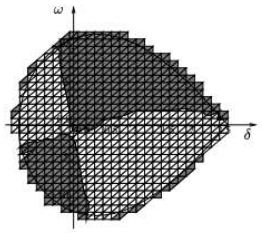
Reinforcement learning: a generic tool for solving sequential decision-making problems for electrical systems



Prof. Damien ERNST

LIÈGE université

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photovoltaic panels

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Environ 18 500 000 résultats (0,49 secondes)

Photovoltaics - Wikipedia

https://en.wikipedia.org/wiki/Photovoltaics ▾ Traduire cette page

Aller à **Solar cells** - Solar **cells** produce direct current electricity from sunlight which can be used to power equipment or to recharge a battery. The first practical application of photovoltaics was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected ...

Photovoltaic effect · Solar cell · Growth of photovoltaics · Concentrator photovoltaics

Solar panel - Wikipedia

https://en.wikipedia.org/wiki/Solar_panel ▾ Traduire cette page

Photovoltaic **solar panels** absorb sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged, connect assembly of typically 6x10 photovoltaic **solar cells**. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in ...

Efficiencies · Performance and ... · Price · Mounting and tracking

Images correspondant à photovoltaic panels

Plus d'images pour photovoltaic panels — Signaler des images inappropriées

Which Solar Panel Type is Best? Mono-, Polycrystalline or Thin Film?

energyinformative.org/best-solar-panel-monocrystalline-polycrysta... ▾ Traduire cette page

6 août 2017 - You are thinking about buying **solar panels**, but got confused about which type to go for? You're at the right place. There's a myriad of variables that you should take into account when you are buying a solar photovoltaic (PV) system – our job here at Energy Informative is to help you sort through them! In this ...

What are solar photovoltaic panels and why have them? Install solar ...

www.ecocetera.com/solar-pv-explained/ ▾ Traduire cette page

Solar **photovoltaic panels** (PV) contain semi-conductors such as silicon, which convert solar radiation into electricity. The electricity produced can be used.

2018 Most Efficient Solar Panels on the Market | EnergySage

https://news.energysage.com/what-are-the-most-efficient-solar-pan... ▾ Traduire cette page

Acheter des photovoltaic panels Annonce sponsorisée

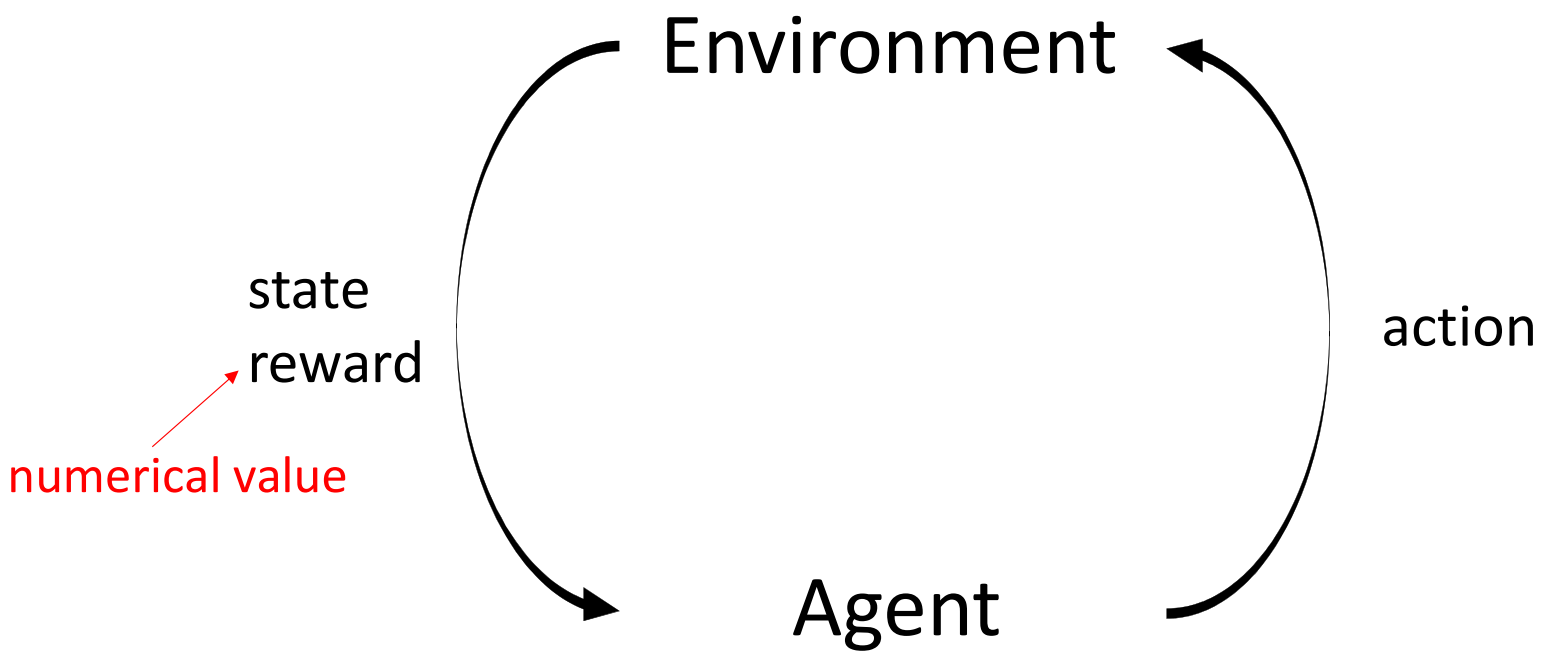
40W Semi Flexible Solar Panel PV Battery Charger
102,90 € · 89,99 £GB
PK Green
+ 12,58 € de frais de port
Par Google

