The impact of cycling costs due to fatigue damage on optimal CCGT operations

Harvard Electricity Policy Group Meeting

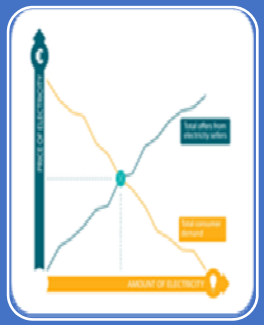
Uneconomic Dispatch: Frontier Challenges in Dispatch and Pricing

Washington, DC, March 10-11, 2016

Sonja Wogrin

Universidad Pontificia Comillas, Madrid, Spain

Economic and technical decisions of CCGT operations



Electricity Market

Optimal pricing and optimal bidding into the market. Economic/commercial decision making – profit maximization of plant (or company).

Power Plant Operations

Optimal commitment, dispatch and power output over time. Technical decision making – cost minimization of total operating costs.

Sequential decision processes that involve CCGT operations

1 Commercial

- Providing power/price bids into the electricity market (economic operators within firm).

2 MO/ISO

- Market clearing process (MO/ISO) yields dispatch of plants, and how much power and/or reserve they have to provide over time.

3 Technical

- The power plant is operated (by technical staff - plant operators) to provide the scheduled output in an optimal way (usually cost-optimal).

4 Commercial

- Firm earns markets' prices for power produced by plant.

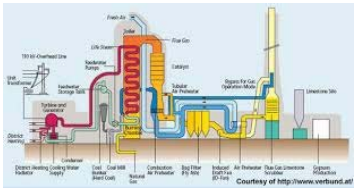
Are we pricing/dispatching CCGTs correctly?

