Electric Power Systems Research 92 (2012) 87–95

Contents lists available at SciVerse ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Cost-saving potential of customer-driven distributed generation

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ARTICLE INFO

Article history:
Received 19 November 2011
Received in revised form 17 April 2012
Accepted 1 June 2012
Available online 15 July 2012

Keywords:
Distributed generation
Customer-perspective approach
Cost minimization
Demand charges
Real-time generation dispatch
Monte Carlo simulation

ABSTRACT

Utilization of distributed generation (DG), in combination with the traditional supply from the grid, may help industrial and commercial customers to decrease their energy bills. The full cost-saving potential of DG would be released only in case when all inputs were known for the overall billing period in advance. Under the realistic conditions, where a set of important input variables exhibit a stochastic change and where the customers are billed not only for energy but also for the monthly peak demand, it remains to search for dispatch solutions capable of bringing the savings as close as possible to the theoretical maxima. In this paper, we propose a novel real-time near-optimal DG dispatching algorithm, which takes into account all the input parameters recognized up to now as respectable. The algorithm has been extensively tested showing an excellent performance over a wide range of operating conditions.

1. Introduction

Along with the traditional supply from the power utility grid, industrial and commercial electricity customers may decide to invest in their own generating units. Such small-scale energy resources, commonly called distributed generation (DG), may under certain circumstances help the customers to improve the cost-effectiveness and reliability of their energy supply [1]. Dispatching the on-site generating units anytime when their operating cost is less then the cost of purchasing electricity will definitely contribute to a lower customer energy bill. If the optimum balance between power generated by DG units and the power purchased from the grid is achieved for every hour within the month, the cost savings will be maximized and therefore the customer total energy bill will be minimized. The greatest achievable savings are then compared to the DG purchasing costs in order to justify the profitability of such kind of investment. This paper deals with the issues of finding the acceptable dispatch strategy and, subsequently, evaluating the resulting economic potential of customer-driven distributed generation.When DG operates in an isolated grid, this task comes down to the classical generation scheduling problem. The generation scheduling problem is more than half a century old and there are a plenty of methods specially developed for its solution [2]. In case when the customer system is connected to the utility grid, the task becomes more complex. However, if the utility tariff does not include the demand charge, this complication is not dramatic since the grid may be considered as just another generating unit represented with its equivalent generation cost curve. The greatest complication arises in a presence of the grid demand charge which is the most common case in the tariffs for industrial and commercial customers. The problem then becomes simultaneous, i.e. the peak load demand which occurs only once in a month may significantly participate in the amount of the customer energy bill. That is the reason why the optimization cannot be performed on an hour-by-hour basis and why the entire month must be considered simultaneously.

Several approaches for valuation of customer-driven DG which include the demand charge consideration can be found in the literature. These approaches differ in the input parameters that are taken into account, in the assumptions that are adopted as well as the mathematical methods used for finding the optimal dispatch strategies.

One of the first definitions for the optimal dispatch problem of the customer-driven DG can be found in [3]. The problem is defined as fully deterministic with the assumption that all the input parameters like customer load diagrams, fuel and electricity prices, etc. are completely known for the whole period under consideration. A DG dispatching method for use in a deregulated electricity market, considering both the monthly demand charges and fluctuating hourly price is presented in [4]. The authors propose a heuristic, near-optimal dispatch strategy based on a concept of keeping the grid peak demand under the threshold predefined at the beginning of a particular month. The approach is limited to the dispatch of a single, perfectly reliable, microturbine which cost curve is

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http://dx.doi.org/10.1016/j.epsr.2012.06.008

assumed to be flat for all of its levels of operation. Some dispatch strategies are illustrated and valuated in [5], but still using assumptions that DG is perfectly reliable and that the customer load and meteorological parameters are perfectly forecast all month long. Although mentioned that the customer may have more than one DG unit, such a case is not treated through models and results. In our previous effort, we have introduced a method based on a search procedure capable of dealing with multiple heterogeneous DG units having non-linear, non-convex and discontinuous cost curves [6]. This method, however, is also restricted only to the deterministic load diagrams and regulated time-of-use electricity pricing. The greatest number of input parameters so far, respecting their full stochastic character, is taken into account in [7]. A heuristic near-optimal real-time dispatch algorithm has been proposed, where a dispatch action for the actual moment is determined by a minimization of the average cost for a set of scenarios randomly generated as a representation of the future until the end of a period under consideration.

