Application of Distributed Energy System in Iron and Steel Industry and Its Policy Impacts

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Abstract: After years of development, the concept and connotation of Distributed Energy System (called as DES) are gradually unified. As a way of energy supply in the demand, a revolution of traditional energy system, DES is a new concept of energy conservation in the iron and steel industry, which has been vigorously advocated by the state, and warmly supported and concerned by the international environmental protection work. Iron and steel industry is a high energy consumption industry. With a large number of complex energy conversion and utilization, the production process has developed or is developing a certain amount of DES. According to the definition of the World Alliance for Decentralized Energy (WADE), this paper describes the most representative several DESs in China, and discusses its influences on the energy system of iron and steel enterprises. Finally, some policy suggestions for distributed energy system utilization in iron and steel industry are put forward for the developing countries.

1. Introduction
The iron and steel industry is an energy-intensive industry. In 2013, the energy consumed by the steel industry accounted for 18% of the total final energy consumption of the global industry [1].

DES (an acronym for Distributed Energy System) is a very popular concept in recent years. After several years of development, the European Union, the United States, the World Alliance for Decentralized Energy (WADE) and China have gradually unified the connotation of DES, which can be generally understood as all the energy resources used and transformed by the distributed system [2]. It is an energy supply mode built on the user side and can operate independently. It can also be connected to the grid for operation. The mode and capacity can be determined by maximizing the resource and environmental benefits. It can integrate and optimize the user's multiple energy needs and resource allocation. The new energy system designed by demand response and modular configuration is a decentralized energy supply mode compared with centralized energy supply. A multi-energy supply system is composed of different modular equipment close to the user side [3]. DES can be said to be a revolution in the field of energy, a more realistic and economic choice for clean utilization of energy, and an effective way to alleviate energy problems in various countries. Generally speaking, DES has the following characteristics: flexible grid connection or off grid; reduction of transmission or conversion loss of centralized energy network; multiple energy input to meet multiple needs; cascade and efficient utilization of energy; miniaturization and modularization of equipment, etc.
According to WADE’s classification, DES can be divided into three categories: local renewable energy, high-efficiency cold/cogeneration and local recovery of industrial energy, which is also a relatively recognized classification at home and abroad [4]. DES has been widely used in iron and steel enterprises [5]. With the requirements of energy reduction, cleaning and low carbon, DES has become more and more important.

The purpose of this paper is to analyze the status and role of DES in iron and steel enterprises and its impact on the energy system of iron and steel industry in China, and then put forward some policy enlightenments for the developing countries.

Firstly, based on the classification of WADE and the energy conservation targets of iron and steel industry, this paper describes three kinds of distributed energy forms, such as local renewable energy, local energy recovery, and combined cold/heat and power generation in the iron and steel industry. Secondly, it also summarizes and discusses the application of distributed energy in the iron and steel industry, as well as the impact of distributed energy on the iron and steel energy system. Finally, we put forwards some recommendations for policy makers of the developing countries.

2. Some types of DES in iron and steel industry
The energy consumption of China's iron and steel industry accounts for about 15% of the total energy consumption of the country. In its energy structure, coal still accounts for the main part. Therefore, in the overall situation of limiting total coal consumption and low-carbon development (carbon market or carbon trading), it is particularly important to develop distributed energy in steel enterprises.

2.1. Local renewable energy in the iron and steel industry
Renewable energy is an important part of energy supply system, mainly including water energy, wind energy, solar energy, biomass energy, geothermal energy and marine energy. The utilization of renewable resources in iron and steel industry can reduce the dependence on non-renewable coal resources. Considering the characteristics of iron and steel enterprises, wind energy, solar energy and biomass energy can be considered for development. Among them, wind energy (such as the use of some steel plants near the river and the sea, which has the advantage of certain wind resources) is being tracked and discussed. It will not be discussed here. The following mainly introduces the use of solar energy and biomass energy.

2.1.1. Solar energy development in iron and steel enterprises
Iron and steel enterprises generally occupy a wide area and have a large number of workshops, which has the natural advantage of developing roof photovoltaic power generation. Photovoltaic power generation structure of iron and steel enterprises is to use photovoltaic modules installed on the roof, and then as connect to the electric room through combiner box, inverter and transformer, and provide it to users in the iron and steel plant for use, so as to absorb photovoltaic energy locally.

