MANAGEMENT TOOLS FOR THE PURCHASE OBLIGATION OF PRIORITY PRODUCTION: THE CASE OF WIND POWER

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Abstract

The implementation of feed-in tariff has enabled a strong development of wind energy in some European countries. In this paper, this support mechanism is considered as a procurement contract between wind power producers and electricity consumers. This contract is furthermore administered by the government [Goldberg, 1976; Langniss, 2003]. In liberalised electricity market, the management of the uncertainty related to the intermittent characteristic of wind power has to be delegated, through the terms of the administered contract, to a third party who could be: the transmission system operator (TSO), the distribution system operator (DSO) or the incumbent firm. The third party develops management tools to manage reliably the uncertainty of wind power. We show that the design of management tools could result in a welfare transfer between the third party and the supplier.

1. Introduction

The integration of wind power into competitive electricity markets has been followed by strong public willingness expressed through the support mechanism policies of the renewable energies. The policy pressure has motivated the development of support mechanisms of renewable energies since the latter are not completely competitive to the conventional units of production due to a lack of industrial maturity. This is particularly adequate on liberalised electricity markets.

The support policies have been implemented through economic mechanisms, which could be price-based (feed-in tariff, premium) or quantity-based (quota, green certificates). Historically pioneer countries in terms of renewable energy development have chosen price mechanisms such as feed-in tariffs. The feed-in tariff model is quite similar to a procurement contract whose terms indicate who has to bear the volume risk related to the wind power variability characteristic. This could be the TSO, the DSO or the incumbent. The first part of this article deals with the supply contract constrained by a strong volume risk, whose management has to be delegated to a third party. Then the second part of the article shows management tools developed by the third party to transfer firm energy blocks to suppliers and the possible welfare transfer between both of them. This welfare transfer is analysed as a side-effect of management tools.

2. Volume risk management of wind power output under a feed-in tariff model

The support mechanisms are either price-based or quantity-based. Price mechanisms and most particularly the feed-in tariff model have been widely used in European countries in order to boost renewable energy investments. We show, in the first section that the feed-in tariff model could be seen as a contractual relationship between different actors. Then, in the second section, we focus only on the management of the variable output of wind power as described in the terms of the contract.

2.1. Feed-in tariff analysed as an administered procurement contract

The feed-in tariff model ensures that each kWh produced by the wind producer has to be purchased at a fixed price whenever it produces. This mechanism is analysed as an administered contract [Goldberg, 1976] binding the regulator, the wind power producer and the obligated party, in our case this means the final consumer. An administered contract is imposed by the regulator, who sets up the terms of contract, between both subcontractors. Both subcontractors have to enforce and respect the administered contract (monitoring and sanction mechanisms). Neither the wind power producer nor the obligated party decide the terms of contract. In this precise case, the regulator is the government and its legislative branch: under the citizen pressure, the government spreads administered contract between renewable energies producer and citizens.

The contract sets a fixed price for the electricity produced which will be injected on the network whenever the delivery time. This administered contract is further a procurement contract [Joskow, 1986] which warranties a price and a particular quantity. The wind power producer has the right to produce and the obligated party has the duty to buy this production.

Nevertheless, conversely to the procurement contract where the seller and the buyer are in a strongly relationship, in our case, another actor would bear the term of administered contract: the electricity supplier. The final consumers delegate their electricity purchase to electricity suppliers, who are the physical interface between producers and consumers in a liberalised electricity market. It means that the administered contract is transferred, implicitly, to the electricity suppliers.

2.2. How does the contract manage the volume risk of wind power

The wind power has to bear a strong risk volume since it is quite difficult to forecast precisely the wind power day-ahead. Furthermore in the feed-in tariff model, the wind power producer has few incentives to develop a sophisticated forecasting tool or mechanism to the control of production. This could be described as a procurement contract constrained by a volume risk on a just-in time market (the electricity market is analysed as a just-in time market). The uncertainty on this market disappears at the last moment, the delivery time.

It could be possible that the electricity supplier manages the volume risk of wind power but it will represent some huge transaction costs to bear (purchase/sale on the balancing market depending on the accuracy degree of the forecasting tool; investment in forecasting tools). Due to the importance of transaction costs, this solution is basically sub-optimal. The balancing between the production and consumption of electricity at each second involves a third party to manage the risk volume of the wind power output.

