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ScienceDirect

Energy Procedia 79 (2015) 169 – 174

Energy Procedia

2015 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Innovative Solutions for Energy Conservation Through Commercial and Domestic Demand Side Management

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Abstract

Development of alternative energy sources must go hand in hand with demand management. This is of particular importance in developing countries where energy consumption will continue to increase as the economy becomes more developed and the people become more affluent. With the market penetration of mobile communications command and control of heating and cooling systems in commercial and domestic buildings is becoming a viable option. Such solutions are particularly applicable to the existing building stock. Tools are available to achieve this task in a cost effective manner. All that are needed are the systems and processes to link the mobile device to a smart command and control system which is then able to manage the appliance to achieve energy savings and at the same time show the consumer the savings that have been made. This paper explores some of the issues and possible solutions.

Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE

Keywords: energy demand management; energy conservation; mobile communications; WiFi

1. Introduction

Energy demand can be addressed on both the generation side as well as the demand side. Increasing supply can be achieved by building more power generating facilities, as well as developing renewable and alternative energy sources. Demand can be addressed by requiring green-rated buildings and energy efficient equipment but retrofitting solutions to existing buildings is a more difficult and costly task.

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Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE
doi:10.1016/j.egypro.2015.11.457

As communities in the Asian tropical areas become more affluent, energy efficient fans are being replaced by power hungry air-conditioning units, in an aging electricity network not designed for such loads. Demand for electricity continues to increase markedly, causing reduction in power availability and reliability.

One key issue that needs to be addressed is the energy consumption of existing commercial and residential buildings. Countries are trying to address demand but are potentially overlooking low cost solutions at the commercial and residential building level. These solutions can be either mandated, voluntary, or community-based.

This paper explores some of the issues and possible solutions.

2. Availability of communication infrastructure

The last decade has brought significant changes with not only the availability of communications infrastructure, but the cost of access to that communications infrastructure. For instance, by 2013 Thailand had over 90 million active mobile phone subscribers with a population of less than 70 million! Even as the government invests in broadband infrastructure, mobile will be a key driver of internet use in Thailand.[1] Even in the intervening two years things have only escalated with widespread acceptance of tablet computers (such as the iPad), and many households going wireless for not only voice communications but also for Internet access. With ubiquitous communications infrastructure, advanced services have become available.

The past year has brought major changes in the infrastructure for WiFi connected embedded devices. At the start of 2014, for instance, the Spark Core WiFi processor at US$39 and the Electric Imp at US$25 were the state of the art in terms of price for prototype development. By the end of 2014, these same modules started to look decidedly expensive with the ESP8266 costing US$2.70.[2]

As the communications infrastructure is becoming ubiquitous in developing countries it provides an opportunity to utilize this technology as a demand management tool for domestic and commercial buildings. The question becomes one as to whether 3G, WiFi or both can be used for command and control.

3. Energy demand management

There are a number of “rules” that should be followed in developing demand management tools. These “rules” include:

- If the energy savings are obtained with making one off adjustments, making the adjustment manually will probably bring higher savings. For instance, there is little benefit in dynamically adjusting the thermostat on a hot water heater;
- Concentrate on the areas of highest use, and do a simple cost benefit analysis on each area;
- Consider whether replacement is a better option than management. For instance, rather than controlling 50W halogen down lights, replacing these same lights with 3W LEDs will probably be cheaper, even without control;
- Consider failure modes of existing technology. Replacing a 100W light that is used for one hour per year does not give savings, until it is realized that this same light can be accidently left on for days or weeks significantly increasing consumption;
- Plan for the communications infrastructure not to work, potentially for months at a time;
- Dynamic pricing is an external price signal that can be used to reduce demand;
- There is a benefit, both environmentally and financially in moving load, even if there are no reductions in consumption;
- Ensure that locally generated renewables, such as solar, are utilized to provide the greatest return on

investment; and

- Manage load when utilizing relatively expensive local generation to augment or temporarily replace grid electricity.

Demand-side management often works best when there is a reservoir on the customer's side where energy can be stored until it is needed. In the case of air conditioning, this would be either storing energy inside the building, through pre heating and cooling, or having the energy stored in a vessel ready to be used on demand. With hot water, the water can be stored in an insulated vessel heated ready for use many hours later.

Another way demand-side management can work is by relying on the inherent property of buildings, for instance, to change temperature relatively slowly thanks to their thermal mass. Therefore, disengaging heating or cooling, particularly for short periods up to thirty minutes can work well. This is especially the case when air flow within the building is maintained.

