Coordination Issues on just-in time market:
Wind power hazard on the electricity market

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Abstract

The wind power integration into electricity system has been realised through the implementation of a special contractual framework called the Feed-in contract. This contract ensures that each electricity quantity produced from wind mills has to be purchased at a cost-plus fixed price that is guaranteed on long term. The feed-in contract is strongly incomplete since it guarantees a fixed price but does not bring features to manage the huge coordination issues raised from the volume hazard of wind power. In particular wind power output is introduced in just in time electricity market where both demand and supply varies whereas the electricity is not storable. From this point, a huge coordination issue emerges and has to be solved both technically and contractually since the electricity system is subject to this double optimisation.

We analyse both kinds of coordination: the physical and transactional one. Technically, we show that tools have been developed to match an intermittent supply to a variable demand in a no-storable system either under a vertically integrated monopoly or under a competitive electricity market. From contractual point of view, the problem becomes wider since the organisation of electricity markets has to be taking into account. Two major issues emerge: (i) the contract design by itself which has to respond to the question: who will absorb the wind energy and how to do it, and (ii) the payment settlement. The issue is bi-dimensional: this is first a contractual measurement issue and an organisational issue (decision-taking).

We conclude that the volume hazard of the wind power has been removed by short term coordination mechanisms through the development of contractual relationships between the TSO and the electricity supplier. By assuring to the electricity supplier that he will receive a fixed amount of wind power each day, the TSO looks like a wizard smoothing the consequences of the wind power hazard. The incompleteness of the feed-in contract is removed by short term coordination mechanisms which could be differently designed according to the TSO choice.

Introduction

To develop wind power into electricity markets is basically attractive since this is a renewable energy which does not create greenhouse gas. Its integration enables to act against the climate change and to foster the sustainable development. Since the production costs of wind power are quite higher than those from conventional units, the integration of wind energy into competitive electricity markets has been pushed by a contractual framework of a certain type: economic mechanisms that could be either quantity-based (quotas) or price-based (feed-in tariff) have been developed. Historically, pioneer countries in term of renewable energy development (Denmark, Germany and Spain) have chosen feed-in tariff mechanisms. The feed-in contract stipulates that the produced renewable energy has to be purchased by an obligated party. The contractual dimensions of the feed-in contract create incentives and hinder any opportunistic behaviour; nonetheless this contract is basically incomplete: although it fixes prices on long term, it set aside the volume dimension: wind energy is strongly variable and weakly predictable.

On just in time electricity system the feed-in contract requires that new coordination mechanisms have to be designed to manage the wind power in a real-time. Electricity markets are designed to supply electricity optimally from a technical and organisational point of view. This double function requires that the coordination mechanisms to manage the volume hazard in a real time have to be both technical and organisational.

The main focus of this article is to demonstrate the incompleteness of the feed-in contract and how this incompleteness is fulfilled through technical and organisational mechanisms. The first part of this article concerns the assessment of the feed-in tariff as an incomplete contract. This contract is analysed as both an administered contract [Goldberg, 1976] and a procurement one [Joskow, 1986]. Two dimensions are deeply analysed: the price and volume dimensions of the feed-in contract of wind energy. We show that this contract is strongly incomplete since it creates a volume hazard on just-in time system. Coordination issues emerge. The second part of this article explains how this coordination issue could be solved through short-term mechanisms implemented. We focus firstly on physical coordination since electricity markets are constrained by physical properties. Secondly, we show that the coordination mechanisms to manage the volume hazard bring any solution to the organisational payment settlement issues. In order to do the payment settlement one main actor, the Transmission System Operator, develops its own tool.

1. Incompleteness of the Feed-In Contract: Price versus Volume Issues

The integration of wind power has been followed by the implementation of support mechanisms in order to help wind power producers to overcome the entry barriers of the competitive electricity markets. We focus here on feed-in contract. This type of mechanism binds the wind power producer to an obligated party that has to purchase all electricity quantity produced by the wind power producer. This feed-in contract involves price and volume dimensions. We firstly analyse the price dimension as a long term guarantee by fixed price and show how it could be powerful. Secondly, we interest on the volume dimension. We shed on light that the volume dimension in this feed-in contract remains fully hazardous. The result of our analysis concerns the huge coordination issues raised by the feed-in contract. By this way, we qualify the feed-in contract as incomplete one.

