Flexible Windowing Approach for Real-Time Simulation of Electricity Prices

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***Abstract*--Electrical market deregulation worldwide has imposed demanding requirements for energy transactions nowadays. Under this market circumstances, government entities, electrical industry, energy consulting bodies and researchers in academia have focus most of their efforts to finding the equilibrium price for energy in a given market instant of time, tackling the many technical difficulties in establishing energy price on that specific time.**

***Index Terms*—Market dynamics, flexible window, time series model**

I. Introduction

ENERGY prices are volatile and these should be calculated with some accuracy, which actually is a challenging task to do. Dynamically changing external and internal system conditions such as network configuration, total energy dispatched to loads, previous energy prices, number and type of generating units delivering energy onto the network, and fuel prices considerably affect the final energy price.

The conditions influencing the energy prices are numerous; however realistic analysis should include the most relevant ones. Among the factors taken into consideration for a real time simulation are:

- Generation cost
- Electricity demand and price
- Transmission cost
- Network topology
- Energy allowance

The main objective of this paper focuses in establishing a realistic strategy for the real time simulation of electricity prices. The real time simulation methodology designed in this research work is primarily intended to calculate electric energy prices but it is also should be helpful to identify least-cost-trajectory considering full-congested lines or the price sensitivity curves for a given transmission corridor

The core of a continuous simulation methodology resides in the analysis of one set of system conditions at time, conveniently named Flexible Window (FW), after which the system conditions are updated, including a time shifting, and another FW is evaluates afterwards. This process continues as long as the simulation is running evaluating each SSW in real-time.

The real time simulation will provide useful short-term prices. However, future electric energy prices might be envisioned if forecasting energy demand and future fuel prices, prospective new generation units are considered. In this case the analysis may be considered as a multi-objective simulation tool, which can also include the influence of quality of the power on the energy final price. It should be remarked that the simulation scheme does not take market distortions, such as hidden subsides, artificial over or under prices, and fixed prices into account.

II. FLEXIBLE WINDOW SCHEME

Normally electricity price prediction models include sets of parameters which should be properly estimated and fitted to the model in order to diminish the deviation between the predicted electricity price and the actual one. Once these parameters have been selected for a final model, to best fulfill all requirements needed to carry out a realistic performance predicting electricity price, the number of parameters and assigned values will remain fix all along the model is being in use[1][2][3].

In the case of an estimation probabilistic model based on a data regression of some kind, the set of historic data used to estimate the electricity price depends on the number of model parameters used on it [4][5][6]. For instance, a model based on dynamic regression, presented in equation 1 [4], requires a number of parameters, ω_l^d and ω_l^p, to "weight" historic demand and electricity prices, d_t and p_t respectively. Then, the basic set of mode parameters determines the number of historic input data (demand and price for this model) required for any estimation of electricity price. The "window" of historic input data is named window length in this work. It can be said, as a sweep statement, that the number of model parameter needed for a given time series model to perform the regression determines the window length. As mention before, the number of model parameters remains unvarying throughout any price estimation time, in consequence, the window length also remain unvarying, which can be seen as a fixed window.

$$p_t = c + \omega^d(B)d_t + \omega^p(B)p_t + \varepsilon_t \tag{1}$$

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$$\omega^p(B) = \sum_{l=1}^{K} \omega_l^p B^l \quad (2)$$

$$\omega^d(B) = \sum_{l=0}^{K} \omega_l^d B^l \quad (3)$$

$B : B^l z_t = z_{t-1}$ Backshift operator

where ω_l^d is a parameter for demand, ω_l^p is a parameter for price, d_t is the demand at time *t* and p_t is the electricity price at time *t*.

In general, the size of the historic data stream used as model input (demand, price, system load etc) required to perform the model regression, which is related with the number of model parameter, have intrinsic information necessary to draw up the boundaries of the window length for calculating a day-ahead electricity price. These intrinsic data are the current data available at present time (those with no regression) and the "oldest" data available (most-backshited data) in the history data. In other words, the top and bottom records of set of model parameters define the fixed window length in terms of time.

