Planning and operation of distribution-level flexibility providers considering power system operators' requirements

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1. Introduction

Fast transition towards the decentralized power system paradigm based on a high share of renewable energy sources creates challenges for system operators. These challenges range from potential bidirectional power flows and voltage deviations to generation uncertainty and the risk of failing to meet demand requirements in a safe and reliable manner.

2. Problem Description

The increasing focus on distributed energy sources has brought the distribution level into the forefront of grid management. The current "fit and forget" approach for managing flexibility at the distribution level is insufficient for the high penetration of renewable energy sources. Therefore, there is a need to develop new methods that provide greater flexibility and stability to ensure the reliable integration of renewable energy sources into the grid.

3. Methodology

We propose the development of locally-based flexibility procurement services within a distribution-level market that operates concurrently with the conventional transmission-level market. Specifically, we introduce two versions of this approach: the **Reactive and Proactive Distribution-Level Flexibility Market** (R-DLFM and P-DLFM). The main difference between the two is the clearing time of the DLFM in relation to the Day-Ahead Market (DAM) clearing time, which determines their level of integration with the existing market structure.

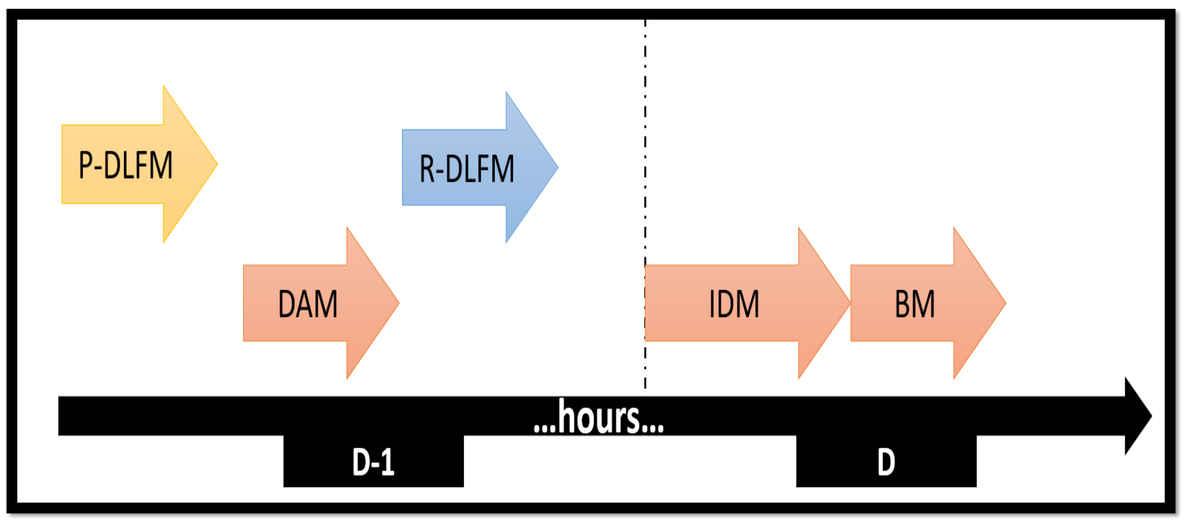

Figure 1 – Different DLFM setups

4. Uncertainties

To effectively address market price uncertainties, we propose a modeling approach that utilizes both robust optimization and stochastic optimization methods. Specifically, we use robust optimization to model the intraday market (IDM) due to its sensitivity to price fluctuations, while we use stochastic optimization to model other pay-as-clear markets. The use of robust optimization in the IDM ensures a more reliable and efficient market outcome by considering the worst-case scenarios, while stochastic optimization in pay-as-clear markets allows for a more comprehensive and realistic modeling of price uncertainties. The combination of these two methods offers a more effective and robust approach to market modeling that can adapt to changing market conditions and uncertainties, ultimately leading to a more stable and reliable energy system.

5. Results

The R-DLFM and P-DLFM market setups are modeled in the same manner to make comparable results. Depending on the chosen budget of uncertainty in the IDM, activities in markets change and, consequently, overall profits differ. Battery storage gains major benefit by acting in different markets and performing inter-market arbitrage, which generates a significant profit and results in trading power capacities higher than the actual battery capacity. Purchasing energy in one market and then selling it in the other may result in zero, or at least lowered, actual battery charging/discharging, which extends the battery's lifetime