1.1 Price Dimension: Long term guarantee by fixed price

The feed-in contract stipulates that each electricity quantity produced by a wind power producer has to be purchased by the obligated party at a fixed price. That means that each kWh produced by a wind mill and fed into the electricity grid is consumed and purchased by the supplier at a fixed price. The wind energy takes priority on the electricity grid towards all other forms of energy.

Price features in the feed-in contract

In general the fixed price is set in a "cost-plus" way. Nonetheless, at the beginning of the wind power development in the US, the price was set at the "avoided-costs" of the utility obliged to purchase this electricity. Nowadays in most countries applying the feed-in contract, the price is a cost plus basis depending on the specific characteristics of the supported energy: for wind power in Germany the fixed price depends on the average wind speed at the individual plant size [Langniss, 2003].

The feed-in contract is an administered contract since this is the regulator who decides the terms of contract. The feed-in contract takes place in wider dimension of Renewable Energy Regulation. From the European point of view, it depends on signals sent by the European Union through directives and laws. Since the feed in contract is an administered contract, we easily understand that the feed-in contract is set for more than 20 years. The lifetime of a wind mill is about 15 to 20 years. By this way, the fixed price for the wind energy production is guaranteed for life. Nonetheless, in some countries a yearly reduced price is applied[1] but still valid for 20 years.

The feed-in contract guarantees a fixed price set on 'cost-plus' basis for the lifetime of the wind mills. Each produced and fed into the grid electricity, whenever the producer produces is purchased at a fixed price. This long term price guarantee brings therefore strongly incentives.

[1] For more information on the design of the feed-in contract, please see [Langniss, 2003] and [Dinica, 2003]

Incentive Nature of the feed-in contract

Feed-in contract creates strong incentives by the long term guaranteed fixed price. The incentives concerns three dimensions. First, the feed-in tariff by setting a fixed price along lifetime of the wind mills creates a revenue warranty. This represents a strong incentive to invest in wind mills since the investor knows exactly that along the lifetime of the wind mills he will receive a fixed price for production. The long term guaranteed fixed price erases price risk and by this way rubs out the price uncertainty. Knowing that the fixed price is set on a cost-plus basis, the investor faces no uncertainties for his revenue. As the investor could forecast for all the life on the wind mills, he is strongly incited to invest in new wind farms. Secondly, as the price is guaranteed for the production, the feed-in tariff creates strong incentive to really produce. As he can produce only when the wind blows, he is strongly incited to capture the maximum of the energy of the wind at each moment. More the wind power producer will produce, more he will earn money and above all he has a strong interest to always produce as soon as possible given weather conditions. Thirdly, the long term guaranteed price offers a strong incentive to minimize costs of production. Since the wind power producer knows in advance that each kWh produced will be purchased at a specific fixed price for life, he has interest to lower a maximum production costs in order to maximize the profit he could earn.

These three kinds of incentives allow us to conclude that the feed-in contract is powerful. Moreover, since the fixed price is guaranteed for life at a cost plus amount, we conclude that this contract rubs out the price hazard. This conclusion fosters the powerfulness of incentives created by the feed-in contract. Another dimension to analyse when designing a contract concerns the opportunistic behaviour that could appear.

Opportunism

The feed-in contract does not create opportunistic behaviour from contractors. The wind power production depends only on weather conditions, which could not be manipulated by nature. To transform wind into electricity, mechanical mills are used. The wind power producer as any other party involved in the feed-in tariff could not act on, first, weather conditions and, second, on mechanical system and mills that allow the transformation of aerodynamics strengths of wind into electrical flow. Since there is no means to control the weather conditions, the wind power producer, by capturing wind energy, could just produce. He has no control on wind energy he could capture. By this way, we can conclude that no opportunistic behaviour could appear. The wind power producers has to maximize the capture of the wind through mechanical processes and other participants of the feed-in contracts could just accept him and pay for it. No other way is possible.

To summarise, the feed-in contract ensures that each electricity quantity produced by a wind mills has to be purchased by the obligated party at a cost-plus fixed price. This creates three kinds of powerful incentives: (i) investment, (ii) production and cost-minimization incentives. No opportunistic behaviour could appear. From the price dimension, the feed-in contracts brings warranty of a long term fixed price and seems to be efficient.

