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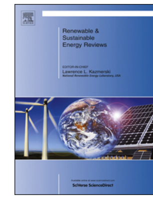

Optimal power dispatching strategies in smart-microgrids with storage

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ABSTRACT

With the development of decentralized power sources based on renewable energy, power grids need smarter operations to be run properly. This paper investigates different procedures for the optimal power dispatching of a grid-connected prosumer with an energy storage consisting in a high speed flywheel. An off-line optimal scheduling for the day ahead aims at minimizing the cost with regards to the daily energy rates and considering the forecasts for both consumption and production. That dispatching is performed thanks to global optimization procedures based on a trust-region method or on a niching genetic algorithm. Another approach using step by step optimization and exploiting an original self-adaptive dynamic programming strategy is also developed. The paper discusses the performance of all the considered methods with regards to the obtained results and the computational time.

Contents

1. Introduction

Global energy consumption has increased by 50% since the 90's and is expected to keep going up with a ratio of 1.6% per year due to the growing population on earth and the new needs that have

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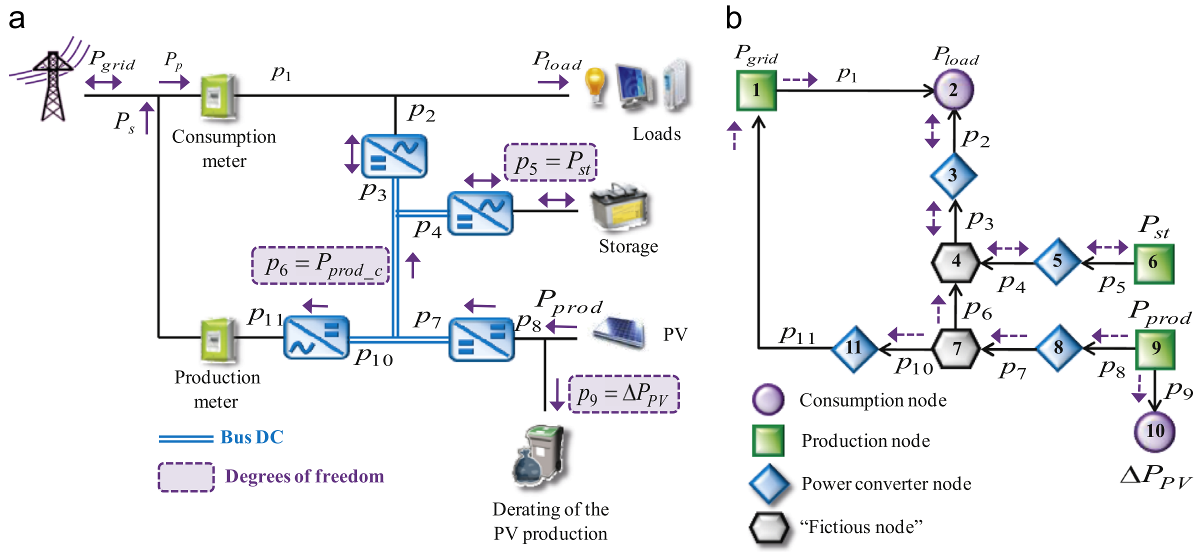

Fig. 1. Considered microgrid (a) and graph representation (b).

emerged [1]. To face that increasing demand of electrical power in compliance with the liberalization of the electricity market and the need of reducing CO_2 emissions, many distributed energy resources have appeared and especially the generation systems that utilize renewable energy sources. Thus, distribution networks evolve towards more meshed structures, and they are likely to become associations of a large number of "microgrids" combining both consumption and production and interacting with the main grid [2]. Due to the stochastic nature of those generations, it requires smarter operations to keep feeding loads in a supply-on-demand system. The improvements in storage technologies allow those operations with a more flexible and reliable management of energy [3]. Renewable energy sources associated with storage units are then considered like active distributed generators, one of the fundamental elements of the "Smart Grid" concept [4]. Adding a storage device deeply questions the most widely used model that consists in selling all the highly subsidized production at important prices and buying the whole consumption. It also allows the owners of microgrids to optimize the power exchanged with the main grid in compliance with the electricity market and the forecasts for the day ahead [5]. Thus, more and more methods based on optimization algorithms are developed to perform the optimal scheduling of power flows within the hybrid electrical systems with load, production and storage [6,7]. In the microgrid considered in this study, all the components are connected through a DC bus (Fig. 1a) with the following data:

- **Consumption**: A building with a maximum contractual power of 156 kW.
- **Production**: Solar PV arrays with a total capacity of 175 kWp.
- **Storage**: A 100 kW/100 kWh storage consisting in ten 10 kW/10 kWh high speed flywheels.

In this paper, an off-line optimal power dispatching problem is introduced with the aim of minimizing global energy cost, considering the forecasts for consumption and production and the possible constraints imposed by the main grid operator. The second section describes the power flow model used to represent the system and the corresponding equations. Then, the next part refers to the proposed optimization methods using an evolutionary algorithms or a trust region strategy that both consider the global load consumption and the PV production over the day. A step by step optimization based on basic Dynamic Programming (DP) is also presented and an original self-adaptive DP is developed. Finally, some results performed with the various algorithms are exposed and discussed, especially in terms of reliability, efficiency and computational time.

2. Power flow model of the microgrid

2.1. Considered microgrid and constraints

Voltages and currents are not considered so far. The study refers to the optimization of active power flows p_i which appear to be a widely used formulation for such a problem [8,9]. A nomenclature of all the used symbols is given in Table 1. Eleven power flows are identified to entirely characterize the system at each time step.

- p_1: power flowing through the consumption meter
- p_2: power flowing between the DC bus and the consumption branch after the converter
- p_3: power flowing between the DC bus and the consumption branch before the converter
- p_4: power flowing between the storage and the DC bus after the converter
- p_5: power flowing between the storage and the DC bus before the converter
- p_6: power flowing between the production branch and the rest of the DC bus
- p_7: effective solar production after the converter
- p_8: effective solar production before the converter
- p_9: derating of the solar production in case of microgrid congestion (section 2.2)
- p_{10}: power flowing through the production meter before the converter
- p_{11}: effective production sold

Due to the grid policy, three system constraints have to be fulfilled at each time step t:

- $P_p(t) \geq 0$: the power cannot return to the grid through the consumption meter.
- $P_s(t) \geq 0$: the main grid cannot feed the DC bus through the production meter.