ETSA UTILITIES AIR CONDITIONER DIRECT LOAD CONTROL PROGRAM - AUSTRALIA

INTRODUCTION

ETSA Utilities is the sole distributor of electricity in the State of South Australia, serving over 800,000 customers with a distribution network covering 178,000 square kilometres.

In September 2003, the electricity industry regulator, the Essential Services Commission of South Australia (ESCOSA), established processes that required ETSA Utilities to publish information regarding forecast limitations or constraints on the distribution system, and to seek proposals for non-network alternatives to address such constraints, including demand side management (DSM).

These processes address a significant barrier to successful take-up of DSM opportunities, ie a lack of publicly available information regarding distribution system constraints that might be addressed through DSM. ESCOSA's intention is that DSM providers will be able to assess opportunities and make bids to ETSA Utilities on the basis of the information provided.

The form of regulation imposed on ETSA Utilities by ESCOSA is expressed as a control placed on the average revenue ($/MWh) that ETSA Utilities can earn in a year. This form of regulation provides an incentive to ETSA Utilities to maximise energy sales, and conversely penalises ETSA Utilities if sales are below forecast levels (eg due to greater than expected impact of DSM measures).

To reduce the disincentive to implement DSM, ESCOSA incorporated into its regulatory determination a correction factor designed to reduce the financial risks faced by ETSA Utilities because of variations in forecast sales. This factor is more directly relevant to application of energy efficiency measures than to reduction of peak demand, but may be relevant to peak reduction measures that also reduce energy sales (eg installation of more efficient reverse cycle air conditioners).

In addition, ESCOSA approved an amount of AUD20.4 million (December 2004 values) as operating expenditure over the 2005-2010 regulatory period for ETSA Utilities to trial specified network DSM measures that may reduce the requirement for peak-driven network expansion. The DSM measures mandated by ESCOSA comprised:

- power factor correction;
- direct load control;
- voluntary and curtailable load control;
- standby generation;
- critical peak pricing; and
- aggregation of demand reductions.
DRIVERS FOR THE PROGRAM

South Australia has a very peaky electricity demand profile. Figure 1 shows the electricity demand profile on the ETSA Utilities network on 17th March 2008, the last day of Adelaide's record 15 day heat wave with temperatures consistently above 35°C, when demand peaked at just over 3,000 MW. In Figure 1, this peak day load profile is compared with the average daily load profile for the 2008 summer. Figure 2 shows that 20% of the capacity of the distribution system in South Australia is used for 2% of the time during the year.

Figure 1. Peak Day Load Profile for the ETSA Utilities System, 17 March 2008, Compared with Summer Average Load Profile

Figure 2. Load Duration Curve for the ETSA Utilities System, 2007/08
The major contribution to the peak is from the residential sector, particularly air conditioning use on hot days. ETSA Utilities estimates that peak demand on hot days, primarily due to air-conditioning load, is about 1,000 MW higher than average daily peak demand over the summer.

PROGRAM IMPLEMENTATION

To implement the DSM program funded through the ESCOSA determination, ETSA Utilities is identifying a range of possible projects within each of the program’s approved categories of DSM measures. The suggested projects are short-listed by a Steering Committee on the basis that the projects are meritorious, are consistent with the regulator's determination, meet budgetary expectations, and have good prospects of producing net benefits in a widespread network roll-out.

In June 2008, the DSM program portfolio consisted of 27 individual projects at various stages of implementation. Several of these projects involved direct load control (DLC) of air conditioners.

DLC Phase 1: Summer 2005/06

An initial trial of DLC technology applied to residential air conditioners was launched in the summer of 2005/06. The primary aim of this trial was to determine customer perception of change in comfort levels resulting from the remote management of domestic air conditioners. Secondary aims were:

- to determine the impact on aggregate demand for the sites in the trial;
- to gain experience in the installation and operation of proprietary DLC technology;
- to test the performance of the selected DLC technology; and
- to gain experience in quantification, metrics and verification.

