

Generation Expansion Planning: Forecasting and investment decisions in a system-dynamics based model.

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Abstract

This paper presents forecasting calculations and investment decisions' modelling details, in a system-dynamics based model representing long-term planning of electricity generation, also called generation expansion planning.

1 MODEL DESCRIPTION

1.1 General structure

The representation of new generation-capacity-investment decisions in the model of this paper can be seen as if it were divided in four main calculation modules, as the ones presented in Figure 1. The first main module is the “Market” module, which calculates market prices and power outputs in a particular time step given the demand and the available generation portfolio as main input variables. After that, the “Forecasting” module calculates forecasts of prices and outputs for a determinate horizon. With these results, the “Decision” module evaluates different generation expansion alternatives and decides how many plants to build by company. Finally, the “Building” module represents the process followed since new plants have been decided until they enter the system.

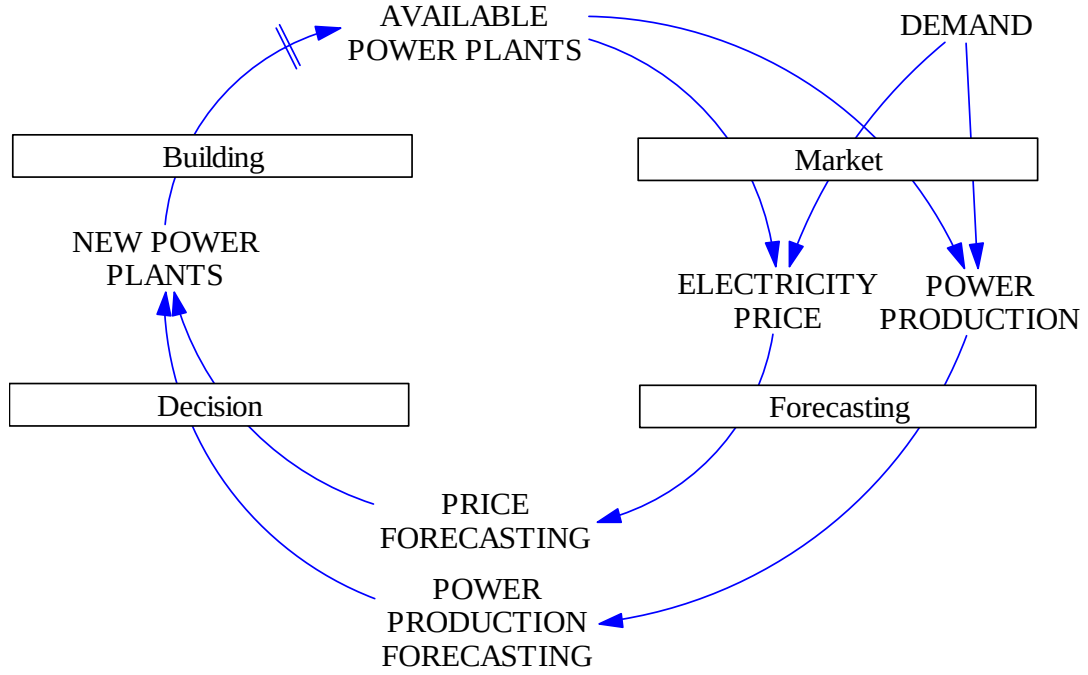


Figure 1.- General overview of a generation-expansion-planning system-dynamics based model

The next sections present the “Forecasting”, “Decision” and “Building” modules in detail.

1.2 “Forecasting” module

The main characteristics of the “Forecasting” module are that it takes into account the current market performance at the moment when the companies make the forecasts and it makes a reasonable assumption for the long-term.

First, the model estimates the optimal generation portfolio for a given year in the future using exogenous data for fuel long-term marginal costs. With this generation portfolio and an exogenous estimation of the demand, an estimated price duration curve is obtained for that given year in the long-term. Then the model approximates the current price duration curve (which has been calculated previously in the simulation, in the “Market” module) to that estimated price duration curve in the future, reducing their differences along the time. The expected price for each load level, of each of the following years to the current one is:

$$E[p_{t'}] = p_t + (E[p_{T'}] - p_t) \cdot \left(1 - e^{\frac{-(t'-t)}{K1}}\right); \quad t' = (t+1), (t+2), \dots, (T'-1) \quad (1)$$

Index t' is any of the following years to the current one t ; T' is the future year which price is calculated by estimating an optimal generation portfolio, as commented above; $K1$ is a factor which increases or decreases the approximation velocity of both prices (the one in T' and the one in t). For example, if the factor is 8, then the price in year $t + 5$ will be $p_t + 0.46*(E[p_{T'}] - p_t)$ and in year $t + 15$, it will be $p_t + 0.83*(E[p_{T'}] - p_t)$. If the $K1$ factor is 2, then the price in year $t + 5$ will be the $p_t + 0.92*(E[p_{T'}] - p_t)$ and in year $t + 15$, it will be $p_t + 0.99*(E[p_{T'}] - p_t)$. So, the lower the $K1$ factor, the quicker the prices of the following years approximate to the price in year T' . Recall that the above formula is applied to every load level, so the final result of this estimation is a price-duration curve for each of the following years to the current one.

