A custom automated bidding solution for short-term operation in Mibel market

João Palma
3KTECH IT Department
3KTECH
Portugal
joao.palma@3ktech.pt

Jorge Leite & Susana Teixeira
Energy Management Department
SU ELETRICIDADE
Portugal
{jorge.leite & susanamartins.teixeira}@sueletricidade.pt

***Abstract*— The automation of bidding processes in energy markets has seen significant evolution in recent years. Initially, market participants used manual methods to calculate and submit bids. However, with advancements in technology, the industry began to adopt automated systems to expedite these tasks. This paper describes the implemented solution at SU ELETRICIDADE to automate the bidding process for short-term operation in Mibel Market (SUTRADE). SU ELETRICIDADE, a subsidiary of EDP S.A., is a regulated Portuguese company who operates as the Last Resort Supplier, with the obligation to provide universal electricity supply services and performs the role of Last Resort Aggregator, purchasing energy from producers, namely to the ones that benefits from guaranteed remuneration schemes (feed-in tariffs), and subsequently selling this energy on the market. SU ELETRICIDADE is involved in promoting renewable energy, with wind energy generation making up a large part of its selling energy portfolio. Given the challenges of forecasting wind generation, it is essential for SU ELETRICIDADE to actively participate in intraday markets, submitting updated forecasts to minimize imbalances. For this purpose, a custom robust solution that automates the bidding process is essential. While there is a wide variety of commercial solutions available for automating bidding processes in energy markets, some of which include algorithmic trading features, SUTRADE is a custom, in-house developed solution based on a cloud platform. The primary goal of SUTRADE is to automate manual and repetitive tasks such as calculating bid prices, determining energy volumes, and submitting bids to OMIE, ensuring accuracy and timely submission. Follows a set of predefined rules and parameters, which users can control and adjust according to market conditions. It also features an advanced energy analytical forecast module and an alarmistic setup that proactively alerts users to significant changes in SU ELETRICIDADE's market operations or potential errors caused by unexpected events such as bidding errors or communication issues. SUTRADE allows SU ELETRICIDADE to reduce market participation operational risks, while achieving substantial cost savings by minimizing the need for manual trading activities**

***Index Terms*-- Bidding, Digitalization, Energy markets, Process Automation, Microservices**

I. Introduction

The automation of bidding processes in energy markets has seen significant evolution in recent years. Initially, market participants used manual methods to calculate and submit bids. However, with advancements in technology, the industry began to adopt automated systems to expedite these tasks. This paper describes the solution implemented at SU ELETRICIDADE to automate the bidding process for short-term operations in the MIBEL Market, known as SUTRADE.

Before the implementation of SUTRADE, SU ELETRICIDADE used a combination of automated and manual processes to manage its market operations. While ETL (Extract, Transform and Load) processes, forecast models, and reporting were automated, the calculation of the bids were still supported by semi-manual processes. The submission of bids to OMIE was also performed manually. This approach was not only time-consuming but also vulnerable to human mistakes, causing inefficiencies and potential financial losses.

SUTRADE has improved the bidding process by fully automating the calculation and submission of bids. This automation ensures that bids are accurate, aligned with market operations principles defined by SU ELETRICIDADE and submitted timely.

II. SU ELETRICIDADE Market Operation

SU ELETRICIDADE, a subsidiary of EDP S.A., is a regulated Portuguese company who operates as the Last Resort Supplier, with the obligation to provide universal electricity supply services. Therefore, is responsible for purchasing in energy markets (spot, futures, or bilateral contracts) the energy to meet the demand of customers portfolio (customers at regulated tariff).

SU ELETRICIDADE also performs the role of Last Resort Aggregator, purchasing energy from producers, namely to the ones that benefits from guaranteed remuneration schemes (feed-in tariffs), and subsequently selling this energy on the market (spot, futures, or bilateral contracts).

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In this paper, to describe SUTRADE solution, we focus only on the operations of SU ELETRICIDADE in the MIBEL spot markets (day-ahead and intraday markets).

SU ELETRICIDADE operations in MIBEL spot markets are executed by four bidding units, each with a specific function:

Unit 1: This unit is responsible for purchasing energy to meet the demand of SU ELETRICIDADE's customers portfolio (customers at regulated tariff).