The trial involved 20 residential customers in the Adelaide metropolitan area. Customers were paid an incentive of AUD100 to participate. The customers were recruited by demographic, geographic area and equipment type. During the trial customers were able to contact a named ETSA staff person to provide feedback and to report adverse impact or problems. After the trial customers were de-briefed on the results of the trial and their perceptions were recorded.

A variety of reverse cycle air conditioners (either split or ducted) were included in the trial. Only air conditioners with an electrical load in excess of 2.5 kW were selected. The compressor load of the air conditioners in the trial ranged from 2.5 to 10.3kW, with the average being 4.27kW.

The air conditioners were controlled using Comverge load control units (LCUs) that had the capacity to cycle air conditioner compressors. The LCUs were located external to the customer premises adjacent to the air conditioner compressor unit (see Figure 3). Each LCU had two integral relays rated at 5 and 30 amps. The relays could be remotely controlled using a variety of communication media. For practical purposes, in this trial ETSA’s radio network was used as the communication medium. Each sample site was also fitted with an interval meter for load monitoring purposes.
Application of direct load control occurred during a period of high temperature days in March 2006. Cycling strategies involved compressors being switched off (with fans continuing to operate) for either 7.5 minutes or 15 minutes in each 30 minute period during the late afternoon (see Table 1).

### Table 1. Application of Direct Load Control in the ETSA Utilities Air Conditioner DLC Phase I Project, March 2006

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Maximum External Temperature (°C)</th>
<th>Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 March</td>
<td>16.15 to 17.15</td>
<td>36</td>
<td>7.5 min off in 30 min</td>
</tr>
<tr>
<td>3 March</td>
<td>16.05 to 18.05</td>
<td>35</td>
<td>7.5 min off in 30 min</td>
</tr>
<tr>
<td>4 March</td>
<td>14.15 to 16.15</td>
<td>35</td>
<td>7.5 min off in 30 min</td>
</tr>
<tr>
<td>11 March</td>
<td>16.30 to 18.30</td>
<td>37</td>
<td>15 min off in 30 min</td>
</tr>
<tr>
<td>12 March</td>
<td>12.09 to 14.09</td>
<td>34</td>
<td>15 min off in 30 min</td>
</tr>
</tbody>
</table>

**DLC Phase II: Summers of 2006/07 and 2007/08**

Based on the results of the initial trial, a much larger air conditioner DLC pilot program was developed for the summers of 2006/07 and 2007/08. An area in metropolitan Adelaide (Glenelg/Morphettville) was selected for this project. This area was chosen because it is supplied by two substations that are expected to become constrained by 2011. In the absence of initiatives to reduce peak demand, augmentation of the distribution network would be required by that date.
A target load reduction of 2.2 MVA was established for the pilot program.

The objectives of DLC Phase II were:

- to further test customer acceptance;
- to gain further experience with DLC technology; and
- to assess the impact and ultimately the potential for wide scale roll out of the technology.

ETSA Utilities initiated DLC Phase II in June 2006 with a media marketing and community education campaign, entitled “Beat the Peak”. The campaign primarily targeted the 12,000 residential customers in the selected region and was designed to secure volunteers to participate in the program. Participating customers were offered a cash incentive of AUD100. A direct marketing campaign (mailout, local advertising, etc) was also used. The marketing campaign attracted significant media coverage, with general support expressed for DSM.

Approximately 4,000 residential customers expressed interest in participating in DLC Phase II as a result of the overall marketing campaign. From this response, ETSA Utilities identified about 1,700 residential air conditioners that were suitable for the program, comprising either split or ducted refrigerative systems. In many cases, air conditioners were deemed unsuitable, being either window installed or portable refrigerative systems, ducted or portable evaporative systems, or ceiling fans.

ETSA Utilities also visited every commercial customer in the trial area and identified a further 700 air conditioners in commercial premises that were suitable for the trial.

In total, about 2,400 air conditioners were identified for DLC Phase II. To monitor demand impacts during the project, ETSA Utilities installed metering equipment in some customer premises, as well as on ten 11 kV feeders and 86 street transformers.