Once we have the estimated price duration curves for each one of the following years to the current one, the model makes power outputs forecasts for a new group of each technology considering that the group is going to be bided by its marginal cost: that is, if the marginal cost of the group in one load level is above the forecasted price in that level, the group do not produce in that level, and the opposite if the marginal cost is below the price).

This model is conservative in the sense that it is assuming that in the long-term, the system tends to the optimal-generation portfolio and to the perfect competition.

1.3 “Decision” module

To decide the number of new groups of each technology that each company is going to build, the model computes the net present value for a new megawatt of each technology g , for each company i . Once the net present value is calculated for each technology, each company asks for a number of construction permits of the most profitable technology. This number is going to depend on the net present value calculated and on a maximum upper bound which depends on a percentage of the assets value of the company or on a percentage of the demand growth (for new entrants and renewable energy). The formula used here is:

$$CPA_{tgi} = CPA_MAX_{ti} - CPA_MAX_{ti} \cdot e^{-\frac{NPV_{tgi}}{K2_{tgi}}} \quad (2)$$

Where CPA_{tgi} are the construction permit applications, CPA_MAX_{ti} is the maximum number of possible applications, NPV_{tgi} is the net present value, and $K2_{tgi}$ is a factor which increases or decreases the approximation velocity of the number of applications to the maximum limit with respect to the net present value. The shape of this function is similar to the one used in (Olsina *et al.*, 2006). On the one hand, this formula represents the fact that the greater the expected profitability, the more likely a company is going to be to invest. On the other hand, it represents the fact that when the expected profitability is too high, there exists a saturation level which can be justified by different causes, as commented in (Olsina *et al.*, 2006): first, because the companies are aware of the high attractiveness for investing and the potential danger of a wave of massive entries; second, because in a concentrated market, a generation company holding a significant market share might limit its own investments, since it would endanger the profitability of its own capacity in place; and third, because of the financial difficulties to fund simultaneously many investment projects, as firms usually must hold an equilibrated debt to equity ratio.

The asked permits will be obtained a number of years later depending on a given constant delay. Each year, when a company receives the permits it has the possibility of deciding how many permits to use. To do this, they reevaluate the profitability of the groups again with a net present value calculation. Note that at the moment when the permits were asked for is simulated previously, the market performance may have changed and so the expected profitability. Companies are going to use an equation similar to (2) in order to decide how many power plants to build but replacing CPA_t by the new power plants decided and the CPA_MAX_t by an upper bound for the new power plants to be decided (which is calculated in the same way). Once they calculate the number of new power plants they are willing to build, they check if they have enough permits. If not, they are going to build just the number of power plants they

are able to build according to their permits. Note that the companies may obtain permits of different technologies the same year, because of different delays for obtaining them for different technologies. In that case, they will invest first in the most profitable technology and if they use all of the permits of this technology and they are still able to invest more because they have not reached their limit, they will invest in the next most profitable technology.

To calculate the net present value, the companies use the prices and power outputs forecasts previously calculated, exogenous cost data, exogenous constant capacity payments and wind subsidies and a discount rate which is calculated endogenously. This discount rate calculation is an important theoretical advance with respect to previous literature, and is described in detail in (Sánchez *et al.*, 2007). It is based on credit risk theory ideas. Assuming that companies need debt to finance their new investments, the debt is going to be provided by an investor which is going to ask an amount in return greater to the quantity lent, because of the risk perceived. The difference between both quantities can be expressed by a factor which will be the required rate of return to be applied by the generation company to its new investment, that is, the discount rate to be used in the next present value calculation. To obtain that difference a debt pricing model is needed. The Black-Scholes-Merton debt pricing model which is explained in (Sánchez *et al.*, 2007) is chosen here. With this model, the debt price and so the final discount rate to be applied by each company depends on the debt-assets ratio of the company, on the volatility of the assets value, on the risk-free rate and on the time to the redemption date. All of these values, as it explained in (Sánchez *et al.* 2007) are known at this point of the model, either because there are exogenous or because they are calculated endogenously in the model.

1.4 “Building” module

A simple constant delay for each technology and company is used here to represent the process that follows since the investment is decided until it enters in the market.

2 REFERENCES

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