Afficher les résultats pour

Panneau solaire
Un panneau solaire est un dispositif technologique énergétique solaire à base de capteurs solaires ...

Cellule photovoltaïque
Une cellule photovoltaïque, également dénommée cellule solaire, est un composant électronique qui, ...

Reinforcement learning agent



State: (i) the battery level (ii) *Everything you know about the market*
Reward: The money you make during the market period.

+ the energy market

The battery setting for the next market period.

The battery controller

Table 1. Summary of RL considerations for electric power system control/decision

Problem	Type of control	RL method	Reference(s)
Electricity market simulation	Market decision	Q-learning	Harp et al. (2000) Rahimiyan et al. (2010) Nanduri and Das (2007) Lincoln et al. (2012) Kim et al. (2016) Krause et al. (2006)
Transient angle instability	Emergency	Q-learning	Ernst et al. (2004) Glavic (2005) Glavic et al. (2005a) Glavic et al. (2005b) Li and Wu (1999)
		Fitted Q iteration	Ernst et al. (2009)
		Policy search	Mohagheghi et al. (2006)
Oscillatory angle instability	Emergency	Q-learning	Ernst et al. (2004) Wang et al. (2014) Glavic et al. (2005a) Ademoye and Feliachi (2012) Karimi et al. (2009)
Voltage control	Normal	Q-learning	Xu et al. (2012) Vlachogiannis et al. (2004)
AGC (Automatic) generation control)	Normal	$Q(\lambda)$ with elig. traces	Yu et al. (2011)
		Q-learning	Daneshfar and Bevrani (2010) Ahamed et al. (2002)
		$R(\lambda)$	Yu et al. (2012b)
Economic dispatch	Normal	Q-learning	Jasmin et al. (2011) Yu et al. (2016)
Wide-area control	Emergency	TD	Yousefian et al. (2016)
		Q-learning	Yan et al. (2016) Hadidi and Jeyasurya (2013)
Households control	Normal	Q-learning	Wang et al. (2016) Yan et al. (2016)
Wind generation control	Normal	Q-learning	Wei et al. (2015) Tang et al. (2015)
		$Q(\lambda)$	Yu et al. (2012a)
Demand control	Normal	Fitted Q iteration	Ruelens et al. (2016) Vandael et al. (2015)
System restoration	Restorative	Q-learning	Ye et al. (2011)
Congestion management	Emergency	Q-learning	Zarabbian et al. (2016)
Microgrids control	Normal	Q-learning	Khorramabady et al. (2015) Li et al. (2012)
		Policy search	Venayagamorthy et al. (2016)

Table taken from: "Reinforcement Learning for Electric Power System Decision and Control: Past Considerations and Perspectives". M. Glavic, R. Fonteneau and D. Ernst. Proceedings of the 20th IFAC World Congress.