For DLC Phase II, ETSA Utilities, in conjunction with the Adelaide-based Saab Systems Pty Ltd, developed a small DLC device (the “Peak Breaker”) to be attached to the external compressor of air conditioners (see Figure 4). This device requires only a simple installation procedure lasting up to 30 minutes with no internal access to premises needed.

However, about half of the 2,400 air conditioners initially deemed suitable for the pilot program were found to be “new generation” units with advanced internal electronic diagnostics that effectively prevented the Peak Breaker from overriding the compressor. These air conditioners were unsuitable for the installation of the Peak Breaker.

The penetration of new generation air conditioners was far higher than had been expected (the air conditioning industry had advised a likely figure of 10%). Ultimately, ETSA Utilities determined that approximately 1,100 (from the sample of 2,400) air conditioners were suitable for installation of the Peak Breaker, while a further 1,160 new generation units would require the development of a different form of DLC device. Consequently, the DLC Phase II project was subdivided into Phase II(a) and II(b) catering for both “Type I” and “new generation” air conditioning units.
Figure 4. Saab Systems “Peak Breaker” Direct Load Control Device Used in the ETSA Utilities Air Conditioner DLC Phase II Project

DLC Phase II(a)

For the summers of 2006/07 and 2007/08, approximately 750 air conditioners (from the pool of 1,100) were fitted with the simple “P1” Peak Breaker device that switched the air conditioner compressors directly. The system for communicating with the devices is shown in Figure 5. The Peak Breakers were activated in a random sequence when signals were sent via the internet to a public radio station which then transmitted the signals to the Peak Breakers. The system was able to communicate with subsets of the Peak Breakers based on substation, product group or individual customer level. Switching the “P1” controllers was performed by ETSA Utilities personnel who had access to the switching system. The switching signals were sent via FM radio from a radio transmitter tower.
Site level monitoring with interval meters was carried out during peak demand days at 90 randomly selected sites, with the remaining sites being monitored at the street transformer level. Monitoring also occurred through the SCADA system operated by ETSA Utilities to demonstrate the impact at the 66 kV sub-transmission system at times of peak demand. In addition, the distribution transformers and 11 kV substation feeders were equipped with metering equipment with remote communications capability allowing interval data to be collected as required.

Application of direct load control at the 750 sites commenced in December 2006. A range of control strategies were tested at various times on peak demand days, including cycling the air-conditioners for different lengths of time over different periods of the day. The following switching periods were used to assess the impacts of different switching protocols:

- 8 minutes off in 30 minutes;
- 15 minutes off in 30 minutes (the ‘normal’ switching period used in the United States);
- 30 minutes off in 60 minutes – used twice on selected street transformers;
- 25 minutes off in 60 minutes – used for one period.

Switching of 15 minutes off in 30 minutes was tested on four occasions and no customer complaints were received regarding comfort levels. ETSA Utilities concluded that residential air conditioning customers can sustain that level of switching.
DLC Phase II(b)

The aim of this project was to trial the operation and installation of enhanced DLC systems on “new generation” air conditioners using “P2” and “P3” DLC controllers.

“P2” controllers were installed on “new generation” Daikin ducted air conditioners and required an additional component to the “P1s”. This was an interface card (a standard Daikin accessory) that was installed at the same time as the Peak Breaker.

“P3” controllers were for “new generation” air conditioners from a range of other manufacturers and required an additional device known as an “emulator” to be installed as an integral component of the Peak Breaker installation. The installation procedure was different for different air conditioning systems and could take up to 120 minutes and require entry into the home and access to the head unit for the air conditioner inside the home’s roof space.

Given the complexity of the installation process, only 54 “P2” and seven “P3” DLC controllers were installed.

One important operational conclusion from DLC Phase II was that achieving effective load reductions requires a random overlapping switching protocol. Simultaneous switching early in the switching period caused a ‘sawtooth’ effect on the demand profile (as shown in Figure 6) with repetitions of a majority of the load switching early in the switching period and little load switching later. This ‘sawtooth’ effect negated any peak reduction. Randomised switching of individual loads required monitoring to ensure that the managed load was evenly distributed throughout the entire switching period. A process of reassigning the DLC units into distinct controllable segments, so as to overcome the ‘sawtooth’ effect, allowed the load to be more evenly switched during each control event.

