Modeling Selected Energy Assets – in the Activities of an Energy Trading Unit

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Motivation for the modeling of energy assets within an energy trading unit (and an assets owner)

Selected Assets

Standard EX and OTC products (power, gas, oil, coal, EUA, etc.)

Transmission and transport capacities

Real power plants and gas storages

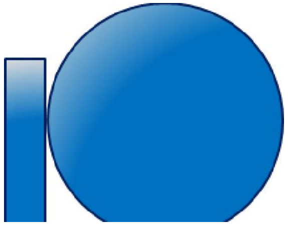
Structured products/virtual assets

frequently with embedded optionality

Motivation/Activities

- **Operating the assets**
  - E.g. power plants dispatch/gas storages utilization
  - Hedging and managing the value of the asset
- **Risk management**
- **Proprietary trading & market forecast**
  - Getting the insights on market fundamentals
- **Structured products**
  - Pricing and managing the value

Gas storage: Set up of the problem



Optimization of the gas storage utilization

- Maximization of the value using the gas storage and marketing the gas
- Given the all technical and non-technical constraints

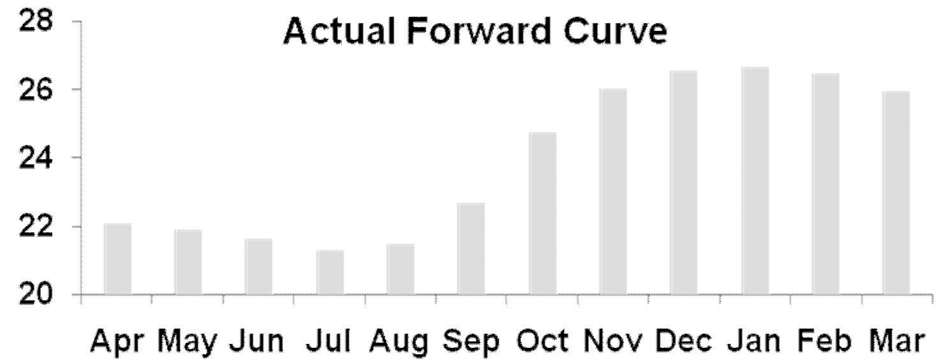
List of potential constraints

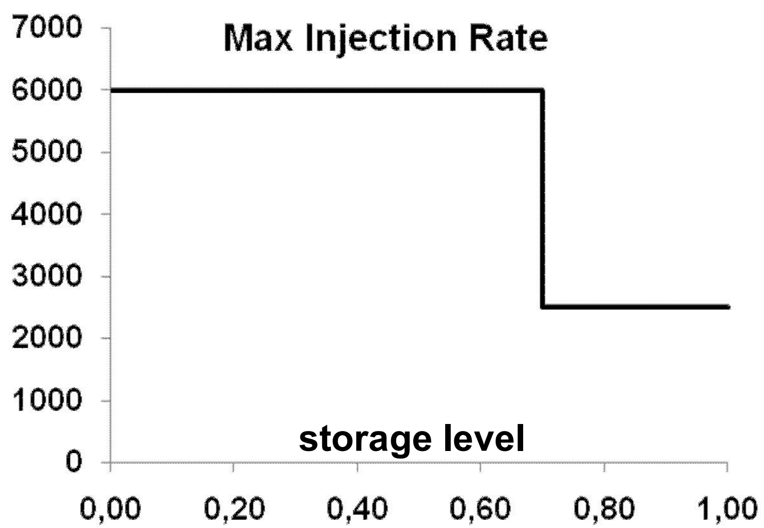
- Working gas volume (WGV) – total capacity of the storage
- Initial gas volume, terminal gas volume
- Maximum/minimum injection rate (IR) - as a function of the actual storage utilization
- Maximum/minimum withdrawal rate (WR) – as a function of the actual storage utilization
- Minimum/maximum gas storage utilization across the time
- Costs:
  - Injection costs
  - Withdrawal costs
  - Costs over the gas volume in the storage
- Etc.

