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Physics Procedia 24 (2012) 328 – 336

Physics Procedia

2012 International Conference on Applied Physics and Industrial Engineering

An Analysis on the Low-carbon Benefits of Smart Grid of China

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Abstract

In order to research the relation between smart grid and low carbon economics, it makes quantitative analysis on the influence exerted by carbon emissions in the power industry over the years, which partially indicates the necessity of low carbon power development. Considered current technology level of smart grid, it proposes suggestions about how to achieve low-carbon electricity. By the method of linear smoothing, it forecasts the value of carbon emissions in the power industry .Meanwhile, figures out the cost of carbon emissions in accordance with the carbon emission prices in international carbon market. Thus, low-carbon benefit of smart grid is 224.57billion yuan, which provides a reference for the construction of smart grid in the coming years.

*Keywords:*smart grid;low-carbon benefit; linear smoothing method

1. Smart Grid state

1.1 Background

With the improvement of market-oriented reforms, the development of digital economy, the exacerbate of climate change the increasingly stringent of environmental regulatory requirements and the latest national energy policy adjustments, the relationship between grid and demand side has become closely[1]-[2]. It brings more requirements of power quality, clean power and environment protection, which general grid cannot afford. Thus, smart Grid is promoted and general grid is upgraded

 doi:10.1016/j.phpro.2012.02.049

1.2 Technology status

The features of Smart Grid are reliable, safety, efficient and friendly to environment, which are achievements by advanced grid technology. According to the grid statement, the related technology can be divided into four parts: （1）High precision measurement technology and system equipment. （2） Advanced intelligent scheduling and protection system. （3） Complete, flexible, strong network construction techniques. （4）Open and friendly communication and decision support system. These technologies include not only machinery manufacturing, software development, programming, topology optimization, but also power market and demand side management. It is system engineering and needs a long time to develop them successfully.

In China, there are some research achievement in software and equipment manufacturing. For instance, large capacity AC / DC transmission technology, AC flexible transmission technologies are applied in the grid construction successfully. Compared with world technology development, we are staying the initial stage. Some problems prevent the promotion of smart grid, such as obsolete distribution and consumption equipments, small scale communication system, unaccepted technology standard and index system. How to solve them is the future research target.

2. Low carbon economy

2.1Low carbon economy in domestic and foreign

Since the concept of low-carbon economy is proposed, and organizations around the world have the response. To meet the target of 2010 CO_2 emissions reduced by 20% and 60% in 2050 [12], compared with 1990, British government takes four measures .First, optimizing the energy structure, developing renewable energy vigorously. By 2010, the proportion of renewable energy will reach 10%. Second, the adjustment of the energy policy, including levying climate change taxes and energy taxes on products. It can promote companies, which work in development and use of fossil energy, to improve energy efficiency. Thereby, greenhouse gas emissions will be reduced. Third, emphasizing on technology innovation, developing low carbon energy technologies. Fourth, take comprehensive carbon reduction. Promoting family reduce carbon emissions, achieving energy saving building, lighting, appliances, low carbon transport and so on. To develop low-carbon economy as the goal of energy policy, not only involved in the production , circulation and related to consumption; Not only on the request of government enterprises, but also the public opinion to guide the community. The German government proposed the implementation of climate protection high-tech strategy, has introduced a five energy research projects. On the basis of balance and coordination of EU Member States interests, in December 2008, the EU finally made agreement about "the EU energy and climate package plan" and formed a policy framework for the low-carbon economy in EU. After the establishment of the new government, Australia approved the "Kyoto Protocol" in 2007.Long-awaited "scheme to reduce carbon emissions" policy Green Paper was published in 2008, which set a clear carbon reduction target. Japan government-funded research group in May 2008, issued a paper which called "12Campaign for low-carbon society". The famous "Fukuda Vision" is the official logo of the formation of Japanese strategy for low-carbon. U.S. government is seeking a strategy of comprehensive, balanced and environmentally beneficial to the long-term energy security, the low-carbon development path of the economy may become important strategic choice for America's future. The United Nations is also actively respond to climate change, with the WMO (World Meteorological Organization) established the Intergovernmental Panel on Climate Change (IPCC) in 1988.

Developing a low carbon economy is put as the objective requirements of China's future economic development and strategic choice.2006, "energy conservation" was firstly proposed in the national "Eleventh Five-Year Plan". 2007, promulgated the "China National Climate Change Programmed" and "Comprehensive Energy Reduction Program of work". Recycling economy, building a resource-saving, environment-friendly society and other initiatives are implemented in china, which opened a prelude to a

low carbon economy and showed our government determination in energy conservation and low-carbon economy development.

