SMAP PROJECT OR HOW TO INTEGRATE CROWDFUNDED DER IN A RURAL DISTRIBUTION GRID

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ABSTRACT

In the context of SMAP project (SMArt grid in natural Parks), this paper will mainly present:

- *Connection studies peculiarities about a new crowdfunded distributed PV structure named Centrale Villageoise*
- *Further measures confirming that the village power grid would be exposed to potential constraints*
- *Simulations evaluating the margins and potential future power grid weaknesses with PV developments.*
- *Solutions tested to achieve better integration: notably PV inverter control without then with full experimental smart meter data integration.*

I. INTRODUCTION

SMAP (SMArt grid in natural Parks) is the first smart grid demonstrator in a rural zone with producers/consumers citizens involved in a crowdfunded distributed PV structure named CVRC: “Centrale Villageoise Région de Condrieu”. This consists in 8 small PV plants totalizing 76kWp in the same administrative structure (CVRC) and the same village, (“Les Haies”), owned by 160 citizen shareholders and connected to the distribution grid.

This experimental project was officially launched in December 2015, after the grid connection of the CVRC in August 2014.

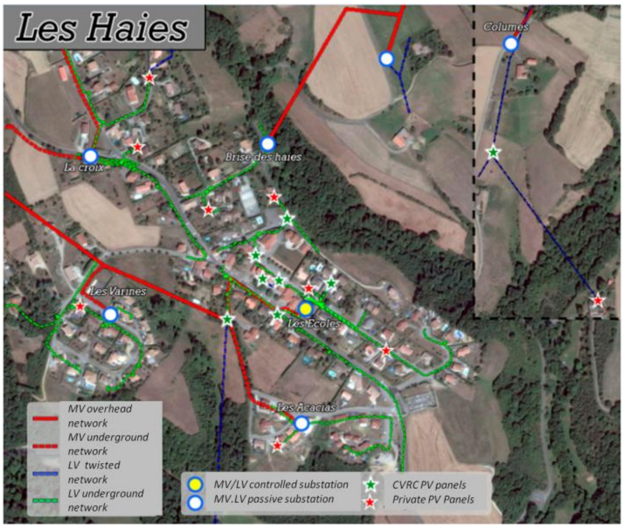

Figure 1: actual grid configuration of “Les Haies”

It aims to find smart grid solutions for a better development of LV DER and balance of the grid between local consumption/production in a non-urban environment.

SMAP is organized in 5 working package and gathers 10 partners together from industrials to regional associations. The technical one about distribution grid integration is driven by the major French DSO Enedis, while Grenoble-INP, a French university, contributes to the research part.

In 2016, this collaboration permitted to obtain the first results. It was mainly load flow computer simulations in order to understand the possible technical issues. From 2017, smart grid solution simulations will be done, and selected ones will be followed by real on-site tests. This could be useful for the energetic transition coming in France, particularly for optimal power grid integration of crowdfunded LV distributed PV and helpful for the French territory planning.

II. CONNECTION STUDIES FOR CROWDFUNDED DER PV

In 2014, the CVRC forecasted a total PV production capacity of 150 kWc. However, the initial grid connection studies realized by Enedis for the CVRC showed that such a capacity could lead to grid constraints, resulting in the necessity of grid reinforcement (namely MV/LV transformer mutation and/or cable changes).

As a matter of fact, this PV production project was also impacted by rural factors, like few tertiary or industrial activities, and city working commuters. Thus, the diversity factor is poor (the aggregation of all consumption loads doesn't compensate their variability and some daylight PV production). Another interesting point is that the CVRC offers to the village inhabitants to rent their rooftops: owners do not have incentives to locally consume the production.

The initial connection simulations realized by Enedis showed that some PV plants would lead to high voltage constraints and even current constraints for some places. Therefore, as the reinforcement of this rural grid comes with high cost, the CVRC had to lower their ambition from 150 kWc to 76 kWc.

That is why SMAP project power grid studies are very important: we want to better understand the behaviors of the quality of supply parameters of this developing situation, the crowdfunded DER PV in rural environment. We can then find new ways to welcome more DER on the distribution grid without any issue and eventually generalize the outcomes.

III. ELECTROTECHNICAL MEASURMENTS TO FORECAST CONSTRAINTS

In early 2016, almost 200 smart meters were deployed on the 6 LV grids of the village and MV sensors will be installed on the MV/LV transformer integrating the most PV production. The data gathered have given some great insights on the behavior of the distribution grid in the environment described. For example, the objective was to identify the local voltage profiles and the potential impacts of distributed PV production.

