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Renewable generation versus demand-side management. A comparison for the Spanish market

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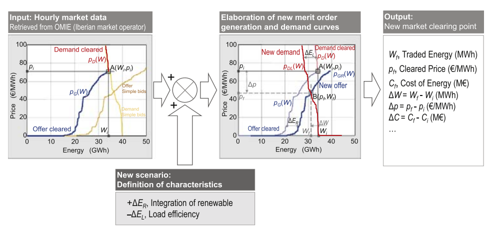
HIGHLIGHTS

- The impact of the integration of renewable production versus DSM has been compared.
- Merit-order effect related to energy efficiency and to load-shifting is identified.
- Large industries achieve energy efficiency with less CAPEX than renewable generation.
- Load-shifting cycle yields a reduction of the traded energy and the economic volume.

GRAPHICAL ABSTRACT



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ABSTRACT

Conventionally the required instantaneous balance generation-load is achieved by adjusting production to fit variable consumer demand. Nowadays, a significant and increasing segment of generation is renewable. But renewable production cannot be scheduled on request since its generation is dependent on nature (wind, sun, …). In this context, demand-side management (DSM) would help since it would be advisable for part of the flexibility to be provided by the demand.

The integration of renewable production and demand-side management (DSM), are compared in this work for Spain throughout 2008–2014. First a qualitative model, based on the linearization of the wholesale market, is employed to explore some hypotheses. A set of scenarios are then examined to quantify the main effects on the market.

The results show that DSM exhibits the best performance in terms of economic efficiency and environmental sustainability, as well as for the reduction of load peaks and losses in the system, what suggests the convenience of promoting plans for the replacement of equipment with other more efficient as well as the implementation of real-time tariffs.

1. Introduction

Historically, power systems have been envisaged, designed and operated from the point of view of electricity generation, and have largely focused on the technical and economic aspects of the diverse production technologies as well as on availability. With this perspective, the main objective of the design of power systems has always been the adequacy and reliability of supply at the lowest generation cost.

Since demand is variable, the required instantaneous balance between power generation and load is achieved by adapting the production to consumer demand (load-tracking or on request). This means that the necessary balance generation-demand is

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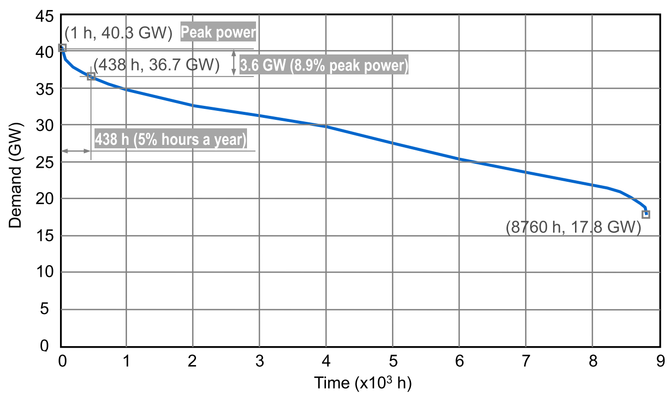

Fig. 1. Load duration curve for the Spanish peninsular system of the year 2014.

achieved by means of the flexibility (ability to control and quick adjustment) of conventional generators. This approach is based on two main underlying ideas: large conventional generators are programmable (time and amount of energy) and their number is relatively small (limited communication requirements).

Conventional planning of power systems is based on the same idea of variable demand and adjustable generation. Capacity growth in the foreseeable future, both of generating equipment and grid infrastructure (transformers, substations, lines …), are estimated so that they meet the expected increase in demand at the lowest cost. A direct consequence of this planning policy is that both the generating capacity and grid infrastructure must be sized for the maximum expected demand, although the duration of peak demand is only for one or a few hours throughout the planning horizon. For example, Fig. 1 shows the load duration curve for the Spanish peninsular system during 2014 (REE, 2015). As can be seen, the maximum power demand was 40.3 GW, which is more than double the minimum demand (17.8 GW), and occurred only for a single hour throughout the year. It can also be seen that the 3.6 GW (8.9%) of peaking power generation is required only for 438 h (5%) or less a year.

