Cerna, Centre d'économie industrielle
Ecole Nationale Supérieure des Mines de Paris

60, boulevard Saint Michel
75272 Paris Cedex 06 – France
Tél. : 33 (1) 40 51 93 13 – Fax : 33 (1) 40 51 91 45
Margaret.Armstrong@mines-paristech.fr

Impact of VPP on the Day-Ahead Market in France

M. Armstrong & A. Galli

Working Paper

Presented at the Winter Energy Seminar Series: "*Price and Decision Support Modelling in Electricity Markets*", Dept of Industrial Economics & Technology Management, NTNU Trondheim, 12-13 February 2009

Date: 10 April 2009

Abstract

After reviewing the structure of the French electricity market since its liberalisation in 2001, we focus on two of its components: the Day-Ahead auction market which fixes the wholesale price of electricity one day before delivery, and VPP option contracts that are auctioned by the historic operator, EDF, every three months. As these contracts have recently been introduced in Belgium, Spain, Germany and Denmark, it is important to understand their impact on other sectors of the electricity market, notably the day-ahead market.

Holders of VPP (an abbreviation for virtual power plants) have the right (but no obligation) to access to electric power at a predetermined price per MWh, called the strike price, in 30 minute slices 24 hours per day, 7 days per week, during the delivery period, after having paid an upfront premium fixed at the auction. In financial terms these are call options. Theoretical work has shown that derivative contracts such as options should mitigate market power.

In this paper we show that the structure of the market allows holders of VPP to exercise strategies of selling power on the exchange when the day-ahead price is above the VPP strike (if they do not need the power) and conversely of buying power on the exchange when the day-ahead price is below the strike of their VPP (if they do want power). By documenting the strike prices of VPP that were active at different times and by carefully examining structure of day-ahead prices we demonstrate that they are doing this. The presence and absence of peaks coincides with the strike prices of active VPP contracts.

Acknowledgements

Thanks to the participants of the winter electricity workshop held at NTNU Trondheim 12-13 February 2009, for their helpful comments.

Thanks to Audrey Mahuet of Powernext for answering our questions on Powernext and the French market, and for her constructive comments on our work.

Thanks are also due to Prof O.J Olsen, from Oskilde University Denmark, for information on Danish VPP.

Introduction

The French energy sector was liberalised much later than the UK or Nordic countries. As France benefitted from cheap electricity from the nuclear power stations constructed in the 70s & 80s neither the consumers nor the historic operator, Electricité de France, were enthusiastic about opening the market to competition and so the French government duly dragged its feet. On July 1 2001, both the gas and electricity markets were opened for competition for "large consumers" (about 30% of consumers), three years later this was extended to middle sized consumers (bringing the part open to competition to about 70%), and finally to householders in July 2007.

This late development explains why the French electricity bourse, Powernext[1], was created in November 2001. At first Powernext provided only a Day-Ahead Auction market, using the clearing system developed by Nordpool, as does the German exchange EEX. In June 2004, Powernext added futures contracts to its range of products. Recently two continuous trading sections were added: a Day-Ahead market and an Intraday market. The different sectors of the bourse provide consumers with access to electricity up to 3 years in advance. See Table 1.

One factor that has hindered the convergence of electricity markets in Europe has been transmission difficulties from one country to another. In addition to the costs, restrictive practices often make it difficult to acquire the transmission capacity that is available. To overcome these problems, the French, Belgian and Dutch markets were coupled in November 2006. Offers to buy & sell power on the three Day-Ahead Markets are now aggregated & settled together. This means that provided the transmission capacity allows, the three markets have a common (and hence lower) price.

In 2008 Powernext and EEX agreed on the development of common trading platforms with the common spot market based in Paris and the power derivatives market in Leipzig, with clearing being done through the European Commodity Clearing AG in Leipzig. The idea is that while it is advantageous for consumers to be able to choose from many suppliers, cooperation between the trading platforms at the wholesale level is important to give a clear signal as to prices. This came into effect on 1 March 2009, under the name of EPEX.

[1] http://www.powernext.fr/

Table 1: Overview of the main sectors of the French electricity market (at 1 January 2009)

Sector	Time to delivery
Balancing market (RTE)	From 5-10 minutes before delivery time
Continuous Intraday market (Powernext)	Several hours prior to delivery on same day
Continuous Day-ahead market (Powernext)	Day to delivery, after fixing time 11 am
Day-ahead auction market (Powernext)	Day prior to delivery, fixing at 11 am
Futures market (Powernext)	Contracts for next 3 months, next 4 quarters & next 4 calendar years
Virtual power plant VPP (EDF)	Option contracts to buy power for delivery over period of 2, 3, 6, 12, 24 36 or 48 months

In addition, the French TSO, RTE[2], runs a last minute adjustment market in which power plants and consumers can bid to provide or withdraw power at short notice. RTE's objective is to balance the power available at all times. Unlike the other markets, it need not take the cheapest bidder. It could take a closer bidder if this improves the stability of the system or reduces congestion.

Another feature of the French electricity market was the development of virtual power plants, VPP for short. The European Commission judged the purchase by EDF (Electricité de France), of 34.5% of the German utility EnBW to be anti-competitive. As a remedy EDF agreed to provide competitors with generation capacity through the VPP, because the government and most of the population were opposed to breaking up the nuclear park. Detailed information on EDF's VPP is available on their website[3].