Figure 1 shows a moving fixed window. As can be notice, for this window format the data needed for calculations remains constant

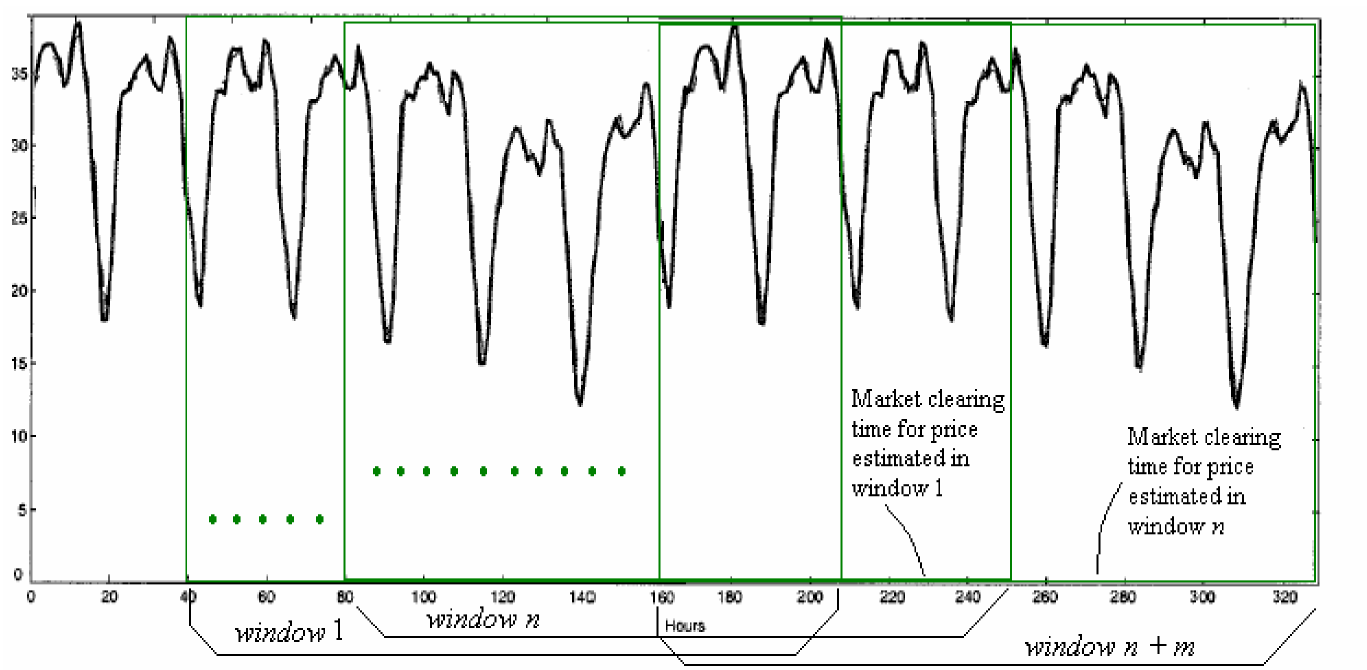

Figure 1. Moving fixed window

A price estimation using a FW scheme is indeed a sensible common way to predict electricity prices with times series models. However, the FW scheme, after a closer review, shows some inconveniences which are related with constant number of model parameters and their respective values. As these data do not present any change, they are, subsequently, insensitive to changing conditions (commodities, transmission system, volatility of prices, misbehaviors of markets, etc) which could be experience in the electricity market as manner of the following:

- An increasing, repetitive, difference between a-day-before predicted prices and the current spot ones.
- The presence of correlative error (or randomness of error is not suitable)

For instance, an increment of the deviation between a predicted and its actual price may indicate the necessity for additional model parameter which is not possible if the window length is fixed. If such deviation comes to be significant then the use of a different window scheme is obliged. This particular circumstance opens the opportunity for a scheme able to dynamically adjust the number and values of model parameters: A FW length scheme. Figure 2 pictures this concept and shows a moving window with a changing length.

