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COMPARISON OF OPTIMIZATION STRATEGIES FOR POWER DISPATCHING IN SMART MICROGRIDS WITH STORAGE

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Abstract. The paper refers to the off-line control of a smart microgrid based on production and consumption forecast and energy costs of grid power flows. The system consists of an association of loads, PV arrays and a high speed flywheel. Several algorithms are implemented in order to estimate the optimal power dispatching for the day ahead that minimizes global energy costs.

Keywords: optimal power dispatching, smart grid, trust region, dynamic programming, clearing genetic algorithm

INTRODUCTION

The growing number of decentralized sources based on renewable energy requires smarter operations to efficiently run power grids. Distribution networks evolve to a more meshed model, and they are likely to become associations of a large number of "microgrids" combining both consumption and production [1]. Adding a storage device allows more flexible operations and the so called "prosumers" are able to optimize the power exchanged with the main grid in compliance with the electricity market and the forecasts for the day ahead [2]. The studied microgrid is presented in Fig. 1 and consists of an industrial load mixed with a 175 kW photovoltaic generator and a 100 kW/100 kWh flywheel. Section 1 describes the power flow model used to represent the system. Then, an off-line optimal power dispatching is introduced with the aim of estimating for the day ahead the grid power evolution that minimizes global energy costs. Several algorithms are developed and explained in this section in order to solve the optimal dispatching problem. Finally, simulations and results obtained with the investigated algorithms are illustrated in section 2.

1-POWER FLOW MODEL AND ALGORITHMS

Voltages and currents are not considered so far. The study only refers to the optimal dispatching of power flows taking account of the power converters efficiency. Equations are automatically generated using graphs theory and incidence matrices to describe the system [3]. In Fig. 1 (right part), the black arrows between nodes represent conventions for power flows while the possible directions (mono or bi directional ways) are illustrated by red arrows. For a given consumption and production respectively at nodes 2 and 9, three degrees of freedom are required to describe the whole system and to calculate all power flows related to each link while fulfilling the power balance on each node. To perform an optimization for the day ahead knowing the forecasts for P_{load} and P_{PV} , the dispatching procedures take account of the purchase electricity rate $C_{purchase}$ and of the sold energy rate C_{sale} . Limitations on the grid power (P_{grid_max} and P_{grid_min}) are also introduced if the shape of the power flowing through the grid has to be limited.

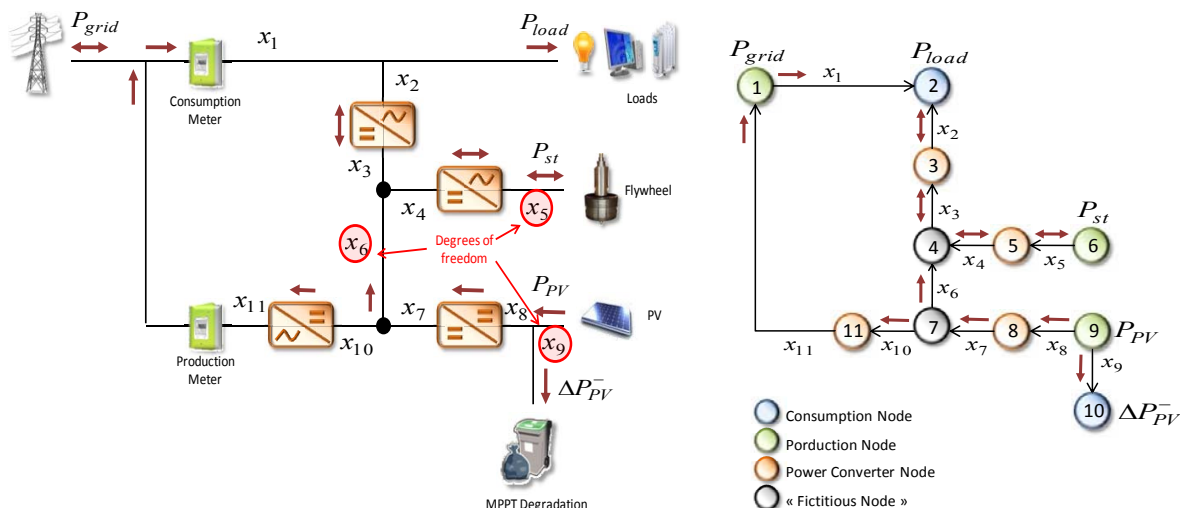


Figure 1: Studied smart microgrid with PV production and flywheel storage

Four strategies are investigated for determining the power flows related to the three degrees of freedoms $\mathbf{x} = [x_5(t), x_6(t), x_9(t)]$ that minimizes the daily energy cost $C(\mathbf{x})$ while fulfilling load, grid and storage constraints. With a time step of 1 hour, all the vectors are 24 points long to represent a whole day. Thus, 72 parameters have to be optimized in order to find a satisfying solution (i.e 24 points for each degree of freedom).

