ALFRED: The Artificial Learning Flexible Renewable Energy System Dispatch Optimizer

A.C. do Amaral Burghi*,[1], T. Hirsch[1] and R. Pitz-Paal[2]
[1]German Aerospace Center (DLR), Institute of Solar Research, Stuttgart, Germany
[2]German Aerospace Center (DLR), Institute of Solar Research, Cologne, Germany
*ana.doamaralburghi@dlr.de

Motivation

- The high penetration of renewable energies in the grid brings imbalance on power market prices and modify typical demand design curves(1).
- Renewable energy systems with storage are able to provide flexible dispatch, bringing the significant advantage of economically meeting peak demand.
- Therefore, renewable systems with storage are expected to participate in whole-sale electricity markets, enabling competition with all the players in the market and ensuring the pathway to a highly renewable energy mix

Objectives

- **Why to optimize the dispatch?**
  - To produce clean energy during electricity demand peaks
  - To reach higher selling prices of electricity produced from renewable energy systems
  - To adapt plant operation practices according to optimal production schedule
  - To allow renewable energy systems with storage to participate in the wholesale energy market
- **Why to consider forecast uncertainties?**
  - To improve the quality of electricity scheduling by actively considering associated uncertainties in weather and pricing forecasts
  - To reduce financial drawbacks related to modification of scheduled energy delivery

Approach & Methods

- **Developed tool:**

Dispatch Optimizer that derives a electricity delivery schedule for the day-ahead. It considers weather and electricity pricing forecasts as input, as well as specific market rules.

- **Methodology:**

Partitioned calculation between a problem-specific(2) rule-based optimization algorithm and the uncertainty processing, based in machine learning techniques.

- **Innovations:**
  - Incorporation of uncertainties associated to forecasts
  - Possibility of dealing with several types of weather forecasts
  - Possibility of combination with several types of optimization methods and system models
- **Benefits:**
  - Development of flexible delivery strategies according to the market setup and decision moment
  - Flexible application for several electricity markets and different renewable energy systems

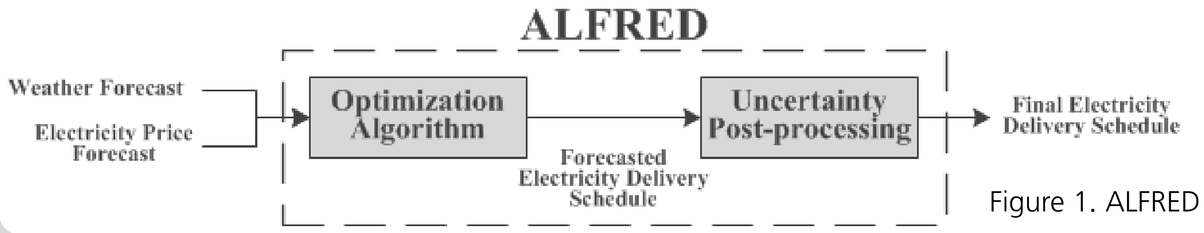

Figure 1. ALFRED scheme: partitioned strategy of optimization and uncertainty treatment.