Unit 2: This unit is responsible for selling energy produced by a group of generators utilizing various technologies: wind, hydro, cogeneration, biomass, biogas, and solar PV. These producers have a total installed capacity of above 8200 MVA and are under guaranteed remuneration schemes (feed-in tariffs). A detailed characterization of production under remuneration schemes in Portugal over time can be consulted in [1]. Currently, wind farms represent 73% of the total installed capacity of this unit.

Unit 3: This unit is responsible for selling energy injected into the grid by a group of small self-consumers, which is the excess energy generated but not consumed by these producers. This portfolio is almost entirely composed of photovoltaic self-consumption units. Currently, there are approximately 4600 installations within this portfolio, with a total installed capacity of 142 MVA. A more detailed description of this portfolio can be found in [2].

Unit 4: This unit is responsible for selling energy produced by a specific portfolio of photovoltaic producers who were the winners of the 2019 Portuguese solar auction. More information about the 2019 Portuguese solar auction can be found in [3]. Currently there are 5 producers in this portfolio with a global installed capacity of 82 MVA.

It is important to note that SU ELETRICIDADE does not have control or planning authority over the energy produced by generators associated with Units 2, 3 and 4. SU ELETRICIDADE represents these producers in the market and must ensure that their energy is sold with a high probability of success. To achieve this, the energy must be bid in the market with an appropriate strategy.

The bidding energy of the four units is divided into different blocks, each with distinct prices. This approach of splitting energy into various blocks with different prices helps in managing the risk.

If unit U_j buys energy for a specific market session (day-ahead or intraday markets), the k-th block bidding value price for hour i, for unit j, $P_{ik}^{U_j}$, is defined by:

$$P_{ik}^{U_j} = f_{U_j}(\theta_1, \theta_2, \ldots, \theta_N, i, k) \quad i = i_1, \ldots, i_T ,$$

where T is the number of hours that can be negotiated in this specific market session.

If unit U_j sells energy for a specific market session $P_{ik}^{U_j}$, is defined by:

$$P_{ik}^{U_j} = g_{U_j}(\theta_1, \theta_2, \ldots, \theta_N, i, k) \quad i = i_1, \ldots, i_T .$$

The parameters $\theta_1, \theta_2, \ldots, \theta_N$ are related to historic prices and metrics about market volatility. Note that the number of blocks used to bid in specific market session can vary between units according to specificity of each bidding unit and market conditions. For example, in a specific session it can be used three blocks for Unit 2 and only one block for another units.

In less compacted way, the $P_{ik}^{U_j}$ values for the four units are defined in the following tables:

TABLE I $P_{ik}^{U_j}$ – DAY AHEAD MARKET

	Day ahead Market	
	If is buying	If is selling
Unit 1	$f_{U_1}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$	Not applicable
Unit 2	Not applicable	$g_{U_2}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$
Unit 3	Not applicable	$g_{U_3}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$
Unit 4	Not applicable	$g_{U_4}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$

TABLE II $P_{ik}^{U_j}$ – INTRADAY MARKETS

	Intraday Markets	
	If is buying	If is selling
Unit 1	$f_{U_1}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$	$g_{U_1}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$
Unit 2	$f_{U_2}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$	$g_{U_2}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$
Unit 3	$f_{U_3}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$	$g_{U_3}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$
Unit 4	$f_{U_4}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$	$g_{U_4}(\theta_1, \theta_2, \ldots, \theta_N, i, k)$

The bidding energy for a specific market session for each unit U_j on hour I, $V_i^{U_j}$ is based on the most updated forecast for each unit U_j, for day d and hour i, $F^{U_j}(d, i)$. Based on $V_i^{U_j}$, the energy volume to bid in the k-th block for each unit U_j at hour i, $V_{ik}^{U_j}$ is calculated as follows:

$$V_{ik}^{U_j} = \alpha_k^{U_j} V_i^{U_j},$$

obviously for each U_j, $\sum_k \alpha_k^{U_j} = 1$.

For each specific market session, and for each U_j, the values of α_k are carefully chosen in alignment with market operations principles defined by SU ELETRICIDADE.

Therefore, for a specific market session, and for each U_j , at hour i, the bid of k-th block is given by $\left(V_{ik}^{U_j}; P_{ik}^{U_j} \right)$.

