Medium voltage products

Technical Application Papers No. 17
Smart grids
1. Introduction

ABB

Contents

1. Introduction

Electricity is the most versatile and widely used form of energy and is available to more than five billion people worldwide. This is why the electricity industry is guiding the conversion of the global energy system and electricity is the final form of energy that shows the fastest growth. In addition, it's the industry that contributes the most to reducing the amount of fossil sources in the world's energy mix.

There are plans to build new installations within 2040 amounting to a capacity of some 7,200 GW so as to meet the growing demand for electricity and replace the existing installations, which will be decommissioned (about 40% of the current structures).

From ABB Review 4-2014

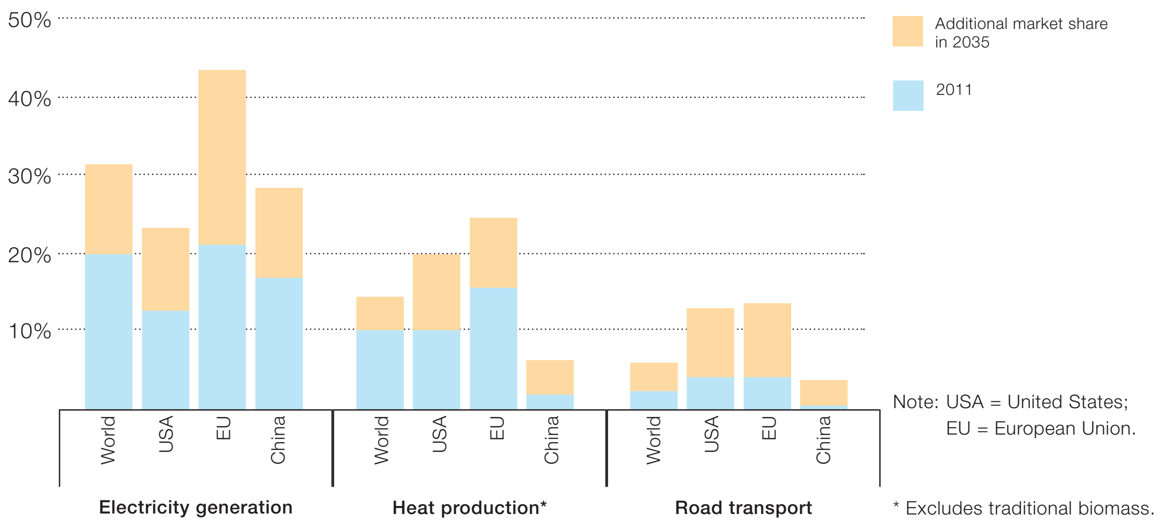
Renewables, which are of crucial importance in the global energy scenario, are rapidly gaining ground, encouraged by the increasing awareness of both public opinion and Governments about climate changes. (Source IEA World Energy Outlook 2014).
As an example, let's consider the strategy defined by the EC for 2020 and 2030. Combating climate change is one of the five main goals of the Europe 2020 global strategy for intelligent and sustainable growth. Among other things, the strategy aims to ensure that greenhouse gas emissions in the EU are reduced by 20% by 2020, that 20% of energy comes from renewable sources and that energy efficiency increases by 20%.

In addition, the EU has set itself the mandatory target for the 2020-2030 period, of reducing European greenhouse gas emissions within 2030 by at least 40% compared to the 1990 values. Since renewable energy is essential in this transition towards a sustainable, safe and competive energy system, EU leaders have agreed to raise the amount of renewables to at least 27% of energy consumption. Lastly, given that energy efficiency is a key component of the framework, an indicative 27% energy saving goal for 2030 has also been approved (Source: EC document: EU policies, Climate action ISBN 978-92-79-41350-6).

