Achieve Social Optimal in Energy Trading Market via MATLAB Programming

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INTRODUCTION

In the future energy trading market, optimizing trading strategies for prosumers is essential due to the growing number of energy prosumers participating in the market. A responsive algorithm and application have been developed for prosumers to facilitate automatic energy trading that maximizes the user's profit.

OBJECTIVES

- Use Energy Sharing Bidding to utilize market resources
- Create an application for prosumers to help with their market decisions
- Design market simulations for further energy trading strategy analysis

METHODOLOGY

Algorithm

- Cost and Utility Function

$$f_{i(p_i)} - u_{i(d_i)} = (\alpha_i {p_i}^2 + \alpha_i{}^2 \mathrm{p_i}) - (\beta_i {d_i}^2 + \beta_i{}^2 d_i)$$

- Self-sufficiency

$$\min_{p_i, d_i} f_i(p_i) - u_i(d_i)$$
$$s.t.\ p_i = d_i$$
$$\underline{p}_i \le p_i \le \overline{p}_i$$
$$\underline{d}_i \le d_i \le \overline{d}_i$$

  - Individual prosumers produce the same amount as their demand

- Centralized Operation

$$\min_{p_i, d_i,\ \forall i \in I} \sum_{i=1}^{I} [f_i(p_i) - u_i(d_i)]$$
$$s.t. \sum_{i=1}^{I} p_i - \sum_{i=1}^{I} d_i = 0 : \lambda_m$$
$$\underline{p}_i \le p_i \le \overline{p}_i, \qquad \forall i \in I$$
$$\underline{d}_i \le d_i \le \overline{d}_i, \qquad \forall i \in I$$

  - The central operator controls the whole prosumer market
  - Main objective: Minimize the total net cost

- Energy Sharing Bidding

$$\min_{p_i, d_i} f_i(p_i) - u_i(d_i) + \frac{(d_i - p_i)^2}{2a(I-1)} + \lambda^k (d_i - p_i)$$
$$s.t.\ \underline{p}_i \le p_i \le \overline{p}_i$$
$$\underline{d}_i \le d_i \le \overline{d}_i$$

  - Users input parameters into smart meters
  - Each prosumer's bid is updated iteratively without knowledge of other prosumers' actions, until an optimal solution is reached.

Application

- MATLAB Optimization Toolbox: fmincon()
  - $x = fmincon(fun, x0, A, b, Aeq, beq, lb, ub)$
  - Defines a set of lower and upper bounds on the design variables in x.
- Dynamic Market Size
  - Transform a fixed-sized market into a dynamic market that can adapt to the varying number of users accessing the system.
- Graphical User Interface (GUI)
  - Design a user-friendly interface for practical use of real-life simulations.
  - Minimize human errors by limiting access to actual coding

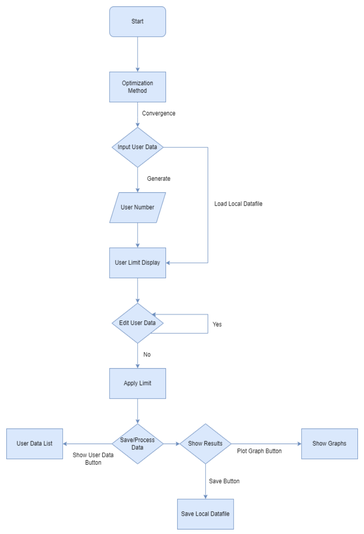

Figure 1: Application Flow Chart

RESULTS

Application Interface

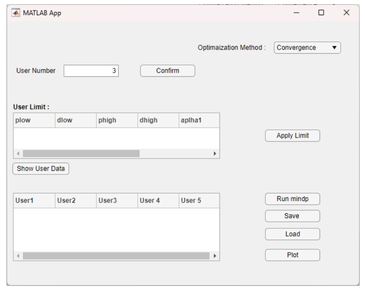

Figure 2 : MATLAB GUI

- Basic Usage:
1. Confirm user number
2. Apply user limit
3. Run mindp

User Limit (n = 20)	$\underline{p}$ *plow*	$\underline{d}$ *dlow*	$\overline{p}$ *phigh*	$\overline{d}$ dhigh	α_1	α_2	β_1	β_2
Lower Bound	0	5	20	18	0.008	0.038	-0.014	0.4
Upper Bound	0	10	30	25	0.015	0.056	-0.008	0.8

Figure 3 :User Limit

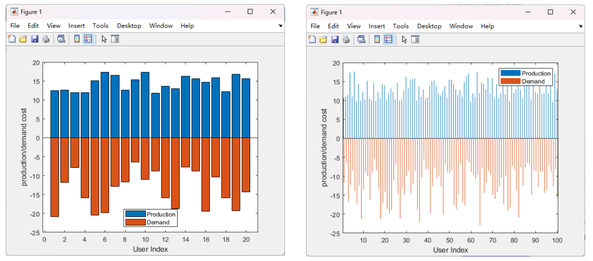

Figure 4 & 5 : Production-Demand Graph

Market Utilization

Total Net Cost	n = 20	n = 100
Energy Sharing Bidding	-82.8	-342.9
Centralized Operation	-88.5	-346.9

Figure 6 : Total Net Cost with Different Approaches

- From the broad market perspective:
  Energy Sharing Bidding ≈ Centralized Operation

Individual Prosumers

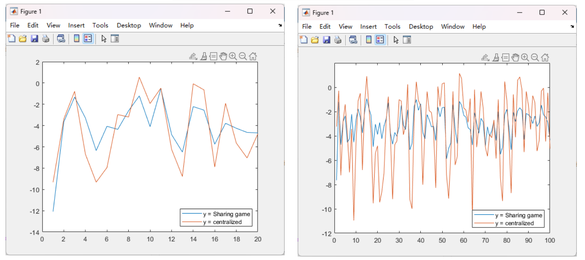

Figure 7 & 8 : Net Cost of each Prosumer

Centralized Operation:
- Extreme net cost distribution

→ Unfair among prosumers

Energy Sharing Bidding:
- Balanced net cost distribution

→ Attracts more prosumers to join the market

- Energy Sharing Bidding strikes a balance between individuals' benefit and market resources

CONCLUSION

- Algorithm performs well with dynamic user base as designed.
- The application acts as a tool for assisting users in the decision-making process and offers insights for analyzing potential market strategies.
- Algorithm ranking:
  - Energy Sharing Bidding > Centralized Operation > Self-sufficiency

REFERENCES

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