Integration of Increasing Wind Power into Electricity Grid in China

With a Focus on Institutional Matters

Ouyang Xin

Supervisors

Andrius Plepys

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Abstract

This thesis focuses on what can be done from institutional prospective to integrate increasing amount of wind power to the system in China. By looking into what are current grid integration problems in China at institutional level and how the best insternational practice, the Danish grid integration, look like and the lessons from institutional prospective and comparison between two systems are made.

It became clear that 1) overall planning of wind power development at central and local levels, among various key stakeholders and finally between wind pwor plants and other power plants shall be further coordinated. Responsibilities in various authorities shall be clearly defined to avoid overlap; 2) Grid integration management system including setup and enforcement of various standards, certification and testing system, mechism to help to improve predicting and forcasting forcasting capacity, and last, the capacity in key institutes are key to the improvement; 3) Policies to prioritize wind power in the dispatching shall be issued and enforced as mandatory, while more flexible price and supporting scheme including environemtn tax on conventional power plants, and Green Certificate Scheme shall be considered. 4) At last flexibility on demand side is needed to better facilitate with shifting the peak load, and dispatching. In conclusion, from institutional prospective, China needs to have a better grid and operation management, policy framework, and and incentives to build a robust and flexible power system to integrate increasing wind power.

Keywords: wind power, power system, grid integration, China, Denmark,

Executive Summary

In order to combat climate change, improve the energy security within a nation, renewable energy particularly wind power has seen fast growth in the past decade. Since 1996, wind power sector has seen an average annual increase of 28%. By the end of 2010, the total installed capacity of wind power has reached up to 200 GW worldwide. In some countries, wind power has taken a large part of its total energy consumption. (GWEC, 2010) A country like Denmark has 25 % of its energy consumption produced by wind power as end of 2011, and it aims to reach a ratio of 50% by 2020. (Danish Ministry of Climate, Energy and Building, 2012). With more investments poured in, and involvement of large multinational ompanies like GE, and Siemense, wind energy has become a more worldwide industry, providing jobs for more than 500,000 people around the world. Even during the financial crisis in 2008, it has seen more than 38% increases globally. Developing countries are actively involved in the wind energy development as well. By 2010, China and India have become two big markets for the wind energy in the world. (GWEC, 2010)

Chinese government has put forward favorable policies regarding tax reduction schemes, price policy, renewable energy target, and mandatory integration of wind power to promote renewable energy particularly wind power development. China has surpassed US in 2010 and became the biggest market in terms of total installed capacity and annual newly installed capacity. By the end of 2011, the total installed capacity reached to 60 GW. However, many obstables have revealed during the fast development, and one of the most critical issues is the grid integration of wind power. By the end of 2011, 20% of total installed capacity is not connected to the grid, while, curtailment of an average of 15% of wind production over the country has been reported. (China Guangdong Nuclear Wind Power Co., Ltd., 2012).

China has been working hard to solve the grid integration obstacles from technical prospective. Reginal grid integration studies have been conducted, and some technical standards, testing and certification system have been established. These measures indeed have helped to soothing the problem, however, to sovle the problem and secure a sustainable development in the sector; more things shall be looked into from institutional prospective including the overall planning, manangement and policy framework. Is overall planning of the wind power development in China adequate? Has integration management been sufficient to secure the stable operation of power system at the lowest costs? Is policy framework good enough to support the increasing wind power integration to the grid?

Following the above mentioned interesting areas, the question therefore becomes: What can be done from institutional prospective to integrate increasing wind power into the system in China.Based on the understanding of situation and existing obstacles of wind power integration in China, and Danish best practice on the grid integration, it became clear that 1) Overall planning of wind power development at central and local levels, among various key stakeholders and finally between wind pwor plants and other power plants shall be further coordinated. Responsibilities in various authorities shall be clearly defined to avoid overlap; 2) Grid integration management system including setup and enforcement of various standards, certification and testing system, mechism to help to improve predicting and forcasting forcasting capacity, and last, the capacity in key institutes are key to the improvement; 3)Policies to prioritize wind power in the dispatching shall be issued and enforced as mandatory, while more flexible price and supporting scheme including environemtn tax on conventional power plants, and Green Certificate Scheme shall be considered. 4) At last flexibility on demand side is needed to better facilitate with shifting the peak load, and dispatching. In conclusion, from institutional prospective, China needs to have a better grid

and operation management, policy framework, and and incentives to build a robust and flexible power system to integrate increasing wind power.

Table of Contents

LIST OF FIGURES ..... **III**

LIST OF TABLES ..... **IV**

ABBREVIATIONS (IF REQUIRED) ..... **V**

1 INTRODUCTION **1**

2 RESEARCH OBJECTIVES AND METHODOLOGY **4**

2.1 OBJECTIVE 4
2.2 RESEARCH QUESTIONS 4
2.3 METHODOLOGY 4
2.3.1 Outline of Methodology *4*

3 BACKGROUND KNOWLEDGE **6**

3.1 CHARACTERISTICS OF WIND AND WIND POWER. 6
3.1.1 Characteristics of wind *6*
3.1.2 Characteristics of wind power *6*
3.2 CHARACTERISTICS OF THE POWER SYSTEM 7
3.2.1 Composition of power system and its operational characteristics *7*
3.2.2 Power system operational requirement *8*
3.3 CHALLENGES IN INTEGRATION OF WIND POWER 9
3.3.1 Key challenges *9*

4 WIND ENERGY AND POWER SYSTEM DEVELOPMENT IN CHINA **10**

4.1 WIND ENERGY DEVELOPMENT 10
4.1.1 Rich wind resource *10*
4.1.2 Favorable legal frame work and pricing (see to *10*
4.1.3 Strong government committions and ambitious plans *11*
4.1.4 Concession projects *11*
4.2 OBSTACLES IN THE DEVELOPMENT 12
4.2.1 Grid integration *12*
4.3 POWER SYSTEM 13
4.4 WIND POWER AND INTEGRATION MANAGEMENT 14
4.4.1 Grid integration management *14*
4.4.2 Dispatching and operation management *14*
4.5 POLICY SYSTEM FOR THE WELL-BALANCED DEVELOPMENT 15
4.5.1 Industry management policies *15*
4.5.2 Tarrif and other fiscal support *16*
4.6 WIND POWER PRICE SYSTEM 17

5 WIND ENERGY AND POWER SYSTEM DEVELOPMENT IN DENMARK **19**

5.1 WIND POWER DEVELOPMENT AND OUTLOOK 19
5.2 POWER SYSTEM 20
5.3 WIND POWER AND GRID INTEGRATION MANAGEMENT 21
5.4 POLICY SYSTEM FOR THE WELL-BALANCED DEVELOPMENT 21
5.5 POWER MARKET DESIGN: NORDPOOL POWER MARKET 21
5.5.1 Nordpool spot market *22*
5.5.2 Nordpool regulating market *23*
5.5.3 Price and support scheme *23*
5.5.4 Wind power impacts to the power market price *24*
5.5.5 Enabling factors to the success in Denmark *25*

6 ASSESSMENT 28

6.1 DEVELOPMENT OF WIND POWER GRID INTEGRATION MANAGEMENT 28

6.1.1 Shortcomings of the current wind power and integration management in China 28

6.1.2 Recommendations based on lesons learnt from Danish Experience 30

6.1.3 Shortcomings of the current policy system in China for the well-balanced development 32

6.1.4 Recommendations based on lesons learnt from Danish Experience 32

7 CONCLUSION 34

BIBLIOGRAPHY 36

List of Figures

Figure 1-1 Gross energy consumption in 1980 19
Figure 1-2 Gross energy consumption in 2009 19
Figure 1-3 High voltage transmission line and large scale power plant distribution 20

List of Tables

Table 1-1 The total installed wind energy capacity in China from 2000 to 2011........................10

Table 1-2 Seven GW-scale wind farm implementation progress..11

Table 1-1 Seven GW-scale wind farm implementation progress..24

Abbreviations (if required)

CEF	Confederation Fiscale Europeenne
CEPRI	China Electrical Power Reseach Institute
CMA	China Metereology Administration
CREIA	China Renewable Energy Industry Association
CWEA	China Wind Energy Association
DEA	Danish Energy Agency
ERI	Energy Research Institute, China
EWEA	European Wind Energy Association
FIT	Feed-in tariff
GW	Gigawatt
GWEC	Global Wind Energy Council
IEA	International Energy Agency
LVRT	Low voltage ride through
MW	Megawatt
MWh	Megawatt hour
MoF	Ministry of Finance of China
NDRC	National Development and Reform Commission of China
NEA	National Energy Administration of China
RPS	Renewable Portfolio Standard
SCADA	Supervisory control and data aquisition
SGERI	State Grid Energy Research Institute in China

1 Introduction

As global wind power market has developed, China also got actively involved in the renewable energy development, particularly in wind power. Started with international development aid programs, China had its first turbine erected in Xijiang. The rapic developemtn took place in 2006 with the issuance of the first Renewable Energy Law in the country. From there on, Chinese government has put forward favorable policies regarding tax reduction schemes, price policy, renewable energy target, and mandatory integration of wind power to promote the industry development. Since then, the annual growth has been around 100% each year. In 2010, China surpassed US and became the biggest market in terms of total installed capacity and annual newly installed capacity. By the end of 2011, the total installed capacity reached to 60 GW.

The total installed wind energy capacity in China by 2011

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MW	346	402	469	567	764	1,260	2,599	5,910	12,020	25,805	44,73	62,364

Data source: GWEC, 2011

However, many obstables have revealed during the fast development, and one of the most critical issues is the grid integration. By the end of 2011, 20% of total installed capacity is not connected to the grid, while, curtailment of an average of 15% of wind production over the country has been reported. (China Guangdong Nuclear Wind Power Co., Ltd., 2012).

China has been working hard to solve the grid integration obstacles from technical prospective. Reginal grid integration studies have been conducted, and some technical standards, testing and certification system have been established. These measures include:

- Establishing a grid code, and adopting it as industrial standard nation wide to facilitate the wind power plants to be grid friendly, and making sure wind turbines conneting to the power system will contribute to its stability. The new grid code has included latest international standards of the same kind. New specifications have been included in the code. Requirements on the Low Voltage Ride Through

- New turbine testing center has been established and a new certification scheme has been established to facilitate with the integration of wind. Specification on testing has been established as well.

- Various grid integration studies in different region in China has been conducted by State Grid in close collaboration with international experts to understand the specific technical issues in integration of wind power to the system

- Furthermore, capacities on key personnel in central and local level have been built through national and international trainings.

- On policy level, a system of supporting policy has been formed, it covers areas of overall development, industry development, industry management, and tarrif and finally fiscal supports have been issued. In these policies, integration of renewable energy is secured by law, and four-level prices are provided. Priority of dispatching is also considered however the specific implementation guidlines are not established.