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**Figure 6. An Example of the “Sawtooth” Effect from the ETSA Utilities Air Conditioner DLC Phase II Project**
DLC Phase III: Summers of 2006/07 and 2007/08

DLC Phase III drew on the findings of the Phase II(a) and II(b) projects and in addition targeted the northern suburbs of Mawson Lakes and Northgate in the city of Adelaide plus the regional centre of Murray Bridge.

Specifically this project aimed:

● to gain more information on the cost benefit of DLC for large ducted air-conditioners;

● to gain further information on the effect of DLC on distribution networks;

● to gather information on the possible maximum customer participation in DLC programs; and

● to compare the impact of DLC in the targeted areas compared with the impact in other geographical areas.

The total sample pool for all three areas was 1,100 potential participants, selected on the basis of their network connection type, tariff assigned and summer consumption. All of the potential participants are characterised by having three phase power, being on residential tariffs and having high summer consumption compared to their annual consumption.

Of the pool of 1,100 customers the most suitable comprised 465 units in Mawson Lakes, 300 units in Northgate and 40 units in Murray Bridge requiring either “P1”, “P2” or “P3” controllers. Ultimately after a concerted recruitment campaign, 125 units at Mawson Lakes, 12 at Northgate and 5 at Murray Bridge were installed. These installations were monitored by interval meters.

For the DLC Phase III project, there was a total of 935 installations in the homes and commercial premises of volunteers in Adelaide suburbs and South Australian country locations. The Peak Breaker device was improved and adapted to over 50 different types of air conditioners. ETSA Utilities provided a comprehensive 24 hour support service and developed a sophisticated digital control system that allows tailored switching on an individual customer level. Customer parameters can be changed remotely even during switching events.

The main locations for DLC Phase III were Mawson Lakes and Glenelg. Mawson Lakes is a new suburb located on 620 hectares in the northern Adelaide metropolitan area about 12 kilometres from the CBD and 10 kilometres inland from the coast. Glenelg on the other hand is an old established Adelaide suburb, dating back to the founding of Adelaide in 1836, on the coast with a diverse mix of house styles, construction and architecture.

In general, houses in Mawson Lakes have larger indoor open plan areas than those in Glenelg and are reliant on air conditioning to maintain comfort levels during temperature peaks of either heat or cold. Also, temperatures in Mawson Lakes during the summer tend to be two to three degrees higher than those experienced in the coastal Glenelg area and Mawson Lakes tends not to have the cooling effects of an afternoon sea breeze.

A particular study of the effect of DLC switching was carried out during a period of hot weather in March 2008. To allow statistical analysis to be undertaken, participants from Glenelg and Mawson Lakes were paired based on air conditioner input power.
requirements. Each member of a pair was then allocated to different groups and switched on alternate days (two groups per trial area). Only one member from each pair was switched for each DLC event. This methodology accounted for: differences in the types of air conditioners between Mawson Lakes and Glenelg; Mawson Lakes having on average larger air conditioners; and Glenelg having a broader range of air conditioner sizes.

The air conditioner compressors were switched over a cycle of 15 minutes off and 15 minutes on. Base load was calculated for each participant using the load data recorded on mild days during March 2008 and air conditioner load was calculated by removing the base load.

RESULTS

DLC Phase I

The results of DLC Phase I showed that the external control of air conditioners significantly reduced the electricity demand of the sample customers, and that no reduction in thermal comfort level accompanied the reduced demand.

For example, Figure 7 shows the aggregate demand on 11 March 2006 for the houses involved in DLC Phase 1. Each bar in the chart represents the total average demand in a half-hour period. The area highlighted in red shows the period under direct load control when the air conditioner compressors were switched off for 15 minutes in each 30 minute period. It is clear that aggregate demand was reduced during the control period.

