and ancillary service markets (A/S) programs [19]. In the following a brief description of four popular market available programs: TOU, RTP, I/C and EDRP model.

5.1. Time of use

Time of use (TOU) is one of the important demand side response programs, which responds to the price and is expected to change the shape of the demand curve [20]. Further on, TOU rate is the most obvious strategy developed for the management of the peak demand in the world, which is designed to encourage the consumer to modify the pattern of electricity usage [21]. For applying this program, the utility does not provide reward or penalty to consumers. To participate, all consumers are required to remove their energy consumption during peak session to off-peak session as soon as their receipt information from the utility. The following fig 4 illustrates the type of hourly price variation consumers would face under the different TOU rates.

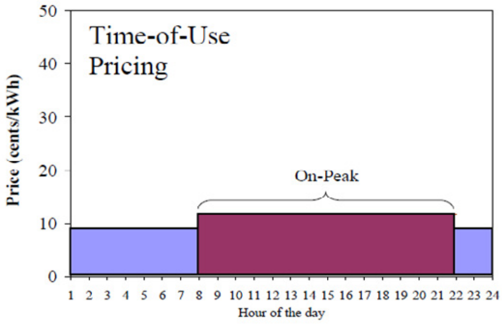

Fig. 4. Time of Use Pricing [19].

5.2. Real time pricing

Real time pricing (RTP) program gives to the consumer's to access hourly electricity prices that are based on wholesale market prices. These prices vary from hour to hour and day to day according to the actual market price of power. Higher prices are most likely to occur on peak session time (e.g. 05.00 PM – 09.00 PM). The consumer can manage the costs with real-time pricing by taking advantage of lower priced hours and conserving electricity during hours when prices are higher [19]. The following fig 5 illustrates how the RTP operate.

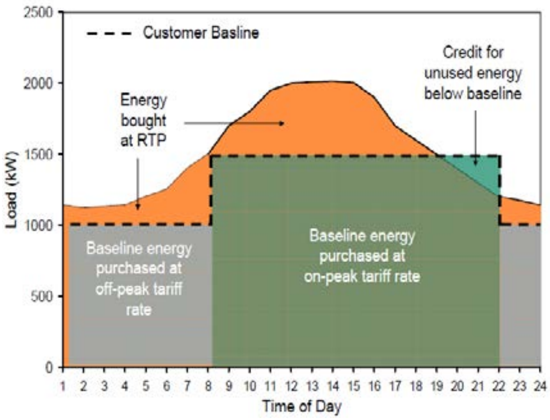

Fig. 5. Operation of Real Time Pricing [19].

5.3. Interruptible/Curtailable program

Interruptible/curtailable (I/C) program has traditionally been one of the most common DSR models used by electric-power utilities. In this program consumers sign an interruptible-load contract with the utility to reduce their demand at a fixed time during the system's peak-load period or at any time requested by the utility [22]. This service provides incentives/rewords to consumers participating to curtail electricity demand. The electricity provider sends directives to the consumers for following this program at certain times. The consumers must obey those directives to curtail their electricity when being notified from the utility or face penalties.

5.4. Emergency demand response program

Emergency demand response program (EDRP) is energy-efficient program that provides incentives to consumers who can reduce electricity usage for a certain time; this is usually conducted at the time of limited availability of electricity. EDRP provides participants with significant incentives to reduce load [23]. To participate on this program, all consumers are expected to reduce energy consumption during the events. This program will determine which houses must be included in the event to minimize cost and disruption, while alleviating the overload condition [24]. When asked to curtail, and verified to have performed, the consumer is paid as high as $500/MWh [25].

6. Methodology

This work aims at developing an integrated energy model that enables electricity consumers an automated control of energy consumption and optimized use of renewable energy sources. The main purposes of this control is for users to be averting peak-demand periods on the electrical network helping thus to mitigate detrimental impacts and risks of heavy congestions.

The model uses programmable internet relay, a router and solid-state switches to control electricity demand at user's premises. The relay is programmed to receive and act upon information received about electricity demand/price conditions from the Australian Energy Market Operator (AEMO) over the internet. In order to achieve the aims and objectives of this research, a multimedia tool was developed in frame of this research for use on user's premises, in order to enable users to effectively and continuously apply the model. Fig 6 illustrates the control regime, where three appliances are controlled by three solid-state switches receiving cycling signals from the relay.

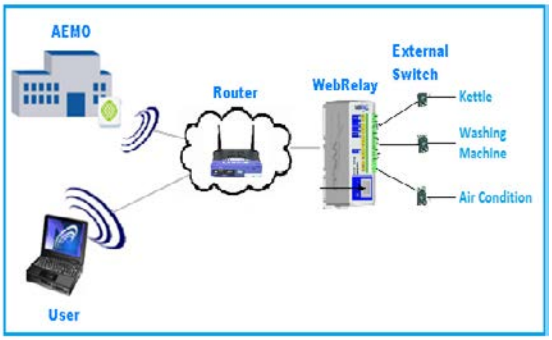

Fig. 6. Consumer's DSR Control

All control systems above are can be implemented by a shell script under a Linux or Windows operation system. The model is applicable for commercial and industrial consumers on fluctuating energy prices as well. The following fig 7 describes the proposed model.