Furthermore, some Power quality analyzers were installed on the 6 MV/LV transformers between August 2015 and September 2016.
Some key results are presented below:

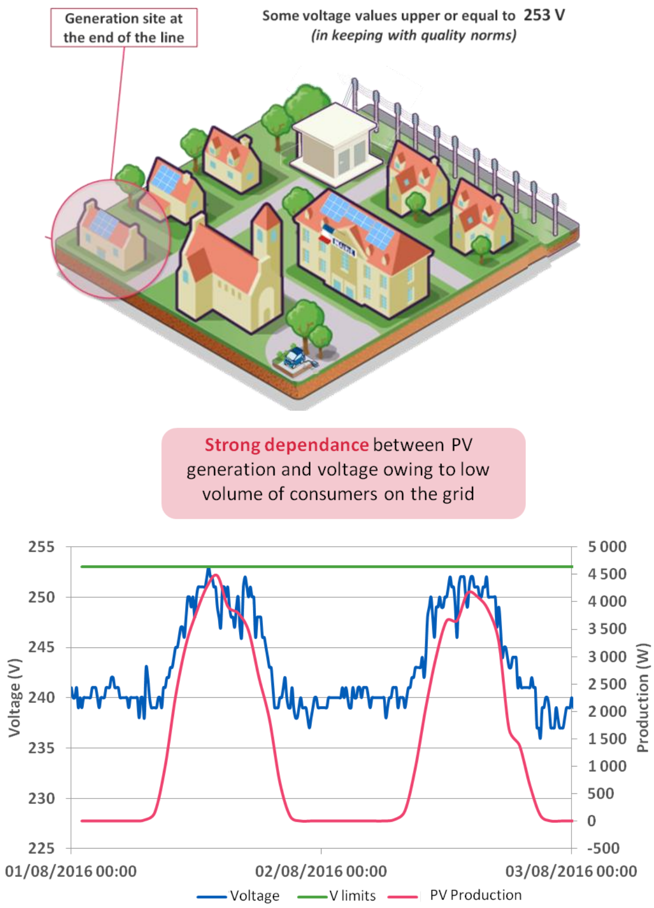

Figure 2: Example of voltage PV production dependence at a generation site in SMAP grid

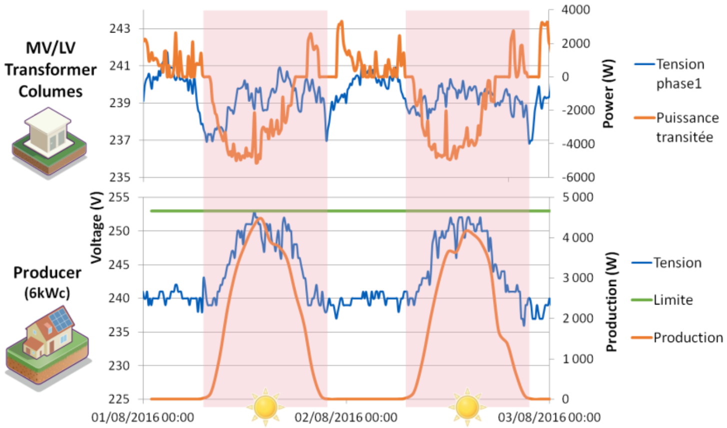

Figure 3: Reverse power flow at a MV/LV transformer and voltage variation at a customer level, correlated with PV production

Study of rural network like the one in Les Haies is interesting owing to weak consumption during hours where solar generation is important (working persons worked mostly in cities and here commute everyday between Les Haies and Lyon, bigger city nearby). Thus we can notice several periods of reverse power flow and high voltage levels.

This actual state of grid studies has shown tendencies of higher voltage levels correlated with the PV production, and although there is not, currently, regulatory quality overpassings, with more DER PV integrated on this kind of rural networks, might create some issues like:

- Risks to damage network installations
- Risks to damage consumers electric appliances
- Risks of power cut increased so reduction of quality of supply [1]

IV. SIMULATION OF GRID MARGINS WITH DER PV DEVELOPMENTS

In 2016, simulations were realized by Grenoble INP in order to verify and forecast constraints that could appear if we add more PV panels in the CVRC. The objective is to identify and evaluate the margins remaining in the grid according to sizing situations.