France is not the only country to have introduced VPP. They have also been introduced by Electrabel in Belgium[4] (December 2003 & May 2005), by Endesa/Iberdrola[5] in Spain from June 2007 onward and in Germany by E-ON in September 2007. These are all ascending clock

[2] http://www.rte-france.com/
[3] http://capacityauctions.edf.com/the-edf-group/capacity-auctions
[4] http://www.powerauction.com/electricity
[5] https://www.subasta-epe.com/en/public

auctions that have been designed by the same company, Power Auctions[6]. Ausubel & Milgrom (2002), Ausubel, Cramton & Milgrom (2004) and Cramton, Shoham & Steinberg (2005) explain how these auctions work and relate this to auction theory. The Danish utility Dong[7] also has also been providing VPP since the fourth quarter of 2005 but they use hybrid Anglo-Dutch auctions. One of the reasons that prompted us to study VPP was their increasingly widespread use in Europe.

Mitigating market power

From a financial point of view, VPP contracts are equivalent to a string of European call options with a physical delivery rather than a financial settlement. Theoretical work has shown that derivatives such as forward contracts and call options tend to mitigate market power. Allaz and Vila (1993) and Stoft (2002) demonstrated this for forward contracts. Willems (2005 & 2006) used the same Cournot game theoretic framework as Allaz and Vila (1993) to study the effect of VPP on the spot and forward electricity markets. In that model, two identical generators have the right to decide between themselves how many VPP to sell. Chao & Wilson (2004) and Entriken (2007) studied a similar 2-stage game but made slightly different assumptions. They showed that the equivalent of perfect competition can be achieved if buyers can acquire portfolios of VPP with many different strikes. All of these papers consider the impact of the VPP on electricity markets via a theoretical model but their underlying assumptions do not correspond to the situation in France. For example, neither the generators nor the buyers have the right to choose what capacity is offered or what the strike prices will be. So the mechanisms that they postulate may not be able to operate in the European context. This paper presents an empirical study of the impact of VPP contracts on the French electricity market.

Structure of the paper

In the next section VPP are described in more detail and we present strategies that can be used by owners of VPP to sell the power on the day-ahead market if they do not happen to need it and if the price is above the marginal cost to them. Conversely they can buy power on the day-ahead market if the price is below the VPP strike. Having outlined two possible strategies, we present evidence in the next section, to show that VPP holders are effectively using them in practice in the 7 year period from January 2002 to December 2008. It is relatively easy to demonstrate the impact of the VPP on day-ahead prices during offpeak periods because the strike price of the baseload VPP has been more stable over time, having been 8 euros per MWh for several years. As the strike price of peakload VPP has varied considerably over time from a

[6] http://www.powerauction.com/electricity

minimum of 23 euros to a maximum of 101 euros, it takes more care to show their influence. Our conclusions follow in the last section.

[7] http://www.elsamvpp.com/page.dsp?area=1435

Electricité de France's VPP contracts

Virtual power plants (VPP for short) were one of the measures brought in by the European Union to introduce competition into the French electricity market, following the purchase of 34.5% of the German utility, EnBW, by Electricité de France. EDF agreed to provide access to 6000 MW of generation capacity located in France to competitors: 5000MW in the form of VPP and 1000MW in the form of back-to-back agreements to existing cogeneration power purchase agreements. The initial agreement which ran for 5 years was extended, with minor amendments, for a further 4 years. From 2001 until the end of 2008, 30 quarterly auctions were held to sell the VPP under EU supervision.

Two types of VPP exist: base load and peak load. Both allow their owners to take power in 30 minute slices 24 hours per day, 7 days per week, during delivery periods ranging from 3 months up to 4 years. The difference between them is that the strike price of baseload VPP is set equal to the marginal cost of running a nuclear power station, whereas the strike of the peakload VPP is set to that of a thermal power plant. Figure 1 shows the evolution of the strike prices over the 30 auctions. As could be expected; the peakload strike tracks the rise and fall of the oil price. These costs are audited by the European Union.

Initially the delivery periods of these contracts were 2, 3, 6, 12, 24 and 36 months, but recently 48 month contracts were introduced. One of the strong points of VPP is that they provide guaranteed access to power at a predetermined price, which makes it possible for independent power suppliers to exist, without having to construct a power plant.