2.2 Characteristics of China's electric power sector carbon emissions

At present, China is in a stage of rapid industrialization, with industrialization as the main feature, modern society depend on cheap coal, oil and natural gas and other fossil fuels. Electricity, steel, machinery and equipment, automobiles, shipbuilding, chemical, electronics, building materials industry is the main driver of economic growth in China, which means inevitably consume a lot of energy and resources .According to statistics: China's energy structure has been showing high-carbon structure, is a big consumer of coal. Coal consumption accounted for about 30% of the world, fossil fuels accounted for 92.7% of China's energy total in 2007. Carbon emissions from coal which accounted for 68.7%, oil accounted for 21.2%.Power, hydropower accounted for only about 20%, "high carbon" thermal power as high as 77% or more, 90% of the power sector fuel is coal [13]. It is estimated that over the next 20 years China's energy sector will reach 1.8 billion $ investment in power. Large-scale thermal power development will remain a huge potential threat on the environment. High-carbon energy structure has caused China's CO2 emissions accounted for 18% of the world, developing low-carbon economy is urgently needed.

For the study trend of quantities and type of power generation, take power generation quantities as object between 1997-2007.It is easy to find footprints of China's electric power industry development. Benefit to economy increases, power supply is increased largely during 11years，figure 2-1.It can be seen that hydropower, nuclear power is rising gradually and Thermal power supply rises quickly, figure 2-2.Figure 2-3 and Figure 2-4 shows that after ten years development, nuclear power increases significantly, increased by 1%, but thermal power still occupy a large proportion, rose to 83% from 82%.As a result, we can see that the process of thermal power production CO_2 emissions are gradually increasing with economic development. Although already aware of the importance of energy saving, but, as mentioned above, thermal power is still a major force in the electricity supply and a major source of CO_2 emissions. If reduce CO_2 emissions, first step is that optimize power structure, the specific methods is discussed in the next section. In electric power production, thermal power is the direct source of CO_2 produced. Calculating the carbon emissions by thermal power generating capacity, it will be found that this type power has always been a "big carbon emissions."According to statistics, the average coal consumption for power generation standard coal is 342g in 2009, the carbon content of coal equivalent is 85%.According to theCO_2 molecular structure, each kWh electricity generated CO_2 is:342g×0.85/12×44＝1065.9g,equal to 1.0659kg.Accordingly, we can see that each unit of thermal power supply will be more 1.0659kgCO_2 emissions .In the 11years, a rough estimate, only brought by the power production reached 181.6323 million tons. If let the clean energy to provide the power, such as photovoltaic power generation, it can make a significant reduction of CO_2 emissions. According to EPIA, considering the factors such as polycrystalline silicon smelting, 1kWh of photovoltaic power generation can reduce emissions CO_2 0.6kg.Therefore, the development of clean energy technology become a major energy saving measures.

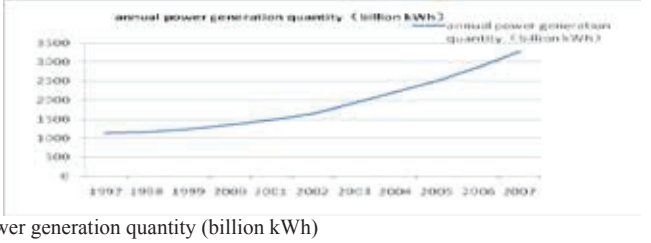

Figure2-1 Total annual power generation quantity (billion kWh)

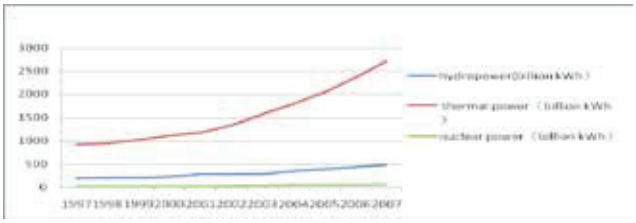

Figure2-2 Type annual power generation quantity (billion kWh)

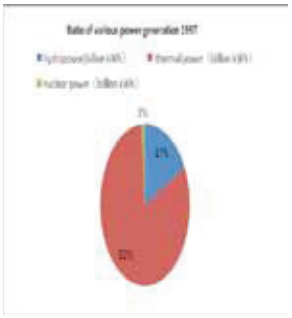

Figure 2-3 Ratio of type power generation 1997

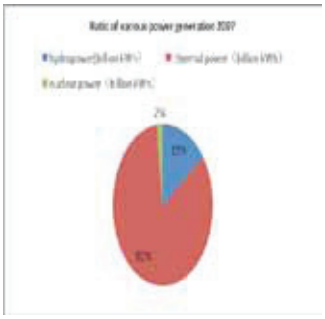

Figure 2-4 Ratio of type power generation 2007

Source: China Energy Statistical Yearbook

Considering the history of China's power industry development and the above analysis, the carbon emissions characteristics of China's power industry are as follows:

