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Supplementing demand management programs with distributed generation options

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ABSTRACT

Ever increasing electrical energy demand is forcing power serving entities around the world to use various demand management programs to help in stressful times of the electric power grid. Demand management programs aim to control electrical energy demand among customers and create load relief for electric utilities. Recently demand management contracts have been designed in which incentives are offered to customers who willingly sign up for load interruption. In recent years much technological advancement has been made in distributed generation, and the cost of using this option can bring about extra flexibility into existing demand management schemes. This paper explores the use of distributed generation technology within the existing demand management ideas. More specifically, it compares economic aspects of using demand management contracts with the use of distributed generation. A key observation of this paper is that there may be cases where it is more beneficial to use distributed generation rather than demand management contracts.

1. Introduction

Demand side management [1–3] aims at influencing customer use of electricity or altering the pattern and magnitude of customer load. This can be achieved either by peak clipping, valley filling, load shifting, strategic conservation, and strategic load growth [4]. Utilities usually use DSM strategies whenever they foresee disturbing loading patterns. They apply it either system wide or at specific locations all in a bid to control customer load patterns. In [20] the authors talk about load shifting to off peak periods being a good strategy, and self generating also helping the customers and the system. Demand side management can be applied both in regulated and deregulated environments, an evaluation of demand management for power markets are analyzed in [21]. The authors in [22] give a review of demand response in deregulated electricity markets and talk about how this affects the electricity prices.

One of the key requirements of demand management programs is that customer participation must be voluntary. Incorporating all these requirements and designing optimal demand management contracts is therefore not an easy task. Some demand management schemes offer lower rates of electricity for the customers who sign up for demand management contracts, and also give them credit on the maximum demand charge depending on how much of their load they designate to be interrupted. In [5] the authors suggest the use of pay per curtailment method when designing demand management contracts. Either way demand management requires a thorough economic analysis. As this paper illustrates, the use of distributed generation can be a better tool than demand management contracts in some cases.

The power grid needs to be healthy in order to provide reliable supply of electric power to their customers. Customers must have sufficient supply availability in order to maximize their benefits of using electricity. Sometimes lower cost of electricity may imply risk of potential unavailability of enough power. Customers willing to share in "availability risk" can derive further benefit by participating in demand management programs. Specifically, whenever utilities foresee dangerous loading patterns, there is a need for a rapid reduction in demand either system-wide or at specific locations. The utility (or the energy serving entity) needs to get relief in order to solve its problems quickly and efficiently. This relief can come from customers who agree to curtail their loads upon request in exchange for an incentive fee. Ref. [5] shows how utilities can get efficient load relief while maximizing their economic benefit. There may be some cases the utility can install distributed generation units at customer sites or certain locations in the grid. This gives the utility the capability to generate the power needed by the customer using distributed resources and having the customer go offline until the problem is solved. For certain situations this might be a cheaper option for the utility. This paper compares the cost of demand management contracts with the cost of distributed

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generation. Preliminary investigations of this idea have been proposed in the conference paper [6].

2. Demand management contracts

Reliable operation under conditions of uncertainty requires that loads be considered adjustable. In [5] the authors assume that participation in demand management programs is entirely voluntary, and that compensation for participation is an integral part of any demand management program. The incentives offered can be optimized if the utility can estimate the outage or substitution costs of its customers. Ref. [7] illustrates how existing utility data can be used to predict customer demand management behavior. More specifically, it shows how estimated customer cost functions can be calibrated to help in designing efficient demand management contracts.

The power grid can be stressed at times by events and contingencies. Demand management programs provide means to relieve this stress. Some problems can be solved by system-wide load reduction, and other problems need location specific attention. Most operational problems can be solved more efficiently if a utility has demand management contracts with customers at critical locations. Ref. [5] also highlights the fact that locational attributes of customers incorporated into demand management contract design can have a significant impact in solving system problems. Locational variance incorporated into demand management contract design can help improve both the engineering and economic analysis of the power system. Demand management contracts become more efficient economically, bringing more monetary benefits to the utility, and system security issues are addressed more efficiently. Fast developing distributed generation technology allows the utilities to consider installing distributed generation units to critical customer locations. In some cases this may prove more efficient for the utility. The next section discusses distributed generation types and how the utilities can take advantage of the current technology.

