International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 5, Issue 4, pp: (66-74), Month: October - December 2017, Available at: www.researchpublish.com

Current DSM Techniques to Improve Energy Efficiency: A Review Article

Mrs. Sowmya G[1], Dr. Surekha Manoj[2]

[1]Asst.Professor and Research Scholar, EEE Department, VVIET, Mysuru
[2]Prof & Head, EEE Department, VVIET, Mysuru

***Abstract*: Energy Efficiency and Demand Side Management (DSM) have significant potential in India. The need for affordable electricity and peak shortages make DSM important for India. (DSM) have significant potential in India. Demand-side management has been recently recognized as a strategic concept in smart electricity grids. In this context, active demand (AD) represents a demand response scenario in which households and small commercial consumers participate in grid management through appropriate modifications of their consumption patterns during certain time periods in return of a monetary reward. This paper intends to highlight the need and scope of implementing DSM Techniques to improve energy efficiency in all major sectors.**

***Keywords:* Aggregated Demand Response(ADR), Demand Side Management(DSM), Load Management Techniques (LMTs), Demand Response(DR), Offline Ranking Analysis (ORA), Real-Time Ranking Modification (RTRM), Integer Programming (IP).**

1. INTRODUCTION

Demand Side Management (DSM) focuses on changing the electricity consumption patterns of end-use customers through improving energy efficiency and the optimal allocation of power. Demand Response (DR) is a DSM solution that targets residential, commercial, and industrial customers, and is developed for demand reduction or demand shifting at a specific time for a specific duration. In the absence of on-site generation or the possibility of demand shifting, the consumption level needs to be lowered to comply with a DR event. Whereas the non-criticality of loads at the residential and commercial levels allows for demand reduction with relative ease, reducing the demand of industrial processes requires a more sophisticated solution. Production constraints, inventory constraints, maintenance schedules, and crew management constraints are some of the many factors that have to be taken into account before one or more processes can be temporarily shut down. Some of these constraints can be viewed along the overall performance of the system, while others need to be analyzed and evaluated in real time. Management constraints are some of the major factors that have to be taken into account before one or more processes can be temporarily shut down. Some of these constraints can be viewed along the overall performance of the system, while others need to be analyzed and evaluated in real time. in this article, a system that dynamically ranks loads and workstations of an industrial site as candidates for demand.

Demand-Side Management (DSM) represents a revolutionary approach to planning at electric utilities. Essentially, it broadens the scope of planning to integrate the customer's needs and desires with the utility's goals. This text brings together in one convenient source a comprehensive volume of information, techniques and guidelines for use in DSM planning and implementation. It examines each major type of DSM program, from thermal storage and appliance efficiency programs to interruptible rate and strategic marketing efforts. Special features include: What to expect in new rate design options. New energy storage options including cooling, heating and electrothermal systems. Customer load control options. Electric load impact of new technologies: Electrothermal heating, Plasma systems, Computer aided manufacturing, Robotics, Desk-top computers.

2. BASIC CONCEPT OF CURRENT DSM TECHNIQUES EMPLOYED

1. Modern DSM Tools and Techniques:

The most common DSM techniques can be classified as below:

A) Energy Conservation

B)Efficiency Programs to save energy

C) Demand/Load Response Programs

These techniques are employed to shift and reschedule energy consumption process Energy Conservation and Efficiency programs It is said that Energy conserved is Energy generated. Energy conservation and efficiency measures are the best alternative energy sources. There are various opportunities and techniques available for reducing energy consumption such as efficient lighting, variable speed drives, solar hot water systems etc. These technologies reduce demand, help in lowering high peak prices and also reduce greenhouse gas emissions due to less stress on generating plants. Load Response Programs (LRP) Load Response Programs are an effective part of Demand Side Management. These are the actions undertaken in response to electricity supply position and wholesale market price of electricity. Or in other sense these refer to switching off or reschedule of non-essential and non-critical loads by the end users in response to the request of IMO or the utilities. This can lead to save the system network from exceeding its peak rating. There are a large variety of load equipments and applications that can be switched on or off at a particular times to reduce electricity demand from the network.

2. Tools for DSM:

Every technology needs some tools to be used to achieve the desired results. Following are the main tools to be used for achieving DSM results:

Dynamic/Real Time Pricing - The present deregulated market is based on real time system of supply and demand. Prices change time to time and hour to hour depending upon these two factors. By exposing customers to Real Time/Dynamic i.e. time-varying prices, they can have a better view of the prevailing market and the information and incentive to reduce their demand at peak times and to shift their usage from high priced periods to low-priced periods.

