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The topic I would like to address is the question of smart grids. The question is "are smart grids just a buzzword or actually a new paradigm". If Alexander Graham Bell, the inventor of the telephone, was suddenly coming back in this room, he wouldn't recognize the telecommunication networks that we are today using. But, if two minutes later, Edison, one of the electrical grid key early architects, entered the room, he would feel relatively comfortable with our grids as they are today. That means that we have had a fantastic evolution in the telecommunications area, but a very slow evolution in all what is related to power generation, distribution and transmission. But it will change, because of smart grids.

So what are smart grids? Smart grids result from the addition to a power grid of an information network. "Power grid" + "communication network" = "smart grid". I will elaborate on that and try to demonstrate why smart grids are today feasible and indispensable. This result from various considerations, one of the main reason being that we have now to consider bidirectional flows of energy on the grids and this implies that we also have at our disposal two ways communication networks and control capabilities.

You can refer to several documents, including the Independence and Security Act of the US dated 2007, if you want a more precise definition of what is or what should be a smart grid. Let us say that the smart grids will be characterized by a two way flow of electricity and information to create widely distributed energy delivery networks.

There are big expectations about smart grids. Their classification may differ from one specialist to another one. I have retained four main drivers which can be divided into several sub-topics.

The first driver is improving the power reliability and quality. I mean reduction of the indexes SAIDI and SAIFI which respectively correspond to the system average interruption duration and the system average interruption frequency. These two indexes are characteristic of the quality of a grid; they have to be improved in almost all the countries including France. Simultaneously we can improve the quality of the

energy delivered i.e. reduce the duration and frequency of voltage sags and of very short interruptions.

Another objective is peak shaving, i.e. reducing the peaks of power demand because peaks of power demand imply very expensive investment for reinforcing the grid and nevertheless may still be the cause of blackouts. And a new factor will be the integration of electrical vehicles. I will elaborate on them later on but you certainly understand that electrical vehicles, when their batteries are fast recharged (typically 10 to 30 minutes), generate very high peaks of power. .

The third objective is environmental benefits, mainly CO_2 emission reduction through various solutions: optimization of the power plants, integration of renewable sources of energy in the grid and reduction of energy losses in the transmission and distribution.

The fourth goal is a very important one but remains questionable: it is the demand side management, which we can define as system assisted energy savings.

On this chart you see the conventional architecture with a top down approach. The electricity comes from power plants and is then transmitted and distributed to consumers in a unidirectional directional power flow. Today decentralized sources are developing: photovoltaics, wind energy etc. Maybe we will have sooner or later some innovative solutions for energy storage. We will also have significant electrical vehicles fleets and, depending on the period, they should be considered as consumers or as a way for storing energy. But this implies that we are able to manage a system with bidirectional flows.

Another major issue is that we cannot rely only on decentralized local solutions for electricity supply. Many people now believe that small is beautiful but it is not so simple. If you consider things only locally, the demand never corresponds exactly to the available power. On this graph you see actual examples which are dating from last year. In France, in the country, in Champagne, a wind farm is connected to a high voltage station. In January you see that the production of this wind farm is sometimes

exceeding very much the demand. But in December it was the opposite: there was almost no wind because very often, when it is very cold, there is no wind while in July there is too much wind. And we have exactly the same phenomena with photovoltaics. If you consider these four graphs with a photovoltaic station connected to a medium voltage station, you see a big discrepancy at certain periods between demand and production.

What are we doing today for integrating photovoltaic farms or windmill farms? We put them on the grid, we connect them and we forget them. They are not actually managed and the balance of the network is only obtained thanks to large generators which can make do with these fluctuations in the production of windmills and photovoltaics. But it generates a lot of problems especially when, sometimes, the windmills are switched off automatically without any control. We had in Western Europe, in November 2006 a very big outage due to a major incident in Germany but this incident was significantly aggravated by the fact that several thousands of megawatts of windmills simultaneously switched off as a side effect of the incident.

