Smart Grids

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1. Theme description

Energy systems are changing fast. The methods to produce energy and the ways to transmit it are changing. The consumption of electrical energy is growing and its generation is becoming more decentralized, with grid management increasingly complex[1].

With the objective to overcome the weaknesses of conventional electrical grids, the Smart Grid was introduced. A Smart Grid is an electricity network based on two-way digital communication. This system allows for analysis, monitoring, communication and control with the aim to improve efficiency and reduce energy consumption and cost[2].

The Smart Grid has the opportunity to move the energy industry into a future more reliability, efficiency, and availability, allowing an improve of environmental health. During this period, it will be critical to carry out technology improvements, study, consumer education and standard regulations to ensure the benefits of the Smart Grid. The advantages of the Smart Grids are[3]:

- Slower time of restoration of electricity after power disturbances;
- Improve the transmission efficiency;
- Reduce costs;
- Increased integration of large-scale system based on renewable energy;
- Improved security
- useful to use the plug-in hybrid technology for electric vehicles[4].

In the following, a review based on smart grid, with example of installation and future development, are reported.

[1] https://www.siemens.com/global/en/home/products/energy.html
[2] https://www.techopedia.com/definition/692/smart-grid
[3] https://www.smartgrid.gov/the_smart_grid/smart_grid.html
[4] https://www.nema.org/Policy/Energy/Smartgrid/Pages/default.aspx

2. Smart Grids

The grid is a network of lines interconnected with other. A smart grid is a new electrical grid that implements analog or digital information and communications technology. Smart Grids are able to control and improve the production of renewable energy, so the current challenge is to use this technology with the current installations to create a big network.

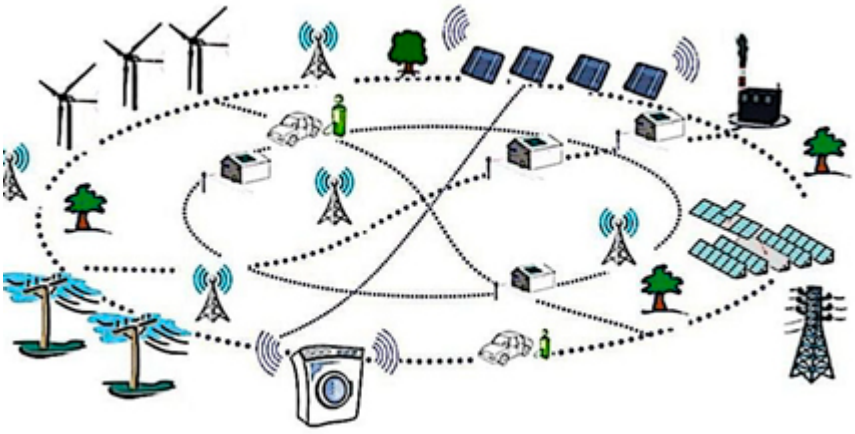

Figure 1. Example of Smart Grids.

There are a lot of new generation technologies included in the Smart Grid system, such as monitoring and analysis, automation or control (robustness, active control of high voltage device, security, efficiency etc). It can also control energy storage systems, to improve the distribution of electric energy at peak demand. To connect all system, Smart Grids need advance satellite, communications system, computers, several sensors and other devices, such as phasor measurement units (PMU) and global positioning system (GPS)[5].

There are different kinds of interconnections: greater is the power to be transported the long distance, greater is the voltage to use; so, it is necessary, for segments, to keep switching and transformers[6].

The Smart Grid controls the generation parts by using remote control and monitoring system, implemented in synergic ways by using SCADA (Supervisory control and data acquisition) or AMI (advanced metering management) operation. Smart Grid operates for both transmission and distribution network. Smart Grid tries to produce a

[5]Massoud Amin S. Smart grid: overview, issues and opportunities. Advances and challenges in sensing, modeling, simulation, optimization and control. Eur J Control 2011;

[6]Hassaine L, Olias E, Quintero J, Salas V. Overview of power inverter topologies and control structures for grid connected photovoltaic systems. RenewSustain Energy, 2014;

smart city linking between them smart meter, household and electrical vehicles etc.:in other words, all components that need caution to perform an efficient grid system[7].

Make interconnection

One of the most common problems to the management of central control facilities is that any equipment changes (to a substation or power plant) must be entered manually into the central computer system's database and electrical one-line diagrams. It should be necessary to enter this information automatically when the component is connected to the substation, like a software of a computer that automatically updates itself[8].

In Smart Grids, when a new device is connected, it establishes a communication path with the substation and give it the ability to report its parameters and interconnects to the central control system, giving the possibility to update the information.

Diagnostic Monitoring

Smart Grids need sensing technologies to do measurement, to support accurately faster any kind of change (such as demand-side management). Advanced components, in superconductivity, storage, power electronics and diagnostics area, are needed to do this. The control system is important too, to monitor essential components, enabling rapid diagnosis and precise solutions to any good and bad event[9].

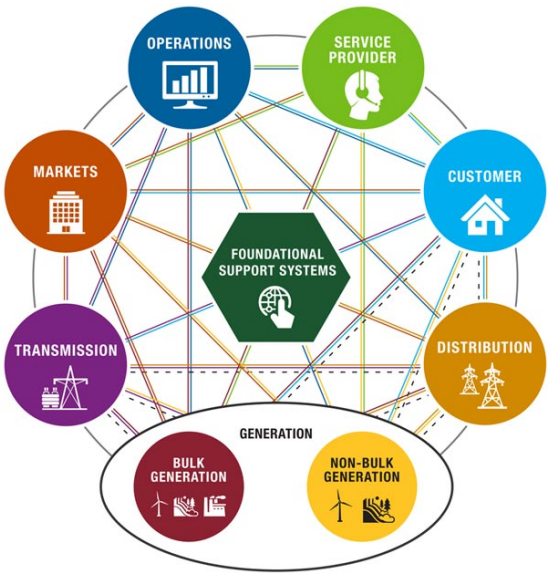

Figure 2. Network System in a Smart Grid.