SU ELETRICIDADE is committed to ensure an efficient and transparent operation in the MIBEL spot markets. The goal is to minimize imbalances in Units 1, 2, and 3. To achieve this, SU ELETRICIDADE is dedicated to a continuous improvement of forecasting models. For Units 1, 2, and 3, SU ELETRICIDADE is responsible for forecasting these portfolios. In the case of Unit 4, SU ELETRICIDADE receives individual forecasts from each producer and aggregates these forecasts to manage the bids for this unit in the MIBEL market.

III. DIGITAL TRANSFORMATION

Nowadays, many definitions attempt to explain "Digital Transformation.". Some examples are: “(...) it’s a full business transformation that places technology at the heart of an organization.” [4] or “To be digital, every company needs to rewire how it works.” [5]. Regardless of the specific definition, there is an agreement that at the core of “Digital Transformation” lies the development and integration of APIs (Application Programming Interfaces), which plays a crucial role in driving this transformation across organizations [4], including public governments [6].

Concerning the electricity markets, there is not much public information available about NEMOs/TSOs (Nominated Electricity Market Operators/Transmission Service Operators) API adoption/usage, but in 2020, Nord Pool published a report [7] confirming that during the past two years (2018-2019) the users that access to theirs APIs increased by nearly 40%. Also, in the same report, they publish some guidelines regarding Algorithmic Trading (*Algo Trading*), classifying it as a “trend”.

A simple search for hosted code related with the usage of API/Webservices of European NEMOs/TSOs like OMIE, Nord Pool, ENTSOE or EPEX on GitHub’s public repositories, demonstrates that the digitalization and code automation on some of Europeans Electricity Markets starts to be more expressive since 2020. At OMIE particular case, the number of public repositories created in 2024 was 5x more that in 2019.

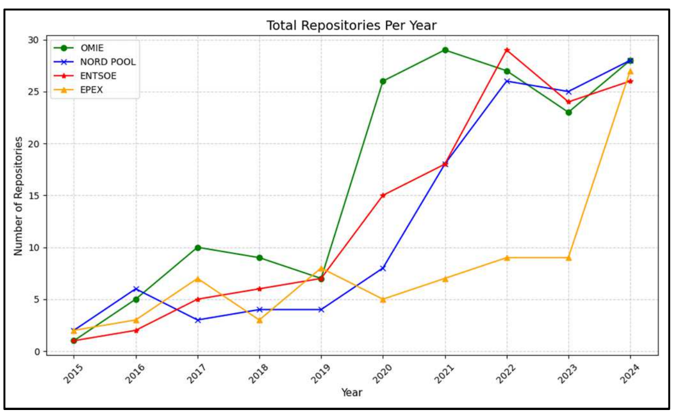

Figure 1. Evolution of Github’s public repositories created per year (2015 - 2024) and related with European NEMOs or TSOs.

APIs usage and adoption by all kind of business companies continues to grow faster and faster. In 2018, Akamai estimated that approximately 83% of Internet traffic in that year was being driven by APIs [8] and, in a more recent study, *Imperva* revealed that in 2023, 71% of the Internet traffic consisted of API calls [9].

Regarding SU ELETRICIDADE’s market operation, the following aspects have led to the necessity of implementing an advanced solution to fully automate the calculation of bids:

- The complexity of functions $f_{U_1}, f_{U_2}, f_{U_3}, f_{U_4}$, $g_{U_1}, g_{U_2}, g_{U_3}$ and g_{U_4} has increased over time to ensure that SU ELETRICIDADE can effectively respond to market conditions with an adequate strategy
- Wind farms represent 73% of the total installed capacity of the Unit 2. Consequently, accurately forecasting this wind portfolio is essential to minimize imbalances for this unit. Given the challenges of forecasting wind generation ([10]-[11]), it is essential for SU ELETRICIDADE to actively participate in all intraday markets, submitting updated forecasts to minimize imbalances. Additionally, due to the characteristics of Units 3 and 4, it is also important to participate in all intraday markets for these units.
- The calculation of $V_{ik}^{U_j}$, and the management of parameters $\alpha_k^{U_j}$ are hard to maintain by semi-manual processes.

IV. SUTRADE

As noted in chapter I, SU ELETRICIDADE already used ETL processes, forecast models and reporting in their daily operation. The development and integration of SUTRADE, a custom, in-house developed solution based on a cloud platform, introduced new features to fully automate the calculation and submission of bids.

SUTRADE was specifically designed for the MIBEL market and to respond to SU ELETRICIDADE’s unique needs and operational requirements. This allows greater flexibility in merging specific business rules and strategies that may not be fully addressed by commercial solutions. As an in-house developed solution, it also has the capability to communicate and integrate with other internal systems.

