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Optimal bidding in a Day-Ahead energy market for Micro Grid under uncertainty in renewable energy production

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ABSTRACT

The power grid consists of various electrical components and of multiple levels: transmission HV (High Voltage), distribution in MV (Medium Voltage) and distribution in LV (Low Voltage). In this framework, the MGs (Micro Grids) are classified as a distribution grid, usually in LV, able to provide services both in autonomous (island mode) and in grid connected mode.

MGs are composed by traditional and renewable energy power plants, storages and loads and, due to their limited capacity, generally the main applications are on residential level (e.g., campus, hospitals, hotels, sport centers, commercial location). Different components, design and rules are defined by the manager of MG: in this work, there is a prosumer which aggregates the capacity of different components and buys or sells, for each hour, power from/to the grid with upper level voltage.

In this paper, a decision making model to formulate the optimal bidding in the Day-Ahead energy market and to evaluate the risk management for a LV grid-connected residential MG, taking into account the uncertainty of renewable power production, i.e., PV (photovoltaic), is proposed. Several investigators have analyzed the role played by MGs into the deregulated electricity market, their contribution to energy price reduction and to the reliability system increase, as well as their impact on the best strategy devising to minimize operating costs.

Although in literature it is possible to find similar decision support models, the use of uncertainty evaluation to make decisions and to participate in a deregulated energy market is at the present an important open research issue.

The uncertainty can be expressed in many different ways, either qualitative or quantitative, and it is possible to generate a reasonable measure of uncertainty by various methods.

In this work an original approach based on AnEn (Analog Ensemble) method to estimate the uncertainty linked to the energy provided by PV plant own to the MG is presented.

The AnEn is able to estimate the pdf (probability density function) of forecasts solutions by sampling the uncertainty in the analysis and running a number of forecast from perturbed analysis. The analogs generated become the input of our optimization model.

Based on a genetic algorithm, the economic model is applied to a heterogeneous residential MG with traditional different power plants and RES (Renewable Energy Sources), i.e., PV, evaluating different prosumer risk tolerances (adverse, neutral and incline). Developed methodology can aid the decision maker to understand the potential impact of a wrong decision throughout information included in a forecast concerning renewable power production.

The effectiveness of the proposed methodology is assessed through the analysis of a case study consisting of a grid connected residential MG. The obtained results show different optimal bids depending on the risk adversity with respect to the uncertainty of PV power production, and how PV energy production can be integrated with optimal results in a MG if the prosumer's strategy takes into account the uncertainty linked to the energy output.

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Nomenclature

Ω_C	Set of CHP plants
Ω_B	Set of boilers
Ω_G	Set of electricity production plants
Ω_{D_e}	Set of electric loads
$\Omega_{D_{th}}$	Set of thermal loads
$P_{Ce_{t,j}}$	Power of the j^{th} cogeneration unit at the t^{th} hour
$P_{G_{t,j}}$	Power of the j^{th} thermoelectric unit at the t^{th} hour
$P_{B_{t,j}}$	Thermal power of the j^{th} heat unit at the t^{th} hour
$PV_{t,j}$	Power of the j^{th} not programmable renewable unit at the t^{th} hour
$C_{G_{t,j}}$	Production cost of the j^{th} thermoelectric unit at t^{th} hour
P_{grid_t}	Power interchanged with the MV network at the t^{th} hour
ρ_t^e	Market price expected value
ξ	Weight coefficient
x	PV expected value
$\bar{x}$	PV probabilistic value (Analog)
α_P	Economic coefficient of second order of the j-ma power plants
β_P	Economic coefficient of first order of the j-ma power plants
γ_P	Economic constant coefficient
β_B	Economic coefficient of first order different for the boiler
η	CHP ratio
MG	Micro Grid
DER	Distributed Energy Source
PV	Photovoltaic
CHP	Combined Heat and Power
RES	Renewable Energy Sources
ED	Economical Dispatch
OPF	Optimal Power Flow
UC	Unit Commitment
AnEn	Analog Ensemble
HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
QR	Quantile Regression
PeEn	Persistence Ensemble

1. Introduction

Recently power systems have been undergoing radical changes to satisfy an increasing energy demand. MGs (Micro Grids) concept is one of the proposed solutions to cope with these new challenges.

It is based on a cluster of time-varying loads and DERs (Distributed Energy Sources), a portion of which can include RES (Renewable Energy Sources) and storages [42,45].

MGs operate as a single controllable system providing power and optionally heat and allowing bidirectional power flow to and from the main MV (Medium Voltage) power grid [41,40,22,32,11,5]. MGs generally are used at residential level (e.g., campus, hospital, hotels, sport center, commercial location), considering their restricted capacity [20].

Different components, design and rules are defined by the manager of MG that is a prosumer in the case under investigation and plays a key role like a price maker managing the elastic demand of all consumers are into own grid.

The role of MGs within into the deregulated electricity market, as well as their contribution to energy price reduction and reliability increase of the system and MGs impact on the best strategy devised to minimize operating cost have been widely discussed in the literature [35,15,43,26]. A prosumer is the manager of a LV (Low Voltage) Micro Grid connected to the main electric grid, where generators are paired with RES [38,41].

A decision making model to express the optimal bidding in the Day-Ahead energy market for a MG that operates under uncertainty conditions is developed. In particular the proposed methodology focuses on solving the ED (Economic Dispatch) that is the first step of a classic scheduling problem that can be divided into three sequential sub problems: ED, UC (Unit Commitment) [46,34,37] and OPF (Optimal Power Flow) [27,4,10] (Fig. 1).

Traditional power plants and CHP (Combined Heat and Power) units, without storage, are considered in the general formulation of the proposed optimization model. About thermal power production, the whole thermal load, net of the thermal energy produced by CHP, is fully satisfied by the independent boiler.

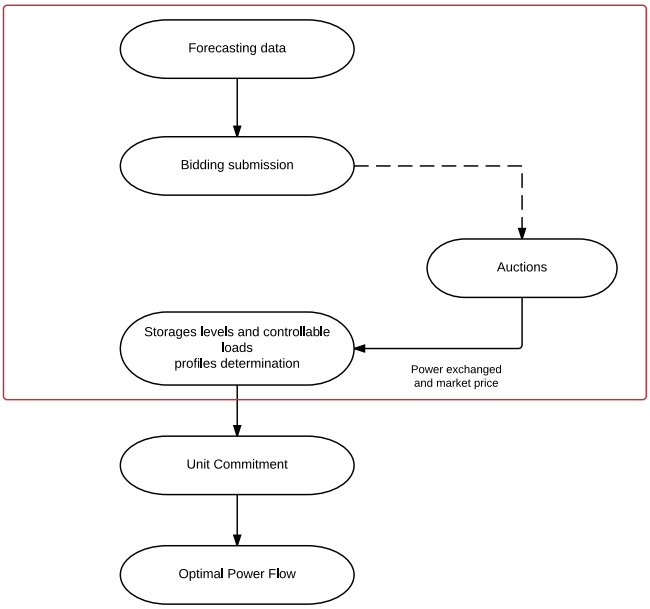

Fig. 1. Temporal sequence of the short-term determinations.

To address the ED problem, the first step is aimed to quantify uncertainty from RES (photovoltaic) production: in fact, basing decisions on a reliable quantification of uncertainty can lead to energy bids can maximize profits and minimize losses.

To resolve this problem is important considering that the role of uncertainty measure to make decisions and participate in a deregulated energy market is a relevant issue to be investigated [1,17,40].

A significant innovation of our work is the use of Analog Ensemble approach to quantify the uncertainty associated with the electricity production from RES [7,2]. The main advantages of AnEn