Smart Grids: a systemic and integrative vision of their development

Eric Morel - November 2010

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He has been involved in Smart Grids development since 2000. He created the first Energy Efficiency and Smart Grids BU at Schneider Electric, is a co-founder and has served as a Board member at the Gridwise Alliance. He has developped for 10+ years, activities and companies delivering Smart Grid solutions; he has led several projects and initiatives and is today an expert recognized by the main public bodies.

This white paper aims at bringing a very personal contribution to the global understanding of the huge emerging stakes about the evolution of electrical grids and the necessary evolution of the different players to address them.

It aims at proposing a systemic vision, taking into account all interactions between all aspects of the topic in order to define a « meta vision » encompassing all visions already expressed about Smart Grids, making them complementary instead of antagonistic.

I have developped this vision step by step, during more than 10 years dedicated to Smart Grids, while being involved in numerous initiatives, observing many others, meeting hundreds of key players in the Smart Grid arena or accompanying some of them.

1- The electrical grids have to be revolutionized

The electrical grids have been developped for more than 100 years, firstly in industrialized countries, with sturdy, robust electromechnaical equipment (breakers, transformers).

The replacement of this equipment has been unusual, especially in the smallest sub-stations. Its evolution has been very slow ; for years, it has been designed for its main function : to trip, to protect, to transform, and has evolved only for being more compact and for better performances thanks to an improved technology. Of course, this evolution has not always been sufficient to justify its replacement in the field.

The electromechanical products have been transformed for 20 years thanks to new communication features : one can now control them remotely and, by this way, dynamically configure the grid to optimize its performance and guarantee the expected level of continuity of service. In addition, these products can also work as sensors able to provide information regarding the products themselves or the current passing through them. Algorythms allow to compute these information and provide additional value and meaning: analyzing a current can help to monitor an industrial process or detect the first weaknesses of a machine that could announce a coming break down.

These new functionalities provide value to the biggest consumers (large buildings, industry) and to primary sub-stations operators. Downstream from the main substations, the equipment has scarcely evolved. In Western countries, the average age of the products is often high.

These electrical grids provide electricity produced by ever more modern, ever larger production units, responding to the growing demand for energy. The increasing size of the power stations have reinforced the present topology of electrical grids organized around a spinal column represented by the transportation lines.

The grids I just described are not any more adapted to present stakes and even less to future ones. Here are the main reasons:

- Kyoto protocol:

By fixing limits to CO^2 emissions, the Kyoto protocol imposed the following evolutions of electrical grids :

- reduction of pollution thanks to the development of renewables energies

- less energy losses[1]
- less power stations thanks to a reduction of peak loads
- better energy use
- reduction of energy consumption, when possible

- The electrical grids have shown significant weaknesses, with very severe impacts on security and service reliability.

The US blackout of 2003 is a symbol : 55 millions of people with no more electricity during 6 hours to 2 days, losses equivalent to 6 billions US. All this just because of « overgrown trees » entering in contact with a transportation line, causing a cascade of incidents affecting in less than 2 hours both the north-east of the US and the Ontario region.

The official investigation report raises a software bug as one of the roots of this disaster. Good. Without reconsidering the question, this conclusion results from a pure linear and logical approach. According to a more systemic one, this black-out reveals a lack of global control over a very complex grid, managed by an EMS (Energy Management System) on which all the complexity is transfered. In this case, are we not facing the normal consequence of the choice to manage complexity thanks to a central system? More and more complex algorithms, more and more high performance machines cannot be the solution to master such an increasing complexity.

This black-out is very symbolic but is not the only one that occurred. Others, with a minor media impact, though very important, showed the same symptoms (Italy in 2003, Indonesia in 2005, Brazil-Paraguay in 2009)

- Need for energy quality

Some industries are very sensitive to the energy quality and require a very advanced service, all utilities cannot provide.

Paper industry, hospitals, microelectronics are among these demanding sector. These industries invest huge amounts in private installations aiming at assuring the right level of energy quality.

2- Stakes of the evolution of electrical grids

The decreasing reliability of electrical grids, the growing dependance of the global economy on electrical energy, the pressing need to protect the planet, push in favor of a fast and radical evolution of electrical grids during the next coming years. What is at stake is:

A better efficiency:

Efficiency has to be considered here as globally. It encompasses both technical efficiency and economical efficiency.

