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Bilateral Contract Correction and Cancellation in the Competitive Electricity Markets

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Abstract—**Bilateral forward contracts are widely applied in the electricity markets. Conclusion of bilateral contracts bears certain risks due to price and demand uncertainty. Both contract parties forecast price levels in the spot market and electricity demand. Both parties estimate expected profits (or losses) from caring out the contract and participation in the spot market. It is important to correct the contract in time.**

The paper considers the sequence of actions to be implemented for contract correction. The statements of optimization problems are given for decision making on contract correction and cancellation. The statements take into account financial compensation for another party in the case of prescheduled contract correction or cancellation. Numerical example illustrates applicability of the proposed procedures for decision making.

Index Terms-- **electricity market, bilateral contracts, delivery scheduling, contract correction**

I. INTRODUCTION

Normally trade in electricity in the wholesale markets has two main forms. They are a day-ahead (spot) trade with an hourly coordination of demand and supply, and a medium- and long-term forward trade based on bilateral forward contracts (BCs). Bilateral contracts for physical delivery are widely applied in the competitive electricity markets. In many countries bilateral trade covers the main portion of electricity delivery.

A bilateral forward contract is a contract, which guarantees the purchaser delivery of a certain amount of electricity at specified time at agreed price. Thus the purchaser knows for certain that electricity will be delivered at time t, and the contract price of electricity will be p^t. But this is only the case if the BC parties strictly follow the fixed contract parameters.

BCs are commonly used to hedge or mitigate a market price risk. They stabilize prices and reduce the possibility of market power abuse in the "day-ahead" (spot) market.

The BC parties are an electricity supplier and a buyer. The supplier is a generation company (GC) or independent power producer. The buyer is an electricity supply company (ESC) that sells electricity to end consumers. Both contract parties forecast price levels in the spot market and electricity demand.

The spot market and bilateral contract market influence each other and interact with each other. The volumes and prices stipulated in BC influence the trade volumes and prices in the spot market. The spot market risks and price behavior have an impact on the contract arrangement strategy of the contract parties. Electricity received under BC may be resold in the spot market and electricity bought in the spot market may be delivered to fulfill bilateral obligations [2, 3].

Bilateral contracts can be concluded for the period from several weeks to several years. Deliveries are scheduled by the contract parties up to the moment of contract conclusion using forecasted data. Potential BC parties schedule the deliveries by time intervals t during the contract period in an optimal way to get the highest profit and elaborate a strategy of their participation in the spot market.

A considerable amount of previous works was devoted to the problem of BC scheduling and arrangement. The paper [1] discusses the price setting in flexible contracts, when deliveries can be changed in some time intervals, whereas the total contract volume is preserved. The works [2-4] present the BC analysis with possible interruption of deliveries by either supplier or buyer. The procedures for scheduling electricity deliveries under contracts are presented in [5, 6]. In [7] weather forecasts are suggested to be taken into consideration to reduce the risk of purchasing expensive electricity in the spot market.

Conclusion of bilateral contracts bears certain risks due to price and demand uncertainty in the competitive market. Contract parties keep track of the market price behavior during the contract period and update price and demand forecasts. Each party estimates contract profit or financial loss expected in changing market conditions. Each contract party can make a decision on contract parameters correction or contract cancellation, if the expected profit is not acceptable. The other party has the right to accept or reject a proposed correction.

The sense of the paper differs of interruptible contract consideration [2-4]. The interruptible forward contracts presume that the consumer grants the power supplier the right to interrupt a given unit of load in return for a price discount. The consumer agrees with possible interruption in advance. Decision on supply interruption is usually made for congestion management, rejection of price spikes or maintenance of system security.

The paper considers contract correction or cancellation for hedging commercial losses. Contract correction is initiated by either of the contract parties. Certainly, decision making on contract correction has to take into account financial compensations for the other partner.

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II. BILATERAL CONTRACT PARAMETERS

Arrangement of BC implies negotiation of the contract parties and setting the following contract parameters.