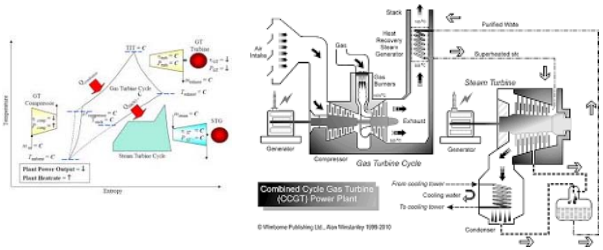
How the ISO sees the CCGT

CCGT 1
Pmax, Cost…

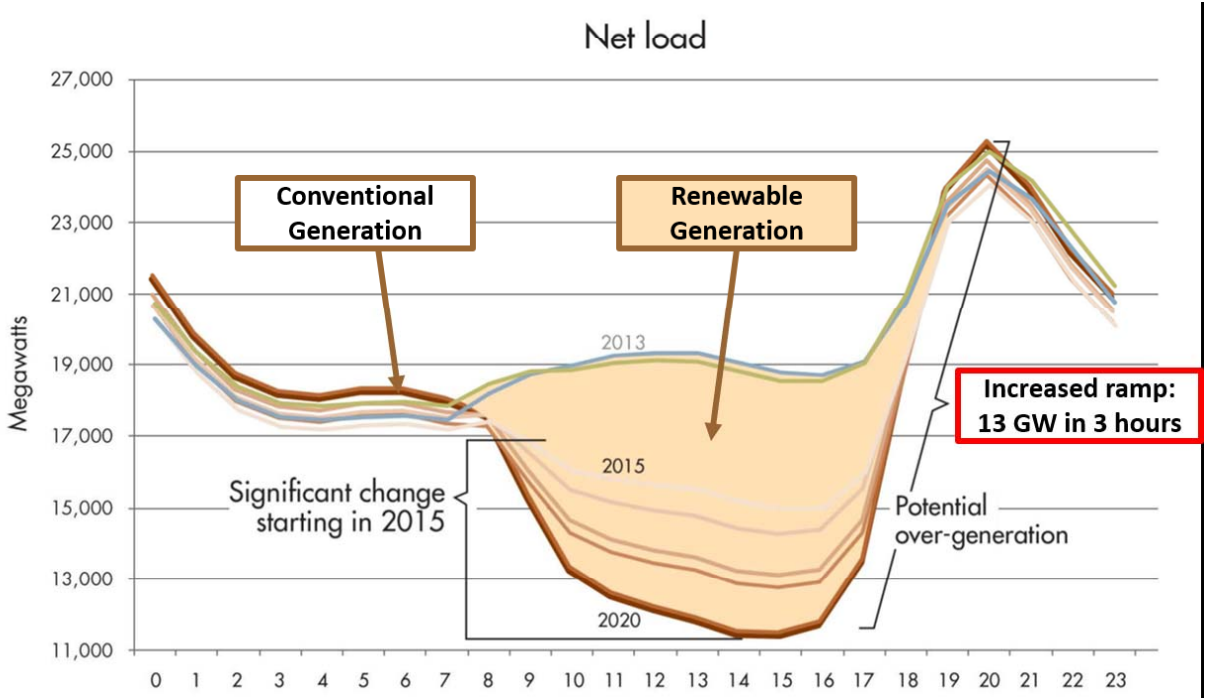
Bus 1

How the GENCO sees the CCGT





Are we pricing/dispatching CCGTs correctly?

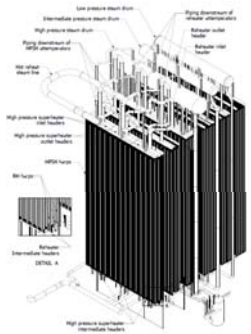


Unit-commitment with useful life expenditure costs due to fatigue

- In collaboration with Innomerics we propose an integrated approach that allows **optimizing the operation and dispatch** of a CCGT,

$$\min_{\Omega} \sum_{t\in\mathcal{T}} \sum_{x\in\mathcal{M}} \left\{ C_x^{NL} u_{xt} + C_x^{LV} e_{xt} + C_x^{F} \Delta p_{xt} + \sum_{y\in\mathcal{M}_{xy}^{F}} C_{xy}^{T} v_{xyt} \right\} + \sum_{t\in\mathcal{T}} \left\{ C_t^{DD} w_t + C_t^{UD} z_t \right\}$$

while taking into account the actual cost associated to life expenditure due to accumulated **fatigue damage during cycling**.

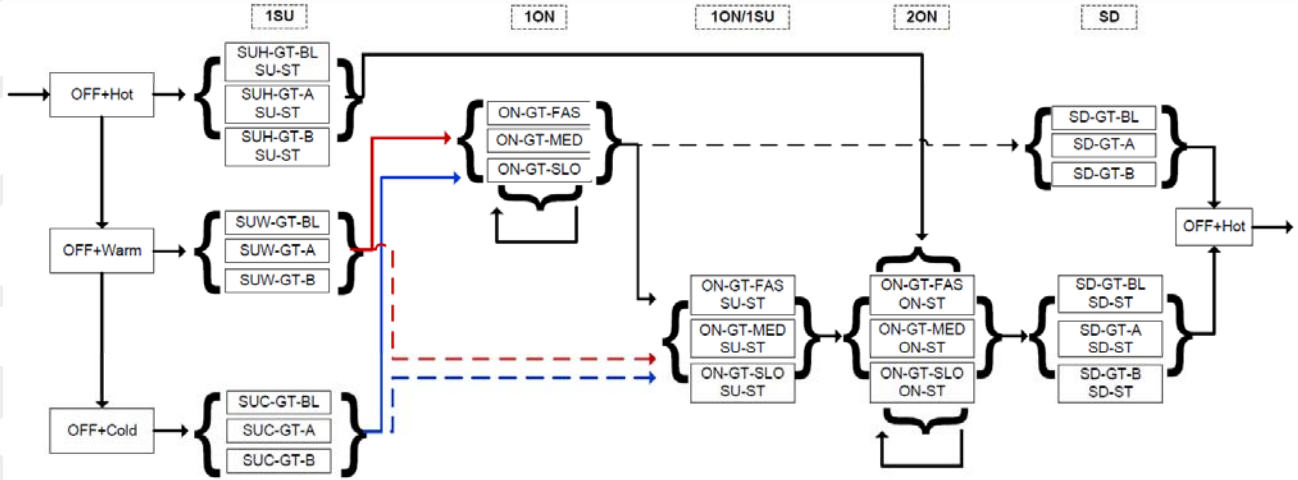


Heat recovery steam generator

Novelties of integrated approach

- Technical details are modeled in great detail in order to characterize operational flexibility and associated wear-and-tear cost.