1. Introduction

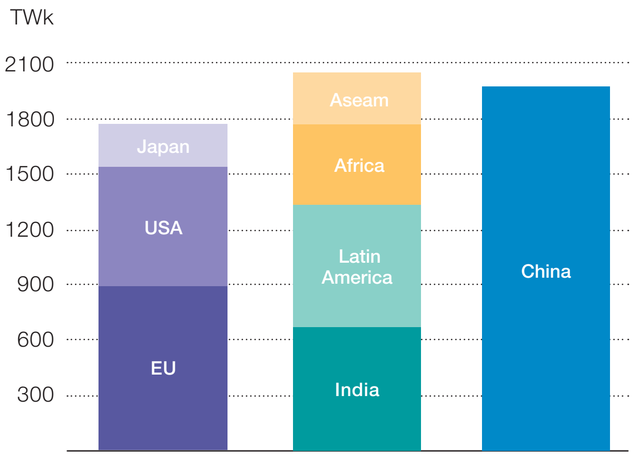
Thanks to these policies, pursued not only by the EU but by all countries, the portion of renewables in the global generation mix will reach about 33% in 2040, according to IEA (International Energy Agency).

These sources will, in fact, contribute more than 7000 terawatt/hours (TWh) between 2011 and 2035, equivalent to around one-third of global electricity generation. Renewables are already the world's second-largest source of electric



Renewable energy share in total primary energy demand by category and region in the New Policies Scenario, 2011 and 2035 (source IEA, World Energy Outlook 2013)

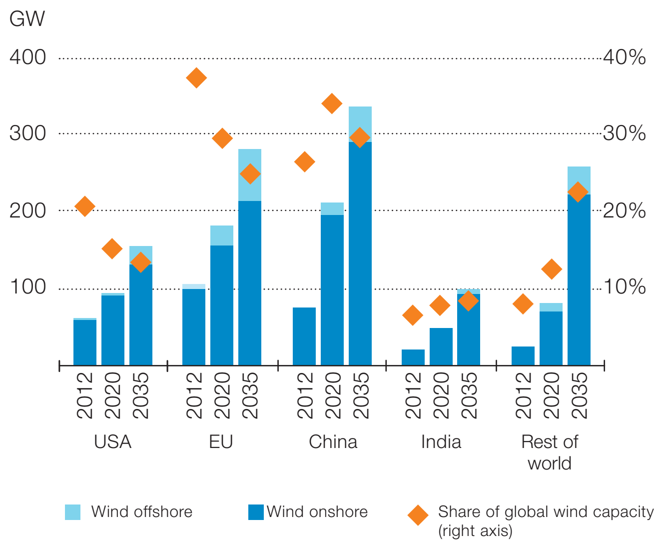
power generation and will approach coal as the primary source before the end of the period, also thanks to the rapid expansion of wind and solar PV.
In terms of growth, this equals almost half the global power generation increase forecast for 2040, which is estimated as 7,200 gigawatts (GW) additional capacity required to meet the growing demand for electricity and replace the obsolete installations.
Obviously, the situation is not the same in all countries: the share of renewables in power generation is expected to increase in the majority of OECD countries, where it will reach 37% and absorb the entire net power production increase in the area. However, power generation from renewable sources will increase more than double in non-OECD countries, especially in China, India, Latin America and Africa



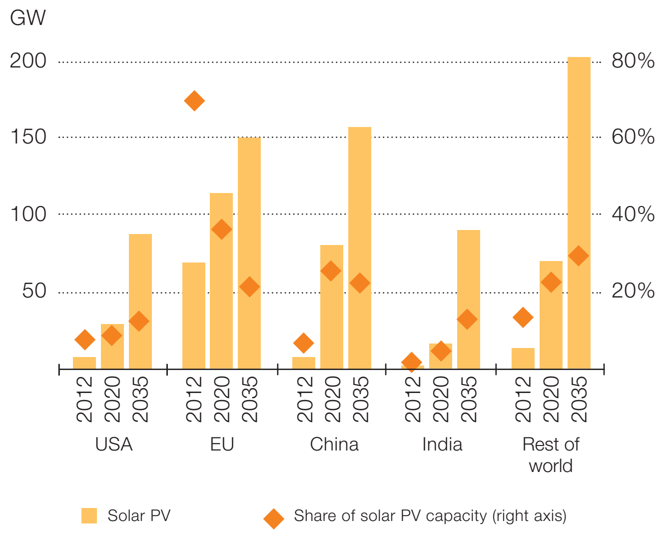
Incremental renewable generation by selected region

Incremental electricity generation from renewables in selected regions, 2011-2035 (source IEA, World Energy Outlook 2013)

At worldwide level, wind power will provide a predominant contribution towards the increase in generation from renewable sources (34%), followed by hydropower (30%) and solar PV technologies. Since the shares of windpower and solar PV in the global energy mix will increase four-fold, their integration in both technical and market terms is becoming increasingly challenging. Two examples can give an idea of the scale of this issue: Wind turbines are expected to account for 20% of total power generation in the European Union while solar PV will meet 37% of the peak summer demand in Japan.