In terms of roof photovoltaic power generation of iron and steel industrial plants, China’s Baosteel Group took the lead, not only complying with the requirements of national and local development, but also developing clean energy for the enterprise itself, becoming an important part of building a ‘clean energy demonstration base for urban iron and steel enterprises’. Literature [6] and literature [7] respectively introduced the application of photovoltaic power generation on the roof of Baoshan base and Meishan base of Baosteel Group, and focused on the combination of photovoltaic modules and plant building surface and grid connection technology. Literature [8] introduces the development of roof photovoltaic in Guangzhou iron and steel enterprises. Literature [9] makes some explanations on the development of photovoltaic in iron and steel enterprises from the design point of view. Different from the above applications, in addition to the development and utilization of solar power generation, the development of solar energy, light and heat can also be considered in iron and steel plants [10]. Literature [11] introduces the situation of solar bathroom in the new workshop of Jigang Group.
2.1.2. Development and utilization of biomass energy

As a kind of renewable resources, biomass mainly refers to the organic substances produced by animals, plants and microorganisms through growth and metabolism, including crops and agricultural organic residues, forest and forestry organic residues, industrial and social organic wastes, etc., which is only the fourth largest energy after coal, oil and natural gas. It plays an important role in the whole energy system. Specifically in the iron and steel industry, the available biomass energy mainly includes the organic residues and wastes of the plant and society.

Figure 1. Technical pathway of biomass development in iron and steel industry

Figure 1 shows the technical pathway of biomass energy development in iron and steel industry, which has been actively explored and studied at home and abroad. In literature [12], the utilization technology of biomass fuel is introduced, including gasification, liquefaction, pyrolysis, solidification molding, fermentation and direct combustion, and the application in sintering, pelletizing, blast furnace iron-making and steel-making is further introduced. Literature [13, 14] put forward the convenient conditions for the development of biomass energy in the metallurgical industry, such as the use of low-temperature steam and flue gas in the metallurgical process to dry and roast biomass fuel; the use of the processing and manufacturing capacity and R & D capacity of iron and steel enterprises to suppress and gasify biomass; the use of steel surplus capacity for biomass treatment, etc. Literature [15] introduces some practical cases of the application of biomass energy in iron and steel industry in the world. In addition to the direct use in the iron and steel production, it is also of great significance to use biomass energy for power generation or heat generation in iron and steel plants.

It should be said that at present, the application of biomass energy in iron and steel production is still in the research or experimental stage, but from the unique characteristics of biomass energy and the research results at home and abroad, biomass energy has a certain potential to be developed in iron and steel production in the future.

2.2. Local energy recovery in iron and steel industry

The manufacturing process of iron and steel industry is also a large-scale energy cycle system, which carries out complex energy consumption, conversion, regeneration and transmission among the internal processes of the system. Due to the strong thermal characteristics of the iron and steel complex, a large amount of residual energy is generated, which is mainly reflected in the form of residual heat [16]. Among them, residual heat refers to the heat energy discharged into the surrounding environment without being used in the process, which can be divided into solid carrier waste heat (such as coke, slag, sinter, pellet and continuous casting slab), liquid carrier waste heat (such as cooling water, condensate) and gas carrier waste heat (such as blast furnace, coke oven, converter gas, waste gas and steam) according to the different forms of heat carriers. Residual pressure refers to the fluid with a certain pressure discharged by the process equipment, which can be divided into gas residual pressure (such as
the residual pressure at the top of the blast furnace) and liquid residual pressure (such as the residual pressure of circulating cooling water) according to the different carrier forms.

2.2.1. Residual heat energy recovery

In the residual energy of iron and steel industry, it mainly exists in the form of residual heat. Efficient recovery and utilization of residual heat resources is the main direction of energy conservation in iron and steel industry at present and in the future, which is mainly to recover sensible heat generated in iron and steel process [17].