With the objective of later studying multiple solutions with Enedis, a set of scripts is created on the software DIgSILENT PowerFactory, (the specific language is DPL, for DIgSILENT Programming Language). With access to Enedis database, and thanks to the gathered data from installed smart meter, the rural grid have been fully recreated and studied.
A “toolbox” is in fact created in order to modify parameters with ease and facilitate comparison.
We have complete control in the simulations on a wide set of parameters (number of clients, loading/production curves, characteristics of lines, etc.).

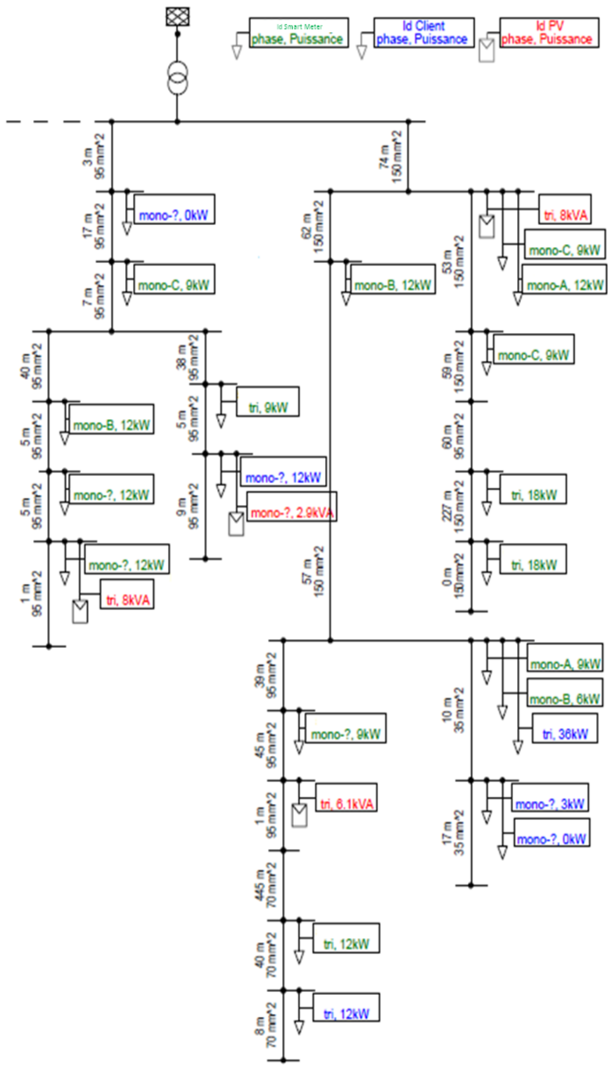

Figure 4: Partial PowerFactory diagram of the main PV connected grid. All characteristics are known except some connection phases

Firstly, we studied the margins of the actual grid, without any modification. For a better visualization, we chose to modify production and consumption from 0 to 100%, and not only the typical case for PV insertion studies (20% consumption and 100% production [2]). This creates figures similar to figure 4.

We verified that in normal conditions, there are no constraints on the grid. However, margins are unequal: whereas some grids can easily accept more PV panels, some are quickly limited. The chosen methodology to display the results of the algorithm is a colored table. As expected, some placements may cause high voltage (red) or current constraints in the MV/LV transformer (orange) and is coherent with former studies. Low voltage and cable currents constraints are also checked but never seen, except for really rare simulations. Other constraints are not studied in this project.

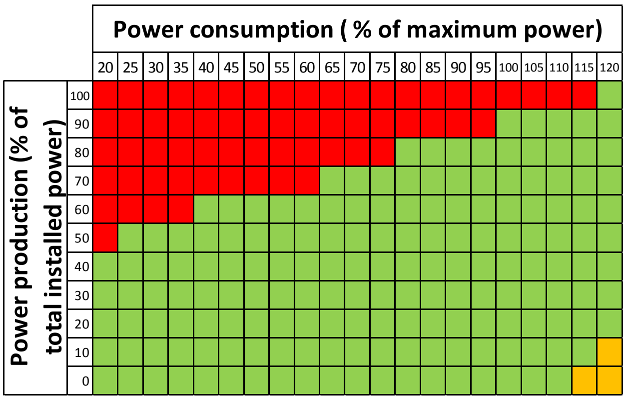

Figure 5: One Table of constraints obtained for adding a new PV plant of 6kVA on the main PV connected grid (red: high voltage; orange: current)

From now on, this work will be used to simulate and compare some smart grid solutions to delete these potential constraints and maximize the PV integration without deteriorating supply quality. Proposed solutions and necessary data are to be given by the different working packages of the project.