Today, the electrical systems of the EU and many others countries are committed with the Kyoto Protocol and its successors (EC, 2009). As a result, the generation fleet has diversified in a significant way in terms of generation technology, mainly due to large-scale integration of production based on renewable energy. Consequently, electrical systems are evolving towards a generation fleet that is vastly more diverse, dispersed and decentralized, with a much larger number of generators, in which a significant and growing generation production comes from renewable sources. This means that an increasing fraction of the generation cannot be scheduled on request since their production is dependent (in both time and quantity) on the natural occurrence of renewable resources, and hence the programming of energy production has to be based on the forecast of the renewable resource.

As a result, the operation of the generation fleet is becoming less flexible (less adaptable to variable demand requirements) since the controllability and quick adjustment of the generators to the load conditions is shrinking, and its production is progressively subjected to a higher level of uncertainty.

In this context, DSM can be seen as a mean of increasing the flexibility of the system in terms of ability to balance generation and demand so that the requirement of flexibility does not fall solely on the generation, but that part of the flexibility requirements may also be provided by the demand.

DSM can help to reduce: network congestion (investment in grid reinforcement) by reducing the demand (energy efficiency) or by shifting the load to other moments with grid capacity surplus; generation (operation) costs by shifting the demand for those moments with more availability of renewables; and the need for investment in new generation equipment, by shifting peak-hour demand to moments with less demand and generation surplus (valley hours). Consequently, the value of DSM lies essentially in the deferral and reduction of the investment needed for grid expansion or reinforcement and generation capacity, as well as in the economic improvement of the operation of the power system (reduction of losses and more intensive use of renewables, by avoiding cuts in the use of renewables).

This work seeks to compare these two strategic policy approaches for the Spanish case: the integration of renewable production as a case of planning generation capacity based on load-tracking, and the DSM (energy efficiency and load-shifting), in order to advance their potential impact on the electricity market. To this end, first a qualitative model, based on the linearization of the wholesale market around the clearing point, is used to explore some basic hypotheses. An appropriate set of empirical-based scenarios with integration of renewables as well as DSM are then generated from the retrieved historical information of the Market Operator throughout the seven-year period 2008–2014, in order to quantify the main effects on the market.

Subsequent to this introduction, the content of the paper is as follows. First the Spanish/Iberian electricity market is briefly surveyed and a qualitative model, based on the linearization of the market, is used to set some basic hypothesis regarding the expected effects of renewables and DSM. The hourly merit-order generation and demand curves throughout 2008–2014, retrieved from the archive of the Market Operator are then used as source data for the generation of realistic DSM and renewable scenarios. The main potential effects of DSM and renewables on the market are subsequently quantified and analysed. The paper closes with the main findings of the comparison.

2. Background

In this section first the background situation for energy efficiency and DSM in Spain and in EU is surveyed and then the Iberian market (where the Spanish system is integrated) will be reviewed.

2.1. Overview of the current situation

For the case of Spain, setting the dichotomy renewables versus DSM holds special interest. Renewables have undergone significant development, and now contribute significantly to the generation mix (42.8% renewable in 2014, 20.4% wind) but energy conservation and DSM actions remain largely unexplored (EC, 2012), (MIET, 2014). Energy efficiency at the EU-28 level improved by 1.2%/year from 2000 to 2013 (15% over the whole period), according to (ODYSSEE-MURE, 2015). The pace of progress has slowed down since the economic crisis: the annual gain dropped from 1.3%/year between 2000 and 2007, to 1%/year between 2007 and 2013. For the period 2000–2012, energy efficiency only improved in Spain by 0.6%/year. Moreover, energy conservation and DSM actions seem especially well suited for the Spanish case for many reasons, such as the high level of energy dependence. Table 1 shows the EU and Spanish rate of gross energy dependence for the period 2001–2013 (Eurostat, 2014). As can be seen, the Spanish rate of gross energy dependency is always much higher than that of the EU average. The record minimum was 70.5% in 2013 (below the 1998 level), but remained 17.3% above the UE average.

The level of emissions of greenhouse gases could provide another good reason to study the Spanish case. The EU sharing agreement on CO_2 emissions allowed Spain an increase of 15% over