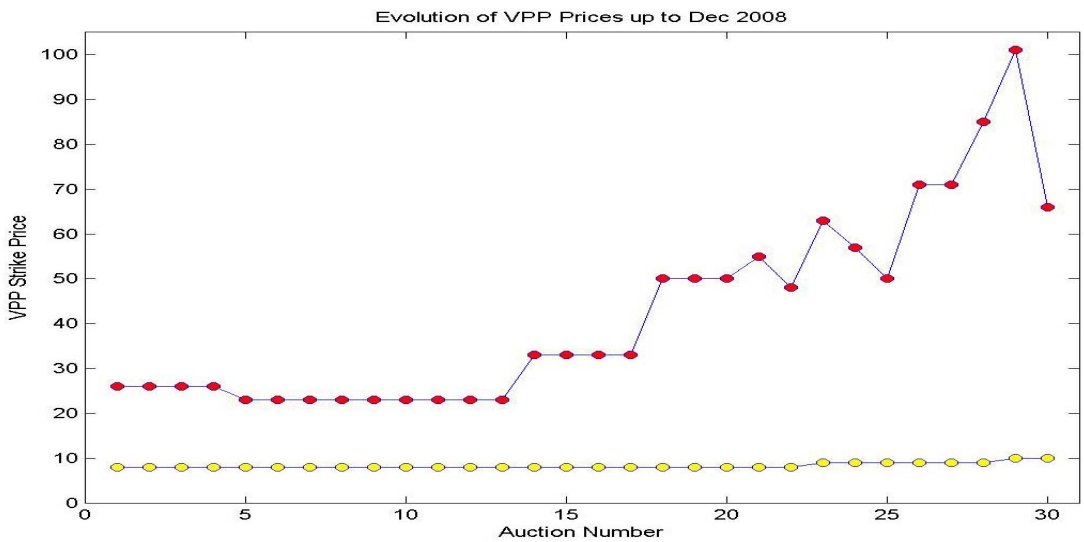

Figure 1: Strike prices of baseload and peakload VPP at the 30 auctions held from from 2001 until December 2008 with the baseload shown in yellow and the peakload in red.

VPP auctions are held every three months. Before each one EDF announces how much capacity will be provided for baseload contracts and peakload contracts, together with the current strike prices. Before each round in the ascending clock auction, the auctioneer announces the new premium for each delivery period, and bidders adjust the quantity for each delivery length, dropping the total quantity in their bid. The rules for the auctions and the results are available to the public on EDF's website.

How can these VPP influence the day-ahead market?

The first question that we address is how do optional derivative contracts with such long delivery periods influence prices one day before delivery. First we describe the strategies used by VPP holders for exercising their options, and explain how this influences the day-ahead market. Having acquired a VPP, the owner has the right to access generation capacity at any 30 minute slice at any time of day during the delivery period at the strike price. If the owner takes the power, she has the right to sell it to a third party. So if she did not need the power at a particular time it would be worthwhile selling it on the day-ahead market provided the price on that market was above the strike price. Conversely even if she does want the power, she is not obliged to get it by exercising her VPP. Nothing prevents her from buying it on the day-ahead market if the price is below the VPP strike price. The owner's strategy depends on whether she wants to use the power or not, and whether the day-ahead price is above or below the VPP strike price. Table 2 summarises these possibilities.

Table 2: Owners strategy which depends on whether the day-ahead price is above or below the VPP strike price and whether or not they actually want to use the power in a given 1 hour period

	Day-ahead price < VPP strike	Day-ahead price > VPP strike
Owner wants power	Buy power on day-ahead market	Exercise VPP
Owner does not want power	Do nothing	Sell power on day-ahead market

The next question is how to execute these strategies which are conditional on the day-ahead price. In order to buy or sell power on the day-ahead market, one must submit an offer to Powernext before closing time (11am) on the day prior to delivery. These offers are expressed as pairs of prices and quantities, starting out at the minimum of 0 euro and ending with the maximum of 3000 euro set by Powernext, and with at most 254 pairs in between. Table 3 (a)

shows an order to buy 100 MW if the price is strictly less than 8 euro which was the strike price for baseload VPP for several years. Conversely Table 3(b) shows an order to sell 100 MW if the day-ahead price is above 8 euro. By convention quantities for sale are given as negative quantities.

Table 3(a) Example of an order to buy 100 MW provided that the price is below 8 euros

Price	0	7.99	8.00	3000.00
Quantity	100	100	0	0

Table 3(b) Example of an order to sell 100 MW provided that the price is above 8 euros

Price	0	8.00	8.01	3000.00
Quantity	0	0	-100	-100

At 11 am each day, Powernext aggregates the offers to buy and to sell and transmits this information to Nordpool which computes the fixing (i.e. the price and volume where the two curves intersect). Powernext notifies bidders by about 11.15am, that is, well before they have to advise EDF whether they wish to take the power or not. So from the timing point of view, these strategies can be put into practice. In the next section we present evidence to show that VPP owners are effectively using them.

Impact of VPP on Day-Ahead Market

The impact of the VPP on the day-ahead prices is most obvious in offpeak periods such as in the early morning hours. Figure 2 shows the day-ahead prices at 4H (i.e. from 3am to 3.59am) throughout 2002 (above) and 2006 (below). During 2002 prices rarely dropped below the baseload strike price of 8 euros per MWh. The overall rise in prices by 2006 means that the impact of the VPP is less obvious in 2006, (Fig 2) but it can be seen when the volumes transacted are plotted as a function of the day-ahead price. (Figure 3) In both cases peaks just above and below the baseload strike price dominate the two figures. This is true for other times in the early morning and for the other years too. This clearly demonstrates the continuing impact of the VPP during offpeak periods.