The ideal solution would be to have a central organization managing all these decentralized constituents as if they were the components of a set of virtual power plants. This objective is still far from being attained but you can imagine how a smart grid would help. I would insist on the fact that the absence of storage is a very huge handicap. If you consider the fluctuation of the demand in a given day, you have at your disposal conventional generation resources: fossil fuel power plants or nuclear power plants. You also have renewable energy sources. Today priority is given almost everywhere to these renewable sources. It is a political decision, I am not discussing this point, I am not sure it may last for very long, but today it is the case. Renewables have the priority. But what are the consequences? The consequences are sometimes that you have too much energy and sometimes not enough. That means that one of the key roles of the smart grids is to balance demand and production and notably to reduce the peak of demand thanks to what we are calling the demand side management.

This concept of demand side management is really a key issue because it can only be successful if it results from a combination of two approaches: an energy management by the consumer himself and a remote management by the grid operator or the power supplier. We do not know exactly how interested will the consumer be in managing his electricity demand. But smart grids also rely on the assumption that the consumers will accept the direct control of the grid operator on certain pieces of their equipment. But too which extent? It has to be debated. A preliminary example resides in what we have been doing for decades in France for water heating - the same approach could certainly be applied to other applications such as heating and air conditioning, certain household appliances such washing machine, escalators in department stores, etc. Will it be accepted by the consumers? It raises technical issues but also the question of privacy. Will the customers accept to have their home equipment managed by their electricity supplier or by the grid operator? We don't know. May be. It has to be tested.

The demand side management implies that we install everywhere smart meters. Smart meters are often confused with smart grids but smart meters are only a piece of the cake. They are necessary but they are not the whole solution. Smart meters are developing almost everywhere in the world. We consider that today there are circa 80 million smart meters installed around the world, notably in Italy. In California PGE has now around 6 million smart meters installed and in France we are today launching the Linky Project. This project has been launched by the major French grid operator, ERDF, which is a subsidiary of EDF but independent from it. The first step is to install 300,000 meters in two regions, one close to Lyon and another one near Tours, in the western part of France. Then if this experiment is successful, it will be extended to the 31 million users we have in France. The principle of this experiment is to have smart meters in each home connected via power line carriers, system concentrators and then the information transmitted via a GPRS system based on the GSM infrastructure.

Where do we stand today? We are still at the beginning of the experimentation. Not all the meters are installed yet. It seems to be more difficult and expensive than anticipated but we are at the beginning of the learning curve. We have not yet

significant feedback about the efficiency because people, who are equipped with these meters, look at them and wonder what they could do with them. Clearly, it is still too early to draw any conclusion but ERDF is quite optimistic about the results, at the end of the day.

A few words about electrical vehicles: France now has a very ambitious policy regarding electrical vehicles. We would like to have in 2020 two million electrical vehicles including rechargeable hybrid vehicles. This is very ambitious. We make the assumption that convenient batteries will be available, probably based on lithium. I know that in Israel there are a lot of researches carried out about batteries. We have a French company, Renault Nissan, which is testing some new equipment and vehicles in Israel, but the reliability of the batteries is still questionable. And the problem is not only with the batteries, it is also with the charging stations and we are currently standardizing on three types of charging stations. Most stations will be home stations or stations at work which will require 8 hours for a car to be fully recharged but with a power limited to 3 kW. It will not be sufficient. All an infrastructure has to be developed so that a car can be refueled when necessary, maybe just for 5, 10 or 30 minutes and so a second version of stations is currently being standardized, what we call the semi rapid station with a power of 24 kW where we can within five minutes refuel for 10 kilometers. We also have under development a third solution, more powerful, of 40 kW. The big question is that if you use a 3 kW charging point, you need an electrical power equivalent to a water heater. It is acceptable during the night, during off-peak hours and also when electricity production does not generate additional CO_2 emissions. But imagine that you need to use a fast charge during the peak hour, in that case in one hour you will need the power equivalent to what a standard building is requesting and if you want to recharge in 3 minutes that is the power of a district which is requested, so it is absolutely indispensable to have a management system of these future stations, via a smart grid solution, in order to limit peak demand and also to avoid additional CO_2 emissions.

