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RECENT DEVELOPMENT IN DEMAND SIDE MANAGEMENT IN SMART GRID

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Abstract – Energy demand management, also known as demand side management (DSM), is the modification of consumer demand for energy through various methods such as financial incentives [1] and education. Usually, the goal of demand side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times such as nighttime and weekends.[2] Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants for meeting peak demands. An example is the use of energy storage units to store energy during off-peak hours and discharge them during peak hours. The term DSM was coined following the time of the 1973 energy crisis and 1979 energy crisis. Demand Side Management was introduced publicly by Electric Power Research Institute (EPRI) in the 1980s.[4] Nowadays, DSM technologies become increasingly feasible due to the integration of information and communications technology and power system, resulting in a new term: Smart Grid.

Keywords: DSM; Smart Grid;

1. Introduction

Electricity use can vary dramatically on short and medium time frames, and the pricing system may not reflect the instantaneous cost as additional higher-cost ("peaking") sources are brought on-line. In addition, the capacity or willingness of electricity consumers to adjust to prices by altering demand (elasticity of demand) may be low, particularly over short time frames. In many markets, consumers (particularly retail customers) do not face real-time pricing at all, but pay rates based on average annual costs or other constructed prices.

Various market failures rule out an ideal result. One is that suppliers' costs do not include all damages and risks of their activities. External costs are incurred by others directly or by damage to the environment, and are known as externalities. One approach would be to add external costs to the direct costs of the supplier as a tax (internalization of external costs). Another possibility (referred to as the second-best approach in the theory of taxation) is to intervene on the demand side by some kind of rebate.

Energy demand management activities should bring the demand and supply closer to a perceived optimum. Governments of many countries mandated performance of various programs for demand management after the 1973 energy crisis. An early example is the National Energy Conservation Policy Act of 1978 in the U.S., preceded by similar actions in California and Wisconsin. Definition - DSM (Demand Side Management) is the 'Scientific control of usage and demand of Electricity, for achieving better load factor and economy, by the Licensee/Supplier'. TOD (Time of Day) Metering and differential pricing is the method/procedure for achieving targets in DSM.

2. Concept

2.1 Logical foundations

Demand for any commodity can be modified by actions of market players and government (regulation and taxation). Energy demand management implies actions that influence demand for energy. DSM is originally adopted in electricity, today DSM is applied widely to utility including water and gas as well.

Reducing energy demand is contrary to what both energy suppliers and governments have been doing during most of the modern industrial history. Whereas real prices of various energy forms have been decreasing during most of the industrial era, due to economies of scale and technology, the expectation for the future is the opposite. Previously, it was not unreasonable to promote energy use as more copious and cheaper energy sources could be anticipated in the future or the supplier had installed excess capacity that would be made more profitable by increased consumption.

In centrally planned economies subsidizing energy was one of the main economic development tools. Subsidies to the energy supply industry are still common in some countries.

Contrary to the historical situation, energy prices and availability are expected to deteriorate. Governments and other public actors, if not the energy suppliers themselves, are tending to employ energy demand measures that will increase the efficiency of energy consumption.