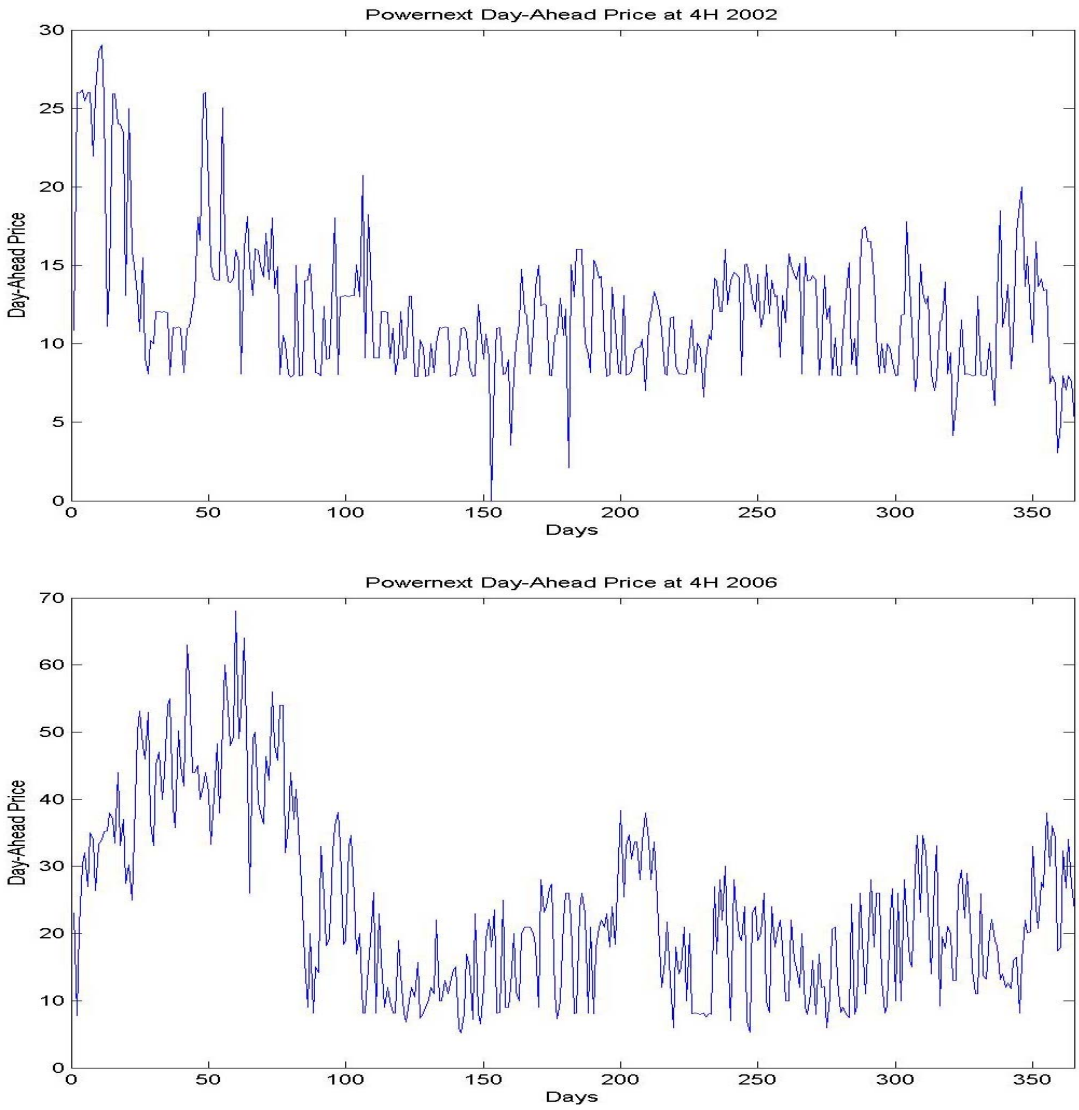

Figure 2: Powernext day-ahead prices at 4H (i.e. from 3am until 3.59am) in 2002 (above) and 2006 (below). Note how the prices hover around 8 euros (baseload strike) during 2002.

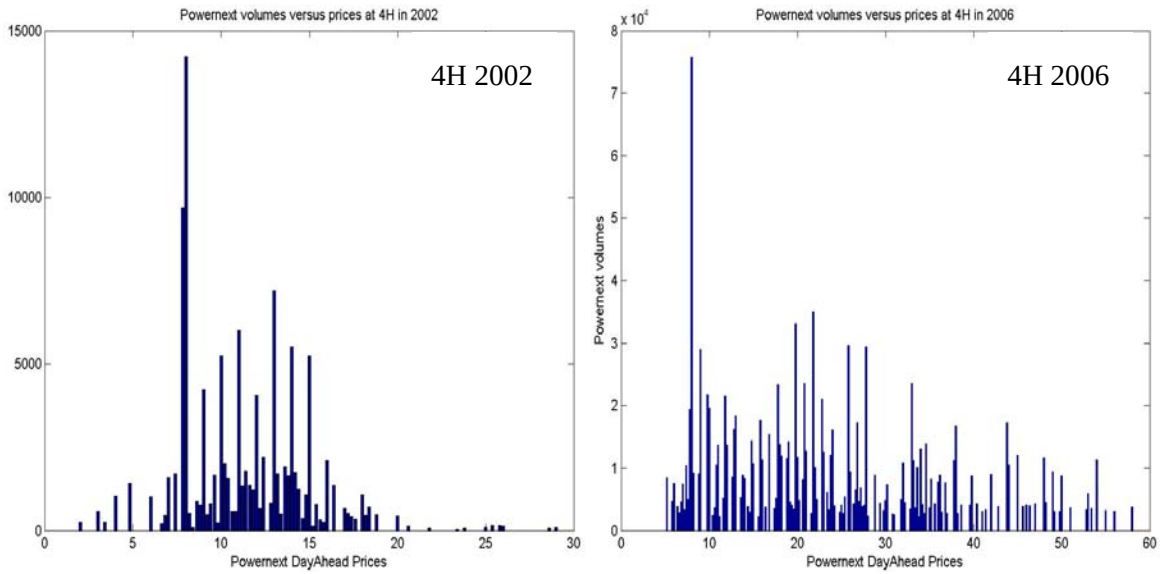

Figure 3: Volumes transacted at 4H in 2002 (left) and 2006 (right). The peaks coincide with the baseload strike of 8 euros. This demonstrates that the VPP are having a marked influence on day-ahead prices.