These measures indeed have helped to soothing the problem. However, as what have been studied in many other countries and regions, the penetration of wind power lower than 10% would have not that much impact to the system, and the existing reserve and operational system should be adequate to deal with the variation of the wind power (EWEA, 2009). Though policies, mechanisms for system management and operation are introduced, their impact may be limited as wind power further develops in the country. There must be something more than just technical aspects to be addressed. To sovle the problem and secure a sustainable development in the sector, more things shall be looked into from institutional prospective including the overall planning, manangement and policy framework.

What are included in the institutional aspects? And what institutional capacity we need? Institution capacity provides enabling environment to secure further development. The concept fot eh institutional capacity is evolving over the time, and today, institutional capacity often "*implies abroader focus of empowerment, social capital, and an enabling environment, as well as the culture, values and power relations that influence us"* (Segnestam & al., 2002) In the grid integration context, the technical part has been looked into, and the training has taken place, however, success also goes hand in hand with with the broader political, economic and social setting of the country, so as to create an internal dynamic of transformation. This is the part that has been neglected in the development of grid integration of wind power in China.

There are three levels of institutional capacities: *micro level, i.e. the individual; a meso level, i.e. the organisation; a macro level, i.e. the broad institutional context including norms, values and values.*

1) For the individual level, *the performance of individuals in their functions is the basis for the success of any action or policy. Are these individuals motivated? Do they have the skills that correspond to their jobs? Is training available? Do they have right incentives, either financial or nonfinancial, in terms of responsibility or career progression* (Willems, S. & Baumert, K., 2003)*?* For the wind power integration situation,the individuals in this context are participants in the whole system from power producer to entities in transmission and distribution and to the end users. Do they have enough incentives and capacities to produce wind power, cope with variation and limited predictability of wind power, deliver wind power, and choose wind power over other conventional power source.
2) For the organization level, it talks many about the management capacity. *The performance of organisations is also a key measure of institutional capacity. Developing a greater understanding about what motivates both public and private organisations and what are their incentive structure is particularly important to ensure effective delivery of any policy.* (Willems, S. & Baumert, K., 2003) For this paper, this level of institutional capacity are related to the system operation management and dispatching set up, which is considered as integration management.
3) For macro level, regulatory framework, and social norms are included here. *The actions of individuals, organisations, or networks of organisations are embedded in a wider institutional context, i.e., the public sector setting as well as the body of laws and regulations that exists in the country. Generally, the overall effectiveness of the public sector in fulfilling its main functions, in other words public governance, is key to the effectiveness of any specific policy.* While *Social norms, values and practices point to an even broader cultural, economic and social environment, within which the public sector functions.*The social norms are important for the acceptance of a policy.(Willems, S. & Baumert, K., 2003)

Based on the above knowledge, this paper will look into the three levels of institutional capacity regarding the integration of wind power, with specific focus and study on 1) integration management 2) policy framework and 3) financial incentives and 4) overall planning. Conclusion will be made based on study of the four areas.

2 Research Objectives and Methodology

2.1 Objective

The overall objective is to better understand what hinders a better integration of wind power in the power system in China from the institutional domestic prospective.

2.2 Research Questions

The research question for the paper is: What can be done from institutional prospective to integrate increasing wind power into the system in China. Three sub-research questions are defined to address the overall research question:

1) What are current grid integration problems in China at institutional level?

2) How do the best international practices, such as the Danish grid integration, look like at the institutional level look like and what lessons could be learnt there?

3) What recommendations could be provided from the comparison of the Chinease and the Danish grid intergration processes?

2.3 Methodology

The research of the thesis was conducted from Feb to April 2012. A field work was carried out from actual work with China Renewable Energy Industry Association and Sino-Danish Renewable Energy Developmetn Programme. The knowledge and basic understanding of sub-question 1 and 2 are gained during the field work via daily contacts and literature reviews. Though grid integration issues have been widely discussed in China, a large number of solutions have been discussed from different prospective. It is difficult to address the problem from institutional prospective, because it requires a wide sphere of displines, and the concept of it is not clear enough, and has been evolving all the time.

Therefore, the analysis of the problem will be approached from different angles, both from inside China and out side of China, from integration management, policy frameworks, financial incentives all the way to the overall planning. Thus an international best practice is necessary in this case to help to analyse what could be a good solution to the grid integration from institutional prospective.

Considering the high penetration of wind power of 25% and the existence of the first and most mature liberalized power market, Denmark is chosen to be the best case to be studied as a reference as on how should China improves its existing power system. It's a country with longest wind power development history, many systems regaring management, policy framework, financial incentives and overall planning strategy will be a good reference to China.

2.3.1 Outline of Methodology

The overall research question will be addressed by three sub-questions.

- The first sub-research question "What are the current grid integration problems in China at institutional level?" will be addressed by looking into the current power system from the grid integration management, policy framework, and financial incentives points of view.

Literature review and interviews are equally important to estabslish the overall understanding and to obtain insights of the problems. Detailed study will be carried out based on the interview results.

- In order to gain a better perspective, the case of Danish wind power system will be studied, which represents this best international practice so far (sub-question 2). The Danish case will be analysed along the same points - the grid integration management, policy framework, and financial incentives.

  Literature review plays main role due to the fact that many information are publicly available in Denmark, and there is a high transparency regarding to power operation management, policy framework setup, and overall plannings. Interviews are needed to understand what key factors for the success are, and what good lessons can be for China.

- In order to provide recommendations for institutional optimisation in China (Sub-question 3) the Danish case and the experiences will be compared to those of Chinese. Particular country specific conditions and prerequisites will be taken into consideration when comparing the two cases

  Interviews play major role. Comparison will be made accordingly. Conclusion will be made based on the comparison.

3 Background Knowledge

3.1 Characteristics of wind and wind power.

3.1.1 Characteristics of wind

Wind energy is a natural resource, and it is unlimited and free. Apart from it, the most important characteristics of it are the wind flow changes through different time of day, year/season, and height.

For changes through time of the day, daily change in a specific place is periodic. Statistics shows that wind flow near the ground is stronger in the nighttime than in daytime. However, wind at greater height, is opposite due to different heat exchange capacity between land and ocean. Offshore wind farms are more affected by the change of wind flow in the greater height; there is typically a sea breeze in daytime and land breeze at night.

For year/season changes, it talks about year change of wind follows season change depending on different climate in a typical area. For a country like China with monsoon weather, affected by cold land breeze from Syberia, and sea breeze from pacific, wind is generally stronger in winter and fall, and weaker in summer and spring. However, China has a vast land, it also depends on specific location. Like some coastal area, the wind is strongest in summer.

For changes at different height, wind velocity grows as height grows. *Wind's friction and turbulence a 0-1,000m from the ground deceases with height. The earth's atmosphere is thin above 1,000 m, thus the influence of friction and turbulence is negligible. Therefore, change of wind is vertical: wind spead grows with height.(EWEA, 2009)*

Wind distribution is not only affected by the above-mentioned factors, but also closely connected to the geographical factors such as terrain, surface roughness, altitude, and others.

Average wind direction and average wind velocity are used as indicators to discribe wind characteristics in an area. The average wind velocity changes with time and space but it foolows certain patterns. The daily variation law of average wind velocity is most remarkable. For the varioation of wind flow in a certain area, it is reflected in the wind pulsation.

3.1.2 Characteristics of wind power

Main features of wind power (wind power generation output), different from conventional power are variation and fluction. It changes with meterological conditions, and variations of wind velocity and direction. It follows some patters, and is not unpredictable. It will not dispear suddenly even in extreme conditions, it transit to zero power over a period of time.

Variation of wind power

Variation of wind power output mainly depends on wind conditions and the availability of wind turebine. Follows the wind flow, there are shorterm and long-term variations. The shorterm variation are those varioations in an hour, several hours, or dozens of hours, and those in a day, month or year are called long term variation.

Short-term variation mainly imapcts the formulation of power schedule, the balance of power and determination of reserve capacity needed. Long-term variation determins the credibility of power capacity in the power system. And it depends on seasonal climate type and inter-annual variability of wind.

The daily variation in most areas is lower in the day than at night. Seasonal variation follows the seasonal wind flow in a certain area as well. For instant in China, where wind is generally stronger in winter and autum, the wind power generating output reaches the highest in winter and lowest in summer.

Predictability of wind power

Wind speed for a certain period of time can be predicted, thus the wind power generation output is predictable. It is important to predict wind power in order to fulfill the grid dispatching management of wind power variation in the system. There are a lot of methods available, the most commonly used is to rely on 10 min average wind speed data (WPP) then combine wind energy data provided by the weather forcast and power generating data provided by WPP, and make use of forcasting software to make detailed calculation and forcasts. (EWEA, 2009)

The error in the forcast result is used to quantify the quality of the farcast. Usually the Root mean square error (EMSE) is used for the purpose. The shorter the time for forcastng, the more accurate forcast is. According to European current forcasting tools and experience, the RMSE for 36 hours ahead forcast is expected to be between 10%-20%, and EMSE for one day ahead forcast is no more than 10%, and it reduces to 5% when comes to 1-4 hour ahead forcasting. (EWEA, 2009)

In China, according to the wind power forcast management, the prediction error for one day ahead forcast shall be no more than 25%, and it gets to 15% in real time forcasting. Comparing with the ideal situation that only 1.5%-3% for peak load, and 3%-5% for one-day advance forcasting, there are still a great potential to improve the current methodology, and tools. (SGERI, 2010)

3.2 Characteristics of the power system

3.2.1 Composition of power system and its operational characteristics

Power system comprises of three parts, which are power plants, power grids and the end users. Power grid is to transimit and distribute electricity generated from the plants to the end user, it has auxiliary system, SCADA system, and communication system to ensure safe and reliable operations and communications. The overall fuction of power system is to convert primiary energy into the common form of electricity and transmit it to end-users. Since electricity currently cannot be stored with large amount, and has a transmission speed of light (about 300,000m per second), the power system in order to accomdate with it thus also must have the characteristics as follow:

1) Generation, transmission, distribution and consumption must take place simultaneously. This requires that the system is well coordinated, and all parts are fast responding and closely related to respond in the best manner. However, to realize it, it is a must that technical requirements operational specifications are established and met.
2) The power generation and the consumption will have to be balanced all the time. This also means that the amount of electricity generated must equal to the amount electricity consumed. However the consumptions change all the time, even by second, it still demands that the power system be adjusted by controlling the power souce link and production, and having multiple power distribution capacities in the grid. Power

dispatching plays an important role in the process to ensure safe and reliable operation in the system.

