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Energy Resources Scheduling in Energy Communities: A comparison between Mixed Integer Linear Programming and Hybrid-adaptive Differential Evolution with decay function

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ABSTRACT

- Two optimization methods examined: Mixed Integer Linear Programming (MILP) and Hybrid-adaptive Differential Evolution with decay function (HyDE-DF).
- Considered generation, consumption flexibility, energy storage, electric vehicles with vehicle-to-grid capability, and grid electricity exchange.
- Insights provided for improving convergence and solution quality.
- Both methods yield comparable operation costs:
  - MILP (159.33),
  - HyDE-DF (153.49).

1. INTRODUCTION

- Energy transition is a multidisciplinary topic of research, bringing innovation to sectors that affect daily life [1].
- European Union has proposed a set of guidelines to achieve net-zero greenhouse gas emissions by 2050, highlighting action on sectors such as electricity, transportation and industry [2], [3].
- Energy Communities (ECs) is a concept that has been gaining a significant amount of traction.
- This work provides with two main contributions – an implementation of the HyDE-DF algorithm [4], and a benchmark against MILP.

References

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2. METHODS

The implementation counts with two major components - a mixed integer linear programming approach, implemented using the Pyomo package, and IBM ILOG CPLEX Optimization Studio. The second component is a fresh implementation of the HyDE-DF algorithm that was originally developed in MATLAB. The operator for HyDE-DF is defined as:

$$\vec{m}_{i,G} = \vec{x}_{i,G} + \delta_G \cdot [F_i^1(\epsilon \cdot \vec{x}_{best} - \vec{x}_{i,G})] + F_i^2(\vec{x}_{r1,G} - \vec{x}_{r2,G})$$

Due to convergence issues, HyDE-DF made use of a heuristic to drive Electric Vehicle behavior and stabilize solution generation.

- Vehicles charge based on the remaining time for departure
- Amount of charge is maximized whenever it is possible

Having as goal the minimization of operational community costs, the objective function was defined for both approaches as the sum of all component costs:

$$obj = gens + loads + stor + v2g + rest$$

Where *gens* represents the total costs associated with generators, *loads* considers the total consumption costs, *stor* symbolizes the storage expenses, *v2g* stands for the electric vehicles' costs, and *rest* defines the costs of grid imports and exports.

To aid convergence, HyDE-DF used an additional penalty term, to ensure balance across the grid and that all solutions respect it. The penalty is based on the absolute difference of energy in the grid, resulting from surplus or deficit.

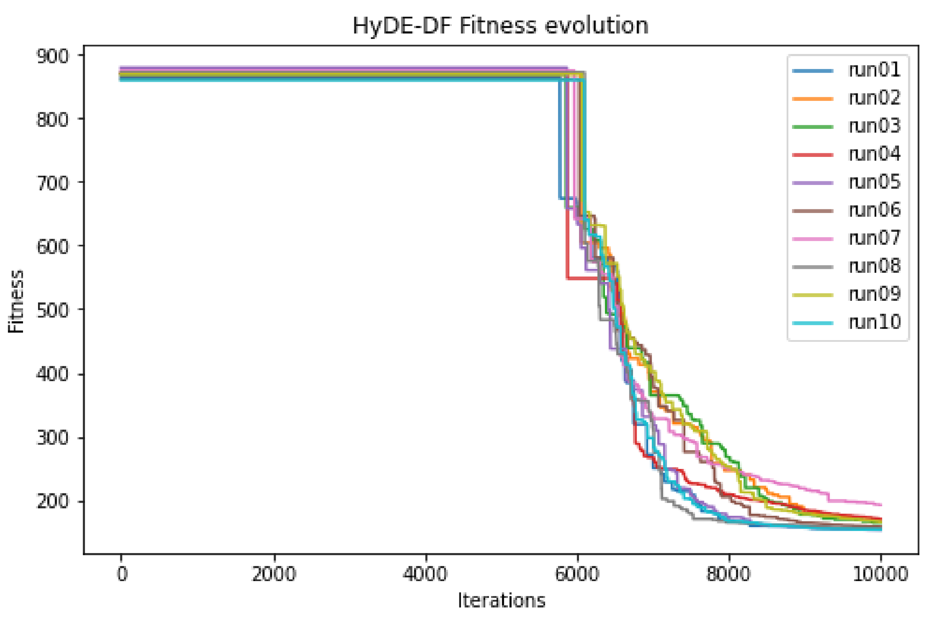
3. RESULTS

HyDE-DF was tested over 10 runs, to reduce variance and assess how the algorithm performs under various random seeds.

	Fit	Time
Run 01	153.7518	1772.2051
Run 02	166.2182	1766.0639
Run 03	164.5539	1769.9617
Run 04	169.9297	1765.9813
Run 05	153.4883	1759.9807
Run 06	158.2969	1768.2374
Run 07	192.2661	1769.2909
Run 08	155.6107	1773.5668
Run 09	165.5723	1770.7336
Run 10	153.8945	1775.9723
μ	163.3583	1769.1994
σ	11.824	4.5095

HyDE-DF Run performance

- HyDE-DF was given an initial solution to guide evolution:



- HyDE-DF achieved consistent results, with small standard deviation.
- Comparable results (153.49) with MILP approach (159.33).
- HyDE-DF actively used the batteries, reducing required importations

4. CONCLUSIONS

- HyDE-DF proved an effective method for energy scheduling in small-scale Energy Communities
- A heuristic for EV handling and initial solution were given to HyDE-DF to aid convergence.
- Solution quality is comparable to MILP
- An extended number of methods should be considered and benchmarked against HyDE-DF
- Time horizon and total of resources considered should be studied
- Sensitivity analysis of algorithm capabilities should be considered in future studies

PyECOM tool

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