Time-of-Use Rates-This is the tool or rate structure by which customers are offered different rates for electricity usage at different times of the day. Offering them lower rates for consumption at off-peak time can make them aware to use some of the power at those low-priced time for related equipments which have the flexibility of operation at different times.

Automated/Smart Metering -Implementing Dynamic/ Real Time Pricing or Time-of-use rate structure and billing accordingly is not a complex program now. Automatic/Smart Metering successfully used by various utilities provide the best effective solution to this problem. This Automatic Meter Reading (AMR) system has the various other benefits which are customer oriented as well as utility oriented.

Web-based/Communication System-This is a tool used along with the above to convey the customer about the prevailing demand, supply, prices on real time basis and the incentives and options for him, which are used by the customer to manage the demand. In addition, there are other methods like E-mail, Cell Phone, Pagers and Fax etc. which can be used as a communication tool to convey the required information and data.

3. Market Drivers for DSM/LRP technologies:

Depending upon the supply and market position, there are two broad categories:

Reliability-based programs: These programs operate in response to the system contingencies. That is why these can also be called as “contingency” programs. These are used whenever there is an emergency of power supply in case of acute shortage due to less generation or more demand or due to some other system constraints. These programs are also called Emergency Demand Response Program (EDRP).

Market/Price based programs: These programs are based on market price signals of electricity. This category includes programs that use time-of-use (TOU) rates/Real Time Prices, Interruptible Rates and Two-part Tariff. These rates are intended to reduce consumer bills through the application of time-differentiated rates. The consumer participants of these programs that curtail their loads at critical times of very high prices can also be paid some extra financial incentive to help maintain system reliability.

These programs can include **Day Ahead Demand Response Program**, where the end users respond to price signals and reduce loads when the price exceeds their set Base Price on day to day or day-ahead time basis.

Types of Load Control:

The two main methods can be used in the market to control the load at consumer premises depending upon the size of load and the infrastructure as:

Direct Load Control- Directly by IMO/Utility operator for large supply consumers in consultation with them after careful planning and installing required infrastructure.

Load Control by Consumer- Where only information is send to the consumer about the quantity of load to be controlled along with the other related information and he has to take the action within the stipulated time.

4. Participants of DSM/Load Response Program

For implementing these programs, we need a strong government support to through its various agencies. Ontario Energy Board (OEB), being regulatory agency in the energy market, can play a leading role in promoting these programs. Other than the Ministry of Energy and OEB, following are the key potential participants for these programs who can promote, implement and monitor these programs:

Independent Electricity Market Operator (IMO)- They are meant for Controlling the electricity grid and large supply consumers.

Utilities/Suppliers- They are meant for supplying electricity to consumers for medium and small supply.

Consumers- They are the end user of electricity.

Each of these units has its own significant role to play. But the optimum results can be obtained by coordination of all of them. Government agencies can make various policies and regulations, provide incentives, subsidies and technical support for these programs and Utilities can implement these more effectively through different cost-effective and customized programs in coordination with the end-users i.e. the consumers.

Factors effecting Load Response Programs:

However implementing these technologies and techniques is not always so cheap. Though there are many opportunities where we can apply these without any additional cost or investment. But to apply them at large scale for the whole market there are various factors to be considered as:

• Cost to the customer to shed and reschedule the load

• Time it takes to activate the load response

• The variation in wholesale price

• Losses to occur in case of reliability problems due to acute shortage • Any losses in production by implementing these programs

DSM Program Approaches: Various approaches can be adopted to achieve benefits of Demand Side Management as:

• General information programs for customers about energy efficiency options.

• Information programs about specific DSM techniques appropriate for industry

• Financing programs to assist customers to pay for DSM measures

• Turn-key programs that provide complete services to design, finance, and install a package of efficiency measures at the consumer end.

• Alternative rate programs by the utilities like time-of-use rates and interruptible rates to shift loads to off-peak periods.

• Schemes and incentives to invest in energy conservation and efficiency programs

• Incentives for new innovations and technologies for Load Response/Load Management Programs.

