HOW TO DEVELOP ADDITIONAL RENEWABLE ENERGY IN ISLAND AREAS?

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ABSTRACT

Islands territories are facing new challenges with the massive deployment of intermittent renewable energy. This paper explains this new issue and presents the alternatives currently studied in order to develop additional renewable energy in these sensitive areas.

INTRODUCTION

Most French island areas have very strong and valuable natural assets: mountains with rivers, geothermal sources from volcanoes, forest and agriculture, wind, sun, etc. Accordingly, renewable energies have a considerable success in these areas. However, the rapid and massive deployment of wind and solar energy may endanger the stability of the electric system: these productions are subject to rapid variations that are difficult to predict and that other local energy source are not able to compensate properly without interconnection with a strong neighbouring electric system. As a consequence, a regulatory technical acceptability limit for intermittent energy has been defined to 30% of power from intermittent energy injected into the system above which it becomes difficult to balance the system. This technical limit has already been reached in Corsica, Guadeloupe and Réunion Islands and several sites were disconnected when reaching the 30% threshold.

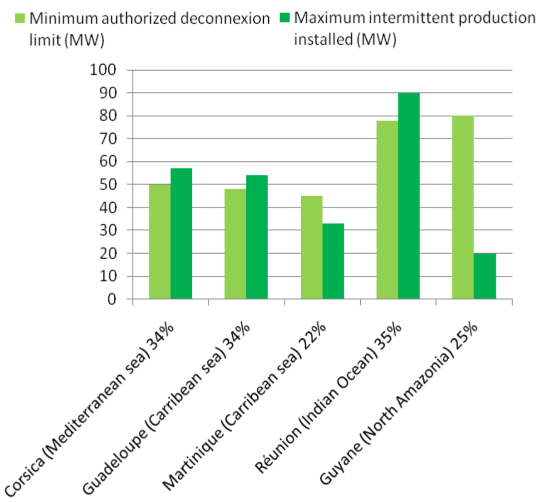

Fig. 1 - Installed power and technical limit in the main French overseas departments and Corsica (2012)

INTERMITTENCY BRINGS NEW CHALLENGES

The intermittency, defined as high variability in the available power from a power station, is a major obstacle. For relatively low penetration rates, the impact of renewable energy generators is limited and can be easily absorbed by the electrical system, even when not interconnected. However, as their proportion increases, it becomes more difficult to define solutions to offset any imbalances between production and consumption. Moreover, in the short term, these plants affect the profitability of existing thermal power stations as the latter are still needed to mitigate the intermittency and yet are forced to limit the amount of energy they inject into the grid. For some renewable energy plants, intermittency may be associated with the difficulty of predicting fluctuations in production. This is the case for wind power, which depends on wind, and, to a lesser extent, for photovoltaic energy, which depends on the sun.

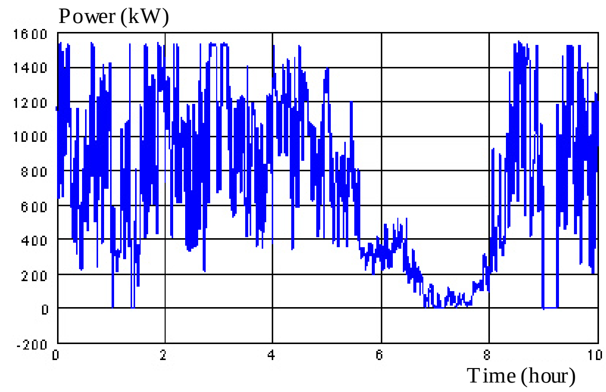

Fig. 2 - Power generated by a wind turbine of 1.5 MW (credit : Labourec)

SOLUTIONS TO INTEGRATE ADDITIONAL RENEWABLE ENERGY

Economic mechanisms

Two economic mechanisms give a first answer to this issue and allow a controlled deployment of renewable energies:

- a purchase obligation for renewable energy at regulated incentive tariffs facilitates the deployment of some selected hydraulic, biomass, geothermal, wind and solar installations. Purchase tariffs for photovoltaic are scaled down every quarter if the volume of connection requests exceeds the target set by the government,
- a tendering system is preferred for larger installations. In this case, the capacity and the characteristics of the future power plants are defined in advance. Calls for tenders were organised by the French energy regulator (CRE) and 66 MW of wind energy with energy regulation and 57 MW of photovoltaic with storage will be installed consequently in the main French overseas departments and Corsica.