In recent years, residual heat recovery has developed rapidly, and the main high-quality and low-quality residual heat of domestic advanced steel plants have been effectively recovered and utilized, such as CDQ technology (an acronym for Coke Dry Quenching; according to incomplete statistics, CDQ has doubled from 2008 to 2013), blast furnace gas dry dedusting, converter gas dry dedusting, coking coal humidification and sintering residual heat recovery, etc. In accordance with the basic principles of ‘source reduction, step-by-step recovery, temperature matching and step-by-step utilization’, low-grade residual heat comprehensive step-by-step utilization is being carried out, power generation, hot water, heating and other aspects are being utilized, and its demonstration projects are being established. Baosteel Group uses the low-temperature residual (waste) heat that cannot be used in production, such as low-temperature flue gas and low-pressure steam, to produce domestic hot water of about 90°C, which is stored in a hot water tank, and transported to the workers' bathroom of the plant area through a mobile heating water truck for the workers to take a bath, which has a good energy saving and consumption reducing effect. At present, the demonstration project (ORC) of power generation with low temperature waste heat from the third sintering ring cooler of Baosteel Group is also under construction and is expected to be put into operation in 2017.

2.2.2. Residual pressure energy recovery

In the iron and steel industry, the energy recovery of residual pressure mainly refers to the power generation by top blowing of blast furnace, that is, TRT [18]. According to statistics, more than 90% of large blast furnaces are equipped with drying TRT. In addition, it is an important way to collect the energy of low pressure steam in the process of temperature and pressure reduction. Literature [19] introduces the low-pressure steam differential pressure power generation technology, which uses the screw expansion power machine to recover the potential energy of steam for power generation. This technology can effectively recover the energy lost in the process of low-grade energy treatment.

2.3. High efficiency of CCHP system in iron and steel industry

In the process of production and smelting, iron and steel enterprises need to consume a lot of power and steam, and there is a certain amount of cold demand, which has the advantage of natural development of CCHP system (Combined Cooling Heating and Power). According to the requirements of specific application environment, the combination of cooling load, heating load and electrical load has the advantages of high efficiency and economy compared with the traditional simple power generation mode. CCHP system also known as the cogeneration of cold, heat and electricity, is an energy system that integrates heating (including steam/hot water supply), refrigeration and power generation processes. Its biggest characteristic is to use the energy of different quality step by step. The heat energy with higher temperature and more available energy are used for power generation, while the low-grade steam after power generation is used for industrial production or refrigeration, and the waste heat of the condenser of the steam turbine generator is used for heating and domestic hot water supply. For the case of only generating electricity and heat, that is, cogeneration has been widely used in the steel industry. Gas steam combined cycle power generation unit (called as CCPP, an acronym for Combined Cycle Power Plant) and extraction condensing thermal power unit belong to the category of cogeneration. The installed capacity of CCPP is from 50MW to 300MW, and the maximum installed capacity of thermal power unit is 300MW, which realizes the cascade utilization of energy to a certain extent. For example, following the concept of distributed energy cascade utilization,
the construction of blast furnace steam blowing and cogeneration equipment in the blast furnace area can realize the local transformation of blast furnace gas and cascade utilization of heat energy, forming a regional heat energy utilization system.

The status and development of cogeneration in iron and steel industry are reviewed in [20]. There is a certain cooling demand for process cooling of iron and steel enterprises and for office buildings and workshop operation rooms of enterprises. According to the actual situation, a combined heat, electricity and cold production cycle system or a combined heat and cold production system shall be established near the user side. Combined with the specific situation of waste heat resource, heat load and cooling load on site, heat pump technology, absorption refrigeration technology, spray refrigeration technology and other cogeneration technologies are used to improve the energy efficiency of the system. For example, according to the principle of regional distributed utilization, the absorption chiller can be driven by the waste heat of blast slag water in the blast furnace area as the cooling source of blast dehumidification system; the absorption chiller can be driven by coke oven gas or CDQ steam in the coking area as the cooling source of coke oven gas purification process; The refrigeration unit is driven by medium and low temperature flue gas such as coke oven, sintering furnace and hot blast furnace.

It is worth noting that natural gas power generation is the clean energy that the state focuses on during the 13th Five Year Plan period. In the 13th Five Year Plan for China’s energy development, it is clearly proposed that the proportion of natural gas consumption should be 10%. In the iron and steel industry, natural gas can not only be used as the fuel of heating furnace, but also be used in the development of distributed gas triple supply. Natural gas is used as the main fuel to drive gas power generation equipment such as gas turbine, micro gas turbine or internal combustion engine generator to operate. The generated power supplies the power demand of users. The waste heat discharged after power generation of the system is used to supply heat and cooling to users through waste heat recovery and utilization equipment (waste heat boiler or waste heat direct combustion engine, etc.). In this way, the primary energy utilization rate of the whole system is greatly improved, and the cascade utilization of energy is realized. It can also provide grid connected power for energy complementation, and the economic benefits and efficiency of the whole system are correspondingly increased. The total energy conversion efficiency of the system can reach more than 80% (power generation efficiency + waste heat utilization efficiency). Based on the above advantages, Baosteel Group is planning to build a natural gas distributed energy station in the plant.