This paper presents another step forward in the methodology for maximizing the cost-saving potential of customer DG. We propose and test a new real-time near-optimal dispatch algorithm, which takes into account all the inputs recognized as respectable, while still being simple enough to be implemented in the automatic controllers.

2. Problem formulation

The primary goal of this research is to assess the expected value of savings which can be achieved by industrial or commercial site through a meaningful utilization of n DG units in parallel with purchase of grid electricity. It is also required to propose a dispatch strategy which will boost the savings as close as possible to the theoretical maximum.

It is important that the utility company charges for the monthly peak demand, while the volumetric energy price may be either constant or variable. All the issues, which have been designated in the prior research as influential, should be incorporated in a general model of the system. The dispatch method should be capable of generating the operating schedules for multiple DG units which can be realized in different technologies. The units may be either dispatchable such as microturbines and diesel generators or non-dispatchable with stochastic power outputs like wind turbines and photovoltaic systems. The cost curves are allowed to be non-linear and discontinuous. The stochastic nature of the customer load diagram should be taken into account, as well as the stochastic change of meteorological variables like insolation and wind speed for DG applications which include renewable energy sources. At the end, numerical examples should be used to analyze which input parameters are truly critical and which could possibly be idealized or completely ignored. Table 1 summarizes the issues considered in this paper including comparisons to the related works referenced in the introductory section.

The following assumptions are added to the initial problem formulation:

- Fuel prices are constant over the month.
- The customer does not sell surplus electricity back to the grid.
- All dispatchable units have fast response so they can participate in the peak shaving.
- Since the paper is focused on valuation of DG, the other cost-saving techniques like demand side management and local energy storage are not considered.

Table 1
Review of the issues considered in the paper.

Issues	References					
	[3]	[4]	[5]	[6]	[7]	Here
Load diagram stochastics	N	C	N	N	C	C
Non-linear and non-smooth DG cost functions	N	M	C	C	C	C
DG start-up costs	N	M	N	N	N	C
Multi DG units	C	M	M	C	N	C
Renewable sources as deterministic (predicted)	C	N	C	C	C	C
Renewable sources as stochastic	N	N	N	N	C	C
Reliability issues	N	N	N	N	C	C
Combined heat and power	M	C	C	N	C	N

N – not considered; M – mentioned as issue, but not included in the models and results; C – considered in the models and results.

3. Inputs modeling

3.1. Customer load diagram

The load curve is represented by a vector of hourly values – $L(h)$. The load time series exhibit seasonality at the daily, weekly and annual timescales, which must be considered during modeling [8]. If long-term measurements are available the models can be more precise. At the beginning, all seasonalities must be removed from the original data. The refined values are then fitted to an autoregressive moving average (ARMA) model. This model is used to generate random artificial load time series which represent the primary input for the valuation procedure of the proposed dispatch algorithm.

If the load measurements were made during only one year or even shorter, it does not make sense to attempt to develop precise models. In such a case we take one week as the cycle and determine vectors of hourly means $L_m(h)$ and hourly standard deviations $\sigma(h)$, which contain 168 items each (Fig. 1). Random scenarios for algorithm valuation are generated by distorting the weekly mean load curve, respecting the level of deviation. A day cannot be chosen to represent the cycle, because a significant difference exists between weekdays and weekend days. It is assumed that the customer has well defined working process with the constant total annual energy consumption. However, due to the time shift of certain activities and the fluctuations of other parameters, such as climatic, the power consumption is allowed to be redistributed during the year. The research published in [9] has shown that daily load diagrams of commercial customers are very similar to each other, while the load of industrial customers exhibit noticeably greater deviation due to intermittent activities like operation of small-size motors.

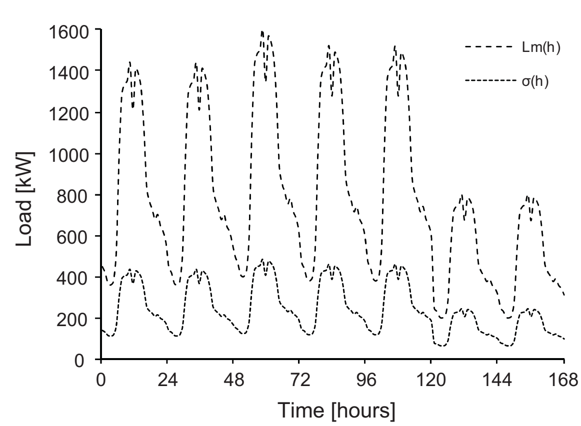

Fig. 1. A week from the expected load and standard deviation diagrams.