Improving the technical efficiency lead to :

- look for the lowest consumption as possible for a given need of electricity users
- minimize the energy losses

[1] ABB reports in « Toward a smarter grid » an icrease of energy losses from 5% in 1970 to 9,5% in 2001

- build meshed networks rather than hierarchical networks to allow faster and dynamic reconfigurations of the grid.

Improving the economical efficiency lead to :

- optimize the use of production units by reducing the peak loads
- reduce the environnemental impact of the power stations and the grid itself
- optimize the life-time of equipment

<u>Reliability, security</u>

The reliability of electrical grids means first a high continuity of service:

- lower dependance on a centralized EMS
- lower dependance on a unique producer
- more options to reconfigure the network to face the failure of a transportation line
- guaranty of the energy quality
- predictive maintenance of the equipment to anticipate the predictible break-downs
- supervision of parameters that can reveal the most frequent failures

Security is very important as energy is a vital blood for the economical and social life. It has to be understood as security:

- against possible intrusions from hackers in IT systems
- against energy thefts

<u>Flexibility</u>

The need for flexibility is a need for self-reaction, self-ajustment and auto-configuration of the grid to face successfully unexpected events and assure the right level of continuity of service. Limiting the human based operations will be a factor of performance.

<u>Protection of the environment</u>

Production, distribution and consumption of electrical energy are at the heart of the concerns for the environmental conservation.

In addition to these stakes, three technical evolutions are driving the transformation of electrical grids:

- the emergence of distributed resources : power stations using renewable energies are much smaller, more numerous and distributed everywhere along the grid. They should be connected with no disturbance, where they are.
- electrical vehicles, whose development may occur soon, need a charging infrastructure that does not exist yet.
- energy storage should be developped

<u>Each player in the marketplace has his own most important present stake :</u>

A electrical utility does not face all issues at once. Each country has its own priorities, its own characteristics making it more sensitive to a specific issue: some countries have to increase their production capacity; others have to improve the reliabilty of electricity delivery; others have to develop renewables energy sources or reduce the peak loads.

Each player is used to define Smart Grid centered on his current stake

The diversity of the situations met explain the multiple lenses through which the players look at the necessary evolution of the grid. Thus, each player gives a definition related to his vision and to his own issues.

Some visions tend to be hegemonic; some players consider smart metering tantamount to smart grid and that deploying smart meters can be a solution for all stakes listed hereabove.

The specificities of each situation, complemented by local characteristics of the energy sector, led some European players, for instance, to reject and misjuge solutions developped for the USA, which were presented to them without having checked before their relevancy. This commercial tactlessness has introduced in many minds the idea that needs may be different from a country to another : that's wrong ! And it would be a pity to prevent, on such a topic, players from various countries to share experiences and solutions.

But in a near future, all players will meet all stakes

Each utility, each country, will face the whole picture and will have to implement a global solution.

This is why it seems to me so important, for all players today, to build one's own vision, to allow all solutions deploy today to address one stake to evolve later naturally and combine itself with solutions provided to address other stakes. Millions of US Dollars are to be saved through such an optimization.

The global picture reveals an ambiguity :

Among all stakes, some are about compliance with the regulation, others are about managing and adapting oneself to evolutions, others are about productivity but very few are about creating additionnal economical value.

This paradox influences heavily the evolution of the grids as, with no value created, utilities are just implementing the minimum to answer to the needs. Some rare players prepare themselves for a better future by seizing the opportunity offered by the needed evolutions to develop additional sources of revenue.

3- What is a Smart Grid?

The answers to be provided to all needs for grids' evolution are pooled today behind three main banners. Nevertheless, they remain strongly dependant on each others.

The Smart Grids are about developping electrical grids, adapted to future evolutions (more Distributed Energy Resources, electrical vehicles), ready for self-ajustment, partially self-control and auto-confoguration for security, quality, flexibility purposes and for allowing a dynamic adaptation to consumption needs.

Energy Efficiency is about optimization of transportation, distribution and consumption of the energy ; it is about consuming less and better, reducing losses and wastefulness. Main actions are for instance: use of low consumption devices, deploy load scheduling, change users' behaviors. Actions for Energy Efficiency address mainly the demand side.

Renewable energies are about producing differently, with low emissions technologies. They allow distributed and shared investment in energy sources and increase the security of supply.

Rightly, on a technical point of view, Smart Grid is often described as an improvement of current grids with IT technologies through the introduction of "intelligence".

