VidyutVanika: An RL and Game Theory based Broker for Power Trading

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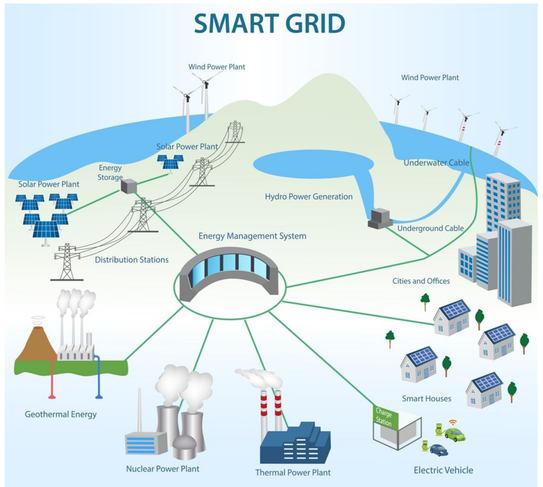
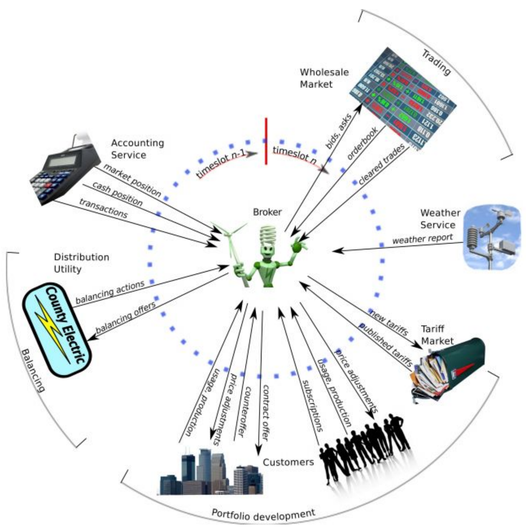
Introduction

PowerTAC is a simulation platform that replicates crucial elements of a smart grid.



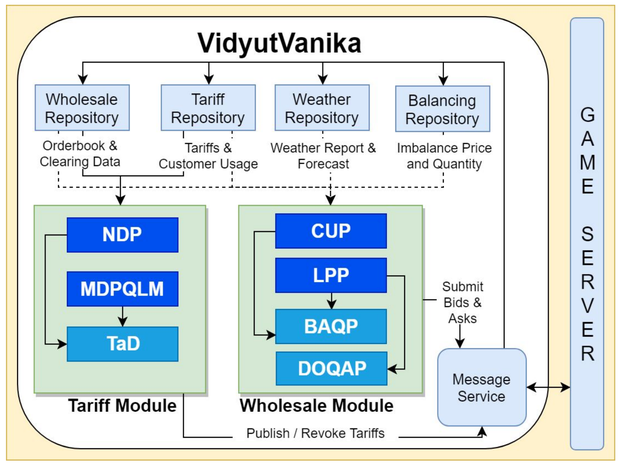
Source - GovTech.com



Source - The 2018 PowerTAC Specification

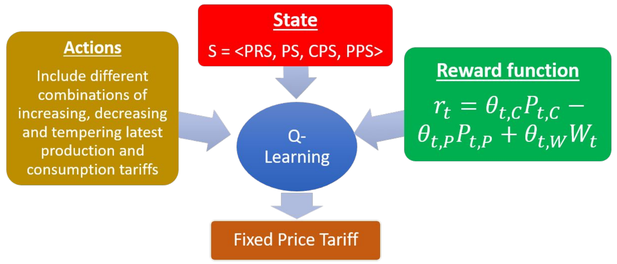
Objectives

- React to competing tariffs & increase market share to generate more revenue.
- Decrease transmission capacity costs.
- Decrease energy procurement cost from wholesale market.



Tariff Module (TM)

- **MDP & Q-Learning Module (MDPQLM):** Models tariff market as an MDP, and produces Fixed Price Tariffs (FPTs).



- **Net Demand Predictor (NDP):** Estimates net demand of the market for future twenty-four time slots.

$$\hat{D}_{t+k} = \beta D_{t+k-24} + (1-\beta) D_{t+k-168}$$

- **Tariff Designer (TaD):** Modifies the FPT from MDPQLM into a Time-of-Use (TOU) tariff to avoid peak usage of the subscribers coinciding with market peak.

$$\pi_{t+k} = P_{t,C} + \rho\left(\hat{D}_{t+k,T} - \frac{\sum_{j=1}^{24}\hat{D}_{t+j,T}}{24}\right)$$

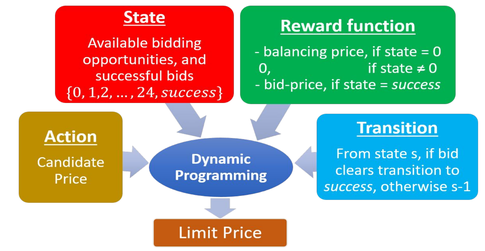
Wholesale Market (WM)

The wholesale market involves 24 PDAs for a target timeslot *t*.

