INTERNATIONAL PERSPECTIVES ON DEMAND-SIDE INTEGRATION

Alex BAITCH	Angela CHUANG	Giuseppe MAURI	Christine SCHWAEGERL
BES – Australia	EPRI – USA	CESIRICERCA – Italy	Siemens PTD- Germany
Convenor CIGRE WG C6.09	CIGRE WG C6.09	Secretary CIGRE WG C6.09	CIGRE WG C6.09
baitch@besaust.com.au	achuang@epri.com	Giuseppe.Mauri@cesiricerca.it	Christine.schwaegerl@siemens.com

ABSTRACT

*In many regions around the world, the electric power system is becoming over-stressed. Peak demand is approaching generation system capacity, boosting electricity costs and increasing the risk of supply shortages in regions of North America, Europe, and Australia. Moreover, permits required to build new transmission and distribution assets are increasingly difficult to obtain. These issues have contributed to a renewed interest in improving efficiency of electricity utilization and reliability of service within the existing power system infrastructure. Many utilities and system operators are addressing these goals by providing customers with demand-side programs. Inconsistencies in demand-side terminology in use, however, unnecessarily burden communication efforts required for regional collaboration towards resolving industry challenges. This paper introduces **demand-side integration** as the underlying technical issue encompassing all aspects of demand-side management in today's restructured industry environment. An international review of demand-side programs reveals common drivers, challenges, and forms of demand-side integration worldwide.*

BACKGROUND

CIGRE established Working Group C6.09 to analyze a wide variety of demand-side integration issues. The initial name considered for the working group was Demand Side Management [1]. However, this was regarded to be inappropriate as it tended to reflect a customer-managed environment driven by the electric utility industry. With the onset of electric power industry restructuring world-wide, many customers are not subject to an environment of centralized management. In order to reflect the market-driven aspect of demand-side behaviour, such as demand response to market conditions, the CIGRE Study Committee on Distribution Systems and Dispersed Generation named the working group Demand Side Response. Nevertheless, this title too was sometimes perceived more restrictive in scope than intended.

At the CIGRE Paris Session 2006, the term *demand-side integration* (DSI) was adopted by the working group to better represent the overall technical area focused on the demand-side and its potential as a source of supply. That is, DSI refers to all activities focused on advancing the efficiency of electricity utilization [2], including demand response and energy efficiency.

The working group's scope includes study of technical issues surrounding demand-side integration, such as:

- Identification of drivers for demand-side integration
- Investigation of the role of demand-side integration for impacting the drivers identified
- Assessment of the various forms of implementation of demand-side integration
- Methods for determining customer value of reliability and differentiation of reliability preferences through demand response, as described in [3].
- Identification of roles, responsibilities, and economic drivers of network owners to support implementation of demand-side integration.
- Improvements needed in distribution network planning to better integrate demand-side resources such as distributed generation, storage, and responsive load.

REGIONAL PERSPECTIVES

Demand-side activities have been implemented around the world to enhance the efficiency of electricity utilization and to support market and system needs. This section describes structures of the electric power industry, implementations of demand-side integration, and some technical issues faced in regions across the globe.

North America

The structure of the North American electric power industry varies by region as dictated by government regulation and utility industry activity in forming regional transmission organizations (RTOs) to oversee the operation of regional transmission systems. Regions can be categorized into one of the following four states of industry restructuring: retail access allowed for most customers, retail access allowed for large customers only, retail access suspended for new customers, or retail access not allowed.

Where restructuring is active, RTOs operate regional transmission systems and markets. Markets are used by many RTOs for competitive procurement of ancillary services, such as real-time balancing energy and operating reserves. In some of these markets, large end-use customers (e.g., those greater than 1MW) may directly participate by providing reserves and/or balancing energy. The mechanisms for participation are either through direct bidding in markets that allow demand-side bidding of demand response as a source of supply, or indirectly through interruptible curtailment programs managed by local utilities or other energy retailers.

A wide range of demand response programs and tariffs are being offered by utilities to encourage customer response. Likewise, competitive energy retailers have structured retail contracts that encourage demand response coordinated with market conditions. Retail contracts offered by competitive energy retailers are detailed in [4].

Australia

The electricity industry in Australia has been substantially restructured since the mid 1990's. It has moved from vertically-integrated state-owned energy businesses to disaggregated businesses with a mixture of ownership structures. The reform process is still in progress with regulation of the electricity distribution networks moving from state-based jurisdictions to a national regulatory structure. Competition has been introduced into the generation and retail sectors, while the transmission and distribution systems operate in a regulated environment.

