Arbitrage Strategy Between Next-day Delivery Prices and Real-time Delivery Prices of Electricity Megawatts on the Physical California Market

submitted by CWP Energy, Montreal, Inc.

CWP Energy is a private company involved in the physical and financial electricity markets. In particular it carries out daily imports and exports of electricity between diverse physical markets in North America (NYISO, NEISO, MISO, ERCOT, SPP, Ontario ISO), thus contributing to a secure equilibrium between the supply of and demand for electricity (which must be ensured in real time) and to the reliability of the North American electricity network. Indeed electricity is an asset that cannot be stored and the demand for electricity at a given time and in a given location (called "demand node" of the network) will be satisfied only if (i) the corresponding quantity is produced (at a node called production node, also in the network) and (ii) transmitted from the production node to the demand node (iii) at the same time.

I. Survey of the physical electricity markets

Independent System Operators (ISO) must ensure that at any given time (every 5 minutes) the appropriate amount of electricity is produced at the various production nodes and transported to the demand nodes (towns and cities). These ISO are often non-profit public entities in charge of a geographic area including one or several North American states (NYISO for New York State, NEISO for New England). Everyday the ISO make sure they have a precise forecast of the demand for electricity and a generating capacity that (i) can satisfy the demand and (ii) is distributed geographically so as to transmit the electricity from the production to the demand nodes. Indeed each of the electrical lines used for the transmission has a maximum capacity, i.e., there is a limit on the number of megawatts it can transmit. When a line serving a town or city is congested, the operator must use another generator to produce electricity that will be transmitted through another (non-congested) line. When a market produces too little (resp. too much) electricity, it can import (resp. export) some from adjacent markets.

In deregulated markets such as the North American markets mentioned above, the electricity delivery price is determined through a matching between the supply and demand curves, provided every 5 minutes by the various market players in the network (electricity distributors, generators, importers and exporters of electricity). Every 5 minutes each player provides the ISO with a curve expressing the relationship between the price and amount of electricity (i.e., a curve giving the number of megawatts the player is willing to buy or sell). If there is no congestion (a theoretical case), the ISO has only to aggregate these curves and select the buying or selling price as the point of intersection of the aggregate supply curve and the aggregate demand curve. In practice many computations of this kind are carried out at the network nodes, resulting in a price for each node. When the price selected for a given time (hour) results from the curves provided one hour beforehand, the price is called real-time price (RT price). Note that if there is no congestion in the network, the price at a node will equal the price at any other node. This is not true if there is congestion, since a line is congested only if one of its nodes is served by a generator that costs more than the generator serving the other node of the line.

The problem of matching the supply and demand is highly complex; to a large extent this is due to the difficulty in evaluating the future demand and the available supply. Some generators may break down and others (such as wind turbines or photovoltaic or hydroelectric generators) may never be able to guarantee a given production level. Line congestion also increases the complexity of matching the supply and demand. As a result the RT price is extremely volatile.

The extreme volatility of the RT price makes the managing of production units and distributors complicated. In order to secure their purchases and sales, the ISO have designed a “day-ahead” delivery mechanism, as follows: (i) at 10:30 AM local time, the participating market players send to the ISO 24 supply or demand curves for the nodes of relevance to them, (ii) the ISO selects a price for each of these nodes by aggregating these supply (or demand) curves (iii) while taking into account his own internal demand forecast, the various production capacities, and congestion. The selected price is called “day-ahead price” (DA price). The market player who buys (resp. sells) at the DA price for a certain hour is committed to buying (resp. producing) on the next day the agreed number of megawatts. The next day the gap between the actual demand and the DA demand, as well as the gap between the actual production and the DA production, are adjusted through a buyout or resale at the RT price.

The day-ahead delivery mechanism enables one to secure the gains or losses of market players. In theory, if the ISO has a good forecast of the events of the next day and the market players provide buying and selling curves reflecting accurately their actual gains or costs, the RT and DA prices will converge and the market will be efficient (i.e., the electricity prize will be optimized and electricity will be sold to consumers at the lowest possible price). On average the RT-DA spread will be close to 0, and the market players will not be able to create an environment where buying or selling at the RT price is more profitable than buying or selling at the DA price.

