PV DEVELOPMENT IN FRANCE : IMPACT ON DISTRIBUTION NETWORK AND POTENTIAL OF INNOVATIVE SOLUTIONS

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INTRODUCTION

PV Panels installations have been booming all along 2009 and 2010 in France with MW new capacity increasing at a very fast rate each month.

Existing grids, designed to supply power to MV and LV customer coming from higher voltage level may need significant adaptation in order to accommodate large amount of distributed generation.

In rural areas, where consumption density is low, thus network long and thin and generation seldom synchronous to consumption, abiding by voltage levels requirements (-10/+10%) would lead to major adaptations in LV and MV network should the pace of PV development keep at present level.
The paper will present and address

- PV development trend by type of PV installations
- Distribution network adaptations needed with associated costs, for connection & long term structural reinforcement, considering immediately available and proofed network solutions
- new technical solutions for DG integration based on voltage control (local/central)

1. RENEWABLE ENERGY SCENARIO AND GRID IMPACT IN FRANCE

1.1 Context

PV installations can be classified in three types and, the following new connections, in numbers & cumulated power (MW) have been observed in France:

PV new connection requests from June 09-June10		
Type of PV	**Connection requests (#)**	**Capacity MW**
P< 36kVA (residential)	100 000	360
36< P<250kVA	8 200	1000
250kVA <P <12MW	1 000	1 700

Small PV installations for residential household are **typically 3kVA** systems, connected in LV and integrated in the roof of individual households (BIPV). Development in this segment is likely to remain at high level. It will be dependent onf tariff and fiscal support.

Medium size installations correspond mainly to barn roofs and commercial buildings (supermarket) or industrials (small factories, hangar). They range **from 36kVA up to 250kVA.** The pace of development is uncertain and highly dependent on buy-back tariff level.

Large ground PV installation connected in MV are dedicated for PV generation ranging between several hundred kW up to several MWs (in distribution network). Their connection requires creation of MV network, often specific when in areas with low load density, and if need be HV must be adapted**.**

Trends in this segment are very difficult to predict since they depend not only on buy back incentives but also on local acceptability of large facilities.

1.2 Repartition scenario of the PV MWs between LV & MV sites

Between 2009-06 and 2010-06 ERDF received a total connection demand of more than 3GW.

Part of it is linked to a demand ‘bubble’ due to an anticipated buy back tariffs reduction, inducing a rush to register projects and secure the higher tariff.

Filtering the ‘demands bubble’ effect, 20 GW in 2020 PV scenario has been extrapolated from recent trends and spread among the 3 types of PV installations.

This scenario highly above initial political target (5 GW) appears clearly as a *maximum maximorum* value considering possible financial impact on end use costumer of such a huge amount of highly subsidized generation.

Type of PV	**#/year avg capacity**	**Capacity in 2020**
P< 36kVA (residential)	150 000 to 200 000 3 kW	6 GW
36< P<250kVA	52 000 : 50 kW 30 000 : 180 kW	8 GW
250kVA <P <12MW	1 600 1 MW 925 4 MW 58 12 MW	6 GW

1.3 Evaluations of network reinforcements

a) Small residential PV

The national 6 GW of small PV have been spread among feeders following a Poisson statistical law.

We calculated for each feeder with PV if voltage levels requirements (+/-10%) where met or if a network adaptation was necessary. For LV PV it includes LV line reinforcement or MV/LV substation upgrading.

In this scenario, the result is that 6GW of small PV :

- require 2 000 000 new connections,
- would be installed on 1 500 000 feeders
- generate 94 000 constraints on LV networks, mainly in rural areas.

b) Medium size PV

Same approach has been used. A large range of situations appears, from zero constraint to heavy network adaptation. PV 36-120kVA requires creation of a new distribution substation & LV feeder in 50 % of cases. Above 120kVA PV should be connected with dedicated LV feeder.

c) MV network adaptation

It may be induced by MV installations and/or influence of LV units. Both have been taken into account.

For MV installations, 3 categories have been defined (<1MW, 3-5MW & 10 MW) and constraints calculations & network adaptation have been estimated for each category.

Depending of total level of constraint appearing, it leads to small MV feeder reinforcement up to dedicated MV feeder. Above 1MVA, MV installation requires mainly creation of dedicated feeders.

