Smart Microgrid Background Review

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***Abstract*—This article introduces some general background conceptions in Power systems area. It covers the current development status in generation, transmission, distribution and demand-side management in power systems. Some challenges in the existing systems are discussed. This article also talks about smart grid technology.**

Keywords—Power system, Smart grid, Advanced metering infrastructure, Demand response, Renewable energy

I. INTRODUCTION IN POWER SYSTEM

A. *Power Generation*

Power generation means the process of producing electric power from other forms of energy, such as chemical, mechanical or nuclear energy.

Thermal power plants convert heat energy into electricity. They usually burn fossil fuels (coals, natural gas, and oil). They work on the principle of transforming the heat energy from combustion into mechanical energy, which drives a generator to produce electricity. These types of power plants are very common in real life. However, they cause pollution.

Hydropower plants use the energy of falling water to spin a turbine connected to a generator. This kind of energy source is renewable and friendly to the environment.

Nuclear power plants involve nuclear reactions to produce heat. Then they use the heat to drive a steam turbine to produce electricity.

There are other renewable energy sources. They are less reliable and more unstable compared to those mentioned above, but they still have some hidden valves and deserves future study. This includes solar panels (which convert sunlight into electricity), wind turbines, geothermal power plants (which use heat from within the Earth), tidal power plants, and bioenergy..

B. *Transmission*

Transmission of electrical energy is carried out at high voltages. This can reduce the energy loss. Transmission lines carry the high voltage electric power from one location to another. Those lines are connected to substations. They are used to change voltage levels using transformers, control the flow of electricity, and protect the system using various protection devices. Transmission lines and substations play an important role in grid networks. This network allows power to be generated anywhere in the grid and delivered to any location.

C. *Distribution*

Distribution refers to the final stage in the delivery of electric power. Electricity from the transmission system is carried to individual consumers. Distribution system lowers the voltage in transmission network so it can be used by users.

D. *Demand-side management*

DSM makes a power system more efficient and reliable. Some actions can be taken on the consumer side to alleviate peak demand and reduce overall energy consumption.

For example, some pricing mechanisms can modify consumption patterns to optimize the energy usage. Time-of-Use (TOU) Pricing makes electricity prices vary based on the time of day, encouraging consumers to use electricity during off-peak times when it's cheaper.

II. CHALLENGES IN THE EXISTING SYSTEM

A. *Fossil fuels vs. renewable energy resources*

While fossil fuels have historically powered industrialization and modernization, there is a global shift toward renewable energy due to the environmental, economic, and sustainability benefits associated with them.

Infrastructures that built to deal with fossil fuels are well-established. They have developed an entire procedure for extraction, refinement, distribution, and consumption. As a result, this makes fossil fuels relatively cheap. In addition, fossil fuels can be burned to produce energy on demand, and it makes them consistent and reliable. However, with the rise of awareness towards global environment protection, external costs become apparent, and they can become more and more expensive in the future.

Renewable energy generally has a much lower environmental impact in terms of greenhouse gas emissions. There still can be some impact on animal living habitat after the construction of hydropower dams or wind turbines. The cost of renewable energy has been decreasing rapidly, especially in solar and wind area. Compared to fossil fuels, renewable energy is more flexible. They can be created in small scales (rooftop solar panels) with decentralized systems, to large centralized facilities (wind farms). Some sources like wind, tide or solar are inconsistent, meaning they cannot produce energy all the time. As a result, renewable energy depends heavily on energy storage technology and grid management to maintain energy supply.

	Hard Coal	Lignite	Oil	Gas-CC	Nuclear
El. Efficiency %	42.0%	40.0%	44.0%	57.0%	34.0%
Fuel Consumpt. t/a	2,000,000	7,600,000	1,289,768	920,000	20
Oxygen Cons. t/a	3,800,000	4,800,000	3,270,047	1,600,000	0
CO_2 emiss. t/a	5,200,000	6,600,000	4,496,314	2,200,000	0
SO_2 emiss t/a	3,800	4,300	3,134	1,200	0
NO_x emiss t/a	3,800	4,300	3,134	3,500	0
Dust emiss t/a	600	640	470	200	0
Radioactivity kBq/a	80	90	0	0	52,800
Ash t/a	150,000	950,000	2,000	0	0
Gypsum t/a	75,000	110,000	220,000	0	0

Figure 1 IMPACTS ON THE ENVIRONMENT

B. *State estimation latency vs. real time*

In modern power systems with updated computing infrastructure, state estimation can be completed in a matter of seconds. However, in real-time power system operations, speed is crucial. Hence, many operators aim for a state estimation every 1-5 seconds to monitor and control the grid effectively, especially in systems with a lot of variable renewable integration.

