

Scalable Complex Orders: How Euphemia Algorithm Improved Scalability while Facilitating Participants Bidding

Eloy Insunza

*Institute for Research in Technology (IIT) Institute for Research in Technology (IIT)
Technical School of Engineering (ICAI) Technical School of Engineering (ICAI)
Comillas Pontifical University
Madrid, Spain*



Jose Portela González

*Institute for Research in Technology (IIT) Institute for Research in Technology (IIT)
Technical School of Engineering (ICAI) Technical School of Engineering (ICAI)
Comillas Pontifical University
Madrid, Spain*



Antonio Muñoz San Roque

*Institute for Research in Technology (IIT) Institute for Research in Technology (IIT)
Technical School of Engineering (ICAI) Technical School of Engineering (ICAI)
Comillas Pontifical University
Madrid, Spain*



Abstract—Euphemia is the algorithm used in the Single Day-Ahead Coupling (SDAC) to clear the European Day-Ahead Market. Scalable Complex Orders (SCOs) were introduced in 2025 to represent generation units fixed costs and technical minima, while improving the scalability of the clearing process. To quantify the impact of SCOs, we analyze one month of data from the Iberian market and simulate three counterfactual scenarios in which SCOs are replaced by other available order types. We then compare these scenarios with the historical market outcome. Results indicate that SCOs help units recover fixed costs and respect the technical minimum, while substantially reducing the algorithm running time.

Keywords—electricity markets, euphemia algorithm, single day-ahead coupling, scalable complex orders

I. INTRODUCTION

The European Day-Ahead Market (DAM) is one of the main electricity markets in the continent, with more than 5 TWh traded per day on average across 27 countries. [1] The Single Day-Ahead Coupling relies on a common algorithm, Euphemia, to compute a single market outcome for all coupled areas. [2] The DAM takes place every day at 12 AM and allocates resources taking into account the bids of participants from all the countries and the available cross-border transmission capacity.

Euphemia is a complex algorithm that allocates energy production and consumption, respects a variety of physical and economic constraints, and defines a clearing price using a marginal cost market scheme. The central element of this algorithm is an optimization problem searching to maximize system economic surplus. Suppliers and consumers can participate in this market through a series of pre-defined types of orders: sets of bids linked by special conditions, what introduces new restrictions to the optimization problem. A certain order will be cleared only if all the specified conditions are satisfied. [3]

Thermal power plants remain key suppliers due to their reliability and their contribution to the inertia of the system.

However, they face physical and economical limitations. First, thermal power plants have limited flexibility due to their rigid start-up and shut-down times which can also represent an important proportion of the total operation costs. Second, they must respect a Technical Minimum, defined as the lowest load level at which they can operate stably without shutting down. Third, they may also face high fixed costs, including the aforementioned start-up and shut-down costs.

For several years, thermal producers lacked an order type that correctly captured their needs when participating in the market: respecting the Technical Minimum for stable operation, recovering both variable and fixed costs, and avoiding sudden shut-downs and start-ups during operation. As a result, participants combined the use of available order types with the positions in secondary markets to optimize their production. Meanwhile, Euphemia faced scalability issues due to the increase in the number of participants combined with the high non-linearity of the order types.

To address these limitations, Euphemia incorporated a new order type called Scalable Complex Orders (SCO). An SCO is a set of stepwise curve orders spreading out along different periods and subject to both economic (fixed costs) and physical conditions (minimum acceptance power). These fixed costs are also inputted in the economic surplus definition to accelerate convergence [3].

The main contributions of this paper are quantifying the impact of SCOs in terms of economic surplus for the thermal power plants, ability to respect Technical Minimum, and algorithm efficiency.

The remainder of the paper is organized as follows. Section II describes Euphemia and the relevant order types and their limitations. Section III presents Scalable Complex Orders. Section IV discusses related works. Section V details the experimental design. Section VI reports and discusses the results. Section VII presents the conclusions.

