TIMES model for the Reunion Island: addressing reliability of electricity supply

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Extended Abstract

Introduction

The Reunion Island aims to have in 2030 an energy consumption based to 100% on renewable energy sources [1]. In 2008, the total primary energy consumption was 1295 ktoe, and as most of small islands, the Reunion Island was highly dependent on fossil fuel imports (86.5%). This paper focuses on the target applied to the electricity sector, where the current use of renewable energy sources is 36% [2]. It means that the mix for electricity generation has to change substantially to reach the announced target. Fortunately, this change can be enabled by high potentials for renewable energy sources such as sugarcane bagasse, solar energy, wind energy, geothermal, marine power.

However, achieving such a wide integration of renewable energy sources on power systems pose two challenging problems to energy planners:

- First, energy policies should be designed to promote efficiently their development, knowing that electricity market designs and appropriate levels of incentives and subsidies are already difficult issues to deal with for small and isolated electricity systems [3, 4].
- Secondly, the technological feasibility and associated cost of renewable energy sources are not adequately assessed. A major issue to address is the reliability of electricity supply, which characterized the ability of the electric system to withstand sudden disturbances [5, 6]. At this point in time, the structure of the electricity supplies is under questions and high shares of renewable energy sources may strongly modify the network architecture and the subsequent level of reliability.

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These issues stress the need for assessing future electrical power systems and the TIMES type of technology-rich models provide a partial solution to this problem [7, 8, 9]. These models enable to compare future electrical power systems for both economical and technicological aspects. Indeed, these models have proven useful to determine plausible evolutions of the energy sector in the mid- to long-term when facing strong environmental pressures.

This paper presents a TIMES model dedicated to the Reunion Island in order to study the feasibility and cost of reaching the target of 100% of renewable electricity production in 2030. The modelling work has been divided into two main contributions: the model development, where attention is paid to the subsidies and incentives system, and the technological feasibility of the model, where we address the reliability of electricity supply.

Model development

The TIMES models optimize energy systems in the long-term with an explicit bottom-up approach through a description of individual technologies by explicit input-output relationships. The main decision variables are investments levels, activity levels and total installed capacities. The study covers the period 2008–2030.

1. The general features of the electricity sector in 2008 were the following [2, 10]:
   - Electricity consumption rose up to 2546 GWh, divided into 50% of coal, 14% of other fossil fuels, 25% of hydroelectricity, 10% of biomass and 1% of others.
   - The electricity peak demand was 408 MW.
   - The total installed capacities were below 650 MW.
   - Since 1995, the growth rate of electricity demand has decreased from 6.7% to 2.8%. It is expected to continue decreasing and reach 2% or 1% in 2025.
   - The power system is small, weakly meshed and without interconnection. As a matter of fact, the French government has put a legal limit of 30% on the level of intermittent capacities of its overseas territories (decree of April, 23th 2008), including the Reunion Island.
   - Specialists estimate at 4 hours/year/consumer the average duration of electricity not supplied, to be compared to 1h15 in Metropolitan France.
2. Experts have proposed the available resources for future energy supply:
   - 130 GWh/year of biomass;
   - 160 MW capacities of photovoltaic units; and
   - 70 MW capacities of hydroelectricity, plus 45 MW of hydraulic storage.
   - Besides, the island promotes the integration of storage capacities on its power system in order to manage more efficiently intermittent sources. Two examples are the installation of a 5 MW NaS battery on the power system, and

the call-for-tenders issued for 10 MW renewable energy farms with storage units.

As an oversea territory, the electricity sector of the Reunion Island strongly relies on subsidies to balance out its geographical situation compared to Metropilitan France. These subsidies are preferentially devoted to renewable energy sources. In particular, photovoltaïcs, and in a lesser extent sugarcane bagasse, benefits from appealing policy mechanisms that encourage their development. Other renewable energy sources are also incentivized but neither their remaining potential can be easily valued nor the policy mechanisms are sufficiently attractive. Hydropower is still developing but the potential for further growth is limited to huge, long-term and expensive projects.

Various scenarios are investigated wherein contrasted hypotheses are made for the potentials of renewable energy sources. These hypotheses enable to compare and discuss the economical feasibility of the future electricity sector of the Reunion Island.

Reliability of electricity supply

At the side of the economical feasibility of 100% renewable energy sources, stands the question of its technically feasibility. Indeed, high shares of renewable – and in particular intermittent – energy sources in power systems induces a decrease of reliability of electricity supply. Thus, restoring an appropriate level of reliability on power systems requires additional investments and extra-losses, which add to the assumed total cost of future power systems.

According to the UCTE handbook [6], the reliability of an electric system is twofold. On the one hand, it is the ability to supply the electrical demand and energy requirements at all times, taking into account scheduled and reasonably expected unscheduled outages. On the other hand, it is the capacity to handle load fluctuations such as electric short circuits and unanticipated loss of system elements. To ensure these features, power systems rely on frequency and voltage management [11]:

- Frequency and voltage are crucial quantities, whose deviations can lead to power outages. This typically occurs when the system experiences transient states (e.g. lightning), or is recovering from production or load fluctuations.

- Maintaining voltage and frequency between appropriate limits depends respectively on the reactive power of the system and on the kinetic and spinning reserves. This emphasizes the need for reactive power and for appropriate reserves levels on power systems.

- Most renewable energy sources, and in particular intermittent ones, do not provide the required reserve levels as efficiently as conventional power units (for example thermal units and hydroelectricity) [12]. Furthermore, intermittent energy sources commonly induce frequent and higher magnitude production fluctuations further increasing the need for reliability of the electric system.

To assess the technicological feasibility of future power systems, we take into account the cost induced for the reliability requirements, which can be provided by a method based on a thermodynamic approach applied to power systems [13, 5]. The resulting cost may increase the total cost assessed with the TIMES model.

Conclusions

This study makes it possible to evaluate the feasibility and cost of reaching the target of 100% in 2030 of renewable electricity production. It also provides the plausible shares of renewable energy sources in the Reunion Island.

This work is still ongoing and we propose to exhibit the results in the light of the economical and technological aspects previously discussed. In particular, several plausible shares of renewable energy sources are depicted through the alternative hypotheses made. The different scenarios are compared through several environmental and economic indicators such as the total discounted cost of the system, technology choices, investment levels, actual shares of renewable electricity production in the future and levels of CO_2 emissions over the years.

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