The Figure 1 shows the different actors concerned by the feed-in tariff. In a purely administered contract, the final consumer is considered as the obligated party since it bears the financial cost of the feed-in tariff paid through a public service tax. This charge represents the integration cost of renewable energies into electricity market. In practice, this is the electricity supplier who manages the delivery of wind power output and the feed-in tariff of the wind electricity.

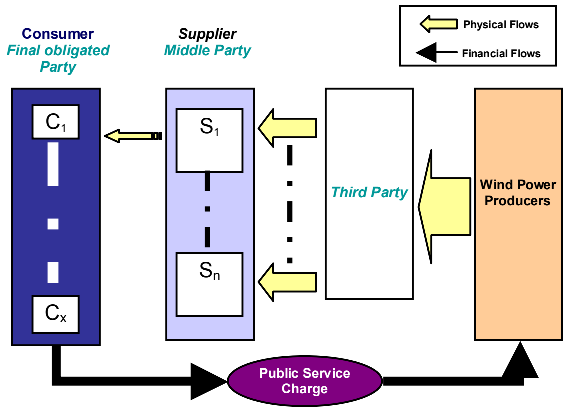

Figure 1 : Role of different actors involved in the feed-in tariff model

The risk volume of the contract concerns the physical management of the wind power output. In general, the transmission system operator is responsible for the management of the wind power. This was the case in Western Denmark between 2000 & 2003 (when the feed-in tariff was applied) and this is the case nowadays in Germany [Eltra, VDN)

The figure below shows the key role of the third party in the management of the wind power volume risk under a feed-in tariff.

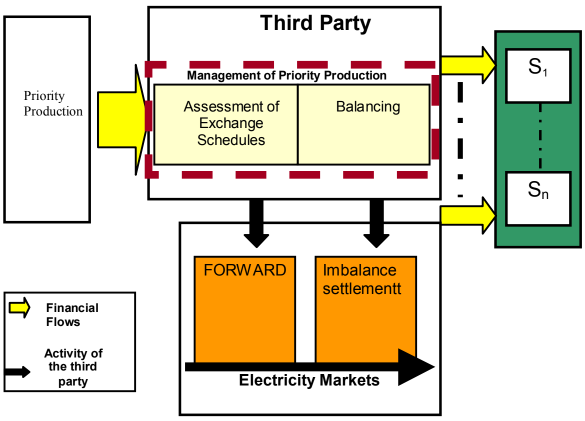

Figure 2 : The third party as the interface in the management of the feed-in tariff of the wind power

The third party has to ensure the integration of the wind power output following that:

- Electricity suppliers have to fulfil their purchase requirements of wind power output in accepting firm blocks of energy. The latter are defined by a exchange schedule of wind power (ESWP) between the third party and the supplier
- The third party is financially responsible for the supply of energy defined in the ESWP. The third party has to manage the balancing of electricity quantity defined in the ESWP and the realised wind power energy. If these quantities are different, the third party has to sell/purchase electricity on electricity markets.

3. Exchange Schedules of Wind Energy

In the framework of a Feed-In Tariff mechanism, the suppliers of electricity must purchase with priority some energy blocks related to wind energy. The ESWP, as previously defined, plans the exchange of blocks between the third party and the suppliers. Thus, the ESWP is a tool which enables the third party to organize the contractual relation between wind producers and suppliers. In a first part, we will present the missions that should be fulfilled by a ESWP. We will then demonstrate that the shape of the daily schedule depends on a given set of parameters, and finally, we will show that the ESWP has a side effect: a welfare transfer between the third party and the suppliers.

3.1. Missions and definition of an exchange schedule of wind energy

The purpose of this part is to mention the main three missions of a ESWP, and, the necessary conditions for the ESWP related to these missions.

(1) *The ESWP leaves the suppliers only partially influenced by the uncertainties of wind power generation ;*

(2) *The ESWP should contain, on average, an amount of energy equal to the amount of energy effectively produced by wind mills generators ;*

(3) *The ESWP should be non-discriminatory toward suppliers.*

On mission (1) – uncertainty on suppliers

The electricity suppliers are responsible for the balance between the consumption of their clients, and the supplying contracts resulting from :

- Transactions on markets ;
- Purchase obligation of wind energy.