II. EUPHEMIA ALGORITHM

Euphemia clears the day-ahead market under a marginal pricing scheme for multiple coupled European bidding zones. The algorithm solves a master optimization problem that maximizes economic surplus (also denominated social welfare) subject to network and market constraints, together with several auxiliary subproblems. Economic surplus is defined as the sum of consumer surplus, producer surplus, and congestion rents. Participants can submit either simple bids or complex orders. A simple bid specifies a quantity to buy/sell and a limit price, whereas an order groups several simple bids and adds additional constraints to better represent the participant's operational requirements.

One key subproblem concerns the determination of hourly clearing prices. After prices are computed, an order is in-the-money if it should be accepted and out-of-the-money if it should be rejected. However, the nonlinearity introduced by certain order types can lead to paradoxically accepted or paradoxically rejected orders. Euphemia addresses this issue by iteratively re-solving the master problem and adjusting the acceptance of some orders, which increases the overall running time. While Euphemia supports a wide range of order types, this paper focuses on those used in the Iberian market: Complex Orders, Block Orders, and Scalable Complex Orders. For a more detailed description, see the Euphemia public description [3], and [4] for a reference of the design of the market.

A. Complex orders

A Complex Order is a set of simple bids (sub-orders) spreading along different periods and subject to a Minimum Income Condition (MIC) that applies to the set of sub-orders as a whole. The MIC is defined by a fixed term (in euros) and/or a variable term (in euros per accepted MW). The MIC constraint requires that the revenue collected from the accepted energy is at least equal to the fixed term plus the variable term times the total accepted energy.

Complex Orders can represent fixed-cost recovery for generators; however, they do not guarantee compliance with a Technical Minimum. Moreover, MIC terms are not included in the welfare objective of the master problem, which can lead to paradoxically accepted Complex Orders and increases the number of iterations required to reach a feasible optimal solution.

B. Block orders

Block Orders are sets of simple bids spanning multiple periods that share a common price and are linked by a Minimum Acceptance Ratio (MAR). While the price is the same for all periods, the bid volume may vary across periods; however, the acceptance ratio must be identical in every period (e.g., a 50% acceptance implies clearing 50% of the offered volume in each period).

The MAR is the minimum fraction of the block that must be accepted. When MAR equals 1, the block must be fully accepted or fully rejected (fill-or-kill); for MAR values below

1, the block can be partially accepted (curtailable block). Block Orders can be used to approximate a Technical Minimum by enforcing minimum acceptance levels across hours, but they do not include explicit fixed-cost recovery. Several variants exist, such as linked block orders (where acceptance of a block depends on another) and exclusive groups (where the acceptance ratios of all blocks in the group sum up to 1).

III. SCALABLE COMPLEX ORDERS

Scalable Complex Orders (SCOs) were introduced in 2025 to address the limitations discussed above: enforcing a Technical Minimum, enabling fixed-cost recovery, and improving algorithm scalability. [5] An SCO is a set of simple bids spanning multiple periods and subject to two key constraints: a Minimum Acceptance Power (MAP) in each period and a Minimum Income Condition (MIC) for the order as a whole.

The MAP specifies the minimum power that must be accepted for the unit in each period. The MIC includes a fixed term, while the variable term is derived from the prices of the submitted stepwise bids (in contrast to the single global variable term used in Complex Orders). If either the MIC or any MAP constraint is violated, the entire SCO must be rejected.

A further distinction is that SCO fixed costs are incorporated directly into the welfare objective of the master problem, which can reduce the number of paradoxical acceptances and, consequently, the number of iterations required to reach an optimal solution.

IV. RELATED WORK

Some research has been carried out before to quantify the impact of some types of market products in the market and in the computational costs.

Adams et al. [6] integrate regular block and linked orders into an agent-based simplified day-ahead market and compare outcomes to a version with only simple hourly orders. They quantify impacts on operational cost, clearing prices, and dispatch composition, showing significant cost reductions and redispatch changes when advanced orders are available.

