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Importance of islands in renewable energy production and storage: The situation of the French islands

Gilles Notton *

Laboratory Sciences for Environment, University of Corsica Pascal Paoli, UMR CNRS 6134, Route des Sanguinaires, F20000 Ajaccio, France

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ABSTRACT

The islands are often not or only partially connected to continental electrical networks and have to manage their energy supplies in reaching themselves the production/demand balance while ensuring the quality of the delivered electricity. The low consumption and the lack of interconnections induce higher energy costs than in other regions. For increasing their security, the islands prefer to use indigenous sources as renewable ones; unfortunately, the intermittence and stochastic character of these “fatal” energy sources make them more difficult to manage and it is aggravated in the case of small island networks. The islands are good locations for using and testing new technologies of energy production and storage. Most islands have a good renewable energy (RE) potential often underused. The difficulties of electricity management in island grids are first shown particularly with the impact on the energy production cost. Then, the problem of the integration of renewable energy sources (RES) in island electrical grids is highlighted. The energy situation of French islands is presented with a particular focus on the part of renewable sources. A higher share of renewable energy in the energy mix can be reached only with the development of the energy production efficient prediction, with the development of energy storage means and with an optimal management of the energy flux via the utilization of smart grids.

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1. Introduction

In Europe, there are about 300 islands (6% of the territory) for 14 M-inhabitants, i.e. higher than the population of some European countries. More than 100.000 islands of all sizes are scattered in the World in all the latitudes and longitudes with almost 500 M-inhabitants [1,2]. The total islands area is 1/6 of the Earth area.

In the Chapter 17 of Agenda 21 adopted at the Rio Conference [3], it is written that “the islands are specific from both environment and development point of view; they are very fragile and vulnerable and in the context of sustainable development, energy is the cornerstone of their planning strategies”.

In the final document of the First European Conference on Sustainable Island Development [4], is stated: “Non-renewable energy sources must be considered as provisional solutions, unsuitable as a long-term solution to the energy problem in islands“.

The aim of this article is to stress that the difficult energy context of islands has led electricity distributors to develop, for a long time, more efficient solutions for managing the network and integrating

* Corresponding author. Tel.: +33 495524152; fax: +33 495524142.
E-mail addresses: gilles.notton@univ-corse.fr, gilles.notton@yahoo.fr

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intermittent renewable energy. Our objective is to show, as said by Marin [5] and Duic et al. [6], that islands have become genuine laboratories of the future of energy sustainability. To reach this objective, this paper is divided into 4 parts:

- In a first part, it will be shown that it is a difficult task for an electrical system operator to maintain a precise balance between the electricity production and the electrical consumption in a conventional electrical network. Since the power installed in the island grid is finite and small, any perturbation (e.g. a sudden production decrease or an increase of the power of a motor working) weakens this energy balance and disturbs the frequency and the electricity quality. Some examples will be given in view to illustrate this difficulty.
- Then, the energy mix of French islands will be presented and it will highlight that fuel generators are mainly used inducing electricity production costs much higher than in inland; which has led each state to adopt specific measures to take into account this specificities.
- In a third part, it will be underlined that the influence of the variability and unpredictability of wind and solar on the electricity management is all the more important that the penetration levels is high; then, other generation units have to compensate the difference and must be operated with a sufficient reserve margin.
- Despite the fact that the intermittent character of the production raises more complex problems for islands than for large interconnected electrical networks, it will be shown that the part of “fatal” renewable energy system in islands is more important that in mainland; it is due to the high cost of the other energy means which pushes islands to use their natural resources; but this objective can be reached only with the development of efficient prediction of the energy production, through the development of energy storage means and an optimal management of the energy flux via the utilization of smart grids.

2. Electricity supply/demand balance

The electricity must be used immediately after being produced! The energy manager must dispatch the electricity and ensure a precise balance between electricity generation and demand. In a power system, the power balance must be maintained at any moment, i.e. the electricity demand must be balanced by the electricity generation at all times. The electrical network must work at a stabilized frequency (50 Hz, sometimes 60 Hz), thus, the production systems must permanently adapt their production to the power consumption either in the electrical stations or in the dispatching centre.

In normal mode, there is a situation of balance: the production is always equal to the consumption and the electricity frequency weaves very little around the reference frequency. If the production decreases suddenly due to the loss of a production means (or a cloud passage above a PV plant), this balance is weakened and the frequency falls below the reference frequency. In this case, a rapid increase of the delivered electrical power by a connected production means has to occur (for example, an increase of the produced power of an engine working at part-load) or the start-up of a new production means is needed. But the rise speed in power of an energy plant and its starting time is not instantaneous as seen in Table 1 [7]. As the run-up time is long, the activation of a new production system must be anticipated; as seen in Table 1, only a hydraulic plant starts rapidly, followed by a light fuel turbine; internal combustion engines (fuel or gas) need about 45 min before producing electricity.

If an increase of the consumption and consequently the start-up of a new energy means are not anticipated, the imbalance continues and it will need to shed a fraction of the load. If this load shedding is too slow or insufficient, there is a risk of blackout. Similarly, if the load is lower than the production, the frequency increases and this presents dangers for the electrical machines, the security system stops the electrical machine and leads to a power failure in the network.

3. Case of island territories

The insular electrical systems are governed by the same electro technical rules as those that are applied in mainland networks but the absence or the limitation of an interconnection to a large network provide it some specificities recognized by the competent European and French authorities [8].

As the islands are not or only partially interconnected, the energy manager has to reach the supply/demand balance without the assistance of external production means located on neighbouring areas. Islands have a structural fragility: a short circuit in the electrical system will generate a voltage drop in all the island [9,10], the low inertia implies a high frequency variability with consequences on the voltage [9,10]; the previous problems are compounded by the high unit size of an electrical generator in comparison with the peak power in the network. The default probabilities in an insular network are very high compared with an interconnected network [10]. Voltage and frequency drops are more numerous and deeper in islands than in mainland (dozens each year) [9]. In Corsica, before the partial AC interconnection with Sardinia, more than 200 failures per year occurred on the transmission network with voltage and frequency dips (less than 46 Hz) [11].

Islands have often a small population, a low and variable energy consumption (in Corsica, a minimum of 130 MW in May and a maximum of 500 MW in December) that prohibits the use of high rated power production means and requires the utilization of electrical plants with a small rated power for a better adaptation to the load and for limiting the disturbances due to the loss of an electrical plant [9]; few electrical systems exist with a low rated power (Table 1). An internal combustion engine operates between 65% and 100% of its peak power (Table 1), using three 20 MW engines allows to have a wider working range (between 13 and 60 MW) than using only one 60 MW engine (between 39 to 60 MW) (Fig. 1).

Table 1
Characteristics of electricity production plants [6].

Type	Size (MW)	Minimum power capacity	Rise speed in power per min	Start-up time (h)
Nuclear power plant	400–1300 per reactor	20%	1%	40 (cold)–18 h (hot)
Steam thermal plant	200–800 per turbine	50%	0.5–5%	11–20 h (cold)–5 h (hot)
Fossil-fired power plants	1–200	50% - 80%	10%	10 min–1 h
Combined-cycle plant	100–400	50%	7%	1–4 h
Hydro power plant	50–1300			5 min
Combustion turbine (light fuel)	25			15–20 min
Internal combustion engine	20	65%		45–60 min