V. SIMULATION OF PV INVERTERS WITH LOCAL OR CENTRALIZED CONTROL STRATEGIES

From the set of selected solutions, PV inverter control is one of the first studied and is described here. The general order was made to prioritize some solutions and to do simulations before on-site test. In this case, only centralized control will be tested, but for comparison, the local one is tested beforehand. Both active and reactive powers are meant to be tested in order to regulate voltage on the LV grid.

LOCAL CONTROL

Local control is a well-studied method. Reactive power control benefits from the knowledge of MV grid, and reactive control is already used and tested [3, 6, 7]. However, critical points in LV grids are mainly resistive, and many studies suggest that active control or power curtailment should be considered [4, 5, 6].

Our goal is not to do a new study, but a mere applicative case representative of the situation in “Les Haies” and adapted for comparison. We then choose to control both active (P) and reactive (Q) power, separately first, then combined. As a matter of fact, we prioritized reactive power over active power if necessary, as it is the technology used by the SMA inverters used in the project. But, some clients and manufacturers may choose to oversize their inverter in order to avoid limiting active power output [3]. We study this with active power priority.

The reactive power supply follows a Q(U) droop function [7, 8] with a 0.15 p.u. (per unit) deadband and 1% droop so that maximum supply comes at +/- 8.5% voltage limit (this is the voltage limit in France specifically on LV grid connection points [2]).

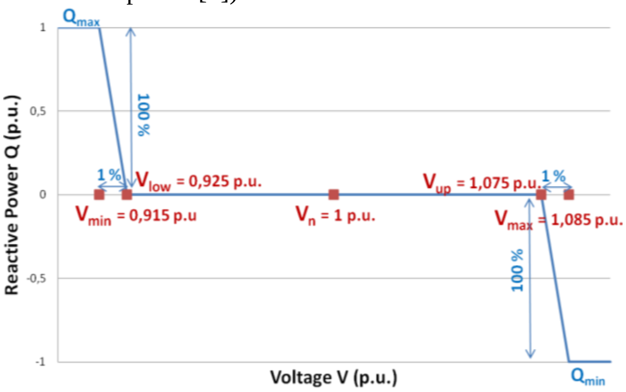

Figure 6: Q(U) droop function

For the power curtailment, we decided to use a P(U) droop function similar, from 100% to 0% production at +8.5% voltage limit:

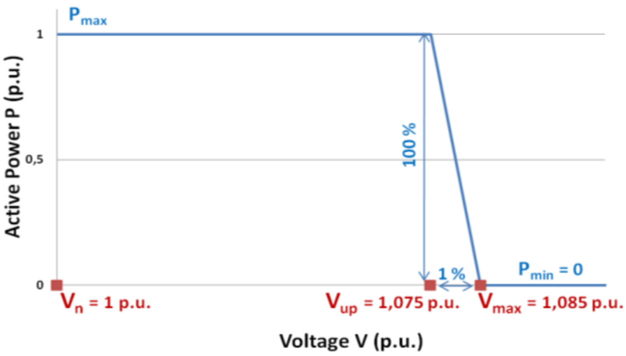

Figure 7: P(U) droop function

At any time, we assume that active and reactive powers are limited by the maximum apparent power capacity (S_{max}) of the PV inverter, namely:

$$P^2 + Q^2 \leq S_{max}{}^2.$$

We also assume that S_{max} is equal to P_{max}, the maximum active power rating of the inverter (this assumption is true on the SMA inverters used in the project). Simulations were realized for two reference days relevant for PV insertion: a summer working day and a summer weekend day. Loading curves were provided by Enedis to correspond to 20% of the maximum consumption at the MV/LV transformer.

Obtained results verify that local control would be an effective way to improve PV insertion on this LV grid. For example, PQ control permitted to resolve every high voltage constraints of the main PV connected grid.

We also illustrate the necessity to oversize inverters or prioritize reactive power supply: at maximum active power production, inverters could be limited and could not control voltage properly with reactive power.