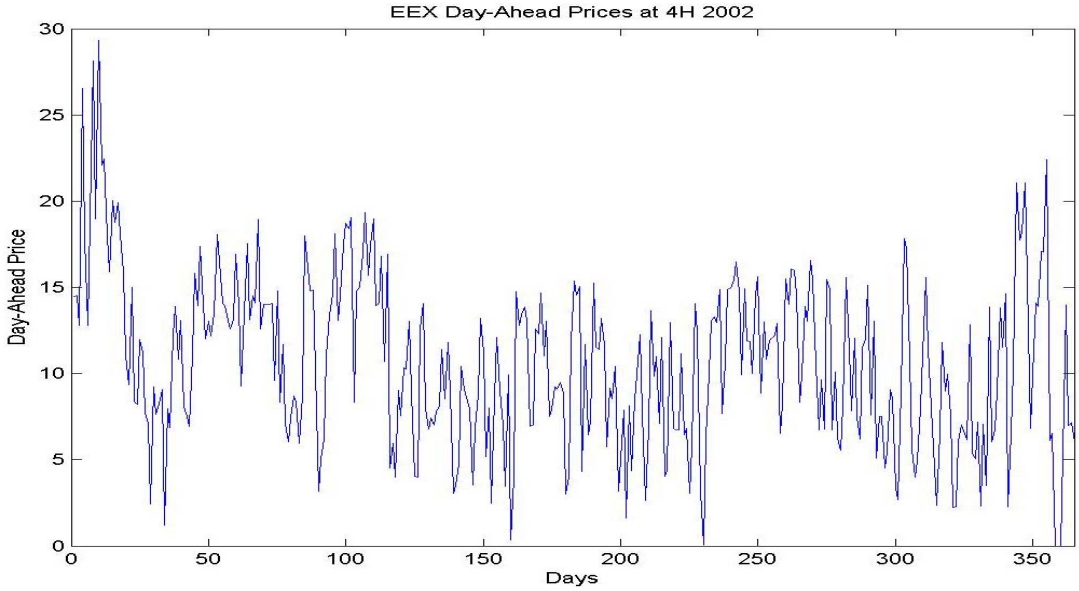

Figure 4: EEX day-ahead prices at 4H (i.e. from 3am until 3.59am) in 2002. In contrast to Powernext these prices do not hover around the baseload strike of 8 euros

Next we ask whether the impact of the VPP is specific to France. To demonstrate that it is, Figure 4 shows the day-ahead prices on the German exchange EEX at 4H during 2002. In contrast to Figure 2 (above) day-ahead prices in Germany do not show the characteristic “hair cut”.

Impact of Peakload VPP

Having demonstrated the effect of baseload VPP on day-ahead prices, we now turn our attention to peakload VPP. To do this we need to know how much capacity was available at each strike price at any given point in time. Table 4 given in the Appendix lists the volumes for each delivery period ranging from 3 months through to 36 months, for the first 30 auctions, together with the strike price. The columns on the left correspond to the standard delivery periods (starting January, April, July or December) whereas those on the right correspond to delivery periods starting in November. These are only auctioned in June and September. The June auction consists of four sub-auctions: two for peak load and two for base load, one starting in July and the other starting at the beginning of winter. This is why some of the auction numbers are listed twice (e.g. 8, 12). The first auction was in autumn 2001, with delivery starting on 1 January 2002 (i.e. just after the creation of Powernext). The delivery period for the 30th auction continues until the end of 2011, that is, 10 years after the VPP started. Looking at the Table it is surprising how little capacity was sold for longer deliveries, particularly in 2002.

Figure 5 shows the quantity of VPP (in MWh) that was available for each strike price as a function of time. The blue, black and red curves stand out from the others: they correspond to strike prices of 26 euros, 23 euros and 33 euros respectively. This is because the strike was the same for several successive auctions.