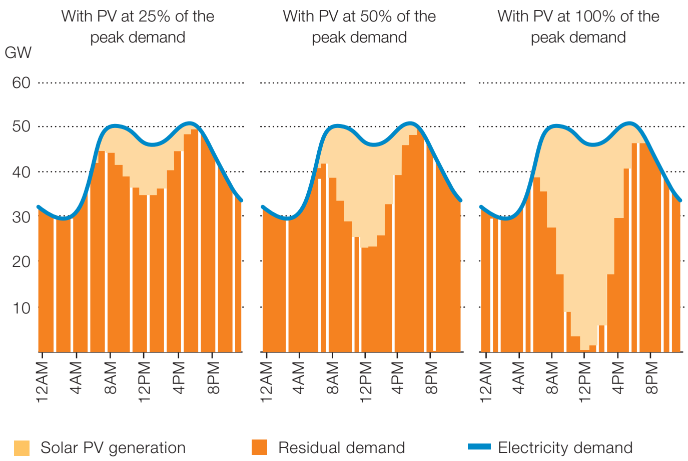
Installed wind power capacity by region in the New Policies Scenario (source IEA, World Energy Outlook 2013)



Installed solar PV capacity by region in the New Policies Scenario (source IEA, World Energy Outlook 2013)

1. Introduction

Now, if we call the energy not supplied by renewable sources but required to meet the energy demand "residual demand", the more variable will be the residual demand and the more flexible the power plants must be, since they must not only contribute towards meeting the demand but also make up for the sudden lack of availability typical of certain renewable sources.



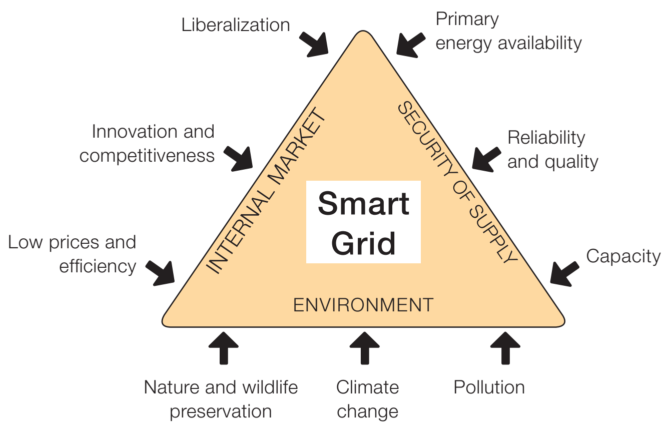
Indicative daily electricity demand and residual demand with expanding deployment of solar PV (Source: IEA, World Energy Outlook 2013)

The availability of storage systems, the flexibility of certain types of conventional plants and the quantity of renewable resources available could mitigate this variability, reduce the additional costs and technical difficulties concerning management. Nevertheless, the challenge is considerable.