Smart grid technologies

In addition to these economic solutions, the introduction of new information and communication technologies (NICTs), which takes the form for example of sensors placed in the grid, facilitates the integration of intermittent electricity generation.

Better monitoring and controlling of the grid

Sensors optimise the use of electricity grids thanks to a more specific knowledge of loads and of critical systems characteristics such as frequency. They allow a better monitoring of the system status at any time (default, congestion, change of voltage, etc.). System operators will therefore be able to anticipate incidents and will be assisted in their decision-making in order to optimise grids and to make them safer. Tools for controlling will also be implemented for a better integration of distributed production while respecting system stability and quality. It will be possible to interact with renewable generation thanks to automation functions (voltage and power settings, reconfiguration after default) or aggregation of distributed generation through a local "virtual plant".

As a first step, EDF SEI has develop the Push system enabling to calculate at a 5 min interval the ratio of the sum of the total intermittent power produced to the total power produced. This system has been developed with Itron.

A meter is installed by every producer having a production power above 36 kVA. Every 5 minutes, this meter sends the value of the power produced to the dispatching through a private Access Point Name (APN) using GPRS. There, an information system sums the power produced by the different category of equipment, evaluate T the average total power produced during the period and compares it with R the average total power produced by intermittent renewable energy sources (Fig 3).

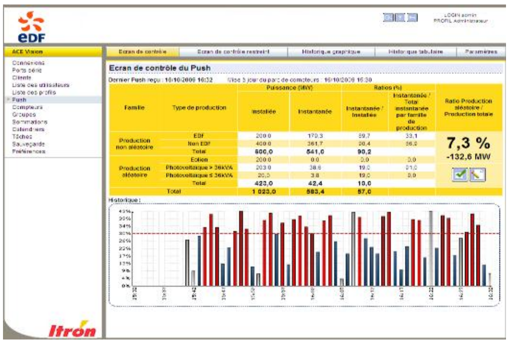

Fig. 3 - Screen of ACE vision, the ASAIS software giving the % of production from intermittent renewable sources.

When R > 30% T, a visual and acoustic alarm is generated and an application helps the dispatcher to choose the production that should be disconnected. The first producers disconnected are the producers who last asked to be connected to the grid. These ones were aware of this risk when contracting for their connection. The disconnection is made individually for solar plants with a power over 100 kW, and by groups for the others corresponding to PV blocs of power.

To disconnect sources, an individual signal is sent to big solar plants and a low frequency PLC signal is sent to other ones, with a code indicating the bloc of producer that should be disconnected. All the producers are equipped with a remote terminal unit (RTU) system able to collect this signal and to automatically and safely stop their production.

Forecast

With some feedback, IT technologies may also bring additional information enabling enhanced forecasting and consequently a better optimisation of the mitigation means used to compensate potential intermittencies of production. Significant progress has been made in forecasting in recent years, for example the insertion of wind and photovoltaic generation into the system involving collaboration between system operators, producers and MeteoFrance (the French weather service).

In this respect, launched in 2011 in Réunion Island, Pegase project is based on solar and wind farms, weather forecast and algorithm to manage intermittency and optimise intermittent energy sources integration thanks to NaS battery installed in December 2009. Its objective is to tackle grid stability issues caused by large-scale PV and wind power generation connected to the grid by using the storage to:

- smooth or schedule PV farm (2MW and 10 MW see Fig.4a) and wind farm (see Fig. 4b) combined with day ahead and intraday forecast,
- supply frequency regulation and spinning reserve.

Fig. 4a - 10 MW wind farm **Fig.4b - 2 MW PV farm**

The following activities are presently being investigated:

- New methods of day-ahead forecast for renewable energy (RE) generation (PV or Wind). A statistical model based on historical hourly solar power generation and numerical weather forecasts from the European Center and Meteo France with high spatial resolution has been developed. The performances are currently being analysed. Spatial forecasting errors are analysed and compared with those obtained by a reference model based on historical data.