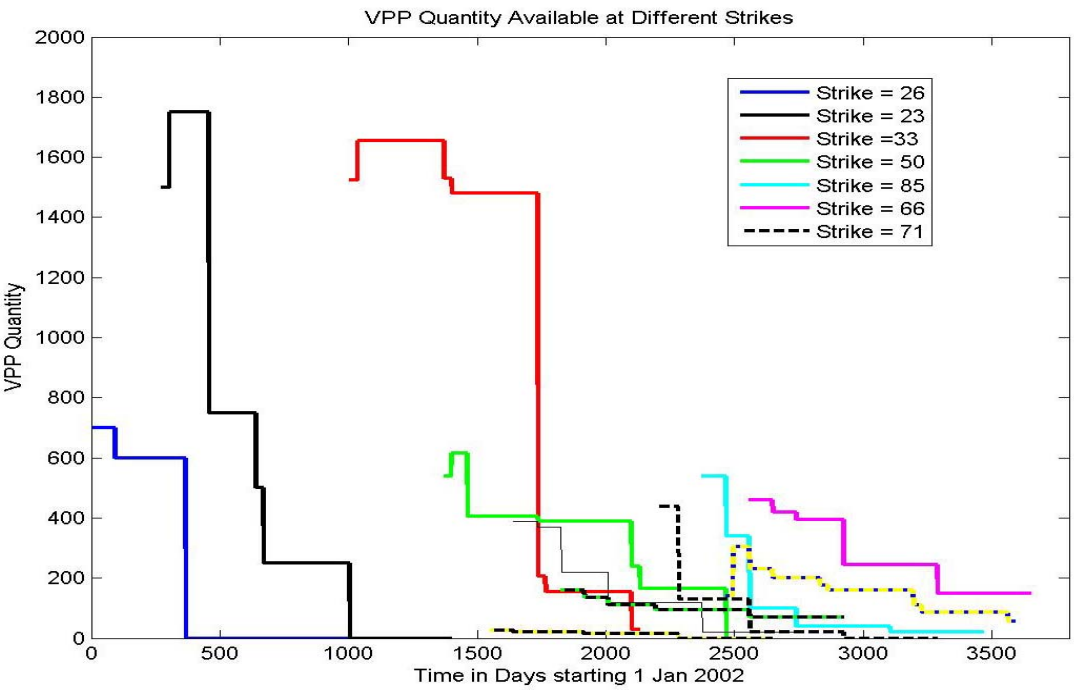

Figure 5: The quantity of electricity available via peakload VPP for each strike price as a function of time over the 10 year period from 1 January 2002 until the end of 2011, (i.e. as a result of the first 30 auctions). During the first half of the period, there were only three strike prices (26€, 23€ and 33€), respectively the blue black and red curves.

As the strike price varied less in early auctions it should be easier to discern the effect of the peak load VPP in the first 4 or 5 years. If the VPP effect prices as was described in the previous section, there should be peaks at the following prices:

- 26 euro during 2002
- 23 euro (but not 26 euro) in 2004)
- 23 euro and 33 euro in 2005

We now test these hypotheses by plotting the volumes transacted at 16H in 2002 (Fig 6), then 16H in 2004 and 2005 (Fig 7) and finally 16H in 2008 (Fig 8). As expected there is a high peak at 26 euro corresponding to the strike price current at that time. We were surprised to see a small peak at the base load strike, 8 euro. As can be seen from the right hand side of Fig 6 these low prices occurred mainly on Sundays.

The peak in 2004 (Fig 7 on left) occurs at 23 euro (and not 26 euro as in Fig 6) because the strike had changed. In 2005, the VPP that were active had two strikes: 23 euro and 33 euro. Peaks occur at both values. Several peaks are apparent in Fig 8 for 2008: 33€, 50€, 61€, 64€ and 71€, corresponding to different VPP.

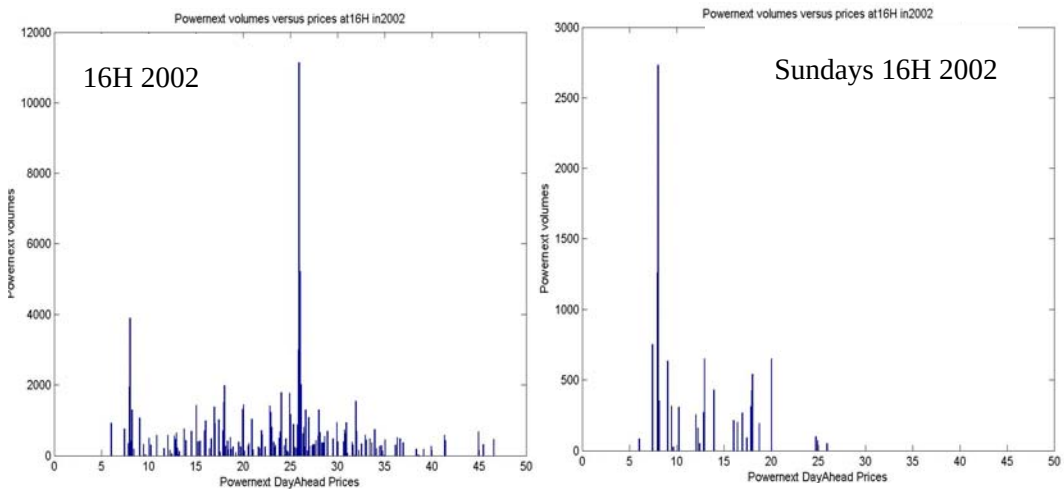

Figure 6: Volumes transacted at 16H in 2002 all days of the week (left) and on Sundays (right). As expected, the highest peak in the figure on the left coincides with the peak load strike at that time, 26 euro. Note the presence of a small peak at 8 euro, corresponding to the baseload strike. As can be seen from the figure on the right, this corresponds to day-ahead prices on Sundays.