- Contract duration from delivery start, T_1 to termination, T_N. The time from T_1 to T_N constitutes a contract period;
- Number N and duration of time intervals t within the contract period;
- Total electricity amount V to be delivered by the contract (contract volume), MWh;
- Electricity amount x^t to be delivered in time interval t, MWh. Amounts x^t, $t=T_{1,\ldots,}T_N$ form a delivery schedule. Contract correction means correction of the schedule x^t, $t=T_{1,\ldots,}T_N$;
- Contract prices of electricity p^t, $t=T_{1,\ldots,}T_N$, delivered under BC, \$/MWh. The prices p^t, $t=T_{1,\ldots,}T_N$ are related to the forecasts of spot prices and seasonal deviation of electricity prices;
- Fine on the supplier in the case of delivery reduction initiated by supplier, p^t_{int}, \$/MWh;
- Fine on the buyer in the case of delivery overdrawing, initiated by buyer, p^t_{ovd}, \$/MWh;
- Financial compensation ΔF to the other party in the case of prescheduled contract cancellation;
- Time Δt required to approve contract correction (time from the point when decision on correction have been made to the point of new delivery schedule start up). The time Δt is needed to inform the partner about proposed contract correction and for registration of contract correction by the System Operator.

Some additional parameters can be fixed at the stage of BC arrangement. Among them:

- List of time intervals when electricity delivery has not to be changed;
- Number of contract corrections allowed during the contract period;
- Maximal reduction or increase in contract delivery in time intervals if BC is not cancelled.

III. SEQUENCE OF ACTIONS FOR CONTRACT CORRECTION

Correction of BC consists of several stages. The sequence of actions is shown in Fig. 1.

Stage 1. Starting from the first time interval T_1 each BC party follows the delivery schedule originally stipulated in BC. Each party keeps track of actual demand and price behavior and updates price and demand forecasts up to the end of contract period T_N. Actual prices and new forecasts may deviate significantly from those predicted before the contract conclusion. Both parties estimate their actual and expected profits (or losses), provided the original BC schedule x^t, $t=T_{1,\ldots,}T_N$ is implemented strictly. If the estimation shows significant reduction in expected profit or losses one of the BC parties goes to Stage 2.

Stage 2. The party-initiator of correction develops a new delivery schedule and estimates its possible profit or loss in the case of the contract correction. The profit is obtained taking into account the fine for changing its obligations. It makes a decision on the contract correction during interval $T_1 - t_H$.

Stage 3. The party-initiator of correction considers possible cancellation of the BC during interval $T_1 - t_H$ and estimates the profit or loss in the case of contract cancellation. The profit is obtained taking into account the financial compensation for contract termination.

Stage 4. The party-initiator of correction chooses the best decision considering the analysis made at stages 1, 2 and 3. It proposes the BC correction or cancellation to another partner at time t_H.

Stage 5. The party-initiator of correction informs thr other partner about its decision during period Δt and proposes a new delivery schedule. The partner estimates consequences of the proposed correction during interval Δt and approves (or rejects) the new delivery schedule. If the contract correction is appropriate for the second party the new delivery schedule should be approved by the System Operator. Both parties follow the original delivery schedule x^t, $t=T_{1,\ldots,}T_N$ during Δt, while the actual situation in the market may differ from that originally predicted. New delivery schedule or contract cancellation starts with interval t_K.

Stage 6. Electricity delivery under BC continues from t_K according to the new delivery schedule. Both BC parties continue to analyze the levels of spot prices and update price and demand forecasts up to the end of the BC period T_N. They continue to estimate expected profits (or losses) using improved forecasts. Decision on the next contract correction can be made by the same or the other contract party.

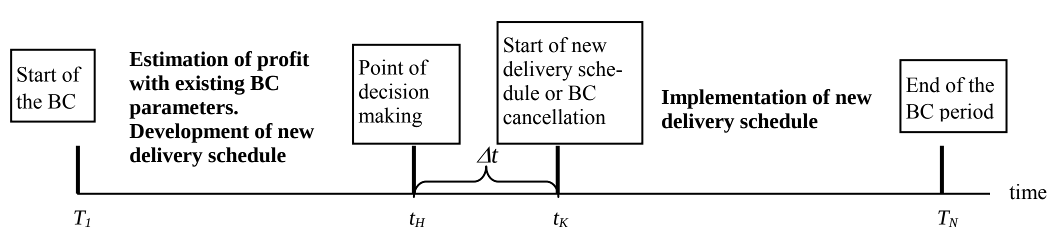

Fig. 1. The sequence of actions for contract correction

IV. DECISION MAKING ON CONTRACT CORRECTION

Let us consider the case when BC is concluded between an electricity supply company (SC) and a generation company (GC) for the period of time between T_1 and T_N. SC sells electricity to end consumers and participates in the spot market. Supply company receives $x^t, t = T_1,...,T_N$ under the contract.

Stage 1. Denote by $\tilde{p}^t_{sF}$ and x^t_{dF}, $t = T_c,...,T_N$ updated forecasts of spot prices and electricity demand. Forecasts of spot prices are considered as random values. Denote by p^t_d electricity price for end consumers, and by E a mathematical expectation symbol.

