Application of Shore Power for Ocean Going Vessels at Berth in China

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Abstract. Based on the analysis of emissions reduction effect results from using shore power for ocean going vessels at berth in China, the work and pilot projects concerned, carried out by China government, to drive application of shore power for ocean going vessels at berth were introduced, and the prospect about application of shore power for ocean going vessels at berth in China was analyzed in this paper. The conclusion is that more and more terminals in China will construct facilities for supplying shore power for ocean going vessels at berth, and more and more ports in China will require vessels at berth to use shore power in the future.

Introduction

With China's economic and social development and international trade grows rapidly, shipping activity in maritime space in China grows rapidly, at present there are more than 3 million ocean going vessels to visit ports in China annually. Ocean going vessels use residual fuel oil as power, it results to massive increase of air pollutant, which comes from ocean going vessels, in China coastal area, and the environmental air quality in this area is influenced. Air pollutant emission from ocean going vessels has attracted much attention of public in China. For ocean going vessels at berth, electricity produced by the auxiliary engines along with steam from boilers are required to operate critical equipment such as fuel heating, lighting, ventilation, refrigeration, pumps, communications and other critical on-board equipment, to maintain essential function and safety of the ship. Air emissions come from the auxiliary engines of ocean going vessels at berth is one of important resources of air pollutants in port area and port city. Since 2010, the Chinese government has committed to pilot application of shore power for ocean going vessels at berth[1], it has achieved initial results and laid a foundation for further popularization and application of this technology.

Most of China's power is generated by thermal power plants, and most of thermal power plants are coal-fired power plants, power generated by consuming coal is usually regarded as dirty power. The effect of emissions reduction results from using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board consuming fuel, has always been questioned. Based on the analysis of emissions reduction effect results from using shore power for ocean going vessels at berth, the works and pilot projects concerned, carried out by China government, to drive application of shore power for ocean going vessels at berth were introduced, and the prospect about application of shore power for ocean going vessels at berth in China was analyzed in this paper.

Effect of Using Shore Power for Ocean Going Vessels at Berth Instead of Power Generated by Auxiliary Engines on Board

The effect of energy conservation and emissions reduction results from using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board has a close relationship with level of power generation and power source.

Although China is committed to reducing the thermal power share, but 74.9% of China's electricity still comes from thermal power in 2014, and most of electricity is coal-fired electricity which is regarded as dirty electricity, however, on the background of Chinese government is committed to building a resource-conserving and environment-friendly society, the great progress in energy conservation and emissions reduction work in coal-fired power plants were made in recent
years. According to the data provided by the China Electricity Council, energy resource consumed per unit electricity generated by 6MW and above power plants in China is 318gce/kWh in 2014, 1gce stand for 1 gram of standard coal, and fuel with low calorific value 29307 kJ is equal to 1kg standard coal in China. According to the report 2014 Baseline Emission Factors for Regional Power Grids in China issued by China's National Development and Reform Commission, the average carbon dioxide emission intensity of generating electricity in regional power grid of north China, northeast China, east China, central China, northwest China and south China are 1058.0g/kWh, 1128.1g/kWh, 809.5g/kWh, 972.4g/kWh, 957.8g/kWh and 918.3g/kWh during 2010-2012 respectively. In 2010, 80.76% of the national power in China was thermal power, the average sulfur dioxide, nitrogen oxide and fine particulate matter(PM$_{2.5}$) emission intensity of electricity generated by thermal power plants are 2.883g/kWh, 2.795g/kWh and 0.295g/kWh [2].