(See Figure 3)

Any imbalance observed in real time is subject to an imbalance settlement, whose price system is particular to each TSO. The price system is generally a financial incentive for the supplier to minimize its imbalances. Unless the ESWP is determined ahead of real time (that means independently of the real wind power output), the ESWP is a disturbance for the supplier's balance.

The ESWP should be determined at least before the gate closure[1], otherwise it creates an imbalance for the supplier. The uncertainties for the supplier are reduced when the ESWP is determined early before the gate closure: knowing the schedule, the suppliers have more possibilities to match the remaining part of consumption[2] with long term contracts, forward markets… This permits the supplier to possibly reduce its global purchase cost. The uncertainties related to the wind power forecast are thus shared between the third party and the suppliers. For the third party, the uncertainty consists in delivering energy blocks, defined by the ESWP, without knowing accurately the wind production.

The uncertainty for the supplier depends on the notice with which it knows the amount of energy that has to be purchased with priority. The longer the notice, the smaller the uncertainty.

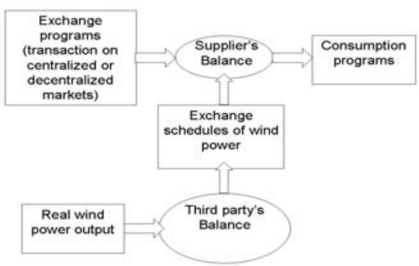

Figure 3 : Balancing responsibility for the third party and the suppliers

On mission (2) – transfer of energy

This mission is fundamental since it allows the third party to pass its purchase costs of wind power on to the suppliers (and *in fine* to the consumers). On a period called *reference period*, the ESWP should contain an amount of energy equal to the estimation of wind power output for the same period. In practice, it is difficult to estimate correctly the wind power production on a given period. Thus it is necessary to set up an *ex post* financial balancing mechanism : if the amount of energy contained in the ESWP during one reference period was above the effective wind power production, it means that the suppliers have been further than their purchase obligation, and the third party must refund the suppliers for the energy purchased in excess; the opposite situation, the suppliers have not properly covered their purchase obligation and they have to refund the third party for the energy not purchased. (See Figure 4)

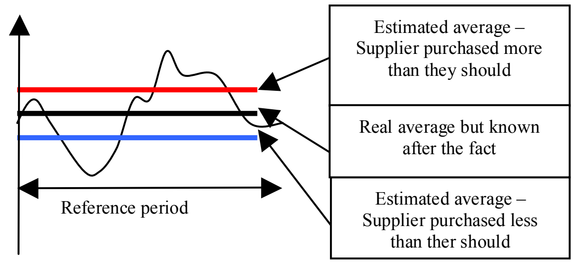

Figure 4: Estimations of wind production on a reference period

On mission (3) – non-discrimination

The most natural means of fulfilling this mission is to forward the ESWP to the suppliers proportionally to their consumption. We call *quota*, the percentage of consumption that each supplier covers by buying the energy blocks defined by the ESWP. This quota is defined for each reference period by the ratio between the estimation of wind power output and the estimation of the global consumption (for all the suppliers) ;

$$Quota = \frac{\int_{reference\_period} \overline{P_{Wind}(t)}dt}{\int_{reference\_period} \overline{C(t)}dt} \qquad \textbf{(1)}$$

$\overline{P_{Wind}(t)}$ stands for the estimation of the wind power output at time t ;

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[1] The Gate Closure is the time from which the nominations of production/consumption/exchange schedules made to the TSO can no longer be modified.

[2] The remaining consumption is the total consumption minus the energy blocks scheduled by the ESWP

$\overline{C(t)}$ stands for the estimation of the consumption of the suppliers subject to purchase obligation at time t.

With the quota defined by equation (1), it is possible to calculate the amount of energy contained in the ESWP forwarded to suppliers. The ESWP can be defined on a time frame shorter than the reference period, that we will call here *delivering period*. On a delivering period, the amount of energy sold to each supplier should be proportional to the consumption of the supplier. The amount of energy contained in the ESWP and forwarded to the supplier « i », on the delivering period « n», is defined by equation (2) :

$$Q(i,n) = Quota \times \int_{Delivering\_period(n)} \overline{C_i(t)} \cdot dt \quad \textbf{(2)}$$

Then the definition of the ESWP on the delivering periode «n» can be defined by :

$$\begin{aligned} ESWP_{i,n}(t) &= Q(i,n) \times F(t) \\ \int_{Delivering\_perode(n)} F(t)dt &= 1 \end{aligned} \quad \textbf{(3)}$$

F(t) is the shape factor, which can be set up independently of the three missions.