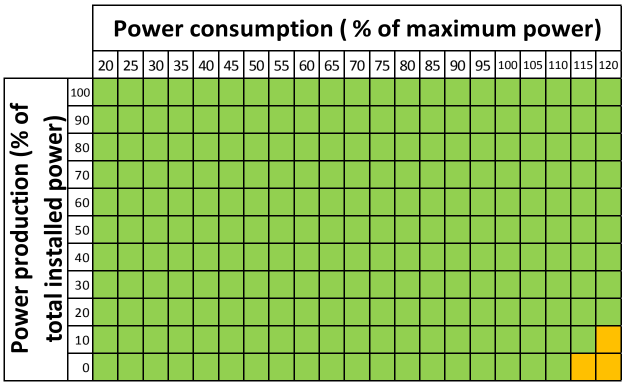

Figure 8: One Table of constraints obtained for adding a new PV plant of 6kVA on the main PV connected grid (red: high voltage; orange: current) with PQ control for a summer working day

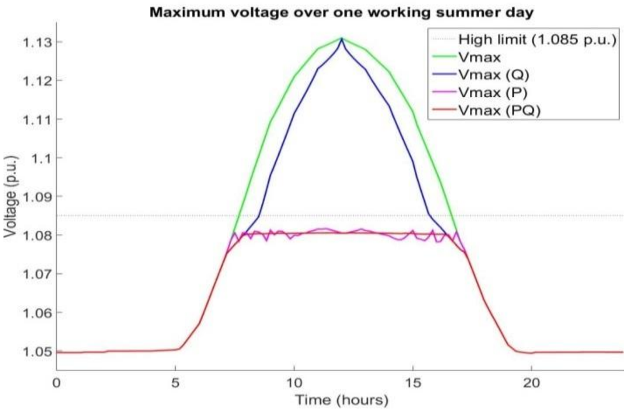

Figure 9: Maximum voltages on the main PV connected grid for various types of control on a summer working day.

However, it is a simplified study which aims to be meaningful in comparison of other tested solutions. This one, and following ones, will be tested on specific scenarios elaborated with the partners of the project.

CENTRALIZED CONTROL

The next solution is an alternative solution for PV inverter control, based on Smart Metering devices. This solution is expected to better optimize PV inverter regulation and to help solving trouble around regulation's repartition between consumers and producers on the LV grid.

For this approach, the Data Concentrator is the point of supervision and control. In classical Smart Metering projects, the Data Concentrator is a smart gateway used for data collection. In this project, an additional function is given to the Data Concentrator: the Data Concentrator technically manages the voltage of a LV area, generally a small number of feeders. In this area, some meters are considered as “Sentinel Meters”. The voltages of these Sentinel Meters are read each one minute by the concentrator.

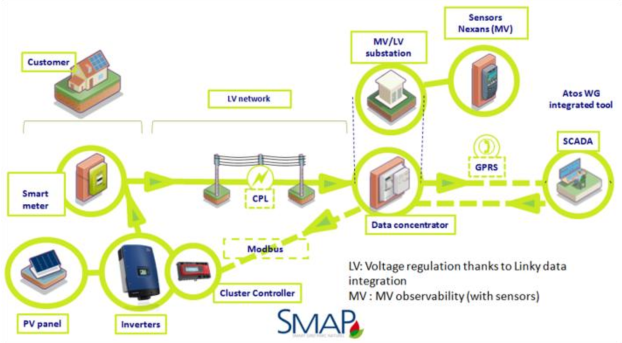

Figure 10: Full experimental smart meter integration for Voltage Regulation tested in SMAP

In case of overvoltage or under voltage, the Data Concentrator starts a dedicated control algorithm. The Data Concentrator computes specific orders to send to PV inverters, in order to manage the voltage issues. These orders can modify active or reactive power, according to the capabilities of PV inverters. For example, the PV inverter is asked to reduce its active production by 10% during 10 minutes, rather than cutting it totally.

With simulated grids, results are very promising: most of voltage troubles are easily managed without complete cut of PV production. SMAP project is expected to confirm interest of this solution, with field experimentation. The solution is only based on a new algorithm downloaded inside the Data Concentrator and a new communication between the Data Concentrator and the PV inverters. Then the cost of this solution is minimized.

PV inverters are not the unique controllable devices for such kind of solutions. Data Concentrator can send orders to devices such as OLTC transformers or Distributed Storage solutions. If different controllable devices are available, the algorithm manages the coordination of the different orders. It makes possible optimized voltage control.

VI. CONCLUSION

These primary simulations about voltage regulations are premises of the further field work in the project. The main interest and innovation in SMAP network working package will be to really implement on site this theoretical centralized control and evaluate its technical and cost-effective value to integrate more PV in a rural grid.

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FURTHER QUESTIONS?

All information is also available at http://www.centralesvillageoises.fr/web/guest/projet_smap (objectives and coming results of the project).