SUTRADE was developed within a cloud environment and following the principle of microservice’s architecture, combining small software pieces that converges to a more complex one. Each service was designed to perform a specific function and communicates with other services through basic protocols (e.g.: HTTPS). There are several references about using this software design pattern to build complex systems for Energy Management [12]-[14]. In all of them, there is an agreement that this architecture can increase scalability and resiliency by treating each service as independent. For example, if a specific service requires additional resources (e.g.: RAM or CPU), it can be resized without affecting other services or the overall system. Similarly, if any component fails, the system remains unaffected and, depending on the infrastructure configuration, the failed component can be automatically replaced by a replica.

For instance, SUTRADE took a more conservative approach by combining different types of architectures:

- Critical components, like the bidding tool and alarmistic modules, were deployed on more simple components (e.g.: Docker instances)
- Less critical components, like ETL or ML/Forecasting modules, were deployed on more complex

architectures (e.g.: Kubernetes), to dynamically adapt to different infrastructure demands.

This hybrid approach balances the reliability needed for critical services with the scalability and adaptability required by more complex modules. Also, it decreases the response time to solve any technical issue/incident concerning SUTRADE's operation, once the critical components require less knowledge regarding DevOps strategies or networking/infrastructure administration and ensures that "each component is smaller, has fewer dependencies, and has simpler runtime behavior. It is, therefore, much easier to understand and maintain." [15].

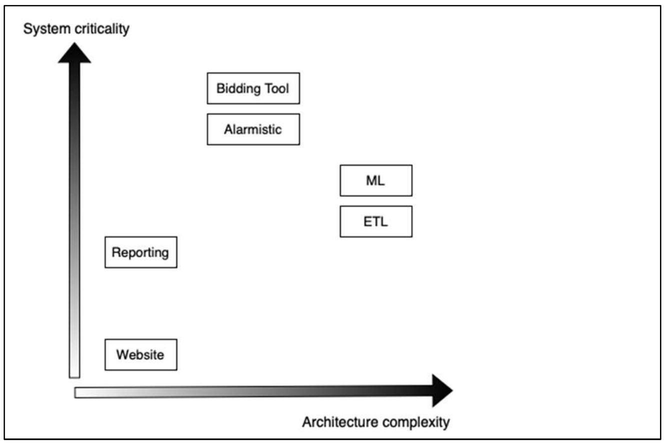

Figure 2. Criticality of SUTRADE components versus architecture complexity

SUTRADE integrates six main components: ETL processes, ML/Forecasting applications, market bidding application, reporting and analysis, alarmistic modules and a web configurator.

ETL: Combination of **E**xtraction, **T**ransformation and **L**oading modules for collecting and loading data. It can process information from multiple data sources (e.g.: SFTP servers, web sites, web services, REST APIs) and guarantees the integration of diverse data types, such as historical consumption data, historical production data, historical weather variables and weather predictions for the upcoming days, ensuring that the forecasting models have access to the most updated data only by querying a relational database.

ML/Forecasting: In the context of energy markets, energy forecasting plays a crucial role in minimizing imbalances. This module generates energy consumption forecasts for the portfolio clients of SU ELETRICIDADE to support bids of Unit 1. Additionally, it produces aggregated energy production forecasts for all technologies needed to support the bids of Unit 2. This module also generates forecasts to support the bids of Unit 3. These forecasts are particularly challenging because it is necessary to predict the excess energy produced but not consumed (rather than just predicting the energy generated by these producers), and the number of installations in this portfolio is constantly changing. For each forecasted quantity, this module has several models that vary in their forecasting methodologies or in input variables.

Bidding tool: SUTRADE's most critical module. It is responsible for all the communication with OMIE and it is divided into two microservices: bidding calculator and bidding submission. The first service calculates the bids $\left(V_{ik}^{U_j}; P_{ik}^{U_j}\right)$ for all market sessions. The volumes to bid $V_{ik}^{U_j}$ are based on the most recent forecasts as is explained in section II. The values $P_{ik}^{U_j}$ are calculated using the functions f_{U_j} and g_{U_j}. This automation reduces the risk of human error and ensures that bids are aligned with the strategic objectives of SU ELETRICIDADE. The second module is responsible for submitting bids to OMIE and ensuring that the information is correctly processed. Through SOAP protocol, this module sends to OMIE the volumes and prices resulting from the calculation module. For intraday markets, it also manages previously submitted bids, cancelling or replacing the older ones.