- **Customer Usage Predictor (CUP):** Predicts the customer usage for a future time slot using past usage and weatherdata. It uses a NN with 2 hidden layers of size 7 each, and 10 epochs of training.
- **Dummy Order Quantity And Price (DOQAP):** Places dummy bids in auctions to predict Last Clearing Price

$$LCP(s) = \min(dummy\text{-}bids_{cleared}, limit\text{-}price[s]_{cleared})$$

- **Limit Price Predictor (LPP):** Modeled as two MDPs - one for buying and another for selling.



$$V(s) = \begin{cases} balancing\text{-}price, & \text{if } s = 0 \\ \min\limits_{limit\text{-}price} \{p_{cleared} \times limit\text{-}price \\ +(1 - p_{cleared}) \times V(s-1)\}, & \text{if } s \in [1, 24] \end{cases}$$

$$p_{cleared} = \frac{\sum_{ac \in auction[s], ac.\text{LCP} < limit\text{-}price} ac.\text{cleared-amount}}{\sum_{ac \in auction[s]} ac.\text{cleared-amount}}$$

- **Bid/Ask Quantity Predictor (BAQP):** Spreads the purchase of the predicted energy amount from CUP among the available bidding opportunities.

$$e(s) = \begin{cases} \frac{E_{t+s}}{\sum_{j=s}^{24} \frac{limit\text{-}price[j]}{limit\text{-}price[s]}}, & \text{if } E_{t+s} > 0 \\ \frac{E_{t+s}}{\sum_{j=s}^{24} \frac{limit\text{-}price[s]}{limit\text{-}price[j]}}, & \text{if } E_{t+s} < 0 \\ 0, & \text{if } E_{t+s} = 0 \end{cases}$$

Results

The Power TAC 2018 Finals had 7 brokers and a total of 324 games. Aggregating different modules, **VidyutVanika (VV) finished runner-up in the PowerTAC 2018 Finals**, thus showcasing its performance.

Broker	7-Broker	4-Broker	2-Broker	Total
AgentUDE	1.091	0.634	1.565	3.291
VidyutVanika	1.056	1.061	0.336	2.453
CrocodileAgent	0.648	0.455	0.552	1.655
SPOT	-0.041	0.322	0.359	0.64
ColdPower18	0.139	0.078	-0.326	-0.109
Bunnie	-1.254	-0.3	-0.609	-2.163
EWIIS3	-1.638	-2.25	-1.878	-5.766

PowerTAC 2018 Finals - Normalized Scores

Broker	7-Broker		4-Broker		2-Broker		Total (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
VidyutVanika	39	21	54	14	19	5	55	20
AgentUDE	39	26	31	21	22	2	45	24
CrocodileAgent	8	34	13	41	15	9	18	41
SPOT	0	0	16	19	9	15	12	17
ColdPower18	0	3	5	29	8	16	6	24
Bunnie	13	15	21	16	9	15	21	22
EWIIS3	1	1	0	0	2	22	1	11

PowerTAC 2018 Finals - Number of 1st & 2nd place standings

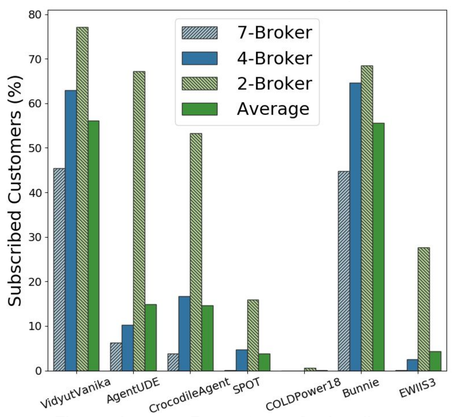


Figure: Average Percentage of subscribers

- TM contributes substantially to VidyutVanika's profit.
- VidyutVanika won the most number of games, and second lowest games with negative profit, while having highest market share.
- VidyutVanika maintained one of the best tariff market income-to-cost ratio (1.14), while having highest market share.

Publication

Susobhan Ghosh, Easwar Subramanian, Sanjay P. Bhat, Sujit Gujar, and Praveen Paruchuri. *VidyutVanika: A Reinforcement Learning Based Broker Agent for a Power Trading Competition*, **AAAI 2019 Main Track**

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