Equations in (4) show that the ESWP as defined so far, effectively allows to transfer an amount of energy equal to the estimation of wind power output. (as required by mission (2)) :

$$\begin{aligned} \sum_{i,n} Q(i,n) &= Quota \times \sum_{i,n} \int_{Delivering\_period\_n} \overline{C_i(t)}dt \\ \sum_{i,n} Q(i,n) &= Quota \times \int_{reference\_period} \overline{C(t)}dt \\ \sum_{i,n} Q(i,n) &= \int_{reference\_period} \overline{P_{Wind}(t)}dt \end{aligned} \quad \textbf{(4)}$$

The three missions identified in this part allow us to define the ESWP as following: ESWP are exchange schedules, known by the suppliers at least before the gate closure, which contain an amount of energy equal to the estimation of the wind power production during the reference period, and from which the supplier receives on each delivering period an amount of energy proportional to their consumption. On a delivering period, the amount of energy contained in the ESWP is fixed, but the choice of the shape factor is a degree of freedom.

3.2. Daily shape of a ESWP

The shape of the daily schedule depends on the choice of certain parameters (reference period, delivering period) and on the choice of the independently set shape factor F(t). (See equation (3)).

We mention here three examples of ESWP applied in Germany (between 2000 and 2005, and from 2006 on) and in West Denmark[3] (between 2000 and 2003). The third party in Germany and Denmark is the TSO. The choices of the reference period, the delivering period and the shape of the ESWP on a delivering period are reported in Table 1. ([VDN],[Eltra])

Table 1 : Daily shape of the ESWP in Germany and Denmark

	Reference period	Delivering period	Shape on the delivering period	Daily shape
Ger 2000-2005	3 months	1 month	flat	*flat*
Ger 2006	1 month	1 month	flat	*flat*
Dk 2000-2003	3 months	1 hour	flat	*~consumption*

The daily shape of the ESWP can be determined out of the three parameters reported in the table.

In the Danish case, the ESWP is fixed on the day ahead, and contains during each hour (the delivering period is one hour) an amount of energy proportional to the consumption forecasts. Consequently, the daily shape of the ESWP is proportional to the day-ahead forecast of consumption. In the case of Germany, the delivering period is one month, so the shape of the ESWP depends only on the choice of the shape factor *F(t).* This shape factor being chosen flat in Germany (*F(t)= constant*), the shape of the ESWP is flat in Germany.

Thus, the ESWP is not related to the forecasts of wind power output, but depends on :

- The estimation of the wind power output on a relatively long period (1-3 months)

[3] Denmark is composed of two non-synchonized networks, West/East.

- The shape factor which is applied.

In the following, three different shapes of ESWP will be studied. A flat shape corresponding to the ESWP used in Germany, a shape proportional to the consumption forecast, corresponding to the ESWP used in Denmark, and a shape proportional to a forecast of wind power[4].

The third party is responsible for the delivering of energy blocks corresponding to the ESWP. Therefore, the third party can purchase and sell energy blocks on the forward markets in order to balance out the forecast of wind power with the blocks defined by the ESWP. The forward markets are the markets placed before the gate closure [Stoft]. We call this step, *the balancing of the ESWP*. Afterwards, any difference between the wind power forecast and the real wind power output should be purchased / sold by the third party on the real time market or the balancing mechanism operated by the TSO. In the next part, we will study a side effect of the daily shape of the ESWP on the cost of the balancing of ESWP[5].

3.3. Analysis of a side effect of ESWP

The cost of the balancing of the ESWP for each delivering period (« i ») is the following:

$$C_{Balancing} = \sum_i \left\{ \int_{Beginning\_i}^{End\_i} \left(\overline{P_{Wind}}(t) - ESWP(t) \right) p(t) dt \right\} \quad \textbf{(5)}$$

$C_{Balancing}$ stands for the cost of the balancing of the ESWP;

$\overline{P_{Wind}}(t)$ stands for the wind power forecast at time t;

ESWP(t) stands for the exchange schedule at time t;

p(t) stands for the gross market price on which the balancing of the ESWP is made.