Let T_c be a current interval when SC analyzes the economic efficiency of existing BC. Denote by x^t_{kF} a portion of x^t received under BC and delivered to end consumers, x^t_{ssF} a portion of x^t received under BC and sold in the spot market, and x^t_{sF} amount of electricity bought in the spot market and delivered to end consumers. So, $x^t_{kF} + x^t_{sF}$ is amount of electricity delivered to end consumers, and $x^t_{kF} + x^t_{ssF}$ is electricity received under BC in interval t.

SC revises its participation in the spot market and estimates expected profit S_F, provided it receives electricity under BC according to the fixed delivery schedule $x^t, t = T_1,...,T_N$. SC solves the problem

$$S_F = \max_{x^t_{kF}, x^t_{ssF}, x^t_{sF}} E[\sum_{t=T_c}^{T_N} (p^t_d (x^t_{kF} + x^t_{sF}) + \tilde{p}^t_{sF} (x^t_{ssF} - x^t_{sF}) - \\ - p^t (x^t_{kF} + x^t_{ssF}))] \quad (1)$$

subject to following constraints:

$$x^t_{kF} + x^t_{sF} = x^t_{dF}, \quad t = T_c,...,T_N, \quad (2)$$

$$x^t_{kF} + x^t_{sF} = x^t, \quad t = T_c,...,T_N, \quad (3)$$

$$x^t_{kF} \ge 0, \quad x^t_{sF} \ge 0, \quad x^t_{ssF} \ge 0, \quad t = T_c,...,T_N. \quad (4)$$

Other constraints can be taken into account in addition to (2)-(4), for example limits on amounts of electricity sold or bought in the spot market, prohibition on sale and purchase in the spot market at a time. The negative value of S_F means expected losses of SC.

If S_F significantly differs from the value of profit expected at the time of contract conclusion SC continues the process of decision making.

Stage 2. Supply company develops a new delivery schedule using updated forecasts $\tilde{p}^t_{sF}$ and x^t_{dF} $t = T_c,...,T_N$. It estimates expected profit S_N on condition that it implements a new delivery schedule. The new schedule may be implemented starting with interval t_K in the case of BC correction.

Denote by x^t_N amount of electricity received by SC under BC according to the new delivery schedule in interval t. Let x^t_{kN} be a portion of x^t_N delivered to end consumers, x^t_{ssN} - a portion of x^t_N sold in the spot market, and x^t_{sN} - amount of electricity bought in the spot market and delivered to end consumers. Amounts $x^t_N = x^t_{kN} + x^t_{ssN}$, $t = T_K,...,T_N$ form a new delivery schedule.

SC solves the problem[1]

$$S_N = \max_{x^t_{kN}, x^t_{ssN}, x^t_{sN}} E[\sum_{t=T_c}^{T_N} (p^t_d (x^t_{kN} + x^t_{sN}) + \tilde{p}^t_{sF} (x^t_{ssN} - x^t_{sN}) - \\ - p^t x^t) - p^t_{ovd} (\left| x^t - x^t_{kN} - x^t_{ssN} \right|)] \quad (5)$$

subject to

$$x^t - x^t_{kN} - x^t_{ssN} = 0, \quad t = T_c,...,T_K, \quad (6)$$

$$x^t_{kN} + x^t_{sN} = x^t_{dF}, \quad t = T_c,...,T_N, \quad (7)$$

$$x^t_{min} \le x^t_{kF} + x^t_{ssF} \le x^t_{max}, \quad t = T_K,...,T_N, \quad (8)$$

where x^t_{min}, x^t_{max} are limits on deliveries under BC in interval t,

$$x^t_{kN} \ge 0, \quad x^t_{sN} \ge 0, \quad x^t_{ssN} \ge 0, \quad t = T_c,...,T_N. \quad (9)$$

Stage 3. Supply company considers consequences of the contract cancellation. It takes into account financial compensation (fee) ΔF for the other contract party. SC estimates an expected profit for the case of contract cancellation using updated forecasts $\tilde{p}^t_{sF}$ and x^t_{dF} $t = T_c,...,T_N$. The contract cancellation may be implemented starting with interval t_K.

Denote by x^t_C amount of electricity received by SC under BC at interval t before contract cancellation. Let x^t_{kC} be a portion of x^t_C delivered to end consumers, x^t_{ssC} - a portion of x^t_C sold in the spot market, and x^t_{sC} - amount of electricity bought in the spot market and delivered to end consumers.