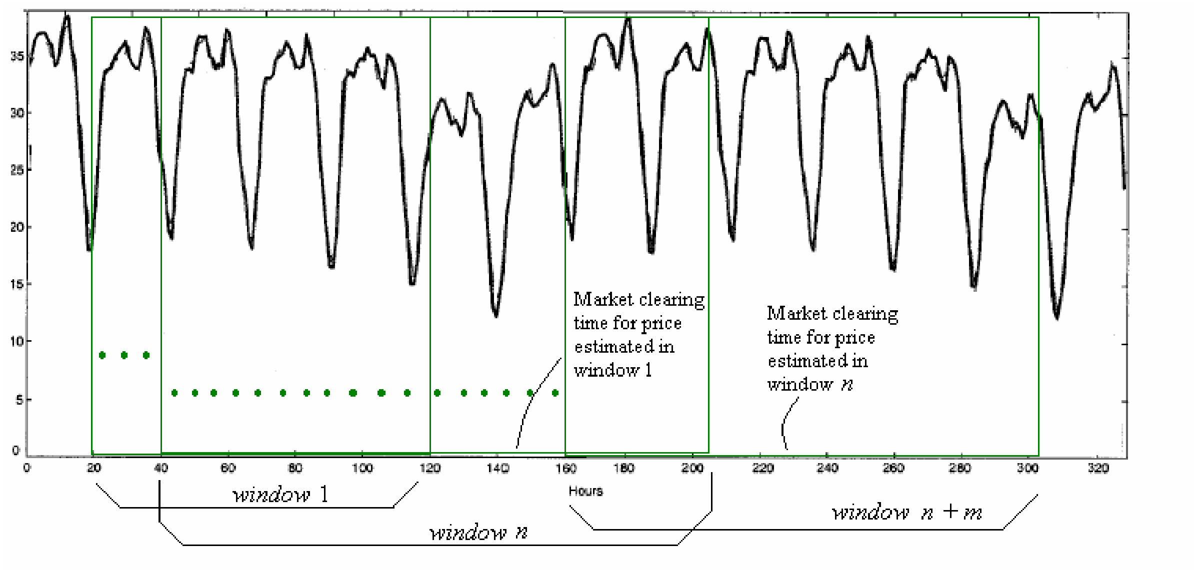

Figure 2. Flexible window length

The introduction of a FW length into a procedure to continuously estimate a day-ahead electricity price and verify a previously predicted one against a current clearing price may dynamically improve the forecasting of electricity prices to more convenient ones. Figures 3a and 3b show a flow diagram stages I and II for a future implementation of a FW concept.