- New method of intraday forecast for photovoltaic generation. Different ways are explored to set up intraday forecast (up to 3 hours) by on-site sky imager and satellite image coupled to image analysing and RE production recorded. Real-time meteorological sensors and a sky imager network surrounding Reunion Island are installed to generate a data flow able to feed PV intraday forecast software.

- Mathematical modelling and software are currently being developed to schedule a day ahead RE & storage plan production taking into account dispatch constraints such as maximising evening production, minimising impact of RE generation forecast errors and managing long term storage state of charge. An intraday optimisation model and software are also currently being developed to update every half-hour the RE & storage production plan with the intraday forecast.

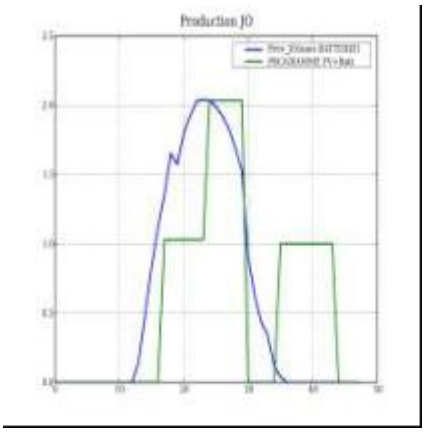

Fig. 5- Day-ahead PV forecast and production plan

- Development of a SCADA and information system to collect in real-time RE farm and storage generation data.

- Development of an output control technology to suppress fluctuation and stick to the schedule production plan with lowest error.

Pegase project is carried out through collaboration with French national meteorological agency and dynamic meteorological laboratory.

At first move, the project is more dedicated to bulk renewable plants but the forecast approach and the optimisation results can be used with some adaptation for the smaller installation such as the one planned in the Millener project.

Demand side management

Smart meters and other smart equipment installed at customer location are a great step towards smart grids. Their applications open up a major field of innovation downstream from the meter. Consumers will play a decisive role in tomorrow's electricity system and consumption will be more and more controllable. It will compensate the not always perfect predictability of wind and solar energy.
The figure below shows the repartition of electricity consumption supposed to be proportional to the subscribed power versus the number of customers. Clearly, the big customers appear as the low hanging fruits: a significant amount of energy may be curtailed without contracting with a lot of customers and sophisticated solution may be used. When addressing residential customers, mass market solutions should be targeted, for instance by taking advantage of already existing gateway such as internet boxes or smart meters that may be used to switch off the curtailable loads. Otherwise, the business model will be harder to elaborate knowing that a large broadcast system is needed to aggregate the load in a flexible virtual power plant. In case of small systems like those of an island, this VPP will be directly controlled by the dispatching. One of the aims of the Millener project is to see if it would be possible and if yes at what conditions. [1].

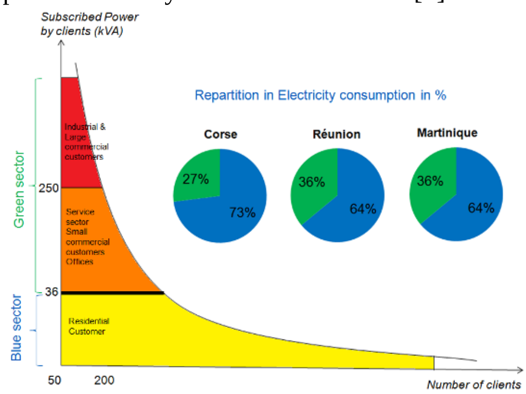

Fig 6 - Distribution of electricity consumption in % depending on the subscribed power

But generally, the customer will not accept its loads to be controlled by the sun or the wind intermittency excepted if the considered load presents a certain buffering capacity such as water heating or EV charging systems. For big customers, the load shedding is ruled by well-defined contracts giving the power requirements with the limits accepted, the minimum duration of the curtailment, the accepted frequency, *etc*. Similarly, the load curtailment system is generally not adapted to the real time compensation of wind or solar fluctuation except for loads having buffering or storage capacity such as big cold storage. Nevertheless, in a day-ahead approach with good weather forecast, load management may probably help to increase the share of renewable.

