Low carbon policies : possible medium term impacts on distribution network

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INTRODUCTION

The paper addresses the consequences for the French DSO of a consistent and realistic scenario of low carbon policies as envisioned in France through the "Grenelle 2 policy" , with a focus in this article on

- a strong support to PV generation, steady support to Wind generation,
- the development of Electrical Vehicles...

Considering the present functionalities of networks,

- What are possible impacts on assets & what reinforcements/adaptations will be required ?
- What are the issues / needs in terms of new technologies, load & voltage management ?

This highlights the Smartgrids potential benefits.

1. RENEWABLE ENERGY SCENARIO AND DISTRIBUTION GRID IMPACT IN FRANCE

1.1 PV generation

The national Target based on the 'Grenelle' is 5 GWs in 2020. PV development is booming across France: Installed capacity doubled in 2009 and connection requests in process amount to more than ten times installed capacity. Small size facilities represent the bulk of new demands measured in number (+7,000/month) while medium size (36-250kVA) and large facilities (MVAs) make the MWs. Although uncertain present trend is well above Grenelle linear trend.

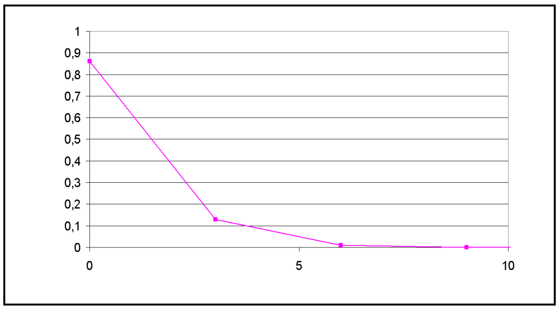
This shows clearly that PV local generation will have a significant role in 2020 and even before, with a magnitude of GWs capacity in operation from small LV to large MV installations

a) Repartition of PV capacity between LV & MV sites
The first difficulty is to scenarize the target. We chosed to spread the 5GW national Target between 3 categories of PV installations, with higher capacities for medium & large installations, according to present dynamic.

Type of PV	Installed capacity Hypothesis
Small Residential 3kVA	1 GW
Medium size 36 –250kVA Farms of small buildings	2 GW
>250kVA up to large floor installations of 10MW	2 GW

b) Evaluations of the amount of network reinforcements needed are done based by using ERDF national planning tools, the main issue is identification and management of voltage constraints. Due to passive structure of distribution networks, scarce natural mitigation of load and generation, and strong customer expectations as regards quality of service, main immediate available strategy is structural adaptation of network.

Small residential PV
The national 1GW of 3kW PV has been spread among regions and network assuming concentration per feeder follows a Poisson statistical distribution law (see below):



PV repartition (kW) probability per LV feeder

Then for each feeder we checked voltage levels requirements (+/-10%) and if necessary selected typical network adaptation : either LV line reinforcement or MV/LV substation upgrading.

In this scenario, 1GW of small PV corresponds to 330,000 individual facilities (3kW), distributed over 200,000 LV feeders, possibly generating 16,000 (8%) LV constraints. Those constraints are mainly in low consumption density area (usually rural) often with no other genuine reason to modify network. Per kW adaptation costs are likely to be high and raise strong debates as regards financing.

Medium size PV
The same approach has been used. A large variety of situations occurred, from zero constraints to heavy network adaptation.
In more than 25% of the cases, PV 36-120kW requires the creation of a new substation & LV feeder. PV >120kVA should be connected with dedicated LV feeder.

MV network adaptations

- MV constraints have been calculated by allocating low voltage PV generation among MV feeders.
- for MV installations, we consider 3 categories (<1MVA, 3-5MVA & 10 MVA) to match different constraints cases and adaptation strategies.
- constraints calculations & network adaptation have been estimated for each category.
- depending on local constraint level, solutions vary from light MV feeder reinforcement up to dedicated MV feeder. Above 1MVA, PV connection requires most of the time the creation of dedicated feeders.
- feeders capacity is 12MVA, so large PV facilities, like wind farms observed today, appear to be more cost effective as regards network integration.

The following Table sums up results for 5GW PV scenario (see 1.1.a).

Number	**< 36 kVA**	**36 – 250 kVA**	**> 250 kVA**
PV connections	330 000	21 000	900
LV feeders reinforcement	16 000	2 500	
LV feeders and substation creation		7 500 6 000	
MV feeders reinforcement or new dedicated feeders	200	800	760

1.2 Wind generation

Similar approach has been used for wind power.
4,4 GW wind power capacity were installed in France by end 2009. 'Grenelle 2' trajectories leads to 19 GW of land Wind Power in 2020. This Wind power development will be organized by regional authorities in wind power dedicated areas to allow the planning & optimization of necessary network developments.