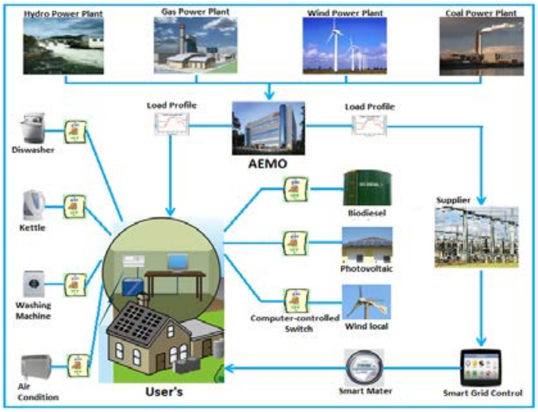

Fig. 7. Controlled Scenario

7. Analysis and Results

In order to evaluate the effect of the proposed scheme on electricity energy savings the electricity price/demand in Queensland for the period 10th-12th May 2010 was used. The following ten scenarios have been formulated to demonstrate the results as presented in figure 8 and summarized in table 1 and 2.

Table 1. Time of operating scenario

Nr	Time to curtail	Time to reconnect	Load to curtail MWh
1	17:00 PM - 19:00 PM	19:00 PM - 21:30 PM	375
2	17:00 PM - 19:00 PM	21:30 PM - 23:30 PM	375
3	17:00 PM - 19:00 PM	23:30 PM - 01:00 AM	375
4	17:00 PM - 19:00 PM	01:00 AM - 03:00 AM	375
5	17:00 PM - 19:00 PM	03:00 AM - 05:30 AM	375
6	17:00 PM - 19:00 PM	05:30 AM - 07:00 AM	375
7	17:00 PM - 19:00 PM	06:30 AM - 10:30 AM	375
8	10:30 AM - 19:30 PM	19:30 PM - 23:30 PM	1730
9	10:30 AM - 19:30 PM	23:30 PM - 01:30 AM	1730
10	10:30 AM - 19:30 PM	01:30 AM - 04:00 AM	1730

Table 2. Results of operating scenario

Nr	Day tariff 18.84 c/kWh ($)	Night tariff 11.32 c/kWh ($)	Saving ($)
1	70650	NA	NA
2	70650	49501	21149
3	70650	42450	28200
4	70650	42450	28200
5	70650	42450	28200
6	70650	42450	28200
7	70650	67125	3525
8	325932	277147	48785
9	325932	195836	130096
10	325932	195836	130096

Scenario 1. In this scenario users are shifting 375 MWh peak electricity usage occurring between 17:00 pm-19:00 pm towards the time period 19:00 pm-21:30 pm when energy demand and prices are low. All participants are suggested to set-up the electricity profile to stop chosen appliances from running during that time. For example, computer, water heating, lighting and laundry could be effectively operated at those times. No savings in energy cost due to applicable day-time tariffs. However, the scheme was still able to remove congestions out of peak demand times.

Scenario 2. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 21:30 pm to 23:30 pm. Achievable savings $21149/day.

Scenario 3. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 23:30 pm to 01:00 am. Achievable savings $28200/day.

Scenario 4. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 01:00 am to 03:00 am. Achievable savings $28200/day.

Scenario 5. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 03:00 am to 05:30 am. Achievable savings $28200/day.

Scenario 6. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 05:30 am to 07:00 am. Achievable savings $28200/day.

Scenario 7. Users are shifting peak demand of 375 MWh occurring between 17:00 pm-19:00 pm to the period between 06:30 am to 10:30 am. Achievable savings $3525/day.

Scenario 8. Users are shifting peak demand of 1730 MWh occurring between 10:30 am-19:30 pm to be operated between 19:30 pm to 23:30 pm. Achievable savings $48785/day.

Scenario 9. Users are shifting peak demand of 1730 MWh occurring between 10:30 am-19:30 pm to the period between 23:30 pm to 01:30 am. Achievable savings $130096/day.

Scenario 10. Users are shifting peak demand of 1730 MWh occurring between 10:30 am-19:30 pm to the period between 01:30 am to 04:00 am. Achievable savings $130096/day.

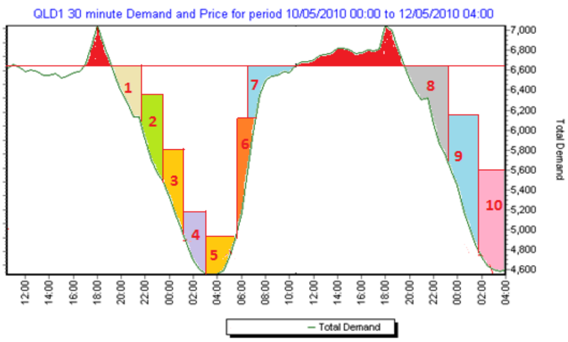

Fig. 8. Scenarios 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10

8. Conclusion

The proposed DSR concept is aiming to reduce energy price volatility by decreasing peak demand. A wide-scale deployment of this concept enables increasing grid reliability, reducing energy cost, and optimizing energy consumption, avoiding or delaying investments in new infrastructure. To achieve that, it allows electricity end-users to "smooth" significant peaks by curtailing or shifting demand. The user's DSR concept is effectively making use of the internet and modern communication systems to maximize benefit for the user and supplier. The technology is practically providing additional capacity more quickly and more efficiently than new supplies. The flexibility provided lowers the likelihood and consequences of forced outages as well. By reducing significant peaks, this concept helps averting the need to use the most costly-to-run power plants, driving electricity costs down for all electricity users.

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