Energy Policy 114 (2018) 165–172

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

To what extent will China's ongoing electricity market reforms assist the integration of renewable energy?

Sufang Zhang[a,b,c,*], Philip Andrews-Speed[d], Sitao Li[a]

[a] School of Economics and Management, North China Electric Power University, No. 2, Beinong Road, Zhuxinzhuang, Changping District, Beijing, China
[b] Institute of Development Studies, University of Sussex, Falmer, Brighton, UK
[c] Research Base for Beijing Energy Development, China
[d] Energy Studies Institute, National University of Singapore, Singapore

ARTICLE INFO

Keywords:
Renewable energy integration
Electricity reform
Institutional constraint
Renewable energy curtailment

ABSTRACT

Poor renewable energy (RE) integration is posing a huge challenge to China's electricity sector. This paper examines the extent to which China's power sector reforms will assist RE integration, and issues to effective implementation. It demonstrates that a well-established electricity market could provide practical solutions to RE integration challenge. China's existing power sector regime heavily regulated by administrative planning constrains RE integration. The on-going electricity reforms (new reforms) in the country such as the transmission and distribution (T&D) tariff reform, the direct trading of electricity, among others, along with new RE policies such as full purchase of guaranteed RE generation and green certificate system, should assist RE integration in the country. However, there are a number of implementation challenges such as the intervention from local governments in direct electricity trades and the lack of a quota system for RE, among others. If these challenges are not properly addressed, the potential positive impacts of the new reforms on RE integration will be undermined. It is recommended that the central government strengthen top-level design and supervision, design and build up electricity spot markets, push forward the regional electricity markets, and facilitate the establishment of a renewable quota system.

1. Introduction

Since China's Renewable Energy Law took effect on 1st January 2006, wind and solar power have witnessed tremendous growth in both installed capacity and generation. The cumulative installed capacity increased from 1.06 GW in 2005–148.64 GW in 2016 for wind power, and from 70 MW in 2005–77.42 GW in 2016 for solar power. Meanwhile, their shares in China's total electricity generation increased from 0.065% in 2005 to 4.02% in 2016 for wind power, and from a negligible percentage in 2006 to 1% in 2016 for solar power (CNREC, 2015; CEC, 2006, 2017).

Along with this unprecedented growth, renewable energy (RE) integration has posed a serious challenge. Large-scale wind curtailment first emerged in 2009 in Inner Mongolia, and spread nationwide in 2010. During the period 2011–2015, the national average wind curtailment rate was 15% (Zhang, 2016). The key region for wind curtailment is China's 'Three Norths' Region (North China, Northeast China and Northwest China), typically in Gansu, Xinjiang, Jilin, and Inner Mongolia where wind curtailment rates were 43%, 38%, 30% and 21% in 2016 (NEA, 2017a). Total wind energy abandoned in 2015 and 2016 was 33.9 TWh and 49.7 TWh respectively (Zhang, 2016; NEA, 2017a). Solar PV curtailment emerged in 2013. The national average curtailment rate of solar PV during the period 2013–2016 was around 15%, and total solar energy abandoned was 14.19 TWh (Greenpeace, 2017). The key curtailment region for solar PV curtailment was Northwest China, including Gansu, Xinjiang, Ningxia and Qinghai (Greenpeace, 2017).

The increasing curtailment of renewable energy has aroused great concern from government agencies, the RE industry as well as academics across the country. Our literature review shows that there are a number of studies on the causes of China's wind energy curtailment or poor integration. The main factors identified by these studies include the geographical mismatch between wind- and solar-resources abundant provinces and load centers, the inflexible generation mix dominated by coal-fired power, the misalignment of transmission capacity and wind farms and large scale solar stations, the lack of energy storage, as well as the recent slow growth of power demand (Kahrl and Wang, 2015; Luo et al., 2016; Xiong, 2016; Zhao et al., 2012; Zhang et al., 2013; Yin, 2017).

Important though these physical factors are, the roots of China's

* Corresponding author at: No.2, Beinong Road, Zhuxinzhuang, Changping District, Beijing, China.
E-mail address: zsf69826313@sina.com (S. Zhang).

https://doi.org/10.1016/j.enpol.2017.12.002
Received 15 September 2017; Received in revised form 14 November 2017; Accepted 4 December 2017
0301-4215/

renewable energy curtailment lie in China's unique electricity sector regime governed by planned economy institutions that has led to the lack of flexibility in generation, operation, pricing and demand necessary to integrate renewable energy. The recent publications of Regulatory Assistance Project(RAP) and the International Energy Agency(IEA) have presented in-depth analyses on the crucial institutional challenges facing China's electricity sector. Cheung (2011) and Kahrl et al. (2011) argued that the rigidity of China's electricity sector regime runs counter to the flexibility requirement for accommodating intermittent renewables, and that it was essential for the electricity market evolve gradually to enhance RE integration. Key deficiencies relate to dispatch, pricing, ancillary services and inter-provincial trading. Kahrl and Wang (2014) held that China's approach to dispatch is one of the major reasons for the large amounts of RE curtailment. Dispatch continues to be carried out on the basis of plans developed at local level and designed to address local economic priorities, a practice which undermines the dispatch of renewable energy (Kahrl and Wang (2015). Pricing for both wholesale and retail power remains under the control of the central government, which fails to provide incentives for flexibility on the part of generators and end-users (Depuy, 2015; RAP, 2008). The application of administrative rather than economic mechanisms for the procurement of ancillary services has led to the undersupply of these services (Pollitt et al., 2017) and the influence of provincial governments over the power system has hindered the inter-provincial electricity trading (Pollitt et al., 2017; Dupuy, 2016). Building on their examination of China's grid company regulations, Dupuy et al. (2015) and Crossley (2015) concluded that the lack of incentives for the grid companies to search for solutions to reduce curtailment is another institutional reason for wind integration problem.