According to 2012 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for New Ships issued by the International Maritime Organization (IMO) [3], fuel consumption rate of power generation for auxiliary engine of ocean going vessels is 215g/kWh, and 1kg fuel consumed generates 3.114kg of carbon dioxide, so the carbon dioxide emissions intensity of electricity generated by auxiliary engine of ocean going vessels is 670gCO$_2$/kWh. According to the research report finished by the International Maritime Organization in 2014, the average sulfur content of fuel used by global ocean going vessels is 2.51%[4]. According to the Emissions Estimation Methodology for Ocean-Going Vessels issued by the California Air Resources Board, based on the use residual fuel with 2.5% sulfur content, the average sulfur dioxide, nitrogen oxide and fine particulate matter emission intensity of electricity generated by auxiliary engines on board are11.10g/kWh, 14.70g/kWh and 1.46g/kWh respectively[5], because the most of sulfur oxides is sulfur dioxide, very small amount of them are sulfur trioxide, all sulfur oxides can be regarded as sulfur dioxide. So, in theory, the effect in energy conservation, greenhouse gas control and air pollutant emission reduction results from using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board is as shown in Table 1.

Table 1. Effect of application of shore power for ocean going vessels at berth in east China.

<table>
<thead>
<tr>
<th>Power from</th>
<th>Energy consumption</th>
<th>Green house gas</th>
<th>Air pollutant emission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard coal [gce/kWh]</td>
<td>Carbon dioxide [g/kWh]</td>
<td>Sulfur dioxide [g/kWh]</td>
</tr>
<tr>
<td>Generated by auxiliary engines on board</td>
<td>307.1</td>
<td>670</td>
<td>11.1</td>
</tr>
<tr>
<td>Shore power</td>
<td>318</td>
<td>809.5</td>
<td>2.883</td>
</tr>
<tr>
<td>Using shore power instead of power generated by auxiliary engines on board</td>
<td>+10.9</td>
<td>+139.5</td>
<td>-8.217</td>
</tr>
</tbody>
</table>

Note: The fuel consumption rate of power generation for auxiliary engine of ocean going vessels is 215g/kWh, which is equal to energy consumption rate is 307.1gce/kWh.

The theoretical analysis results show that using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board in China will a small amount of increasing energy consumption and CO$_2$ emissions, but reduce air pollutant emissions effectively.

The above theoretical analysis of energy consumption and greenhouse gas emissions about using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board in China is based that the fuel consumption rate of power generated by auxiliary engine on board is 215g/kWh. In fact, for ocean going vessels at berth, the electric power demand is lower than power supplied by auxiliary engines on board, it leads to waste electricity at most of time during vessel at berth. In addition, with time goes, auxiliary power generation efficiency of auxiliary engines on board will drop, these factors all result that the fuel consumption rate of power generated by auxiliary engine on board will increased. A conclusion can be drawn that using shore power for ocean going vessels at berth instead of power generated by auxiliary engines on board in
China will not be good at saving energy or reducing greenhouse gas emissions possibly, but it will reduce air pollutant emissions effectively.

Work Carry Out by China Government to Drive Application of Shore Power for Ocean Going Vessels at Berth

In view of using shore power for ocean going vessels at berth can improve port environmental quality effectively, China Ministry of Transport adopted policies, standard specifications, pilot demonstration projects and economic incentive measures comprehensively, to push application of shore power for ocean going vessels at berth in ports in China.

Policies

The Energy Conservation and Emission Reduction Planning for Highway and Waterway Transport Sector during the National 12th Five-Year Plan, which was issued by China Ministry of Transport on June 27, 2011, pointed out that driving application of shore power for ocean going vessels at berth is one important part of Green Port and Waterway Construction Project. It encourages to construct facilities for supplying shore power for ocean going vessels at berth for new terminals to be constructed and facilities for receiving shore power for new vessels to be built, and encourages to add facilities for supplying shore power for ocean going vessels at berth by reconstruction for existed terminals and add facilities for receiving shore power for Chinese existed vessels. It requires that for international cruise terminals, main passenger terminals and large container and bulk terminals with a certain condition, the ocean going vessels at berth should use shore power instead of power generated by auxiliary engines on board.