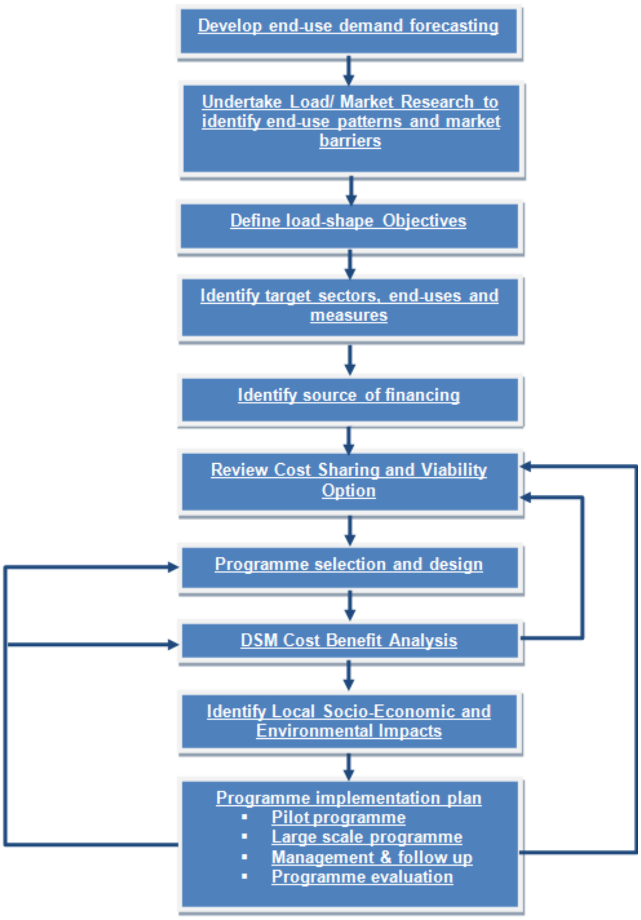

Figure 1: Demand Side Management Planning Procedure

Types of energy demand management

Energy Efficiency: Using less power to perform the same tasks.

Demand Response: Any reactive or preventative method to reduce, flatten or shift peak demand. Demand Response includes all intentional modifications to consumption patterns of electricity of enduser customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption.[5] Demand Response refers to a wide range of actions which can be taken at the customer side of the electricity meter in response to particular conditions within the electricity system (such as peak period network congestion or high prices).[6]

Dynamic Demand: Advance or delay appliance operating cycles by a few seconds to increase the Diversity factor of the set of loads. The concept is that by monitoring the power factor of the power grid, as well as their own control parameters, individual, intermittent loads would switch on or off at optimal moments to balance the overall system load with generation, reducing critical power mismatches. As this switching would only advance or delay the appliance operating cycle by a few seconds, it would be unnoticeable to the end user. In the United States, in 1982, a (now-lapsed) patent for this idea was issued to power systems engineer Fred Schweppe.[7]

2.2 Examples

The government of the state of Queensland, Australia plans to have devices fitted onto certain household appliances such as air conditioners, pool pumps, and hot water systems. These devices would allow energy companies to remotely cycle the use of these items during peak hours. Their plan also includes improving the efficiency of energy-using items, encouraging the use of oil instead of electricity, and giving financial incentives to consumers who use electricity during off-peak hours, when it is less expensive for energy companies to produce.[8]

In 2007, Toronto Hydro, the monopoly energy distributor of Ontario, had over 40,000 people signed up to have remote devices attached to air conditioners which energy companies use to offset spikes in demand. Spokeswoman Tanya Bruckmueller says that this program can reduce demand by 40 megawatts during emergency situations.[9]

Problems with DSM

Some people argue that demand-side management has been ineffective because it has often resulted in higher utility costs for consumers and less profit for utilities.[10]

One of the main goals of demand side management is to be able to charge the consumer based on the true price of the utilities at that time. If consumers could be charged less for using electricity during off-peak hours, and more during peak hours, then supply and demand would theoretically encourage the consumer to use less electricity during peak hours, thus achieving the main goal of demand side management.

Another problem of DSM is privacy: The consumers have to provide some information about their usage of electricity to their electricity company. This is less of a problem now as people are used to suppliers noting purchasing patterns through mechanisms such as "loyalty cards".

2.3 DSM in systems based on hydropower

Demand-side management can apply to electricity system based on thermal power plants or to systems where renewable energy, as hydroelectricity, is predominant but with a complementary thermal generation, for instance, in Brazil.

In Brazil's case, despite the generation of hydroelectric power corresponds to more than 80% of the total, to achieve a practical balance in the generation system, the energy generated by hydroelectric plants supplies the consumption below the peak demand. Peak generation is supplied by the use of fossil-fuel power plants. In 2008, Brazilian consumers paid more than U$1 billion[11] for complementary thermoelectric generation not previously programmed.

In Brazil, the consumer pays for all the investment to provide energy, even if a plant sits idle. For most fossil-fuel thermal plants, the consumers pay for the "fuels" and others operation costs only when these plants generate energy. The energy, per unit generated, is more expensive from thermal plants than from hydroelectric. Only a few of the Brazilian's thermoelectric plants use natural gas, so they pollute significantly more. The power generated to meet the peak demand has higher costs—both investment and operating costs—and the pollution has a significant environmental cost and potentially, financial and social liability for its use. Thus, the expansion and the operation of the current system is not as efficient as it could be using demand side management. The consequence of this inefficiency is an increase in energy tariffs … passed on to the consumers.

