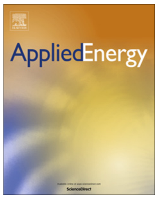
Applied Energy 161 (2016) 533–551

Contents lists available at ScienceDirect

Applied Energy

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



Assessing the benefits of residential demand response in a real time distribution energy market

Pierluigi Siano [*], Debora Sarno

Department of Industrial Engineering, University of Salerno, Fisciano, Italy

HIGHLIGHTS

- A new probabilistic methodology, integrating DR in a distribution energy market is proposed.
- The method can alleviate distribution network congestions.
- This method based on D-LMPs allows cost savings for end-user customers.
- Innovative thermal and shiftable loads Real Time control algorithms are also presented.

ARTICLE INFO

Article history:
Received 21 February 2015
Received in revised form 27 September 2015
Accepted 1 October 2015
Available online 11 November 2015

Keywords:
Demand response
Distribution systems
Smart grids
Distribution locational marginal price
Transactive controller
Monte Carlo simulation

ABSTRACT

In the field of electricity distribution networks and with the advent of smart grids and microgrids, the use of Distribution Locational Marginal Price (D-LMPs) in a Real Time (RT) distribution market managed by a Distribution System Operator (DSO) is discussed in presence of empowered residential end-users that are able to bid for energy by a demand aggregator while following Demand Response (DR) initiatives. Each customer is provided by a transactive controller, which reads the locational market signals and answers with a bid taking into account the user preferences about some appliances involved in DR activities and controlled by smart plugs-in. In particular, Heating Ventilation and Air Conditioning (HVAC) appliances and shiftable loads are controlled so that their consumption profile can be modified according to the price of energy.

In order to assess the effectiveness of the proposed method in terms of energy and cost saving, an innovative probabilistic methodology for evaluating the impact of residential DR choices considering uncertainties related to load demand, user preferences, environmental conditions, house thermal behavior and wholesale market trends has been proposed. The uncertainties related to the stochastic variations of the variables involved are modeled by using the Monte Carlo Simulation (MCS) method. The combination of MCS and RT distribution market simulation based on D-LMPs are used to assess the operation and impact of the DR method over one month. Simulations results on an 84-buses distribution network confirmed that the proposed method allows saving costs for residential end-users and making the distribution network much reliable against network congestions thanks to the use of D-LMPs.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

In the last decades, the innovation in the new renewable energy technologies, the incentives to renewable sources usage and the introduction of the Information and Communication Technologies (ICTs) have been some of the drivers to the restructuring of the electric power industry. One of the main innovations in the electrical energy management has been the introduction of smart grids, which are electric grids integrating advanced sensing technologies, control methodologies and communication infrastructures. In this way the interaction of all connected users with the objective of efficiently managing the variation of load demand is facilitated [1]. At the distribution level, the smart grid concept is realized by microgrids [2], electrical networks composed of small scale independent power producers, Distributed Generators (DGs), local storage devices and controllable loads managed by hierarchical system control architecture in a small geographical area [3].

In this complex environment, an essential role is played by Demand Response (DR) [4–6] which, according to the US Department of Energy, denotes variations of the electric consumption by users in response to the energy price changes over the time,

---

[*] Corresponding author. Tel.: +39 089964294.
E-mail addresses: psiano@unisa.it (P. Siano), desarno@unisa.it (D. Sarno).

http://dx.doi.org/10.1016/j.apenergy.2015.10.017
0306-2619/© 2015 Elsevier Ltd. All rights reserved.

Nomenclature

Acronyms

D-LMP	Distribution Locational Marginal Price
DL	dispatchable load
DG	distributed generation
DR	Demand Response
DSO	Distribution System Operator
EVs	Electric Vehicles
HVAC	Heating Ventilation and Air Conditioning
ICT	information and communication technology
LMP	Locational Marginal Price
MCS	Monte Carlo Simulation
RT	Real Time

Indexes

m	type of shiftable load
t	time slot, with $t \in TimeHorizon$
s_h^w	subset of houses with similar load profile belonging to w
w	bus of the distribution network, with $w \in N_{bus}$
G	generator
L	load
Z	wire or power transformer

Sets

N_{bus}	number of buses
N_h	set of generator buses
N_j	set of load buses
$TimeHorizon$	time horizon of analysis