（1）It shows rapid growth in CO_2 emissions and the total amount of the increase. In 2007, the relative power industry's carbon emissions increased by 2.95 times in 1997; the total proportion of fossil fuel carbon emissions increased year by year, account for almost the total half CO_2 emissions in the country.

（2）A larger proportion of thermal power generating capacity. From the above chart shows, the total installed capacity of thermal power ratio is 83%, a smaller proportion of clean power in the eleven years, but the proportion of thermal power increase by 1%.

（3） Electricity carbon emission coefficient is higher. China's carbon emissions coefficient is much higher than that of developed countries. In 2005, it arrived at 222.95g/kWh, higher than the major developed countries over the same periods, which are between100 ~ 150 g /kWh.

2.3 Analysis of low carbon electricity impacts on economy

As a pillar industry in economic development, the implementation of low carbon measures is very significant to society and economy. The low-carbon development should be coordinate in the process of low-carbon economy, and good support in the power industry development. In this way, it takes into account industrial structure adjustment of country, environmental pollution control and other aspects of macroeconomic policy. Therefore, low-carbon electricity can transform national economic to a low carbon economy and appear profound effects. It is an important way to achieve power industry sustainable growth. There are 3 benefits from low carbon electricity, as follows: （1）Good to improve the power structure. The situation that over-reliance on fossil fuels, particularly coal will be changed. It will form the diversification energy structure and a clean energy supply system.（2）Promote the upgrading of power generation technology and energy efficiency. By the introduction of clean power generation technology, pollution will be reduced.（3）Good to improve efficiency of energy production, transmission and consumption. It is useful to reduce consumption of energy resources and energy conservation. In response to the call of a low carbon economy, the power industry has taken some measures in favor of low-carbon: 2007, the State Council issued the "Measures for Energy save”, according to the main characteristics of the

thermal power, provide some energy-saving operations to reduce industry-wide CO_2 emissions."Renewable energy development" Eleventh Five-Year "plan": by 2010， the ratio of renewable energy in energy consumption rose to 10% from less than 1%.The provisions of such binding will be implemented on low-carbon of power generation structure. Huaneng Power Group, carry out "green coal" project ,which focus on clean power generation and CO_2 emission technologies, especially carbon capture and storage technology (carbon capture and storage, CCS).This project will play an important role in low carbon technologies study. China is the world's largest CDM projects country, which approved emission reductions (CERs) accounted for 50% of the world. It is helpful to get large number of CO_2 emission reduction credits and attract lots of low carbon technology and capital.2009, energy saving and emission reduction of power industry show a great change. By statistics, the capacity of small thermal ,which was shut down annually, reach 26.17 million kw.Thus,the mission that shutting down small thermal power during "Eleventh Five-Year" was completed ahead of schedule.2009, a substantial increase in cogeneration units nationwide, the annual production was 16,147,000 kilowatts; National raw coal consumption of electricity production was 1.399 billion tons, increase 6.08%;National power supply standard coal consumption of 6000 kilowatts and above is 342g/kWh, lower than the previous year3g/kWh; The national power grid transmission line loss rate is 6.55%, decrease 0.24% over the previous year.

3. The low-carbon strategy of smart grid

3.1 Analysis in power generation

Grid, which connected power generation and sale of electricity, is a bridge in power industry. If grid is changed a little, the effects will be enlarged in power supply and demand side. It is useful to reduce emission and resources waste by smart grid. On the power generation aspect, low carbon can be realized by Bidding Policy in electricity market. Through smart grid, some Low energy consumption and clean power supply unit will be allowed to have priority to access grid. This measure could encourage plants to take energy saving and clean technologies, and finally reach the goal of technology innovation. In addition, technologies derived from smart grid, such as the large capacity electricity storage technologies, carbon capture and sequestration technology, are effective to reduce carbon emission by power plant.

