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## **Engineering Challenges and Innovation in Power Engineering**

**– Perspectives from my 2008/09 Vocational Employment**

### **Experience**

**Australian Power Institute Essay Competition**

**2008/09 Placement in the Network Performance Division – ENERGEX**

In the current economic, resource and carbon constrained climate, it is imperative that power distribution companies invest in only necessary network augmentation. However, with electricity demand growth over recent years doubling the electricity consumption growth, capital expenditure is following in a similar fashion relative to operational expenditure [1]. The need for greater infrastructure capacity is primarily driven by peak demand. The cause of this peak demand is from multiple customers using electricity concurrently, particularly during extreme hot / humid weather when air conditioning systems are in use. This objective of this essay is to detail the challenges facing the power engineering industry identified in my 2008/09 vocational employment experience.

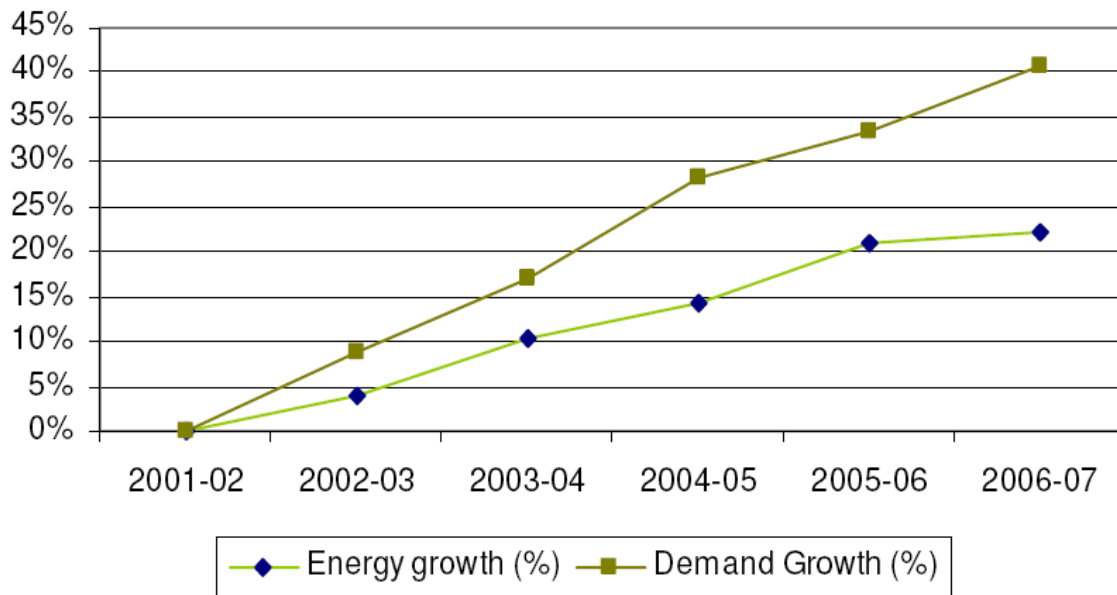
In the 2008/09 summer I was privileged to gain valuable experience in ENERGEX's Network Performance division. ENERGEX is a government owned corporation with over 85 years of industry experience and \$7.3 billion in total assets, distributing energy to approximately 2.8 million homes and businesses in South East Queensland [2]. My main task over the course of employment was

construction of an industry report entitled 'Small Scale Photovoltaic Generation Metering and its Effect on the ENERGEX Network.' This report investigated the impact of solar photovoltaic systems on ENERGEX's residential, commercial and industrial load curves, with particular concentration on the different metering schemes available for grid-connected systems.

As a member of the Demand Management group, a large proportion of my initial weeks of tenure was spent gaining an understanding of the purpose of the department. As a result, it has been identified that a suitable topic for challenges presented in the power engineering industry is that of reducing peak demand on assets across the ENERGEX distribution network in order to facilitate network augmentation deferral.

I would like to extend my sincerest gratitude to the Australian Power Institute Committee and Partners and ENERGEX for the opportunity presented over the 2008/09 summer in the Vacation Engineering Student Program.

For the 30 years leading up to 2006, there was an increase in Australia's total energy consumption of 107% [1]. By 2020, CSIRO predicts that electricity demand will double from Australia's 2006 value [3]. Further, Australia's peak demand is growing at a rate twice the increase in the base demand growth [4]. This is of relevance to the distribution network service providers as they are required to maintain a network capable of servicing the peak demand, not only base. Figure 1 depicts annual energy and demand growth within the ENERGEX network; with recent years' demand growth approximately double the energy growth.