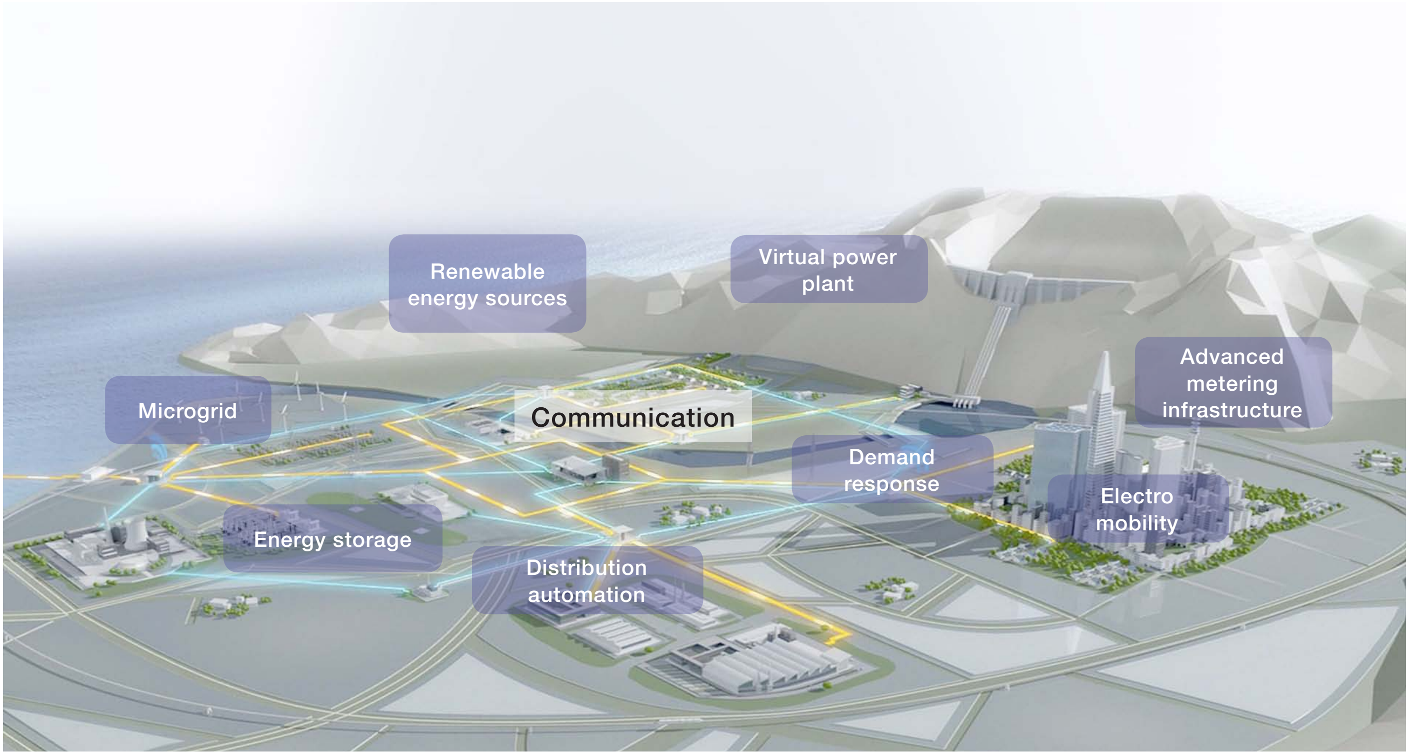
In this scenario, many of the conventional power plants will still be necessary but will be used to an increasingly lesser extent, especially in countries where the increase in renewable sources is higher. This need is due to the variability and uncertainty of supplies from renewable sources such as wind and solar PV, for which the generation capacity that can be actually counted on is much less than the capacity installed.

Thus, if electricity consumption and the generation decentralization level, mainly due to use of renewables, are set to increase, the management problem can be technically resolved in two ways: by increasing the capacity of the existing grid (mainly the distribution network, thus medium and low voltage cables and transformers) or by using the capacity of the existing grid in a more efficient, intelligent, “Smart” way, i.e. by developing a Smart Grid. (Source: IEA, World Energy Outlook 2014)
In accordance with the vision and strategies promoted by the European Union, rather than being a product, Smart Grids are a research and development project that demonstrates the feasibility of a future European electricity supply network, which must be:

- flexible, so as to meet customers' needs whilst responding to the changes and challenges ahead
- accessible, granting connection access to all network users, particularly for generation from renewable and/or high efficiency sources so as to reduce greenhouse gas emissions
- reliable, assuring security and quality of supply, consistent with the development of new digital and computer technologies
- economic, thanks to innovation, efficient energy management and able to encourage competition and relative regulation.



European Guidelines for Smart Grids (Source: European Commission and European Technology Platform Smart Grids, “Vision and Strategy for Europe's Electricity Networks of the Future,” Brussels, Belgium, 2006)



Thus the guidelines for smart grids in more operational terms are:

- increase the use of electric power
- handle the increase in power produced from renewable sources and by generation distributed over the area
- handle the introduction of electric vehicles
- integrate the power storage systems
- improve efficiency
- improve the energy market and demand management capabilities
- enhance the reliability and quality of the supply
- optimize the running costs and investments.