3) Power supply must be continuousand uninterrupted. Because currently the electricity cannot be stored at a large amount, and the users must be supplied with continuous, uninterrupted supply. (EWEA, 2009)

3.2.2 Power system operational requirement

As mentioned above, the objective of power system is to provide users with adequate, reliable, qualified, addordable electricity. Therefore,

1) the system shall meet the end user demands at all times, except for the situation that demands exceed the total installed capacity, or block of transmission or distribution, or power failure, can limitations of supply will occure. Usually, the power supply capacity is scheduled based on the maximum annual power load demands. It takes into account of uncertainties of load growth, accidents, equipment functioning failure and so on, and the total supply capacity is set 20%-25% higher than the system maximum peak load. For this part, voltage and frequency are two important technical specifications to measure the power quality. Electricity are supplied to users at constant frequency, which in China and Europe is 50Hz, and 60Hz for U.S.. In the same power system, distribution, transmission, and electricity consuming equimentsar are designed at fixed frequency and voltage, and if different frequency and voltage happens, performance, efficiency and life expectancy of the equipments will be affected. In each country, there are frequency and voltage specifications to ensure the quality of the electricity supply. A certain percentage of tolerances of deviation are also applied depending on different countries. (SGERI, 2010)
2) Further more, the power system shall ensure the secure and stable operation. In this regard, all components in the power system including power producers, grid, end-users, bear responsibilities and obligations. In a power system, random load changes, equipment failure, sudden accident will affect the stability and security for the system. To avoid it, to have sufficient power generation, great transmission distribution capacities and flexible contrable regulation capacities. If the balance is broken, frequency specifications will not be met, or exceeds the tolerance rate, then the decline of frequency will occure, and more seriously, a chain reaction will happen which may lead to blackouts due to frequency collapse. Same with voltage, if the local voltage stability is affected, blackout may hapoen due to voltage collapse.
3) Power system shall provide users qualified and affordable electricity. Mainly articles especially in developed countries states that quality and affordability here means that the the electricity shall generated with the minimum environment and ecological cost, and at the lowest cost possible. This maybe differently considered in countries where government has limited budget, and locals have very little income. However, noticeably, author agrees that this shall be the trend, and a factor to consider for a sustainable development. As power industry has gradually diversifying its energy mix from conventional power generation such as gas, coal, oil to introducing more renewable energies. A robust power system is needed to best coordinate great variety of power sources with different strengths, with minimum impact, or costs.

The basis for the securing and stabilizing power system operation system is to achieve instant response to the changing demand or say load through effective control of the power outputs. So the controllability of the power output is the basic technical requirement for the stable and secure power system. (EWEA, 2010)

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3.3 Challenges in integration of wind power

Like other conventional power, wind power does have impact to the power system. The impact depends on the size of the power grid, penetration level of wind power in the whole system and generation mix of electricity in the system. A single turbine or a small wind farm's impact to the power system is too small to be noticed. The variation will be levelled out by teh system itself. The impact would be hardly noticed until the penetration reach up to 10% of the total demand. While as studies show that penetration at 20% and above will require the upgrades of system, and control method otherwise, the current established system, reserves in most countries will be adequate for additional variation come alone with wind power in the system. This also depends on specif system. (EWEA, 2009)

The impact of the wind power on the power system is shortterm and longterm. Shorterm are related to power balancing, operation controlling, while the longterm impact are about wind power's contribution to the system, which will further influence the planning of the system. While for the short term planning, there are impacts at local, regional and system wide levels. For the local and system levels, it mainly talks about that locally, wind power will influence the voltage level and power flow in the network. As penetration grows in a certain area, it may require certain upgrades for the transmission and distribution lines and other grid infrastructure in order to accomondate the wind. This is specially the case for large scale wind farm located in remote but resource concentrated areas, such as offshore wind farm. Since variation of wind power can be smoothened as size of how distributed wind farms grows, cross border transmission to expand the grid size is necessary to manage a high level wind penetration system.

3.3.1 Key challenges

All in all, in order to integrate more wind power into the system, the key challenges are 1)how to secure the stability of the power system (upgrades, extension of the grid and transmission lines), 2)how to make coordinated planing which will allow grid to have the capacity to obsorb increasing wind power, 3)how to optimize the dispatching capacity in the system via introduction of both regulatory framework and a more flexible system, and 4) finally how to address all the costs in relation to the upgrade of the system.

4 Wind Energy and Power System Development in China

4.1 Wind energy development

China had its first wind turbine erected and connected to the grid in the early 1980s. However, fast development in the wind energy sector started in 2006 with the enforcement of Renewable Energy Law. Since then, an annual growth of more than 100% has been obtained. By the end of 2010, total installed capacity of wind energy has reached up to 44.73 GW, with an annual installed capacity alone in 2010 of 18.93GW.(CWEA, 2011) By the end of 2010, China has surpasses US to become the world number one in terms of total installed capacity and newly added capacity. In 2011, China is the biggest country with regards to total installed capacity and newly installed capacity in the world.

Table 4-1 The total installed wind energy capacity in China from 2000 to 2011

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MW	346	402	469	567	764	1,260	2,599	5,910	12,020	25,805	44,73	62,364

Source: GWEC 2011

29 provinces out of 34 provinces have their own wind farms, and 7 provinces have total installed capacities above 2 GW. Inner Mongolia has total installed capacity of 13.86 GW by the end of 2010. (GWEC, 2012)

Offshore wind farms have also seen great development in the past five years.

Local developers are dominant in the market, having a total of 100% market share. State owned companies are taking up the major piece of the market. Five big utilities alone own 56% of the market share across the country. Furthermore, there are 86 local turbine manufactures in China, which has a total domestic market share of around 70%.

The reason for and the result from the fast development are described as follow:

4.1.1 Rich wind resource

China has rich wind resources. Based on the latest national wind resource assessment by China Meteorological Administration, China has a total commercial onshore potential between 1,000 and 4,000 GW; and the offshore potential in waters from 5-50m deep is another 500GW. (GWEC, 2012) Wind rich areas in China are in the northeast, north, and northwest, small area in the south and coastal area in the east. Areas with best wind resources are provinces like Inner Mongolia, Gansu and Xinjiang province.

4.1.2 Favorable legal frame work and pricing (see to

Legal framework starts to form in 2005, with enforcement of renewable energy law. In the following paragraph policy instruments adopted, which accelerate wind power development will be introduced.

- Renewable energy law in 2005 and its Implementation guidelines regarding pricing and management
- Medium and Long-term Development Plan for Renewable Energy in China in 2007

- Amendment to China Renewable Energy Law in 2009
- Feed-in Tariff and other tax reduction instrument

4.1.3 Strong government committions and ambitious plans

Establishment of National Energy Administration in 2008

National Energy Administration was establishing in 2008. It's aimed to overall coordinate and manage the energy industry and its development, accommodate the emerging energy supply and demands, and to facilitate with the sustainable development in China, the booming energy demands. One of its main functions is to promote the energy efficiency and renewable energy technology development and research via demonstration projects.NEA is overall responsible for energy planning in China now, and it will gradually eliminate the overlap of repspobsibility in the system.

Funding of researches programmes.

Government has actively funded programmes to pave way for the wind energy development, in 2010, 16 energy research centers have been established, and national wind resource assessment was initiated in 2007, during which 400 met masts with heights varies from 70m to 130m were erected. With more accurate wind resource data nation-wide, government at central or local level are able to make better plans for the overall wind power development.

Hundred GW Wind Power Base Programme

The programme is that National Energy administration selected provinces with best wind resources, and set target for each of them to be reached by 2020. The total estimated installed capacities would be 138 GW. It will have seven GW scale wind bases, with a total of 83 wind farm projects. By 2010, the installed capacity in this programme has reached to 22,706 MW.

Table 4-2 Seven GW-scale wind farm implementation progress

Wind Power Base	2010 (installed)	2015 (planned)	2020 (planned)
Heibei	4,160	8,980	14,130
Inner Mongolia East	4,211	13,211	30,811
Inner Mongolia West	3,460	17,970	38,320
Jilin	3,915	10,115	21,315
Jiangsu	1,800	5,800	10,000
Gansu Jiuquan	5,160	8,000	12,710
Xinjiang Hami	0	5,000	10,800
Total (MW)	**22,706**	**69,076**	**138,086**

Source: GWEC, 2010

4.1.4 Concession projects

Concession projects first started in 2003, and lasted 5 years till 2008. In the concession projects, the power produced for the first 30,000 production will be purchased at the fixed price, then the price for the rest will depend on the market price. Additionally, the Grid Company has to unconditionally purchase and integrate all the wind power produced. The additional costs in terms of wind power, and relevated balancing cost are shared at whole grid system nation-wide

4.2 Obstacles in the development

There are many obstacles identified in the fast development in terms of technology of turbine manufacturing, operation and maintenance services, insufficnet technical standards, regulations to securea healthy development, and lack of people with relevant expertise etc. Among all, the most critical issue is the grid integration problems.

4.2.1 Grid integration

Wind power, unlike conventional fuels, it fluctuates. The amount of wind power differs within each minute, or second. Within one second, the situation can change from 0 wind to 9 or 10 m/s.

In China, good wind resources are in regions or provinces where are least developed and least populated, and are away from the load center. The power consumption is low, thus the grid capacity is relative low and grid infrastructure is poor.

Because wind fluctuates, in order to balance the power supply and demand, integration of wind power to the grid requires reserves from other energy sources. So when wind does not blow, there are still other power capacity or power capacity from connected electricity market abroad providing sufficient power to satisfy end-users demand, on the contrary, when wind blows, the other power station shall have the capacity to flexibly adjust its production downwards but without shutting themselves down, which will cost much more money and time to start up the power plant again. So not only a robust grid system is need but also more flexible reserve capacity are necessary which can adjust its production within a wide range to accommodate with wind fluctuation. This will make additional cost and more technological requirement to the grid, which make the grid companies unwilling to integrate wind power.

As required the grid entities have to absorb renewable energy power, and indeed all the projects are connected to the grid, however, in China, curtailment of wind power always happen when wind blows and there is surplus of power produced than what is needed. In order to reduce the cost and risk, only certain percentage of wind power produced is allowed to connect to the grid system. By the end of 2011, the total installed capacity ahs reached to 60 GW in China, however, the total integrated wind power capacity nation wide has only been 47 GW, which means 20% of the installed power is not connected to the grid. While curtailment has increased dramatically, in 2011, curtailment has reached to 15% of wind power production in China with 5% increase compared to 2010, and has reached to 20% to 30% in the northen area covering provinces of Inner Mongolia, Gansu, and three northeast provinces. (China Guangdong Nuclear Wind Power Co., Ltd, 2012)

Because China has different grid companies, and the transmission of electricity among different companies are very difficult. Because absorption of wind power will requires reserve capacity, which increase the costs of the operation of grid system, it makes it difficult to transmit surplus wind power to the other grid system through different companies.

In some areas, where several projects from seven GW scale wind energy project are located, the grid infrastructures are poor, and reserve capacity from other power plants is low due to a lack of resource in the local grid.

To upgrade grid infrastructures requires similar amount of investment as it is for the wind farm. The cost for certain area is too high.