It consists indeed in developping and introducing :

- predictive maintenance
- advanced network monitoring
- extended network control
- auto-configuration of the network for instance in case of a line failure
- self-reaction of the network for instance in case of a sudden increase of the consumption
- shedding programs in case of peak loads

But the main and most important characteristics of Smart Grids is that they are fully integrated networks and more precisely fully decompartmentalized networks.

- horizontally, producers, distributers and consumers have to share information real time : for instance, consumptions read at meters' level and aggregated can help to reconfigure more quickly the network or predict more precisely, at any moment, the energy needed that exceeds the available capacity.
- vertically : data collected at meters' and electromechanical products' level should be partly processed locally. Products may become by this way part of the information system.

This decompartmentalization of the networks requires links to be developped between all applications, all data, all players and a permeation of all products and software.

Thus, the network itself is now encompassing all power stations and meters. By the same way, products are part of the information system and the different layers describing all IT systems have now a symbolic value.

This fundamental characteristics of Smart Grid explains all the complexity of their implementation.

4- How each player understands and describes Smart Grids today ?

There are only few players who are competent enough to address Smart Grid issues globally and successfully. At the present moment, Smart Grid products and solutions have not been designed as the best answer to emerging needs but are existing offers packaged differently and stamped recently with an up-to-date label. As they are solved as a solution to needs, they tend to introduce misunderstandings about what Smart Grids are.

- Most of the main manufacturers have lost the needed intimacy with the market to develop an accurate vision. In their organization, strategists are often far from salesmen and customers, preventing them to have a right and precise understanding of the market and preventing the salesmen to understand the global picture. They are always dependant on their existing offer and, for commercial and business reasons, they reduce the Smart Grids to the picture that can be addressed by their existing offer. Even worse, their understanding of Smart Grids is a projection of their own organization : some have difficulties to provide solutions, others project their own internal partitioning, none have a real ability to counsel neutrally their customers.

- The main integrators are coming either from the electrical world and miss IT competences or from the IT world and miss the electrical knowledge and the ability to integrate the electrical devices as part of the IT system. They have scarcely the ability to set up alliances with manufacturers that bring value to the market place.

- The giants coming from other businesses, such as Microsoft and Cisco, miss electrical knowledge, sometimes access to the market, often consulting competences and cover a small part of the requested offer.

- Electrical utilities are very different :

    - The smallest ones cannot address the coming stakes; they have nor the competences neither the means to implement the relevant and necessary changes. They will be sooner or later involved in concentration moves.

    - The largest ones are facing several difficulties: their organization is fragmented, and address separately production, distribution and sales of the energy; it is difficult for them to lead transverse projects. These difficulties are sometimes increased by national regulation and law, forcing these different entities to be legally separated. In addition, deciders in these organizations are far from experts able to draft a vision and design the associated solutions.

    - The mid-size utilities (between 50000 and 1000000 customers) are those among which we can find the most elaborated visions and the most advanced projects thanks to more flexible organizations and shorter distance betwwen deciders and experts.

    - For utilities, Smart Grid is a real rupture they are not always prepared for. This is the reason why many projects are pushed by solution providers instead of being pulled by utilities and demand. They often need complementary perspectives to refine their strategy, to define ways to create value, to avoid pure technological approaches and to manage the transformation they face.

The vision adopted by various providers is often shaped by past experimentations, their Smart Grid offers and vertical approaches.

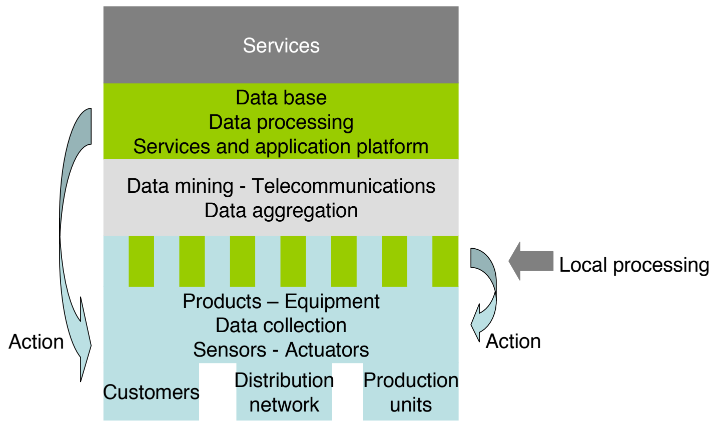
Smart Grids and more generally, all evolutions of electrical grids, are a fantastic and well identified growth opportunity ; they attract many companies, often moved by pure opportunism, which provide a limited value to their customers and the whole community and maintain the confusion around this topic.