In practice, since the market is deregulated and the number of network nodes is huge (the MISO market includes 4500 nodes), the distributors or generators can use the day-ahead bidding mechanism to manipulate the market and introduce a bias in the RT-DA spread. To reduce or even eliminate this market power, the North American ISO have completed this mechanism by introducing a *virtual bidding* mechanism that allows financial firms without any physical asset to speculate on the RT-DA spread at any node. These virtual bidding contracts allow any physical network node to buy (resp. sell) a certain number of megawatts at the DA price (a long-short position) and to resell (resp. buy out) automatically the same number at the RT price. No physical flow takes place when such a contract is carried out. A virtual supply curve and a virtual demand curve are simply added to the real supply and demand curves (respectively) at the time when the day-ahead bidding takes place; these virtual curves may offset the real positions and rebalance a DA price that is too high or too low. Through the introduction of new broker-traders, this virtual bidding mechanism allows one to reduce the market power of electricity producers and distributors: it plays a central role in the efficient management of an electricity production base.

II. The proposed problem

CWP Energy proposes to design an automated algorithm for trading virtual products at three important nodes of the physical market called CAISO (CAlifornia Independent System Operator): SP15, NP15, and SP26. At 10:30 AM on a given day and for a given node, the algorithm must decide which hours **on the next day** warrant a short, long, or neutral position (i.e., no position at all). This algorithm should result in profits on an annual, trimestrial, and monthly basis, while satisfying criteria on the maximum daily loss. The design of such an algorithm is difficult, because of the extreme volatility of a DA-RT spread (around $7/Mwh) and the frequent occurrence of extreme values ($200/MWh, sometimes even $1000/MWh, the maximum price in the CAISO market being equal to 2500$/Mwh). Indeed it is not enough for the strategy to yield a positive average return in the long run: one must ensure that the daily losses are small enough to enable the strategy to survive in the long run.

Given the particular nature of electricity, it is crucial to base the required algorithm on forecasts of the variables having an impact on supply and demand. Note that at 10:30 AM on a given day, the trader who must choose a position for the next day has only a limited knowledge, i.e., forecasts for the 24 hours of the next day (whose performance may be very poor on certain days). Hence the algorithm must take this uncertainty into account to make decisions that are profitable on average and in the long run.

CAISO provides numerous forecasts, extending over long horizons. It is a market with a very diverse production: in particular a high proportion of its production comes from renewable resources (solar, hydroelectric, wind). The required algorithm will naturally be based on variables such as

1) the forecast of wind, solar, and hydroelectric production;
2) the temperature and wind speed in different Californian cities;
3) the demand forecast;
4) the prices observed in the past;
5) the forecast of the capacity; and
6) the congestion.

Many other data are available and long time series of data will be provided by CWP Energy. The very large number of potential explanatory variables seems to indicate that machine learning is the preferred avenue for designing the required algorithm.

CWP Energy is considering two ways of attacking this problem: (i) through so-called forecasts methods and (ii) through reinforcement learning. In the first approach a neural network or random forest model could predict the average spread of the next day, the volatility of this spread, and (maybe) the worst possible daily loss. If the predicted average is positive, the algorithm would choose a position (short, long, or neutral) and use the predictions of volatility and worst loss and a constraint on the VaR or expected shortfall to select the amount to buy or sell. In the second approach (reinforcement learning), a neural network would select a position (short, long, or neutral) for every hour and every node and would be calibrated so as to optimize a gain function under a risk criterion (VaR or expected shortfall). In this approach one does not try to predict the value of the spread but rather selects a position with the minimum downside risk.

Let us mention another factor underlying the complexity of the problem: the correlation of spreads between nodes. As mentioned above, one of the important goals of an ISO is to minimize congestion and thus ensure a price that is relatively constant across the nodes. Efforts to reach this goal may result in a strong correlation between nodes and make the design of a strategy “playing” on several nodes more difficult.