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Expanding renewable energy by implementing Demand Response

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Abstract

We evaluate the impacts of DR in future electricity systems and to what extent they can facilitate the spread of high shares of renewable energy while maintaining a given level of reliability. We propose an approach based on long-term planning models, the MARKAL/TIMES models and our analysis is demonstrated by the case of Reunion Island, which aims to produce electricity using 100% renewable energy sources by 2030. We demonstrate that higher shares of intermittent sources weaken reliability of supply and can be counter balanced through demand response solutions.

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Keywords : Energy planning; Intermittent energy sources; Demand Response; Power system reliability; La Réunion island.

Nomenclature

DR	Demand Response
TIMES	The Integrated MARKAL-EFOM System

1. Introduction

To cope with the scarcity of fossil and to mitigate greenhouses gas emissions, renewable energy sources are expected to expand in electricity production. In the meantime, introducing high shares of renewable energy sources, including intermittent energy sources, may threaten supply reliability [1] of power systems where reliability refers to the ability of the power system to lock back into steady-state

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conditions after sudden disturbances (e.g. load or generation fluctuations). In this context, Smart Grid solutions such as Demand Response (DR) programs are often presented as attractive alternatives to support the expansion of renewable energy sources. Nevertheless, it is difficult to assess to what extent Smart Grids could curb the trend.

In this study, we propose to evaluate the benefits of DR while considering the long-term development of future electricity system with high shares of renewable sources. Namely, we will illustrate how technological modeling (bottom-up) helps guide energy strategy, namely in the electricity sector and with regard to high level of intermittency.

Section 2, defines the statements of our approach for the Reunion Island electricity sector, based on energy planning models from the TIMES family [2] and develop how Demand Response is implemented in such models.

In section 3, the share of renewable intermittent production compatible with specific supply quality requirements are discussed and illustrated by the results showing how Demand Response increases the share of intermittency permitted in the power mix.

2. Demand Response in the TIMES-Reunion model

TIMES model of Reunion Island belongs to the TIMES family of models [2] which are useful tools to provide plausible options for the long-term development of energy and power systems. The models are demand driven and may consider a wide variety of demand aspects such as electricity, heat, and transport. The TIMES-Reunion model was developed by MINES ParisTech, Center for Applied Mathematics. It offers a technology-rich representation of the electricity system. Each step of the energy chain, from raw materials to final energy demand, is represented in the model by processes (e.g. fridges, electricity distribution, coal power plants) and commodities (e.g. underground gas, electricity). Each process is defined by a set of attributes (e.g. investment costs, variable costs, residential capacities). The model minimizes the total energy system cost under constraints (i.e. technical, demand fulfillment, capacity and activity boundaries) over a time horizon (typically several decades). The Reunion Island's power system development was evaluated until 2030. In the TIMES-Reunion model, each year is split into two seasons of equal length (sugar season and summer), and each day is divided into 8 time-slices. Electricity demand is split between three sectors: industry, service and residential each of them divided in sub-sectors. Each use from each sector is associated with an overall electricity consumption level and a load curve.

In order to assess the impact of demand management solutions, we have implemented an enhanced model version, where DR programs (load-shifting) are considered. This requires knowing the evolution of the load curve over time and to know which demands take place during the peak. Indeed, we cannot assume that the overall peak can be translated to another period of the day, as only some uses can be carried forward or postponed to off-peak hours. This DR program is related to uses classified into three categories depending on their ability to be postponed or not:

- Uses that enable "long-length postponement". These uses can be translated from one time-slice of the day to another (for instance water heaters and machines for washing clothes, dishes, and drying clothes);
- Uses that enable "short-length postponement". For instance 20% of refrigeration, heating, cooling and ventilation can be stopped;
- Uses for which no postponement is possible, *e.g.* TV, IT…

3. Share of renewables energy sources

The TIMES-Reunion model is used in order to assess long-term scenarios so as to achieve the 100% renewable energy sources target in 2030. The future electricity production mix obtained strongly relies on intermittent sources, mostly based on photovoltaic and wind energy as shown in Fig. 1.