4.3 Power system

The power system in China is simple. Thermal and hydropower are the two main powers. The thermal power is dominat in the power generation mix, and the coal powered thermal plants has a share up to 76% of the total production. Recent years, China has been a leading country in the world in the development of renewable energy, but the penetration of renewable ernegy in the power system is very limited still. By 2010, the total installed power capacity in China reached to 966.41GW, among which hydro power amounted to 216.06 GW with a share of 22.4%, thermal power was 646.61 GW, 67% of the total installed capacity, and 29.58 GW for wind power, and 10.86GW for nuclear. (SGERI, 2009)

The regulation capacity of the system is low, and can onlu regulate the maximum of 5% of the total capacity. It is due to the fact that most thermal power plants are not equipped with regulating down or upward capacity, and most power plants are old. Though country has been working on changing the power production mix in the country by fast developing large scale, medium size hydro power and wind power, the change is gradual.

By the end of 2010, transmission lines above 35kV had reached to 1,340,000 km. Among it, 1000kV lines are 1006 km long. (SGERI, 2009)

It has formed seven cross-province and five provincial grid areas in China. These cross-province areas are northeast grid, north grid, east grid, central grid, northwest, Sichuan-chongqing grid, and southern grid. The whole power system is dominated by state-owned entities. On producer side, central government owned companies have close to 58% of the market share, among which, five big ultility companies that are directly owned by the central government have 47% share. Private and foreign owned producers have small share, and the share is decreasing over the year. On the transmission and distribution side, state-owned company plays the major role. State Grid the largest transmission company in the world, its transmission service covers 26 provinces and autonomous regions, covering 88% of the national territory, with 1.5 million employee, and 128 million customers, while the Southern Grid Company, the second biggest in China covers 5 provinces and autonomous regions. (Wu j., 2011)

Nation-wide wind power is less than 1% in the total installed capacity and even less in the total production as of end of 2010, however, in many provinces where there is rich wind resource, the wind power penetration has reached above 10% in the regional power system. The highest penetration has reached up to 32.6% in Inner Mongolia, and 12.1% in Hebei province. (SGERI, 2009)

Load center is in the developed area in the east and coastal area, the consumption in this area has taken up 56.07% share, which is more than the total amount of the rest parts of China all added up. (SGERI, 2000) China has rich hydro power resource, and more than half of it locates in the southwest regions which is far off from the load center. In order to best ultilise the resource in the country, interconnection and coorperation of different grids are needed. Wind power will face the same problem as the rich wind resources are in remote area far away from load center, in order to integrate more wind into the system, interconnections of transmission lines and co-operation among grids are required.

Currently in the system grid area, they have capacity to balance the demand and supply within the system, and the transmission among different grid is not common. However, due to the imbalanced resources and fast development of hydro and wind power in specific area where the demand is low, and flexibility is limited. Therefore, to level out the variations from hydro and wind power in the future, it is necessary to increase interconnect grids at nation-wide scale to secure stable and liable grid system, at lowest possible way.

4.4 Wind power and integration management

4.4.1 Grid integration management

The technical standard for connecting the wind power to the grid, the Grid Code, was established in the country. The first Grid Code was prepared in 2006, and it was a national standard, but only at mandatory level, and was just guidlines for integration. It describes basic principles in integration, without touching many key specifications that may cause problems in the integration. For instance, low voltage ride through (LVRT) requirement. The standard expired after three years automatically, and a newer version of Grid Code was prepared since then to facilitate with increasing problems of wind power integration. A new version was issued in 2009 by the State Grid Cooperation Group, requiring that wind farms must meet specifications including LVRT, regulating, wind faorcasting, monitoring and communication before they can be connected. The new added specifications are in line with main stream international practice. However, this new version is not mandatory, but an industrial standard.

Testing capacity building and implmentation have been established. A series work has been done to form a testing plat form in the country. This include capacity building in the key institutes and the real implementation in the field. For the capacity building to key personnel, in 2009, NEA has agreed to establish a Wind Power Technology Testing Center, and the major function consitutes of three parts which are 1) capacticiy building in research in wind power simulation, forcasting, dispatching, monitoring etc; 2) mobile testing capability building turbines and in 2010, the first test on LVRT was successfully conduced; and 3) the testing field for experiments. For the real implmentation, in 2010, NEA issued While in 2010, Wind Turbine Grid Integration Testing Interim Measures, and it states that only turbines that meet grid code and and pass the testing can be connected to the grid, starting from Jan of 2011. Followed, NEA issued another act requiring that testing for LVRT for all the existing wind farms shall be conducted within a time frame of two year.

4.4.2 Dispatching and operation management

Installation of forcasting features in the grid and wind farms have been gradually required by the government as wind power develops. The change took place in the grid side first, grid companies starts to develop, install and operate the system in its settings. It started with Jilin Power Grid Cooperation back in 2008, and by year 2010, 12 grid companies had the system, covering a total installed wind capacity of 12GW. While in 2011, NEA issued Wind Power Predictin and Forcast Interim Measures, which requires that all the wind farms that have been connected to the grid must establish the prediction and forcasting system, and reporting the generation plans of the plants. While for the new wind farms, they must have the above-mentioned system before they can be connected to the power grid. The implementation will offically start in July 2012, and by then all prediction and forcasting system will put into operation.

Real time monitoring and management are in place but at premilary development phase. By the end of 2010, all the wind farms that are integrated to the grid are connected to the state grid dispatching center for real time monitoring of operation, and their wind prediction and farcasting. For the monitoring of the operation, more than 380 wind farms are being monitored at real time, and some individual wind turbines are also connected for the purpose. While, to better cope with variation of the wind power, it is important to make accurate prediction. Therefore, real time meterological data obtained from the measurement mast are also connected and used for better dispatching purpose. These meterological data includes wind speed, velocity, temperature and others.

Better dispatching management facilitated with forcasting system is in use. Based on forcasting system installed forcasting data are obtained by the grid company. Vased Grid Company starts to integrate these wind power prediction data into their monthly, and daily balancing plans. This facilitates them with better dispatching, giving the priority to the wind power, through knowing how much spinning reserves may be needed within the grid, and how much power needed from other grid. This will increase the cooperation and interconnection with other grid, while best ultilizes the resource at a large system by reducing pressures within one grid. This will also encourage more thermal power plants to develop further on their regulating capacity in order to compensate for deficit or eliminate surplus power in one system. This system also helps to coordinate the development between wind power and other conventional power plants. This dispatching with forcasting system has been implemented in Jilin and Gansu provinces.

4.5 Policy system for the well-balanced development

Generally speaking, policy system in the country has been developed together with the development of the industry. With the implementation of China Renewable Energy Law in 2006, wind power has seen fast growth, and a foundamental policy system has been thus established. The policy system to support wind power development are constitute of four parts, and they are industry development related policies, industry management policies, tarrif and fiscal supports.

These policies are derived from the Renewable Energy Law. The renewable energy law formed basic policy framework for promoting the renewable energy development in the coutry. In this law, the system shall 1) sets target for the development of renewable energy; 2) make grid integration of renewable energy to the system mandatory; 3) introduces feed-in-tariff for different renewable energies; 4) have a nation-wide cost sharing scheme and 5) establish renewable energy funds to facilitate with the renewable energy development.

4.5.1 Industry management policies

Following the Renewable Energy Law, more policies were issued to secure a healthy development of renewable energy in the system. These policies were issed by various government agencies such as National Energy Administration, Ministry of Finance etc. These policies are summerized as follow:

1) **Project management policy.** The National Development and Reform Commission (NDRC) issued regulations with specifications how administration, project management grid integration and power generation procedures should be in regards to the renewable energy generation.

2) **Power purchase priority policy.** The State Electricity Regulatory Committee issued a set of policy on Regulatory Measures for Grid Entities' Purchase of Full Amount of Renewable Energy Generation. It clearly states that power system must give priorities to integrate and purchase power generated from six renewable energy source (which

are hydro power, wind power, biomass, solar, wave and geothermal power) at full amount. While the power generated from the above mentioned renewable energy do not need to participate in the integration bidding, and the grid company needs to give priority to purchase the power and arrange the dispatching. Large and medium scale hydro power plants are excluded for this case.

3) **Dispatching and operation management policy.** In August 2007, NDRC together with other agencies issued Energy Conservation and Power generation Dispatching Method (Tentative). In the policy, renewable energy has the first priority in the dispatching compared to the conventional power which is easier for adjustment.

   While in 2010, Wind Turbine Grid Integration Testing Interim Measures was issued by NEA, and it requires that only turbines that meet grid code and and pass the testing can be connected to the grid, starting from Jan of 2011.

   In may, 2011, NEA issued Wind Power Predictin and Forcast Interim Measures, which requires that all the wind farms that have been connected to the grid must establish the prediction and forcasting system, and reporting the generation plans of the plants. While for the new wind farms, they must have the above mentioned system before they can be connected to the power grid.

4) Technical regulation management policy. New set of Grid Code was developed, and set as industrial standards in the country. However it is not yet a mandatory standard.

4.5.2 Tarrif and other fiscal support

1) In 2009, National Development and Reform Commission issued a Notice on the Optimization of Wind Power Feed-in Tariff. It provides a fixed price to wind power for 20 years. There are four categories depending on the different wind resources. These tariffs are: 0.51 RMB/kwh (EUR 5.7 cents), 0.54RMB/kwh (Euro 6.1 cents), 0.58RMB/kwh(Euro 6.4 cents) and 0.61RMB/kwh (EUR 6.8 cents). (For detailed description please refer to chapter 3.4)

2) Price sharing of renewable energy in the power system. Considering the fact that wind power is still in de prelimilary development phase, with immature technology, the investment cost compared with conventional power is still high. With that high cost, it cannot compete with conventional power in a market. Particularly in China, the wind resources are concentrated in certain area, and these areas will have high wind penertration than the rest of country. However, due to the comparatively high tariff, if the extra costs will have to be shared within the local consumers, this will have negative impact to the development of wind power in local area. Therefore, according to the renewable energy law, the extra costs from wind power will be shared in the whole grid system nation wide, and every consumer in the country will need to take the share.

3) Followed the Renewable Energy Law, NDRC issued Renewable Energy Tariff and Price Sharing Management Procedures. The extra costs related to the renewable energies are defined in the procedure, and they are 1) Deviation from the renewable energy tariff compared with coal powered thermal power tariff for all renewable energy plants approved by energy authority belongs to the government since 2006; 2) deveiation between the average local power sale price and the operation and maintenance cost per MWh from the government subsidized or funded individual power operation system; and 3) extra costs for grid connection

of renewable energy. By increasing the sale price of the electricity nation wide, the money is collected to cover all the extra costs caused by renewable energy. (Ren,D.M., 2009) In 2009, the sale price has increased by RMB 0.004 per kWh (Euro 0.0004 per kWh at exchange rate of 10). With this increase, RMB 9-10 billion extra is collected every year. Worth mentiong, the price takers are limited to big consumers, and residence, agriculture related consumers and all Tibet region are excluded. The money was collected by local grid companies, and shall be separated booked in the financial system. The collected money is first used to cover the additional costs in their own system, when it clears, the surplus will be used for uncovered costs in other regions. (SGERI, 2009)

4) According to the Renewable Energy Law, a special fund has been established to support the renewable energy development. Ministry of Finance at central and provincial levels have put up the special fund for the purpose. While a management guidlines for the fund and project mornitoring has also been set up. The fund focuses on supports to wind, solar and ocean power. It defines that the fund is only used for R&D for renewable energy technology, setup of various industrial standards, demonstration projects, projects for rural area's electricity consumption, establishment of independent renewable energy power system in remote area or on islands, exploring, assessment and establishment of information system for renewable energy resources, promotion of local produced renewable ernegy equipments. (Ren,D.M., 2009)

5) China enterprise income tax law issued in 2008 that high-technology industry supported by government will receive tax reduction, and will only be charged of 15% tax. (CREIA, 2011)

6) Notice on Adjustment of Taxation on Massive Equipment states that import of wind turbines with an individual capacity bigger than or equal to 1.5MW will receive import tax exemption. (CREIA, 2011)

4.6 Wind power price system

In China, as wind power developed, the wind power price has gone through five phases. It has gone through no government incentives to the current pricing with fixed prices depending on different wind classes across China.