3.2 Suggestion in power transmissions

The main advantage of the smart grid is intelligent grid, after the improvement related equipment; its performance is greatly improved. By self-healing, the power grid is stronger. By intelligent network, the risk of blackout also is reduced. As self-healing technology improved, when there is failure, the location can be determined and maintenance accurately. So, the cost of fix is decreased. At the same time, improve grid reliability, will reduce economic losses to the user side. It can reduce network losses and improve power transmission efficiency by advanced smart grid technology. To environment and itself, it can be said that smart grid is low carbon grid. The cost of various types of expenditure is reduced by smart gird, to some extent, which reduces carbon emissions. Thus, improving the level of its self-healing and reducing the failure rates are shortcuts to build the low carbon transmission grid.

3.3 Measure in power distribution

Whether achieve low-carbon in power distribution, depending on the distribution is reasonable. Intelligent distribution is an important part of smart grid construction. As a technical support, intelligent scheduling can enhance ability of transmission grid as an energy carrier to optimize the allocation of resources, services for special high-pressure, big coal, big water, big nuclear power, a large renewable energy, distributed energy resources access. Under the goal of low-carbon, intelligent distribution should work from two ways: 1.Making use of clean energy as much as possible.2.Distribution by gird feature,

getting less transmission losses. The first hand emphasizes the impact of external conditions. It can be achieved in this way, when choosing power supply source, hydropower, nuclear power and other clean, low carbon energy should be considered. The second focus on internal conditions impacts. Because of complicated structure, it needs to select the optimal grid path. In this way, make sure the demand side is met and transmissions cost is lower. These ways can be achieved or not, it depends on the effectiveness of power distribution. By advanced technology and equipment, smart grid could meet the requirement of them.

3.4 Strategy in power sells

Demand side plays a major role in the power industry, it is also important in smart grid. As the technology improved, the ability of coordination and classification users is stronger than traditional grid. For instance, it takes a better performance on direct power supply, retail and wholesale electricity. In general, the demand side is sensitive to electricity price. Therefore, demand side management of smart grid also take price as method. Under comprehensive price system, it can remind users consume power rational. With smart electric meter, intelligence appliances are used widely, the process of power consume will be precise visualization. When the price is high or power users are crowded, the other users can choose avoid this time and use electricity in another time. By this way, the grid burden and loss will be less. In addition, a number of distributed energy sources, such as solar roofs, small fans, etc. They can not only meet user own demand, but also transmissions surplus power to other users through smart grid. It just shows the optimal allocation of resources and reduces CO_2 emission. It can be seen that the growth of smart grid will be benefit to grid and demand-side interactive friendly and energy distributed rationally.

4. The cost-benefit analysis of low carbon power

4.1 The cost of CO_2 emission in future power industry

With the development of power industry, electricity demand will be growing, and the corresponding power supply quantities will also increase. In the process of development, reform of the electricity market will be gradual deepening; electricity price system will be more perfect. Meanwhile, smart grid construction and power structure will be progressive optimization. On one hand, smart grid will promote grid Interactive and upgrade the entire power industry, on the other hand, it will show a huge role in improving energy efficiency and reducing carbon emissions. For example, smart grid takes grid of UHV as the backbone, which can promote development of large-scale pit power stations and large-scale clean coal-fired power units. It also creates a bridge for the application of clean coal (IGCC), carbon capture storage (CCS) and other advanced low-carbon technologies. So as to enhance the utilization efficiency and economies scale interest of large coal power basements, reduce impact on the natural climate. Because smart grid can adapt to most randomness and intermittent power supply, it is easy to access clean energy and promote low-carbon power structure. Smart grid not only improves the uniformity and reliability of power grid, but also optimizes the power installed capacity of the structure, and promotes diversification of electricity supply structure.

It is foreseeable that smart grid will make specific contributions to the low carbon field. In this section, low-carbon benefits of smart grid will be quantified through prediction method of power supply. According to thermal power supply among1997-2007, build the prediction linear smoothing model of supply by E-views .On the basis of power supply, CO_2 emission can be got. Then, calculate the cost of emission by price in international carbon trading market.

4.1.1 Modeling

Thermal power production data show a smooth increasing curve, so the smoothing model is suit to simulate the linear trend and get more satisfactory results. Input data, the simulation results obtained are shown in TABLE 4-1.

TABLE 4-1LINER SMOOTHING MODEL CHECKING

Parameters:	*Alpha*		1.0000
	Beta		1.0000
Sum of Squared Residuals			3098024.
Root Mean Squared Error			530.6963
End of Period Levels:		*Mean*	27229.33
		Trend	3533.300

From parameters, it shows that the model pass he correlation test, and has a high degree of fitting. In other word, it qualifies to forecast a more reasonable future value. The comparison chart of actual value and simulated value is in Figure 4-2.