During the last few years, a considerable effort has been made at various levels in the industry for both trial and implementation of a wide range of DSI activities. The most significant practical implementation has been the establishment of the commercial company Energy Response as an open access aggregator of demand response for all participants in the Australian Electricity Markets (NEM and WEM) and the New Zealand Electricity Market. Energy Response provides its DSI services to retailers, transmission network service providers, distribution network service providers and the system operator.

South Africa

In South Africa there is an internal electricity market. Within the market rules are the requirements for contracting operating reserves. The reserves are contracted from generators and customers known as Demand Market Participants (DMP). These typically large industrial customers (currently ~800 MW) provide Instantaneous, Ten-minute and Supplemental reserves. Such customers receive both capacity and utilization payments. The capacity payments are negotiated annually and the utilization payments are as per the bid price through the balancing mechanism.

Due to generation capacity constraints, the utilization of such customers has increased significantly in the last year. Smaller customers (<1MW) are aggregated by an aggregator and dispatched accordingly. Due to the large number of customers participating, the SO is investigating ways of automating the call-up of such customers.

Europe

The European electricity supply system is the result of technological and institutional developments over many years, with most of the electricity being generated in large central power stations. Currently, Europe is facing an opening up of the electricity market to new players and the unbundling of integrated energy companies as well as a growing integration of distributed generation technologies. In some countries, the large customer size requirement for participating in markets and programs is still a limiting factor.

In Europe, the UK and Nordic countries of Norway, Finland, and Denmark are heading DSI initiatives development. UK has been the first country to implement Demand Side Bidding operations and other demand response programs.

There are several European projects related to DSI, partly funded by the European Commission in the 5th or 6th framework programme for research and development, by national or regional governments, or by different stakeholders such as industry and utilities. Project results comprise R&D studies, equipment design and development as well as dissemination and awareness campaigns.

FORMS OF DEMAND-SIDE INTEGRATION

DSI activities may be commonly classified into 1) demand response activities designed to impact load shape, and 2) energy efficiency or 3) strategic load growth activities designed to affect load level.

Objectives of load shaping through **demand response** include the following.

- Reducing demand peaks, particularly when power utilization approaches supply limits
- Shifting load between times of day or even seasons
- Filling the valleys of off-peak demand to better utilize existing power resources
- Inducing variations in demand with variable incentives to achieve a desired flexible load shape

These objectives are further described in [5].

Load levels may be affected through

- **Energy efficiency** programs designed to reduce overall demand while maintaining a comparable level of service and/or user comfort.
- **Strategic load growth** activities designed to increase load level in a strategic fashion, such as shifting between one type of supply to another with more favourable characteristics (e.g., environmental impact).

As supported by [6] and [7], primary forms of DSI implementations that appear internationally include:

- **Energy efficiency** programs that encourage an efficiency increase leading to a demand reduction intended to be effective in the long term.

- **Dynamic pricing and time-of-use** implementations that are based on variable pricing to customers. Both prices and time periods can be fixed and pre-established, or can be completely variable. Critical peak pricing, time of use rates, and real-time pricing fall in this category.
- **Load curtailment** programs which notify customers to reduce their consumption during certain periods. A main characteristic of this type of implementation is that the actual reduction is executed by the customer.
- **Interruptible contracts** that obligate large customers to reduce a given amount of consumption when requested by the system operator. The yearly number of reduction requests, economic incentives and activation time (i.e., time between the emission of the request and the actual demand reduction) are pre-established by customer contract.
- **Direct load control** programs that allow system operators to directly control end-use equipment. These programs require a direct communication link between the program facilitator and participating customer equipment.
- **Demand bidding** structures that allow direct participation of customers offering load reduction. Under these structures, a customer can bid to reduce load at a given price. If the bid is accepted, the customer will execute a demand reduction according to the awarded bid.

Demand response includes the forms of DSI implementations listed above, excluding energy efficiency programs. The various forms of demand response implementations can be differentiated by timing requirements, as illustrated in Figure 1.

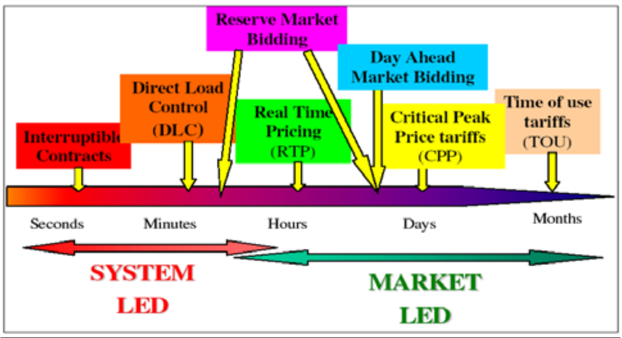

Figure 1 Classification of various DSI implementations by operational time interval after signal receipt [8]

DRIVERS

Common industry drivers are encouraging development of demand-side integration around the world. These drivers include the following.

