

# GreenLine: A Delay-tolerant Mechanism Design for Grid Capacity Allocation

Extended Abstract

Athina Georgara\*  
University of Southampton  
Southampton, United Kingdom  
a.georgara@soton.ac.uk

Jayati Deshmukh\*†  
University of Southampton  
Southampton, United Kingdom  
j.deshmukh@soton.ac.uk

Sarvapali D. Ramchurn  
University of Southampton  
Southampton, United Kingdom  
sdr1@soton.ac.uk

## ABSTRACT

This work presents *GreenLine*, a new auction-based mechanism for integrating renewable power plants (RPP) in the power grid. We address a challenging task, where RPP owners want to maximise their profits by installing new power plants in the grid; while, the Distribution Network Operator (DNO) seeks to maximise the generated power while reducing potential installation delays due to growing power demand. This paper formulates this task as a multi-agent system, studies its useful properties such as incentive compatibility, individual rationality and economical efficiency, and discusses *GreenLine* under different deployment variations.

## KEYWORDS

mechanism design; power grid; resource allocation; auction

### ACM Reference Format:

Athina Georgara, Jayati Deshmukh [1], and Sarvapali D. Ramchurn. 2026. *GreenLine: A Delay-tolerant Mechanism Design for Grid Capacity Allocation: Extended Abstract*. In *Proc. of the 25th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2026)*, Paphos, Cyprus, May 25 – 29, 2026, IFAAMAS, 3 pages. <https://doi.org/10.65109/NORV5629>

## 1 INTRODUCTION

The global power demand is growing as the demand of industries, transport, and data centres increases [3]. At the same time, renewable energy sources become more popular, and by 2030, they are expected to contribute 46% of global electricity generation [4].

However, integrating renewable power plants (RPPs) into the existing power grid brings its own challenges. Among others, long queues of new RPP projects waiting years to connect have become a bottleneck in renewable energy integration. Currently, the power grid fails to quickly incorporate new RPPs due to insufficient grid capacity and ageing infrastructure. Additionally, the so-called phenomenon of “Zombie projects” slows down both power grid expansion as well as transition to a more sustainable power grid. Such projects pile up in the queues, prolonging the time from acceptance to becoming operational. As per Ofgem (an energy regulator for

Great Britain), almost 60-70% of projects in the connections queue ultimately fail to materialise or connect.<sup>1</sup> Typically, the grid expansion is carried out by the *Distribution Network Operators* (DNOs). A DNO is responsible for operating and maintaining the electricity distribution network and for expanding its part of the grid, as it manages new connection requests from both customers and renewable power plant generators.

This paper addresses the problem of allocating grid capacity to new RPPs, models the problem as a multi-agent system and puts forward a novel auction-based mechanism, called *GreenLine*, to help in accelerating the integration process of RPPs into the grid. In what follows, we present *GreenLine*, introducing the notation, the bidding process and the payment scheme. Thereafter, we discuss three desirable properties under two different deployment conditions.

## 2 GREENLINE MECHANISM

The grid capacity allocation problem involves multiple stakeholders with diverse interests. On the one hand, RPP owners want to maximise their profits by installing new power plants in the grid. On the other hand, the DNO seeks to maximise the generated power while reducing potential installation delays due to growing power demand. As such, here we cast the problem as a multi-agent system, and propose *GreenLine*, an auction-based mechanism to solve it.

### 2.1 Notation

Let  $A = \{a_1, \dots, a_n\}$  be a set of bidders, representing the RPP-owners. Each agent submits one bid reporting an estimated installation time  $t_i \in \mathbb{R}^+$  and an estimated delay  $\delta_i \in \mathbb{R}^+$  for their RPP; while the RPP’s capacity  $c_i \in \mathbb{R}^+$  corresponds to public information. The DNO agent  $a_{DNO}$  reviews the bids and selects a subset of them ( $S \subseteq A$ ) to integrate into the power grid.  $T_w \in \mathbb{R}_+$  denotes a look-ahead time window;  $T_w$  is sufficiently large and allows both the DNO and the bidders to plan. Upon selection of  $S$ ,  $a_{DNO}$  observes the *actual* installation time of each selected bid, denoted as  $\tau_i$ . A bid  $\langle t_i, \delta_i \rangle$  is *truthful* if actual installation time falls within the reported installation time and reported delay ( $t_i \leq \tau_i \leq t_i + \delta_i$ ), and *untruthful* if the actual installation time exceeds the reported delay ( $t_i + \delta_i < \tau_i$ ). Finally, an untruthful bid is called “Zombie-bid” if the actual installation time exceeds the look-ahead time window ( $t_i + \delta_i \leq T_w < \tau_i$ ).