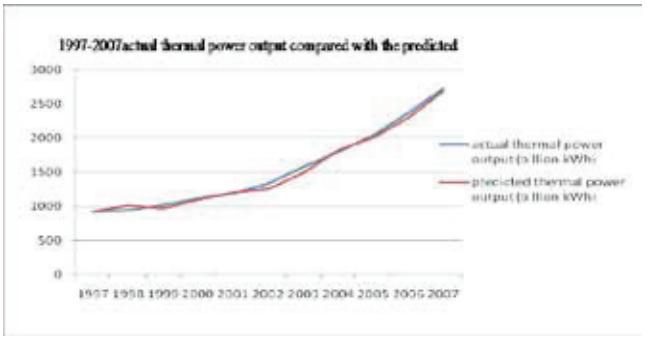

Figure 4-2 1997-2007actual thermal power output
Compared with the predicted
Source: China Energy Statistical Yearbook

The figure shows that the model forecasts can be a good fit with the original data and its predicted value is credible.

4.1.2 Forecast

According the model feature and rules, forecast period is set in 2010-2015.The reason is that prediction accuracy is higher in this stage. And it is also the stage of smart grid rapid development, which makes the prediction, is more practical significance. Predicted results as follows:

TABLE 4-2 2010-2015 PREDICTED THERMAL POWER OUTPOUT

Year	*2010*	*2011*	*2012*
Predicted thermal power output （billion kWh）	3782.92	4136.25	4489.58
	2013	*2014*	*2015*
	4842.91	5196.24	5549.57

4.1.3 The cost of CO_2 emission

According to the results: the thermal power supply production 1kWh electricity can be discharged 1.0659kgCO_2.In the next five years, the total amount of CO_2 emissions will reach 29842.52 million tons. By CER and EUA prices, which two types of carbon emissions in international carbon trading market: 107.5yuan / t and 125.2yuan / t, the cost of their carbon emissions can be calculated, they are 3208.07billion yuan, 3736.28billion yuan separately. While, if develop smart grid, the cost will be largely reduced. How much cost will be saved? Next section will give an answer.

4.2 The cost of smart grid construction

As it relates to many new technologies, new equipment, the pre-and post-investment operation and maintenance of smart grid will inevitably create large costs. According to expert estimates, for the realization of the digital grid, more than 1 million of substations needs to be updated and 30 to 50 million meters need replacing by smart meters from 2009.According to the prevailing price level, a piece of smart meters will cost 143$.In America, 5 days after Obama took office, the White House released the "economic recovery plan progress report". It announced that 40 million U.S. households will be installed smart meters, and more than 40 billion dollars will be invested to promote the grid modernization. By implication, the investment of China smart grid construction is also a large account. Only smart meter installation will cost 260 billion yuan. (Computing by143$ per meter, 0.3 billion household in China).In addition, other research and development costs, equipment manufacturing fees will be relatively large.

4.3 The benefit of smart grid

Without a doubt, the smart grid construction requires huge investment, but the benefit cannot be ignored including: Promote technological progress, protect environment, and strengthen economic cooperation and electricity market, especially in environment protection. Smart grid play an important role in promoting clean cars, clean appliances, clean power generation technology, forming the trend of low carbon energy structure. Based on the power structure and the transmission process, this section quantifies the low carbon-effectiveness of smart grid. According to experts, "if the power network information realize, it will directly reduce the energy loss of transmission, distribution and other aspects, saving 5% to 10% power per year". There will be 2% of thermal power production replaced by low carbon power. Thus, once smart grid construction complete, thermal power output will reduce 279974.9×0.07=1959.82billion kWh (Assuming 7% of thermal power supply is replaced by smart grid), so, the quantities of CO_2emission is that: （19598.24×1.0659）÷1000=2.09billion tons. It equals the value of CER emission right is 20.8898×107.5=224.57billion yuan (or EUR emission right value is 20.8898×125.2=261.94billion yuan) .Although this is only one of many benefits from smart grid; it appears that there will be great benefits in future.

5. Conclusions

In conclusion, smart grid will support the new energy and renewable energy development and utilization by strategic, and foster a sustained, stable growth renewable energy market. It's estimated that the low-carbon benefits of smart grid of China can reach 224.57billion yuan (261.94billionyuan).Meanwhile, it is help for improve market environment and institutional innovation, and gradually form a complete low-carbon economy.

Low-carbon economy and the new energy revolution is an irreversible trend, it will be keep a good development status by smart grid. And also, it could make great contribution to build a resource-saving and environment-friendly society.

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