Moreover, because electric energy is generated and consumed almost instantaneously, all the facilities, as transmission lines and distribution nets, are built for peak consumption. During the non-peak periods their full capacity is not utilized.

The reduction of peak consumption can benefit the efficiency of the electric systems, like the Brazilian system, in some senses: as deferring new investments in distribution and transmission networks, and reducing the necessity of complementary thermal power operation during peak periods, which can diminish both the payment for investment in new power plants to supply only during the peak period and the environmental impact associated with greenhouse gas emission.

Energy portal

- Alternative fuel
- Battery-to-grid
- Dynamic demand (electric power)
- Demand response

3. Smart grid

A **smart grid** is a modernized electrical grid that uses analogue[1] or digital information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.[2] Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid.

Smart grid policy is organized in Europe as Smart Grid European Technology Platform.[3] Policy in the United States is described in 42 U.S.C. ch. 152, subch. IX § 17381.

Roll-out of smart grid technology also implies a fundamental re-engineering of the electricity services industry, although typical usage of the term is focused on the technical infrastructure.[4]

A common element to most definitions is the application of digital processing and communications to the power grid, making data flow and information management central to the smart grid. Various capabilities result from the deeply integrated use of digital technology with power grids, and integration of the new grid information flows into utility processes and systems is one of the key issues in the design of smart grids. Electric utilities now find themselves making three classes of transformations: improvement of infrastructure, called the *strong grid* in China; addition of the digital layer, which is the essence of the *smart grid*; and business process transformation, necessary to capitalize on the investments in smart technology. Much of the modernization work that has been going on in electric grid modernization, especially substation and distribution automation, is now included in the general concept of the smart grid, but additional capabilities are evolving as well.

3.1 Historical development of the electricity grid

The first alternating current power grid system was installed in 1886.[5] At that time, the grid was a centralized unidirectional system of electric power transmission, electricity distribution, and demand-driven control.

In the 20th century local grids grew over time, and were eventually interconnected for economic and reliability reasons. By the 1960s, the electric grids of developed countries had become very large, mature and highly interconnected, with thousands of 'central' generation power stations delivering power to major load centres via high capacity power lines which were then branched and divided to provide power to smaller industrial and domestic users over the entire supply area. The topology of the 1960s grid was a result of the strong economies of scale: large coal-, gas- and oil-fired power stations in the 1 GW (1000 MW) to 3 GW scale are still found to be cost-effective, due to efficiency-boosting features that can be cost effective only when the stations become very large.

Power stations were located strategically to be close to fossil fuel reserves (either the mines or wells themselves, or else close to rail, road or port supply lines). Siting of hydro-electric dams in mountain areas also strongly influenced the structure of the emerging grid. Nuclear power plants were sited for availability of cooling water. Finally, fossil fuel-fired power stations were initially very polluting and were sited as far as economically possible from population centres once electricity distribution networks permitted it. By the late 1960s, the electricity grid reached the overwhelming majority of the population of developed countries, with only outlying regional areas remaining 'off-grid'.

Metering of electricity consumption was necessary on a per-user basis in order to allow appropriate billing according to the (highly variable) level of consumption of different users. Because of limited data collection and processing capability during the period of growth of the grid, fixed-tariff arrangements were commonly put in place, as well as dual-tariff arrangements where night-time power was charged at a lower rate than daytime power. The motivation for dual-tariff arrangements was the lower night-time demand. Dual tariffs made possible the use of low-cost night-time electrical power in applications such as the maintaining of 'heat banks' which served to 'smooth out' the daily demand, and reduce the number of turbines that needed to be turned off overnight, thereby improving the utilisation and profitability of the generation and transmission facilities. The metering capabilities of the 1960s grid meant technological limitations on the degree to which price signals could be propagated through the system.

Through the 1970s to the 1990s, growing demand led to increasing numbers of power stations. In some areas, supply of electricity, especially at peak times, could not keep up with this demand, resulting in poor power quality including blackouts, power cuts, and brownouts. Increasingly, electricity was depended on for industry, heating, communication, lighting, and entertainment, and consumers demanded ever higher levels of reliability.

Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air-conditioning led to daily peaks in demand that were met by an array of 'peaking power generators' that would only be turned on for short periods each day. The relatively low utilisation of these peaking generators (commonly, gas turbines were used due to their relatively lower capital cost and faster start-up times), together with the necessary redundancy in the electricity grid, resulted in high costs to the electricity companies, which were passed on in the form of increased tariffs. In the 21st century, some developing countries like China, India and Brazil were seen as pioneers of smart grid deployment.[6]

3.2 Features of the smart grid

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. Because of the diverse range of factors there are numerous competing taxonomies and no agreement on a universal definition. Nevertheless, one possible categorisation is given here

3.3 Reliability

The smart grid will make use of technologies, such as state estimation,[13] that improve **fault detection** and allow **self-healing** of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack.

Although multiple routes are touted as a feature of the smart grid, the old grid also featured multiple routes. Initial power lines in the grid were built using a radial model, later connectivity was guaranteed via multiple routes, referred to as a network structure. However, this created a new problem: if the current flow or related effects across the network exceed the limits of any particular network element, it could fail, and the current would be shunted to other network elements, which eventually may fail also, causing a domino effect. See power outage. A technique to prevent this is load shedding by rolling blackout or voltage reduction (brownout).[*citation needed*]

The economic impact of improved grid reliability and resilience is the subject of a number of studies and can be calculated using a US DOE funded methodology for US locations using at least one calculation tool.

3.4 Flexibility in network topology

Next-generation transmission and distribution infrastructure will be better able to handle possible **bidirection energy flows**, allowing for **distributed generation** such as from photovoltaic panels on building roofs, but also the use of fuel cells, charging to/from the batteries of electric cars, wind turbines, pumped hydroelectric power, and other sources.

Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues.[14] A smart grid aims to manage these situations.[7]

3.5 Efficiency

Numerous contributions to overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during short-term spikes in electricity price, reducing the voltage when possible on distribution lines through Voltage/VAR Optimization (VVO), eliminating truck-rolls for meter reading, and reducing truck-rolls by improved outage management using data from Advanced Metering Infrastructure systems. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

3.6 Load adjustment/Load balancing

The total load connected to the power grid can vary significantly over time. Although the total load is the sum of many individual choices of the clients, the overall load is not a stable, slow varying, increment of the load if a popular television program starts and millions of televisions will draw current instantly. Traditionally, to respond to a rapid increase in power consumption, faster than the start-up time of a large generator, some spare generators are put on a dissipative standby mode[*citation needed*]. A smart grid may warn all individual television sets, or another larger customer, to reduce the load temporarily[15] (to allow time to start up a larger generator) or continuously (in the case of limited resources). Using mathematical prediction algorithms it is possible to predict how many standby generators need to be used, to reach a certain failure rate. In the traditional grid, the failure rate can only be reduced at the cost of more standby generators. In a smart grid, the load reduction by even a small portion of the clients may eliminate the problem.

3.7 Peak curtailment/leveling and time of use pricing

To reduce demand during the high cost peak usage periods, communications and metering technologies inform smart devices in the home and business when energy demand is high and track how much electricity is used and when it is used. It also gives utility companies the ability to reduce consumption by communicating to devices directly in order to prevent system overloads. Examples would be a utility reducing the usage of a group of electric vehicle charging stations or shifting temperature set points of air conditioners in a city.[15] To motivate them to cut back use and perform what is called **peak curtailment** or **peak leveling**, prices of electricity are increased during high demand periods, and decreased during low demand periods.[7] It is thought that consumers and businesses will tend to consume less during high demand periods if it is possible for consumers and consumer devices to be aware of the high price premium for using electricity at peak periods. This could mean making trade-offs such as cycling on/off air conditioners or running dishes at 9 pm instead of 5 pm. When businesses and consumers see a direct economic benefit of using energy at off-peak times, the theory is that they will include energy cost of operation into their consumer device and building construction decisions and hence become more energy efficient. *See Time of day metering and demand response.*

According to proponents of smart grid plans,[*who?*] this will reduce the amount of spinning reserve that electric utilities have to keep on stand-by, as the load curve will level itself through a combination of "invisible hand" free-market capitalism and central control of a large number of devices by power management services that pay consumers a portion of the peak power saved by turning their device off..

3.8 Sustainability

The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage. Current network infrastructure is not built to allow for many distributed feed-in points, and typically even if some feed-in is allowed at the local (distribution) level, the transmission-level infrastructure cannot accommodate it. Rapid fluctuations in distributed generation, such as due to cloudy or gusty weather, present significant challenges to power engineers who need to ensure stable power levels through varying the output of the more controllable generators such as gas turbines and hydroelectric generators. Smart grid technology is a necessary condition for very large amounts of renewable electricity on the grid for this reason.