The **first phase** (1990s), prices for wind power were totally market based, and wind power had to compete with other conventional power without any subsidies provided. The income was just sufficient to maintain the operation and maintenance of the power plants. However, at that time all the equipments were funded by international aid money, therefore, the investment was low. The price is same as other thermal power, less than CNY 0.3 per kwh (Euro 3 cent per kWh.).

The **second phase** started from 1998 and lasted to 2003. In this period of time, the power price were decided by the responsible authorities locally, then the prices were reported to the central government. Prices differed at large extend throughout the country. The lowest price used was similar to the thermal power, and the highest reached to CNY1.2 per kWh (Euro 12 cents per kWh at exchange rate of 10.).

The **third phase** was from 2003 to 2005. It was when the first three concession projects were initiated in China. During this period, a bidding wind power price and market prices were both used. Only the concession projects were using the bidding price.

The **fourth phase** started from 2006, when the Renewable Energy Law was issued. According to the law, wind power feed in price is based on bidding price, and shall be used in the country. (Shi, J. L., 2009)

However, using the same price regardless of wind resource at specific location has withdrawn dispute over the price system. Therefore, in 2009, National Development and Reform Commission issued a Notice on the Optimization of Wind Power Feed-in Tariff. It provides a fixed price to wind power for 20 years. There are four categories depending on the different wind resources. These tariffs are: 0.51 RMB/kwh (EUR 5.7 cents), 0.54RMB/kwh (Euro 6.1 cents), 0.58RMB/kwh (Euro 6.4 cents) and 0.61RMB/kwh (EUR 6.8 cents). (CREIA, 2010)

5 Wind energy and power system development in Denmark

5.1 Wind power development and outlook

In 1970s, Denmark depended 90% of oil in its energy consumption, during the oil boycotts, it had to adopt car free Sunday to reduce the energy consumption. However now, renewable energy shares 22% of its final electricity consumption, and by 2012 wind has taken up to 25% of the total energy consumption in the nation. Wind power development started in late 1970s, when the oil boycotts hit the country. It went through rapic growth during 1990-2000, the annual growth rate reaches to 21.7%, and the rate reduced to 4% during 2000-2008. Then Denmark started to take lead in the industry, with most advanced turbine technologies, and favourable policies. By the end of 2010, the total installed capacity reached to 3,752 MW, number 9 in the world. While wind turbine produced in Denmark has 1/3 of share of world wind turbine market, and it also has 63% market share of EU offshore market. (GWEC, 2011)

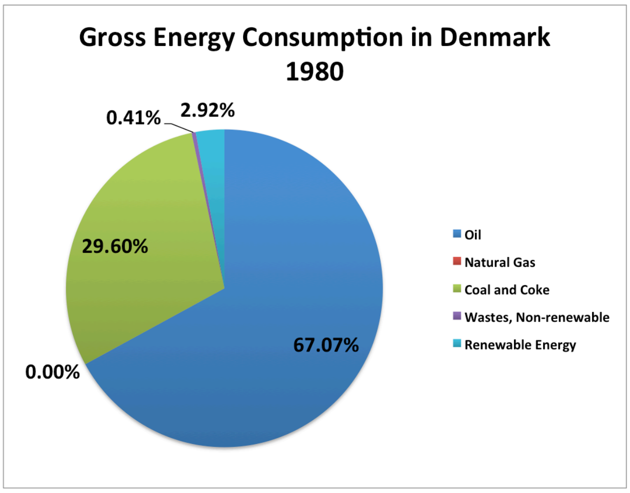

Figure 5-1 Gross energy consumption in 1980

Source: DEA, 2010

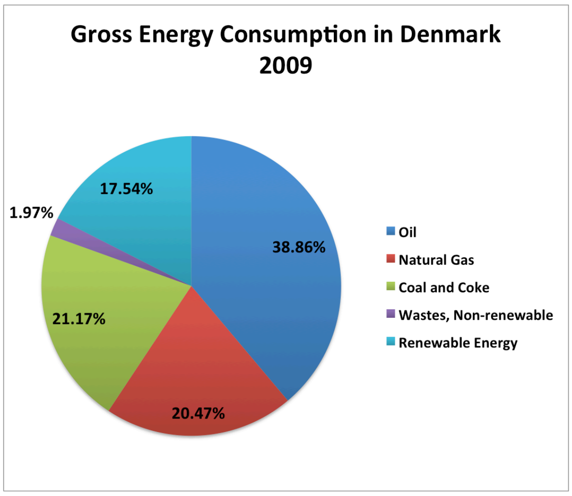

Figure 5-2 Gross energy consumption in 2009

Source: DEA 2010

Denmark has rich wind resources both on the mainland and offshore. The mean average wind speed over the country is Wind farms are spread out across the country. By 2009, there are more than 5,500 turbines installed, with a total capacity of 3.48 GW, accounting for approximately 26% of the country's total generation capacity.

In March 2012, Denmark isssed a new policy that: *In 2020 half of the electricity consumption will come from wind power and the energy consumption will decrease by more than 12 % in 2020 compared to 2006. (DEA, 2012)* The government has also deciede to build more wind power with a mount of 3000MW which will enhance the wind capacity by 2020. The new capacities are mainly from offshore, and partialy from the combination of onshore and turbines in the coastal area.

5.2 Power system

The Danish energy supply structures are characterized by three feasures: 1) among thermal units, cogeneration plants play an essential role, covering up more than 92% of the total installed capacity of thermal power in the country. While 80% of the heating system can generate power simultaneously. 2) Most thermal plants are hybrid-fuels plants, with coal/oil units, hybrid fuels covers about 55.7% of total installed capacity of thermal units, making the electricity supply system more flexible; and the last 3) The electricity system across the country is highly decentralized and the access to voltage grate is farely low.

The Danish power system is part of Nordic power system. The transmission systems mainly consists of 400 kV and 150/132 kV installations or say transmission lines. All 400kV owns by Energinet.dk, whereas the 150/132kV lines are owned by reginal transmission companies, which make the 150/132 kV grids available to Energinet.dk. However 132kV grid in northern Zealand is still owned by Energinet.dk. (Energinet.dk, 2012)

The system is interconnected to the transmission systems of Germany, Sweden and Norway, with 14 transnational lines (8 AC lines, and 6 DC lines) designed to tranmit power over 5 GW. Furthermore, Denmark's eastern grid operates with Nordic Grid, and western grid operates with European mainland grid.

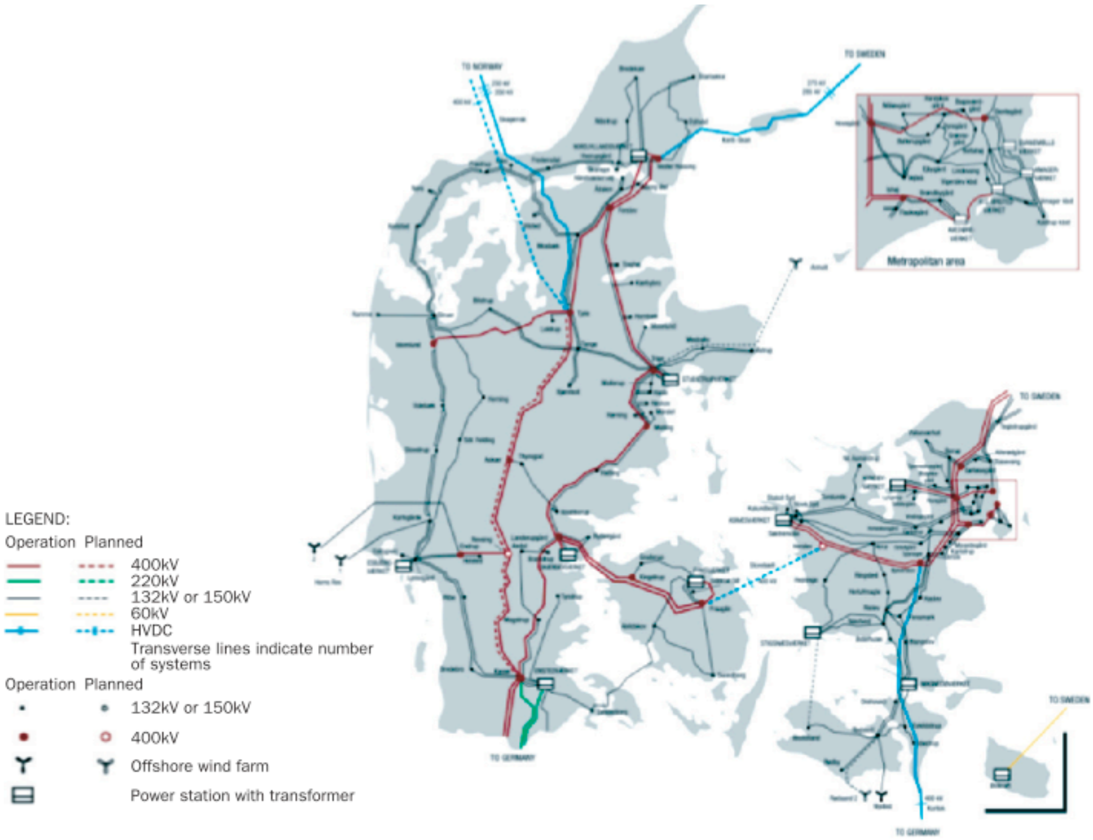

Figure 5-3 High voltage transmission line and large scale power plant distribution

Source: energinet.dk, 2012

Majority of installed turbines are connected to the distributed power system, where 88.7% of the installed wind power accesses to 20kV or lower voltage distribution networks. Large -scale wind farms accessing to 132/150kV transmission lines accounts for only around 10%. However, it is believed that with more offshore wind farms, there will be more than 60% of the wind power will be integrated to 132kV or even 400kV transmission lines. (Energinet.dk, 2012)

With highest wind penertration in its power system, Denmark has rich experience in the grid integration of large scal wind power, and could be considered as best practice in the field.

5.3 Wind power and grid integration management

It has a comprehensive system for integration management. First of all, it has very strict grid code with strict specifications about integrating turbines to the power syste. The standards are set at a very high level in order to secure the stability of the system. Only equipments that meet the specifications are allowed to be connected to the grid.