SC solves the problem

$$S_C = \max_{x^t_{kC}, x^t_{ssC}, x^t_{sC}} E[\sum_{t=T_c}^{T_N} (p^t_d (x^t_{kC} + x^t_{sC}) + \tilde{p}^t_{sF} (x^t_{ssC} - x^t_{sC}) - \\ - p^t (x^t_{kC} + x^t_{ssC})) - \Delta F] \quad (10)$$

subject to

$$x^t - x^t_{kC} - x^t_{ssC} = 0, \quad t = T_c,...,T_K, \quad (11)$$

$$x^t_{kC} + x^t_{ssC} = 0, \quad t = T_K,...,T_N, \quad (12)$$

[1] Objective function (5) is written on the assumption that reduction and increase in delivery under BC is played at the same price p^t_{int}. Real contracts can provide other requirements.

$$x_{kC}^t + x_{sC}^t = x_{dF}^t, \quad t = T_c,...,T_N, \qquad (13)$$

$$x_{kC}^t \ge 0, \quad x_{sC}^t \ge 0, \quad x_{ssC}^t \ge 0, \quad t = T_c,...,T_N. \qquad (14)$$

Stage 4. Supply company compares values of S_F, S_N, S_C and chooses the best decision concerning the existing BC. It continues to receive electricity according to the originally stipulated delivery schedule, proposes the BC correction or cancellation to the other partner.

Stage 5. If SC has decided to correct the existing BC it proposes a new delivery schedule to generation company (GC). GC estimates its commercial benefits or losses of the proposed correction.

For interval t denote by x_{gc}^t amount of electricity generated by GC and delivered to SC under BC, x_{gss}^t - amount of electricity generated by GC and sold in the spot market, x_{gs}^t - amount of electricity bought in the spot market and delivered to SC under BC. The total generation of GC is $x_g^t = x_{gc}^t + x_{gss}^t$. Amount of electricity delivered under BC is $x_{gc}^t + x_{gs}^t$. Assume that the production cost function $C^t(x_g^t)$ is known and obtained by GC based on the optimal unit commitment.

Generation company solves the following problem to estimate its expected profit (or loss) of new delivery schedule implementation[2]

$$S_G = \max_{x_{gc}^t, x_{gss}^t, x_{gs}^t} E[\sum_{t=T_c}^{T_N} (\tilde{p}_{sF}^t (x_{gss}^t - x_{gs}^t) - C^t(x_{gc}^t + x_{gss}^t) + \\ + p^t(x_{gc}^t + x_{gs}^t) + p_{ovd}^t(\left| x^t - x_{gc}^t - x_{gs}^t \right|))] \qquad (15)$$

subject to

$$x_{g\,min}^t \le x_{gc}^t + x_{gss}^t \le x_{g\,max}^t, \quad t = T_C,...,T_N, \qquad (16)$$

where $x_{g\,min}^t$, $x_{g\,max}^t$ are limits on electricity generation of GC,

$$x_{gc}^t + x_{gs}^t = x^t, \quad t = T_C,...,T_K, \qquad (17)$$

$$x_{gc}^t \ge 0, \quad x_{gs}^t \ge 0, \quad x_{gss}^t \ge 0, \quad t = T_c,...,T_N. \qquad (18)$$

Analysis of S_G allows GC to make a decision on approval or rejection of proposed new delivery schedule.

V. NUMERICAL EXAMPLE

It is assumed in the example that BC is concluded between supply and generation companies. Contract period consists of four time intervals of equal duration.

Both contract parties agreed that the total amount of electricity to be delivered under BC is $V = 78$ MWh. The price of electricity delivered under BC is $p^t = 70.51$ \$/MWh for all intervals $t = 1,...,4$. The necessary period Δt for correction approval is one time interval. Electricity price for end consumers is p_d^t=100 \$/MWh for all intervals.

The following parameters are stipulated in the contract:

- delivery schedule x^1=8.0, x^2=5.0, x^3=58.0 and x^4=7.0 MWh;
- fine on supplier in the case of delivery reduction initiated by supplier, p_{int}^t=75 \$/MWh;
- fine on buyer in the case of delivery overdrawing, initiated by buyer, p_{ovd}^t=72.5 \$/MWh;
- financial compensation for another party in the case of contract cancellation $\Delta F = p_{int}^t \sum_{t=T_K}^{4} \Delta x^t$, where $\sum_{t=T_K}^{4} \Delta x^t$ is amount of undelivered electricity.

The SC forecasted the following average levels of spot prices p_s^t and demand x_d^t at the contract conclusion, Tab. 1[3].

