SoFLEX'hy

EDF Hydro-PV-virtual power plant demonstrator

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***Abstract*—Virtual power plants (VPP) are considered to be a promising solution for integrating renewable energies, intelligent consumers and innovative storage systems into the existing energy supply system in an economically sensible manner. This presentation focuses on EDF SoFLEX'hy project, which is an industrial size VPP demonstrator combining 250 MW of hydro generation, 10 to 50 MW of PV generation and potentially a 5 MW battery and a 10 MW wind turbine. A variety of local flexibility services will be demonstrated, such as stabilizing and balancing the fluctuations of the solar generation, day / night energy transfer to cover the evening peak load, and controlling grid congestions. The objective is to illustrate the complementarity between renewable energy sources and to demonstrate the role of hydro generation as a facilitator of the integration of variable renewable energy sources through the provision of local flexibility services. With the entrepreneurial vision of EDF Mediterranean Unit to support local politics, Durance Cascade was a good opportunity for this demonstrator because of numerous constraints such as irrigation, drinking water supply, complex generation management. Such hydro-hybrid solutions have a wide field of application in solar and hydro rich regions in the world, from large size power systems to smaller off-grid systems.**

Keywords- Virtual power plant, information system, generation management, forthcoming ancillary services

I. INTRODUCTION

New and Renewable Energies (NRE) are known as distributed generations and are located in areas where their profitability is the maximum. However, these places are also where consumption is usually low. A way to integrate mass NRE is to develop high voltage networks so as to use geographical generation spread in different areas. Nevertheless, this development may take a long time and may be expensive. Subsidies for NRE development tend to disappear to make room for market payment and the necessity for NRE to supply new services (flexibility, capacity, ...). The mass development of NRE in Europe will lead to an increasing variability and more intermittency on electric networks that may lead to congestion problems for some high-voltage lines.

In view of those considerations, it would be interesting to develop a joint management of NRE with local and flexible generations. For that, thanks to its renewable, regional and historical flexibility, hydroelectricity is a suitable candidate. Hydroelectricity is a field to investigate as a part of a Virtual Power Plant with NRE generation.

II. THE SOFLEX'HY PROJECT

A. Birth of the project

In April 2015, the French government decided to send out a call for projects to develop regional smart power grid. Hydro Generation Mediterranean Unit of EDF, supported by the Hydro Engineering Center of EDF, participated in the tender of the southern French region (Flexgrid Project). It put forward the idea of demonstrating a virtual power plant with part of the hydro power plant of the Durance Cascade (taking into account its operating constraints), in order to specify and test new local and flexible services. One of the aim of the VPP is to increase the capacity of the regional network of integrating new Renewable Energy.

In May 2016, Flexgrid was chosen by the French government to be developed.

From June 2016 to September 2017, EDF carried out a business plan and searched for funding for part of the project. The kickoff of the project occurred at the end of November 2017.

B. Organization of the project

This project is divided into 3 parts:

- The first axis is directed by R&D in order to determine hydroelectric potential future services in electric systems with a high rate of NRE. To make it simple, the objective is to determine :
  - Which services will be needed by the operators (RE, DSO, TSO),

  - o On what kind of electricity systems (generation, network topology, markets, size, interconnection level, …) will be developed,
  - o Taking into account which market rules,

and then to model services on chosen use cases.

- The objective of the second axis is to develop a VPP demonstrator, in order to test in operation services provided by the first axis. VPP takes into account the specific constraints of Durance Cascade and the existing services.
- The third axis is to determine business models linked to the services suggested by the first axis.

C. The project launch

SoFLEX'hy project was officially launched in November, 2017, as far as the first and the second axis are concerned. A first test of service is carried out on Durance Cascade in June, 2018.

First of all, the project was carried out with EDF staff and EDF means of generation. Then, in the second stage, EDF will integrate in the project new partners and new means of generation (PV, battery and maybe wind turbine) belonging to private generators.

Thanks to the second axis demonstrator, services were tested step by step. The period between two steps is called a "run". For each run:

- a list of generation means is carried out. New means are integrated into the information system,
- a service to be tested is selected,
- development of Energy Management System (EMS) and hydro algorithms is made to fulfill the service,
- on site tests are realized during less than two weeks (then the system is back into normal operation),
- a feedback report is made.

