The effects of nuclear fuel storage on competition in electricity.

by

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Introduction

High fixed costs + Low variable costs => Nuclear technology is used to cover the baseload demand by functioning in a constant way to the maximum of its capacity :

(i) It helps covering its fixed costs.

(ii) Reduction of total exploitation costs.

Change of the electricity market structure : Vertically integrated monopoly organization → Competitive markets.

Cost of KWh in 2005

Euros/MWh (35 dollars/baril)	nuclear	natural gas	coal
Capital	14.9	5.1	9.3
Operation + Fuel	11	42.9	25.1
Total	25.9	45	34.4
Total + CO_2 (25 dollars/tonne)	25.9	52	50.6

Source : Annual report TVO/2006-CM-CIC Securities

Question

What is the optimal management of the nuclear generation set in that competitive regime?

We distinguish two aspects :

(i) Short-term aspect : Daily demand variations.

(ii) Medium-term aspect : Seasonal demand variations between winter (high demand) and summer (low demand).

Medium-term aspect

Idea : Nuclear fuel functions like a reservoir.

Nuclear plants stop periodically ($12/18$ months) to reload their fuel.

Objective : Analysis of the management of the nuclear "reservoir" as well as the effects of storage in a perfectly competitive electricity market.

Goal : Construction of a theoretical dynamic medium-term optimization model in a flexible operation frame like the one of the French nuclear set. Numerical illustration.

Model : Perfect competitive case

General framework :

(i) Equilibrium between supply and demand.

(ii) Perfect information.

(iii) Perfectly inelastic demand.

Two types of electricity generation technologies :

(i) Nuclear.

(ii) Thermic.

Length of the campaign : 12 months $= 1$ month of reloading $+$ 11 months of production.

9 types of units $>$ each type corresponds to a different month of reloading (Mars, ..., November).

3 months of high demand (December, January, February) during which reloading does not take place.

Functions of production costs :

(i) Linear cost function of nuclear production.

(ii) Quadratic cost function of thermal production.

Optimization problem : Profit maximization subject to the constraints :

(i) Min/Max production capacity constraints regarding the nuclear production.

(ii) The minimal thermal production is zero and the max thermal production capacity constraint is not binding.

(iii) Evolution of the current nuclear stock given the current nuclear production.

(iv) The value of stock of each nuclear unit at the end of the exploitation period has to be superior or equal to its initial value.

Implications :

(a) : $(i) + (iii) > (v)$ Current level of stock $\geqslant$ Total quantity of fuel that a unit has to reserve in order to reach at least to the minimum level of nuclear production at each of the remaining months of the campaign.

(b) : The maximum nuclear production that a unit is able to provide during a month depends on the month and the level of stock at the beginning of this month.

Perfect competitive solution :

(a) In the case of marginality of nuclear $>$

(i) Redistribution of the total nuclear production between the units in order to respect the constraints of our optimization problem and a rule of "equal treatment".

(ii) Thermal production is zero.

(iii) The optimal price is determined by the marginal cost of the nuclear production according to the merit order.

(b) In the case of marginality of thermal $>$

(i) The nuclear production reaches its maximum value.

(ii) Each thermal unit produces symetrically in order to cover the residual demand which corresponds to it.

(iii) The optimal price is determined by the marginal cost of the thermal production according to the merit order.

Data

(i) : Levels of demand $>$ Grid System of Electricity (RTE).

(ii) : Levels of nuclear and thermal capacity $>$ Grid System of Electricity (RTE).

(iii) : Fixed (investment costs + fixed exploitation costs) and variable costs (variable exploitation costs + fuel costs + CO_2 costs and taxes) of nuclear, coal and gas production $>$

"Reference Costs of Electricity Production" realized by the General Direction of Energy and Raw Materials (DIDEME) in 2003.

Numerical Illustration

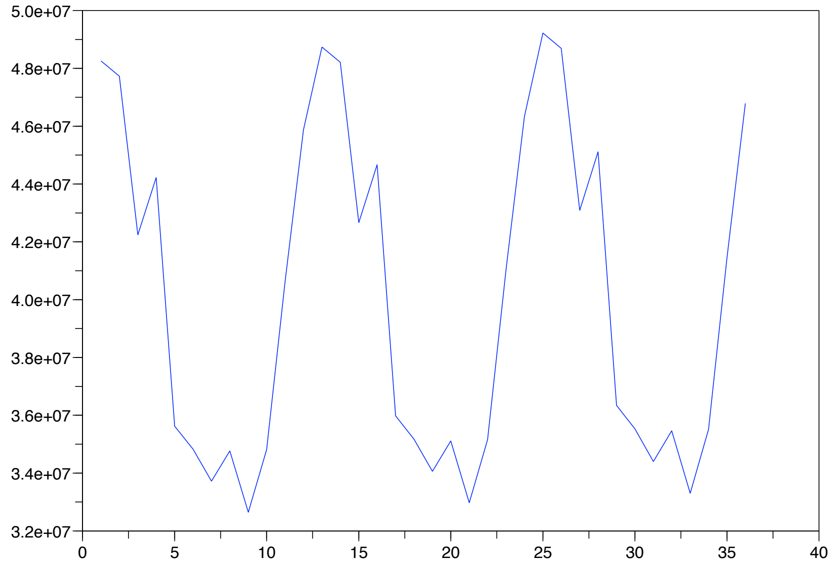

Figure 1: Simulated demand

(i) Demand is high during winter and low during summer.

