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ScienceDirect

Energy Procedia 61 (2014) 858 – 861

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

How Smart Grid Contributes to Energy Sustainability

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Abstract

With the increasingly serious energy shortage and global warming, sustainable development has become an urgent requirement all over the world. The integration of smart grid technologies, sustainable energy resources and low-carbon emissions in power system is an important route to sustainable development. However, the difficulties in dealing with intermittent power and the low utilization efficiency of power system appeared to be obstacles. This paper gives an overview of the role smart grid playing in energy sustainability. Firstly, smart grid techniques improve the amount of intermittent renewable generation in power system, increasing the capacity of grid-connected clean energy such as solar energy, wind energy and photovoltaic system. Secondly, smart grid promotes energy saving in power system. The main advantage of smart grid is that it can improve the utilization efficiency of power system and the power consuming efficiency. Lastly, this paper discusses the interrelationship of energy, environment and climate sustainable development and draws the conclusion that smart grid can make a significant and comprehensive contribution to energy and environment sustainability, and also helps to control climate change.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: clean energy; energy sustainability; energy saving; smart grid

1. Introduction

The first challenge of energy development is increasing levels of renewable energy generation and reducing reliance on fossil fuels generation. In 2012, oil, coal, gas, accounted for 33.1%, 29.9% and 23.9% of the world's total primary energy consumption respectively, and the total reached 86.9% of primary energy consumption, in which fossil fuels are dominated [1]. The global environmental degradation and the greenhouse effect caused by carbon dioxide emissions have seriously threatened to the global environment. Therefore, to reduce fossil fuel consumption and achieve sustainable energy are great significance [2]. In energy system, electricity energy is not only the main terminal, but also an important medium of other energy utilization. Electricity energy is the main route for development and

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Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.11.982

utilization of non-fossil energy through power generation. The traditional power system can't meet the needs of a large number of renewable energy connected, so new frameworks and technology must be used to support the efficient utilization of energy [3]. Smart grid is defined as the electricity networks that can intelligently integrate the actions of generators and consumers, and can deliver electricity which has the advantages of low losses, sufficient capacity and high quality and coverage area accessible, reliable, efficient, safe, economic, and sustainable [4]. The key goal of smart grid is to enhance the safety, reliability and economy of power system operation, and improve the efficiency of energy utilization to achieve energy conservation and emissions reduction [5].

2. Smart grid improves the capacity of intermittent renewable generation in power system

2.1. The utilization of renewable energy resources

The global generation of renewable energy, including wind, solar and hydro power, are shown in Table 1. We can see that the utilization of global renewable energy shows an increasing tendency, but the total power generation of renewable energy is still small, the reason of which is the integration of intermittent power sources has the following obstacles.

Table 1. Global power generation of renewable energy from 2009 to 2012

	Wind power (billion kWh)	Solar power (billion kWh)	Hydropower (billion kWh)	The sum (billion kWh)
2009	277.9	19.1	3,260.4	3557.4
2010	348.1	30.4	3,456.5	3835.0
2011	440.1	58.7	3,512.0	4010.8
2012	521.3	93.0	3,673.1	4287.4

- The grid-connected intermittent power sources may cause voltage fluctuation and flicker in local distribution lines, which will lower the power quality.
- The power electronic equipment in intermittent power sources with inverter interface will generate harmonic in the operation, and even will cause waveform distortion.
- Wind power and PV generations are highly dependent on the environment and climate, and the outputs are unstable, which reduce the reliability of power supply.
- Due to the instability of intermittent power sources, grid frequency will decrease after losing power, which will affect the stability of the grid frequency.

2.2. Technologies of improving the capacity of grid-connected renewable energy

Renewable energy grid-connected technology, which based on the smart grid can effectively improve the development scale of renewable energy, and can enhance the capacity of grid-connected renewable energy. The main renewable energy grid-connected technologies are as follows:

- Active and reactive power flow control method. The method adopts frequency recovery algorithm based on frequency droop, which can well meet the requirements of the frequency quality [6].
- Advanced fault management techniques based on smart grid. It can provide all the pretreatment conditions of island operation beforehand, and can improve the stability of generating units.
- Virtual power plant control technology. The technology integrates renewable power sources, controlled load and energy storage system to participate in power grid operation.