So you see the ultimate objective of smart grids would be to have a management system, more or less centralized, which could control the production side as well as the demand side. Electrical vehicles will participate in both sides and once again the

major issue, still open, is whether we will we have in the future new solutions for storing electricity such as regenerative fuel cells, new kinds of batteries, superconducting devices, super-pressurized materials, etc. I purposely do not mention hydrogen, because I personally do not believe that hydrogen is a very credible solution but some people are not of the same opinion.

In conclusion, I would like to repeat that smart grids are very promising. It is a field of innovation which is absolutely fantastic. Of course it is a little bit fashionable but it deserves more than mundane consideration. A lot of issues have to be addressed. Some of them are technical, the general architecture of the grid, more or less decentralized, the modelization, the forecasting tools for monitoring and controlling intermittent resources. We need smart meters, cheap, reliable, and easy to use. We need solutions for improving the capacity of transmission of the lines, what we call the dynamic line rating, depending on the temperature and the weather conditions. We need new power electronic devices for collecting electricity from windmills and other intermittent sources and for building new transmission infrastructures. As for communications - I will come back later on them - we must pay attention to cyber-security issues. Pricing is also an issue an we need a clear and logical delineation between the role of the grid operator and the role of the power suppliers. Who will be responsible for what vis a vis the customer? Standardization is also a major worldwide issue. Customers do not accept to be dependent on a single supplier for their electricity and for the associated services.
Financing. Smart grids will mobilize huge amounts of investment which require decades before being amortized. Who will pay for them?
Sociological acceptance has to be evaluated because, for example, smart grids will result in France in a network of 31 million people connected onto the same information network with the risk of cyber attacks-or just of attempt to their privacy.

My last slide will be about communications because we need information but how to transmit this information? Starting from the water heater or from the washing machine, we have to convey the relevant information until the most upstream control centers.
Today we distinguish four segments in the analysis:

- The first meters, which will certainly be covered by wireless communication solutions such as ZigBee, ISA100, maybe PLC.
- Then we have the segment between the rooms or the buildings and the first concentrator. Probably, but not necessarily, it will be PLC or wireless solutions such as GPRS, 3G, possibly Wi-Fi
- Then we have the segment from the concentrators to the high voltage station, we don't know exactly what we should adopt, maybe 4G (or LTE), maybe optical fibers. Some people say WiMAX could be a solution but it raises questions of frequencies and performances.
- Finally we have the segment leading to the central operating stations. Probably, at this stage, we'll have to use optical fibers because the volume of data which will have to be conveyed in the network will be very important, if we want all the relevant data, during the peak periods, coming either from homes, offices or industries, be simultaneously transmitted on the network.

I also stress again the importance of cyber-security. We cannot develop smart grids without paying sufficient attention to this dimension because we know that a lot of people, including students, will spend hours trying to crack the system and to penetrate the meters, possibly introducing virus or other malwares into the grid. It would be a disaster if the grid was collapsing because of such attacks without even knowing where they would come from.

Answer to a question from a participant:

You are perfectly right: electrical systems can no longer be considered as isolated and we have several interconnections between France and neighboring countries such as Germany, Italy, Spain and United Kingdom. As a consequence, part of the smart grid program has to be addressed at the European level. But it is only a part of the problem. Not everything can be centrally addressed even if you raise a fundamental question: how should be designed the future smart grid architectures, how decentralized should they be. I cannot say that we have the answer yet. Today we have in France two organizations: the transmission grid (RTE) and the distribution grid (ERDF). Both of them are working in close cooperation with each other and the transmission operator (RTE) is working very closely with its colleagues at the European level. But should the responsibilities evolve in the future, because of the

development of smart grid architectures, I have to say that it is a question worth to be debated but I have not any answer yet.