3. The policy impacts of distributed energy on the iron and steel energy system

Although the application of distributed energy technology in the iron and steel industry has made great achievements in energy utilization and waste heat and residual energy recovery, the overall level of waste heat and residual energy recovery is not high due to the large amount of energy consumption, rich waste heat and residual energy, scattered points, low parameters and other factors in the production process of iron and steel industry. The development of distributed energy technology, because of its advantages of safety, reliability, environmental friendliness, high utilization rate and flexible regulation, and the promotion of the national contract energy management (EMC) and other commercial operation mechanisms, has a good prospect in the traditional steel industry. Projects with development prospects include:

3.1. Distributed gas utilization technology

At present, the utilization of by-product gas in iron and steel industry is mostly CCPP or ultra-thermal power generation, which has the advantages of high efficiency and large gas consumption, but its investment is large and its payback period is long. The demand for gas is rigid and hard to adjust. There is a large amount of investment in the transformation of power grid, and many business owners are stagnant in decision-making. In view of the characteristics of rich gas stage and wide gas network in the plant area of iron and steel industry, the distributed gas internal combustion engine power generation technology (called as CHP, an acronym for Combined Heat and Power) can be popularized,
and the minimum capacity of CHP single unit can reach several hundred kilowatts. According to the literature [21], CHP system adopts modular design, and the power generation unit is a separate module. The whole power plant can increase more units according to the increase of gas volume of the enterprise, which has good expansibility. No matter how many power generation units are, it will not affect the overall efficiency of power generation. A number of peak load regulating units are, it can be set up in the plant area, which can be started flexibly, connected to the grid at the nearby low voltage, and adjusted according to the production needs.

3.2. Distributed residual heat recovery technology
At present, the recovery rate of residual heat is not high and the recovered residual heat is not fully utilized. According to the concept of distributed energy system, residual heat recovery must be based on the principle of ‘local recovery, local conversion and local use’, according to the characteristics of residual heat and the energy demand of surrounding systems, establish multiple independent ‘energy islands’, form a small energy supply system with structure networking but independent operation, and follow the principle of direct use priority.

Try to reduce the intermediate conversion link and convert the low-grade residual heat into high-grade electric energy, but too many intermediate links not only reduce the recovery efficiency, but also increase the investment recovery period of the recovery system, but many production processes can directly use the residual heat for heating and driving. At present, the technology of residual heat recovery is developing rapidly, but in the choice of technology, we should follow the principle of ‘on demand recovery’, reduce the conversion link, shorten the process of residual heat conversion, and use the energy of residual heat recovery to replace or partially replace other high-quality energy.

3.3. Distributed hot water supply station
At present, the living facilities in the plant are mainly canteen, bathroom and heating, most of which are directly heated by steam, resulting in waste of high-quality steam. At the same time, the drainage system of the pipe network is directly discharged, which not only affects the environment but also causes waste of high-quality condensate. According to the concentration of personnel, hot water processing points are set up respectively in the north and south areas. For steam pipe network drainage, gas tank heating, etc., hot water centralized recovery stations are set up in sections and transported to the hot water station by car. The insufficient part is heated by steam, which can not only reduce the heat loss, but also effectively recover the condensed water.

3.4. Distributed renewable energy system for waste utilization
In the process of iron and steel production, a large number of combustible wastes such as carbon containing oil rags, oily sludge, rubber belt tires and so on will be produced. The biomass power generation unit will be established by using the existing biomass power generation technology and combined with the comprehensive utilization of domestic waste.

4. Conclusion and Recommendations
Distributed energy technology is widely used in the field of iron and steel industry, especially in the utilization of residual heat and energy. The use of distributed energy technology has an irreplaceable role in improving the recovery level of scattered and low parameter residual heat and energy compared with the centralized energy system.