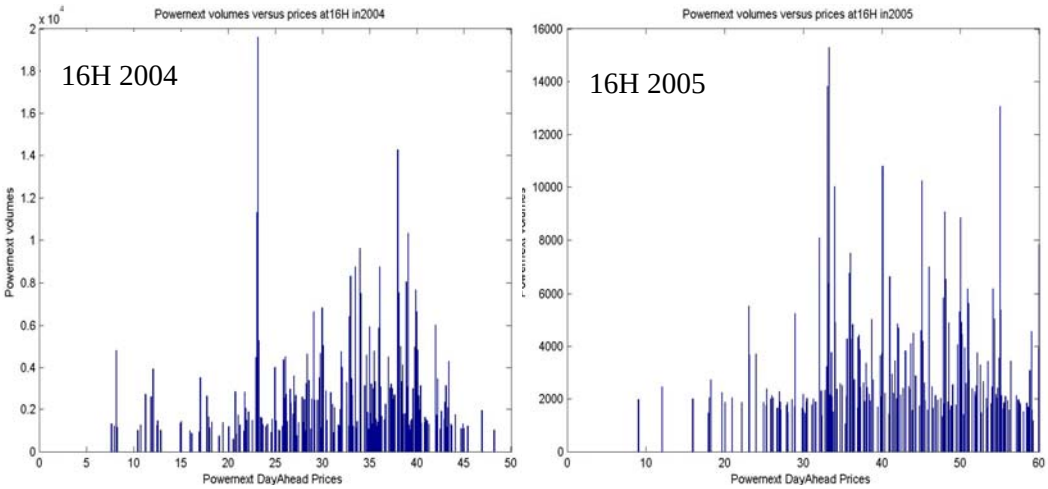

Figure 7: Volumes transacted at 16H in 2004 (left) and 2005 (right). As expected, the peaks coincide with the peak load strike at that time, respectively 23 euro in 2004, and 23 and 33 euro in 2005. Note the absence of a peak at 26 euro in the left figure because no VPP with this strike were still active in 2004.

To sum up, the peaks seen in Figs 3, 6, 7 and 8 correspond precisely to VPP that were active at the time. We also noted that the peak at 26 euro disappeared when the VPP with this strike were no longer active. The presence (and absence) of these peaks demonstrates that VPP holders are effectively using the strategy outlined in the previous section: namely selling power on the exchange when the day-ahead price was above the VPP strike and conversely buying power on the exchange when the day-ahead price was below the strike of their VPP.

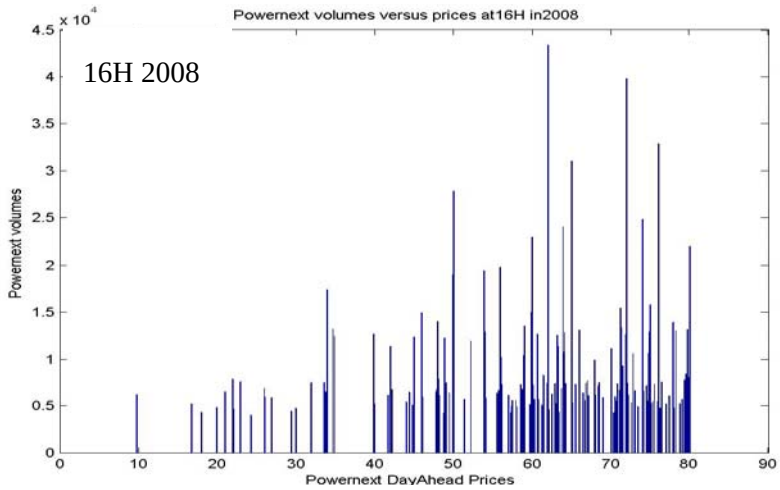

Figure 8: Volumes transacted at 16H in 2008. Several peaks can be seen: 33 €, 50 €, 61 €, 64 € and 71 €. These correspond to VPP that were active in 2008.

Conclusions

This study focuses on two of the key components in the French electricity market: the day-ahead auction market which fixes the wholesale price of electricity one day before delivery, and VPP option contracts that are auctioned by the historic operator, EDF, every three months. Holders of VPP have the right (but no obligation) to access to electric power at a predetermined price per MWh, called the strike price, after having paid an upfront premium fixed at the auction. Two types of VPP exist: base load and peak load. Both allow their owners to take power in 30 minute slices 24 hours per day, 7 days per week. The difference between them is that the strike price of base load VPP is set equal to the marginal cost of running a nuclear power station, whereas the strike of the peak load VPP is set to that of a thermal power plant. Delivery periods range 3 months, 6 months up to 4 years (Table 4). Theoretical work has shown that derivative contracts such as VPP should mitigate market power.

In this paper we argue that the structure of the market allows holders of VPP to exercise strategies of selling power on the exchange when the day-ahead price is above the VPP strike (if they do not need the power) and conversely of buying power on the exchange when the day-ahead price is below the strike of their VPP (if they do want power). The question is “Are they actually doing this”? By documenting the strike prices of VPP that were active at different times (Fig 5) and by carefully examining structure of day-ahead prices we demonstrate that they clearly are doing this. The peaks seen in Figs 3, 6, 7 and 8 correspond precisely to the strike price of VPP that were active at the time. We also noted that the peak at 26 euro disappeared once the VPP with this strike were no longer active. The presence and absence of peaks coinciding with active VPP contracts proves that these strategies are being used.

Having established that these strategies are being used the next question is “What overall effect does this have on the efficiency of the wholesale electricity market?” It is clear that the existence of VPP has made it possible for new players (such as Poweo, DirectEnergy etc) to enter the retail sector without having to construct a power plant. The only alternative would have been to dismantle the historic operator, EDF, and after Chernobyl most French people would prefer to avoid that. Further empirical work is planned on the impact of VPP on the efficiency of the wholesale market. Although VPP were first introduced in France they have recently been introduced in several other countries (Belgium, Spain, Germany and Denmark). This makes it important to understand their impact on other sectors of the wholesale electricity market, notably the day-ahead market.