DSM Programs Strategies- The following strategy may be adopted to design and implement DSM program:

- Identify the sectors and end-users as the potential targets
- Visualize the needs of the targeted sectors
- Develop marketing strategies for the programs
- Develop the customized program
- Conduct analysis for cost-effectiveness
- Prepare a Program Execution Plan
- Implement programs
- Monitor programs for their deliverables and further modifications

3. RESEARCH WORK EMPLOYING DSM TECHNIQUES

Demand Response Techniques:

Electric DR is becoming one of the main pillars of the smart grid paradigm. It refers to the changes in the electricity usage by the end-use customers from their nominal consumption patterns. These changes in consumption are often in response to changes in the price of electricity over time or to incentive payments that are designed to induce lower electricity use at times of high wholesale market prices or when the system reliability is jeopardized. In addition to improving the reliability of the power system and having short-term impacts on the electricity markets, DR can offer considerable environmental benefits by reducing the system's peak load in the long term, thereby postponing the need for building new power plants and other related capacity-expansion projects. DR can provide efficient system capacity relief at a lower cost compared with many peaking power plants, while at the same time the service can be offered at a faster rate. The successful deployment of a DR program can lead to substantial financial returns, benefiting both the utility and the customers.

DR for Industrial Plants upon receiving the demand reduction signal from the utility, many industrial plants can switch to backup generation units. This way, the overall demand of the industrial plant— from the utility's standpoint—will be reduced. the energy storage systems within the plant can also achieve the same feat. these may include traditional battery systems or electric vehicles at plants offering vehicle-to-grid capabilities. if on-site generation or energy storage are not available, demand shifting may be used as another viable option. the maintenance scheduling, crew constraints, and other operational requirements of the plant can be analyzed to see if it is feasible for the production to be shifted to a later time, e.g., when the electricity rates are low or when the dr event terminates. Many researchers have focused on real-time scheduling of industrial loads. Sequential ordering of loads is used to improve the load factor through actions such as load shifting and peak shaving. Some authors have adopted solutions that are used in the field of real-time computing systems. Deferrable loads are modeled as tasks with attributes, such as arrival time, departure time, and energy requirements, and proposed algorithms for allocating resources to these tasks based on their energy needs and/or deadlines.

Finally, demand reduction/curtailment could be considered as an alternative. in fact, efforts have been made in the literature to develop intelligent schemes for load shedding in an industrial plant. Much of the focus in load shedding is on maintaining the security and stability of the isolated industrial system—following a disturbance in the grid—when using backup generation. the solution methods have been developed based on the priority ranking of the loads, expert systems and neural networks. In addition, solutions have been proposed for energy efficiency and demand conservation through DSM techniques.

However, the efficient demand reduction for a DR event requires a more detailed analysis and thorough evaluation of the industrial process. Through analyzing the operational constraints of the plant, processes can be prioritized as candidates for being shut down or for operating at reduced capacity. the revenue losses incurred by the plant must be compared with the direct gains, i.e., incentive payments and/ or discounted electricity rates, as well as indirect gains, e.g., concurrence of the process shutdown with an upcoming maintenance scheduling or crew bottleneck. this can be used either as a stand-alone DR tool or in conjunction with other such as demand shifting and onsite generation.