Furthermore, it also has specifications on testing and certifications. The national laborotary, Risoe DTU is fully responsible for the testing, and certification. While it is also take responsibilities in performance auditing and monitoring whether the specifications are continuously met as time goes by. The testing specification includes security system testing, yaw efficiency, system testing and other.

5.4 Policy system for the well-balanced development

Well balanced development starts from the coordinated planning for the system. Denmark has set a good example for it. Long term and short-term development goals have neem set by the government in Denmark. By 2025, the renewable energy shall reach to 30% in the total power consumption in the country, which means for a wind power dominant country, wind power will have to reach up to 50% of the total power consumption by then. However, this number has been renewed recently in March 2012. New target has been set, that by 2020, wind power penetration in the market will be 50%.

In order to reach the goal, strategies have been set as well. Both offshore and onshore needs further development to reach the goal. Hwoever, Denmark is limited on land space, and it is quite packed with more than 5000 turbines on land, therefore, the focus for development has been shift to offshore. In 2012, 800MW offshore will start to be added up, together with 300MW onshore. The 800MW is from three offshore wind farms, and half of the onshore power is from upgrading of the existing wind farms.

The transmission system operator, which is Energinet.dk in Denmark is taking care of the planning of the transmission lines, extension of the grid, construction of infrastructure and so on. It proposes and makes plans with specific plans for further development of power system every year according to latest development, and goals.

5.5 Power market design: Nordpool power market

The dispatching and operation management is market based, and it is reflected from its power market operation and design. In order to promote wind power, and increase the integration of wind power in its power system, power market has played an important role in Denmark. It provides incentives for the market to accept and develop wind power and for conventional power plants to downward or upward their capacity to facilitate with the fluctuating wind power in its system to reach the cheapest possible way to manage the system with high penetration of wind.

Denmark's grid is connected to Germany, Sweden and Norway, and it is part of the Nordic power market, where electricity are traded based on market mechanism, and non discrimitory rules are applied.

Electricity market are liberalized in Europe, generally the power market consists of five different sub market and they are: Bilateral electricity trade, spot market which is also known as one day ahead market, the intra day market, the regulating power market and balancing market. In the bilaterial electricity market, the trading of the electricity are down outside of the power exchange, and the prices and quantity are not made public. The spot market is a physical market where the price and quantity are based on supply and demand. The market is one day ahead; all the bidding and tradings finish at noon for deliveries from midnight and 24 hours ahead. The intraday market happens after the spot market closes, and before the next market starts. In the market, the participants from the day-ahead market can trade bilaterally and the product is one-hour-long contract. Like day-ahead market, prices and amounts are based on supply and demand. The regulating power market is a real time market including the operation within an hour. It is to provide power regulation response to imbalances casued from the day ahead. In this market transmission system operator plays an important role to act to make up demand side. For the balancing market, the transmission system operator acts on the supply side to deal with imbalances from the previous 24 hours, and this market is linked to the regulating market. Participants from spot market, and intra day market with imbalances in the end will have to be price takers in the regulating and balancing market. (EWEA, 2009)

The design of Nordpool follows the above structure. It has three markets: spot market (Elspot), intra day market, and regulating market.

5.5.1 Nordpool spot market

In this spot market, it consists of day-ahead market and intra day market.

In the day-ahead market, the power is traded in 12´to 36 hours ahead before the delivery. The price, quantity of demand and supply are based on the supply and demand and are stated publicly. The object of trade is 1MWh electricity during an hour. The market has 24 units, each unit corresponds to one hour. The trade is based on quantity of power during one-hour time. The contract is made based on it too. The bid is submitted by the participants in a form of price and quantity of power for an hour or several hour, which shows the quantity the participants are willing to buy or sell at certain prices. Then the market will clear the price for each hour of the day ahead. This price is called system price, however, if there is constraints or congestion in the transmission, then their will be market clearing area price at certain region. In practice the financial settlements are done on weekly basis. (Bergman. L.etc.1999)

In principle, all power producers and consumers can take part in the market, however, the reality is only big producers and consumers participate. These consumers include distribution and trading companies, and big industries. (EWEA, 2009) Suppliers are those big generators, for those small power plants if they want to participate, they have to form cooperative company or take part in big trade company to participate in the market. In Denmark, its 80% of electricity is traded in the spot market, while in 2008 in general 70% of the electricity in the Nordic countries are traded in the market. . (Energinet.dk, 2009) The rest electricities are arranged with long-term contracts with suppliers

Ideal situation is there is only one market with one price. However, due to the fact that the congestion in the transmission in various situations, power flow cannot freely, the market is divided into many sub markets, with different prices. In Denmark, wind is stronger in the west than the east, and there is high penetration of wind power in the west, sometimes, when wind blows hard, the penetration in the west power system can reach to 100% of the total electricity demand in the area, in this case the supply and demand in this area balances out at a different price than the area with less wind. There are two submarkets in Denmark, one is Jutland, the other is Zealand.

Intra day market ELBAS was introduced to enable participants to adjust their deals to address changing situation during the day after day ahead market closure and 2 hours before the operation. It opens for 18 hours a day.

5.5.2 Nordpool regulating market

Regulating market and balancing market are considered as one unit here, and both are run by the system operator. System operator acts as facilitator to address the imbalances from the spot market. The principal is that imbalances are priced, and participants causing the imbalances have to bear the cost to secure a balanced system. (Bergman, L.1999)

In Denmark, wind has its priority. When wind power producer delivers less wind power than it was promised, if it helps to eliminate surplus power in the system, then the producer is paid full amount as agreed; however, if the other power generator has to regulate up to facilitae with the re-establishment of balance then the producer will have to pay penalty, which often higher price. Vice versa, if there is surplus of wind produced than commitment, then depending on the overall power system situation, the producer has possibility to pay for the imbalance if other generators have to regulate down the production. The further it is off-track, the more penalties will be. This is also why sometimes the wind power price is "negative" in the market.

This market happens 1-2 hours before the operation. When imbalances occure, TSO will send out information for the amount of deficit or surplus, the producers on the regulating market has to make their offers 1 or 2 hours before the delivery and the production has to be available within 15 minutes since the notice is given. In this case, only fast responding producers can deliver the regulating power. (EWEA, 2009)

5.5.3 Price and support scheme

Many price and support mechanisms are adopted by different countries, depending on development level to promote the renewable energy. There are indirect and direct supports, and under them, there are investment–focused and generation-focused strategies. Another important classification criteria is whether the mechanism addresses price or quantity. The direct aims to stimulate the installation whiel the indirect aims to improve long-term framework conditions. Investment-focused strategies include investment subsidies, or soft loans or tax credits provided by the government. While generation-based refers to feed-in-tariff (FIT) or a fixed premium that a government institution, ultility or suppliers is legally obligated to pay for renewable enery from generators. (EWEA. 2009)

The overview of mechanism normally used are as shown in the chart.

Table 5-1 Seven GW-scale wind farm implementation progress

Types of renewable energy price and support mechanism			
	Direct		Indirect
	Price-driven	Quantity-driven	
Regulatory			
Investment-focused	Investment incentives	Tendering system for investment grand	Environment taxes
	Tax credits		Simplification of authorization procedures
	Low interest/soft loan		
Generation-based	(fixed) FIT	tendering system for long term contracts	Connection charges
	Fixed premium system	tradable green certificate system	Blancing costs
Voluntary			
Investment-focused	Shareholder programs		Voluntary agreements
	Contribution programs		
Generation-based	Green tariffs		

Source: Ragwitz, M., 2007

Commonly adopted mechanism is FIT, fixed premium system, tradable green certificate system, and environment taxes (ERI, 2009). Price for the FIT is normally fixed for a certain period of time. In Gernany, it started to use FIT since 2000, and the FIT was revised every two year. In 2004, the FIT for wind power in the country was Euro cent 8.7/kWh, doubling the average tariff. FIT provides incentives to fast develop specific energy, and its technology. During 2000 to 2002, Germany gave highest priority to develope wind power, and the annual newly installed capacity in the country during 2000 to 2004 was the highest in the world (ERI, 2009). Fixed premium is to add a fixed amount to the market price of electricity. Compared with FIT, the price is less predicatable. The premium reflects the external costs of the conventional power. If the premium is set at a right price whih equals to the external costs of conventional power, then it can penetrate into the market quickly and compete with the conventional power. The green certificate scheme is that goverment set a quota following its renewable energy deployment goal, and generator, wholesaler, consumer or broker can trade the certificates for finacial gains. Finally the environment tax is also a effective means, and it can be achieved via either taxing the non-renewable energy, or exemptiong renewable energy from tax. Like premium strategy, it can make renewable energy more competitive on the market.(EWEA, 2009)

In Denmark, premium and environment tax are used. Since 2008, new wind turbines - onshore as well as offshore -receive a price premium of 25 øre/kWh for 22.000 full load hours. Additional 2,3 øre/kWh is provided in the entire lifetime of the turbine to compensate for the cost of balancing etc. Household wind turbines below 25 kW receive a fixed feed in tariff of 60 øre/kWh.For offshore, the subsidy is settled by a tender procedure. In previous tenders the Horns Rev II wind farm of 200 MW ended at a fixed feed in tarif of 51,8 øre/kWh in 50.000 full load hours, while Rødsand II wind park of 200 MW ended at a fixed tariff of 62,9 øre/kWh for 50.000 full load hours. (Ministry of Climate and Energy of Denmark, 2008)

Environment tax covered many things, and it tax on products, discharge of pollutants,adn scarce resource. Carbon dioxide and sulphur are relevant in this case. The Carbon Dioxide tax is balanced around 90DKK/tones. (CEF, 2012)

5.5.4 Wind power impacts to the power market price

According to statistics from Energinet.dk and nordpool market price, in general, when wind power is strong, the market price drops.When 5,500 turbines works at full throttle, and everybody is off work, the market price hits the bottom. This situation occurs 50-100 hours a year. The reasons for it are the wind power has priority access to be connected, and the marginal cost of wind power is low. With large penetration of wind power in the system, Danish system is sensitive to wind production, and which also forces other power producers to keep an eye on the prices all the time and to produce the electricity when it is profitable. When wind power production is more than consumption, market price may drop to zero for suppliers. (Energinet.dk, 2009) Thus, penetration of wind power in the system has saved end user money and reduced the environment impact to the minimum by reducing the power generation from the conventional power plants.

5.5.5 Enabling factors to the success in Denmark

Besides technical aspects regarding turbine quality, robust grid, grid infrastructure, this part will look more into the grid integration management, policy framework, financial incentives. In addition to it, in order to connect all of the above together, overall planning of the whole system is also considered to find out about what exactly have made Denmark as best practice in terms of highest penetration of wind power in its power system.

Integration management leads to a robust and flexible grid system

5.5.5.1.1 A clear system with clear rules.

1) **A comprehensive set of technical standards and rules are in place, they are implemented by the responsible players in the system.** There are technical standards and rules and market standards and rules.

