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THE ROLE OF RENEWABLE ENERGY SOURCES IN THE DAMP OF CYCLES IN DEREGULATED ELECTRICITY MARKETS

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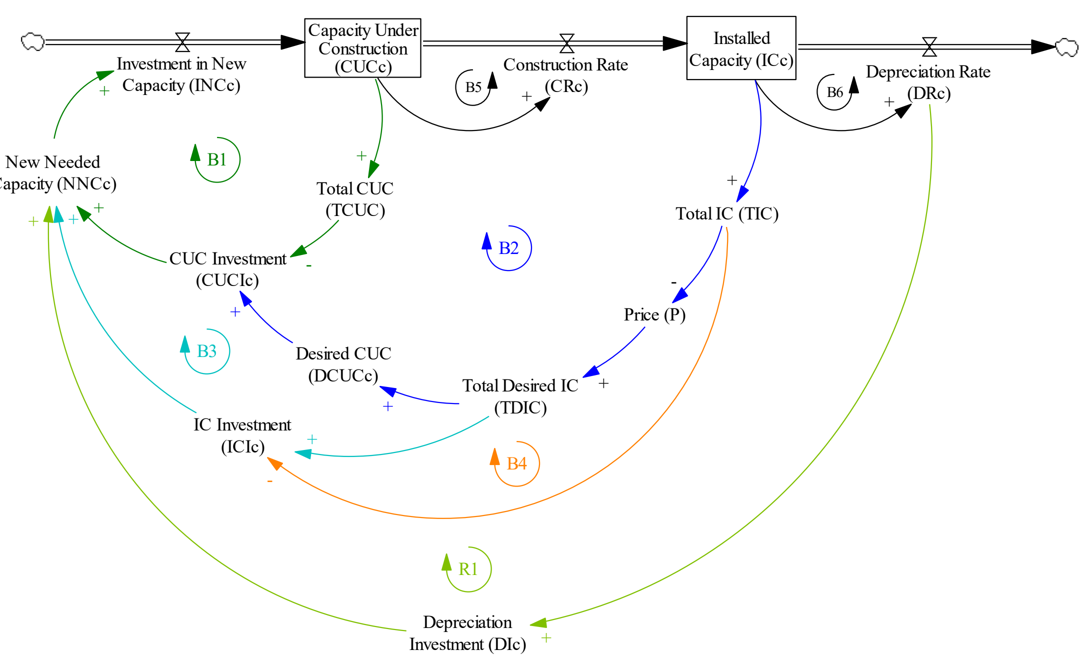
Overview

The deregulation of electricity markets was the beginning of cyclic behaviour in generation capacity causing price cycles, threating the security of supply, and jeopardizing the financial sustainability of power systems and the involved actors [1]. These cycles create uncertainty for all stakeholders, from policymakers, regulators, investors, and customers, as the price become unpredictable in the medium term. The cause of these cycles can among other issues, be linked to the high cost and long construction time of new conventional generation capacity, as well as the long life time of the investments. Our main research question is what could be the effect of the introduction of renewable generation in these markets with respect to capacity cycles. Renewable generation is less "chunky" than conventional and has a shorter construction life time. We use a previous proposed model [2] that has been used to study the effect of mothballing [3], long-term strategic reserves contracting, centralized auctioning [4], [5], and forward markets [6]. Here, we adapted this model, to investigate the effect of the introduction of renewable energy sources (RES) on the observed capacity cycles in deregulated electricity markets.

Methods

We present a stylized and highly aggregated model of capacity expansion of a power market. The model was implemented using system dynamics, a computer modelling approach that allows to manage systems with high levels of dynamical complexity [7], [8]. We start with a base case which corresponds to a simple generic electricity market, dominated by one conventional energy source (CES). In the next step, we add a renewable energy source (RES) to this electricity market. The model of the base case is presented in Figure 1, where one can identify six negative balancing feedback loops (B1, B2, B3, B4, B5 and B6) and only one positive reinforcing feedback loop (R1).



Note - The subindex denote the type of energy source, where c is conventional, and r renewable. The sign at the head of each arrow denotes the nature of the relationship between two variables as follows: $x \to^{+} y$ means that $\partial y/\partial x > 0$, and $x \to^{-} y$ that $\partial y/\partial x < 0$. All constants were omitted for clarity. Own elaboration in Vensim [9].

Figure 1 – Model structure for the base case.