[7]] Ilhami C, Ersan K, Gianluca F, Stavros L. A survey on the contributions of power electronics to smart grid systems. RenewSustain Energy, 2015

[8] Toward a Smart Grid, S.Massoud Amin, Bruce F. Wollenberg, September/October 2005

[9] https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages%281%29.pdf

Efficiency and Security

Smart Grids improve the capability to found an error and it can resolve automatically it[10,11] .

From a security point of view, considering the information network in Smart Grids that allows many features, the Smart Grids could be prone to attacks. The solution for this problem could be the using of an intrusion detection system (IDS) or by randomly hiding information inside normal readings[12].

Integration for existent energy source

Distributed energy resources (DER) are small sources of power, such as a storage and renewable energy, that are usedcurrently to reach the regular power demand. The renewable technologies are wind generators, photovoltaic generators, etc. Smart Grids can facilitate the transition from fossil sources to the use of only renewable energy, following the growing consumer demand[13].

Demand response

Demand response allows at the consumers the possibility to be involved in grid operations: they can reduce or shift their electricity usage during peak periods and reduce their cost[14].

Energy Storage

Smart Grids need to be implemented with electricity storage and technologies that attempt to moderate and reduce peaks. Energy storage is indispensable specially for electricity generation from renewable energy (that it's not stable during the day). So, storage devices store the electricity in excess when renewable energy generation has a peak, providing the using of energy at demand. Electric vehicles can use the electric grid to recharge and stock energy: they can remain connected to the grid after they

[10] He Q, Blum RS. Smart grid fault detection using locally optimum unknown or estimated direction hypothesis test. Energy Procedia 2011

[11] Xia S, Luo X, Chan KW. A framework for self-healing smart grid with incorporation of multi-agents. Energy Procedia 2014

[12]LiuTing, SunYanan, Liu Yang, GuiYuhong, Zhao Yucheng, Dai Wang CS. Abnormal traffic-indexed state estimation: a cyber–physical fusion approach for smart grid attack detection. FuturGenerComputSyst 2015

[13] https://mn.gov/commerce/energyfacilities//documents/EQBFileRegister/04-87-CON-Monticello/2004%20EPRI%20DEG%20Roadmap%20for%20the%20Future%20Final.pdf

[14] https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/demand-response

are parked, so deliver the energy from their batteries in a technology called vehicle-to-grid[15].

3. Smart Grid Installations

Next examples are a list of some Smart Grid installations (project and working):

- Enel S.p.A. Italy, it is a Smart Grid installation born in 2001 with the name Telegestore. It is regarded as the first commercial Smart Grid technology used for home;
- Austin, Texas, there are currently about 200.000 device based on Smart Grid technology in the city (smart meters, sensors, smart thermostats)[16];
- eEnergy Vermont consortium, it is US state-wide initiative, where the Smart Grid technology is used in the state (about 90% of Advanced Metering Infrastructure)[17];
- LIFE Factory Microgrid, is a demonstrative project of 2013, that demonstrate the efficacy of Smart Grid and microgrid, using a full-scale technology[18];
- US Dept. of Energy, with the name ARRA Smart Grid Project, it is one of the largest deployment programs in the world. 9 billion dollars required for program. The installation included a wide variety of Smart Grid technologies, like smart meters, cyber security, energy storage, etc[19].
- Boulder, Colorado, it is implemented smart metersfor home and controls smart sockets and devices[20];
- Hydro one, Ontario, Canada, it is a large-scale Smart Grid initiative conforms at Trillian standard[21];
- Australia, some cities like Adelaide and Sydney implemented the Smart Grid technology[22];
- Chicago, US, the installations of Smart Grid technology is a priority for the city, with an investment over 2.6 billion dollars since 2010. Now there are about 4 million smart meters installed[23];

[15] https://www.sciencedaily.com/releases/2007/12/071203133532.htm
[16] https://austinenergy.com/ae/about/environment/integrated-smart-grid
[17] http://publicservice.vermont.gov/electric/smart_grid
[18] http://www.factorymicrogrid.com/en/index.aspx
[19] https://www.smartgrid.gov/
[20] https://www.greentechmedia.com/articles/read/boulders-smart-grid-leaves-citizens-in-the-dark#gs.7FMyXKA
[21] https://www.hydroone.com/rates-and-billing/meters/smart-meters
[22] https://www.energy.gov.au/government-priorities/energy-programs-closed
[23] https://www.cityofchicago.org/city/en/progs/env/smart-grid-for-a-smart-chicago.html

Figure 3. Example of Enel smart meters.

4. Conclusion

The Smart Grid is a technology in development in these yeas. The discovery of new ways to do sensors, control systems, is able to help the formation of a more intelligent grid. Almost all the nations help the diffusion of Smart Grid with new initiatives. This paper has talked about the fundamental aspects and benefits of a Smart Grid, pointing out some actual Smart Grid installations and a lot of project in development. In conclusion, the traditional grid became limited and needed more features to be efficient.