Alarmistic module: Provides monitorization and validation of bid submission. It controls if all the information was correctly sent to OMIE, confirming that the bids submitted match those received by OMIE. If there is a discrepancy, which indicates a possible error, then multiple communication alerts (SMS, phone calls, emails) will be sent to a list of contacts that will address those issues. These alerts are categorized into different levels, with separate contact lists and with different system's actions (e.g.: cancel all bids or send them to OMIE but with warning emails).

Web configuration board (website): Web application that allows users to control some features of SUTRADE, such as configuring ETL workflows or fully parameterizing the bid calculation process. Some example of this parametrization are: change parameters $\theta_1, \theta_2, \ldots, \theta_N$ or functions f_{U_j} and g_{U_j} that are described at Section II; define the values of $\alpha_k^{U_j}$ and k_{U_j} (the number of blocks per unit that must be considered for each market session) for all market sessions over the next seven days. Also, it gives to users some overview regarding SUTRADE bidding workflow (e.g.: accepted offers, current market session, market status or available market results).

Reporting module: Effective reporting is crucial for successful trading activities in the market. The reporting module of SUTRADE utilizes Microsoft Power BI to extract relevant data directly from the database, providing important insights. This module provides a clear and transparent record of all bids, including whether energy is effectively sold or bought in the market. It provides a detailed view of the performance of forecast models and delivers valuable information about market conditions, such as price volatility and the bidding behaviour of market participants. These insights are essential for making informed decisions about adjusting the parameters of the bid calculation process. Furthermore, this module is important for sharing relevant information with different stakeholders.

As presented in the following figure these components are hierarchically related and all of them are connected. At the bottom layer are data sources, then applications that manage and use this data to generate automatic bidding and reporting.

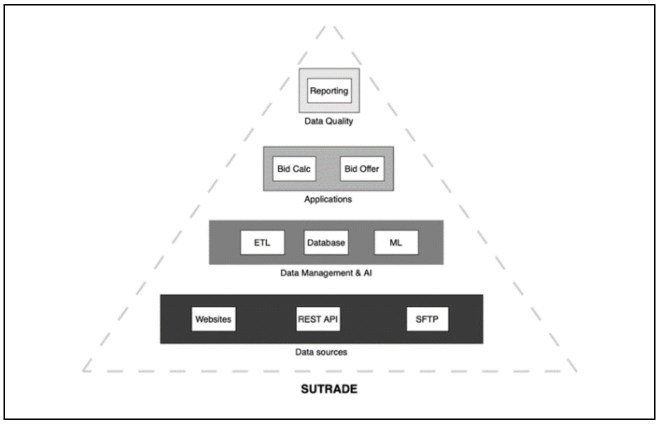

Figure 3. Relation between SUTRADE components

V. CONCLUSIONS AND FUTURE WORK

SUTRADE's implementation marks a significant advancement in the automation of bidding processes at SU ELETRICIDADE. By transitioning from semi-manual to fully automated systems, SU ELETRICIDADE has enhanced its operational efficiency, reduced the risk of human error, and achieved substantial cost savings. This custom solution, developed specifically for the unique requirements of SU ELETRICIDADE, integrates various modules such as ETL, ML/Forecasting, bid calculation, submission, alarmistic and reporting. Given that the forecasts available in the ML/Forecasting module for wind energy are updated periodically with a higher frequency than the number of intraday markets, it may be possible to further minimize imbalances in Unit 2 through participation in the continuous market. To achieve this goal, as part of future developments, the intention is to assess the evolution of SUTRADE to a solution that supports bidding in the continuous market.

Committed to a process of continuous improvement and operating in an increasingly complex energy market, SUTRADE will need access to larger datasets and more data processing capabilities. Therefore, more powerful ETL clusters will be required to handle the pressure on infrastructure side. This is already being addressed by revising ETL microservices and breaking them into smaller components and migrating some of them to powerful auto-scalable frameworks to increase performance and efficiency of overall system. This is like a "never ending story" once technology is constantly evolving and there is always space for improvements. "Digital transformations (…) are long-term efforts (...)" [5].

In conclusion, this in-house developed solution not only meets the current operational needs but also provides the flexibility to adapt to future market conditions and regulatory changes.

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