   Technical standards or rules include regulation for grid connection, facilities and system operation. *The standards and rules specify function requirements and principles for the entire power system, including rules for system dimensioning, load shedding requirements, system requirements for Mvar balance, etc.(Energinet.dk, 2012)* Regulation for grid connection, the Grid Code it defines propertises that plants MUST have to be able to connected to the grid, while, it also defines what impacts from the system the plant shall be able to bear to continuously provide power. Regulation for facilities governs specifications for installation and operation of cables, transmission lines, substation, transformer etc. For the operation rules, they tell what each player in the system (plant owners, operator, TSO, grid company,) must do to ensure stable operation of the system. It only just provdes standards, but also implementing procedures for the work.

   Market standards and rules are set to secure the functioning of the electricity market. Stanadards address how market shall perform, each party's responsibilities, physical adn financial settlement. This part will be explained further later.

   All together, they ensure a stable power system, a basis for grid friendly wind power and wind power friendly power system are. These rules are mostly set by the transmission operator, which is Energinet.dk in this case.

1) **Players' responsibility and obligations are clearly defined, they must be performed, and penalties are applied.** Producers are to provide qualified electricities to or buy from TSO, meanwhile carry obligations to regulating down or upwards to facilite with system stability, finally, they also bear costs for the imbalances caused by themselves. Therefore, for their own profits, producers have to make their forcasting as accurate as possible. Transmission system operator is responsible for

system balancing, managing, and developing rules to for the system. Since 1999, the TSO in Denmark has become unbounded from power generation,this helps to ensure equal access to grid to all parties. Grid company distributes network operation, meters data on both producer and consumer side, while provide data to TSO for balancing. Electricity suppliers (trade companies) can be shosen by users, which help with market competition.

5.5.5.1.2 Existence of Liberlized power market with flexible rules

Liberalized power market is critical for efficient dispatching and system operation. The settings of the market help to promote wind energy penetration in the system.

In the market, wind power tarrif competes with conventional power, and the market price fluctuates as supply and demand change. With fluctuating prices and prioritized wind power, it provides incentives for conventional power to help with dispatching. They do not produce power when price is too low to make profit.

In case there's need for conventional power plants to regulate down or up than the production amount stated in the power purchase agreement, compensation will be paid to them by TSO. Meanwhile, if a conventional power plants keep producing large amount of the power when wind is strong, power producers have to pay to connect the surplus power produced to the grid This also ensures that when wind farms fails to deliver what are promised, or wind is strong, other producers are incentived to facilitate with the system by reducing or increasing their production. This alos requires a high regulating capacity in the powerplants.

System prices are mainly bidding prices against the demand in the spot day market. Imbalances caused will be settled with penalties, which are the same for wind power. However, since wind power has the priority, producer is only punished when surplus or deficit wind power does not contribute for the system balancing. This provides incentives for investment for the wind power, and improves their forcasing capacity.

Unbundling of transmission system operator from generation has ensured fair access to market players to be connected to the grid. In 1999, Act on Energinet.dk was issued, it clearly set that Energinet.dk as an independant pubic company carries the responsiblity to ensure the stable operation and expansion of electricity infrastructure and to ensure open and equal access for all users of grid.

Interconnections with other four countries

Interconnections help to maintain the balance in the system. Interconnection with other countries actually phsically expand the grid. In a larger system, as mentioned before, the impact of variation of wind power is smaller compared it to a smaller system. Because, it the surplus or deficit are leveled out. This also helps with dispatching.

Flexible generating units in the system and flexibility on demand side

There is a high percentage of CHP plants in Denmark, and these plants have high regulating capacity, it can regulate its power output to close to zero. The regulating capacity helps with dispatching when critical situation happends.

While in the system, CHP plants are also used as a way to consume surplus of wind power by connecting wind power to these plants.The surplus wind power will be changed into heat and used for district heating system. More and more heat pumps are used in Denmark as well, and heat pumps can be a good source to consume surplus wind. Furthermore, in 2012, Dong

Energy has put electrical vechicle in the market, and it helps to consume surplus power, particularly during night. All of these faciliaties form a flexible demand side, which participate actively in the balancing and make the system run most economically.

6 Assessment

In conclusion, Denmark has a robust grid, felxibile generation units, high flexibility on demand side, interconnection capacity is high, and efficient power market. All together it makes the system possible to integrate such large penetration of gridl.

Furthermore, the system is interactive among players from producer, transmission system, and end users. Each part are behaving according to strict rules that clearly define each party's responsibility and obligation. These rules also help them to interact with each other in the system further to secure a healthy function.

Transmission system operator plays a critical role in terms of making a constant balanced system, and provides all players fair access to the grid possible. Price and support scheme also provide incentives to all players to take part to ensure a stable system with increasing capacity to accomondate increasing wind penetration.

In addition to it, in order to connect all of the above together, overall planning of the whole system is also considered to find out about what exactly have made Denmark as best practice in terms of highest penetration of wind power in its power system.

It is a common goal for China, or any country planning to address variation of wind in the power system to have a robust grid, felxibile generation units, high flexibility on demand side, high interconnection capacity, and efficient power market. Each country's strategy to get there may be different due to different setups, but it is still necessary to have good system structure with clear responsibilities, coordinated overall planning, efficient TSO, and coorperative market player and flexible demand side. Following the thinkings behind Danish lessons, the assessment and recommendation of Chiense power system come as follow:

6.1 Development of wind power grid integration management

6.1.1 Shortcomings of the current wind power and integration management in China

Lack of neccessary technical standards in the system, and lack of enforcement.

There is a lack of a comprehensive system with all the required standards. For instance, Technical Standards for the Design of Large Scale Wind Farm Integration was just issued, while the large-scale wind farm has been a development focus since 2006. The grid integration of wind power standards shall comprise grid integration standards, grid testing, and dispatching and operation. However, in Chinese system, The Testing Procedures on the Wind Turbines' Low Voltage Ride Through Capacity has been drafted but not yet approved. The Wind Power Dispatching and Operation Management Procedures and Wind Power Forcasting Guidlines have been drafted but not approved yet. Since China has become the biggest country for wind power development, a comprehensive set of technical standards shall be in place for current and future healthy development.

Though some of them have been established, the established standards are barely mandatory which make the enforcement of the standards difficult. For example, the Grid Code, since the first version issued in 2006, the Code was just guidance for the industry, though it is a national standard. The draft of high standard Grid Code has gained critics from domestic turbine manufacturers most of whom only have less than 7 year experience in the industry. Their arguements were the standards were too strict to reach without significant investment, and expertises. If the the that Grid Code is mandotary, many of them willhave a hard time to survive.. Thus to protect the local players, it is understandable to prolong the time before the introducing mandatory standards. However, the longer it takes, the more negative impact would be for a healthy growth of the industry, and those who can not meet the standards sooner or later will have to fade out the market.

Immature forecasting system, which needs further development.

China, compared with many developed countries like Denmark, UK, Germany, is a new comer to the wind power development. Due to the fast development that has been stimulated majorly by the favarable policy, many faciliating systems were neglected at the beginning of the development. Now, the testing system was newly established. capacity building has been provided, and regulation regarding the implmentation has been issued in 2011. However, the all the regulations nor the policies are mandatory like the aboved mentioned technical standards. While, the regulation and policy are comparatively general, that no specific guidelines have been established to facilitate with a healthy implementation of these policies.

Immature testing system, which needs further development

The testing system was newly introduced. The efforts have been focused on capacity building of key institutes, while testing experiment site was also in operation for the purpose. The system is still young, and capacity building to an institute will take a certain time before it could fully function as expected. So there is a limited capacity to do the work in the system.

Although the government has a demand that all wind farms need the equipment and system testing within two year time, the fact is that most existing wind farms, including many large scale ones, were never tested before their operation. Given the shortcomings in quality of many domestic turbines, there is a great difficulty in integrating these turbines into the grids. Furthermore, many accidents happened in the past years and many turbines had to work off-grid. This also caused lower frequency of the generated power, generating risks to the power system' stability.

Uncoordinated planning amoung key stakeholders in the system.

The previous three shortcomings mentioned reflect a problem in the whole system, which is the uncoordinated planning among stakeholders. The planning of wind farms are much faster than the planning of grid. Generally speaking, low wind penetration will have very limited impact to the grid system, and existing power reserves for the current system shall be adequate to cope with variation of wind power. However, development of large scale wind farm at a highly concentrated location or large scale wind farm installed in remote areas, where the grid infrastructure and its obsorbtion capacity is low, will cause a series of problems to the security of the power system.

First of all, uncoordinated planning between central government and local government is observed. Before 2011, the wind farms above 50 MW were approved by the central government, and those below are approved locally. There was no specific national planing regarding the development scale, time line, and locations. Wind farms were constructed in any place where there was good wind resource, As a result, the actual number of wind farms established was bigger than what central government had expected.

Second, the uncoordinated planning between government and the grid entities is obvious. Wind farms were constructed with no further consideration towards the local grid obsorbtion capacity, transmission capacity, local reserve capacity. Often the case in China, wind resources are highly concentrated in the north, northwest, northest regions which is away from the load center, and large amount of wind power can not be consumed locally, which further caused congestions in the transmission. This has directly threatened the local power system stability. Large penetration of wind power will require upgrade of grid system and infrastructure, but the upgrade of grid takes much longer time than construction of a large scale wind farm. Therefore, when if the grid situation was not considered during the planning phase of wind farm, and it indeed has difficulties in integration, this will take a much longer time to solve the problem.

Third, uncoordinated development between wind project and grid project has also deepened the integration problem. Authorities for approving wind power projects are different from those approving grid construction. Coordination between these authorities is limited. As a result, the construction of grid or upgrade of grid does not meet the requirement for integrating fast developing wind power in the area.

6.1.2 Recommendations based on lesons learnt from Danish Experience

Based on the assessment, the major problems that hinder China from increasing the integration of wind power to the system are related to 1) lack of comprehensive standards, and development of these technical standards are not in accordance with the industry development; 2) lack of testing and certification system, and development of these technical standards are not in accordance with the industry development; 3) uncoordinated planning and coordination among different key stakeholders in the industry has caused imbalanced development between transmission system and the wind farm development.

A comprehensive set of technical standards and rules shall be established as soon as possible to secure a healthy development in the sector.

These standards and rules include grid integration regulations, faciliteis and system operation. The regulations shall set by the TSO in the country in close collaboration with players in the industry. The upgrade Grid Code shall be issued soon, and country shal consider making it mandatory. The grid integration of wind power standards shall comprise grid integration standards, grid testing, and dispatching and operation. Technical Standards for the Design of Large Scale Wind Farm Integration, the large-scale wind farm, The Testing Procedures on the Wind Turbines' Low Voltage Ride Through Capacity, The Wind Power Dispatching and Operation Management Procedures and Wind Power Forcasting Guidlines shall all been drafted, approved, and issued as mandatory standard in the country.