The most important difficulty I have seen in all corporations concerned by the Smart Grids is their ability to decompartmentalize their organization to address stakes that require first a global decompartmentalization !

5- The Smart Grid's architecture

The vision of Smart Grids I developped in paragraph 3 suppose the ability to develop solutions based on the following architecture and to address the associated problems.

The usual representation of such an architecture based on various layers reaches here its limits because, thanks to the distribution and the repartition of intelligence and processing capabilities, all layers are interconnected and with a mutual interpenetration.



Who owns data, especially data concerning the customers' consumption, premises and installations, is not always defined and may be a question leading to business struggles. This data has an important value as it may be used to create value and provide high value added services as optimizing the customers' bill or activity or maximizing the performance of the customer's process.

This ownership may be claimed by the customers themselves because this data may be considered as being private or confidential. It may also be claimed by the energy distributor, the contractor or the energy reseller owning sometimes the meter.

6- What could be the path to organize the players and develop Smart Grids?

Taking into accounts what I just described, here are the main points that can lead to the success of the utilities in front of this unique challenge:

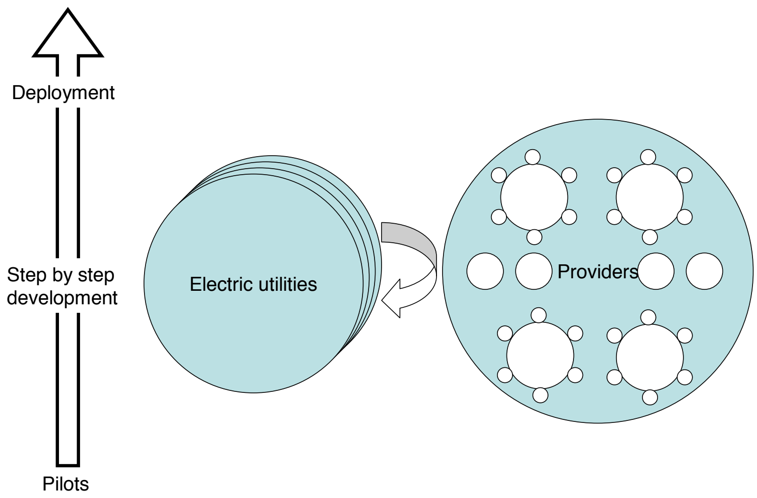
Utilities should take the lead and organize themselves

- They should work together to express their needs and give orientations to solutions providers. Products and solutions providers may be invited to join working sessions but not to lead them.
- The natural consequence is the need for utilities to lead the main Smart Grid standardization initiatives. A powerful and strong alliance between utilities seems to be mandatory to offer them the opportunity to share their vision and to be a lever to influence both regulation and standardization initiatives as well as technological developments.
- Each utility should develop its own vision about its data communication network and its data processing architecture, compliant with its global vision, and define the associated deployment time schedule.

- Each utility should find its own way to create and capture value with Smart Grid solutions.

Products, software and solutions providers should also organize themselves

- Big manufacturers should expand their catalog to cover the whole mandatory scope of Smart Grid solutions through alliances, partnerships and acquisitions.
- Partnerships between products manufacturers and IT specialists are needed to develop the interpenetration between products and software and to develop distributed architectures
- Consortiums in which all bricks of offer can be provided are necessary to experiment global solutions and the way to share values between the different providers. Two or three valuable groups partnering with some leading utilities could allow an harmonious progression of Smart Grids.
- The main solution providers should rely on a wide network of start-ups to develop innovative bricks. They need to be more involved in such networks to provide them with vision and valuable and consistent orientations.



The step by step decompartmentalization of applications should be managed through experimentations

- The Smart Grid's stakes are so complex that no real size deployment can be envisaged before the successful completion of dozen of pilots enriching them mutually and allowing a progressive adjustment of strategies for decompartmentalizing applications.
- Experimentations should be proposed, led and assessed by utilities and consumers.
- This framework may also be relevant for driving the development of energy efficiency solutions ; in this case, experimentations have to be led by both utilities and consumers.