This base case model consists of two state-variables, CUC and IC, representing the capacity under construction and the current installed capacity. The state variables in Figure 1, corresponds to the following integral equations, where the subindex x denote the type of energy source (e.g. c for conventional, and r renewables).

$$CUC_x(t) = CUC_x(0) + \int_0^t INC_x(s) - CR_x(s)\, ds \quad (1)$$

$$IC_x(t) = IC_x(0) + \int_0^t CR_x(s) - DR_x(s)\, ds \quad (2)$$

In the case where renewables are introduced, the conventional generation stays the same as in the base case, and a structure equal to that of Figure 1, but this time with subindex r is introduced, which represents the generation capacity and the capacity under construction of the RES. In this new case, the total capacity under construction ($TCUC$) will be defined as $TCUC = CUC_c + CUC_r$, and the total installed capacity (TIC) as $TIC = IC_c + IC_r$. The price (P) and the total desired installed capacity ($TDIC$) formula remains the same, but this time depending on the sum of the capacity of conventional and renewables. Therefore, the $TCUC$ and the $TDIC$ are the variables that motivate the investment of both technologies. In both cases we assume the same constant demand. We use Powersim Studio 10 Academic SR4 [10] for the simulation with the first order Euler numerical method, for a total of 70 years.

Results

The total installed capacity and the price of the market are shown on Figure 2 and Figure 3, respectively. In both figures, the simulation results of the base case (black line), which is a power market with conventional generation; and the RES case (red line), with the introduction of renewable generation, can be oserved. Both simulations are presented along their respect Cournot-Nash equilibriums (pink line).

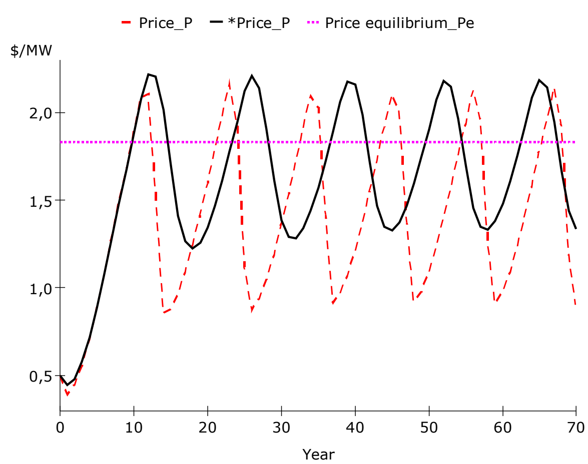


Figure 2 - Price (P) in the base case (black), and the RES case (red), oscillate around the Cournot-Nash price equilibrium (pink).

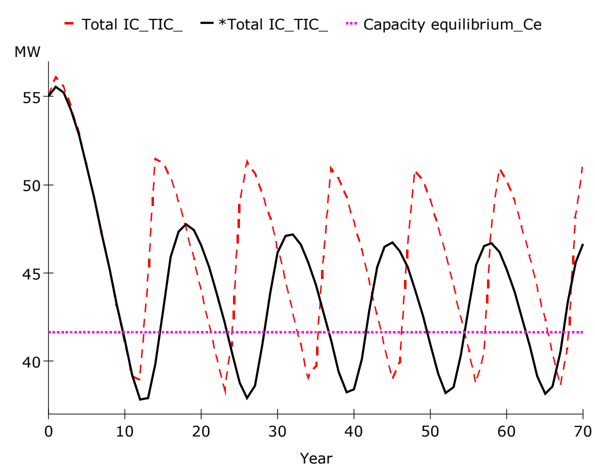


Figure 3 - Total Installed Capacity (TIC) in the base case (black), and the RES case (red), oscillate around the Cournot-Nash capacity equilibrium (pink).

Results shows that the inclusion of a renewable generation in a simple generic electricity market dominated by a conventional generation increase the amplitude and reduce the wavelength, of the price and the total installed capacity oscillations.

Conclusions

The combination of balancing (negative) feedback loops and delays, give origin to the oscillations observed. Therefore, intuition suggests that a decrease in a delay time, would lead to a reduction of the cycles amplitude. However, as shown here, our results are counterintuitive because instead of observe a reduction in the cycles amplitude, we detect an increase. This, highlight the importance of simulation exercises to study dynamic complex systems as the electricity markets, where feedbacks and delays difficult to draw conclusions of what to expect from changes on the structure of those systems.

References