Capacity of feeders are 12MMW, so large PV installation 10MW such as the wind power installations observed today are more cost effective regarding network integration.

d) Synthesis of network adaptations

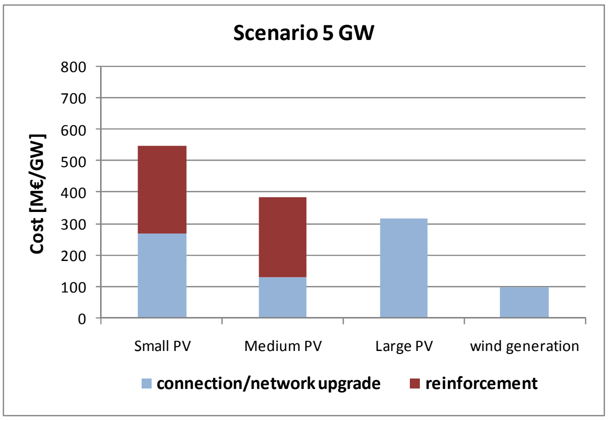
The following Table gives the synthesis of the results for the 20 GW scenario of PV production

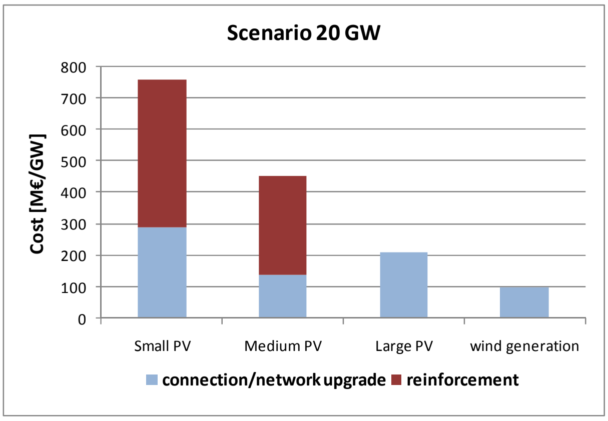
<table>
<tr><th>Thousands
of operations</th><th>< 36
kVA</th><th>36 – 250
kVA</th><th>> 250
kVA</th></tr>
<tr><td>PV connections</td><td>2 000</td><td>82</td><td>2.6</td></tr>
<tr><td>LV feeders reinforcement</td><td rowspan="2">94</td><td>10.7</td><td></td></tr>
<tr><td>LV feeders and substation creation</td><td>30
24</td><td></td></tr>
<tr><td>MV feeders reinforcement or new dedicated feeders</td><td>2.4</td><td>3.3</td><td>0.8</td></tr>
</table>

To this adaptation of distribution network should be added the cost of creation of primary substation and if need be HV network adaptation.
The former amount is roughly 460 M€/GW the second is to be evaluated by TSO.

1.4 Synthesis of Results for PV integration in Networks

The following table gives the relative levels of network development/adaptation for the different type of ENR taking into account connection/network upgrade & network reinforcement for different trajectories of development.
This does not include the Transmission network reinforcement/adaptations that were not addressed in this study.





It shows clearly that PV requires a significant development/adaptation of the distribution network.

The main explanation is that PV needing space tend to develop in areas where network is thin and long. Since in France peak load is concentrated on winter early night time, PV is badly correlated with consumption and often activates voltage constraints. Thus the deeper the PV is in the network the more expensive it appears because it must be evacuated.

However these are average values and a great variety of situations appears, from easy integration when units are close to consumption and more synchronised, to heavy network adaptations.

Modelization of impacts on network will have to be adapted on the actual total volume of PV installations but also on spatial structure of it. Both of them remaining uncertain.

However, it remains clear that PV generation will have a major impact on existing grids, especially, in rural areas. This is a challenge and mission for DSO:

- **Total cost for the 5GW national Target was estimated at €2 billion (cf CIRED 0042 paper 06/2010)**
- **20 GW maximal scenario based on recent observed trend requires €9,3 billion (excl. Primary substation reinforcements).**

It should be noted though the comparison of the 2 scenarios shows that the network cost/GW installed does not evolve in a linear way with the total GW installed.

When the PV installed capacity increases by a factor 4, the total scenario costs increases consequently by a factor 5. In fact the accumulation of PV systems, small and medium, leads to a progressive saturation of the existing PV integration capacity of the LV and MV networks. It then leads to a progressive increase of the number of network constraints appearing with additional PV GWs installed.

Reduce the volume and cost of network adaptations requires

- Volume control (GWs) of PV connections
- Incentives to develop PV where local consumption is at least equivalent to the PV production capacity and possibly synchronous.
- Innovative solutions, such as voltage regulation using voltage reactive control capabilities of the PV systems: locally at the scale of the PV system or driven centrally at the scale at the distribution network.

2. ALTERNATIVE TECHNIQUES FOR DG INTEGRATION

2.1 Local reactive power management: maximising network capacities

Alternative - and cheaper - solutions are implemented in France to better utilise network capacities. A common solution consists in using reactive power capacities of generators, especially those with power electronics, in order to minimise connection costs.

A study has been carried out by including reactive power management in the rectifiers for the connection of PV farms whose the power is lower than 1 MW and between 3 and 5 MW . Generators of power greater than 10 MW are not taken into account.

The network capacities benefit by using reactive power capacities strongly depends on its structure:

- **40 % earned capacities**, if the part of underground cables on the feeder is lower than 25%
- **20 % earned capacities** if the part of underground cables on the feeder is greater than 50%.