In the Implementation Plans for Energy Conservation and Emission Reduction for Waterway Transport Sector During the National 12th Five-Year Plan, which was issued by China Ministry of Transport on August 31, 2011, Three tasks including application of shore power for ocean going vessels in container terminals and bulk terminals, pilot application of shore power for ocean going vessels in cruise terminals and passenger terminals, and study of policy measures to encourage application of shore power for ocean going vessels at berth were assigned to push application of shore power for ocean going vessels at berth in China.

Standard Specifications

The Technical Code of Shore-to-Ship Power Supply System (JTS155-2012) was released by China Ministry of Transport on July 4, 2012. It requires that new built terminal must construct facilities for supplying shore power for ocean going vessels at berth, and give a standard for designing and constructing of these facilities. It lay a foundation to put forward application of shore power for ocean going vessels at berth.

Another two standards named Shore-to-Ship power Supply System Technical Condition (JT/T 814-2012) and Shore-to-Ship power Supply System Operating Procedure(JT/T 815-2012) were released by China Ministry of Transport on July 5, 2012. The two standards presents the technical and operation requirements of facilities for supplying shore power for ocean going vessel at berth to ensure quality of facilities for supplying shore power in terminal and safety of application of shore power in ports.

Pilot Demonstration Projects

On June 28, 2010, China Ministry of Transport held a seminar about application of shore power for ocean going vessels at berth in Port of Qinhuangdao, and assigned Port of Shanghai, Port of Lianyungang and Port of Shenzhen to undertake pilot demonstration projects about application of shore power for ocean going vessels at berth.

The on-site exhibition of application of low voltage shore power system was held in Port of Shanghai On July 5, 2010. The on-site exhibition of high voltage shore power system was held in Port of Lianyungang on October 12, 2011. The ceremony to use high and low voltage shore power system was held in Port of Shenzhen on April 24, 2012.
Economic Incentive Measures
Since 2011, supporting by the Special Fund for Energy Conservation and Emissions Reduction for Transport Sector, China Ministry of Transport gave awards to terminals which construct facilities for supplying shore power for ocean going vessels at berth, and China shipping companies which add facilities on board in their vessels to receive shore power. Port of Lianyungang, Port of Shenzhen and Hebei Ocean Shipping Group Co., LTD. received more than 10 million RMB in total.

Pilot Projects of Shore Power for Ocean Going Vessels at Berth
Since 2010, China Ministry of Transport completed the three pilot projects of shore power for ocean going vessels at berth[6].

Low Voltage Shore Power System in Port of Shanghai
The mobile low voltage shore power system developed by Port of Shanghai was put into trial operation in terminal of Zhengdong branch of Shanghai International Port (Group) Co., Ltd. on March 22, 2010. The system adopts low-voltage power supply scheme, its equipments for frequency conversion and voltage transformation is installed in terminal, facilities installed in vessel for receiving shore power is simple and reconstruction on board is easy. It need to use 9 cables, which are a part facilities for supplying power in terminal, to supply 2MW electricity, which voltage is 440V and frequency is 60Hz, for a vessel at berth, it is time-consuming for connecting and disconnecting these cables. The vessel at berth can use electricity received from terminal directly. The diagram and equipment of mobile low voltage shore power system developed by Port of Shanghai is as shown in Figure 1.

High Voltage Shore Power System in Port of Lianyungang
The digital high voltage shore power system developed by Port of Lianyungang was put into operation in berth 59 of the port on October 26, 2010. The system adopted high voltage supply scheme, its frequency conversion equipment is installed in terminal, it is necessary for a vessel
using low voltage electricity to install voltage transformation equipment on broad. 1 cable is enough to supply 1.25MW electricity, which voltage is 6600V and frequency is 60Hz, for a vessel at berth, it is convenient to connect or disconnect the cable, which is a part of facilities for receiving shore power on broad. The diagram and equipment of digital high voltage shore power system developed by Port of Lianyungang is as shown in Figure 2.