![Figure 7. Aggregate Demand on 11 March 2006 for the Houses Involved in the ETSA Utilities Air Conditioner DLC Phase I Project](image)

The approximate load reduction resulting from cycling of compressors in the initial trial was 5 kW in a total demand of about 30 kW, ie a reduction of about 17%. Customers reported no reduction in their thermal comfort levels, with several commenting that they noticed no difference at all.
DLC Phases II and III

Figure 8 demonstrates the impacts on peak demand resulting from the cycling of air conditioners in a group of 68 premises in Glenelg. The Figure shows the aggregate load profile, with no load curtailment, for days with maximum temperatures of 35 degrees and 40 degrees Celsius, and the average profile for those two days.

Figure 8 also shows the profile for a day with maximum temperature of 36 degrees Celsius in which the air conditioner at each premises was cycled between 4pm and 7.30pm. A significant reduction in peak demand was achieved for this day, equivalent to about 40 kW, in comparison with the average peak demand of the two days for which there was no air conditioner cycling.

![Graph](image-url)

**Figure 8. Load Reductions Achieved in the ETSA Utilities Air Conditioner DLC Phase II Project**

Figure 9 shows a significant load reduction of about 150 kilowatts achieved across 187 homes in Glenelg and Mawson Lakes during a DLC event from 3.30 to 7.30 pm on a very hot day in March 2008.

Figure 10 illustrates the impact of a DLC event on separate groups of participants in Glenelg and Mawson Lakes. It can be clearly seen that DLC has an impact under all circumstances but that its impact was more pronounced in Mawson Lakes than in Glenelg because of housing composition, mix and diversity and distance from the coast. Another important feature highlighted by Figure 10 is that because Mawson Lakes is a newer suburb with homogeneity of housing style and reliance on air conditioning, more load reduction can be achieved there during a DLC event than in more established suburbs such as Glenelg.
Figure 9. Load Reductions Achieved in the ETSA Utilities Air Conditioner DLC Phase III Project

Figure 10. Load Reductions Achieved by Separate Groups of Participants in the ETSA Utilities Air Conditioner DLC Phase III Project
The average reduction for Glenelg and Mawson Lakes is shown in Table 2. This table shows that the load reduction from a DLC event is highly dependent on location. Also, the load reduction is highly variable as illustrated by the standard deviation of the load reduction in Table 2.

### Table 2. Average Load Reduction Achieved in the ETSA Utilities Air Conditioner DLC Phase III Project

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Air Conditioner Capacity (kW)</th>
<th>Average kW Reduction per A/C</th>
<th>Standard Deviation kW Reduction per A/C</th>
<th>95% Confidence Interval for Proportion of A/C Capacity Reduced by DLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenelg</td>
<td>3.08</td>
<td>0.45</td>
<td>1.88</td>
<td>(0.057, 0.214)</td>
</tr>
<tr>
<td>Mawson Lakes</td>
<td>5.07</td>
<td>1.34</td>
<td>3.01</td>
<td>(0.155, 0.354)</td>
</tr>
</tbody>
</table>

Figure 11 shows the demand (kW) for DLC activated households during the periods immediately prior to (the “fore” period), and during, a DLC event.

![Figure 11](image.png)
Statistical analysis of these results show that the households participating in the trial can be divided into four categories illustrated by four regions in Figure 11:

**Region 1:** These are households with low demand in both periods. It is reasonable to infer that no significant air conditioner usage occurred in these households and that a DLC event did not reduce load.

**Region 2:** These are households with low demand in one of the two periods. This could happen if, for example, the air conditioner was off during the fore period and on during the DLC period.

**Region 3:** These are households where the demand was high and differed little between the two periods. It is reasonable to infer that for these households there was a significant source of load not controlled by DLC.

**Region 4:** These are households where the demand was high in both periods but significantly lower during the DLC period. It is reasonable to infer that these were the households in which DLC had the intended effect.

The interpretation of the demand patterns suggests that the impact of a DLC event is likely to be lower than its theoretical maximum (eg 50% for a 15 minutes off, 15 minutes on switching protocol) because not all houses will be using their air conditioners during a DLC event.

*This article was contributed by David Crossley, Managing Director of Energy Futures Australia Pty. Ltd and Senior Advisor at The Regulatory Assistance Project. For more information on this case study and others, visit Task XV, Network Driven DSM at:*  