

# The Broker Strategies of a Winner Agent in Power TAC

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## Abstract

In the light of government's energy transformation policies, the future electricity grid will encourage new participants such as local producers, storage units and interruptible consumers to the current electricity grid along with the challenge of sustainability. The Power Trading Agent Competition (Power TAC)<sup>1</sup> is a comprehensive simulation platform to enable and verify various smart grid studies from the perspective of sustainability as well as an annual competition in which autonomous agents trade in energy markets and make profits. AgentUDE won the Power TAC 2014 Final as the newest agent of the competition utilizing an adaptive and reactive agent. This paper details the basic retail and wholesale market strategies of AgentUDE as well as tournament results.

## 1. Introduction

While new energy participants are being involved in the electricity grid that make possible to store electricity in a distributed way, future smart grid has been an inspiring theme for researchers and businesspersons. At this point, data, money and energy stream between these energy actors have to be practiced and confirmed within a realistic smart grid simulation environment in order to close the gap between theory and practice. Power TAC offers an open source, future smart grid simulation with the purpose of addressing a solution to this challenge through allowing autonomous broker agents to trade in a smart grid environment. The platform enables numerous smart grid studies based on the power models such as customer and renewable energy models. Besides, it simulates typical energy markets such as wholesale market, retail and balancing markets [1,2].

From the brokers' side, there is a limited number of publications are available. From those, TacTex implements a "Markov Decision Process" method to minimize costs in the wholesale market [3]. Another broker team, cwiBroker utilizes a trading technique using equilibriums in continuous markets and a strategy inspired by Tit-for-Tat in the Iterated Prisoner's Dilemma [8]. Besides, there are a number of review papers in which key performance indicators are used [4][7].

This paper explains the wholesale, retail and balancing market activities of AgentUDE as well as a comprehensive performance assessment of the tournament. In the meantime, the key focus of this paper is the aggressive tariff strategy of AgentUDE, which provided the first place in Power TAC 2014 Final games.

## 2. The Power TAC 2014 Final Games

Power TAC 2014 Final games were held in April 2014 during the AMEC/TADA 2014 Workshop<sup>2</sup>. Here, 72 games were played in 3-player, 5-player and 8-player game sizes. As

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<sup>1</sup> Power TAC, <http://www.powertac.org>.

<sup>2</sup> AMEC/TADA Workshop 2014, <http://users.ecs.soton.ac.uk/vr2/amectada2014>.

a result, AgentUDE took the first place as the newest participant among seven brokers by means of having the most profit.

**Table 1.** Official results of Power TAC 2014 Final games.

Broker	Game Size 3	Game Size 5	Game Size 8	Total
AgentUDE	0.279	1.499	1.976	3.754
cwiBroker	1.557	1.026	0.600	3.183
CrocodileAgent	0.952	-0.893	-0.560	-0.501
Maxon	-0.921	0.142	-0.643	-1.423
Mertacor	-0.945	-0.492	-0.865	-2.302
coldbroker	-0.922	-1.281	-0.509	-2.712

Table 1 presents the official results of Power TAC 2014 Final games. Game sizes represent the number of competing brokers. Here, total profits of the brokers are normalized for each game size and summed in order to generate final ranking. In total, seven broker agents participated in the tournament. Unfortunately, TacTex is not counted in the official results since TacTex team decided to withdraw from the tournament due to some problems. At first sight, it can be clearly understood that AgentUDE and cwiBroker dominated the games by having the best scores among other brokers. AgentUDE took the first place in game size 5 and game size 8, and third place in game size 3. A comprehensive review paper is already published by Jurica Babic and Vedran Podobnik [7].

### 3. AgentUDE as a Broker Agent

AgentUDE was developed at University of Duisburg-Essen in DAWIS chair. The Power TAC 2014 was the first tournament that AgentUDE joined in.

Generally speaking, the broker facilities of AgentUDE can be divided into three sets: Wholesale, retail and balancing market activities. Due to the complexity of the broker activities, these modules are explained separately in the following sections.