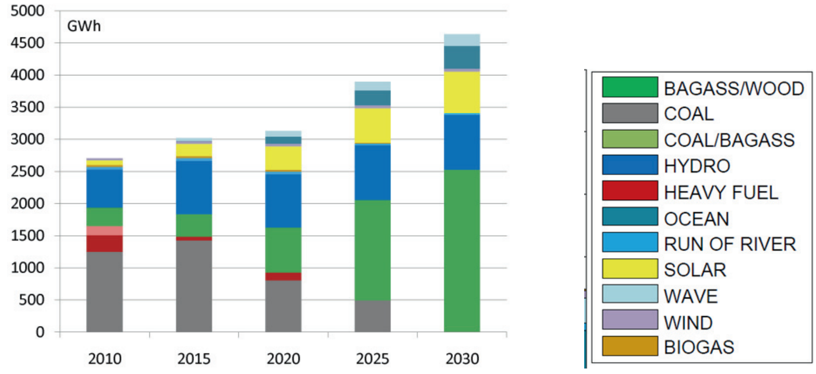

Fig. 1. 100 % Renewable in 2030 : a scenario assessed with TIMES-Reunion model.

This large share of intermittent sources questions reliability of power supply. Referring to the stored level of kinetic and magnetic energies according to the power plant's type and capacity in the power mix [3], the future electricity system cannot maintain the reliability indicators during a typical day of 2030 (Fig. 2(a)) at their reference level given in 2008 (denoted REF2008 therein).

These results confirm that magnetic and kinetic reserves are critical issues for production mixes that include high shares of intermittent sources (nearly 60% here). The implementation of Demand Response solutions does not raise the indicators and may even worsen them during some time-slices (see Fig. 2(a)) but it enables a 16.7% decrease in the total installed capacity. This is why, in order to handle these reliability issues, the French government set, in 2008, a legal limit of 30% of instantaneous electricity production from intermittent sources for its overseas territories, including Reunion Island.

In the sequel, we investigate the share of intermittency (over 30%) that can be achieved when the supply of a given level of reliability is mandatory. To that end, the future 100% renewable is assessed with a constraint put on the reliability (2008 level): we demonstrate that a need for new capacities (9,4%) is required when Demand Response is unavailable in comparison with the 100 % reference scenario given Fig. 1. In this case, the power mix that fulfills the reliability constraint (only for the kinetic indicator) relies strongly on intermittent sources (up to 60% as shown in Fig. 2(b)).

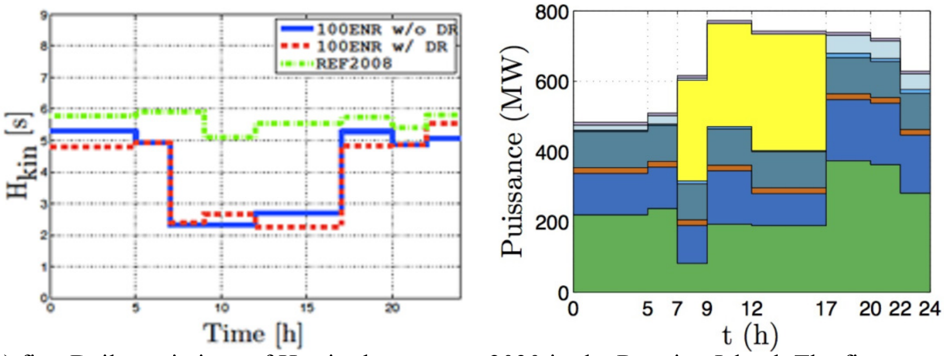

Fig. 2. (a) first Daily variations of H_{kin} in the summer 2030 in the Reunion Island. The figure presents the impact of a high penetration of intermittent renewable energy sources without (w/o DR) and with (w/ DR) demand response. Both scenarios are compared to the 2008-H_{kin} indicator level; (b) Electricity generation by source with the reliability constrained scenario with Demand Response for an average day in 2030 during the summer.

4. Share of renewable energy sources : conclusion

A link between Demand Response solutions, reliability, and the development of the energy system, allows a broader assessment of the impacts and limits of Smart Grid solutions. The study showed that a huge implementation of intermittent sources may dramatically decrease both kinetic and magnetic reserves, thus weakening the reliability of the electricity system. However, we have shown that by constraining the reliability level, the power mix can rely on a significant share of intermittent sources, even though the total installed capacity increases. Total installed capacity can be maintained by combining renewable sources and Demand Response solutions while constraining the reliability level. Further developments will also consider other Smart Grid flexibility such as storage [4].

A production mix that relies on 100% of renewable sources may include a higher share of intermittent sources than the legal limit (30%), with slightly higher installed capacities, and while maintaining the reliability level at its original 2008 value. It also shows how Demand Response increases the share of intermittency permitted in the power mix.

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