Learning:

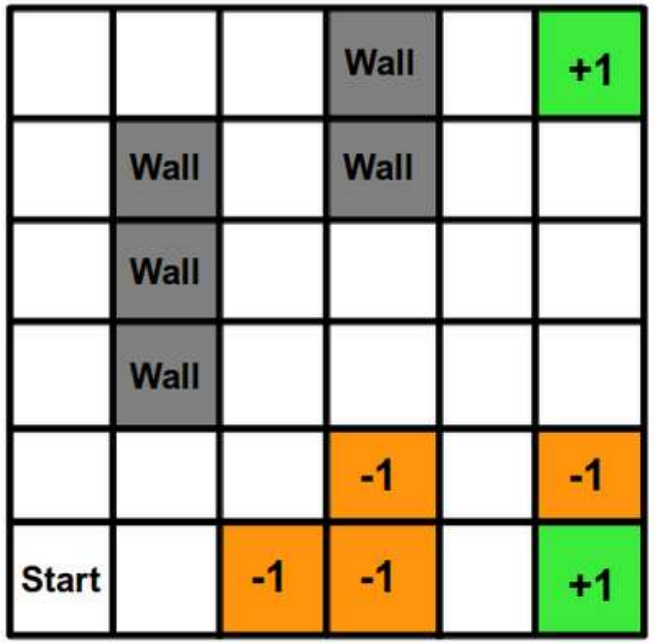
Input : x_t, u_t, r_t and x_{t+1}

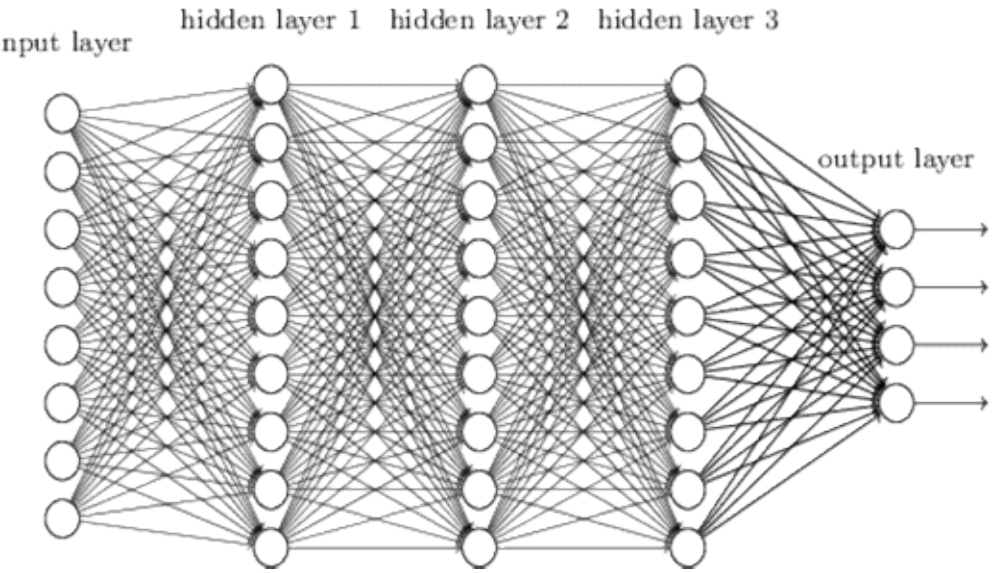
$$\delta \leftarrow (r_t + \gamma \max_{u \in U(x_{t+1})} Q(x_{t+1}, u)) - Q(x_t, u_t)$$

$$Q(x_t, u_t) \leftarrow Q(x_t, u_t) + \alpha\delta$$

Exploration/exploitation: Not always take the action that is believed to be optimal to allow exploration.

Generalization: Generalize the experience gained in some states to other states.