1.2 Volume Dimension: Strong hazard

By reading the price dimension of the feed-in contract, one may find that there is no problem. The wind power producer receives incentives to produce as soon as the wind blow and is paid a fixed price which gets rid of the price hazard. No opportunistic behaviour could be involved since this is a natural risk. This natural risk, as being natural, is a volume issue. Concerning the volume dimension, we have to keep in mind that the wind power is strongly variable and weakly predictable. This represents a volume hazard. But it is a volume hazard introduced in just-in time market, namely the electricity market.

Assessment of the Wind Power Hazard

A wind mills produces electricity only when the wind blows. The produced electricity depends on the wind speed at the individual power plant site. The wind speed is rarely constant over a specified time period. The wind could blow in gusts at a moment then could cool down. That means that the energy issued from wind is similarly variable. So the natural risk of weather conditions makes the wind energy variable. More than variable, the wind power production is weakly predictable. Weather conditions are really difficult to forecast, as we can seen each day with our own weather forecasts. In fact, we can never know when the wind will blow and to what extent it will do it. It could be possible to have a light wind during the day, and before the sunset the wind can blow in gusts. As the wind energy is transformed by only mechanical mechanisms, the wind power output is similarly strongly variable and weakly predictable. We consider the wind power output as an intermittent energy or hazardous one. The natural risk due to wind implies that the wind power output is subjected to production hazard which is only a volume hazard. The difficulty to accurately forecast the wind energy production creates a strong volume risk or a strong volume hazard. By now we consider the volume hazard as the "wind power hazard" since it is here an intrinsic characteristic of wind energy.

Price incentives and Wind Power Hazard

The feed-in contract has a strong price dimension. The fixed guaranteed price rubs out the price hazard. Since the price is known ex-ante and that each electricity quantity, whenever produces, has to be purchased, the wind power producer has a strong incentive to always produce as soon as possible given weather conditions. By doing that, the wind power producer transfers at the same time all electricity quantity but the entire wind power hazard.

Furthermore, there is strong imperfect information since the wind power producer does not know in advance what electricity quantity he will produce. By this way, it could be difficult to assess in advance how much electricity quantity the wind power producer will therefore produce and so how much he will receive from the sell of his wind power output. To assess the future possible revenue, the investor has to forecast yearly wind production since the site implementation of wind farms is made on windy areas. The wind power hazard does not play any role on the other incentives. In fact, the wind power hazard as being a volume hazard is important because it creates an incomplete information area since the produced volume is uncertain.

Given these two information, the wind power producer has strong interest to always produce and to better capture each day the wind energy to transform it into electricity.

Wind Power Hazard on Electricity market

When integrating wind power into electricity markets, electrical specificities have to be explained. As we have shown, the wind power bears a strong volume issue, since the production depends on weather conditions that could not be really accurate in advance. The uncertainty related to the quantity of wind power output disappears at the last moment, which is at the delivery time. The first issue concerning the integration of wind power into electricity system concerns the physical constraints. First, the electricity cannot be economically stored [Hunt, 2002]. All electricity has to be generated when it is needed. In our case, that means that the intermittent wind power generation has to be introduced in a system without storage. The second important constraint for our purpose is that the electricity travels at the speed of light so that at each second output has to be precisely matched to use [Hunt, 2002]. If this is not, the entire system could collapse and blackouts could take place. All electricity produced by wind mills and subject to the feed-in contract has to be consumed exactly when it is produced. This raises our interest for the feed-in contract volume dimension. The wind power subject to strong volume hazard has to be introduced in just in time market strongly constrained by physical laws where production has to be entirely consumed exactly when it is produced. Otherwise the whole system collapses.

The electricity system bears other strong constraints as that electricity takes the patch of least resistance and that the transmission of power over the network is subject to a complex series of physical interactions, but these conditions are not on first importance for our case study. The other interesting feature of the electricity system concerns the variation of demand. In fact, the demand varies all along the day, the season and the year. The electricity consumption is done "at will". When a consumer needs electricity, he does not think on prices or availability of generation units. When you want to switch on the light, you need at this moment electricity. This kind of behaviour when applying to all consumers explains that the demand is hazardous too. We know that usually in European countries, use of electricity is low at night and rises in the morning, usually reaching a peak at the end of the afternoon. On electricity markets demand is particularly weakly predictable and could change in few minutes, so that a generator is obliged to produce to maintain the system since this is just in time.