**Figure 1: Cumulative energy and demand growth within ENEREX [5].**

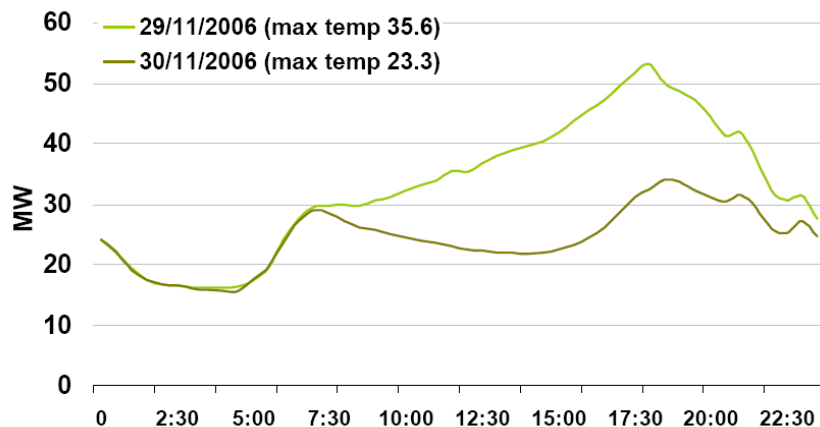
The difference between energy consumption and demand is that consumption is a measure the total quantity of energy used (kWh), while demand is the instantaneous rate of consumption [6], or level of load on the system [7] (kW / kV.A). The capacity of a network is the largest amount of instantaneous demand it can supply [6].

The traditional method of accommodating peak demand is constructing additional infrastructure. In the 2007-08 fiscal year, ENEREX's network capacity was increased by 552 MV.A, with over \$950million invested in building and maintaining the network [2]. However, the top 10% of load (12.5% of network capacity) occurred for less than 1% of the same year [8]. This corresponds to approximately 3 days, making the network reinforcement relatively expensive for such a short duration of time and therefore an inefficient use of capital [5]. In addition, electricity consumers are unlikely to be made aware of the impacts of their peak demand, as they pay an average price for electricity [5] and

residential customers are typically only made aware of their consumption (rather than demand) [6].

An alternative to the traditional method of coping with network peaks is to reduce their severity. Demand management is the range of techniques applicable to altering the demand patterns of customers, with the intent of deferring network augmentation. This has the potential to improve the utilisation factor of network assets, calculated as the peak demand divided by rated capacity.

It is the residential customers that tend to have the most substantial peaks throughout the day, generally between 6 and 8pm, accounting for almost 50% of ENERGEX's network load at the time [9]. This peak is significantly exaggerated with hot summer weather, with increases in peak demand on *consecutive* days historically being as great as 65% (see Figure 2) [8].



**Figure 2: Impact of temperature on local demand on ENERGEX's Albany Creek substation [8].**

Air conditioning is a main driver of the record summer peak demand, not just a contributor to the consumption of electricity [2]. In 2005, approximately 35% of summer peak demand was attributable to air conditioning [9]. The penetration of

air conditioners increased to 65% in 2007/08, from 45% in 2003/04 [2], and so it is reasonable to assume that the household cooling contribution to summer peaks has consequently increased since 2005. Air conditioners are designed to turn their compressors off when they have reached a desired temperature and cycle with their fans on [10]. Direct load control may be implemented to control the time and duration air conditioner systems are cycling, as demonstrated in ENERGEX's Time for a Cool Change trial [2]. The trials of over 900 residents in the Albany Creek / Arana Hills area resulted in a 17% reduction in peak demand being obtained [2]. Importantly, over 90% of the customers reported either negligible or no impact on their household comfort levels during the trials on the top nine hottest days of the summer [2].

Direct load control is the remote operation of loads that can be temporarily interrupted/cycled without major negative impacts on the consumers (such as thermal loads, including hot water systems, air conditioning and refrigeration, that can retain thermal energy for amounts of time without power), and is one of the many examples of non-network solutions for deferring network augmentation. Other techniques include distributed generation, load shifting and pricing initiatives, as detailed below.