Marneris et al. [7] introduce resource-specific orders (thermal, demand response, storage) into a European DAM model and compare against a benchmark using standard block orders. They evaluate schedule feasibility, social welfare, revenues and consumer costs, and also compare pricing rules (discriminatory with side-payments vs non-discriminatory European rule).

Csercsik [8] studied the minimum income condition to demonstrate that it opens the possibility of strategic bidding and proposes a change in the objective function to prevent this possibility.

Signer et al. [9] studied the computational cost of introducing different order types in power market models. This inclusion could lead to a 10 times increase in computational times, that could be solved by relaxing fill-or-kill conditions of block orders without a significant impact in market outcomes.

This research is the first to focus specifically on Scalable Complex Orders. We selected the most important metrics from

related work—including economic, physical, and computational measures—and conducted experiments using real-world data.

V. EXPERIMENTAL DESIGN

The objective of this paper is to quantify the impact of SCOs. We use market data from OMIE, the Nominated Electricity Market Operator (NEMO) for MIBEL, covering the period from August 1 to September 1, 2025. Over this month, 2.01 TWh were cleared through SCOs (more than any other order type) across 18 bidding units. In addition, 25 bidding units submitted SCOs that were never cleared.

We simulate the Euphemia clearing process for MIBEL (Spain and Portugal) under the following scenarios:

- I. **Original scenario:** simulation with the original orders.
- II. **SCO → Block Orders:** SCOs are converted to Block Orders by translating the Minimum Acceptance Power (MAP) into a Minimum Acceptance Ratio (MAR); the MIC fixed term is removed.
- III. **SCO → Complex Orders:** SCOs are converted to Complex Orders by keeping the MIC fixed term and removing the MAP constraints.
- IV. **SCO → Complex Orders (MAP in FT):** as in the previous scenario, but the payment required to reach the Technical Minimum is added to the fixed term (FT) to discourage clearing below the Technical Minimum.

All scenarios have been run using `iberian-day-ahead-market-simulator`, an open-source Python package that simulates the MIBEL day-ahead market clearing process. [10] [11] The simulator implements the Euphemia algorithm and allows for modifications of the order types and their parameters.

Scenarios are compared using several metrics. Market-wide effects are assessed through daily mean prices, total cleared power, total economic surplus, and the number of iterations required to reach an optimal solution. The fixed costs indicated in the original SCO are inputted to the calculation of the economic surplus. Unit-level effects are evaluated through SCO-related welfare, the number of units losing money (i.e., not recovering fixed costs), and the number of hours under the Technical Minimum.

For each metric, the overall mean is reported. In some cases, the mean daily change relative to the Original scenario is also presented. To compute this value, we first calculate the relative change with respect to the Original scenario for each day; we then average these daily changes. This avoids giving disproportionate weight to scenarios with larger magnitudes.

VI. RESULTS

Table I reports the main system-level metrics across scenarios always comparing the Scenario I (Original). Relaxing SCO constraints increases the number of SCO bidding units that are cleared. The most pronounced changes occur in Scenario II (SCO → Block Orders), where the average price decreases by 11.6% and the total cleared energy increases by 3.6%. Despite these seemingly favorable market-wide outcomes,

total economic surplus decreases by 2.2% because many units are cleared without recovering their fixed costs. These effects are largely absent in Scenarios III and IV, where the MIC is preserved through Complex Order formulations.

SCOs were also introduced to improve computational performance. Table I shows that the number of iterations required to reach the optimal solution when SCOs are replaced by Complex Orders (Scenarios III and IV) is up to 35 times higher. This is consistent with the fact that, unlike SCOs, Complex Orders do not include their MIC in the economic surplus objective of the master problem, which leads to more paradoxical acceptances and requires additional iterations to restore feasibility.