References

Allaz B and Vila J L (1993) Cournot Competition, Forward %Markets and Efficiency, J Economic Theory, 59, pp1-16

Ausubel L M , P Cramton & P R Milgrom (2006) The Clock-Proxy Auction: A Practical Combinatorial Design. in *Combinatorial Auctions*, (eds) P Cramton , Y Shoham & R Steinberg, MIT Press pp115-138

Ausubel L M & P R Milgrom (2002) Ascending Auctions with Package Bidding, Frontiers of Theoretical Economics, Vol 1 N° 1, 42pp available from

http://www.bepress.com/bejte/frontiers/

Chao H-P & R Wilson (2004) Resource Adequacy & Market power Mitigation via Option Contracts, EPRI Working Paper 40pp

Cramton P, Y Shoham & R Steinberg (2006) Introduction to Combinatorial Auctions, in *Combinatorial Auctions*, (eds) P Cramton , Y Shoham & R Steinberg ,MIT Press pp1-14

Entriken R (2007) Elementary Analysis of Energy Options for Resource Adequacy, Proceedings of 40th Hawai International Conference on System Sciences,

Stoft S (2002) Power System Economics: Designing Markets for Electricity, IEEE, 460pp

Willems B (2005) Cournot Competition, Financial Option Markets and Efficiency, Centre for the study of Energy Markets, Working paper 139, 27pp available at

http://www.ucei.berkeley.edu/PDF/csemwp139.pdf

Willems B (2006) Virtual Divestitures, Will they make a difference? Cournot Competition, Financial Option Markets and Efficiency, Working paper, European University Institute (Italy), available at http://repositories.cdlib.org/ucei/csem/CSEMWP-150/

Appendix: Volumes pf peakload VPP

Table 4: Peakload VPP volumes sold by auction at the first 30 quarterly auctions. In addition to the volumes for each delivery period (3 months, ... 36 months), the starting date and the strike price are given for each auction. The columns on the left correspond to the normal delivery period; those on the left to deliveries starting in November rather than October. Once a year in June, two sets of delivery dates are proposed, starting in July or in October. This explains why some of the auction numbers (e.g. 8, 12, ;...) appear twice .

			PEAKLOAD									
Auction N°	Strike	Start Date	3 Months	6 Months	12 Months	24 Months	36 Months	Start Date	2 Months	12 Months	24 Months	36 Months
			Normal delivery period						November			
1	26,00	01/01/02	25	0	150	0	0	01/11/01	98			
2	26,00	01/01/02	11	90	0	0	0					
3	26,00	01/04/02	383	50	135	0	0					
4	26,00	01/07/02	75	5	100	0	0					
5	23,00	01/10/02	0	100	25	25	0	01/11/02	0	25	0	0
6	23,00	01/01/03	245	0	85	0	0					
7	23,00	01/04/03	50	100	225	100	0					
8	23,00	01/07/03	296	50	0	0	0					
8	23,00	01/10/03	25	50	125	0	0	01/11/03		0	0	0
9	23,00	01/10/03	0	25	160	0	0	01/11/03	0	37	4	0
10	23,00	01/01/04	0	0	25	42	0					
11	23,00	01/04/04	65	75	175	0	0					
12	23,00	01/07/04	30	0	0	75	75					
12	23,00	01/10/04	10	0	0	0	0	01/11/04		0	0	0
13	33,00	01/10/04	0	0	25	255	25	01/11/04	0	10	10	6
14	33,00	01/01/05	35	80	25	0	11					
15	33,00	01/04/05	144	35	0	80	10					
16	33,00	01/07/05	0	50	75	0	4					
16	33,00	01/10/05	0	0	0	0	0			0	10	5

PEAKLOAD

Auction N°	Strike	Start Date	3 Months	6 Months	12 Months	24 Months	36 Months	Start Date	2 Months	12 Months	24 Months	36 Months
			Normal delivery period						November			
17	50,00	01/10/05	70	0	5	50	55	01/11/05	0	0	25	0
18	50,00	01/01/06	25	25	50	0	105					
19	55,00	01/04/06	5	0	5	15	0					
20	48,00	01/07/06	10	75	50	50	10					
20	48,00	01/10/06	0	0	20	75	0	01/11/06		0	0	0
21	63,00	01/10/06	45	0	50	60	10	01/11/06	0	0	10	10
22	57,00	01/01/07	25	25	15	25	70					
23	50,00	01/04/07	0	55	0	25	0					
24	61,00	01/07/07	50	0	25	0	0					
24	61,00	01/10/07	55	0	10	30	20	01/11/07		0	0	6
25	64,00	01/10/07	50	90	25	0	0	01/11/07	65	0	0	0
26	71,00	01/01/08	154	0	55	10	0					
27	71,00	01/04/08	71	40	15	5	0					
28	85,00	01/07/08	100	120	30	10	10					
28	85,00	01/10/08	10	40	0	0	0	01/11/08		20	0	0
29	101,00	01/10/08	5	30	25	50	30	01/11/08	68	15	25	55
30	66,00	01/01/09	40	25	149	95	150					