Variables and parameters

B_{ki}	imaginary part of the element in the bus admittance matrix (*i-th* row and *k-th* column)
$B_j(d_j)$	benefit of consumer j
$C_h(g_h)$	production cost of producer h
$\cos\varphi_g$	power factor of DG g
$\cos\varphi_d$	power factor of DL d
$\mathbf{d}$	demand vector
d_j	consumer j demand (MW h)
DR_g	ramp-down rate limit of DG g at time t
$EOST$	earliest OST
EST	Earliest Starting Time, that is the earliest time at which a shiftable appliance can be switched on
φ	first time in which the shiftable load bid is accepted
$\mathbf{g}$	supply vector
g_h	producer h offer (MW h)
G_{ki}	real part of the element in the bus admittance matrix (*i-th* row and *k-th* column)
LET	Latest Ending Time, that is the latest time at which a shiftable appliance can be switched off (deadline)
$LOET$	latest OET
$LOST$	latest OST
OET	Optimal Ending Time of a shiftable appliance
$on.sg_{shift}^t$	shiftable load switching on signal at time t
$on.sg_{ther}^t$	Heating Ventilation and Air Conditioning (HVAC) appliance switching on signal at time t
OST	Optimal Starting Time of a shiftable appliance
OT	Operating Time, time needed by a shiftable appliance to perform its work
P_b	active power at the slack bus
$P_b^{\min}/P_b^{\max}$	min/max value for active power at the slack bus
P_d	active power absorbed by DL d
$P_d^{\min}$	minimum value that P_d can assume
P_g	active power generated by DG g
$P_k^G - P_k^L$	active power injected at bus k
Pr_{shift}^t	variable representing the price bid of shiftable load at time t as a function of the state of the appliance between LOST and the completion of its operation
Pr_{ther}^t	variable representing the price bid of HVAC at time t as a function of the temperature at the same time
$PrAvg^t$	Average Distribution Locational Marginal Price (D-LMP) of the day before at time t
$PrBid_{fixed_w}^{t+1}$	bid price of fixed load made at time t for time $t+1$
$PrBid_{shift}^{t+1}$	bid price of shiftable load made at time t for time $t+1$
$PrBid_{ther}^{t+1}$	bid price of HVAC made at time t for time $t+1$
$PrCap^t$	bid price without price indication
$PrClear^t$	D-LMP at time t
PrF^t	Price Forecast of the energy at the slack bus at time t
$PrFmax$	maximum PrF^t during the convenient starting window of a shiftable appliance
$PrFmin$	minimum PrF^t during the convenient starting window of a shiftable appliance
$PrMax^t$	maximum price at time t, according to the previous 24-hours D-LMP
$PrMin^t$	minimum price at time t, according to the previous 24-hours D-LMP
PW_{shift}	active power of a shiftable load
q	number of time slots used to enlarge the shiftable load working interval
Q_b	reactive power at the slack bus
$Q_b^{\min}/Q_b^{\max}$	min/max value for reactive power at the slack bus
Q_d	reactive power absorbed by DL d
Q_g	reactive power generated by DG g
$Q_k^G - Q_k^L$	reactive power injected at bus k
$QBid_{fixed_w}^{t+1}$	quantity bid of a fixed load made at time t for time $t+1$
$QBid_{shift}^{t+1}$	quantity bid of shiftable load made at time t for time $t+1$
$QBid_{ther}^{t+1}$	quantity bid of HVAC made at time t for time $t+1$
S_Z	apparent power transfer through wire or power transformer Z
$S_Z^{\max}$	maximum thermal capacity for wire or power transformer Z
$Tcurr^t$	indoor temperature at time t
$Tdes^t$	desired indoor temperature, set by the client at the HVAC switching on at time t
$Text^t$	outdoor temperature at time t
$Tmax$	maximum indoor temperature allowed by a client
$Tmin$	minimum indoor temperature allowed by a client
$(\theta_k - \theta_i)$	difference in voltage angle between the *i-th* and *k-th* buses
$\mathbf{u}$	vector of control variables
UR_g	ramp-up rate limit of DG g at time t
V_i	voltage magnitude at *i-th* bus
$V_i^{\min}/V_i^{\max}$	min/max value for voltage magnitude at bus i
V_k	voltage magnitude at *k-th* bus
$\mathbf{x}$	vector of dependent variables

or in the presence of financial incentives and reliability signals. In particular, a DR classification has reported a distinction between incentive-based programs (Direct Load Control, ancillary Service Markets, etc.) and time-based ones (among the others, Real Time (RT) pricing) [7], which are beginning to be explored at the distribution level [8]. In the former case the main adopted scheme involves curtailing the customers' load of a specified agreed quantity [9], while the latter case regards with energy price tariffs

Download English Version:

https://daneshyari.com/en/article/6685089

Download Persian Version:

https://daneshyari.com/article/6685089

Daneshyari.com