Figure 1 presents the daily evolution of the main performance metrics across scenarios. In Scenario II (SCO to Block Orders), prices are consistently lower than in the Original case, reflecting the higher cleared volumes. However, economic surplus is also consistently lower in this scenario. Finally, the bottom-right panel shows that the scenarios based on Complex Orders require substantially more iterations to converge.

Table II summarizes SCO-related unit metrics. Scenario II performs worst: converting SCOs to Block Orders results in roughly six times more units being cleared, but also in large losses (on average 3.66 M€) and the highest number of hours below the Technical Minimum. In contrast, the Complex Order scenarios reduce the number of units losing money by partially capturing fixed costs through the MIC fixed term. The poor Technical Minimum performance of Scenario II highlights that translating MAP (an hourly requirement) into MAR (a block-level acceptance ratio applied across multiple periods) can be inaccurate.

VII. CONCLUSIONS AND FUTURE WORK

This paper quantified the impact of Scalable Complex Orders (SCOs) within Euphemia, the algorithm used to clear the Single Day-Ahead Coupling. SCOs were introduced to better represent operational constraints of thermal units, such as, fixed-cost recovery and compliance with a Technical Minimum (the lowest stable output), while (iii) improving algorithm scalability.

To assess these objectives, we compared the historical Iberian market (MIBEL) outcomes with counterfactual simulations in which SCOs were replaced by Complex Orders, which can include the fixed costs, or Block Orders, which can somehow incorporate the Technical Minimum. Converting SCOs to Block Orders increases cleared energy (by 11.6%) but reduces total economic surplus (by 2.2%), as more units are cleared without recovering fixed costs. In contrast, replacing SCOs with Complex Orders substantially increases the number of iterations required to reach an optimal solution (up to 35 times), reflecting the fact that MIC constraints are not embedded in the welfare objective. Another important effect is the increase in the number of hours where the units are under the Technical Minimum, showing the difficulty in transposing the Minimum Acceptance Power (MAP) of the SCOs to other type of orders.

TABLE I.

SCENARIO COMPARISON SUMMARY (DAILY SYSTEM-LEVEL METRICS).

FOR EACH METRIC, THE FIRST COLUMN REPORTS THE OVERALL MEAN, WHILE THE SECOND COLUMN (CHANGE), WHEN APPLICABLE, REPORTS THE MEAN DAILY CHANGE RELATIVE TO THE ORIGINAL SCENARIO. THIS AVOIDS GIVING DISPROPORTIONATE WEIGHT TO SCENARIOS WITH LARGER MAGNITUDES.

Scenario	Mean prices		Cleared energy		Economic surplus		Algorithm iterations	
	€/MWh	Change	TWh	Change	M€	Change	#	Change
I. Original:	67.46	—	6.42e+02	—	2.22e+02	—	1.5	—
II. SCO → BO:	59.99	-11.6%	6.65e+02	3.6%	2.17e+02	-2.2%	1.5	-1.5%
III. SCO → CO:	67.04	0.6%	6.42e+02	0.1%	2.22e+02	-0.1%	26.4	2124.7%
IV. SCO → CO, MAP in FT:	67.39	1.1%	6.41e+02	-0.1%	2.22e+02	-0.1%	43.2	3586.6%

TABLE II.

SCENARIO COMPARISON SUMMARY (DAILY SCO-RELATED METRICS).

FOR EACH METRIC, THE FIRST COLUMN REPORTS THE OVERALL MEAN, WHILE THE SECOND COLUMN (CHANGE), WHEN APPLICABLE, REPORTS THE MEAN DAILY CHANGE RELATIVE TO THE ORIGINAL SCENARIO. THIS AVOIDS GIVING DISPROPORTIONATE WEIGHT TO SCENARIOS WITH LARGER MAGNITUDES.