3.1. Localized demand management

Most of the interest in demand management comes from utilities who are using it during periods of peak load on the electricity grid. In developing countries, there is a generally overlooked subset of the demand management issue. In some countries, the electricity network is so unreliable that a large percentage of the commercial buildings have their own backup power supplies to ensure continued operations. These supplies come with a large capital and operational cost.

Most demand management systems accept inputs only from one source, the organization providing the electricity grid. Whilst this may meet the interests of the grid, it may not meet the interests of the customer with their own generator. When operating a generator, the cost of electricity is normally significantly higher than the cost of electricity from the grid. Thus, when operating using a generator, different energy saving schemes may come into play. An obvious one would be to delay the heating of water as far as possible until grid electricity returns. By monitoring the use of generators and uninterruptable power supplies, and feeding this into local demand management schemes, it is not only possible to significantly reduce energy bills, but also to reduce CO_2 production as grid generation generally produces lower CO_2 output than local generation.

Local demand management places some potentially difficult constraints on the control mechanisms. Throughout this paper we have assumed that the demand side management technology is generally Internet based, or at least has access to network services.

Once a power system becomes unreliable, the communications infrastructure often also becomes unreliable, as power is required to provide constant connectivity. During a power induced communications outage, devices are not able to connect to the remote control mechanism. Whilst it is possible to create rules for where connectivity is unavailable, there is no guarantee that the loss of connectivity is because of a power outage, either locally or further afield. If there is a power outage, it may even be on another continent, depending on the system architecture.

Therefore it is important for local demand management to be able to provide local control specifically when the connectivity to the remote server is unavailable.

3.2. Consumer driven versus supplier driven demand management

Traditionally the thought has been to drive the demand management from the supplier side, either using a carrot or a stick approach. Sometimes this has been through offering services such as off-peak hot water, progressive electricity pricing based on consumption or time-of-use tariffs. These schemes have ceased to drive appreciable savings, and future savings are only being driven by increases in tariffs and the removal of services such as off-peak hot water to new customers.

An alternative has been seen with the introduction firstly of compact fluorescent light globes, and then with LED light globes. Consumers were able to make savings with their energy consumption through purchases at the supermarket. Whilst these globes did not always get used immediately, they did get used once the existing globes failed. This compares favourably with anecdotal reports that fully 30% of home energy usage displays, supplied to customers so that they could monitor their energy consumption from their kitchens, were still in their boxes over one month following delivery.

In Australia, when the Carbon Pricing Mechanism (CPM) was implemented, there was an apparent reduction in energy usage. The CPM had the effect of increasing electricity prices by about A$0.025/kWh. When the CPM was withdrawn, energy consumption increased, although it did not increase consumption to the level had it been if the CPM had never been implemented. The important thing to note is that the CPM with a price increase of roughly 10% on the retail energy price pushed people into looking at their own energy consumption and reducing it in areas that made sense to them. Each organization and individual looked at where they could best make savings and implemented schemes accordingly. The Australian experience has shown that energy usage has a negative correlation with electricity pricing, driving individual solutions with demand management.

The best savings are ones that happen automatically and do not need to be monitored.

For local demand management, there are three supply scenarios to keep in mind: grid electricity, local generation, and a combination of grid and local supply.

3.3. Altruism and local generation

Consider a large business in an area with a constrained distribution network. The business may decide that it is in their best interest as a good corporate citizen to actually supplement their internal needs by the use of local generation, reducing their reliance on the constrained generation network. By reducing their demand, they are able to reduce the likelihood that the supplies to the area will be disconnected due to excessive loading. In this case, the company can receive signals from the distribution network informing them when the distribution network is becoming close to being constrained, and then add generation to reduce their grid loading, as well as performing demand side load shedding.

But localized demand management is more than this. Due to the capital cost of generators, as well as growth of loads over time, generators are often undersized for the work they need to do. In this case, immediate load shedding would be needed. A better solution to ensure that all users within the organization or building have access to some electricity is to implement rolling load shedding to keep the energy utilization under a certain amount. This requires a feedback process.

3.4. Battery powered WiFi

In the past, the infrastructure required for distributed sensing and monitoring was significant. Over the past few years, the vast majority of commercial and residential buildings with Internet capability have been retrofitted with WiFi capability. Once configured, this permits devices to use existing infrastructure to communicate between themselves and also back to Internet based servers.

There have been significant advances in power management of WiFi based devices over recent years. This has both been on the access point side as well as the embedded device side. The technology is now to the point where it is possible to have a WiFi based temperature sensor report back to the Internet every 2-3 minutes for two years on a pair of AA batteries. With 10 minute monitoring, the energy drain is more limited by the shelf life of the battery rather than the energy consumption of the device. Such low energy devices make it possible to implement distributed demand management tasks.