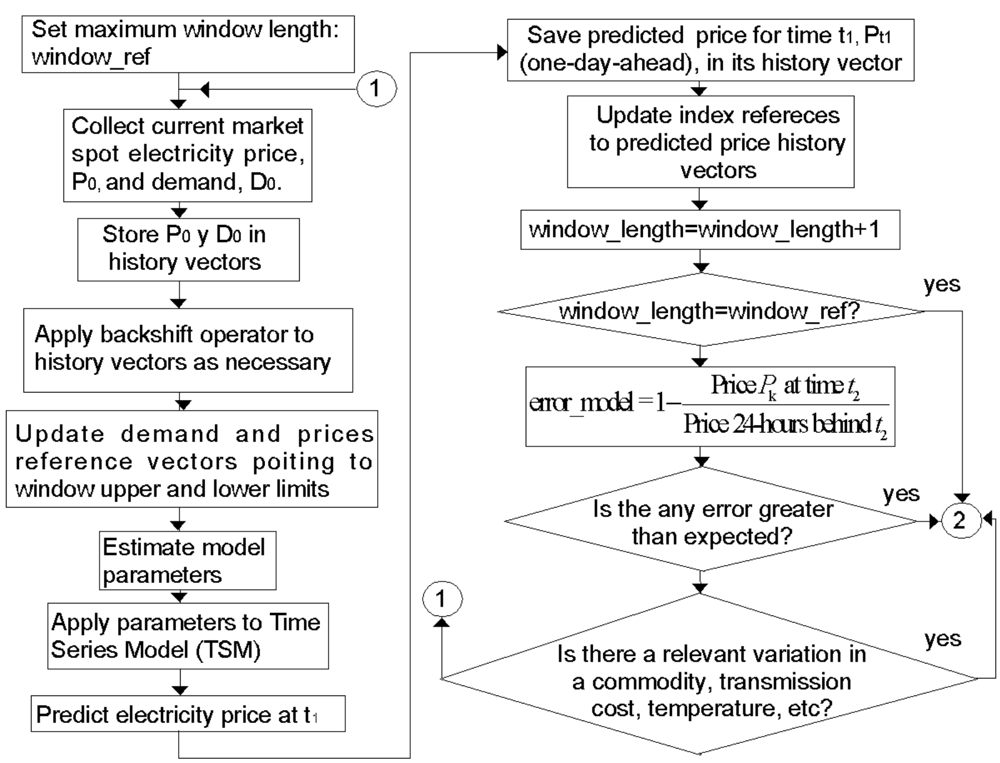

Figure 3a. Flexible window flow diagram stage I

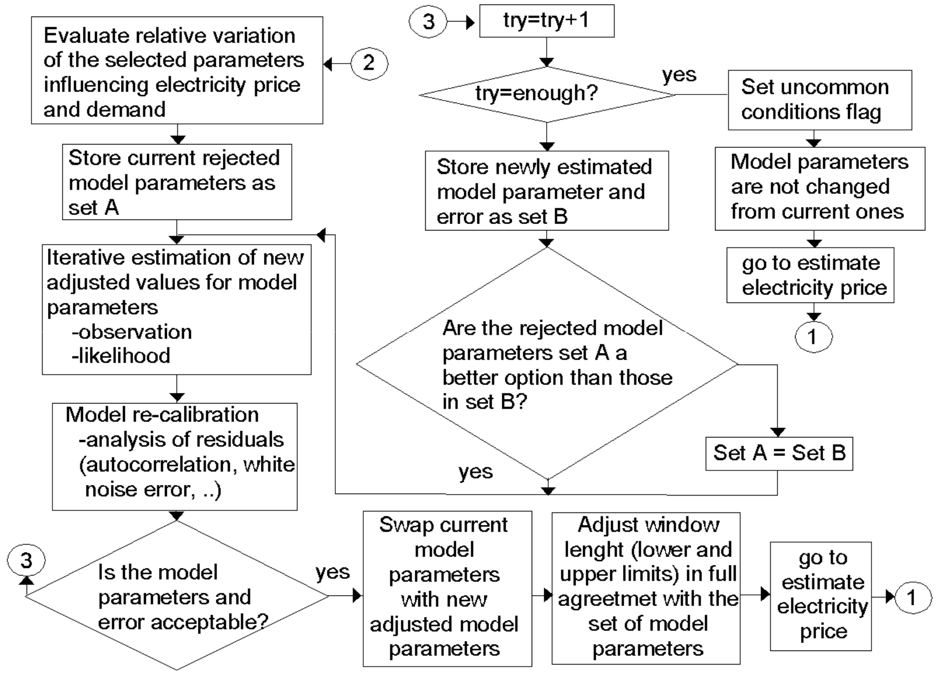

Figure 3b. Flexible window flow diagram stage II

Several technical difficulties should be overcome to make the FW concept approachable for a time series model. Once the probabilistic model has been selected, a fundamental problem to solve focuses to estimate the number of parameters and its values, that is, the FW length. As can be notice, the scheme relies on the capability of a robust algorithm to reduce or increment the number of model parameters, simply changing their values, or both. However, in any case, for a reliable estimation, the window length should be not arbitrary chosen.

A ruling condition in full liberalized electricity markets many indicates that many factors can influence in setting an electricity price in the pool. Under this provision, high variation in price due to circumstances as unexpected electricity demand, several abnormal transmission network conditions (a blackout for instance), misbehavior of markets, or a fuel shortage (or other unpredicted condition provoking highly volatile prices) will require a estimation model having relatively more model parameters than a estimation model for smooth and highly repetitive electricity price (which actually gives a perception of approaching to a state-controlled prices and commodities, a monopolist market, or an ineffectual “liberalized” market).