Feasible transitions of operating modes



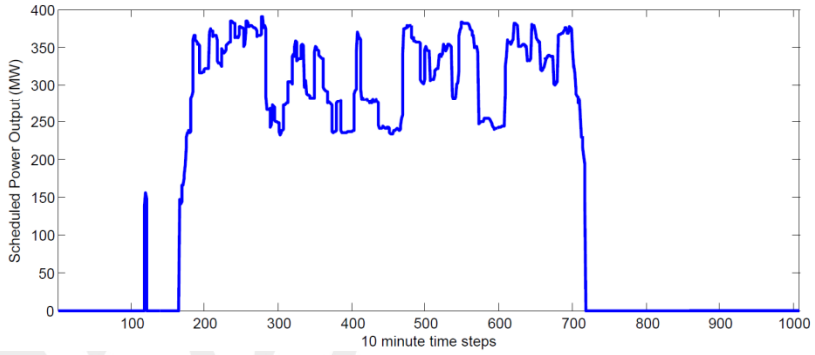
SU	startup	ST	steam turbine	SD	shutdown
H/W/C	hot/warm/cold	BL/A/B	baseline/alternative A/alternative B	ON	on-mode
GT	gas turbine	FAS/MED/SLO	fast/medium/slow ramping	OFF	off-mode

Impact of wear-and tear costs on dispatch

Numerical tests for a 1x1 CCGT

Hypotheses:

- the market has already been cleared;
- the scheduled power output has been decided;
- market prices are exogenous;
- energy only market (no reserves);
- 1 week of operation; 10-minute time steps.



Numerical tests for a 1x1 CCGT

Operating Costs and Profits

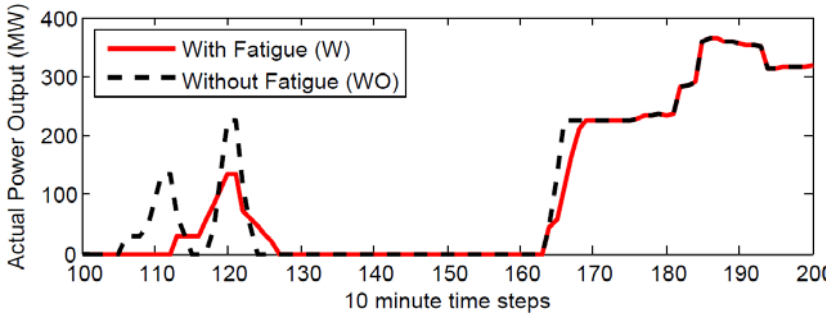
Cost Concept	Taking into account fatigue (M€) ; [%]	Disregarding fatigue (M€) ; [%]
Total Cost	1.340 ; [100]	1.378 ; [100]
No Load Cost	0.173 ; [12.9]	0.174 ; [12.6]
Linear Variable Cost	1.147 ; [85.6]	1.152 ; [83.6]
Ramp Fatigue Cost	0.002 ; [0.2]	0.005 ; [0.4]
Transition Cost	0.014 ; [1.0]	0.044 ; [3.2]
Deviation Cost	0.005 ; [0.4]	0.002 ; [0.2]

- Disregarding fatigue leads to **wear-and-tear costs** that are twice as high, but still <1%.
- The **average cost of production** increases from 46.80 €/MWh to 47.86 €/MWh when fatigue is disregarded (affects profits).
- Hence, **average profits of CCGT decrease** from 4.47 €/MWh to 3.34 €/MWh.