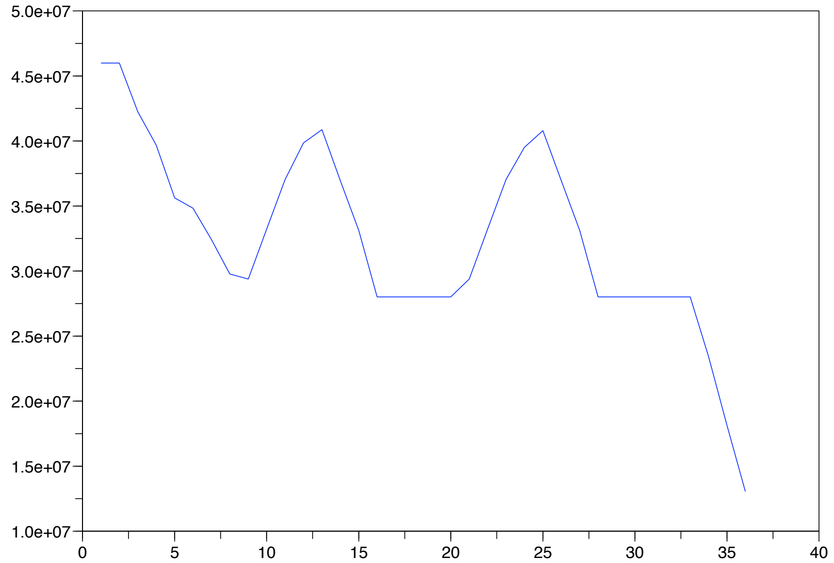

Figure 2: Simulated nuclear production

(ii) High levels of nuclear production during winter and low levels during summer.

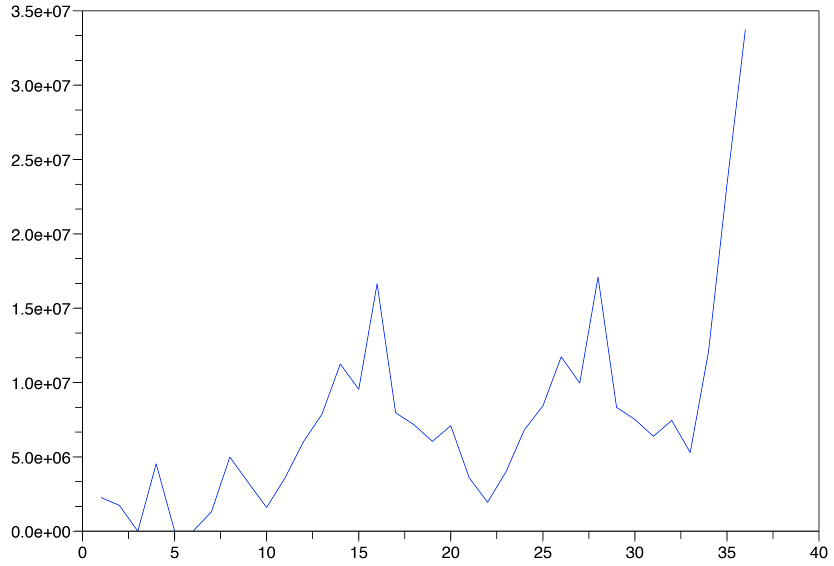

Figure 3: Simulated thermal production

(iii) High levels of thermal production during the periods of low levels of nuclear production and inversely.