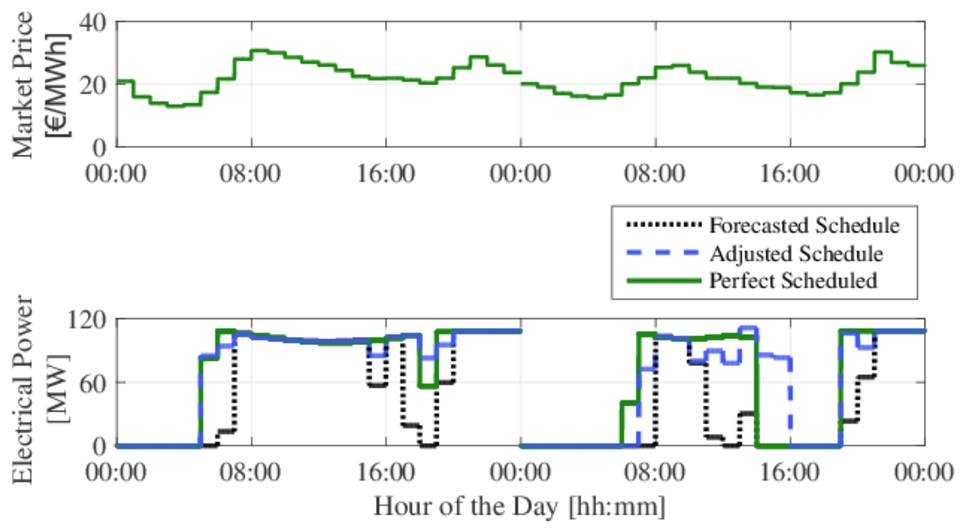

Figure 2. Forecasted, final (adjusted) and perfect schedule for two simulated days.

Results

- **Annual Simulations:**
  - Considering a 120 MW concentrated solar thermal plant with 10h storage following ALFRED's strategy
  - Three different weather forecast sets: perfect, persistence and ECMWF probabilistic sets
  - To evaluate ALFRED's benefit, simulation of the same plant following a solar driven strategy was carried out

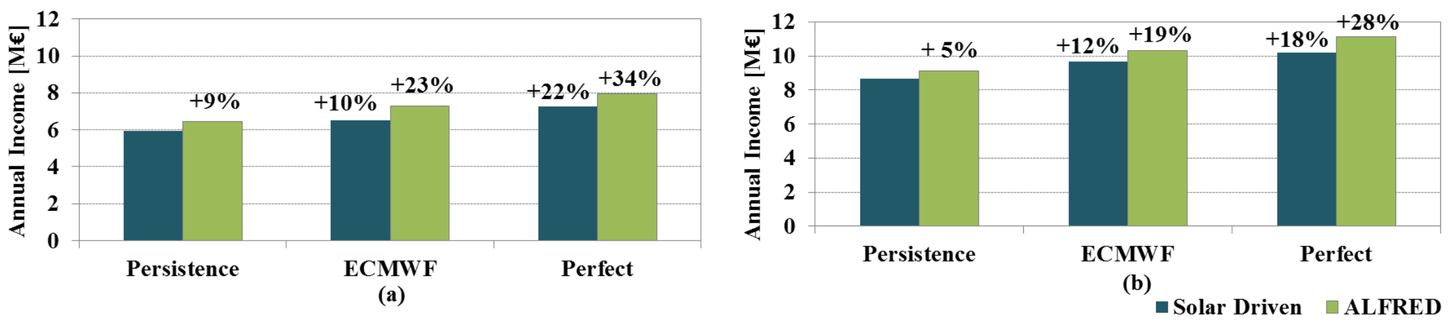

Figure 3. Annual financial income improvement in comparison to benchmark scheduling strategy for 2016 (a) and 2017 (b).

- **Improvement in Financial Income:**
  - Due to possibility of achieving more accurate delivery
  - Related to the quality of the weather forecast and enhanced with the uncertainty post-processing
  - ALFRED scheduling over performs a simple scheduling strategy
  - ALFRED is able to improve revenues independently on the quality of the weather forecast
  - **Illustrating Example:** financial income comparison
    - for different weather forecast sets
    - compared with benchmark scheduling strategy (solar driven + persistence forecast)

Conclusions

- Uncertainties included in dispatch optimization
- More accurate delivery scheduling
- Quality of schedules is not exclusively bounded to quality of weather forecasts
- Possibility of combination with several types of optimization methods and system models
- Possibility of dealing with several types of forecasts (deterministic or probabilistic)
- Flexible application for different renewable energy systems with storage
- Flexible application for different market scenarios
- Improvement in financial income of renewable energy systems with storage , which leads to possible participation in wholesale energy market

References

(1) IRENA, "Adapting market design to high shares of variable renewable energy", Abu Dhabi (2017).
(2) D.H. Wolpert and W.G. Macready, "No free lunch theorems for optimization", in IEEE Transactions on Evolutionary Computation, Vol.1, No. 1 (1997).

Acknowledgements:
This work was conducted in cooperation with partners from the PreFlexMS project, under Grant Agreement no. 654984 of European Union's Horizon 2020 Programme.