On the reference period, the amount of energy contained in both the ESWP and the wind power forecasts should be equal on average (mission (2)). That means that the net balance regarding the quantities of energy bought and sold should be equal to zero. Practically, the estimation of wind power production is very unlikely to be accurate, and so the net balance unlikely to be equal to zero. As seen in 3.1/mission(2), a financial regulation compensates for this lack of accuracy in the wind power production estimation.

The quantities being bought and sold at different prices, we can expect that the cost of the balancing of ESWP will not equal zero.

In the following we analyse the impact of the shape of the ESWP, assuming that the forecast of wind production and consumption are known. The cost of the balancing will be calculated in the cases of a flat shape, a shape proportional to the forecast of consumption, and a shape proportional to the forecast of wind production.

We also assume that the reference period is the day. According to mission (2), the ESWP should be defined so that:

$$\sum_{1 \le k \le 24} ESWP(k) = \sum_{1 \le k \le 24} \overline{P_{Wind}}(k) \quad \textbf{(6)}$$

ESWP(k) stands for the exchange schedule at hour k ;

$\overline{P_{Wind}}(k)$ stands for the forecast of wind generation.

We assume that there is only one supplier, which has to purchase with priority the blocks defined by the ESWP. We call D(k) its inelastic consumption at hour k, Its remaining consumption, which has to be bought on a market is defined by:

$$D_{remaining}(k) = D(k) - ESWP(k) \quad \textbf{(7)}$$

We define the following three ESWP, whose daily shape have respectively the shape previously named[6] :

$$ESWP_{flat}(k) = \frac{1}{24} \sum_{1 \le k \le 24} \overline{P_{Wind}}(k) \quad \textbf{(8)}$$

$$ESWP_{Consumption}(k) = \left(\frac{\sum_{1 \le k \le 24} \overline{P_{Wind}}(k)}{\sum_{1 \le k \le 24} \overline{D}(k)} \right) \cdot D(k) \quad \textbf{(9)}$$

$$ESWP_{Wind}(k) = \overline{P_{Wind}}(k) \quad \textbf{(10)}$$

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[4]The shape can result from a ESWP similar to the one used in Germany, and a shape factor corresponding to a normalised forecast of wind power production.

[5] The cost of the balancing of ESWP should not be confused with the balancing cost, which is the settlement cost of balancing mechanism.

[6] Under the assumption : $\sum_{1 \le k \le 24} \overline{D}(k) = \sum_{1 \le k \le 24} D(k)$ the three ESWP respect the mission (2).

The global purchase cost for the supplier is :

$$C_{Purchase} = \sum_{1 \le k \le 24} D_{remaining}(k) \cdot p(k) \qquad \textbf{(11)}$$

p(k) is the market price at hour k.

The market price depends both on the remaining consumption $D_{remaining}(k)$ and on the third party, which trades on the market a quantity: $ESWP(k) - \overline{P_{Wind}}(k)$:

$$p(k) = f\left(D_{remaining}(k) + ESWP(k) - \overline{P_{Wind}}(k)\right) \qquad \textbf{(12)}$$
$$p(k) = f\left(D(k) - \overline{P_{Wind}}(k)\right)$$

It is worth noticing that equation (12) shows that the market price doesn't depend on the ESWP. The cost of the balancing of the ESWP is given by :

$$C_{Balancing} = \sum_{1 \le k \le 24} \left(ESWP(k) - \overline{P_{Wind}}(k)\right) \cdot p(k) \quad \textbf{(13)}$$

We calculate the global purchase cost for the suppliers, the cost of the balancing for the TSO, for each of the three shapes. The curves for the market price, the wind power output and the consumption used in this analysis are given in Figure 5. The chosen set of curves is derived from mean values, observed in July 2004 in western part of Denmark. [NordPool]

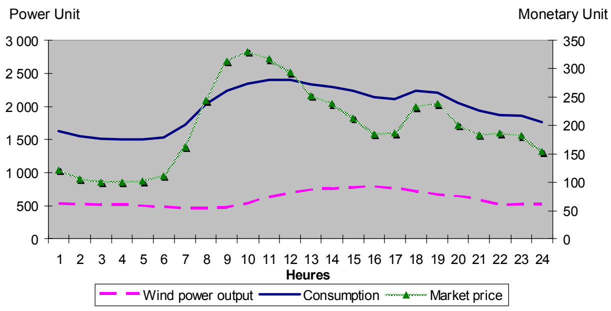

Figure 5 : Wind power output, consumption and market price

The Figure 6 shows the daily shape of the ESWP used in this study.