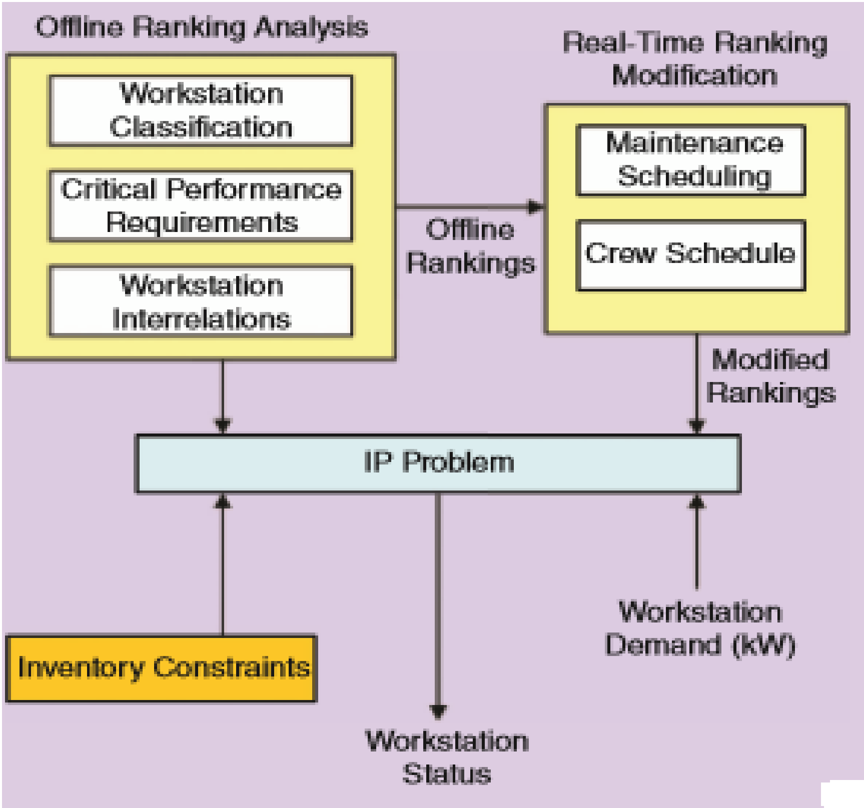

Figure:1 Proposed DR Technique

Dynamic DR Scheme:

The system proposed here is created and expanded with an objective to design operation statuses for the workstations (fully operating, partially operating, or shut down) in such a way that the industrial plant is able to participate in a DR event while satisfying all real-time operational constraints. The structure of the proposed solution is shown in Figure 2. In short, the proposed solution comprises three modules:

■ An Offline Ranking Analysis (ORA) module ranks the workstations on the basis of their priorities for demand curtailment during a DR event. The module uses offline information to achieve this goal.

■ A Real-Time Ranking Modification (RTRM) module modifies the rankings received from the ORA on the basis of the daily operational constraints such as maintenance and crew.

■ An Integer Programming (IP) module then receives the modified rankings from the RTRM, the workstation connections from the ORA, as well as the inventory constraints; in return, it determines the optimal schedule of operation for the workstations.

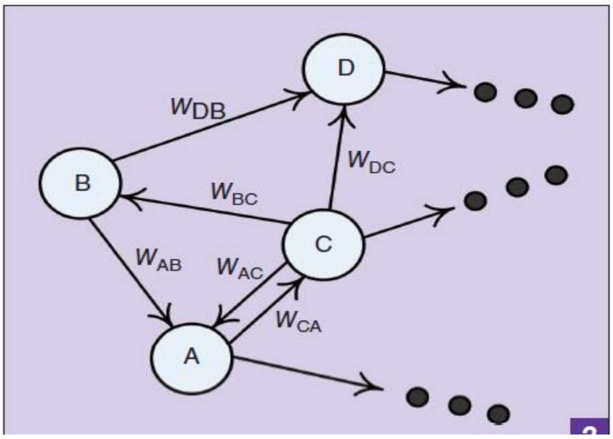

Figure 2-The FCM-based modeling of the interrelations of workstations.

Offline Ranking Analysis Module:

The ORA is designed to prioritize the existing workstations as candidates for demand reduction. The module performs the ranking on the basis of the information received on the offline classification of the workstations, critical performance requirements, and process interrelations. This information is associated with the long-term performance of the plant and will often not be modified in real time. A fuzzy cognitive map (FCM)-based design is used here for implementing the ORA (Figure 2). The workstations are defined as the nodes (vertices) of the FCM, while the links (edges) denote the interrelations between the workstations. Within this framework, the impact of a workstation is defined as the total effect of the workstation node on the end product node. The ranking of the workstation, i.e., priority for demand reduction, is defined as the logical inverse of the impact.

Without loss of generality, the weights of the FCM links have been assigned the fuzzy terms low, medium, and high, which are determined on the basis of how critical the corresponding node would be. For instance, if node A represents a critical workstation, the weights represents the rest of the nodes of all of the links leaving A will be denoted high. This is because the impact that A has on the final product of the plant would be considered high. This scheme would ensure that the workstations that are classified as noncritical and time flexible would become natural candidates for receiving higher-priority demand reduction, whereas being critical or needing a long start-up time can be grounds for assigning lower priorities for DR. The rules in Table-1 are used for identifying critical and noncritical workstations.

TABLE 1. THE WORKSTATION CLASSIFICATION.

Criticality Classification	Examples
Critical (high)	Workstations that highly affect the completion of the end product; workstations that process the product of multiple other workstations
Semicritical (medium)	Workstations with a large number of crew members; workstations with a long setup time; workstations that carry high-value inventory
Noncritical (low)	Workstations not included in the above categories; those with flexible schedules and/or a low number of crew members

Real-Time Ranking Modification Module:

The RTRM updates the rankings determined at the ORA on the basis of the information on maintenance scheduling and crew management. This module is expected to receive updated information on a regular basis; therefore, it can reflect the latest operational requirements of the plant.