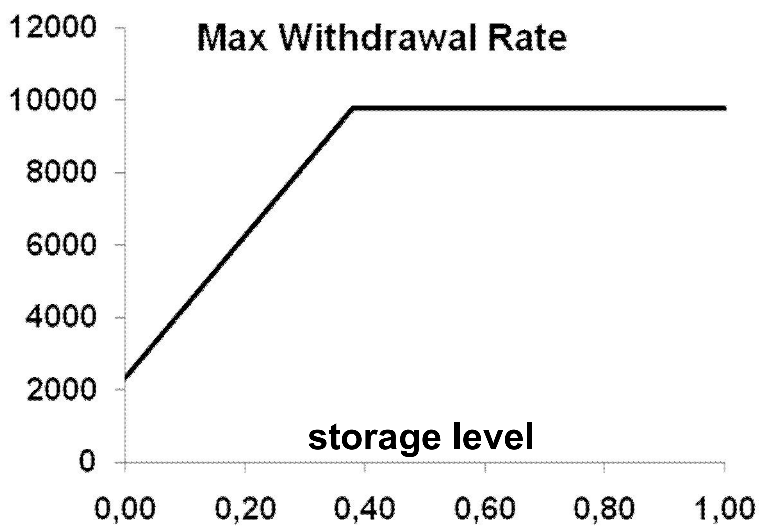
Gas storage: Term sheet example

Gas storage specification

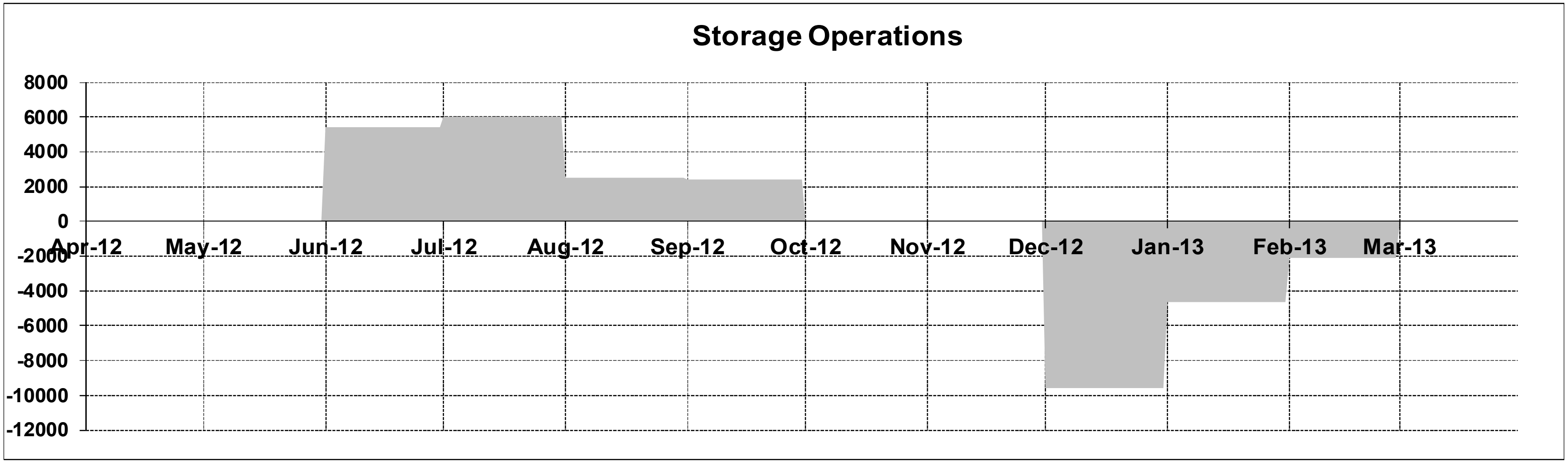
- Area: NCG
- Period: 1.4.2012 – 31.3.2013
- Working gas volume: 500 000 MWh
- Initial gas volume = terminal gas volume = 0
- Injection and withdrawal rates as defined
- No additional costs on top of the price