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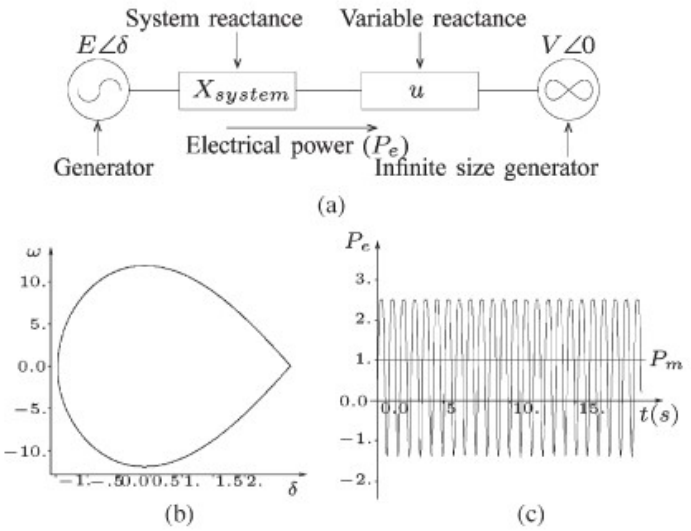
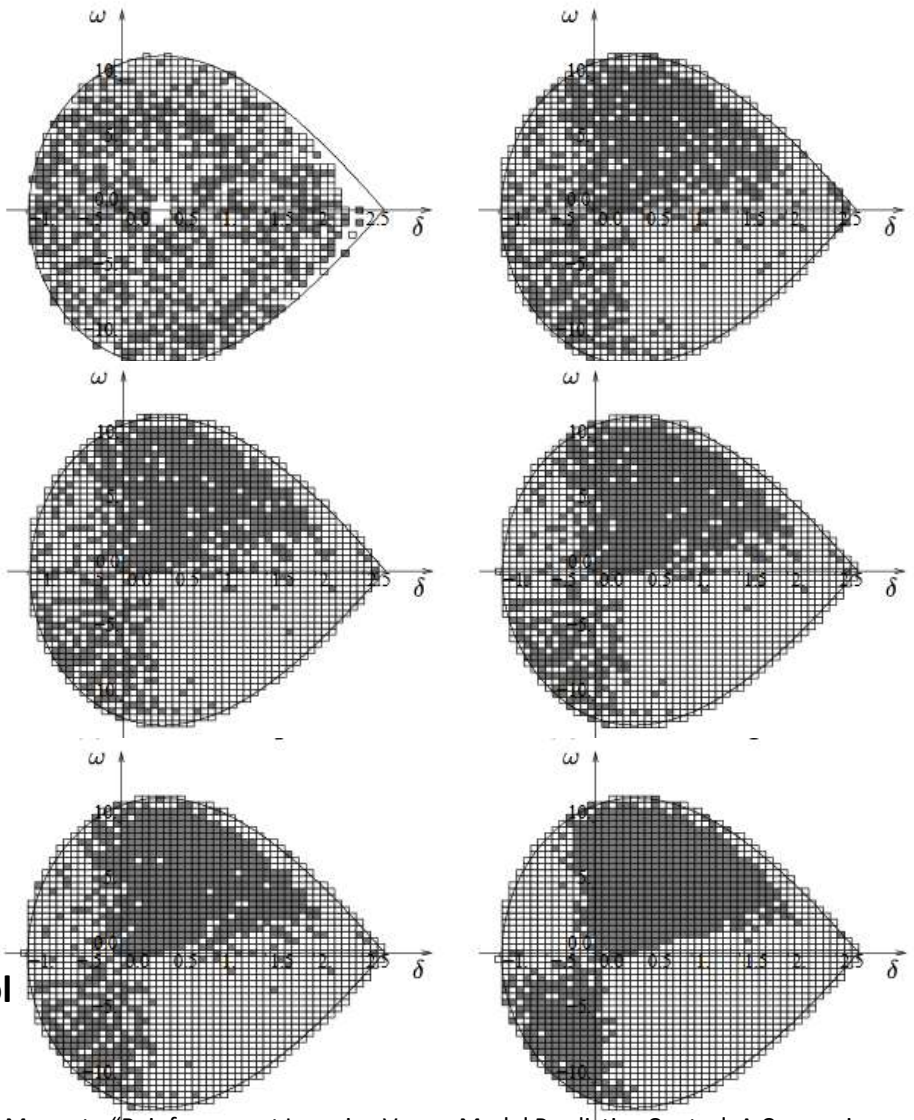
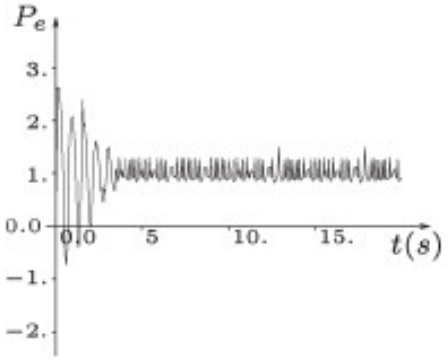
hidden layer 1
hidden layer 2
hidden layer 3
output layer