![Figure 2. The diagram and equipment of digital high voltage shore power system.](image)

From then on, a vessel named China-Korea Star, which navigated between Lianyungang in China and Incheon in South Korea twice a week, always use the system to receive shore power when it is at berth in Port of Lianyungang. Every year, the vessel visits Port of Lianyungang 102 times, and use the system for 1800h in total, and reduce fuel consumption about 437t.

**High and Low Voltage Shore Power System in Port of Shenzhen**

The acceptance check of the pilot project to develop high and low voltage shore power system, which was carried out by Shekou container terminals Limited of China Merchants Group in Port of Shenzhen, completed on April 24, 2012. The system adopted high voltage and low voltage supply scheme, its frequency conversion equipment is installed in terminal, it can be used to supply 6600V high voltage or 440V low voltage shore power for vessels at berth. The system uses 2 cable only to supply 5MW high voltage power to a vessel at berth, but it need to use 9 cables to supply 2MW low voltage shore power to a vessel at berth. For shore power system developed by Shekou container terminals Limited of China Merchants Group, its equipment for supplying high voltage shore power is as Figure 3 and equipment for supplying low voltage shore power is as Figure 4.

![Figure 3. The equipment for supplying high voltage shore power, in Port of Shenzhen.](image)  ![Figure 4. The equipment for supplying low voltage shore power, in Port of Shenzhen.](image)

In view of these facts that on the one hand, for vessels visiting the terminal, number of vessels
installed facilities to receive shore power is less, on the other hand, when a vessel use shore power, power supply company ask the terminal to pay for not only electricity consumed, but also the additional installation capacity of the system, it results that there were few chances to use the system in past years.

The overview of characteristics of the above three shore power systems is as Table 2. Although there were few chances to use for 2 of them, practices of using these systems still proved that the technology of shore power for ocean going vessel at berth is reliable and using the technology results to remarkable emission reduction effect. Because these pilot demonstration projects are successful, some other terminals in Port of Dalian, Port of Tianjin, Port of Qingdao and Port of Guangzhou are constructing or have constructed their facilities for supplying shore power for vessels at berth.

Table 2. Overview of characteristics of three pilot shore power systems in China.

<table>
<thead>
<tr>
<th>System Type</th>
<th>Low voltage</th>
<th>High voltage</th>
<th>High and low voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>Port of Shanghai</td>
<td>Port of Lianyungang</td>
<td>Port of Shenzhen</td>
</tr>
<tr>
<td>Equipment for frequency conversion</td>
<td>Mobile in terminal</td>
<td>Fixed in terminal</td>
<td>Mobile in terminal</td>
</tr>
<tr>
<td>Equipment for voltage transformation</td>
<td>Mobile in terminal</td>
<td>Fixed on board</td>
<td>Mobile in terminal</td>
</tr>
<tr>
<td>Vessel power voltage[V]</td>
<td>450</td>
<td>450 (6600)</td>
<td>6600</td>
</tr>
<tr>
<td>Vessel power frequency[Hz]</td>
<td>60 (50)</td>
<td>60 (50)</td>
<td>60</td>
</tr>
<tr>
<td>Shore power voltage[V]</td>
<td>10000</td>
<td>6600</td>
<td>10000</td>
</tr>
<tr>
<td>Shore power frequency[Hz]</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Power capacity[MW]</td>
<td>2.0</td>
<td>1.25</td>
<td>2.0</td>
</tr>
<tr>
<td>Number of cables</td>
<td>9</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Source of cables</td>
<td>Terminal</td>
<td>vessel</td>
<td>Vessel</td>
</tr>
<tr>
<td>Max. time for connect cables[h]</td>
<td>1</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Max. time for disconnect cables[h]</td>
<td>0.5</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Complexity of vessel retrofit</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>

Application Prospect of Shore Power for Ocean Going Vessels at Berth in China

The main reasons why there were few chances to use the shore power systems developed by Port of Shanghai and Port of Shenzhen are that, for vessels visiting the terminals concerned, number of vessels installed facilities to receive shore power is less, and there is no mandatory regulations to ask vessels at berth to use shore power in China at present.