Scenario	Units cleared	Economic surplus		Negative surplus units	Hours under TM
	#	M€	Change	#	#
I. Original:	5.5	2.09	—	0.0	0.0
II. SCO → BO:	31.0	-3.66	-274.8%	25.0	40.0
III. SCO → CO:	13.5	1.79	-14.3%	6.3	14.0
IV. SCO → CO, MAP in FT:	10.4	1.80	-14.1%	6.4	0.0

Performance Metrics Over Time Across Scenarios

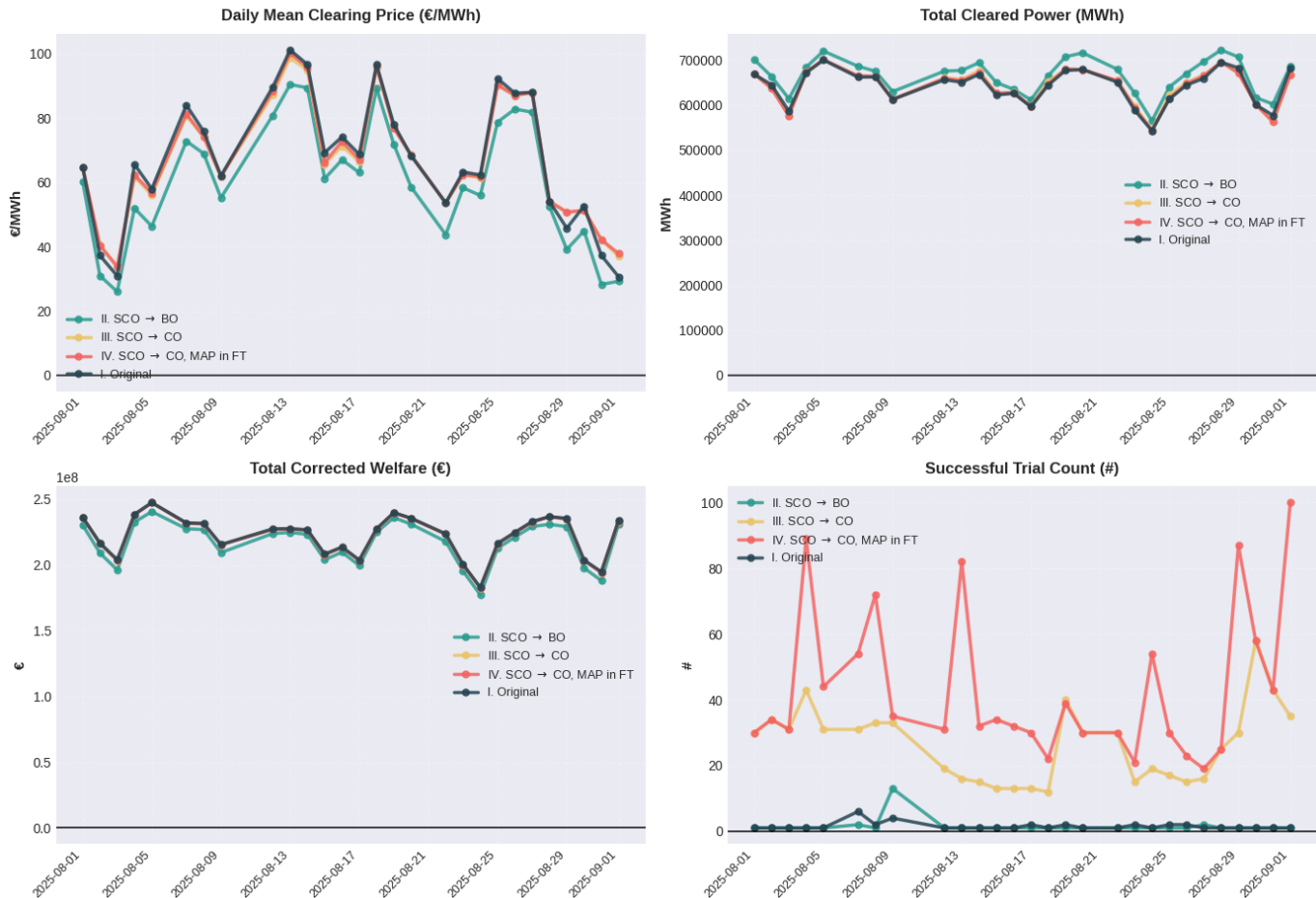


Fig. 1. Performance metrics over time across scenarios.