As a result, if the window length is too wide for a given market conditions, then, presumably, the accuracy of the predicted electricity price tend to be higher. On the other hand, if the number of model parameters is reduced in excess, reducing the window length, then the estimated price can becomes far from realistic. The model parameters adjustment can be performed in real time. However, the algorithm should have the capability to establish a compromise between the number of parameters, the error produced after the electricity price is estimated and the computing time needed for the estimation. In any case, higher the number of model parameter the most computational time and effort is required.

III. Real-time Approach

Normally only complex and costly special-purpose computer are used to analyze market perspectives for electric energy in a given condition of large electrical systems. The high cost of this computational equipment is afforded by the less, including in these many research bodies. In this context, lower cost computational platforms are urgently required having also high performance. The real-time simulation strategy proposed for this research work will be embedded into a specialized stand-alone DSP, more specifically a C6000 from Texas Instruments, as a next step.

A general view of the computational scheme to realize the flexible window length concept is presented in figure 4. In this modular scheme the electricity price is estimated in the workstation. The DSP-based computational platform provides the numerical support to carry out:

a) The evaluation of the error variation, predicted-actual price deviation, and a significant variation in commodities
b) The adjustment (estimation and calibration) of model parameters for a times series-based model

To accomplish with real time requirements, all calculations and decisions to predict a price, to estimate and re-estimate parameters, and to determine the window length should last less than one hour time.

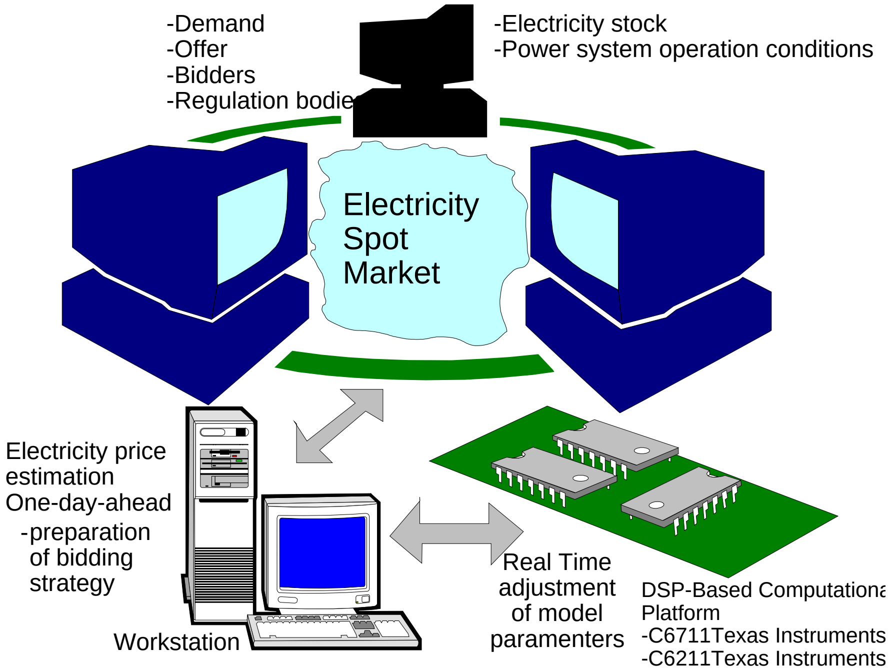

Figure 4. Computing Platforms for flexible window scheme

IV. Conclusions

In the open literature various approaches have been proposed to predict electricity market prices. Throughout a brief analysis of a time series model for prediction of one-day-ahead electricity spot price, the number of model parameters has been visualized and linked to a FW length. In this paper the FW concept is introduced in the sense of improving the estimation of the electricity price by means of adjusting (re-estimating and calibrating) a new set of model parameters. The decision about the change of the model parameters directly depends on the off-limits variation of market variables and conditions influencing the price. Further exploring the FW concept an additional benefit has been put forward: The adjustment of the FW can be performed on-line with the current electricity prices. As a next step, the research is directed to the implementation and test of the FW in real time and extends the concept to long term electricity prices[7].

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