**Towards Information-aware Policymaking on DER remuneration**

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## Overview

Decarbonization of energy systems benefits strongly from the deployment of distributed energy resources (DERs) with little or zero carbon footprints such as solar, wind, and small hydro. Thus, appropriate remuneration policies for stimulating DER deployments are crucial for efficient energy transition and achieving low-carbon goals. To better align remuneration with the value of DERs, some jurisdictions have introduced advanced remuneration policies, replacing the legacy approach of net energy metering (NEM). For instance, the Department of Public Service of New York designed a value stack approach to compensate DERs at a rate reflecting their energy, environmental, capacity value, among others [1]. Distribution locational marginal pricing (DLMP) is another remuneration alternative, which can account not only for the energy value but also for losses, voltage regulation, and congestion and, therefore, provide more accurate pricing signals [2], [3].

However, unlike NEM, more dynamic remuneration policies such as the value stack or DLMP described above include inherent uncertainties. Energy prices in both transmission and distribution networks vary depending on the time and location, and the estimation of values that flow into the value stack (e.g., carbon emission reduction, avoided capacity costs) is uncertain as well since they are set on an occasional basis [1]. This information problem brings profit uncertainties to DER developers, which may increase and aggregate these risk exposures. As a result, DER investors could make sub-optimal investments, and in turn, the overall social welfare can be diminished compared to the omniscient case without any information problem. In order to avoid a sub-optimal DER roll-out and maximize the social welfare, decision-making tools for DER remuneration policies must account for profit risks.

This paper aims to analyze the impact of information awareness on DER aggregators under different DER remuneration policies. We take the perspective of the regulator and develop two frameworks: information-aware and information-unaware models. Similar to [4], the information-aware model assumes omniscient knowledge of the policymaker. In contrast, the information-unaware model formulates a risk-informed stochastic optimization problem. Both models account for the interests of different stakeholders (regulator, DER aggregator, power utility, wholesale electricity market, consumer) by exploiting a multi-level structure that allows capturing strategic interactions among them.

## Methods

We develop policymaking support tools that represent the decision-making process of each entity involved. Thus, the regulator sets the optimal tariff for DERs and consumers to maximize the total social welfare while meeting the exogenously set renewable portfolio standard (RPS) goal. DER aggregators are assumed to make investments (how much DER to build?) and operation decisions in the wholesale and distribution-level marketplaces (how much capacity to offer and at what price?). Also, we consider power utilities as profit-seeking entities that operate a distribution grid and serve consumers that maximize their surplus. Lastly, the wholesale electricity market maximizes the social welfare within a market service territory.

We also propose a risk-informed optimization for the information-unaware model using risk measures: value-at-risk (VaR) and conditional value-at-risk (CVaR) [5]–[8]. Both VaR- and CVaR-based optimizations have the advantage of known deterministic reformulations. Additionally, to overcome the complexity of the proposed multi-level models that cannot be solved directly using off-the-shelf solvers, we first reduce the multi-level optimization to a bi-level problem, and then customize the column-and-cut (C&CG) algorithm [9] allowing for solving the original problem iteratively.

## Results

The case study solves the information-aware and -unaware models using the NYISO and Manhattan test systems with the NEM, value-stack, and DLMP remuneration policies. In both models, the DLMP policy attains the greatest social welfare followed by the value-stack and NEM. A better ability to accurately predict the remuneration value results in greater social welfare regardless of the policy chosen, because it reduces risk exposure of DER aggregators and avoids underestimating its revenue, while optimizing the investment decisions.

Also, to robustify the investment decisions against the uncertainty, the DER aggregator secures a greater profit in the information-unaware model, through the risk-informed optimization even if it has the same expectation of the DER tariff compared to the information-aware model. Moreover, a more conservative value of risk tolerance increases the profit attained by DER aggregators, resulting in a decreased social welfare while achieving the same RPS goal.

## Conclusions

This paper proposes information-aware and unaware decision-making support tools for policymakers to investigate the effects of information-awareness of DER aggregators on DER remuneration policies. These tools facilitate policymaking on consumer and DER tariffs as well as RES incentives under different RPS goals. A multi-level optimization structure is adopted for both the information-aware and -unaware models to capture interactions among multiple stakeholders within the market while coherent risk measure-based optimization is introduced for the information-unaware model. The numerical analyses on the NYISO-Manhattan test systems reveal that the DLMP-based remuneration achieves the highest social welfare among the three policies under all RPS goals simulated. Moreover, we present the quantified value of information-awareness on the DER remuneration tariff for the low, medium, high probabilistic perception scenarios.

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