TABLE 1
INITIAL PRICE AND DEMAND FORECASTS

	Time intervals			
	1	2	3	4
Spot price, \$/MWh	65.00	70.37	71.75	70.00
Demand, MWh	9.8	11.4	14.5	13

The strategy of participation in the spot market for SC is shown in Tab. 2. The strategy is developed before the BC conclusion taking into account forecasts, Tab. 1. The total profit of the SC expected at contract conclusion is \$1503.75 including \$298.8 in interval 1.

TABLE 2
DISTRIBUTION OF ELECTRICITY RECEIVED UNDER BC

Time intervals	x_k^t	x_{ss}^t	x_s^t	$x_k^t + x_{ss}^t$
1	8.0	0	1.8	9.8
2	5.0	0	6.4	5.0
3	14.5	43.5	0	58.0
4	7.0	0	6.0	7.0

Let us assume that the SC has received 8.0 MWh under BC during the first time interval and got \$298.8 of profit. At the beginning of the second interval SC updates forecasts for spot prices and demand behavior. According to new expectations the spot prices are p_{sF}^2=68.26, p_{sF}^3=69.6, p_{sF}^4=74.9 \$/MWh. Amounts of demand are x_{dF}^2=11.4, x_{dF}^3=10.0, x_{dF}^4=11.0 MWh.

SC solves problem (1)-(4) at *Stage 1* to revise its participation in the spot market and estimate expected profit S_F on the assumption that it receives electricity under BC according to the fixed delivery schedule. Intervals T_c=2

[2] It is assumed in objective function (15) that GC uses price forecast $\tilde{p}_{sF}^t$, $t = T_C,...,T_N$ updated by SC. In real life it can obtain new forecast itself.

[3] Random character of prices and demand values is not taken into account in the example for simplicity.

and T_K=3 for problem (1)-(4). New amounts of sales and purchases are given in Tab. 3. According to (1) the expected profit of SC S_F for intervals 2 – 4 is \$908.3 including profit of \$350.5 in interval 2. Taking into account the profit in the first interval the total expected profit of the SC is \$1207.1.

TABLE 3
REVISED PARTICIPATION OF SC IN THE SPOT MARKET

Time intervals	x_{kF}^t	x_{ssF}^t	x_{sF}^t	$x_{kF}^t + x_{ssF}^t$
2	5.0	0	6.4	5.0
3	10.0	48.0	0	58.0
4	7.0	0	4.0	7.0

Stage 2 implies development of a new delivery schedule for intervals 3 and 4. SC solves problem (5)-(9) and obtains new deliveries under contract, Tab. 4. According to (5) the expected profit of SC S_N for intervals 2 – 4 with the new delivery schedule is \$ 697.0. Taking into account profits in intervals 1 and 2 the total expected profit is \$1346.3.

TABLE 4
UPDATED DELIVERIES UNDER BS

Time intervals	x_{kN}^t	x_{ssN}^t	x_{sN}^t	$x_{kN}^t + x_{ssN}^t$
3	10.0	48.0	0.0	58.0
4	11.0	54.0	0.0	65.0

Estimation of the profit S_C expected after the BC cancellation needs solution of problem (10)-(14) at *Stage 3.* If the contract is cancelled and delivery under contract is interrupted from interval 3, the SC will buy electricity in the spot market and x_{sc}^3=10.0, x_{sc}^3=11.0 MWh. SC will pay to GC financial compensation ΔF =75(58.0+7.0)=\$4875. Taking into account profits got in intervals 1 and 2 the expected total profit of SC in this case S_C is equal to minus \$3645.4. The negative value of S_C means loss for SC.

Comparison of S_F, S_N, and S_C shows that the best decision for the SC is correction of BC. Correction has an aim to implement new deliveries under BC in intervals 3 and 4, Tab 3. After making the decision SC proposes new contract parameters to GC. If the new delivery schedule is approved by GC and System Operator it comes into force from interval 3. Otherwise, SC should continue to receive electricity under BC according to the fixed delivery schedule.

VI. CONCLUSION

The paper considers the sequence of actions to be implemented for contract correction during the BC period. The correction may reduce the risk of financial loss and increase the profit of the contract in force.

Contract parameters necessary for contract correction and cancellation are described. Decision making process on contract correction consists of the sequence of stages dealing with forecast updating, actual and expected profit estimation and proposal approval.

The statements of optimization problems are developed for decision making on BC correction and cancellation.

Numerical example illustrates applicability of the suggested technique for contract parameters correction or contract cancellation.

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VIII. BIOGRAPHY

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