\*Both authors contributed equally to this research.

† Author’s current affiliation: *Birla Institute of Technology and Science, Pilani – Hyderabad Campus*



This work is licensed under a Creative Commons Attribution International 4.0 License.

<sup>1</sup><https://www.theguardian.com/business/2023/nov/13/ofgem-rules-zombie-projects-grid-wind-solar>

## 2.2 Bids' Selection

The DNO seeks to maximise the generated power to be integrated into the grid, while respecting the capacity constraint. Let  $v$  be a function that maps each bid with a value, which is proportional to (i) the capacity of the corresponding RPP, and (ii) the declared operational time, i.e., the time between declared installation time until the end of the look-ahead time window. Formally:

$$v(t_i, \delta_i) \propto c_i \cdot (T_w - t_i - \delta_i) \quad (1)$$

Given a selected set of bidders  $S \subseteq A$ , function  $f : A \rightarrow \mathbb{R}$  aggregates the individual bidders' values, and denotes the expected capacity to be operational within the look-ahead time window if bidders in  $S$  are accepted. Therefore, the DNO agent needs to select the subset of bidders  $S$  that optimises the aggregated function  $f$ . That is,  $a_{DNO}$  seeks for the set of bidders  $S^*$  that satisfies:

$$S^* = \text{optimise}_{S \subseteq A} f(S) \quad (2)$$

## 2.3 Payment Scheme

In order for a new RPP to be integrated into the grid, the bidder needs to bear the cost of installation. That is, if bidder  $a_i$  is selected, they need to pay an amount proportional to the RPP's capacity:

$$q_i^{\text{installation}} \propto c_i$$

Additionally, the bidder is charged with a penalty in case the installation exhibits a delay larger than the declared one. That is, the bidder needs to pay to the DNO an amount proportional to the unreported delays as follows:

$$q_i^{\text{penalty}} \propto \alpha \cdot (\tau_i - t_i - \delta)$$

where  $\alpha \in \mathbb{R}^+$  is delay-penalty factor.

## 2.4 Bidder's profit

The profit of a bidder  $a_i$  derives from the amount of power their RPP will produce and provide to the grid. That is, the DNO utilises (i.e., sells to consumers) power, which is obtained from the operational RPPs. As soon as an RPP becomes operational, its power is utilised by the DNO, and therefore the bidder (RPP owner) is paid for the consumed power. In this light, the bidder's profit is proportional to the RPP's capacity and to its actual installation time:

$$p_i \propto c_i \cdot (-\tau_i)$$

Intuitively, the higher the capacity, the higher the profit, and at the same time, the sooner the RPP is actually integrated, the higher the profit.

## 2.5 Properties

In this section, we discuss three desirable properties for a mechanism design, such as GreenLine. (i) *Incentive Compatible* (IC) [2]: A mechanism is incentive compatible if being truthful is the dominant strategy; i.e., when bidding truthfully bears higher expected utility compared to any untruthful bidding. (ii) *Individual Rationality* (IR) [1]. A mechanism is called individually rational if being truthful results in a non-negative utility. (iii) *economically efficient* (EE) [10] A mechanism is called economically efficient if when the agents are truthful, the mechanism ensures that the mechanism maximises the expected total welfare of all the agents in the system.

Our proposed GreenLine mechanism has all three properties; it is incentive-compatible, individually rational, and economically efficient, under appropriate selection of parameter  $\alpha$ . Due to space limitations the formal proofs are omitted; however, one can obtain them by computing the bidder's profit and the payment in expectation.

## 3 RELATED WORK

MAS can be used to model a power grid as a network of agents, which might be power sources, RPP owners or users using power in different parts of the power grid and also model different aspects of the power grid like sensing, control, communication, etc. [8, 13]. Work has also been done to locate RPPs in a power grid using a geographic information system (GIS) approaches [5, 15, 17] and spatial mapping techniques [9, 11]. Different mechanisms like price-cap incentive regulation mechanism and merchant mechanism have been explored in power grids [6, 14]. There is also a fistful of research that addresses the problem of integrating new RPPs into the grid [7, 16] However, these works involve auctions that focus mainly on the selling price and entirely neglect the installation delay aspect. Looking at the installation delay as a failure of the bidder to commit to their declared timing, we relate this problem to other designing mechanisms where agents can fail to complete tasks assigned to them [10, 12]. These mechanisms have been designed in other settings and have been demonstrated to be incentive compatible, individually rational and efficient.