III. THE DEMONSTRATOR

A. VPP composition

In the first instance, the virtual power plant consists of:

- 7 Hydro Power Plants (HPP) of the Durance cascade line n°4 (250 MW all together). The cascaded HPP are separated by canals. (owner : Hydro Generation Mediterranean Unit of EDF),
- 2 solar power plants with an installed power of 10 MW (owner: EDF New Renewable).

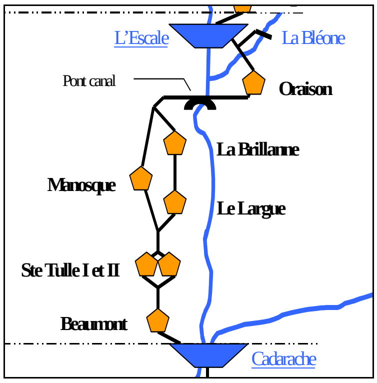

Figure 1 : The 7 HPP of the Durance Valley

In the further stages, the virtual power plant will potentially consist of:

- 7 HPP of the line n°4 of the Durance cascade (250 MW),
- 2 EDF solar power plants with an installed power of 10 MW,
- solar power plants in addition with an approximately installed power of 30-40 MW (not EDF),
- 1 battery system of 1 to 5 MW (not EDF),
- 1 potential wind turbine of an approximately installed power of 12 MW.

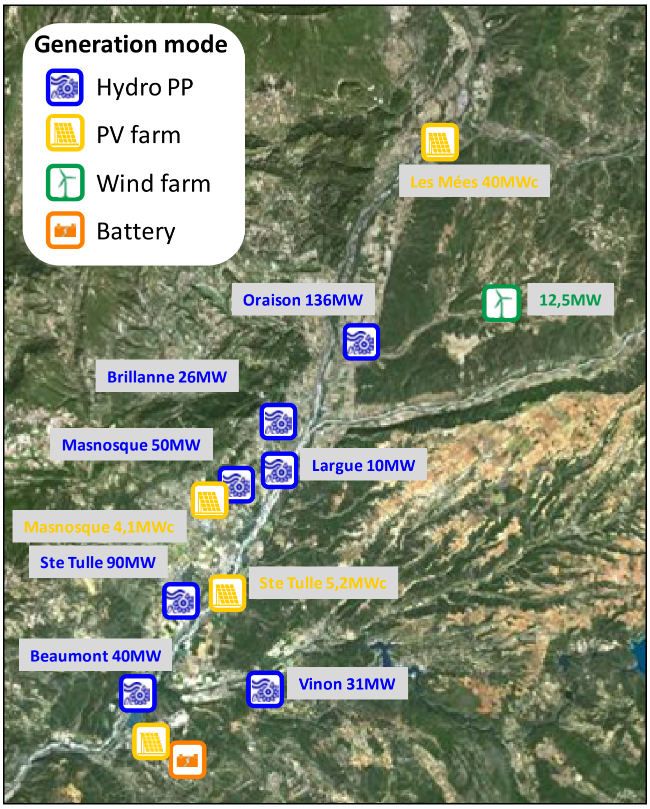

Figure 2 : Geographic situation of the Durance

B. VPP principles

The virtual power plant:

- integrates the different types of generation (dispatchable and non-dispatchable) to give a reliable and optimized overall power supply to the grid,

- tests services in order to reduce the impacts of NRE's intermittency and variability (Hydro-generation/Battery compensation),
- tests services in order to improve grid stability, line use rate, peak shaving, …

C. *Work distribution*

Since the project launch, three teams of EDF have worked on the demonstrator:

- Store&Forecast (EDF spin-off) is in charge of PV generation forecast, data collection (either forecast or real-time date), supervision and generation distribution (hydro, PV, batteries), battery management. Store&Forecast has already commissioned a VPP without Hydro generation mean in a French island (Sein island).
- EDF-EN (Subsidiary of EDF-SA), owner of the PV power plants, provides PV data.
- EDF-Hydro (EDF-SA), owner of the HPP, is in charge of providing Hydro data, hydro generation forecast transmission and real time PV offset adjustment (distribution between several HPPs taking into account existing services already provided).

D. *VPP Information system*

One of the main issue of the project was to build a secure information system (IS) between all the components of the VPP. The most important difficulty was to link the specific information systems of each partner and to find interoperability solution to make the IS of the VPP efficient.

The information system has been built as presented on the scheme below.