The network capacities benefit for mixed networks follows a linear dependency and can be calculated according to the formula below:

$$Gain = 40\% - \frac{20}{25}(L_S - 25\%)$$,

Ls being the length of underground network

Based on this, a comprehensive evaluation of MV feeders shows that reactive power management in rectifiers limits network reinforcement up to:

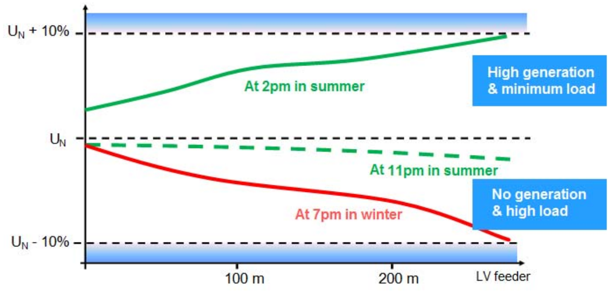
- 27 % of the feeders targeted to be reinforced due to the connection of generators < 1MW
- -6% of the feeders targeted to be reinforced due to the connection of generators between 3 and 5 MW.

Furthermore, the strong development of small PV plants, piled up on MV feeders, tends to lead to voltage issues that can be smoothed by using reactive power management in LV rectifiers, as shown in the next paragraph. An experimentation has been launched in 2010 to investigate its feasibility and to assess properly the potential benefits and risks.

2.2 Local reactive power management: improving power quality

Besides, once the reactive power capabilities have been used for increasing the network capacities, more sophisticated reactive power management can be studied to improve power quality.

As a matter of fact, current voltage regulation by DG in France consists of a static power factor for summer and another one for winter inside the required range: -0,35<tan phi<+0,4 compliant with the voltage level requirements (+/- 10%) both in LV and MV.



ERDF investigates DG supplying or absorbing reactive power following a dynamic regulation law given by the DNO as this has been enabled by the French grid code and pricing policy.

A working group has been launched in July 2010 between the DNO, DG producers and manufacturers in order to set the dynamic law and its mode of enforcement into ERDF technical guidelines.

The regulation mode for reactive power management is being discussed amongst three approaches: a target value would be set by

- an active factor Q(P) or
- a fixed reactive power in MVar or
- a reactive power/voltage characteristic Q(U). An illustration is being given bellow.

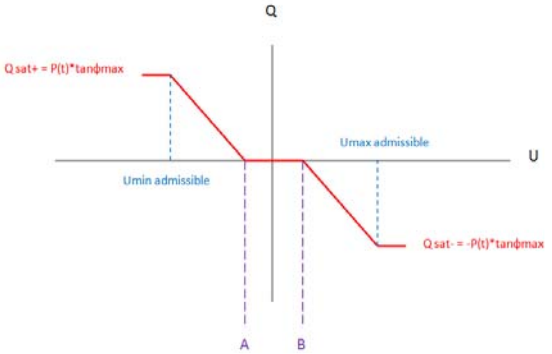


Figure 1: Regulation within nominal range with dead zone

The benefits and downsides of each solution are being studied, especially regarding the following issues:

- Which approach brings the most benefits to the grid users, both to the consumers and the producers?
- Are there any technical issues that have to be considered, such as stability problems due to the regulation mode or equipments capabilities to be taken into account?
- How should these new requirements been implemented?
  - o To all producers connected to MV network or to those with the most significant impact in terms of voltage rise?
  - o Shall a single approach be applied to all producers, or should it depend on the network structure and needs?
  - o What is the best way to ensure the reactive power requirements are met?
- What is the impact in terms of network losses?

In order to answer these questions, dynamic simulations are carried out to assess the best and more efficient way to decrease the impact of DG connection by using their full capabilities in terms of reactive power management. On the top of that, an experimentation will be launched in 2011 which will consist in the implementation of a reactive power/voltage characteristics Q(U) by the producers and measurements to assess the impact on the equipments and the distribution network.

2.3 Perspectives: an optimised voltage management through centralised voltage regulation

Local voltage regulation is a first step towards centralized voltage management: research projects have been launched to develop and experiment advanced methods based on network sensors measurements and state estimators to calculate optimized voltage and reactive power target values set to active network components such as the primary substations or distributed generations.

CONCLUSION

PV generation requires significant adaptation and development investments on the distribution network, which are linked to:

- The connection process and therefore immediate (connection/network upgrade) .
- Further reinforcement works that will be required and realized later on.

Two scenario of PV development in 2020 are proposed and the associated costs are determined by a comprehensive method:

- The initial 5GW national PV Target was estimated at a global cost of €2 billion (cf article CIRED 0042 paper 06/2010).
- New 20 GW scenario based on recent observed PV trend requires an investment of € 9,3 billion.

These are average values and it should be noted that it is still very difficult to predict the volume and future real situations of PV installations.

In order to optimize the volume of network adaptations, it is important to

- Control the PV volume control (GWs) though Feed-in tariff and fiscal policies.
- Promote PV development where local consumption is at least equivalent to PV production will also help to reduce costs significantly.

In the same time, ERDF considers alternative and new technical solutions to integrate decentralized production, like using the full capabilities of PV equipments in terms of reactive power management locally and is strongly committed in research project concerning centralized voltage management tools.