Maintenance Scheduling:

This sub module looks into the scheduled maintenances coming up for different workstations. Clearly, stations that are scheduled for maintenance soon enough would normally move higher in the priority list to be interrupted. This way, the demand reduction target may be met while the workstation undergoes its scheduled maintenance. For this purpose, a fuzzy variable time to maintenance is defined on the basis of the time remaining to DR event.

$$T_m = \frac{Time\ to\ Scheduled\ maintenance}{Time\ to\ DR\ event} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Without a loss of generality, the fuzzy terms short, medium, and long are defined for T_m.

Crew Schedule:

This submodule investigates whether the crew scheduled to work on a specific workstation can be assigned to a different workstation for the duration of demand reduction. Although the number of crew members at a workstation is a key aspect to avoid labour wastage, it is also important to distinguish between single-skilled workers and cross trained crew. The former may not be dispatched to another Workstation, whereas the latter have more flexibility in reassignment.

Without loss of generality, three fuzzy terms, i.e., low, medium, and high, have been considered here for the number of crew at each workstation. Based on the number of crew at each workstation and their skill levels, the rule base in Table- 2 is used to derive the so-called crew constraint measure. A low crew constraint would be grounds for crew reassignment, whereas a high crew constraint would indicate low priority for crew reassignment.

TABLE 2. THE RULE BASE FOR CREW MANAGEMENT.

Crew Number	Crew Skill	Crew Constraint
Low	Specific skilled	Medium
	Cross trained	Low
Medium	Specific skilled	High
	Cross trained	Low
High	Specific skilled	High
	Cross trained	Medium

RTRM Ranking:

Based on the time to maintenance and the crew constraint, the real-time operational rankings are derived as in Table 3.

Ranking Adjustment:

The output of the RTRM (i.e., the priority based on real time operation) will be combined with that of the ORA (i.e., the priority based on long-term operation) to achieve an overall DR priority index for the loads/workstations. These data would then be used by the optimization module to assign weights to different workstations (see the "IP Module" section). A simple rule base is used for this purpose as shown in Table 4.

IP Module:

The objective of this module is to determine the statuses of the workstations (fully/partially operating or shutdown) that would provide the maximum possible demand reduction while ensuring that the dynamic constraints of the overall plant are met. This module considers the real-time dynamics of inventory accumulation after each workstation (i.e., postprocess inventory) as well as the interrelations between the workstations. It is assumed that the problem is solved and revisited every delta *t* units of time, e.g., every hour or every half hour. Although the performance of this algorithm is not dependent on the choice of time step, this range has been chosen to stay consistent with the common time frames used in DR programs. The problem is solved over multiple time periods to incorporate the concept of accumulation of inventories over time as well as the capacity impact of the loads.

TABLE 3. THE RULE BASE FOR REAL-TIME RANKING MODIFICATION.

Time to Maintenance	Crew Constraint	Priority Determined by RTRM
Long	High	Low
	Medium	Low
	Low	Medium
Medium	High	Low
	Medium	Low
	Low	Medium
Short	High	Low
	Medium	Medium
	Low	High

The workstation loading decision is formulated as an IP problem and is provided in (2). The objective is to find the integer variables u_i for each time period, indicating the level at which the i^{th} unit is operational for each Δt period.

In this article, $\mu i$is assumed to be capped at four, which means that every workstation can operate at 25, 50, 75, or 100% of the rated capacity. Clearly, μi=0 indicates a unit that is shut down. The objective function is defined as

$$Min \sum_{t=1}^{T} \sum_{i=1}^{n} \alpha_i \cdot \left(\frac{P_{i,base}}{4 \times \Delta t}\right) . u_i(t) \text{ ………………(2)}$$

which is subject to the following:

■ Upper and lower limits on post process inventories for the individual workstations as well as the overall plant

$$\forall t = 1 \dots T : \sum_{i=1}^{n} I_i(t) \leq I_{max} \text{ ………………(3)}$$

TABLE 4. THE COMBINED PRIORITIES BASED ON THE ORA AND RTRM OUTPUTS.