Technically speaking, smart grids must employ more advanced concepts as to network and component design so as to achieve improved efficiency, safety and performance. Energy storage technologies can provide a considerable contribution when it comes to integrating renewables into the network. Improved flexibility in the distribution and transmission of electric power is a must if fluctuations in power generation are to be reduced and efficiency increased. Control and monitoring systems can help to prevent disservice and outages. Use of all these intelligent technologies and their interconnection via a communication system leads to the smart grid in its most advanced concept.

In a broader sense, the smart grid is not a single network but a group of networks. The purpose is to link the structures of different electric power producers at various levels and, through automatic coordination, enhance connectivity, automation and coordination among suppliers, consumers and network so as to optimize power transmission and distribution.

The functions and solutions for smart grid components will be described in detail in the following chapters.

2. The different components and functions of a smart grid

2.1 Integration of distributed renewable energy sources

As mentioned previously, the most demanding challenge for the future grids will be to integrate a large percentage of power produced from renewable sources while maintaining high quality and security of supply.
The distribution of generated power will tend to spread and this will consequently lead to increasingly complex distribution networks as to bi-directional power flows, reliability, stability, grid management, capacity of the grid itself, etc.
One of the first problems concerns voltage stability put at risk by power flows due to both low and medium voltage distributed generation. In this case, the voltage could exceed the minimum and maximum limits defined. In addition, the rated values of the grid are unable to withstand such flows and this would lead to important components such as cables, overhead lines and transformers being overloaded. Aside from the objective technical difficulty, it is essential to find a solution to the problem. These solutions could include:

- progressive change from radial networks to mesh networks able to distribute the power flows. To achieve this, it may be necessary to increase the number of secondary distribution substations
- introduction or improvement of the Distribution Energy Management Systems (DEMS), introduction of distributed energy storage systems, planned and balanced installation of loads such as charging stations for electric vehicles, for the purpose of controlling and reducing the power flows
- direct control of the power fed into the grid by renewables
- replacement of certain passive components with an equal number of active ones, e.g. distribution transformers with automatic voltage regulators.

Use of information technology and modern communication systems can provide a major contribution to solving the problem by decentralizing intelligence and implementing the appropriate algorithms.

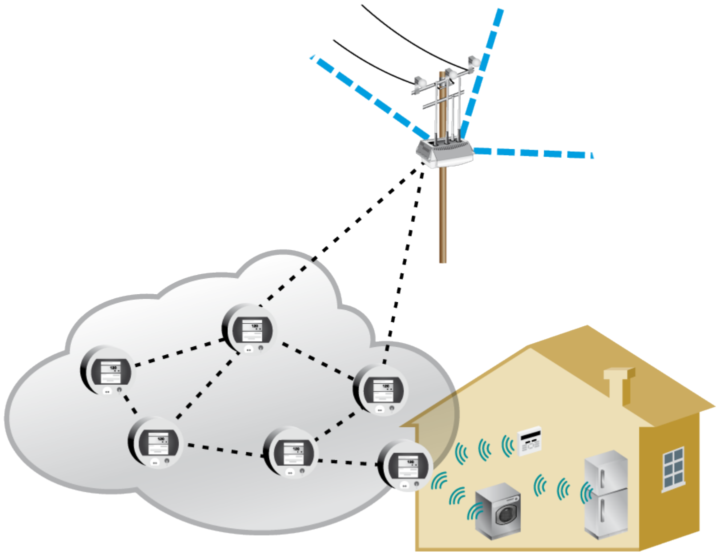
2.2 Distribution automation

Automation of power distribution systems, or Distribution Automation (DA) is becoming more and more important as distributed power sources increase, the aim being to enhance the quality and reliability of the medium and low voltage grid. The focus is mainly on the primary and secondary distribution substations of the power grid owned and managed by the public utility company, subject to increasing demands as to automation, control and protection.
When it comes to automation, the main goal is monitoring the state of the grid and transmission of measured quantities. This to upgrade the level of knowledge about the grid and its governability via remote monitoring of the IED (Intelligent Electronic Devices) installed in the grid itself. This will allow faults to be automatically detected and eliminated and possibly to automatically or manually restore the electricity supply in particularly critical situations.