The issues come from the specificities of the electricity market. Constrained by strong physical properties we explained, the electricity system is qualified as just-in time market where any imbalance between production and consumption could destabilize the whole system and destroy it. Due to physical laws, the system has to be balanced at each second. The willingness to integrate into the electricity system wind power units means the following requirements: we have to integrate a hazardous energy into a system where at each second the supply has to match a hazardous demand. The feed-in tariff sets aside the volume hazard. But, as we have seen, the volume hazard faces the consumption hazard whereas the electricity system is strongly constrained by physical properties.

As the electricity is not storable, this situation leads to a huge coordination issue that is not solved even discussed in the feed-in contract. In order to manage this huge issue on coordination, coordination mechanisms have to be designed in order to manage the volume hazard in real-time

2. Designing coordination mechanisms to manage the volume hazard in a real-time

Coordination mechanisms have to be designed to manage the volume hazard of the wind power into the electricity system. The electricity system aims at optimising the electricity supply both technically and contractually. The technical coordination means that the physical constraints of the electricity have to be exactly respected. In other words, technically the entire production has to match the consumption at each second. The organisational coordination means that the transactions made on the electricity market have to be respected: the seller has to deliver the consumer with the traded quantity at the traded price. The payment settlement has to be done. This section shed the light on both the technical and organisational coordination mechanisms that have been developed for the management of volume hazard in a real-time. One thing to keep in mind is that the feed-in contract is mute on the volume hazard management.

2.1 Physical Coordination on electricity markets

To realise the physical coordination on electricity market, the balance between production and consumption have to be precisely matched. Any imbalance could be fatal. As the consumption is strongly hazardous too, since it could vary all along day, month, season and year, the production is the adjustment variable of the consumption: the production must vary at exactly the same time of the consumption. From the technical point of view, neither the wind power producer since he has the priority on electricity grids (since all his production is accepted on the network) nor the final consumer can deal with the physical coordination which more particularly concerns the active market agents.

One technical way is to improve the forecasting tools in order to better know the possible production of wind mills. If the forecasted production could be more accurate one day-ahead, so it could possible for the wind power producer and the electricity supplier to act on the electricity market, since the imbalances between forecasting electricity and really produced electricity could be know in advance. The major problem with wind power is that the production is widely variable and weakly predictable. Improving the forecasting tools is the way to handle the intermittency issues of wind power. Nonetheless, the problem of forecasting tools improvement covers a technical dimension, since it does not depend on the contractual dimension of the feed-in tariff. This is furthermore an R&D issues since the development of accurate forecasting tools depends on R&D expenditure.

From the technical optimisation constraint of the electricity market, coordination finds a solution. We firstly analysed how a vertically integrated monopoly managed the volume hazard of wind energy and secondly how the new competitive electricity market manages it.

Coordination under vertically integrated monopoly

The physical functions of electricity system concern the generation of electricity, the transmission of power over networks, the local distribution system and the retailing. Until mid-nineties the electricity system was organised in general as a vertically integrated company which had the monopoly on specific area (country as in Europe or local area in the US). A single company in each area typically produced, transported and retailed the electricity and it operated the whole system. This company could be government-owned company or private-owned one[2]. Under this type of organisation, the mechanisms to manage the wind power hazard were technically done since the single company served all final consumers. The company owned enough generation capacities to match at each second the whole centralised demand. As the vertically integrated company operated the system too, it had to deal with the demand hazard. For managing it, the company had different types of production technologies among which some generation units were fully dispatchable: generation units could be started up/stopped down very quickly in order to respond to a demand variation. The vertically integrated company took profit for its quite "complete information" since it owned all generation units and all final consumers and since it operated the transmission system too. We called these generation units the "dispatchable generation".

For managing the volume hazard of wind power into this kind of organisation is derived from the management of the demand hazard. From a technical point of view, both demand and wind power hazards are volume hazard. As the single company holds complete information concerning the production, transmission and distribution of electricity on the grid, it considers the wind power hazard as a demand hazard since the demand varies and finally the wind power output varies too even if quite differently than the demand. The vertically integrated company has to aggregate the volume hazard of the wind power production to the volume hazard of the demand. By doing that, the vertically integrated company has to set going the dispatchable generation when the wind power fluctuates. In fact, the single company is used to aggregate all volume hazards into only one and to manage the latter with its dispatchable generation units. From the technical point of view, the single company used dispatchable generation units to balance supply and demand. This is naturally possible if the wind power units do not represent the entire production plant. Wind power generation needs dispatchable generation like gas turbine units whose output does not depend on hazardous conditions. This kind of management of the volume hazard of power is only possible if a vertically integrated company has the monopoly on a specific area since this is complete information which allows it to manage all volume hazards. But for more than ten years the electricity system moved from a vertically integrated organisation to an

[2] Many papers and articles deal with the existence of vertically integrated company in electricity. For further information, you could refer to [Hunt, 2002]

unbundled one where competition can play a role. In that case, another mechanism has to be applied.