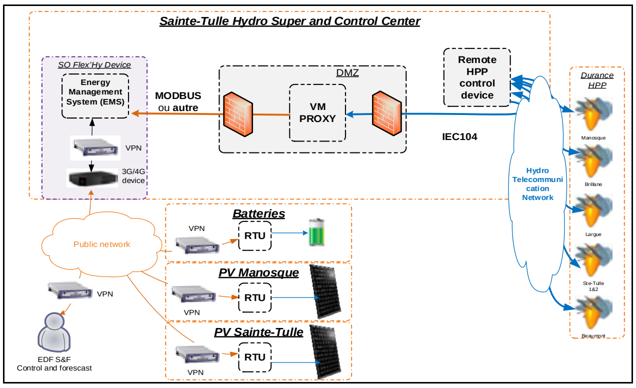

Figure 3 : Information System of the demonstrator

With the development of the Energy Management System, a specific Human Machine Interface HMI was created.

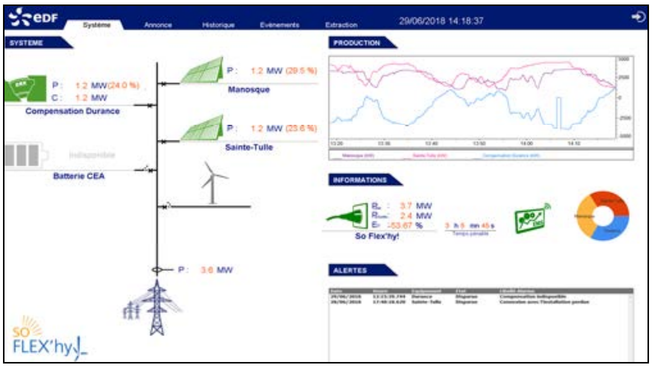

Figure 4 : Specific VPP HMI

E. *First run description*

After simulating VPP behavior, the first run consisted in:

- Forecasting the day ahead the two PV power plants
- Scheduling as usual the day ahead generation of durance file 4 (optimized in the stock of facilities of Hydro)
- Selecting a generation band (used normally for the frequency secondary reserve) in order to take into account PV compensation.
- Supervising the gap between what has been planned for PV generation and what is real-time realized by PV power plants
- Sending a new generation setting point to durance file 4 (taking into account durance file 4 planned generation and real-time gap)
- Distributing the new setting point between the hydro power plants of file 4 Durance taking into account :
  - o unit availability,
  - o other services in operation (potable and industrial water distribution, tourism constraints such as water body level, agriculture watering),
  - o flow management of the entire Durance valley

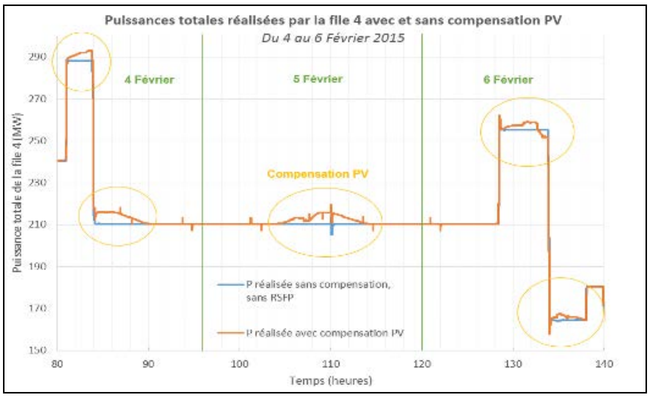

Figure 5 : Results of first demonstrator simulation

For that, the demonstrator was developed as follow:

- Generation Means :
  - File 4 Durance (Hydro Power Plant) : 250MW
  - Manosque (PV power plant) : 4MW
  - Sainte Tulle (PV power plant) : 5MW
- Tested service :
  - VPP Forecast respected during real time operation (without PV curtailment)
- Work achieved :
  - Design and Commissioning of the VPP Information system
  - Design and development of EMS software, PV forecast algorithm, and new real time hydro algorithm including the update of cyber security devices
  - HMI design and development
  - Data exchange definition and validation
  - Implementation of additional sensors
  - Test platform set up
  - On site tests scheduled the first week of July, 2018 and realized in 2 steps (2018.06.28 and 29 plus 2018.08.23 and 24)

F. *First run results*

Gaps between what has been planned for PV generation power plants and what is real-time realized by PV power plants have been compensated but gaps were not big enough.

