Energy-Neutral Demand Response from a Large Population of batch-process loads

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Large Electricity grids are nowadays at a milestone of their development. In Europe, the organisation of electricity supply is being profoundly re-organised. Since electricity liberalisation, a constant effort towards integration of electricity markets has been undertaken, and is not yet in place. At the same time, the European Union has committed to develop renewable energies, particularly in the power sector. Power production is more and more decentralised, more volatile, and more uncertain.

In this context, new challenges appear for electricity grid operators. They need to provide greater efforts to perform their most critical daily duty : balancing at every second the power production with the power demand. Therefore, transmission system operators (TSO's) are searching for new sources of flexibility. This flexibility would be used in daily operations, and serve as frequency restoration reserve (FRR - secondary control) or frequency containment reserve (FCR - primary control), more generally as ancillary services.

One possible answer may be found in flexible electricity demand, or Demand Response. Demand Response represents all ways that may influence and change electricity consumption in response to external signals, such as high electricity prices, or for electricity system security. Historically, Demand Response was developed for emergency purpose or for peak demand reduction. Participating loads were controlled very infrequently, in case of large contingencies, or during high demand periods.

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However, there are nowadays examples of Demand Response initiatives that are able to provide constant balancing services to the TSO. Mainly, heat/ventilation/air-conditioning (HVAC) applications or other *thermostatically controlled loads* are managed in different ways in order to change consumption and provide flexibility.

There exist other kinds of possible sources of flexibility. We study the dynamic and control of the instantaneous power consumption of a large group of batch-process loads (pumps, conveyor belts, etc.). The purpose of the control is to provide constant balancing services to the electricity grid operator without compromising the initial needs of the process the load is part of. Essentially, this means that the control will have to be energy neutral, on a certain time period (e.g. 1 hour quarter).

In our context, the power consumption of each participating load may be increased/decreased proportionally to a single, common to all loads, control parameter (i.e. the common modulation factor α). This parameter may evolve over a limited range (i.e $\pm 10\%$) around the nominal power of the load. In other words, each load will be allowed to change its instantaneous consumption, but not to shut down completely or being postponed in time.

We firstly show, in a simple example, what are the important parameters that govern the total consumption of the group, and also its dynamic response to the modulation factor. In a second step, we develop an optimisation model, that will choose the modulation factor such as to minimize the total cost of balancing the grid.

For this purpose, a very simplified model of the Western-European interconnected Electricity system is used, were the Belgian system is a little more accurately described, especially in terms of ancillary services. A State-Queuing model of the total consumption of the group of load is developed. This leads to a non-linear optimisation model that performs system balancing at the lowest possible cost.

The results of the study are threefold.

1. The benefits for the system to implement centralised, energy neutral control are assessed, for a single day of the year.
2. The dynamic of the consumption of the load population is described, and lead to interesting controllability limits.
3. Implementing this control would require the development of additional market mechanisms. They are also described at the end of the study.

The next steps of this study will consist in generalising the approach to a more diversified group of loads, to integrate more realistic figures (based on real-life survey) and to assess the benefits on a yearly basis.

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