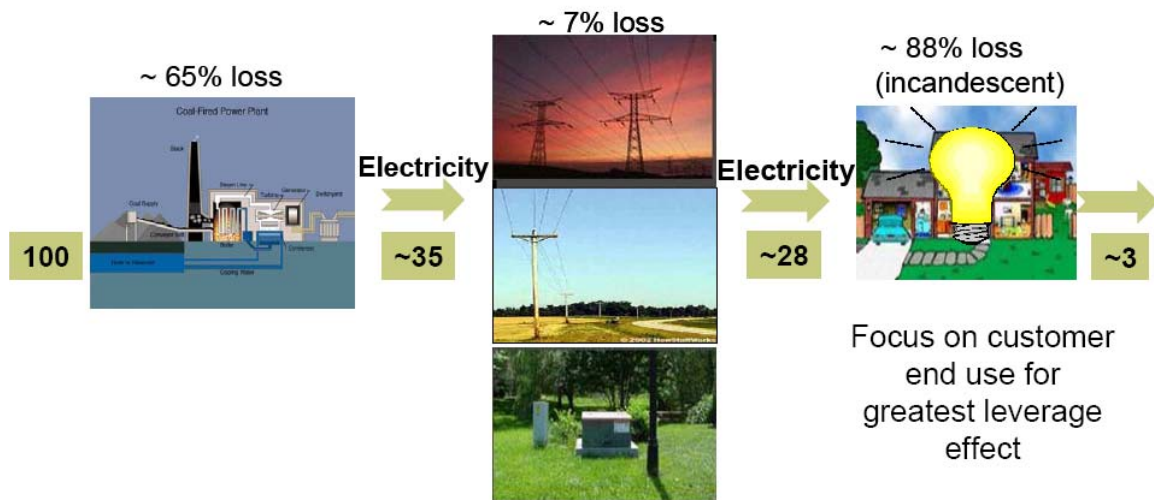
Distributed generation targets portions of the network under stress with energy injected close to the load it serves, reducing the demand on the asset that would otherwise supply the load, with the added benefit of reduced distribution losses. Portable generators may be used to provide contingency support during peak periods [11]. ENERGEX has a mobile generation fleet of 37 60-500 kV.A low voltage and four 1.25 MV.A 11 kV generation units, totaling 21 MV.A capacity [11]. Additional low voltage generators are hired if necessary (as decided each August / September) for feeder contingency support during extreme summer events.

Load shifting targets the time of use of peak loads that can be run in the troughs, rather than peaks, of the daily zone substation / feeder load curves. Not all loads are shiftable (e.g. lighting), but others (e.g. washing machines) may be moved without negative effects to the consumer, while flattening the customer's usage curve. ENERGEX negotiates each year (since 2006/07) with customers with suitable shiftable load, standby generation, or agreements with ENERGEX to locate generators onsite, that are located in areas which required additional support for network load at risk over the summer [11].

Pricing initiatives aim to particularly alter the time at which electricity is being consumed by customers by providing price signals to consumers at times of peak electricity demand [12]. This is implemented with variable prices charged for electricity, depending on the demand and time of use during consumption. ENERGEX currently employs tariffs structures for large customers (consumption of over 100 MWh per annum) that incorporates demand and time of use charges, in addition to the standard fixed and volume charges [7].

Some incentives incorporate multiple techniques mentioned, for example off-peak hot water heating economy rates. These tariffs (31 and 33) offer cheaper electricity rates in exchange for control of availability of power to the permanently connected domestic equipment [13]. This integrates aspects of off-peak pricing initiatives for customer participation encouragement, direct load control to manage the (generally thermal) equipment, to achieve controlled load shifting. This has the potential benefit of flattening the customer's daily load curve, and when significant penetration is achieved on particular zone substations / feeders, the total effect may be enough to improve the asset utilization factor. This is done by reducing specifically the peak loads that drive network construction of otherwise under-utilised assets.

Figure 1 illustrates the leverage effect exhibited in the electricity supply industry [1]. After taking transportation losses into account, the ratio of the energy generated to the electricity consumption for an incandescent bulb, for example, is 100:3. This indicates that for every 3 units of demand side solutions found, 100 units of supply side solutions are avoided, and consequently by reducing the customer demand by 1 unit, the supply can be reduced by approximately 33 units. As a result, the effect of demand management solutions also correlates to reduced CO<sub>2</sub> emissions from electricity generation plants.



**Figure 3: Illustration of the leverage effect for the electricity supply industry [1].**

In a carbon constrained industry such as power, this leverage effect is becoming of increasing pertinence. It also demonstrates how a small alteration in a customer's household electricity efficiency behaviour can multiply to a significant effect on the generation required in the large scheme of the electricity network.

Energy efficiency targets the efficiency of appliances/machines to minimise energy used per unit of output. Depending on the load, this may have concentrated effects on the usage curve (e.g. dishwashers) or continuous reductions (e.g. refrigeration).

To summarise, the demonstrated complications arising from peak load on network assets within ENERGEX is being tackled with an appropriate approach to network demand management from ENERGEX. This includes multiple concurrent, coordinated initiatives targeting multiple end-use appliances and multiple customer segments. Among these initiatives included in the portfolio approach is research, trials and implementation relating to direct load control, distributed generation, load shifting, pricing initiatives and energy efficiency, with the common objective of facilitating network augmentation deferral.

In conclusion, the challenge and therefore cause for innovation identified during my tenure in ENERGEX's Demand Management group over the 2008/09 summer was the under-utilisation of network assets resulting from peak demand. There are currently initiatives implemented in the areas of direct load control, distributed generation, load shifting, pricing initiatives and energy efficiency, aimed at altering customer's energy consumption behaviour throughout the day and increased network contingency support for load at risk during the summer extreme hot weather events that result in record demand.

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