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Increasing shares of intermittent sources in Reunion Island: Impacts on the future reliability of power supply

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ABSTRACT

This paper analyzes the capability of Reunion Island to achieve electricity autonomy by 2030. Currently, electricity production in Reunion Island is mainly based on imported fuels while it is blessed with high levels of renewable energy potentials. The issue addressed in this paper is the technical and economical feasibility of this ambitious target. The approach relies on a prospective study conducted by the TIMES-Reunion model which provides future production mixes according to different scenarios. It is combined with a quantitative assessment of reliability of power supply with two reliability indicators, regarding that intermittent sources may highly develop and consequently worsen reliability. This study enables us to draw three main conclusions: (i) electricity autonomy can be achieved thanks to high levels of biomass production and of intermittent sources; (ii) however, since fuel oil's power plants appear as back-up units, the reliability of power supply will be lowered. This is illustrated by the decrease of the reliability indicators over the time horizon; (iii) however, provided that appropriate rules on the instantaneous production are enforced, a generation mix that both complies with the electricity autonomy target and with a satisfying reliability of power supply is possible.

Contents

1. Introduction

Pushed by the need for carbon emission abatement and the expected depletion of fossil fuels, significant changes will impact future generation shares in electricity production and architecture of power systems. Among possible options of development,

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increasing shares of renewable energy sources are attractive alternatives for a cleaner and unlimited power generation. In particular, high shares of renewable energy sources may become a critical aspect of future energy systems, both for centralized scheme and for distributed architecture. The integration of renewable energy sources in electricity production has indeed been widely studied to determine their development's challenges and options [1–4]. Current studies analyze drivers and barriers to the target of decarbonizing the electricity mix [5–9]. These studies provide methods to estimate the impacts the decarbonization will have on the electrical sector and the changes required. In this context, the emergence of different paradigms for serving electricity than those for which the system was designed [10] challenges the future changes of the electricity production mix.

These features have rapidly been encountered in remote territories as small islands. Small islands indeed mainly rely on imported fossil fuels for energy production [11,12] so that they are likely to be pioneers regarding the latter changes. In this paper, we focus on the case of the Reunion Island which is a salient example of the "decarbonization" of a production mix since its local authorities have set the ambitious objective by 2030 of reaching self-sufficiency. Considering that a little above one third of electricity production is currently based on renewable sources and that most of existing power plants will be removed within the next two decades, the power sector in Reunion is thereby expected to change substantially.

Several analyses have already studied possible options that will draw Reunion towards a more sustainable energy system [13,14]. They exhibit the available potentials for renewable energy sources and show that Reunion is blessed with abundant resources such as sugarcane bagasse, solar, wind, geothermal and marine energies. Beyond these studies, a prospective analysis is conducted herein to determine the long-term development of the Reunion's power system and to evaluate its capability to reach a production mix with 100% renewable sources by 2030. The analysis, performed with the long-term energy-planning model TIMES-Reunion, enables an evaluation of power sector investment options and activity levels against a multiplicity of load growth and resource supply scenarios.

However, since power supply is usually weakly reliable on small islands, a large integration of renewable energy sources, and especially of intermittent sources, raises technical issues and may lower the reliability of power supply. It is therefore recommended to consider reliability of supply when building options with large integration of intermittent sources, especially for the small, weakly meshed, and remote power system of the Reunion Island. In fact, the reliability of power supply, in Reunion Island is currently lower than in a wide and integrating power system (the average duration of electricity not supplied is estimated at 4 h/year/consumer, compared to 73 min in Metropolitan France as stated by ERDF, the main distributor system operator).

In this paper, we propose to analyze both in terms of renewable energy potentials and of economical and technical feasibility the capability of the Reunion's power system to achieve electricity autonomy by 2030. This approach is, to the best of our knowledge, the first prospective study combined with a quantitative assessment of reliability of power supply.

Section 2 briefly explains the context of power production in Reunion Island. In Section 3, we then describe the main principles of the TIMES-Reunion model, used to perform the prospective analysis, and reliability indicators that assess the reliability of power systems' management according to their dynamical properties. In the fourth section, we present the main characteristics of the electricity production in 2030 in Reunion Island for the different scenarios and discuss their relevance through analyses that study both economical aspects and the long-term evolution of supply reliability.

2. Context for power production in Reunion Island

2.1. A necessary change in power production: currently based on imported fuels while high levels of domestic renewable sources are available in Reunion

First, electricity production in Reunion strongly relies on coal and fuel oils as illustrated in Table 1. For the year 2010, two thirds of the 2699 GWh produced were based on fossil fuels. The electricity sector is therefore almost responsible for half of CO_2 emissions in Reunion, i.e. 49% in 2010 [15]. The production facilities are mainly composed of thermal units: 221 MW work either with coal or sugarcane bagasse, used for base loads, and 265 MW work with heavy or distillate fuel oils, used for semi-base and peak loads. Besides, nine diesel engines of 18.3 MW have in the recent years replaced old fuel oils units (125 MW). Their future activity is driven by the future prices of fossil fuel imports provided by the World Energy Outlook [16].

Secondly, Reunion Island is blessed with high potentials of renewable energy sources, whose development has known a noticeable increase in the last decade thanks to local and national energy policies. Two plans, one launched by the Regional Council of Reunion (called PRERURE) in 2000 and one national (called GERRI) launched in 2008, have indeed promoted investments to achieve an energy mix with 100% renewable energy sources by 2025 through incentive mechanisms such as tax exemptions, direct subsidies or feed-in tariffs.

Since, photovoltaics systems have strongly developed and amounted to 130 MW at the end of 2011. This growth has lead the authorities to set a limit of 30% of intermittent sources in the instantaneous electricity production following the recommendations of EDF, the electricity provider, on the impacts of intermittent generation in a remote island power system [18].

The increase of renewable energy sources in the electricity production mix can continue considering the renewable energy potentials of Reunion Island which are presented in Table 2. The given figures rely on data provided by [13,14] and on discussions with experts. More details are given in [19].

2.2. A power demand driven by the possible development of electrical vehicles

Focusing on the electricity demand, the average growth rate of electricity consumption was approximatively 5.3% per year

Table 1
Shares of electricity production in Reunion Island in 2010 and installed capacities at the 1/1/2012 [17].

Sources	**Shares** (%)	**Installed capacities** (MW)
Imported fossil fuels		
Coal[a]	49	52.5
Fuel oil (heavy and distillate)	18	265
Domestic and renewable sources		
Sugarcane bagasse	10	159
Hydroelectricity	20	146
Wind energy	0.6	16.5
Photovoltaics	2.8	130
Municipal waste	0.3	4

[a] Most capacities functioning with coal also work with sugarcane bagasse and are therefore included in sugarcane bagasse capacities.