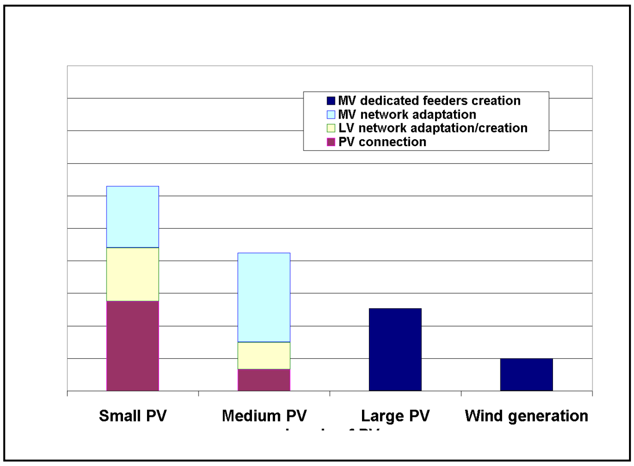
Wind farm facilities average capacity is 9MVA. They are connected through 12 MVA dedicated MV feeders with sometimes additional reinforcements or creation of primary substations. It proves to be a rather cost effective connection scheme.

On this basis MV network development costs is evaluated in the range of 100M€/GW.

This does not include HV transmission network reinforcement/adaptations, that are not addressed in this study.

1.3 Synthesis of results for ENR integration in Networks

The following figure gives the relative levels of network development/adaptation for the different types of PV & for Wind Power, taking into account connection & network reinforcement/adaptation



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

The deeper the PV goes into the network, down to LV, the deeper network adaptation is, and the more expensive it is. It certainly affects all voltage levels (LV & MV) with a costs pan-caking effect and possibly the likeliness of a natural mitigation of load and generation is fading.

These values are averaged and a great variety of situations appears in reality, from easy integration to heavy network adaptations.

PV generation will have a major impact on existing grids, especially in rural areas: this is a new challenge and mission for Distribution Network.

Considering the potential of innovative technologies to solve these issues by different and cheaper means we can foresee three main areas of expectations:

- **local voltage control possibilities** : using reactive capacities of PV systems or specific Voltage control regulators in MV feeders or MV/LV substations;
- **load management** to absorb the exceeding PV generation during high voltage episodes;
- **observability** of voltage at grid connection point & loads, through smart meters, and at substations & MV feeders

This means moving towards Smartgrids, and first through demonstrations research projects.

2. ELECTRICAL VEHICLE DEVELOPMENT

EV development is a major component of French strategy for CO_2 emissions reduction. Government plan aims at 1-2 millions of EV in 2020. This could build up above 8-10 millions in 2030+, therefore a potential huge power demand for electric system.

The development of charge infrastructure is a key point for the success of the whole EV strategy. It is a matter of timing, space and costs.

It should be done in a progressive & optimized way:

First step is to define the dominant recharge mode of the recharge system infrastructure : normal charge 3kVA or fast charge 24kVA.

- In France, household existing LV connections are single phase (phase – neutral) and < 12kVA in most cases (even with electrical heating); average substations size in urban zone is 400kVA for 100 to 200 customers.

Normal charge is well suited for residential charge.

On the contrary fast charge at 24kVA would lead to:

- the necessity for residential homes to build systematically new 3 phase connections line : >+2 k€/ homes, >+2 Billions for 1million EV.
- very heavy network reinforcement from LV network (cable & substations) to MV and primary substations.

Therefore, fast charge points have to be developed and placed in accordance with their utility : limited complementary / 'insurance' recharge points for day time travel.

Scenarii : we consider two scenarios consistent with a progressive development of EV and a strategy of optimization of risks and global cost of infrastructure deployment. They both include :

- a development focused on urban zones;
- normal charge for residential,
- mainly normal charge & some rapid charge for public charge infrastructure
- or mainly with rapid charge for all parking & public charge points

Charge points (millions units)	Scenario 1: normal charge 3kVA	Scenario 2 : Fast Charge 24kVA
Residential	1,8 (3kVA)	1,35 (3kVA)
Parking (offices, commercials)	1 (80% 3kVA, 20% 24kVA)	1,2 (24kVA)
Public infrastructure	0,3 (3kVA)	0,15 (3kVA)

Figures consistent with a target of 1.5 million EV.

Results

Global EV charge infrastructure costs levels have been estimated in urban zones considering:

- network connections & reinforcements, and internal installations (parking/charge station with multiple charge points)
- with EV recharge at homes when users comes back from work and at offices during the day work.

Scenario 2, based on rapid charge for public & parking:

- represents more than 5 billions € investments;
- costs more than 3 times scenario 1 which is based mainly on normal charge

Scenario 1 with normal 3kVA recharge is estimated at

- 1 billion € for connections;
- 350 Million € for reinforcement

Important : costs in rural areas would be significantly higher and they have not been addressed in this first scenario.

