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ELECTRICITY SPOT PRICES: MODELING & SIMULATION USING DESIGN OF EXPERIMENTS AND ARTIFICIAL NEURAL NETWORKS

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The introduction of deregulation on the electricity sector has turned the short-term electricity price one of the most important variable in the power market. Actually, the basic objective of deregulation on these markets consists in maximizing the efficiency in electricity generation and transmission besides reducing the price of electricity. On this way, efficient forecasting methods of electricity spot prices have became crucial. Producers and consumers trust on the forecasting information to prepare theirs bidding strategies. If producer agents have a fine forecasting of price to the next months, they can develop one strategy to maximize their benefits.

The changes introduced on the Brazilian market model in 2004 by the Law 10848, established the new rules for the commercialization environment. It created the regulated market environment and kept the free wholesale market. This law made clear that the contracts on the regulated environment must be conducted by Brazilian Electrical Energy Commercialization Chamber (CCEE) after an auction procedure regulated by the National Regulatory Agency (ANEEL). The prices at the free market named PLD (clearing prices of the differences) are set by calculating the operational marginal cost (OMC) of the energy derived from a hydrothermal dispatch optimization program (NEWAVE) [1-2].

The NEWAVE program provides the OMC as the Lagrange coefficient of the load balance constraint. The objective is to minimize the production costs considering the operation of the power plant reservoirs. A stochastic dynamic dual programming is used for this purpose because a today decision affects the future costs and the overall optimization. Therefore, the NEWAVE is main tool to compute the returns and risks of investment portfolios and of selling and buying contracts. However, this computer program is time consuming. Simulating the OMC and its volatility has been the major problem in Brazil because if, for instance, a Monte Carlo Simulation (MCS) is used for analyzing risk and return, the NEWAVE became the critical point of the whole process because the excessive number of iterations necessary for the MCS.

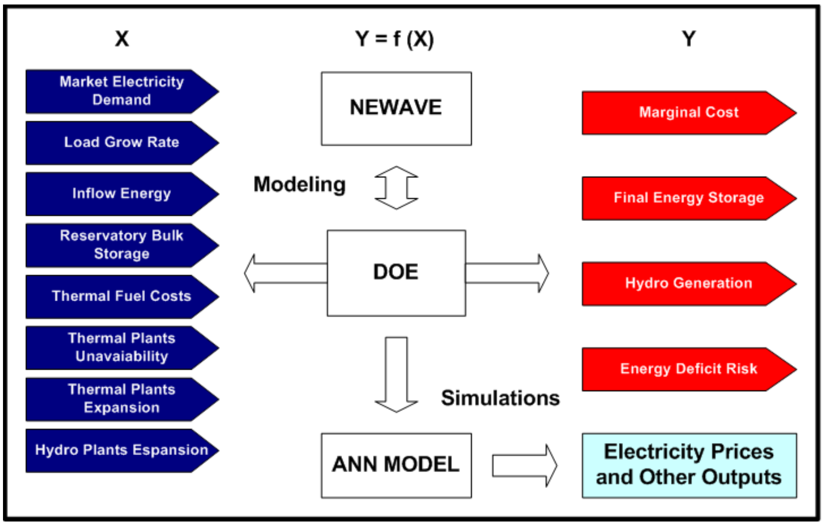
Then, the first step to forecast free market prices in Brazil is to solve the optimization problem in few seconds. In other words, it is needed to find a fast substitute for the NEWAVE. This paper will show a procedure to overcome this problem. In [3], it was built a clone for NEWAVE using Design of Experiments (DOE) [4] and Artificial Neural Networks (ANN) techniques [5]. The model was developed to simulate the OMC for the four regions but in this paper only the prices of Southeast Brazilian Submarket will be shown. So, two main objectives are presented: develop a model to clone the NEWAVE program to simulate the prices and other variables for the whole Brazilian system and validate the results of this simulator.

A model with several neural networks that can perform the calculations of NEWAVE program is presented. Primarily the input variables are analyzed based on DOE to define the principal and secondary variables. The DOE also design the sample necessary to train the ANNs. Secondly, the structure of ANNs is chosen and the training stage is performed.

Firstly it is described how the software NEWAVE works. Only the most important variables that affect directly on the outputs, like: demand of energy market, thermal generation fuel costs, reservoir bulk storage, and others. Changes on these variables produce great impacts on the final energy price.

Secondly it is generated the dispatch scenarios when there is no information about which variables have more influence on some specific outputs. The definition about which factors have larger influence on the outputs is important to build the simulator structured by ANNs. An efficient manipulation of data is realized on the input variables using DOE. It establishes the minimum number of cases to be simulated on NEWAVE and captures the weight of each variable.

The DOE determines the scenarios or cases that are necessary to assess the output of the NEWAVE program, i.e., the cases that must be ran using the NEWAVE. Then, based on the assumed values of the inputs (X) it is generated the output vector Y. For example Y contains the OMC. From the assumed outputs values, it is possible to verify the dependence relation Y = f (X) as shown in the figure.



Three steps are performed to define the main variables and their correlation in order to develop the sample necessary to build the ANN simulator. These steps are shown in the paper and it was necessary 328 cases of NEWAVE to complete the whole process.

The NEWAVE simulations works as the data for the neural network training, i.e., inputs and outputs are used to forecast the OMC for each Submarket. Besides the OMC other NEWAVE output variables are included like: final energy storage, hydro generation and energy deficit risks. The total number of output variables treated in this process reaches 32.

Since the ANN predictor is a clone of the NEWAVE program, it is necessary to assure that its results will always be in consistence with NEWAVE outputs. A back-test procedure was also designed to validate the model ability to respond to changes on NEWAVE. After performing such tests with the current version, it was verified that the ANN model can successfully substitute the NEWAVE program in this application.

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