#### 3.1 Wholesale Market Activities

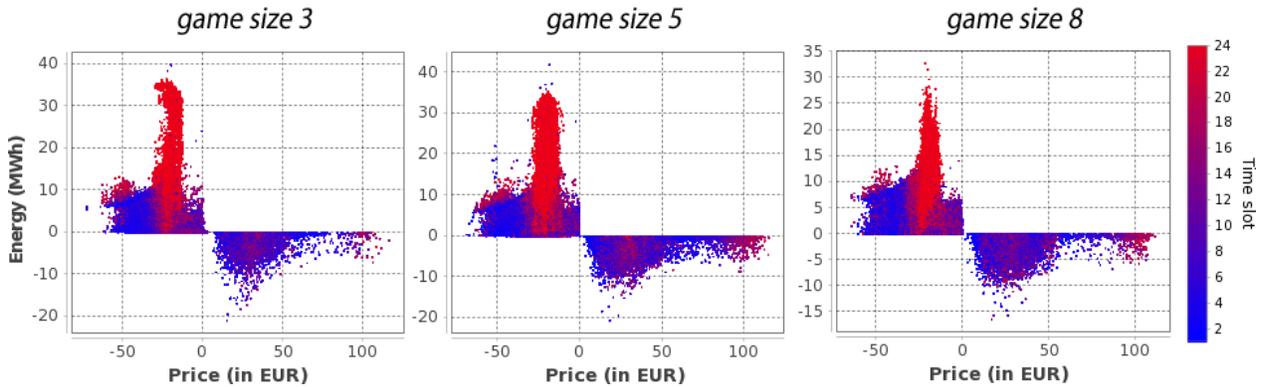
Wholesale trading has a vital role for all brokers since they have to diminish their imbalanced energy. Beside that brokers are challenged to buy the cheapest energy in order to be flexible against their competitors. In the end, customers tend to subscribe to the cheapest tariff available.

AgentUDE uses an adaptive way to predict future wholesale market price. Each market order is calculated using an adaptive method. The Price estimation takes place in two stages: The base and final price determination. Note that base price is non-optimized and used as a prediction value for a future time slot.

$$P_{t,T} = C_{t-1,T} * \omega_1 + \left( \frac{1}{t+24-T} \sum_{i=t}^{t+24-T} C_{i,T} \right) * \omega_2 + Cost * \omega_3$$

Where  $P$  is the predicted base price for the given current time slot  $t$  and future time slot  $T$ . Here,  $C$  stands for the market equilibrium price for  $t$  and  $T$ .  $Cost$  is the wholesale market

bidding cost up to time slot  $t$ . Note that the formula satisfies  $\omega_1 + \omega_2 + \omega_3 = 1$  and  $C_{t,T} = \{ \text{Cost} : C_{t,T} = 0$ .

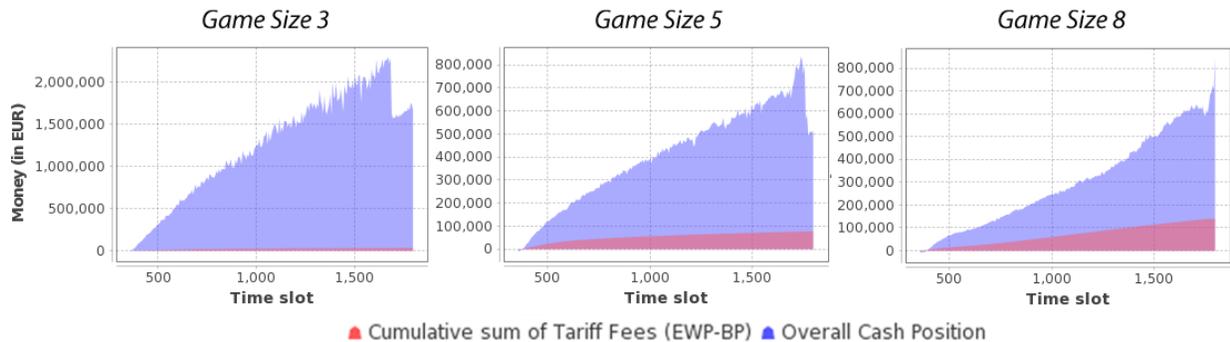


**Fig. 1.** Cleared bids and asks of AgentUDE.

Figure 1 demonstrates the cleared bids and asks of AgentUDE in all game sizes. Generally, bidding activity of AgentUDE is narrowed between 25-15 EUR/MWh. AgentUDE's average wholesale market cost is 22.7 EUR/MWh and selling average is 28.9 EUR/MWh where the consumption share is around 23% of the total energy distribution (See Table 2). In this landscape, AgentUDE is the second best broker after cwiBroker in terms of the lowest market cost. Despite these cost differences, it is difficult to grade brokers based on the wholesale market activity. Because, these values are very close to each other and do not have a serious contribution to the overall profits of the brokers.

### 3.2 Retail Market Activities

AgentUDE implemented a new approach in the retail market, which has not used by another broker so far: Publishing aggressive tariffs, relatively with the lowest tariff values and consumer binding tariff fees such as early withdrawal penalty and bonus payment. During the course of the competition, this strategy provoked other brokers to publish cheaper tariffs which triggered early withdrawal penalties of AgentUDE tariffs. As a summary, AgentUDE forced its customers to change their tariffs. In the end, this strategy provided about 20% contribution to overall cash balance. Following figure demonstrates the contribution of tariff fees.



