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# POWER FLOW OPTIMIZATION IN A MICRO-GRID WITH TWO KINDS OF ENERGY STORAGE

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**Abstract.** The paper presents the optimization of the power flows inside a micro-grid with renewable sources and two kinds of storage. The optimization is carried out on a period of one day at one hour discretization and the variables are the degrees of freedom that allow controlling the whole system in order to minimize the electrical bill. Different optimization approaches are used and results compared both in terms of accuracy and of computational efficiency.

**Keywords:** Clearing, elitist niching, differential evolution, mixed integer linear programming, optimal power flow, smart grids.

## INTRODUCTION

A micro-grid is a portion of the electrical distribution system, containing both Distributed Generation (DG) and local electrical loads, which can exchange power with the main electrical network through a point of delivery. The management of the micro-grid requires to choose the most appropriate mix of power production and power purchase from the grid to minimize the overall energy cost fulfilling both user needs and technical constraints at the same time. This optimal scheduling is often performed considering prices policy and forecasts for both consumption and production. If DG is controllable, as in the case of internal combustion engines gensets, it can be a variable of the optimization, on the contrary, if it is based on a renewable energy source like Photo-Voltaics (PV) it is taken as an assigned power production profile. If energy storage is present another degree of freedom is available: energy storage can in fact decouple the time instant of power production from that of its consumption or its sell to the grid when the price is economically more convenient. Different optimization techniques can be used for the optimal power flow definition depending on the simulation model of the micro-grid: if all components are described by linear input-output relations, Mixed Integer Linear Programming (MILP) technique can be used [1] but if nonlinear relations are present heuristic optimization techniques should be considered [2].

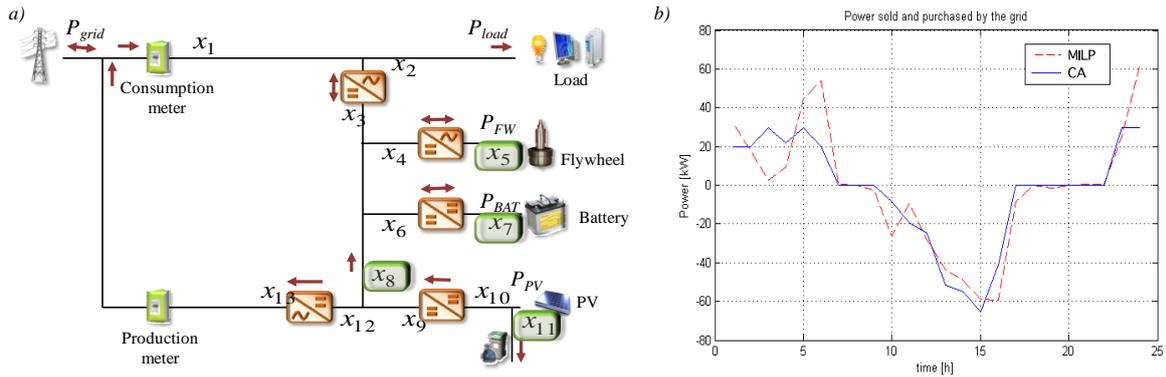
## MICRO-GRID OPTIMIZATION

The micro-grid used for optimization is outlined in Fig. 1a and contains:

- Consumption: a building with a commercial load with a daily peak value of 50 kW;
- Production: PV arrays with a total capacity of 175 kW;
- Storage: a 50 kW/50 kWh high speed flywheel and a 50 kW/50 kWh Li-Ion battery;
- Grid: connection to the electrical infrastructure takes into account a Time-Of-Use fare scheme for the purchasing of electrical power with on and off peak unit costs, while a flat selling cost of energy to the grid is considered. In addition a limit on the maximum level of power sold to the grid can be inserted.

The model of the flywheel is extracted from data provided by the manufacturer and the ageing effects are considered. The Li-ion battery is represented thanks to the Shepherd model [3] and the state of health (SOH) of the elements is computed by integrating the energy exchanged with the system as in (1) where  $E_{BATexch}$  represents the total amount of energy that the battery can exchanged before its end of life.

$$(1) \quad SOH(t) = 100 - \frac{100}{E_{BATexch}} \int_0^t |P_{BAT}| dt$$



**Figure 1:** Power flow optimization - a) studied microgrid - b) example of obtained results for the grid power  $P_{grid}$

The time scheduling period is one day discretized on a one hour basis within which the variables are considered to be constant. The optimization variables are the four degrees of freedom that allow controlling the whole system knowing the values of the consumption ( $P_{load}$ ) and the production ( $P_{PV}$ ):

- the power flowing from/to the flywheel unit;
- the power flowing from/to the battery unit;
- the share of the power flowing from the PV arrays to the common DC bus which is not sold to the grid;
- a derating factor of PV production which denotes the capacity to decrease the PV production (MPPT degradation) in order to fulfill grid constraints, in particular when the electrical grid does not allow (or limits) the injection of the PV production.

The power flow optimization aims at minimizing the total cost on a given day computed from the cost of the purchased energy ( $C_p$ ) and the prices of the sold production ( $C_s$ ). It finds the appropriate values of the degrees of freedom that control the power through the meters (i.e  $x_1$  and  $x_{11}$ ) and allows the computation of the final cost  $C$  as in (2):

$$(2) \quad C = \sum_{t=0}^{t=24h} x_1(t) \times C_p(t) - x_{11}(t) \times C_s(t)$$

Different constraints related to the the power flows direction are also introduced and limitations of the power exchanged with the main grid ( $P_{grid}$ ) are taken into account. Three different optimization procedures have been used: the first based on a MILP optimization considering a linearized model of the system [1] and two evolutionary algorithms, in particular on Clearing Algorithm (CA) [4] and Niching Differential Evolution [5]. For both metaheuristics the constraints are computed in a vector  $\mathbf{C}_{nl}$  and are included into the objective function  $f_{obj}$  with a penalty coefficient  $\lambda$  (typically  $\lambda = 10^6$ ) as in (3):

$$(3) \quad f_{obj} = C + \lambda \times \sum \mathbf{C}_{nl}$$

We have displayed in Fig. 1b the grid power obtained from MLP and CA on a particular day. Those results show a convergence to the same attraction region. An extensive discussion and comparisons will be shown at the Workshop. The different approaches will be analyzed according to the optimal cost and computational time. A particular attention will also be paid to the power profiles of both storage devices with regard to their ageing effects.

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