In summary, the existing literature on the institutional barriers to RE integration have provided an understanding of how China's current institutions and practices within the electricity sector have constrained the integration of RE. However, to the best of our knowledge, there are few studies on the likely impacts of China's new electricity market reforms ('new reforms') launched in March 2015 on RE integration in the country. This paper seeks to fill this gap. To this end, the remainder of this paper proceeds as follows: Section 2 presents a theoretical analysis of the relevance of electricity market to RE integration into the power system. Section 3 identifies the institutional barriers to the RE integration in China. The subsequent section summarizes the main elements of China's new reforms, as well as new RE integration policies pertinent to the new reforms. Section 5 examines the main challenges facing the new reforms and the new RE integration policies. Building on these analysis, policy implications are provided in Section 6. The last section presents conclusions.

2. Theoretical analysis: Relevance of electricity market to RE integration

Like any other commodity, electricity can be traded in markets, and used in any quantity. Yet, a number of features distinguish it from other commodities: it can only be stored to a very limited extent in a commercially viable way and must be consumed immediately it is generated; and, as a result, its supply must exactly meet demand at any given time across the grid. In a wholesale electricity market, commodities traded include not only energy-related commodities, namely, generation output (usually measured in megawatt-hours, MWh) but also power-related commodities (usually measured in megawatt-hours, MW) such as ancillary services. Energy can be traded in forward markets (in the form of long-term contracts), and spot markets. Ancillary services maintain the proper flow and direction of electricity, address imbalances between supply and demand, and help the system recover after a power system event.

The integration of RE into a power system increases variability and uncertainty and requires a higher level of flexibility, that is the ability on the part of the system to respond rapidly to changes in demand and supply. Numerous options for increasing flexibility are available. Flexibility reflects not just the physical systems, but also the institutional framework. The economic cost of different options for achieving flexibility varies, but institutional change may be one of the least expensive. The experience from leading RE countries such as Germany, the United States and Spain where grids are operating with 20–30% RE output (RAP, 2014) demonstrates that electricity market mechanisms can enhance power system flexibility.

2.1. Relevance of electricity spot markets to RE integration

REs are weather-dependent. Wind power can be highly variable at several different timescales (hourly, daily, or seasonally), and, in many places, more wind energy is generated at nighttime. Solar power can only generate energy during daytime. As a result, the available supply of RE at any given time is inflexible. In the absence of flexibility in power supply or in demand-side response, the instantaneous balance of electricity generation and consumption can only be maintained at the expense of grid security (frequency disorder) or economic efficiency (curtailment of wind and solar power).

Since RE generation can be forecast one day ahead with reasonable accuracy, RE is usually traded in electricity spot markets, including day-ahead, intra-day and/or real-time (also called balancing) markets. In electricity markets, the power generation schedule is determined by the outcome of energy trading resulting from the interaction of the demand curve (the purchase amount and price offered by electricity buyers) with the supply curve (the sales amount and price offered by electricity sellers). Although it has significant fixed capital costs, RE has near-zero or zero variable production costs because of the free source of fuel. Where production-based subsidies exist, this variable cost can be negative. Hence, utilizing its marginal cost advantage in an electricity market, RE can make very competitive offers and achieve priority dispatch. Meanwhile, affected by the low electricity prices resulting from RE's competitive bids, other less competitive conventional power sources have to reduce their output as much as possible. In contrast, when RE output is low, the clearing price in electricity market rises, and all types of flexible power can be stimulated to generate as much as possible.

The experience of Germany illustrates this well. On 30th April 2017, Germany set a new record in its RE deployment. On that day, 85% of electricity consumption was provided by RE, including wind power, solar power, biomass power and hydropower. This achievement was largely attributable to several factors including the electricity spot market, strong power regulations, a strong cross-border transmission network and advanced dispatching operation technology. During the period 25–30th April 2017, the highest clearing price in the day-ahead market was 0.053 euro/kWh. This appeared at 08.00 h. on 26th April when wind and solar power output was very low. The lowest clearing price was −0.075 euro/kWh at 14.00 h on 30th April (Martinot, 2015; Huang and Wang, 2017). This price mechanism in the spot market had the effect of motivating other sources, such as coal, to undertake retrofitting to enhance flexibility, to produce less when electricity prices are low and produce more when electricity prices are high.

Flexibility is also needed on the demand-side. In a real-time market, time-of-use (TOU) tariffs can guide the behavior of end-users so as to balance electricity demand and supply. In Germany and the United States, the establishment of a real-time electricity market has facilitated the promotion of price-based demand-side responses (RAP, 2014). For example, since the electricity price at nighttime tends to be lower than that at daytime because of the higher wind power output, and lower electricity load, power end-users have been guided to consume more power at night, thus promoting wind power consumption. In addition, real-time markets have promoted the development of energy storage technology. Theoretically, energy storage facilities can undertake arbitrage by making use of the spread of prices at different times. This