- **Resource-constrained regions** face shrinking reserve margins amidst growing demand and local opposition against capacity expansion. A not-in-my-backyard mentality increasingly creates difficulty for traditional bulk transmission and generation expansion.
- **Improved economics** is sought by the demand-side of electricity markets which includes end-use customers and energy retailers. Savings can be achieved through customer participation in energy efficiency, demand response, and other coordinated demand-side activities.
- **Reliability concerns** have compelled regional system operators to structure programs designed to integrate demand-side participation in electricity markets. In some regions, system operators are encouraged by regulators to design programs that treat demand-side resources on an equal footing with supply.
- **Environmental concerns** over carbon emissions are promoting conservation and energy efficiency
- **Enhanced innovation** is an expected by-product of electric power industry restructuring. Increased product and service options enable and enhance customer participation in demand-side opportunities.

Electric power infrastructure problems are becoming significant in countries where electricity demand is outpacing supply and network infrastructure is aging. As loads grow and infrastructure reaches the end of its useful life, the costs for capital investment are escalating along with risks to system reliability. This has contributed to increasing power costs and price volatility, which in turn enhance the economic appeal of DSI. Improved efficiency of electricity utilization also leads to reductions in greenhouse gases. With energy efficiency and net reductions in energy usage achieved through demand response, environmental concerns can be addressed through DSI.

Another important driver of DSI is customer desire for increased flexibility in supply and innovative services to meet demand. The possibility of meeting demand through grid-purchased power in combination with onsite energy resources is attractive to some customers. This configuration also allows for localized trading of supply provided by onsite resources in a deregulated environment.

CHALLENGES

Despite the drivers, common challenges are found internationally that inhibit widespread integration of demand-side resources. These challenges include:

- **Aggregation** of many smaller demand-side resources (e.g., less than 1MW) for market participation requires updating operating procedures, computer systems, and business processes of regional operators and various demand-side market participants (e.g., utilities, aggregators, and other energy retailers).
- **Automation** of demand response is needed to affect widespread integration of end-use resources that could be made available to support grid and market operations. From a system operator's perspective, demand-side resources may also include distributed generation or electric storage, both of which are alternative means of achieving an impact on system load.
- **System operator confidence** in relying on demand-side resources to support real-time grid and market operations is often lacking

- **Cost** of the required hardware infrastructure investment for enabling integration is difficult to justify. The typical program implementation requires the presence of interval metering and two-way communication systems. A massive implementation of two-way communication systems between utilities and small electricity consumers must be motivated by a combination of factors. End-use energy savings alone often do not justify the required investment in many cases. The economic viability of enabling infrastructure and information technology systems must be evaluated taking into account the benefits of automatic meter reading and other utility related functions.
- **Retail rates and tariffs** are needed to consistently provide customer incentives for demand response. However, utility retail rates are generally bundled, leaving much room for unbundling and incorporation of structures that incentivize demand response when most needed to support grid operations. For example, rates could allow for differentiation of customer preferences for electric service including service reliability, perhaps another worthwhile dimension of customer choice.
- **Wholesale market structures** predominantly lack a demand-side connected with actual customer preferences for electric service. The price of wholesale power could be disciplined, however, by customer willingness to pay. This could be accomplished through consideration of customer preferences for electric service, including service reliability in the procurement of ancillary services and other wholesale commodities.
- **Reluctance of customers** to modify the way in which they consume electricity is another challenge. Customers must perceive that the reward that they are obtaining compensates for the inconvenience and cost of modifying their habits. The strongest incentives are almost always economic ones, but some other incentives may also motivate customers. In places of frequent supply interruptions customers may be more receptive if they perceive that the demand-side measures are significant for improving reliability of supply. Customers can also be motivated by means of public campaigns.

The challenges described above are indicative of technical, economic, policy, and other issues that must be addressed to integrate smaller end-use customers. The majority of the described regional experiences target large and medium-sized customers, as these customers offer more resource capability per site. However, small domestic customers represent a substantial potential demand-side resource as well. The aggregation of their contribution is the subject of recent research [2] [7] aimed at addressing technical and operational difficulties.

CONCLUSIONS

Despite significant challenges in achieving widespread integration, demand-side activities exist internationally to advance the efficiency of electricity utilization. This paper identifies common issues with demand-side integration to provide an international perspective. Common drivers, challenges, and forms of demand-side integration are described, along with examples of regional implementations. DSI activities come in various forms, including demand response, energy efficiency, and strategic load growth. Further details about these and other DSI implementations are contained in the references provided.

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