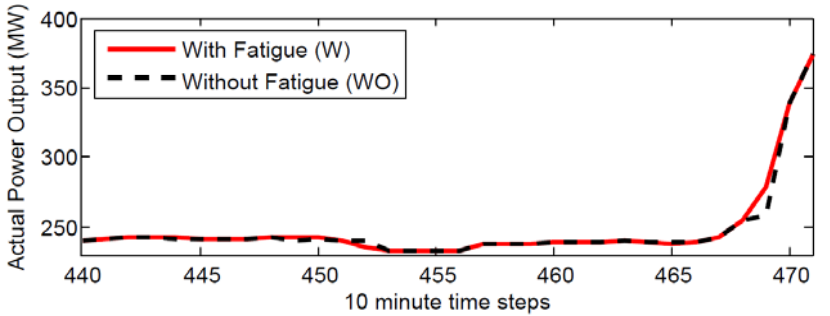
Numerical tests for a 1x1 CCGT

Optimal operations

- Taking into account fatigue **changes optimal operations**: 3% difference in total costs.



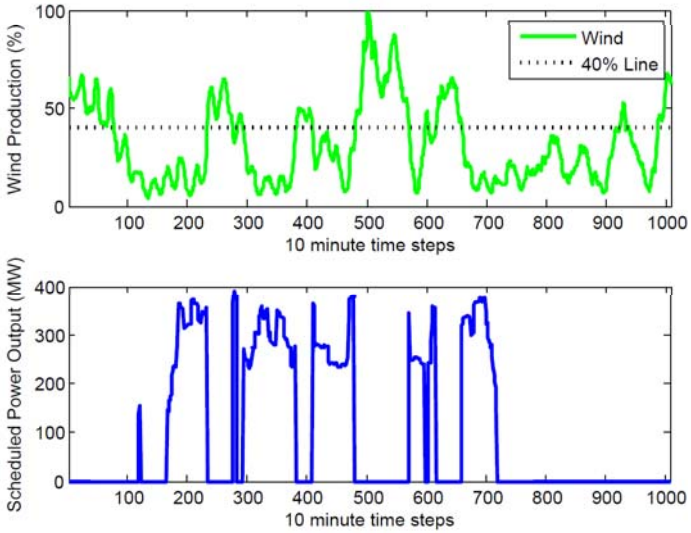
From hour 16 to 33



From hour 73 to 78

How do renewables change the picture?

- Assuming that the CCGT have to counter-balance wind production, the resulting operating profile changes.



Numerical tests for a 1x1 CCGT
Operating Costs and Profits - WIND

Cost Concept	Taking into account fatigue (M€) ; [%]	Disregarding fatigue (M€) ; [%]
Total Cost	0.822 ; [100]	0.878 ; [100]
No Load Cost	0.103 ; [12.5]	0.104 ; [11.9]
Linear Variable Cost	0.651 ; [79.2]	0.658 ; [74.9]
Ramp Fatigue Cost	0.005 ; [0.6]	0.009 ; [1.0]
Transition Cost	0.038 ; [4.6]	0.090 ; [10.3]
Deviation Cost	0.025 ; [3.0]	0.017 ; [1.9]

- **Wear-and-tear costs** slightly exceed 1%.
- The **average cost of production** increases 6%, from 50.64 €/MWh to 53.53 €/MWh when fatigue is disregarded.
- Hence, average profits of CCGT decrease from -0.07 €/MWh to -2.96 €/MWh.

Main conclusions of case studies

&

Higher penetration….

- Higher the impact of disregarding fatigue.
- Higher the **wear-and-tear costs**.
- Higher the **average operating costs**.
- Lower the **average profits**.

Arising questions?

In a high wind penetration context, Are we remunerating the CCGT correctly?

Should consumption of fatigue be considered in pricing?

If economic bidding decisions were to be made taking into account the technical nature of wear-and-tear, would CCGTs still be producing at all? And at what price?

Thank you for your attention!

- Contact: Sonja Wogrin

sonja.wogrin@comillas.edu

- This work has been carried out in collaboration with Prof. Andrés Ramos from Comillas and David Galbally from Innomerics.

- This work was partially supported by Project Grant RTC-2014-2301-3, awarded by the Spanish Ministerio de Economía y Competitividad.