Overall, the results highlight the value of SCOs in jointly capturing both Technical Minimum constraints (via MAP) and fixed-cost recovery (via MIC) while maintaining computational efficiency through the inclusion of the MIC fixed term in the master objective.

The results were obtained using an in-house simulator for MIBEL and a limited set of counterfactual scenarios. Future work should explore a broader range of participant strategies, additional coupled regions, and the interaction with other markets (e.g., intraday and ancillary services), which may compensate losses in some scenarios and influence bidding behavior after the introduction of SCOs. Another important line of research is the possible use of SCOs for strategic bidding, as the MIC fixed term could be used to influence market outcomes.

REFERENCES

- [1] A. N. Committee. CACM Annual Report 2024. Tech. rep. All NEMO Committee, 2025. <https://www.nemo-committee.eu/assets/files/cacm-annual-report-2024.pdf> (visited on 02/02/2026).
- [2] Single Day-Ahead coupling (SDAC). https://www.entsoe.eu/network_codes/cacm/implementation/sdac/ (accessed Feb 2, 2026).
- [3] Nemo Committee. (2025). EUPHEMIA public description: Single price coupling algorithm. <https://www.nemo-committee.eu/assets/files/euphemia-public-description.pdf> (visited on 02/02/2026).
- [4] Estermann, A., Schrade, M., Anderson, L. (2025). European Electricity Market Coupling: A Practitioner's Guide (p. 368). Springer Nature.
- [5] A. N. Committee. Scalable Complex Orders - Supporting document for the DA products list public consultation, 2020. https://www.nemo-committee.eu/assets/files/200408_SCOs_public_consultation_information-b28a39ed639f2676f5d7cd465eac5f16.pdf (accessed March 10, 2026).
- [6] Adams, J., Harder, N., Weidlich, A. (2024). Do Block Orders Matter? Impact of Regular Block and Linked Orders on Electricity Market Simulation Outcomes. 2024 20th International Conference on the European Energy Market (EEM), 1-7. <https://doi.org/10.1109/eem60825.2024.10608956>.
- [7] Marneris, I., Ntomaris, A., Biskas, P., Dourbois, G. (2023). Resource-specific Orders in European Day-ahead Market Under Different Pricing Rules. *Journal of Modern Power Systems and Clean Energy*. <https://doi.org/10.35833/mpce.2022.000651>.
- [8] Cserecsik, D. (2021). Strategic bidding via the interplay of minimum income condition orders in day-ahead power exchanges. *Energy Economics*, 95, 105126.
- [9] Signer, T., Mack, J., Kleinebrahm, M., Slednev, V., Weiskopf, T., Fichtner, W. (2025, May). Integration of Block, Linked and Loop Bids in a Market Coupling Algorithm. In 2025 21st International Conference on the European Energy Market (EEM) (pp. 1-7). IEEE.
- [10] Insunza, Eloy and Portela, José and Muñoz San Roque, Antonio, iberian-day-ahead-market-simulator: A Python Package to Simulate the MIBEL Day-Ahead Market Clearing. Available at SSRN: <https://ssrn.com/abstract=6722443> or <http://dx.doi.org/10.2139/ssrn.6722443>. (Visited on 06/05/2026).
- [11] Insunza, Eloy and Portela, José and Muñoz San Roque, Antonio, iberian-day-ahead-market-simulator <https://github.com/EloyID/iberian-day-ahead-market-simulator> (visited on 06/05/2026).