C. Uncontrolled load in distribution system

"Uncontrolled load" refers to electrical loads or devices that consume power without any active management or modulation in their consumption pattern based on external factors or grid conditions.

One example is electricity vehicles. They need to be charged when the battery is low. It is hard to predict or regulate car owners' charging time. Some people may charge twice a week, while others can charge on a daily basis. This kind of load in power grid is uncontrolled. Therefore, a low latency in state estimation is very important.

III. SMART GRID

Smart energy grids (SEGs) are energy networks that promise to enhance the operational efficiency of energy supply via distributed generation with bidirectional energy flow. This objective is achieved by allowing intelligent monitoring and control of different components within the multi energy systems (i.e., electricity, natural gas, thermal energy, and water), while maintaining the quality, security, reliability, and safety with minimal environmental impacts.

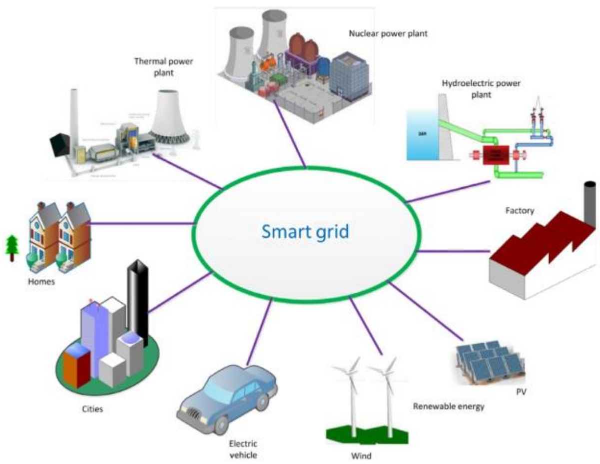

Figure 2 Smart grid architecture

A. Advanced Metering Infrastructures

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.

The AMI, combined with customer systems can achieve substantial grid impacts and benefits for customers and utilities. It reduces costs for metering and billing. Nowadays customers can pay the autogenerated bill on the internet. No working labor is needed to track the usage of power from one house to another building. Old mechanical meter is inaccurate and may cause customer disputes.

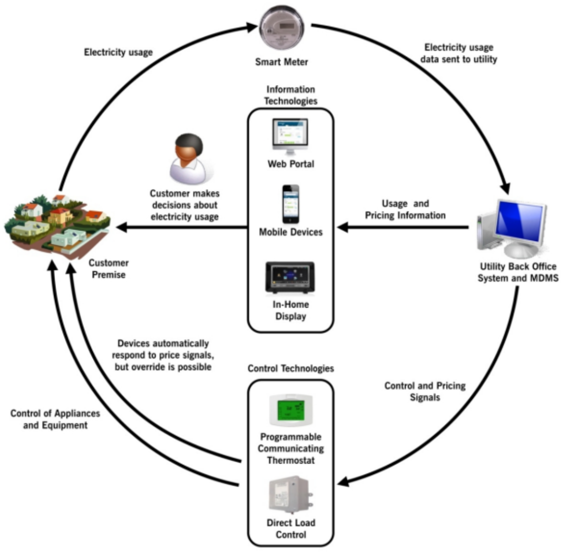

Figure 3 AMI and Customer Systems Work Together

B. Demand Response technologies

Just as we discussed before, AMI allows stations to monitor the power usage in real time. All the data can be used to change the price of electricity or to add financial incentives. Home Energy Management Systems (HEMS), or smart home appliances contribute a lot in this process. They collect data automatically and make adjustments to the home's energy consumption. Some works from computer science can help the development of DR. For example, AI and Machine Learning can predict demand patterns, renewable energy generation, and optimal DR strategies, making the entire process more efficient. As technologies evolve, end-users will have more control over how, when, and from where they consume energy, with DR being a core component of this shift.

C. Smart Grid technologies combine broadband communication and intelligent electronic devices

The data transfer in smart grid is different from regular networks. It does not require extremely large bandwidth like Wi-Fi or 5G network. It requires stability and security. Smart grid devices are running 24/7 and its data is of great importance, which directly affects the decision made by other devices. With countless devices connected to the network, it is similar to IoT devices. Nowadays more and more technologies that first appeared in IoT fields are being applied to smart grid. Such as the MQTT transmission protocol.

D. Smart grid conclusion

Smart grid is more than a simple word 'smart'. It combines multiple efforts from different areas like information technology, mechanical engineering, electrical engineering and computer science. It has to adapts those old systems, some of which may seems to be perfect in the last century. It also needs to demonstrate its flexibility for future upgrade. With the development of smart grid, those infrastructure in power grid will become more and more intelligent. People can manage the power network with ease and react to different situation quickly.

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