**Fig. 2.** Cumulative cash position and contribution of tariff fees.

Based on the data in Table 2, the tariff publication frequency of AgentUDE is 27 which is the largest number of tariffs submitted to the retail market. After AgentUDE, Mertacor

and TacTex are runner-up tariff publishers. On the other side, only AgentUDE, CrocodileAgent published production tariffs. However, AgentUDE publishes a new producer tariff if the sum of minimum production tariff value and distribution fee is less than wholesale market cost. Otherwise, production tariffs are not published.

**Table 2.** Tariff activities of the brokers in Power TAC 2014 Final.

Broker	$N_{tariffs}$	Frequency	$M_{cons}$ ( $\text{C}/kWh$ )	$M_{prod}$ ( $\text{C}/kWh$ )	$S_{cons}$ ( $\text{C}/kWh$ )	$S_{prod}$ ( $\text{C}/kWh$ )	$P_{bids}$ ( $\text{€}/MWh$ )	$P_{asks}$ ( $\text{€}/MWh$ )
AgentUDE	3791	27	6.0	1.52	6.3	1.52	22.70	28.90
cwiBroker	1071	97	7.8	-	7.8	-	22.49	27.60
CrocodileAgent	1106	94	7.1	1.58	9.7	1.58	43.11	13.08
Maxon	1426	73	522	-	7.7	-	23.15	53.30
Mertacor	2732	38	7.3	-	6.7	-	26.36	-
coldbroker	607	171	5.3	-	5.4	-	27.87	27.49
default broker	144	725	50	1.50	50	1.50	29.10	26.49
TacTex	1670	62	7.3	-	5.6	-	22.94	19.81

Table 2 lists the tariff statistics of the brokers.  $N_{tariffs}$  is the number of total published tariffs. Frequency indicates the publication cycle in terms of time slot.  $M_{cons}$  is the mean of consumption tariffs. Similarly,  $M_{prod}$  is the mean of production tariffs.  $S_{prod}$  and  $S_{cons}$  are the average prices of energy that is bought from customers and sold to customers. Finally,  $P_{bids}$  and  $P_{asks}$  indicate the average bidding and asking prices. AgentUDE uses multiple parameters to create competitive tariffs. These parameters are the number of subscribed consumers, cash position, market cost, number of active brokers, competitors' tariffs, current time slot. The rhythm indicates the profit achievement acceleration of the broker where a higher value means better profit performance. The idea behind it is to improve decisions in tariff creations and wholesale market activities.

Thanks this strategy, AgentUDE collected serious amount of cash from tariff fees. Surprisingly, only AgentUDE and TacTex benefitted from tariff fees. Maximum profit achieved from game size 8 due to high competition. In order to have more profit from this strategy, some requirements have to be met: Active customers and good competitors. Customers have to have some reasonable and profitable tariffs to make a transfer decision. If not, customers tend to ignore them and resume their tariff. In this case, the aggressive tariff strategy of AgentUDE does not work well. The second condition is also related to first one: Another broker has to offer competitive tariffs so that customers can evaluate their position and change their tariffs if needed.

### 3.3 Balancing Activities

Brokers have to meet their demand and supply. If they cannot, they lose their serious portion of profits by paying huge imbalance fees. The most challenging issue at this point is to predict future consumptions. AgentUDE uses the consumption data of customers to make predictions. However, this method does not always give the best result due to changing conditions such as weather. Balancing market sends signals to brokers regarding their imbalance status. Consequently, needed energy is calculated as the sum of predicted consumption and imbalance signal. Final amount of needed energy is smoothed and submitted to the market.

AgentUDE is the second best broker who pays less money to distribution utility. However this payment only consists of imbalance penalties since the total imbalance energy is close to zero. For a typical negative imbalance, brokers have to pay price of imbalanced energy in addition to penalty fee. TacTex and cwiBroker paid 100k EUR for their 1700 MWh and 1450 MWh imbalanced energy, respectively. If a comparison is needed at 70k EUR, where the imbalanced energy of AgentUDE was almost zero, TacTex and cwiBroker paid this 70k EUR plus 17.6 EUR/MWh and 20.6 EUR/MWh for their negative imbalances. In respect to wholesale market costs shown in Table 2, TacTex and cwiBroker got a good deal on the balancing market over AgentUDE.

#### **4. Conclusion**

This paper details the trading approach of AgentUDE from the business perspective. As has been noted in the wholesale market section, the gaps between the market performances of brokers are very close to each other. It is clearly seen that all the brokers have a decent market performance based on their customer profiles and risk levels. What makes AgentUDE one step ahead is its competitive and aggressive tariff strategy. On the other hand, the results showed that AgentUDE earned the serious portion of its profit through tariff fee manipulation. This strategy was never used before by another broker and, no doubt, this ability made AgentUDE more competitive and flexible against other brokers. Lastly, Power TAC 2014 Final showed that it has an enormous benchmark capacity for smart grid studies.

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