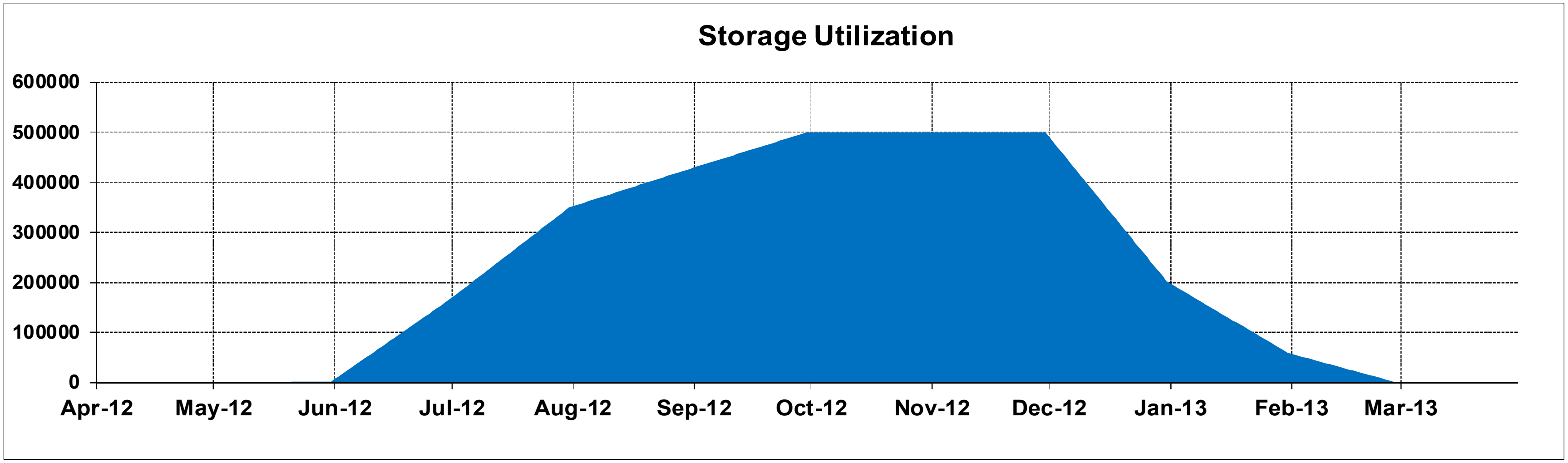






Gas storage: Intrinsic value of 4.7 EUR/MWh as for the example

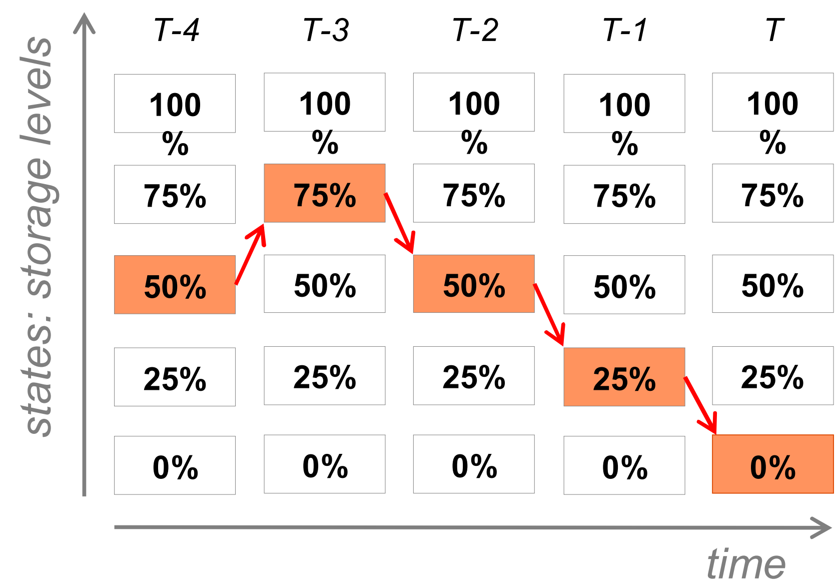




Dynamic Programming approach (DP)

- Dynamic programming breaks down complex problem into simpler sub-problems. DP solves sub-problems, and doing this recursively the overall solution is revealed
- DP problem.
  - 1. Define the world you live in terms of “states” for every point of the time (e.g. discrete levels of the gas storage)
  - 2. Define what state transitions are allowed
  - 3. Work backwards through time and store per state and time the ‘continues values’
  - 4. Select the optimal path from state to state

- **Advantages:**
  - It can very quickly solve the complex problems faster than other methods
  - Hence, the DP is often combined with stochastic approach
- **Disadvantages**
  - It struggles to incorporate time overlapping constraints (number of starts, fuel take-or-pay)
  - It needs to be very much tailor-made, difficult to have as module system



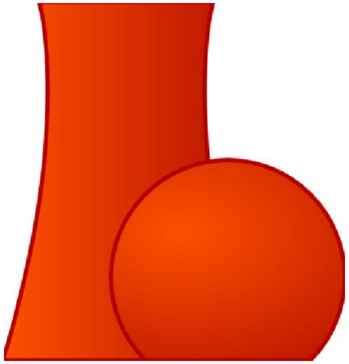
DP more formally

$$K(t) = K(x(t), a(t), Z(t))$$

$$V_t(x_t) = max_{a_t}(K(x_t, a_t, Z_t) + \beta V_{t+1}(L(x_t, a_t), Z_t))$$

- V(t) – value at time t
- a(t) – set of control variables or actions (e.g. inject/withdraw) at time
- x(t) – set of state variables at time t
- Z(t) – set of other independent variables at time (e.g. gas price)
- K(t) – cash flow at time t