3.9 Market-enabling

The smart grid allows for systematic communication between suppliers (their energy price) and consumers (their willingness-to-pay), and permits both the suppliers and the consumers to be more flexible and sophisticated in their operational strategies. Only the critical loads will need to pay the peak energy prices, and consumers will be able to be more strategic in when they use energy. Generators with greater flexibility will be able to sell energy strategically for maximum profit, whereas inflexible generators such as base-load steam turbines and wind turbines will receive a varying tariff based on the level of demand and the status of the other generators currently operating. The overall effect is a signal that awards energy efficiency, and energy consumption that is sensitive to the time-varying limitations of the supply. At the domestic level, appliances with a degree of energy storage or thermal mass (such as refrigerators, heat banks, and heat pumps) will be well placed to 'play' the market and seek to minimise energy cost by adapting demand to the lower-cost energy support periods. This is an extension of the dual-tariff energy pricing mentioned above.

4. Demand response support

Demand response support allows generators and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators, cuts wear and tear and extends the life of equipment, and allows users to cut their energy bills by telling low priority devices to use energy only when it is cheapest.[16]

Currently, power grid systems have varying degrees of communication within control systems for their high value assets, such as in generating plants, transmission lines, substations and major energy users. In general information flows one way, from the users and the loads they control back to the utilities. The utilities attempt to meet the demand and succeed or fail to varying degrees (brownout, rolling blackout, uncontrolled blackout). The total amount of power demand by the users can have a very wide probability distribution which requires spare generating plants in standby mode to respond to the rapidly changing

4.1 Power usage.

This one-way flow of information is expensive; the last 10% of generating capacity may be required as little as 1% of the time, and brownouts and outages can be costly to consumers.

Latency of the data flow is a major concern, with some early smart meter architectures allowing actually as long as 24 hours delay in receiving the data, preventing any possible reaction by either supplying or demanding devices.[17]

4.2 Platform for advanced services

As with other industries, use of robust two-way communications, advanced sensors, and distributed computing technology will improve the efficiency, reliability and safety of power delivery and use. It also opens up the potential for entirely new services or improvements on existing ones, such as fire monitoring and alarms that can shut off power, make phone calls to emergency services, etc.

4.3 power with kilobits, sell the rest

The amount of data required to perform monitoring and switching one's appliances off automatically is very small Provision megabits, control compared with that already reaching even remote homes to support voice, security, Internet and TV services. Many smart grid bandwidth upgrades are paid for by over-provisioning to also support consumer services, and subsidizing the communications with energy-related services or subsidizing the energy-related services, such as higher rates during peak hours, with communications. This is particularly true where governments run both sets of services as a public monopoly. Because power and communications companies are generally separate commercial enterprises in North America and Europe, it has required considerable government and large-vendor effort to encourage various enterprises to cooperate. Some, like Cisco, see opportunity in providing devices to consumers very similar to those they have long been providing to industry.[18] Others, such as Silver Spring Networks[19] or Google,[20][21] are data integrators rather than vendors of equipment. While the AC power control standards suggest powerline networking would be the primary means of communication among smart grid and home devices, the bits may not reach the home via Broadband over Power Lines (BPL) initially but by fixed wireless.

5. CONCLUSION

DSM in its various forms is an important tool for enabling a more efficient use of the energy resources available to a country. For example, DSM applied to elec - tricity systems can mitigate electrical system emergencies, minimize blackouts and increase system reliability, reduce dependency on expensive imports (in some countries), reduce energy prices, provide relief to the power grid and gen - eration plants, defer investments in generation, transmission and distribution networks and contribute to lower environmental emissions. Similar benefits can be achieved from DSM when applied to the use of other types of energy. Thus DSM can offer significant economic and environmental benefits.

Housekeeping and preventive maintenance are simple and cost-effective ways to reduce demand and have other benefits like process improvement. Opportunities may exist to take advantage of special tariff rates by changing load profiles or entering into contractual agreements with the utilities. It is therefore important to market DSM programmes to show potential customers their life cycle benefits and the techniques—often quite simple—for reducing demand.

5. Biography

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