3. Smart grid promotes energy saving

3.1. Improve the utilization efficiency of power generation resources by optimizing scheduling

Optimization scheduling technologies have been already extensively applied in renewable energy generation such as wind, solar, PV systems and distributed generation. [7] proposes a novel solution for generation scheduling problem in power systems with large capacity of grid-connected wind energy. [8] proposes a multi-agent system for energy resource scheduling of an islanded power system with distributed resources. [9] proposes a methodology of designing a maximum power point tracking controller for photovoltaic systems using a adaptive fuzzy gain in scheduling of Proportional-Integral-Derivative type controller. Optimization scheduling can improve the utilization efficiency of power generation resources, enhance the capacity of connected renewable energy, and reduce the consumption of fossil fuel at the source.

3.2. Reduce line loss by optimizing reactive power compensation

With the development of high voltage and long distance transmission systems, reactive power in power lines is increasing rapidly, causing problems such as voltage loss and deterioration of power quality. It is significant to utilize reactive compensation to regulate voltage and improve power quality of power system. In smart grid, main technologies for reactive power compensation include capacitor control and FACTS. Intelligent reactive power compensation technologies by capacitor control include network communication technology, zero cutting technology, etc. FACTS can control power system robustly. FACTS devices utilize reliable digital control that is flexible and able to adjust a wide range of compensated reactive power. FACTS devices only utilize small capacitors and can compensate voltage instantaneously.

3.3. Improve the utilization efficiency of electrical equipment by demand response (DR)

DR is a market behavior which makes a response to market price or incentive mechanism to change ordinary electric consumption. Advanced information, control and communication technologies are integrated in smart grid, which provides strength technical support to DR projects. Key techniques of DR are as follows:

- Smart meters, record the real-time data on the electricity use, and provide data support for the DR.
- Two-way communication technology, can complete real-time and high-speed information interaction.
- Home domain network, enhance the user participation in DR project.
- User measurement data management, improve the accuracy of load forecasting, and help to formulate reasonable DR project.

3.4. Improve the power consuming efficiency

Smart grid improves the power consuming efficiency of power users [10-11]. Smart grid provides all kinds of necessary information for electric power users, such as current and historical electricity consumption, carbon dioxide emissions from the consumption of electrical energy, instant demand, environment temperature, humidity, and illuminance, etc. The electricity information is fed back to the users, which helps the users adjust the power consumption mode, change the concept of power consumption to improve the efficiency, and promotes the access of distributed power to the grid as well, so as to achieve smart interaction and green energy saving.

4. Energy sustainability contributes to climate and environment sustainability

Climate warming influences human living conditions and natural environment, which is the basis for social and economic development, at the same time, the rapid development of the society aggravates the

environmental pollution, and also GHG emissions that result in climate warming. Climate change has negative impacts on ecosystem services, human health and many other areas. Climate and environment sustainability have strong coupling with energy sustainability. The sustainable climate and environment are helpful for realizing the efficient utilization of energy supply and security, energy sustainability has a closed-loop positive feedback effect on the climate and environment sustainability [12].

5. Conclusion

This paper has provided an overview of the role smart grid playing in promoting energy sustainability. Smart grid technologies used in power generation side can effectively improve the amount of intermittent clean energy generation in power system, improve energy utilization; smart grid can also promote energy saving in power grid links. We have shown that smart grid can make a significant and comprehensive contribution to energy and environment sustainability, achieves energy saving and emission reduction, and mitigates environmental degradation and climate warming.

Acknowledgements

The authors thank to the College of Electrical and Information Engineering of Hunan University.

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Biography

Zhuangli Hu was born in Hunan Province, China. She received the B.Eng. degree from the College of Electrical and Information Engineering in Hunan University, Changsha, China in 2013. She is currently pursuing the M.Eng. degree at Hunan University.