Under competitive electricity market

Competition could be introduced in generation and retailing, since transmission and distribution tasks are natural monopoly. Electricity market reforms could be quite different into their designs[3]. With the introduction of competition into generation and retailing, that means that: independent power generators might not own other technology generation units, consumers could change their electricity supplier and above all that there is no link between the production and the consumption. The industry is unbundled. If the industry is unbundled, that strongly means that conversely to the vertically integrated monopoly the information is not complete and perfect.

As explained above the management of volume hazards of both wind power and consumption has to be solved by new coordination mechanisms. There are different power producers that own diverse generation units and technologies and they are all competitive. Consumers can change from electricity suppliers and increase or decrease their consumption at will. In spite of this new organisation, all supply have to meet load to hinder the system collapse.

Because of the physical laws, the transmission system is quite fragile so that electric flows have to be managed on a continuous real-time basis. [Hunt, 2002] specifies that "*the transmission system requires the constant attention of a system operator to integrate the operation of the generating plants with the transmission system on a second by second basis*". The Transmission System Operator (TSO) is the flow-specialised authority and has to balance the whole system technically at each second. Since consumer usages are not controlled, the generation units have to be controlled to meet the load at all times. The TSO main function is to maintain the stability of the whole system by coordinating electrical flows so that supply matches demand at each second taking into account all physical electrical laws.

Both wind power and demand hazard still exists in this new electricity system. But as information is not complete, new coordination mechanisms have to be found. As being the coordinator of the electrical flows, the TSO receives information from the entire system so that he is the more qualified actor of the system to manage the volume hazards. Technical coordination is done in this case by applying the same idea that the one developed in the vertically integrated monopoly case. To respond to any imbalance coming from demand hazard or

[3] For further information on market designs, please see [Wilson, 2002], [Glachant, 2002], [Staropoli, 2001], [Perez, 2002], [Stoft, 2002] and [Hunt, 2002]

production volume hazard, TSO runs a “balancing mechanism” that allows him to match supply with demand. These mechanisms could be either a balancing market or balancing mechanisms[4]. The principle is to counter-act extremely rapidly any volume variations related to the production or consumption. In order to apply it, dispatchable generation units have to stand by. These units could start and stop extremely rapidly. The TSO knows exactly if he need to start units because there is an increase of demand or if he has to stop units because there is not enough consumption through technical information index: the frequency of the system. When the system is in balance (all demand corresponds exactly to the all supply), the frequency is stable at 50 hertz. As soon as there is an imbalance, either the frequency increases that is to say the consumption is not enough and some generation units have to be stopped or the frequency decreases that means that there is not enough generation to supply all consumption and some generation units have to start. This index is strongly accurate. With the balancing mechanism, it is possible to match supply to demand at each second so that both the demand and wind power hazard find a physical solution.

Either the demand hazard or the wind power hazard could be solved technically in both vertically integrated monopoly and competitive electricity markets. The main issue of the coordination concerns the organisational coordination since the electricity system has to coordinate both the technical dimension and the organisational dimension of the volume hazard of wind power. The execution of the feed-in contract requires other mechanisms when managing the volume hazard.

2.2 Execution of the feed-in contract

Organisation of transactions

We have to explain the role of actors in electricity transaction. Power producers sell electricity on the day-ahead market to electricity suppliers. The electricity supplier has to provide electricity to final consumers so that they have to implicitly buy wind power under the feed-in contract. Electricity suppliers are responsible for the balance between the consumption of their customers and the supply contracts resulting from both transactions on electricity markets and purchase requirement of wind power output.