Distribution automation comprises the following tasks:
- real-time monitoring of the devices installed in the grid and all sensors able to improve grid control
- use and control of active components, i.e. ones able to automatically deal with certain situations, such as transformers with automatic voltage regulators
- two-way communication between IEDs and control room
- integration of the devices into the information system of the public utility company so as to handle maintenance, emergency repairs in the event of faults, enhanced customer management, etc.
- management of distributed resources, generators and loads.

2. The different components and functions of a smart grid

2.3 Advanced metering infrastructure



Public utility companies are setting their sights on advanced metering infrastructure (AMI) to an increasingly greater extent. The aim is to develop a system able to manage the electricity demand, especially for passive and active residential users, these latter on the sharp increase thanks to the use of solar PV. The ultimate goal of telereading is to achieve dynamic management of user contracts and adopt more complex but more advantageous multi-hour rates. All thanks to exchange of information between the public utility company's information system and the user's smart meter. This reading and control combination could lead to new business management prospects for public utility companies, which could offer new services and monitor the grid-bound loads in a better way, thereby making electricity supply more competitive on the free market.
The opportunities offered by the use of smart meters and the relative communication system include:

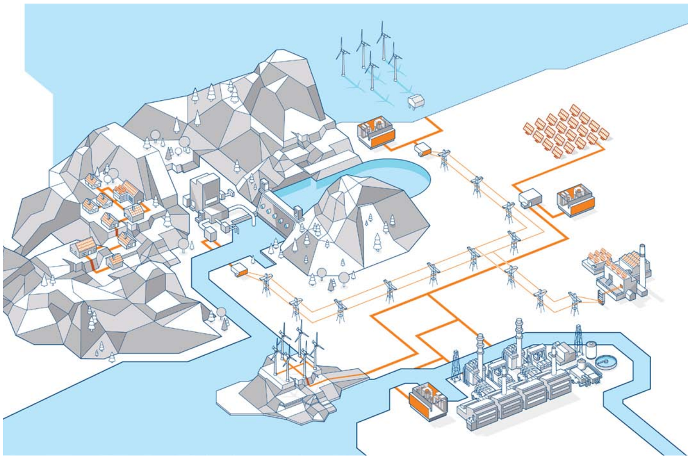
- acquisition of electricity consumption data for the purpose of pricing and managing customized contracts for special users. For example, the power limit could be changed in the event of a new contract, more complex multi-hour rates could be applied, or the load diagram of important customers could be recorded for the purpose of proposing better terms
- certain users could be disconnected from the grid is this were overloaded (when consistent with the contract) or in the case of non-payment
- different services (illumination, water, gas, district-heating, etc.) could be offered and integrated
- improved supervision to prevent theft of electricity and fraud
- automatic intervention in the case of faulty meters
- minimized disservice thanks to acquisition of additional information
- easy integration of new active users into the distribution grid by remote reading of the power supplied.

2.4 Energy storage

Major investments in the research and development of energy storage systems are now being made, so it is reasonable to suppose that they will be extensively used in the future, in conjunction with solar PV and wind power installations.
The extremely variable nature of the electricity produced from renewable sources and the consequent unbalance between power generation and consumption that could suddenly occur in the grid, has encouraged public utility companies to search for solutions able to balance the positive and negative power peaks so as to reduce the running costs and optmize loss-of-load.
These systems can have numerous benefits and effects on the distribution system, i.e.:

- by acting as generators, they can contribute towards the stability of grid voltage and frequency
- they can minimize the power flows, consequently reducing the investments required to strengthen the grid
- they allow islanded management of certain areas temporarily isolated from the grid
- they level out the consumption peaks
- they improve the security of supply in general and become a power reserve for industries, buildings and infrastructures.