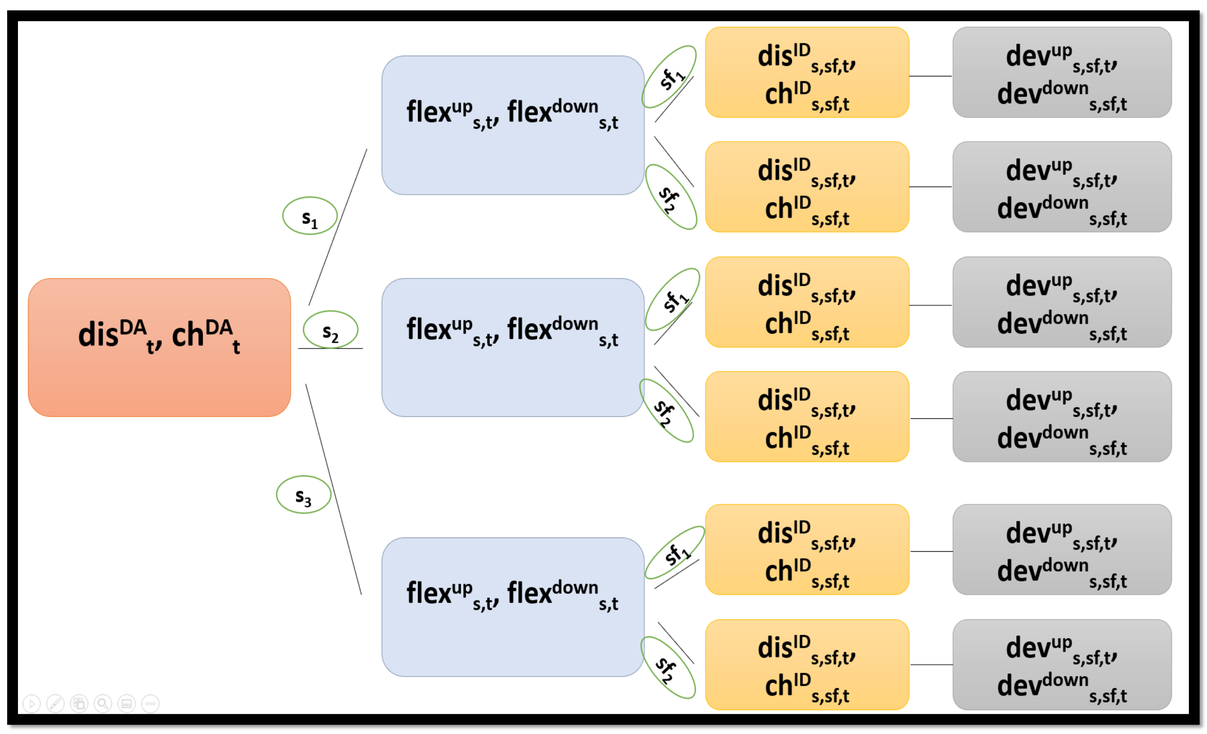

Figure 2 – R-DLFM concept decision stages

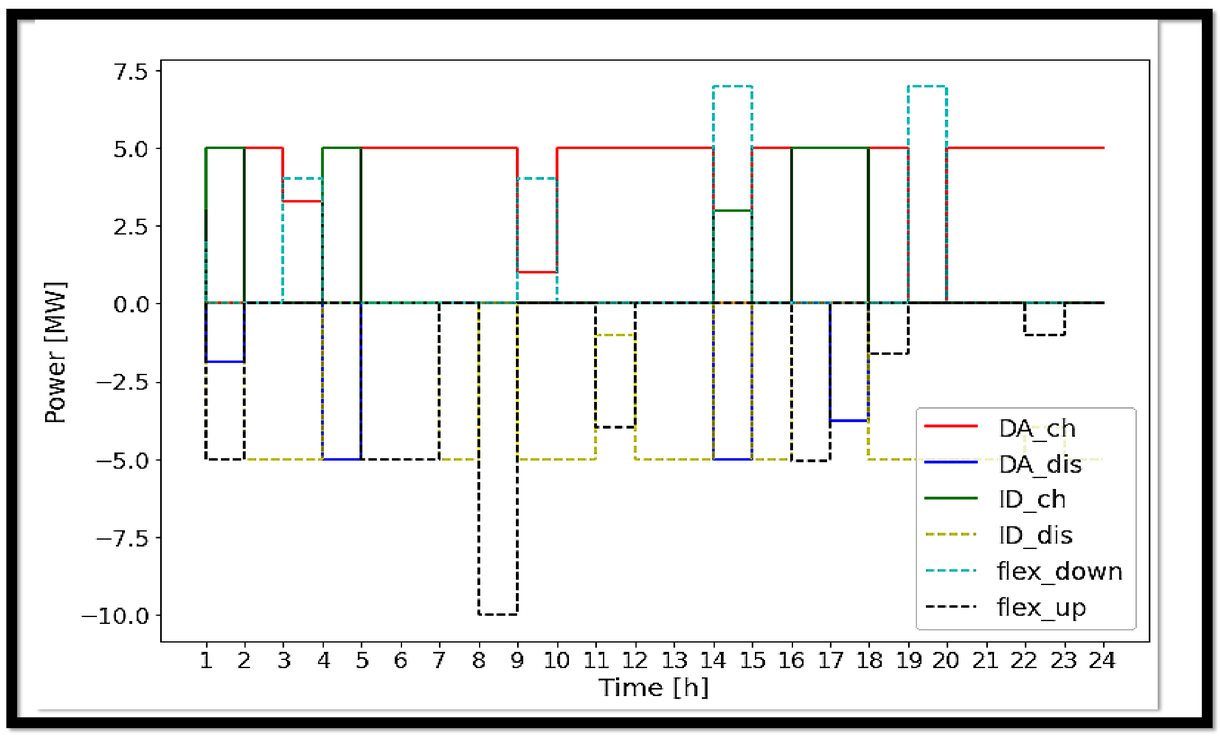

Figure 3 – Battery storage unit market activity with R-DLFM setup

6. Conclusion

The R-DLFM is a better fit to the existing power market structures, whereas the P-DLFM provides greater profit potential for the flexibility service provider. Both concepts encourage inter-market arbitrage. Proposed concepts require an adequate TSO-DSO coordination as the DSOs transform from passive entities to active players. Furthermore, flexibility pricing mechanism should be researched to address challenges such as market liquidity and flexibility provision attractiveness.

Acknowledgments

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