80
OXYGEN



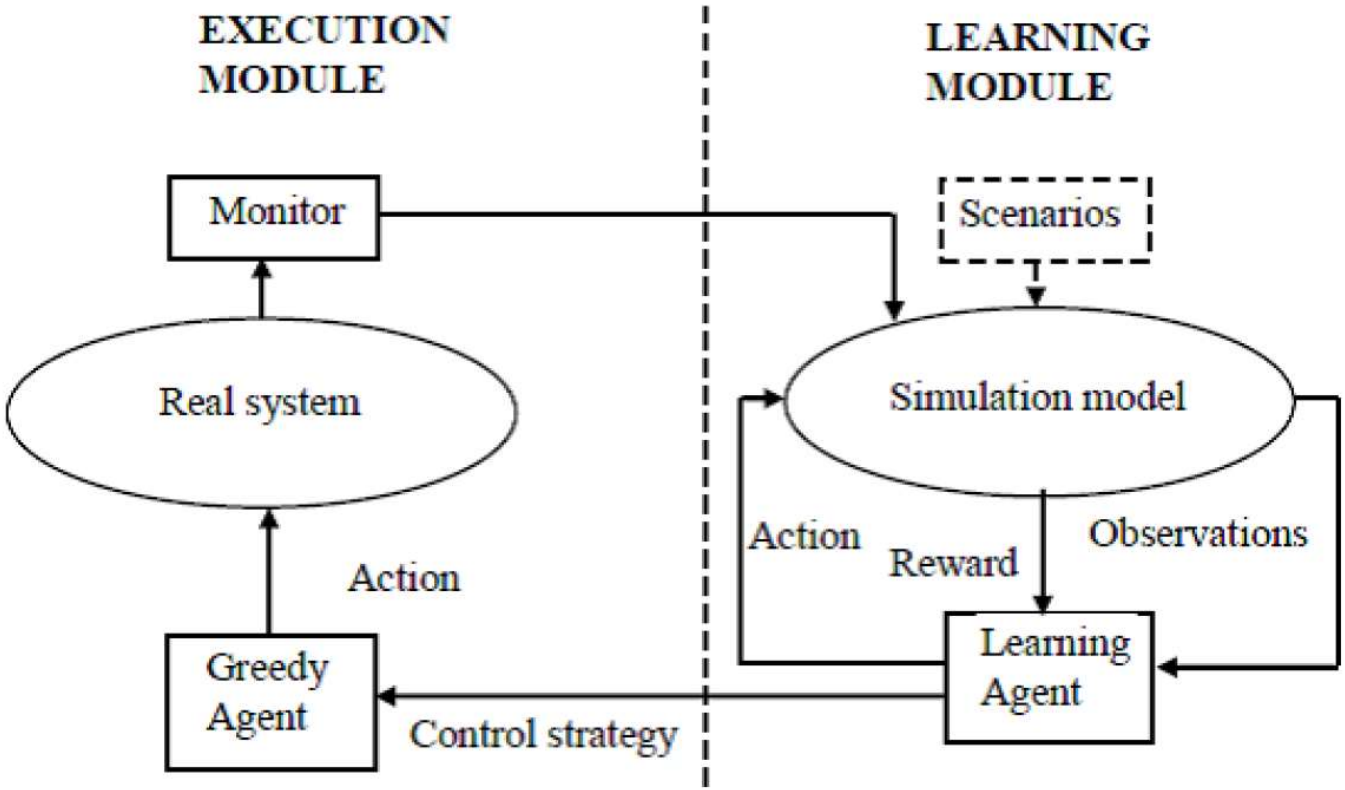
Learning phase





Effect of the resulting control policy

First control law for stabilizing power systems every computed using reinforcement learning. More at: "Reinforcement Learning Versus Model Predictive Control: A Comparison on a Power System Problem". D. Ernst, M. Glavic, F.Capitanescu, and L. Wehenkel. IEEE Transactions on Syestems, Man, An Cybernetics—PART B: Cybernetics, Vol. 39, No. 2, April 2009.


EXECUTION MODULE
LEARNING MODULE
Monitor
Scenarios
Real system
Simulation model
Action
Reward
Observations
Action
Greedy Agent
Learning Agent
Control strategy

