Assessing electricity prices and its driving mechanisms in Brazil with Neural Networks

1. Background and problem description

In the commercialization of electric energy in the free market, companies and large businesses usually buy energy in long-term contracts. However, these long-term situations may change with discrepancies in companies' energy needs as a result of changes that occur over time. Thus, companies can end up making a contract that ends up being greater or, more commonly, smaller than what they actually consumed, and the same can occur with energy supplying agents [1].

Therefore, it is necessary to settle this difference between the contracted amount and what was consumed/supplied. This operation takes place in the Short Term Market (MCP), and is subject to the Settlement Price of Differences (PLD), which dictates how much the energy will cost to be settled. The PLD is a variable obtained by optimization and is updated weekly.

The value of the PLD is based on the Marginal Cost of Operation (CMO), which takes into account the energy supply in a study period and the energy demand in the same period. According to the Electric Energy Commercialization Chamber (CCEE), the CMO is based, on the predicted values of energy demand, hydrological conditions, and on the declared generation availabilities using the NEWAVE and DECOMP methods to produce a weekly result for the CMO for each submarket [2]. The first is used for long-term operation planning, up to five years; the second is used as a short-term tool, up to twelve months. The fundamental objective is minimize the marginal cost of operating the Brazilian electrical system [3]. From this result, the PLD is obtained, which is also limited by a maximum price and a minimum price [4]. The PLD is an output of the above mentioned computational models managed by the ONS (National Electric System Operator) and not a product of the relationship between supply and demand only.

Brazilian electricity is currently composed mainly of hydraulic generation, which corresponds to about 65% of production of the country's electricity matrix. Therefore, the Brazilian energy production capacity is directly influenced by natural factors, depending on seasons and climatic factors, resulting in a high PLD volatility, as shown in Figure 1 .

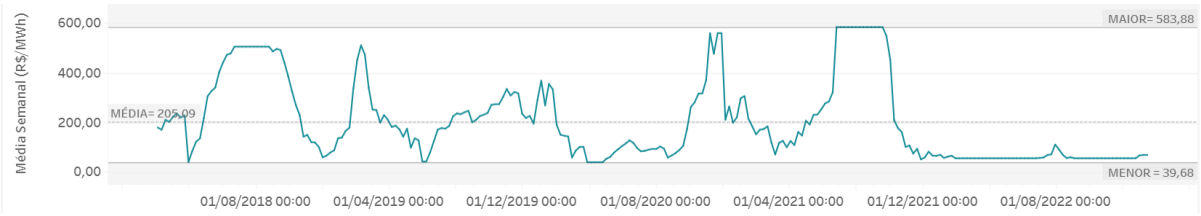

Figure 1 - Settlement of Differences for the Southeast/Midwest submarket [5].

2. Objectives and Research Questions

The supply of electricity in the Brazilian market is closely linked to hydro power generation, given the current layout of the country's energy mix. This form of energy generation is strongly linked to the level of the reservoirs, in addition to other stochastic variables. The whole structure for determining the values of the PLD and the idiosyncratic characteristics of the energy matrix bring high volatility to

prices, leading market agents to invest in risk management alternatives for their portfolio of contracts. Thus, there is great interest in models that help energy market agents in their work processes.

This study has as general objective for the development and evaluation of Artificial Neural Networks, specifically the LSTM (Long Short Term Memory) model as a tool for forecasting the behavior of electricity prices in the Brazilian short-term market.

The specific objectives can be summarized as follows:

- Study the theory and functioning of the Recurrent Neural Network model called LSTM;
- Develop an application of the LSTM model for forecasting short-term prices maturity of the Brazilian electricity market.

3. Scope and limitations

The scope of the project is intended to focus on the Brazilian Energy market. For the electricity prices it is intended to work around all four Brazilian bidding zones. The most relevant data required for this work is available from the ONS (National Electric System Operator) database. It is possible to face limitations regarding access to some specific data that may be relevant, either because the data does not exist or because it is private.

4. Research methodologies and methods & expected results

It is intended to bring a literature review to explore two main topics: (1) Brazilian energy market and (2) Non-linear prediction models using Neural Networks. Also, it will be important to conduct interviews with relevant stakeholders (including co-workers at XP Inc., such as Energy Traders and Energy Markets Analysts/Researchers).

Moreover, it is intended to go deeper explaining how LSTM technology works and how it will be used in the project. Then, develop an application of the LSTM model for forecasting short-term prices of the Brazilian electricity market. For conclusion, it is expected to evaluate the performance of the projections of the developed model, based on well-defined performance metrics in the evaluation of time series projections.

5. Sustainability aspects and ethical considerations

From the aspect of sustainability, it is expected to bring data and discussion on how energy market agents can benefit from having access to better ways of predicting the price of electricity. From these benefits it will be possible to trace a relative to better investments in the area which, consequently, make room for better technologies and a more sustainable ecosystem.

The systematic literature review should be performed transparently, without favouring any types of research papers based on, e.g., the authors' nationality or gender. It is important to conduct a rigorous examination of the literature, choosing only those studies that have undergone peer review from other researchers. All the techniques and results will be openly transparent in order to guarantee compliance with Aalto University, KTH and XP Inc.

6. Plan for validity, scalability, replicability, and reliability

With an extensive literature review, peer review, and feedback from the project supervisor, the study intends to guarantee validity of the energy market description. The research process will be continually supervised by XP Inc. co-workers and the final report, i.e., the master's thesis, will be reviewed externally by an examiner to further improvements. Furthermore, the resulting model will

be validated by testing it in real conditions, showing the expected results with error and accuracy metrics that will clarify validity. The research methodology, limitations, and proposals for future work will be presented transparently in the final report to ensure replicability and scalability. The methods of constructing the model can then be used as a benchmark to further scale it up or down, for example, to broader or more specific regions.

7. Time plan

The Thesis Project will have twenty weeks to be completed (Gantt Chart). The tasks will be overlapped with transition weeks. During the first week (starting on February 6th), there is time for the first supervisor meeting. The following twelve weeks are reserved for the research process, including systematic literature review, interviews, and model development. The report will be written simultaneously during this part of the thesis. The research methodology is followed by two weeks of presentation preparation along with writing the results and discussion sections. During the last four weeks, there will be time to improve the report (based on supervisor feedback on draft report), take care of final details, such as formatting and references, and review the report before the final submission (intended to be by the end of June).

Master Thesis
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Research Prosposal
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Gantt Chart

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Research Process																				
Energy Market Review																				
Modeling Review																				
Model Development																				
Report Writing																				
Introduction																				
Literature Review																				
Methodology																				
Results																				
Discussion																				
Conclusions																				
Report Improvements																				
Report Format Check																				
References Check																				
Report Review																				
Final Submission																				
Presentation																				
Prepare Presentation																				
Supervisor Review																				
Presentation																				
Supervisor Meeting																				

References

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[5] “Electricity Prices Panel” Available: https://www.ccee.org.br/web/guest/precos/painel-precos