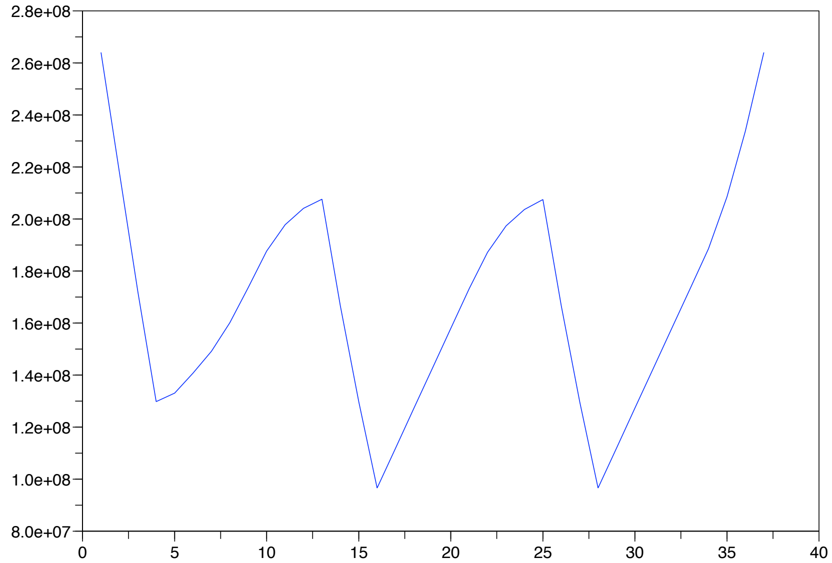

Figure 4: Simulated nuclear fuel stock

(iv) The evolution of the nuclear fuel stock is inversely proportional to the evolution of the nuclear production.

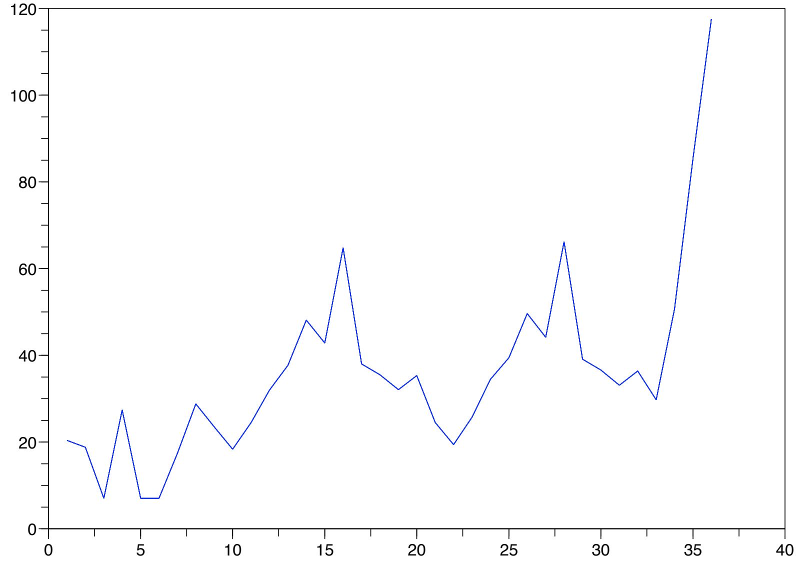

Figure 5: Simulated price

(v) Prices are high during winter and low during summer.

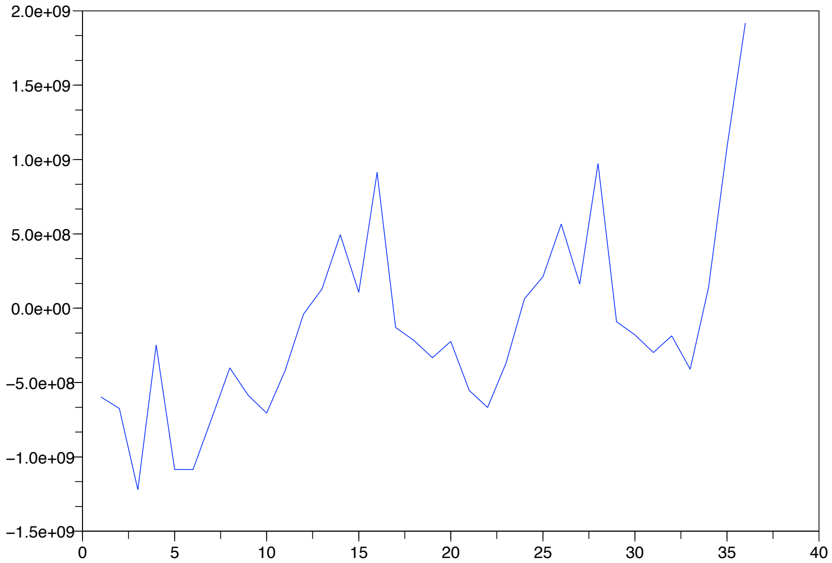

Figure 6: Aggregated total profit

(vi) The profit is higher during the winter and at the beginning of spring and lower during the summer and at the beginning of autumn.

Future work

(i) : Case of 12 types of units / Disymmetry with respect to the production capacity of each unit.

(ii) : Incorporation of the hydraulic production (run-of-river).

(iii) : Study of imperfect competition (oligopoly).

(iv) : Perfect competitive price VS oligopolistic/observed price $>$ Measurement of market power (Smeers 2007).

(v) : Consideration of other electricity markets (e. g. Belgium, Germany) $+$ interconnection capacities.

(vi) : Private monopoly and social welfare.

(vii) : Consideration of demand's incertitude (stochastic case).

Thank you for your attention!