Reinforcement learning for trading in the intraday market

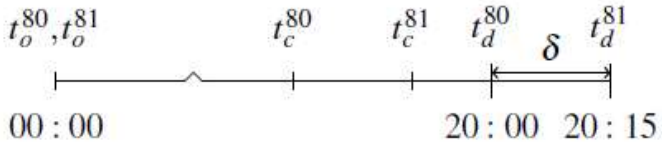


Figure 1: Trading time-line for products Q-80 and Q-81

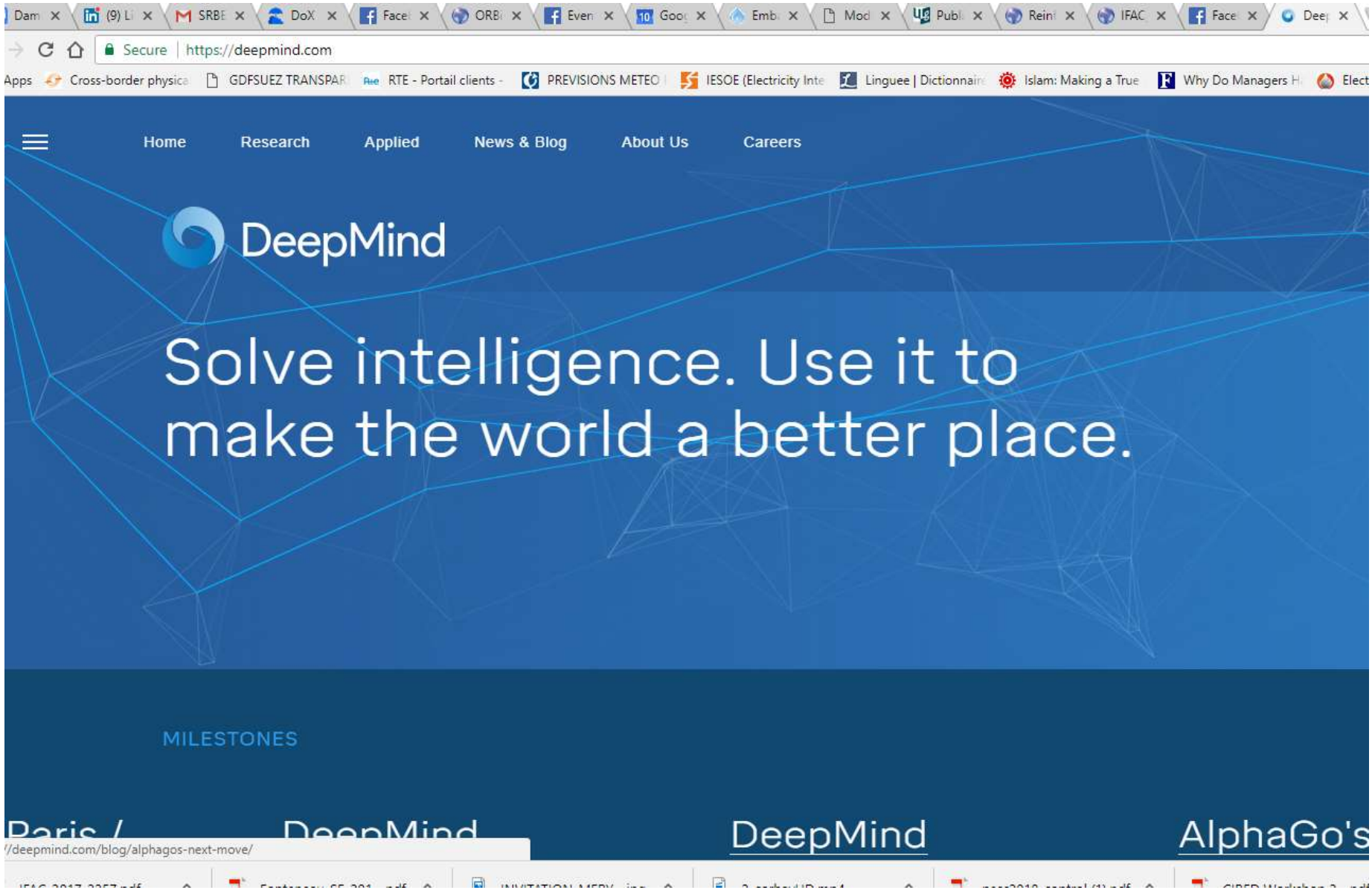
Table 1: Order Book for Q-80 and time-slot 20:00-20:15

i	Type	v [MW]	p [€/MWh]	
4	"Sell"	6.25	36.3	
2	"Sell"	2.35	34.5	⟵ ask
1	"Buy"	3.15	33.8	⟵ bid
3	"Buy"	1.125	29.3	
5	"Buy"	2.5	15.9	

Complex problem:
- Adversarial environment
- Highly dimensional
- Partially observable

Best results obtained with optimisation of strategies based on past data together with supervised learning to learn from the optimised strategies (imitative-learning type of approach)

More: "Intra-day Bidding Strategies for Storage Devices Using Deep Reinforcement". I. Boukas, D. Ernst, A. Papavasiliou, and B. Cornélusse. Proceedings of the 2018 15th International Conference on the European Energy Market (EEM).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