Further development on the forcasting and testing capacity and system.

Due to the fact that forcasting of power generation and testing are just introduced to the system, the capacity in the key instititution is still to be developed further while the system for testing and forecasting shall also be developed and optimised in the up coming years.

In China, according to the wind power forcast management, the prediction error for one day ahead forcast shall be no more than 25%, and it gets to 15% in real time forcasting. Comparing with the ideal situation that only 1.5%-3% for peak load, and 3%-5% for one-day advance forcasting, there are still a great potential to improve the current methodology, and tools (EWEA, 2009). The accuracy of forcasting directly influences on the dispatching. While accurate forcasing will smoothing the way for transmission system operator to prioritise the dispatching for wind power.

Testing and certification system of equipments are basis for implementation of grid integration standards. It shall not only test whether the facilities meet the standards and rules, but also monitor the performance in the future. This will help to secure a stable power system operation for a long run. Before the system is well established, international certification shall be considered as an alternative. Internatinonal certification may have higher requirement than the existing standatards in China, which may impose additional costs in regards to manufacturing cost and again the personnel cost related to training.

A more coordinated planning and collaboration among stakeholders shall take place.

The planning between central and local government shall be coordinated. Central government shall have an overall planning, and the local government shall respect the central planning and make their plans within the framework. With the overall national plan made by the central government, the local government shall do the planning accordingly for the local situation. The plan shall be made or adjusted once a year or twice. In order to limit this, central government has decieded that all wind projects need approval from the central government now. This will certainly improve the situation and reduce the heat on the fast installation of the wind power in the country.

Coordinate planning with the grid entities shall take place. Grid planning and development goal for the wind power development are closely linked together and are critical for the integration. Given that wind farms were constructed with no further consideration towards the local grid obsorbtion capacity, transmission capacity, local spinning reserves, planning for the wind power shall be coordinated with the grid planning for the country. The production and dispatching plans shall also include wind power in the transmission system. When a large scale wind farm is approved, local transmission capacity should take into full consideration, and coordinate the work with the TSO.This will also help to improve the situation that the the transmission capacity development is behind the wind power development at specific area.

Dispatching shall be strengthened in terms of planning, with further help from installation of more flexible regulating conventional power plants.

With more accurate prediction and forcasing data, widn power production plan shall be made for annually, monthly, daily or even hours before operation. These plans will help with the establishment of dispatching management plan in the system. This also helps the TSO to give priority to wind power access to the grid at the lowest costs as well. The dispatching plan shall be made according to the prediction and forcasting plans.

In order to increasing the system flexibility, two ways can be considered. One is to improve the regulating facilities in existing or new conventional power plants. The second is to conbine the wind power to CHP plants to help with comsuming surplus of wind power by chaning them into heat. For the second solution, it is better to be implemented in the north of China where heatings are needed for more than half a year, and there are a large amount of CHP plants already. For the south, the district heating does not exist yet, however, new CHP power plants shall be considered.

Capacity building on key institutions

Capacity building on key institutions shall take place to make sure the technology, management and policy framework are always in place to secure a fast growing healthy industry. Trainings shall be provided to personnel in the key institutions, and formal education in the wind energy shall be set up in the university education. The four year wind power education has been set for bachelor degree education in Beijing in 2006.

6.1.3 Shortcomings of the current policy system in China for the well-balanced development

Current policy has played an important role to accelerate fast wind power development. However, with fixed price and limited compensation for additional costs regarding balancing, infrastructure upgrade, it does not provide incentives to encourage grid companies to purchase wind power, and provides no incentive to consumers to use energy when there is a surplus. In Denmark, due to flexible market rules, and regulations, players are highly motivated. Conventional power producers are compensated if they regulate down their power output in case wind blows harder than expected. When wind blows, it is cheap to use wind energy, and it is not profitable for conventional power, therefore CHP plant will use wind power to produce heat, and stop produce electricity when it is not profitable. A comprehensive system involving power producers, transmission and distribution system, consumers need to be established, there is no interaction amoung these entities. They are acting on their own under obligations from the law. However, to make it sustainable, a better system providing incentives for power producer to facilitate with wind power generation, for transmission and dispatching entities to make priority for wind power, and for comsumer to use wind power shall be further studied and considered. Reasons for lacking incentives are as follow:

The regulations The Energy Conservation and Power Generation Dispatching Method (Tentative) which shall help with the dispatching has played limited role in the industry now, because the guidlines are just tentative, and there has no specific implementation guidlines introduced neither. It is difficult in reality to really follow the policy due to lack of guidance.

6.1.4 Recommendations based on lesons learnt from Danish Experience

A flexible price system in Denmark is the premium system based on the power market. However, in China, the power market does not exist nation wide, and is only being tested in specific areas . The Danish example is not applicable in this context. However, a more flexible price and supporting scheme could be considered in order to provide incentives to all players to increase the penetration of wind power.

First of all, China shall adopt an environmental incentive tax on conventional power to indirectly promote the wind industry, by increasing conventional power cost and increasing the competitiveness of wind power. The system can be learnt from Danish experience, and the tax scope could include discharge of pollutants, and emission of carbon dioxide, sulphur etc.

Second, China uses FIT, which provide a fixed price. In order to consider a more flexible price scheme, quota system with green certificate may be considered. The quota system is also called Renewable Energy Portfolio Standard (REPS) or Green Certificate shceme. In the scheme, the goverment set a quota following its renewable energy deployment goal, and generator, wholesaler, consumer or broker can trade the certificates for finacial gains. To run the system, obliged actors, quantitative obligation (the obligation each actors shall take), eligible resources (scope of renewable energies to participate in the system), green certificate system, supervisors (monitoring whether the obligations are fulfilled) are needed. Penalties are applied to those who failed to deliver their obligations. The REPS has included the external costs of conventional power plants in the system, and it has increased the competitiveness of the renewable energy price. By selling the green certificate, the additional cost to produce and balancing the renewable energy are share in the whole electricity system particularly with conventional power plants. This provides incentives for the power producer directly. While, this scheme is market based, and costs are shared within the industry unbundling from the sole support from the government, which will excelerate the development of wind power or even renewable energy industry further. This scheme has been discussed in China, and many concerns are raised. These concerns are about whether the renewable energy market is ready for the scheme, whether the power producers will stop producing renewable energy power when it finishes the quantative obligation as assigned. Renewbale energy development is in deed in its early stage in China, and the market is not mature enough. However, after entering the WTO, China is ready to introduce any market mechanism in the country. The share market is a good example for it. The REPS is not a complicated market mechanism, the green certificate system is much simpler than the share market set up. About the second concern, it is certain that power producer will not stop procuding when its own quota is met, especially when a good system with proper incentives are provided.

In the dispatching operation in Denmark, wind power has the priority to dispatching. This makes wind power dispatching a priority in the plan. Thus high requirement on forcasting are needed. Proper inventives also make other conventional power plants to regulate down or up to facilitate with power system balancing in order to settle variations from the wind power. In China,Prioritize Wind Power Dispatching Management Procedures needs to be mandatory and specified further to improve the dispatching management. More implementing procedures regarding corss-province dispatching shall also be established.

7 Conclusion

China is experiencing a rapid development of wind power and the main bottlenect for it is grid integration (CWEA, 2010). China has been working on the technical side to solve the problem, however several issues need to be addressed from the institutional prospective as well.

What hinders the increasing integration of wind power in the power system in China from the institutional domestic prospective are from grid integration management, policy framework and financial incentives levels. Further more, it is noticed that the overall planning of the system has also been a major obstables in integration of wind power.

Grid integration problem in China at institutional level by looking into current power system, grid integration management, policy framework, and financial incentives.

In general, **at grid integration management,** there is lack of comprehensive standards, and development of these technical standards are not in accordance with the industry development; 2) lack of testing and certification system, and development of these technical standards are not in accordance with the industry development; 3) uncoordinated planning and coordination among different key stakeholders in the industry has caused imbalanced development between transmission system and the wind farm development.

At policy framework level, current policy does not provide incentives to encourage grid companies to purchase wind power; for TSO to make plans for dispatching, neither for other power generators to regulate down or up to help to settle the imbalances in the system. A comprehensive system involving power producers, transmission and distribution system, consumers need to be established, there is no interaction amoung these entities. They are acting on their own under obligations from the law.

At financial incentives level, current FIT applied is not attractive to provide economic incentives for wind power dispatching priority. The price is fixed at four levels, and price does not change as wind generation goes up or down. The compensation scheme for the balancing cost, and infrastructure upgrade is low, which does not provide sufficient incentives for dispatching and integration of the wind power in the system.

Lessons could be learnt from other international expriences, such the well know Danish wind power case. In general Denmark has a robust grid, felxibile generation units, high flexibility on demand side, interconnection capacity is high, and efficient power market. All together it makes the system possible to integrate such large penetration of grid. Furthermore, the system is interactive for all players - from producer and transmission system providers, to end users. Each part is behaving according to strict rules that clearly define each party's responsibility and obligation. These rules also help them to interact with each other in the system further to secure a healthy function. The transmission systems operators (TSO) play a critical role in terms of making a constantly balanced system, and providing all players a fair access to the grid possible. Price and support scheme also provides incentives to all players to take part to ensure a stable system with increasing capacity to accomondate increasing wind penetration.

First of all, a comprehensive set of technical standards and rules are in place, they are implemented by the responsible players in the system. There are technical standards and rules and market standards and rules. Second, Players' responsibility and obligations are clearly defined, they must be performed, and penalties are applied. Third and most important is the existence of the liberalized power market. On the market, the TSO is completely unboundled from the generation, which secures equal access to all players to be connected to the system. While the priority of dispatching of wind power in the system, low marginal cost wind wind power has motivated other players and reasonable compensation rules and panalties have provided motivation for the establishment of accurate forcasing, and increased flexibility of power regulation. Forth, interconnections with other four countries have helped to minimize the costs for settling the variations of the wind power. And last, flexible generating units in the system and flexibility on demand side have helped with dispatchin, and to consume surplus or wind power.

Recommendations for improving the institutional capacity in China based on the Danish lessons

The Danish practice has provided an overview of how a healthy development could look like, and it gives a good guidance on how a system should be set up. However, due to specific situation in China, where the system is not mature, and powers are not interconnected to other countries, flexibilty of generation units are limited, and no liberalized market available etc, the Danish practice can not be 100% copied in China. Recommendations for improvement are as follows:

At grid integration management:

- A comprehensive set of technical standards and rules shall be established as soon as possible to secure a healthy development in the sector.
- Further development on the forcasting and testing capacity and system.A more coordinated planning and collaboration among stakeholders shall take place.
- Dispatching shall be strengthened in terms of planning, with further help from installation of more flexible conventional power plants.
- Capacity building on key institutions shall be provided

At policy and financial incentives level:

- Policies on Prioritize Wind Power Dispatching Management Procedures needs to be mandatory and specified further to improve the dispatching management.
- Various prices and supporting scheme including environemtn tax on conventional power plants, and REPS shall be considered.

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