Information System worked correctly enough and cyber-security was efficient.

Telecommunications means of the VPP (4G) have to be straightened (as it was a proof of concept, the project did not invest in robust means).

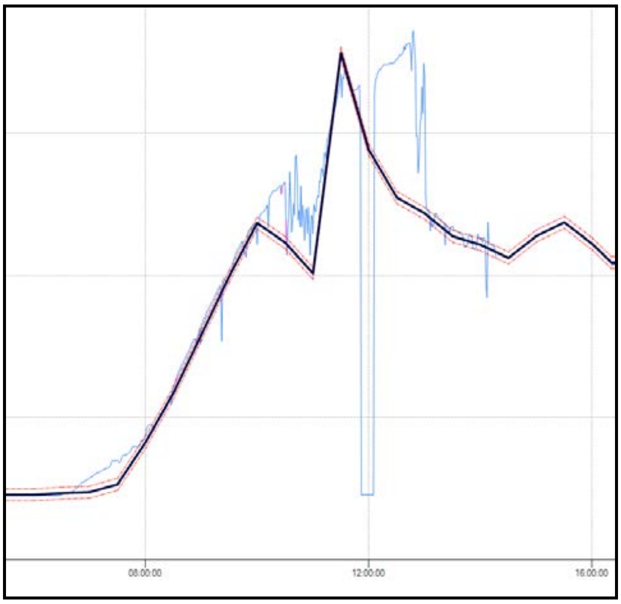

Figure 6 : First run results – VPP forecast and real time powers

G. *Second run description*

In April 2019, new tests of the VPP were launched with the additional solar power plant of Istres-Saint Martin.

The 2nd run was commissioned on the 3rd and 4th of April 2019 :

- Generation Means :
  - File 4 Durance (Hydro Power Plant) : 250MW
  - Manosque (PV power plant) : 4MW
  - Sainte Tulle (PV power plant) : 5MW
  - Istres-St Martin (PV power plant) : 20 MW
- Tested service :
  - VPP Forecast respected during real time operation (without PV curtailment)

H. *Second run results*

Results are more relevant than the first run because of the amount of PV generation to be compensated.

Weather forecast was perfect to evaluate algorithms (rainy period and sunny period, relevant and irrelevant forecast).

Information System has been tested in depth (computing switching, loss of connection, …).

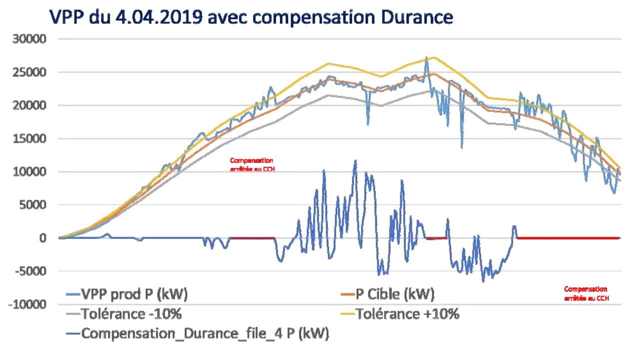

Figure 7 : Second run results

I. *Future runs*

Due to Durance Cascade's constraints, the future runs will probably deal with:

- use of a battery or a wind turbine in order to extend VPP components and improve VPP optimization,
- new local services such as peak shaving, generation shifting … (to be determined and validated).

IV. Conclusions

SoFLEX'hy is the first step to demonstrate the flexibility of very constrained hydro power plant for local NRE integration. The second step will be to find out and demonstrate what should be the type of HPP (PSPP, poundage PP, reservoir power plant) to be used in order to fulfill future services.

These services will be clearly useful in the near future for Distribution and Transport network in order to integrate more and more Renewables.

SoFLEX'hy concept is rather dedicated to local network which are not interconnected or coherent electrical zone management (generation shifting on a line, congestion management, peak shaving,..). This is a big issue for the years coming. French island, such as La Réunion, (which has hydro power plant and renewables installed on its territory) can benefit from SoFLEX'hy 's services.

Though, the concept can mix national or trans-European existing services such as balancing, capacity, automatic frequency regulation and local services as mentioned above.

By stacking a part of these services, existing Hydro Power Plant can be one of the solution to integrate, on a large scale, renewables in the future.

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