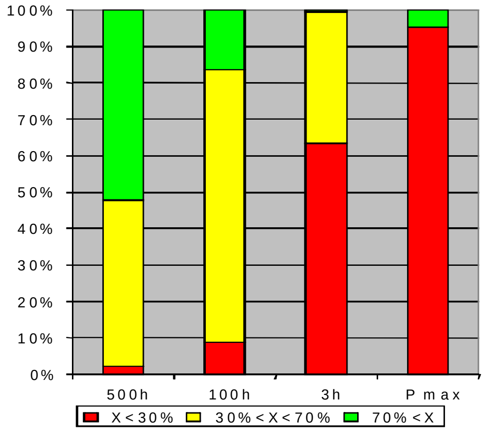
Recommendations for an efficient integration of EV in the distribution grid :

- ❑ **Promote Normal charge at 3kVA** for residential recharge & mainly for offices and public parking as a good compromise between economy and needs
- ❑ **Limit fast charge installation** & dedicate it to some recharge public stations, preferably connected on MV level, accordingly with its purpose of 'insurance' of energy for specific situations of EVuse.
- ❑ **Regulation of EV charging** should be developed **through tariff incentive and real time automation** between different interacting levels of aggregation, customer side and network side, **to avoid local as well as global peak demand** and minimise network costs and carbonated electricity.

Proposals of Smart/effective modes of EV charge, both effective for the production CO2 content of the kWhs and the local distribution impact :

- ❑ From a generation point of view, it may be enough to avoid national peak hours for EV charge.
- ❑ However this does not match DSO interests:
    - There is a **strong local/spatial shift of constraints at the distribution network scale**
    - local network distribution constraints/peak loads today are largely also during national production off-peak periods (see graphic below)

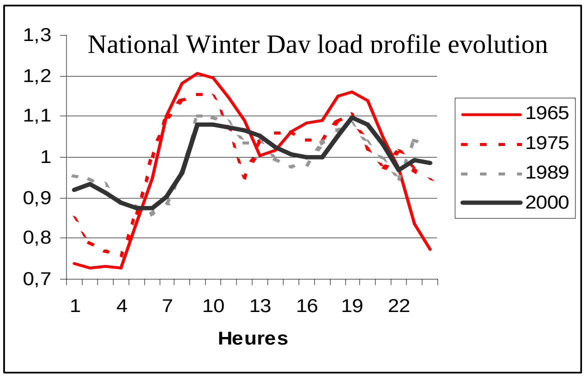
Correlation levels of peak period times : primary substations vs national peak periods



EV Charge management : How can past experience with electric water heating inspire future solutions ?

Since the 70s, electric water heating system has allowed to flatten the national load curve, by transferring loads at night and more recently during mid day periods. The system is based on

- **an incentive tariff** with reduced kWh price during low load period and increased price during loaded hours (8-12h & …)
- **an automatic regulation** : the emission of 175Hz signals (coded on 40 impulsions) from primary substations down to the customers meters. A reception relay besides meter then starts/stops residential water heating electric system.
- **the distributor defines & manages the 'low load' periods** at each primary substation: up to 4 different time order to reduce the peak effect of the start of the hot water electric heater.



A short term EV charge regulation could be based on the same principles : may be_delayed after hot water heating during the night for residential EV charge ?

Research & validation through experiments should focus on :

- what **EV load management / incentive tariffs** & regulation system are needed acceptable by customers to mitigate distribution network local constraints and national generation optimization ?
- use of the **smart meters,** (ERDF 'linky' from 2017 in France) to enable the Smartgrids functionalities and locally manage the network capacity and integrate/combine the EV and the DER.

4. SYNTHESIS & CONCLUSION

- **PV generation will have a major impact** on the existing grids, especially, in rural areas.
- the deeper PV goes into the network, down to LV PV, the deeper and more expensive network adaptation & development will be required in the long term,.

The potential of innovative technologies should be addressed, with a focus on

- **local voltage control possibilities** from PV systems themselves or from systems installed in the network in substations or feeders
- **load management** to match load and generation
- **observability of voltage and load** at different levels

EV efficient & sustainable integration

- is needed : 10 Millions EV in 2025-2030, even with 3kVA charge, could lead to 20-30GW of additional peak evening peak load (65GW today at Distribution level in France)
- should be be based from the start on :
- **normal charge 3kVA** mostly **during off peak periods** for both production & network
- **incentive tariffs & associated regulation system at customer side** are needed and possible, like DSM management of hot water heating in France managed by the DSO.

Therefore **Smargrids** with observability & operability of networks and loads management are needed for the Distribution networks development optimization :

- **to invest more in intelligence than heavy & capital intensive network infrastructure**
- and bring significant value to society

However impact/adaptations of PV & EV will be real and deep in the next ten years within an existing network that faces also a growing & significant long term challenge of ageing components renewals.

The development of low carbon policy through PV & EV added to maintenance/renewal issues of the ageing network leads to a **long term increase of investments, that should be optimized by the Smartgrids, but will still be growing in the future.**