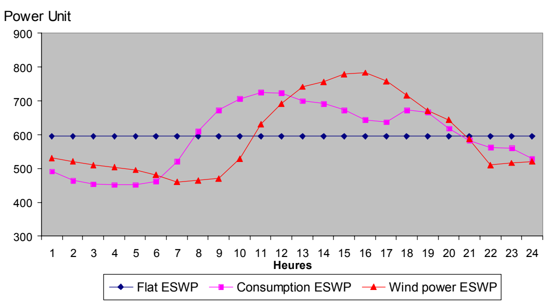

Figure 6 : Daily shape of the ESWPProfils journaliers des PEPE considérés

The amount of energy exchanged by the third party in order to balance out the wind power forecasts with the blocks determined by the ESWP are showed in Figure 7. The positive quantities (respectively negative) correspond to pruchase (respectively sale) of energy.

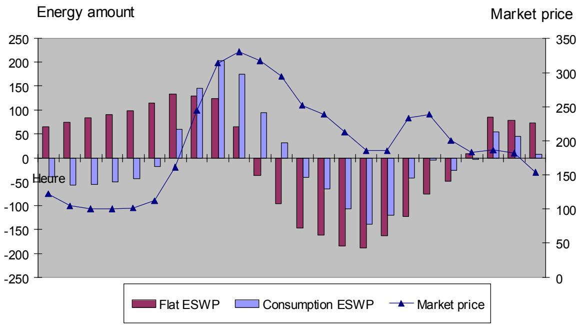

Figure 7 : Balancing of the wind power forecast with the ESWP

The cost of energy purchase for the supplier, and the cost of the balancing of the ESWP for the third party are presented in Table 2.

Table 2 : Cost of purchase for the supplier, and cost of balancing of the ESWP (in virtual monetary unit)

	Flat shape	"Consumption shape »	« Wind shape»
Purchase cost for the supplier	7077 k	6930 k	7014 k
Cost of balancing of the ESWP	-63,1 k	83,7 k	0

The « wind shape » is the base case because the ESWP exactly fits with the wind production. Therefore, the ESWP and the forecast of wind power are obviously already balanced. The cost of the balancing of the ESWP is equal to zero in that base case. Compared to this base case, the balancing of the ESWP has the side effect to induce a welfare transfert :

- In the case of the flat shape, the balancing of the exchange schedules generates a surplus of 63,1 k m.u. (virtual monetary units) for the third party, and a symetric cost for the supplier (7014 k m.u. → 7077 k m.u.) ;
- In the case of the consumption shape, the balancing of the exchange schedule generates a cost of 83,7 k m.u. for the third party, and a symmetric surplus for the supplier

(7014 k m.u. → 6930 k m.u.).

For a given shape of wind power output, the direction and the value of the welfare transfer, depends not only on the daily shape of ESWP, but also on the daily shape of the market price curve. Starting from an average wind production shape, and from the main features of a power system (market price curve, consumption curve), it is possible to make an estimation of the welfare transfer between the third party and the suppliers for different types of daily shapes of the ESWP.

4. Conclusion

The setting up of feed-in tariff is an efficient support mechanism for the development of wind power. This mechanism can be seen as an administrated contract set up by the regulatory authority, binding the wind producers to the end consumers. This administrated contract defines a tariff at which the electricity generated by wind mills is purchased. In a liberalised context, the management of volume risk is delegated to a third party, which is generally a TSO, a DSO, or the incumbent firm. The third party elaborates a Schedule of Exchange of Wind Power, which allows each supplier to fulfil its purchase obligation of wind energy in a non-discriminatory way. Moreover this exchange schedule, when known long time ahead, also minimises the impacts of the uncertainties of wind power output on the global purchase cost of suppliers. The setting up of the ESWP generates a welfare transfer between the third party and the suppliers. For a given power system (with a given market price curve, consumption curve and wind production curve), the features of the welfare transfer depend on the daily shape of the Exchange Schedule of Wind Power. This side effect should be carefully monitored at the time the Exchange Schedules of Wind Production are designed. The monitoring of this side effect shouldn't be done on a single day, but rather on an extensive set of data covering at least one year since market price and wind power output have a seasonal effect.

5. References

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