Power plant: Set up of the problem



Dispatch optimization

- Can be formulated either as cost minimization (central dispatch) or gross margin maximization (market approach) – as the objective function
- Given the all technical and non-technical constraints

List of potential constraints

- Generation capacity and efficiency curves for particular units and across time
  - Min/max generation capacity – Pmin a Pmax
  - Heat (fuel) efficiency, consumption of EOH
- Regime switching: time and additional variable costs and EOH associated with regime switching
  - Cold, warm and hot starts, Pmin and Pmax for particular units in operation
  - Minimum on/off/stay time, minimum ramp-up or cool-down time
  - Associated fuel costs, EOH or other costs
- Operational constraint: e.g. number of starts
- Fuel constraints: e.g. take-or-pay obligation and/or flexibility, limit on emissions
- Load constraints: e.g. power must-run
- Maintenance schedule
- Ancillary services
- Etc.

LP and MILP

Formulation of LP or MILP

$$\min\ c^T \times x$$
$$A \times x \leq b$$
$$x \geq 0$$

,if some x are integer than we have MILP

- **Dispatch optimization can be either simplified into a linear problem, or many non-linear constraints can be LINEARIZED**. This however at the cost of increasing complexity (dimensionality) of the problem.
- LP and MILP are implemented with many solvers

- **Advantages of LP or MILP**
  - Efficient treatment of time-overlapping constraints (e.g. fuel take-or-pay, limit on the number of starts per period)
  - Very standard formulation of the problem, hence possibility to built the “module solution”
  - Many commercial/free solvers available

- **Disadvantages of LP or MILP**
  - Additional constraints increases the complexity (dimensionality) of the problem with exponential rate -> this is than reflected in the computational time

Example of formulation of a very simple dispatch problem within the LP framework

illustrative

Gas power plant simplified within LP

- Focus on CSS, gas contract and virtual storage
- Contracted gas (CG)
  - Buy & burn, buy & inject, withdraw & burn
- NCG
  - Buy & burn, buy & inject, withdraw & burn

$$c = \begin{bmatrix} css1 \\ inj1 \\ with1 \\ wgv1 \\ css2 \\ inj2 \\ with2 \\ wgv2 \end{bmatrix} \quad A = \begin{bmatrix} A1 \\ A2 \\ A3 \\ \cdots \\ \cdots \\ A10 \\ A11 \\ A12 \end{bmatrix} \quad b = \begin{bmatrix} b1 \\ b2 \\ b3 \\ \cdots \\ \cdots \\ b10 \\ b11 \\ b12 \end{bmatrix}$$

Variables

-*css1:clean spark spread for CG*
-*inj1: injection of CG*
-*with1: withdrawal of CG*
-*wgv1: CG in the storage*
-*…*
-*…*
-*…*
-*A1: gas contract, DCQ_COMB*
-*A2: gas contract, ACQ_COMB*
-*A3: gas contract, DCQ_AL_MAX*
-*A4: gas contract, ACQ_AL_MAX*
-*A5: gas contract, ACQ_AL_MIN*
-*A6: gas contract, DCQ_AM_MAX*
-*A7: upper limit on capacity (in MW)*
-*A8: storage, upper limit on daily withdrawal*
-*A9: storage, implicit CG storage*
-*A10: storage, implicit NCG storage*
-*A11: storage, upper limit on total storage*
-*…*

Lessons learnt regarding some alternative techniques

Linear programming	**LP**	**Linear programming**	▪ Fast and easy to implement for truly linear and simple problems ▪ Quickly fails in dealing with non-linear constraints ▪ More variables bring the curse of dimensionality, at the costs of computational time	**Deterministic *(mostly)***
	MILP	**Mixed integer linear programming**	▪ Helps to absorb specific constraints and linearize some non-convex constraints ▪ More variables bring the curse of dimensionality, at the costs of computational time	
Dynamic programming	**DP**	**Dynamic programming**	▪ Efficiently solves problems with many variables and various constraints ▪ Requires the breaking down of the complex problem into sub-problems ▪ As a consequence, there are limitation to incorporate time overlapping constraints	
	SDP	**Stochastic dynamic programming**	▪ Allows incorporation of the probabilistic view on the problem ▪ This adds another dimension into the optimal solution - robustness	**Stochastic**

THANK YOU