$$(1) \quad C(\mathbf{x}) = \sum_{t=0}^{24h} C_{purchase}(t) \cdot x_1(t) - C_{sale}(t) \cdot x_{11}(t).$$

A trust region method [4] and the clearing genetic algorithm [5] with constraint handling based on penalty functions are independently used for estimating the optimal references $x_5^*(t)$, $x_6^*(t)$, $x_9^*(t)$ over the day ahead. Dynamic programming is also investigated through a standard scheme and an original self-adaptive algorithm so as to explore step by step the minimization of the cost. Both procedures exploit the Bellman-Ford algorithm for the determination of the shortest path between the initial and final point while discretizing the state of charge of the flywheel with a step size of 1kWh [6]. All investigated optimization strategies will be detailed in the final paper.

2-SIMULATIONS AND RESULTS

All procedures are tested and compared with regard to the quality of the objective function $C(\mathbf{x})$ and the computational time on a standard PC computer with a clock speed of 2 GHz (see Table 1). The results below are obtained with $C_{sale} = 0$, $C_{purchase} = 0.13\text{€}/\text{kWh}$ from 6 a.m. to 10 p.m. and $C_{purchase} = 0.08\text{€}/\text{kWh}$ otherwise. No limit on the grid power P_{grid} is considered in this particular example. Table 1 shows the good efficiency of the trust region method that quickly finds an optimal solution with a non-feasible starting point arbitrary chosen. Good results were also obtained with the dynamic programming especially with the self-adaptive scheme that notably decreases the computational time. The clearing genetic algorithm was outperformed for the given hypothesis but it will be shown in the final paper that it can be relevant in other cases.

Table. 1 Comparison of optimal dispatching strategies

Dispatching strategy	Trust Region	Basic dynamic programming	Self-adaptive dynamic programming	Clearing genetic algorithm
Cost $C(\mathbf{x})$	17.43 €	17.52 €	17.52 €	21.80 €
CPU Time	2 min	90 min	19 min	75 min

Fig 2 shows some results obtained for a particular transient solution \mathbf{x} that fulfills the constraints and for the optimal solution \mathbf{x}^* found by the trust region method. In Fig 2.b. the storage unit is used in a more efficient way for \mathbf{x}^* with full cycles from 0 to 100%. It allows the objective function to decrease from 40.07 € for \mathbf{x} to 17.43 € for \mathbf{x}^* . As shown in Fig 2.a., the optimal solution limits the power flowing through the consumption meter when the energy cost is high.

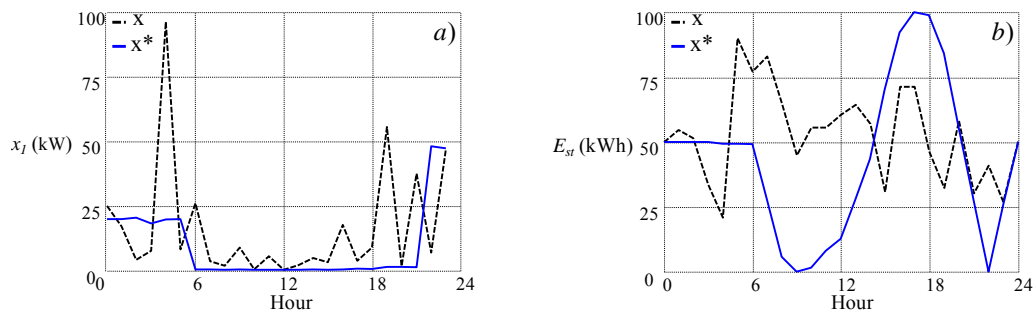


Figure 2: Illustration of the optimal dispatching. Comparison a particular solution (\mathbf{x}) with the optimal solution (\mathbf{x}^*) : grid power flow x_1 (a) and resulting energy storage E_{st} (b)

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