On the day-ahead market, supply meets demand and a market-clearing price is set. Transactions on this market allow the TSO to forecast the stability of the system day ahead. Then it could be possible to have an intraday market to modify

[4] For explanation of the difference between balancing market and adjustment mechanism please see [Saguan, 2006].

until the gate closure[5] the schedule of exchange but intraday markets are not always implemented. Since the just in time electricity market requires that at each second production serves all consumption, and both consumption and production (to a lesser extent) create volume hazard, it could be possible to be few minutes before the delivery in imbalances that have to be solved through "balancing mechanism". If generators cannot respect their exchange schedule of the day-ahead market either they overproduce or the under produce, they have to sell/purchase electricity on the real-time market in order to be at equilibrium. If the electricity supplier forecasts a demand variation and that he does not purchase enough electricity, he has to purchase electricity on this real-time market. In fact, electricity suppliers are always supplied otherwise the system could collapse. This is the TSO who coordinates electrical flows. Ex-post nevertheless the electricity suppliers have to pay for this electricity at the balancing price. This price is volatile since it is the "last-resort" energy. To summarize any imbalance between forecasted electricity and really consumed electricity has to be purchase/sell on the balancing market.

We can imagine easily that if the wind power produced has to bear the cost of balancing related to the weakly forecasted and strongly variable wind energy output, the price of balancing would act as a penalty [Menanteau, et al. 2003]. This penalty could be more or less high depending on the design of the real-time market and more particularly depending on the gate closure. If the gate closure is quite far from the delivery time, the wind power producer would bear the cost of the weakly predictability of the weather condition for wind. On another hand, if the supplier could not really forecast in advance the amount of wind power he has to purchase, we could imagine that he might buy/sell on the balancing market the amount of electricity between forecasted amounts and really consumed quantity. By doing that, the electricity supplier would bear the price hazard and could pay a quite higher price added to the fixed price for wind power produced. Furthermore the electricity supplier must yet deal with the demand hazard.

The organisation issue concerns firstly who has to absorb the fluctuating energy of wind mills? Secondly how the coordination mechanism is set and thirdly who will pay?

Designing contractual mechanisms to absorb hazardous wind power output

There are different means to reduce the uncertainty of the wind power and so to lower the volume hazard. As it is not possible to lower the volume hazard itself

[5] The gate closure is the time from which the nominations of production schedules made to the TSO can no longer be modified

because it depends on weather conditions, the tools are based on the decrease of the consequences related to the volume hazard in the feed-in contract. These mechanisms are short term based. Since the uncertainty related to the wind power output disappears at the last moment, mechanisms to be found have to deal with short term and real-time mechanisms.

A day before the delivery time, exchanges are made on the day-ahead market. This is a forward contract market [Hunt, 2003]. Another forward market is the intraday market, where generators could realise some fine adjustments (if some parameters change over time). The gate closure determines the time from which the nominations of production exchange schedules made to the TSO can no longer be changed. After the gate closure, the transactions are considered as firm and the TSO has to coordinate the production scheduling to the network constraints. If, for a reason, the production scheduling could not be respected, two main means are possible for balancing the production with consumption: (1) a real-time market, namely the Balancing Market, and (2) an adjustment mechanism[6].

Concerning the wind power, it is really difficult to know one day before the delivery time what will be the realised production. The tools developed by the TSO to deliver wind power output without penalizing neither the electricity supplier nor the wind power have to make it certain: the TSO as a wizard of the electricity market should transform a variable input into a firm one. For doing that, the TSO has to ensure that:

(1) Electricity suppliers have to fulfil their requirements of wind power output in accepting firm blocks of energy. The firm blocks of energy are defined as “Exchange Schedule of Wind Power” between the TSO and the electricity supplier

(2) The TSO is financially responsible for the supply of energy defined in the firm blocks. If the electricity quantity defined in the firm block is different from the realised wind power energy, he would have to purchase/sell electricity on the electricity market.

The firm block is a tool which enables the TSO to organize the contractual relationships between the wind power producer and the electricity suppliers. Three main missions of these firm blocks are determined:

(1) the firm block leaves the suppliers only partially influenced by the uncertainty of wind power generation

[6] For futher information on electricity market design, see [Saguan, 2005].