With the United States California State regulation of Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a Port of California takes effect on January 1, 2014, the shipping lines are responsible for complying with the regulation when their fleets, which composed solely of container or refrigerated cargo vessels that visits the same California port more than 25 times total in a calendar year or composed solely of passenger vessels that visits the same California port more than 5 times total in a calendar year, calling at California ports must shut down their auxiliary engines and plug into the shore power grid while at berth. The Maersk Line Shipping Company, China Ocean Shipping (Group) Company and other large shipping lines concerned have retrofitted their vessels visiting California ports to meet the regulation's requirments. As long as China ports concerned install facilities for supplying shore power, there is no technical barriers to ask these company's vessels calling corresponding ports in China to use shore power when they are at berth.

In present, air pollution is very serious in China, vessels activity is one of important sources of air pollution in port cities[7]. The 2012 Emission Inventory in Hong Kong published by government of Hong Kong Special Administrative Region shows that air emission from vessels' acvitiy in Hong Kong is largest source of air pollutants including sulfur dioxide, nitrogen oxides, particulate matter and fine particulate matter. According to data provided by Human Settlements and Environment Commission of Shenzhen Municipality, the weight of sulfur dioxide, nitrogen oxides and fine particulate matter emitted by vessels visited Port of Shenzhen in 2013 is 19254t, 16300t and 1635t
respectively, and is about 66.1%, 14.1% and 5.8% of total weight of corresponding pollutants emitted from all sources in Shenzhen respectively. According to research results coming from Shanghai, the weight of sulfur dioxide, nitrogen oxides and fine particulate matter emitted by vessels visited Port of Shanghai in 2010 amount to 12.0%, 9.0% and 5.3% of the total weight of corresponding pollutants emitted from all sources in Shanghai respectively. So China government is working to take a more strict emission control measures[8], one of the viable options is requiring ocean going vessels at berth to use shore power by implementation of incentive or compulsory policies.

Green Port Action Plan from 2014 to 2020 in Guangdong Province[9], which was issued by Department of Transport of Guangdong Province in 2014, requires that all new cruise or large container terminals to be constructed should construct facilities for supplying shore power for ocean going vessels at berth, and support to popularization and application of shore power for ocean going vessels at berth in Port of Shenzhen mainly. On September 23, 2014, Shenzhen was the first to announce that it will implement incentives policies, which encourage shipping companies and ports to take steps to reduce emission from vessels at berth including using shore power for ocean going vessels at berth. The polices include the following three parts: the government of Shenzhen Municipality will give subsidy, which is about 50% cost of construction of facilities for supplying shore power to ocean going vessels at berth, to terminals to construct facilities concerned. Shipping companies pay RMB0.70/kWh for electricity consumed when their vessels at berth using shore power only, the price difference between the real price and the price payed by shipping companies will compensated by the government of Shenzhen Municipality, it means that shipping companies' electricity spending is far lower than the cost of electricity generated by auxiliary engines. The government of Shenzhen Municipality will responsible for paying for the additional installation capacity of shore power system. The above economic incentive policies encourage terminals to construct facilities for supplying shore power to ocean going vessels at berth and shipping companies to construct facilities for receiving shore power on broad effectively, so most of ports and shipping companies concerned promises to do as policies required. The linkage mechanism between 3 Provinces (Jiangsu, Zhejiang and Anhui provinces) and 1 municipality (Shanghai) located at Yangtze river delta region, has established to control air emission from vessels in area concerned, the incentive measures to encourage ocean going vessels at berth to use shore power are being studied in present.

In recent years, China has begun to cut down production capacity of heavy industry, it results that the electric power production capacity become surplus, it is necessary for the State Grid Corporation to find new ways to consume the surplus power, so the State Grid Corporation also become an important supporter of shore power for ocean going vessels at berth in present.

In view of the above factors, more and more terminals in China will construct facilities for supplying shore power for ocean going vessels at berth, and more and more ports in China will require vessels at berth to use shore power in the future.

References