Priority Based on ORA	Priority Based on RTRM	Overall DR Priority
High	High	Very high
	Medium	High
	Low	Medium
Medium	High	High
	Medium	Medium
	Low	Low
Low	High	Medium
	Medium	Low
	Low	Very low

$$\forall_t = 1 \dots .T, \forall_i = 1 \dots (n-1)$$

$$I_{min,i} \leq I_i(t) \leq I_{max,i} \text{ ……………..(4)}$$

Determining the lower thresholds Iminwould explain the policy adopted for the manufacturing process. A nonzero value for Iminmoves the process further away from a just-in-time manufacturing strategy. In this article, the workstations have been required to buildup sufficient inventory at any point of time such that other workstations (that depend on their product) can operate at least at 25% capacity, regardless of whether or not the original workstation will be shut down for the next period. In other words

$$\forall i = 1 \dots n : I_{min,i} = \sum_{j=1,\neq i}^{n} 0.25 \times C_j . V_{ji} \text{ ……………(5)}$$

Equality constraints expressing the accumulation of post process inventory based on the interrelationships between workstations

$$\forall t = 1 \dots T, \forall i = 1 \dots n$$

$$I_i(t) = u_i(t-1) + u_i(t) . \frac{C_i}{4} - \sum_{j=1,\neq i}^{n} u_j(t) . \frac{C_j}{4} . V_{ji} \text{ ………(6)}$$

Inequality constraints for the maximum operational levels of the workstations: Clearly, the level at which a workstation can operate will be limited by the amount of pre-process inventory available. For a workstation *i* that is fed from multiple workstations, all of the products (or post process inventories) of those workstations would need to be considered, and assuming that they are all necessary components (with equal weights) for the product of workstation *i*,

the production level of workstation i would be limited according to

$$\forall t = 1 \dots T, \forall i = 1 \dots n:$$

$$u_i(t) \leq \frac{\min_{j=1\dots n, j\neq i} I_j(t-1).V_{ij}}{c_i/4} \text{ …………..(7)}$$

In an effort to maintain linearity in the optimization constraints, and at the expense of some computational inaccuracy, the min function in (7) is replaced by the average function in the calculations.

■ Constraint on the overall production demand: If true based on the configuration of the industrial process, the plant output can be viewed as the output of the last workstation, i.e.,

$\forall t = 1 \ldots T: I_n(t) \geq d(t)$ …………(8)

The parameters and variables used in the formulation of the optimization function are defined in Table 5. The optimization problem would start from time *t* =0, where, without loss of generality, it is assumed that all workstations are operational and creating post process inventories. The initial post process inventory

Amounts *Ii* (0) should also be provided as inputs to the optimization module.

4. CONCLUSION

The scope for improving energy efficiency using modern DSM techniques is growing rapidly. This paper intends to brief out the requirements and outlines of research oriented DSM strategies in part-A followed by detailed proposed model of DR Technique which can employed for an existing system to improvise energy efficiency in residential, commercial as well as industrial sectors with slight modifications in part-B.

DR is an integral part of the smart grid paradigm. For residential and most commercial customers DR is relatively straightforward to implement, mostly due to the non-criticality of the loads involved. However, DR for industrial customers faces unique challenges. This Article proposed a scheme based on fuzzy systems and mathematical optimization techniques for implementing DR at an industrial site. The proposed solution first considers the offline and quasi-dynamic operational dynamic constraints such as post process inventory build upto suggest workstations that can operate under demand curtailment or demand reduction while ensuring that the overall demand of the plant is met.

REFERENCES

[1] Federal Energy Regulatory Commission.(2012, Dec.).Assessment of demand response and advanced metering. Staff Report. [Online].

[2] T. W. Partners, “A primer on demand response,” White Paper, Oct. 2007.

[3] S. Kiliccote, M. A. Piette, and D. Hansen, “Advanced controls and communications for demand response and energy efficiency in commercial buildings,” in *Proc. Carnegie Mellon Conf. Electric Power Systems*, Pittsburgh, PA, Jan. 2006, pp. 1–10.

[4] J.M. Morales, A.J. Conejo, and J. Perez-Ruiz, “Economic valuation of reserves in power systems with high penetration of windpower,”IEEETrans.PowerSyst.,vol.24,no.2,,May2009.

[5] A. Papavasiliou, S.S. Oren, P.O' Neill, “Reserve requirements for wind power integration: Ascenario-based stochastic programming framework,” IEEE Trans. Power Syst., vol. 26, no. 4, pp. 2197–2206, Nov. 2011.

[6] M.Vrakopoulou,K.Margellos,J.Lygeros,andG.Andersson,“AprobabilisticframeworkforreserveschedulingandN-1securityassessment of systems with high wind power penetration,” IEEE Trans. Power Syst., vol. 28, no. 4, pp. 3885–3896, Nov. 2013.