## 4 ONGOING AND FUTURE WORK

In this paper, we study the problem of allocating grid capacity towards new renewable power plant integration. GreenLine is formulated as an auction-based multi-agent system; and it includes (i) an approach for selecting new RPP connections as a bundle, under capacity constraints, and (ii) a payment scheme that penalises unreported installation delays. As such, our mechanism has three desirable properties of IC, IR and EE, which promote truthful bidding, manage installation delays, and facilitate integration both with and without the need for grid reinforcement.

## ACKNOWLEDGMENTS

This research was supported by the Engineering and Physical Sciences Research Council (grant number EP/Y009800/1), through funding from Responsible Ai UK.

## REFERENCES

- [1] Kenneth J Arrow. 1981. *Risk perception in psychology and economics*. Technical Report.
- [2] Leonid Hurwicz. 1972. On informationally decentralized systems. *Decision and organization: A volume in Honor of J. Marschak* (1972).
- [3] International Energy Agency (IEA). 2024. Electricity 2024. <https://www.iea.org/reports/electricity-2024> Licence: CC BY 4.0.
- [4] International Energy Agency (IEA). 2024. Renewables 2024. <https://www.iea.org/reports/renewables-2024> Licence: CC BY 4.0.
- [5] Mehdi Jahangiri, Reza Ghaderi, Ahmad Haghani, and Omid Nematollahi. 2016. Finding the best locations for establishment of solar-wind power stations in Middle-East using GIS: A review. *Renewable and Sustainable Energy Reviews* 66 (2016), 38–52.
- [6] Tarjei Kristiansen and Juan Rosellón. 2006. A merchant mechanism for electricity transmission expansion. *Journal of Regulatory Economics* 29, 2 (2006), 167–193.
- [7] Jason Lin, Manisa Pipattanasomporn, and Saifur Rahman. 2019. Comparative analysis of auction mechanisms and bidding strategies for P2P solar transactive

- energy markets. *Applied Energy* 255 (2019), 113687. <https://doi.org/10.1016/j.apenergy.2019.113687>
- [8] Om Prakash Mahela, Mahdi Khosravy, Neeraj Gupta, Baseem Khan, Hassan Haes Alhelou, Rajendra Mahla, Nilesh Patel, and Pierluigi Siano. 2020. Comprehensive overview of multi-agent systems for controlling smart grids. *CSEE Journal of Power and Energy Systems* 8, 1 (2020), 115–131.
- [9] Beomjun Park and Jin Hur. 2018. Spatial prediction of renewable energy resources for reinforcing and expanding power grids. *Energy* 164 (2018), 757–772.
- [10] Ryan Porter, Amir Ronen, Yoav Shoham, and Moshe Tennenholtz. 2008. Fault tolerant mechanism design. *Artificial Intelligence* 172, 15 (2008), 1783–1799.
- [11] TV Ramachandra and BV Shruthi. 2007. Spatial mapping of renewable energy potential. *Renewable and sustainable energy reviews* 11, 7 (2007), 1460–1480.
- [12] Sarvapali D Ramchurn, Claudio Mezzetti, Andrea Giovannucci, Juan A Rodriguez-Aguilar, Rajdeep K Dash, and Nicholas R Jennings. 2009. Trust-based mechanisms for robust and efficient task allocation in the presence of execution uncertainty. *Journal of Artificial Intelligence Research* 35 (2009), 119–159.
- [13] Robin Roche, Benjamin Blunier, Abdellatif Miraoui, Vincent Hilaire, and Abder Koukam. 2010. Multi-agent systems for grid energy management: A short review. In *IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society*. IEEE, 3341–3346.
- [14] Juan Rosellón and Hannes Weigt. 2011. A dynamic incentive mechanism for transmission expansion in electricity networks: Theory, modeling, and application. *The Energy Journal* 32, 1 (2011), 119–148.
- [15] D Voivontas, D Assimacopoulos, A Mourelatos, and J Corominas. 1998. Evaluation of renewable energy potential using a GIS decision support system. *Renewable energy* 13, 3 (1998), 333–344.
- [16] Andreas Voss and Reinhard Madlener. 2017. Auction Schemes, Bidding Strategies and the Cost-Optimal Level of Promoting Renewable Electricity in Germany. *The Energy Journal* 38, 1\_suppl (2017), 229–264. <https://doi.org/10.5547/01956574.38.SI1.avos>
- [17] In-Ae Yeo and Jurng-Jae Yee. 2014. A proposal for a site location planning model of environmentally friendly urban energy supply plants using an environment and energy geographical information system (E-GIS) database (DB) and an artificial neural network (ANN). *Applied Energy* 119 (2014), 99–117.