(2) the firm block should contain on average an amount of energy equal to the amount of energy effectively produced by wind mills

(3) it should be non-discriminatory towards energy supplier

Electricity suppliers are responsible for the balance between the consumption of their customers and the supply contracts resulting from both transactions on electricity markets and purchase requirement of wind power output. By delivering a firm block of wind energy through the Exchange Schedule of Wind power in advance, the electricity supplier can realise the exact amount of electricity transactions he needs to balance his supply contract with the customer consumption. The second mission depends on the tools deployed by the TSO to approximate the yearly wind power production and redistribute it on average to all electricity suppliers. In the case where more wind power production is realised than the one set on the firm block, the TSO has to refund the electricity supplier for having too much purchased compared to the average of the firm block. To fulfil the mission 3, the most natural means is to forward the firm block proportionally to their consumption[7]. In fact, the TSO have the right to choose independently the design of the formulae to change a variable output into a firm proxy. Diverse ways to design it are possible. [Hiroux et al., 2006] explained that what is important is the daily shape of the Exchange Schedule of Wind Power whose form depends on three kind of parameters: the reference period defined as the period during which the exchange should contain an amount of energy equal to the estimation of wind power output for the same period and the delivery period defined as the period during which the amount of energy sold should be proportional to the consumption of the supplier. Three study cases in [Hiroux, et al. 2006] show that the reference period in Germany is one month and is decided by VDN (the association of German TSOs) whereas in Denmark it was from 2000 to 2003 a period of 3 months. In fact, the determination of the blocks design depends on the choice of the TSO. [Hiroux, et al. 2006] shows that the way the TSO determines the rules of the exchange schedule of wind power, have an impact on the gains and losses of the block determination.

In order to not be imbalanced by the intermittent nature of wind power, the electricity supplier knows in advance each day the amount of wind power he has to purchase so that the imbalance issues disappear. Nevertheless who bears these costs?

[7] See [Hiroux, et.al, 2006] for complete description of the Exchange Schedule of Wind Power.

Payment settlement

The exact produced quantity of wind power is known ex-post. The payment of the wind power purchases is done ex-post. The design of the firm block could be quite different from another. As we have seen, it is possible to manage from a technical point of view the volume hazard of the wind power. Nevertheless, on a contractual dimension, even if the TSO designs short-term coordination tools to complete the feed-in contract incompleteness, an issue raised from the payment settlement appears. First of all, this concerns the transfer in value of the volume hazard. We have seen how it could be possible to manage the wind power hazard. But the wind power producer in the feed-in contract does not bear the costs related to this volume hazard.

All costs are born by final consumers through either service public charge or special tariff for renewable energy. Even if the final consumer does not consume the wind power, he has to bear the cost of its volume hazard. Most countries impose to final consumers or to citizens to provide a special service public charge. If all extra costs could be passed on the final consumer through increase of average price of electricity or public service charge, the electricity supplier as the TSO – the TSO passed the cost on the final consumer by increasing the use-of-system charges paid by the load – receive any incentive to better forecast wind power output. The fact that final consumer bears the extra-costs relating to the integration of wind power under a feed-in contract does not provide incentives to better forecast wind power output or to respond to the volume hazard.

Conclusion

In this paper we have shown that the wind power integration has been realised through the implementation of a special contractual framework called the Feed-in contract. This contract ensures that each electricity quantity produced from wind mills have to be purchased at a cost-plus fixed price that is guaranteed on long term. The price dimension of the contract brings strong incentives to invest, to produce and to minimize the generation cost. Furthermore, wind creates a strong volume hazard that could not be manipulated. No opportunistic behaviour from the wind power producer could apply. Nonetheless, the feed-in contract just imposes terms with the price dimension. When dealing with the volume dimension, we have shown that the wind power output is subject to a strong natural hazard that makes it strongly volume hazardous. This raises lot of issues since the wind power output has to be introduced in just in time market where both demand and supply varies whereas the electricity is not storable. From this point, we determine a huge coordination issues that has to be solved both technically and contractually since the electricity system is subject to a double optimisation.

From the technical point of view, there is no problem to match an intermittent supply to a variable demand in a no-storable system. Under a vertically integrated monopoly where the company has complete information, the solution is to aggregate both hazards since the company yet has developed mechanisms to respond it. Under a competitive electricity market, the TSO as flow-specialised authority whose function is to coordinate the electrical flows, runs a balancing market or an adjustment mechanism. Technically there is no problem to match supply and demand.

From contractual point of view, the issue becomes wider since a lot of different agents are used to play on the electricity markets. The major issues concern: the contract design and the payment settlement. The issue is bi-dimensional: this is first a contractual measurement issue and an organisational issue (decision-taking). We conclude that the volume hazard related to the intermittent nature of the wind power has been removed by short term coordination mechanisms through the development of contractual relationships between the TSO and the electricity supplier. By assuring to the electricity supplier that he will receive a fixed amount of wind power each day, the TSO looks like a wizard smoothing the consequences of the wind power hazard.

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