A Peer-to-Peer Market-Based Control Strategy for a Smart Residential Community with Behind-the-Meter Distributed Energy Resources

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Abstract

This paper develops a distributed peer-to-peer market control strategy to manage and to enable resource sharing of behind-the-meter distributed energy resources in a residential community. The proposed framework has the following major steps:

1) Each consumer or prosumer determines the flexibility of their point of connection to the power network such that the obtained flexibility is network-feasible.
2) Based on the feasible flexibility, the consumers and the prosumers trade power among each other at each time instance to fulfil their preferred load requirements while maximizing their payoffs and helping to regulate node voltages inside the community.
3) Because the problem to be solved is non-convex, a distributed particle swarm optimization algorithm is used to coordinate the consumers/prosumers in a fully autonomous manner

Control Objectives and Constraints

Objective = Maximize Flexibility + Product of Cost Advantage of Prosumers and Consumers

$$minimize\ F_{p2p}^t = -F_{flex}^t - \prod_{i\in N_p^t, j\in N_c^t} U_{ci}^t U_{pj}^t$$

$$= \alpha_{flex} \sum_{i\in N^+} [min(\hat{p}_i^t - \breve{p}_i^t) + min(\hat{q}_i^t - \breve{q}_i^t)] +$$ ← *Flexibility of the homes*

$$\prod_{i\in N_p^t, j\in N_c^t} \left\{ c_p^t p_i^t - \left[\sum_{j\in N_p^t} \bar{\pi}_{s,ij}^t \bar{p}_{s,ij}^t + c_p^t \left(p_i^t - \sum_{j\in N_p^t} \bar{p}_{s,ij}^t \right) \right] \right\} \times$$ ← *Cost Advantage for Prosumers*

$$\left\{ -\left[-\sum_{j\in N_c^t} \bar{\pi}_{b,ij}^t \bar{p}_{b,ij}^t + f c_p^t \left(p_i^t + \sum_{j\in N_p^t} \bar{p}_{b,ij}^t \right) \right] + f c_p^t p_i^t \right\}$$ ← *Cost Advantage for Consumers*

Subjected to:

Linear Voltage Estimation: $\breve{v}_i^t, \breve{p}_i^t, \breve{q}_i^t, \hat{v}_i^t, \hat{p}_i^t, \hat{q}_i^t$

$\hat{p}_i^t \geq \breve{p}_i^t, \quad \hat{q}_i^t \geq \breve{q}_i^t,$

$\underline{v} \leq \hat{v}_i^t \leq \bar{v}, \quad \underline{v} \leq \breve{v}_i^t \leq \bar{v},$ ← *Network voltage constraints*

$f c_p^t \leq \bar{\pi}_{s,ij}^t \leq c_p^t$

$\breve{p}_i^t \leq p_i^t \leq \hat{p}_i^t$

$0 \leq \bar{p}_{s,ij}^t, \quad p_i^t \geq \sum_{j\in N_p^t} \bar{p}_{s,ij}^t$ ← *Prosumer trading constraints*

$f c_p^t \leq \bar{\pi}_{b,ij}^t \leq c_p^t$

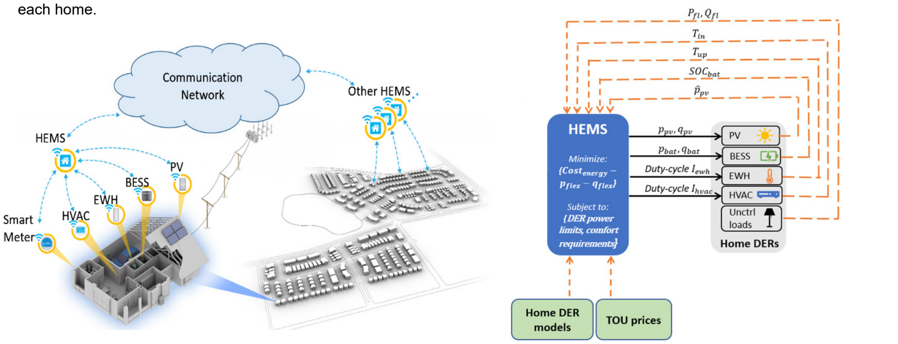
$\breve{p}_i^t \leq p_i^t \leq \hat{p}_i^t$

$0 \leq \bar{p}_{b,ij}^t, \quad p_i^t \leq -\sum_{j\in N_p^t} \bar{p}_{b,ij}^t$ ← *Consumer trading constraints*

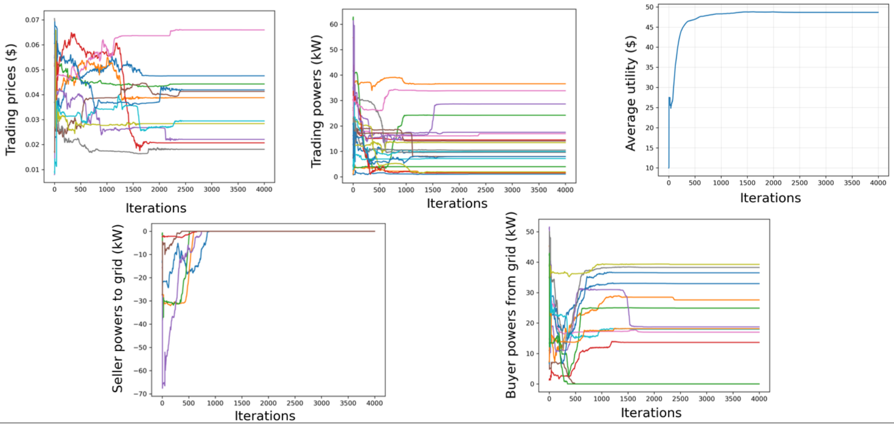
$\bar{\pi}_{b,ij}^t = \bar{\pi}_{s,ji}^t, \quad \bar{p}_{b,ij}^t = \bar{p}_{s,ji}^t$ ← *Trading boundary constraints*

The Distributed P2P Framework

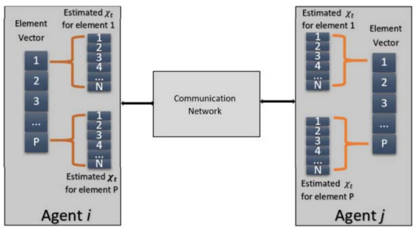
The envisioned framework considers a home energy management system (HEMS), which manage DERs, such as rooftop photovoltaics, battery energy storage systems, electric water heaters, and heating, ventilating and air-conditioning appliances, in each home.



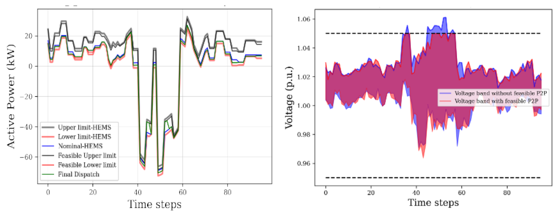
Numerical Results



Consensus-based PSO



Solution Feasibility



Conclusions

1) A distributed P2P trading framework is developed to enable resource sharing of behind-the-meter DERs in a residential community
2) Unbalanced power flow formulation and network voltage constraints are considered
3) The proposed approach can be effectively used for optimal sharing of energy from customer-owned DERs with other consumers within the community and with the upstream distribution grid

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