3. Distributed generation

Distributed power generation is getting more attention in the energy market than ever before because of its flexibility. Distributed generation refers to any small-scale power generation technology that provides electric power at a site closer to customers than the central electric generation station. Ref. [23] provides a comprehensive review of distributed generation, and Ref. [24] talks about how to integrate distributed generation into power systems by giving some real life examples. Distributed generation provides a multitude of services to utilities and consumers, including standby generation, peak shaving capability, base load generation, or cogeneration. Electricity markets being set up in different countries can also benefit from the emergence of distributed generation [25]. In the deregulated power market, the buyers and sellers of electricity will have to be more responsive to market forces. A distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system. Easy to install and varying in size from 1 kW to 40 MW, these units could be planted easily behind electric transmission bottlenecks to provide peaking services. Distributed power units could be located (or moved) quickly to alleviate transmission congestion or other circumstances that raise costs or threaten system integrity, reliability, and efficiency. Its ability to respond quickly to system problems could reduce the investment in transmission, distribution and generation required to meet projected demand growth. Typically a distributed power unit can be started in a very short time. For example, a large turbine can produce electricity at near maximum rates within 15 min of a cold start and within seconds if the unit is in "spinning" mode. In smaller turbines the cold start time is even faster. This ensures a fast reaction of power generation to system demands in contingencies.

Economic efficiency is one major concern of distributed generation customers. Various technologies are available for distributed generation, including turbine generators, internal combustion engine/generators, micro-turbines, photovoltaic/solar panels, wind turbines, and fuel cells. Due to developments in technology, the installation cost of distributed power units have dropped dramatically. Based on the data from DPCA (Distributed Power Coalition of America), the capital cost of a turbine generator is as low as \$450–870/kW. Any doubt about the economics of distributed generation should have been dispelled when spot prices for electricity in the ECAR (East Central Area Reliability) region reached \$4000/MWh. In the Chicago region, under bizarre trading, prices reached the \$5–\$6/kWh range. These prices demonstrate the economic viability of distributed generation.

4. Importance of location and changing spot prices

It is no secret that some customers are at more critical locations than others. Existing demand management contracts usually offer rates depending on the size of the customer load but these tend to be uniform across all locations. The Game Theory formulation developed in [5] illustrates how customer location can be incorporated into demand management contract design. Once the formulation of contract design is developed, any power system can be analyzed to show the importance of location. This section will talk about the concepts that can help in the understanding of the locational attributes of the demand management contracts and distributed generation.

Sensitivity analysis can be used to determine the locational value of interruptible power contracts for the utility, at the same time it can point out critical locations for distributed generation.

In [8], the authors compute the sensitivity of the loading margin of a system with respect to arbitrary parameters. If loads are the parameters, sensitivity of the loading margin can be computed with respect to each load. Let Eq. (1) to be the set of power balance equations.

$$g(\alpha, \gamma, p) = 0 \tag{1}$$

In Eq. (1) α is the vector of state variables, γ is the vector of real and reactive power injections, and p is the vector of loads. If a pattern of load increase is specified with a unit vector k, the point of collapse method [9] can be applied to yield the left eigenvector ω. The sensitivity of the loading margin (L) to a change in any load is:

$$\frac{\Delta L}{\Delta p} = L_p = \frac{-\omega g_p}{\omega g_\gamma k} \tag{2}$$

Once we have the sensitivity of the loading margin to a change in any load, we use it to rank loads. The above formula lets us construct an expression relating changes in individual loads (Δp_1, Δp_2, etc.) to changes in the security margin:

$$\Delta L = L_{p1}\Delta p_1 + L_{p2}\Delta p_2 + \ldots + L_{pm}\Delta p_m \tag{3}$$

In Eq. (3) m is the number of loads of interest. As Eq. (3) suggests, the load with the highest sensitivity would help increase the loading margin the most. By using these sensitivities and the dollars per kWh figures from the designed contracts, the utility can estimate how much it costs to increase system security:

$$\frac{\Delta L}{\Delta \$} = \frac{\Delta L}{\Delta p}\frac{\Delta p}{\Delta \$} \tag{4}$$

The term $\Delta \$$ is the amount the utility will spend. Eq. (4) helps to determine how much it costs to increase the loading margin by curtailing one of the loads. The same kind of analysis can be applied