4. Comparison between hot water control mechanisms - the user is still important

When it comes to demand response, the intent is generally to stop the user from overriding the control mechanisms. Often, such as in the case of off-peak tariffs, this will involve the use of seals to ensure that metering and controllers are not interfered with. This however does miss a key consideration when it comes to demand response – that there may be times that the user may wish to override the control, either by turning a device off that would otherwise be on, or by turning a device on that would otherwise be off. Turning devices off has been a feature of electricity reticulation networks, but they have generally been blunt instruments, requiring the device to be turned off physically, and then turned back on physically.

A better solution would be to have the demand response controller having an input from the user that permits them to turn the device off for a period. An example of this in practice would be permitting a demand response controller for storage hot water permitting a heater to be switched off whilst the user is on holidays, and then automatically turning back on for the off peak period just before the user returns. Ideally, there would be some remote control capability that permits the householder to change the settings remotely should they return home early.

Where demand response turns a device off, the normal reasons for doing this are lack of capacity in grid or generation, or increased cost of electricity, either on the retail or wholesale side. It may also be that the user is offered better pricing in return for less availability of power, or to encourage them to use energy at certain times for the reasons noted above. If the user is then given the ability to power an otherwise inactive unit, this will have impacts throughout the electricity supply chain. The immediate effect is that the retailer will then generally have to meet increased input costs which need to be passed onto the user somehow. Alternately, where availability is an issue, other users will need to be encouraged to reduce their consumption or additional plant brought online, even when this plant has a higher operational cost.

From the point of view of users, the system can be modelled as an energy supply with a variable tariff and over-rideable demand response control. Ultimately, when they make a decision to power a device that would not normally be powered, they are choosing to accept that higher price for the energy.

5. Areas of energy consumption in commercial and domestic buildings

5.1. HVAC – heating, ventilation and air conditioning

Despite being 200-300% efficient, space heating and cooling using air conditioners and heat pumps can consume significant amounts of energy. Many buildings are being installed with individual split system units rather than centrally controlled units, making central control and monitoring more difficult. Manufacturers are starting to make devices connected, but this is still a premium feature missing from the lower end of the market. It also does nothing for the existing stock of units in the field.

A system on centralizable, retrofittable WiFi devices is proposed as a way to gain energy reduction. Such a system provides savings primarily through enforced timers, temperature range limits and central command and control. Varying the thermostat by $1^{o}C$ has the potential to reduce energy consumption by up to 15%.[3] Larger variations have the potential for greater savings.

5.2. Electric solar hot water units

Whilst electric solar hot water units use less energy than normal storage hot water units, over the course of a year, their energy consumption is approximately 15% of a similarly sized electric only unit. This energy is used for circulating water through the roof panels and also for boosting the water in the tank when there has not been enough solar activity to sufficiently heat the water. It is the boost heating that has a potential for energy savings.

In hotels, the peak hot water usage is for bathing in the mornings and evenings. The cheapest price for electricity is currently generally overnight; the peak time for solar heating will be during the middle of the day. There is therefore a discontinuity between the times where hot water is consumed, and the best times to heat the hot water.

5.3. Electric hot water units

The traditional schemes for Storage Electric Hot Water within Australia are to turn the heating of the water on and off either through a timer, or through tones superimposed on the electricity network. Other countries use a separate control wire from the electricity distributor to turn the hot Water Heater on and off. They all fail to a certain extent when time of use energy is used for heating water, be it on an off peak or general use energy rate. Ideally, when water is heated using electricity on a time of use tariff, customers would like to:

- Decide the maximum rate they would like to pay to heat their hot water;
- Be able to adjust the maximum rate through a simple interface;
- Be able to override the maximum rate for a few hours, once they have used all their available hot water; and
- Provide daily feedback on energy used to heat water to provide a tighter feedback loop.

6. Conclusion

Development of alternative energy sources must go hand in hand with demand management. This is of particular importance in developing countries where energy consumption will continue to increase as the economy becomes more developed and the people more affluent. Whilst new products are likely to incorporate energy saving devices it is difficult mandate retrofitting. On the other hand, the consumer is likely to retrofit a suitable device if it can be shown that there are immediate cost benefits.

Tools are available to achieve the task. All that are needed are the systems and processes to link the mobile device to a smart command and control system which is then able to manage the appliance to achieve energy savings and at the same time show the consumer the savings that have been made.

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