Storage

Last but not least, deployment of energy storage in smart grids will enable high penetration of intermittent energy sources. With remotely controlled energy storage, it will be possible to exceed the 30% threshold while maintaining the stability and security of the electricity system. Several families of energy storage technologies have improved during the last decade in terms of performance and costs. Several field experiments, aiming at validating earlier laboratory tests and obtaining broader feedback in the perspective of large scale deployment, have started in the French overseas areas. For instance, Pegase project in Réunion Island will test a NaS (sodium–sulphur) battery with a capacity 1 MW associated with advanced forecast.
It is supplied by NGK Insulators (Japan) and built by assembling twenty 50-kW battery modules as depicted in the Fig. 1. It is capable of storing about 7,2 MWh of electricity, with a 1,2 MW charge and 1 MW discharge process. At the beginning, the NaS battery has been used with satisfaction for daily load shifting. It means that charge was made during night and afternoon and discharge in the evening and at noon during austral summer. It has been stopped to be upgraded and will be restarted at the beginning of 2013.

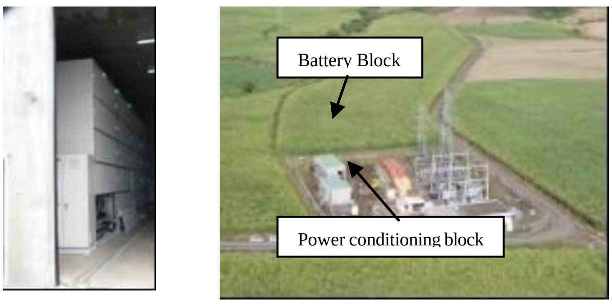

Fig.7 - NaS battery module stacking. Internal view of the building. Substation view.

As photovoltaic production is purchased under feed-in tariffs, it has the highest priority in the dispatch merit order and conventional combustion plants have to decrease their power to match the supply demand equilibrium. It leads to a lack of primary reserve (as conventional production is lowered) without any participation in frequency control by the photovoltaic production. In case of a sudden outage, frequency decreases even faster if the photovoltaic power plant's decoupling device is triggered. This leads to an automatic load shedding to avoid frequency collapse.

The SEPMERI project in Guadeloupe aims at installing a seawater pumped-hydro storage plant with a capacity of 50 MW.

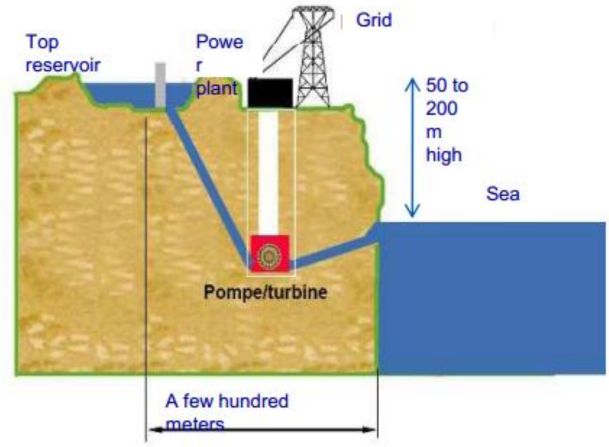

Fig. 8 - SEPMERI: Sea water pumped storage plant

In a more prospective approach, the Millener project will also test the association of small lithium-ion batteries combined with rooftop photovoltaic and energy boxes for residential customers in Corsica, Guadeloupe and Réunion Islands. The combination of these projects will help in optimising the size and location of energy storage in the grid depending on the technology used and in refining the associated business models of these systems.

CONCLUSION

There is a range of solutions, both technical and economic, which strongly reduce the negative impacts of the integration of renewable energies in the grid. Smart grids projects are currently evaluating these solutions. Feedback from these projects will be decisive in order to define an appropriate framework for such solutions.

REFERENCES

[1] N. Buriez, 2012, "WILL SMALL-SCALE PV CONTRIBUTE TO FRENCH INSULAR GRID OPERATION ?", *CIRED Workshop - Lisbon 29-30 May 2012*, Paper 261