2.5 Microgrids



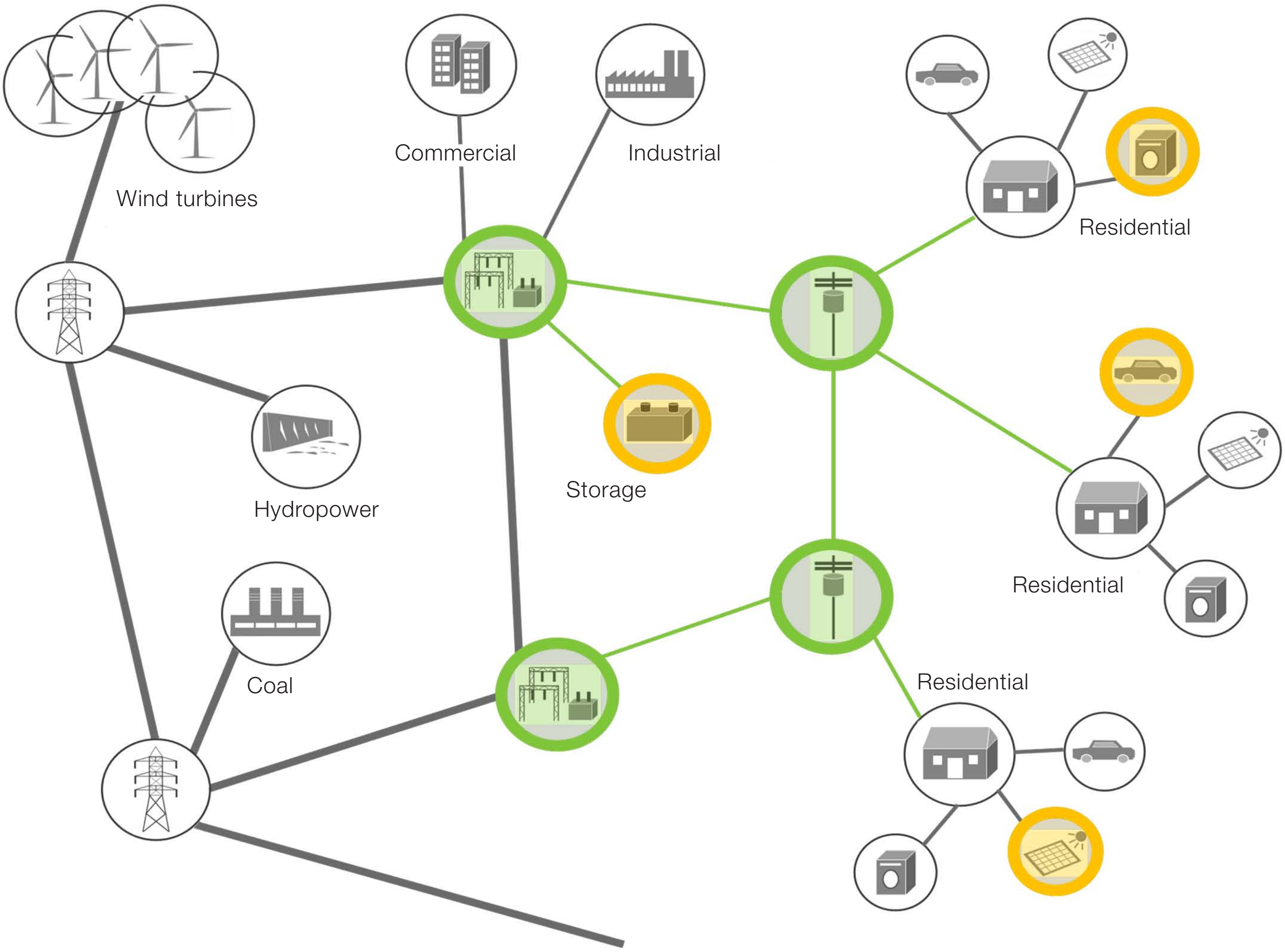
A microgrid is a network that can operate in the islanded mode, in parallel to the public utility company's main grid, where there is a considerable percentage of energy produced from renewable sources, mainly by wind power and solar PV. This is a medium and low voltage grid, since it covers a limited area. It can also include synchronized generators energized by diesel engines with power ratings of up to a few megawatts. Microgrids are generally complete with energy storage devices so as to balance the system and improve security of supply, in view of the large amount of power generated from renewable sources. Lastly, it is complete with its own monitoring and communication system. Microgrids can be used for equipping islands and rural areas situated far from the main grid, for the use of electric power.
Creation of a microgrid provides the following main benefits:

- independence from the public utility company's main grid, with the ability to supply electric energy even in a main grid blackout
- lower energy costs, especially in isolated areas, owing to a reduction in the need for fossil fuels
- reduced CO_2 emissions.