In order to further improve the application level of distributed energy technology, the following main policy governance points are needed:

First of all, strengthen the management level of energy. The grid connection of the distributed energy system will have many impacts on the original energy system, which needs to improve the management and control ability of the energy management and control center of the traditional iron and steel enterprises to ensure the safety of the energy system.
Secondly, in order to further promote the distributed energy system and increase the recovery of residual heat and energy, flexible operation mechanism should be adopted, and external funds should be vigorously introduced to share benefits.

Thirdly, in terms of the selection of energy conversion technology, the principle of nearby utilization must be considered when using distributed energy technology to recover residual heat and energy.

Fourthly, with the development of distributed energy, energy storage facilities and mobile energy technologies need to be developed in the internal energy network of enterprises.

References

[1] International Energy Agency (IEA). Energy balance flows. Available from: ⟨http://www.iea.org/Sankey/index.html⟩.

[2] Ying-hua, S., Min-ji, Z., Gang, X., (2011) Distributed Energy Overview. Wuhan University of Technology Press, Wuhan Hubei in China.

[3] Jian-Zhong, X., Jian-ling, D., (2014) Definition and Characteristics of Distributed Energy. J. Hua-dian Technology, 36(1):3-5.

[4] Xiao-yu, L., Ke, H., (2015) The Literature Review for the Study on Development Policy of Distributed Energy. J. NCEPU (Soc), 1: 20-25.

[5] Chao, X., Xiao-mao, C., (2011) Cascade Utilization of Distributed Energy- The important direction of energy conservation in iron and steel industry during the 12th Five Year Plan period. J. China's steel industry, 12:25-27.

[6] Feng, Q., (2014). The application of PV generation technology in the Baosteel. J. Shanghai Energy Conservation, 000(012): 3-6.

[7] Guang-li, L., Chao-qing, S., Qi-hang, H., etc., (2015) Application of distributed photovoltaic power generation technology in iron and steel enterprises. J. Energy Research & Utilization, 4:31-34.

[8] Yu, Z., (2016) Application of photovoltaic power generation in urban steel enterprises. J. Industrial & Science Tribune, 15(7):85-86.

[9] Yang Bing, O., (2016) A Discussion on Development of Photovoltaic Power Generation in Steel Enterprises. J. Metallurgical Power, 9:48-50.

[10] Xing-liang, Z., Xiao-dan, D., (2011) Application analysis of solar energy in iron and steel enterprises. J. Metallurgical economics and management, 3:20-22.

[11] Qiu-dan, Z., Zeng-qiang, L., (2008) The application of solar energy in the bathroom of steel workers. J. Shandong Metallurgy, 12:145-147.

[12] Xiao-li, Y., Qifeng, L., Wei, H., etc., (2014) Research Progress of Biomass Fuels on Iron and Steel Industry. J. Chongqing University of Science and Technology (Natural Sciences Edition), 16(1):106-109.

[13] Dong-feng, C., Xia-yu, H., Xiao-jing, L., (2015) Energy utilization of biomass resources in iron and steel enterprises in China. J. Research on Iron and Steel, 43(3):60-62.

[14] Dong-feng, C., (2015) Biomass resource utilization and its application in iron and steel enterprises. J. Anhui Metallurgy, 1:55-58.

[15] Yu-ling, Q., Yan-li, M., Xin, J., etc., (2015) Application and prospect of biomass used in steel production. J. SHMET. 37(005), 70-74.

[16] http://www.csteelnews.com/sjzx/yjjs/201405/t20140529_244264.html

[17] Jiu-ju, C., Jian-jun, W., Chun-xia, C., etc., (2007) Recovery of Residual-Heat Integrated Steelworks. J. IRON & STEEL, 42(6):1-7.

[18] Fu-zhong Y., (2010) Study of Dry Process Operation of TRT. J. Metallurgical Power, 6:33-35.

[19] Yu, Q., Chun-he, Z., Wei, W., (2014) Application on the technology of power generation with differential pressure of low-pressure steam. J. Heavy Machinery, 2:14-18.

[20] Bing, L., (2013) Current situation and development of combined heat and power in China's steel industry. J. China Steel, 11:19-22.
[21] Yadong, S., (2014) Investment Analysis of CCPP, CHP and Conventional Generators in Power Projects of Steelmaking Enterprises. J. METALLURGICAL POWER, 5:42-45.