On the other hand, the risks include increased grid instability, making it more difficult to coordinate the protections.

2. The different components and functions of a smart grid

2.6 Decentralized energy management systems and Virtual power plants



While it is clear that consumers would benefit both economically and environmentally by decentralization of electricity generation in conjunction with liberalization of the energy market, their integrated management is not without difficulty. The solution lies in representing the distributed resourses as virtual power plants (VPPs) so as to create an interface able to highlight the technical and economic synergies of the complex generation system.
Thanks to this interface, the public utility company can obtain the following benefits:

- generate more accurate load forecasts
- resolve grid faults in a more selective way
- sell energy in advance, at the most convenient price
- balance the power flows.

The VPP concept allows visibility and control of the various energy sources to be increased thanks to a management system able to acquire data from all the sources and process forecasts, plan tasks and monitor them. More generally, these systems also integrate energy storage units and certain consumers so as to enhance overall efficiency.
Creation of a virtual generation system requires a computerized distributed energy source dispatching system (also known as DEMS, Decentralized Energy Management System) to optimize and plan the tasks of the distributed units, a load forecasting system and especially generators for producing power from renewable sources (also in relation to the weather forecasts) as well as an appropriate communication system.

2.7 Demand response and Generation management

Demand Response (DR), comprises the system of incentives or rules aimed at persuading end customers to change their electricity consumption. Key factors include price, availability, environmental impact, etc.
This allows public utility companies to:
- modify the consumption peaks as to value and time.
- reduce the total energy demand.
- balance generation and consumption
- avoid risky overloads and guarantee security of supply
- reduce the cost of energy and be more competitive in the energy market.

While the users can:
- save on electricity bills by reducing consumption
- obtain better rates.

A reduction in peak power demands or their different distribution over time allows public utility companies to limit their investments in grid and installations while improving the quality of the supply and efficiency of the system.
Besides the decentralized energy management system (DEMS) and Virtual Power Plant (VPP) an Advanced metering infrastructure (AMI) is also required so as to integrate the end customer by notifying and applying updated rates in real time, thereby allowing him to change his consumption habits on the basis of his contract.

2. The different components and functions of a smart grid

2.8 Electro mobility

As the number of electric and hybrid vehicles powered by batteries charged via the power supply grid (known by the term Electro Mobility (EM) multiplies, power consumption due to these charging systems is bound to increase to a considerable extent.
This will lead to major impact on the power grid, which is currently unable to bear such a rise in distributed loads. The aim with smart grids is to bear these loads while avoiding overloads, instability in the grid parameters and impaired quality of supply. The smart strategies that can be adopted include reducing charging power if overloads occur, typically in peak periods, use of off-peak rates to encourage users to choose different time bands, modification of the charging power depending on the availability of electricity generated from renewable sources. The ability to communicate with electric vehicles could allow recharging to be postponed or performed in advance, depending on the rates. This, in turn, would allow the loads created by moving electric vehicles to be piloted. Energy storage systems can play an important role in levelling out these loads. The fixed system for communication with the charging stations and mobile system for communication with the electric vehicles are fundamental for the development of this strategy.

Focused as it is on sustainable development, ABB intends to play a leading role in the evolution of the smart grid.
ABB possesses a complete range comprising cutting-edge dispatching systems through to all the most advanced electricity generation, transmission and distribution components and technologies required for the development of reliable, efficient and sustainable power grids.

These technologies and products have been installed in an experimental facility, the ABB Smart Lab in Dalmine. The only one of its kind, this facility is dedicated to research and to demonstrating the most innovative technologies in the electricity transmission and distribution industry.

Note

Contact us

ABB S.p.A.
ABB SACE Division
Medium Voltage Products
Via Friuli, 4
I-24044 Dalmine
Tel.: +39 035 6952 111
Fax: +39 035 6952 874
e-mail: info.mv@it.abb.com

www.abb.com

1VCP000593 - Rev. A - en - 2017.01 - (Technical guide - Smart grids - 1. Introduction) (gs)