Rapid economic growth in China has lead to an increasing energy demand in the country. In combination with China’s emission control and clean air initiatives, it has resulted in large-scale expansion of the leading renewable energy technologies, wind and solar power. Their intermittent nature and uneven geographic distribution, however, raises the question of how to best exploit them in a future sustainable electricity system, where their combined production may very well exceed that of all other technologies. It is well known that interconnecting distant regions provides more favorable production patterns from wind and solar. On the other hand, long-distance connections challenge traditional local energy autonomy. In this paper, the advantage of interconnecting the contiguous provinces of China is quantified. To this end, two different methodologies are introduced. The first aims at gradually increasing heterogeneity, that is non-local wind and solar power production, to minimize production costs without regard to the match between production and demand. The second method optimizes the trade-off between low cost production and high utility value of the energy. In both cases, the study of a 100% renewable Chinese electricity network is based on 8 years of high-resolution hourly time series of wind and solar power generation and electricity demand for each of the provinces. From the study we conclude that compared to a baseline design of homogeneously distributed renewable capacities, a heterogeneous network not only lowers capital investments but also reduces backup dispatches from thermal units. Installing more capacity in provinces like Inner Mongolia, Jiangsu, Hainan and north-western regions, heterogeneous layouts may lower the levelized cost of electricity (LCOE) by up to 27%, and reduce backup needs by up to 64%.

© 2018 Elsevier Ltd. All rights reserved.
This paper is inspired by similar studies for large scale integration of wind and solar power in Europe [10,11], US [12,13] and Australia [14], where the analysis are implemented on a continental level, yet still with starting points of high spatial and temporal resolution wind-solar generation time series. As an emerging titan, the Chinese power sector is growing more and more renewable, but for lack of high resolution data, studies for this new regime has yet to appear. The present paper focuses on a simplified 100% renewable power system for the 31 contiguous provinces of China. Hourly time series of wind and solar power generation, as well as load covering eight years for each of the 31 provinces are generated and used in the analysis of the interconnected network, the structure of which is illustrated in Fig. 1. The time series are based on high quality weather data and have been validated to the extend that it was possible using state-of-the-art practices [15–17].

In our opinion, our primary addition to the literature is filling the gap with this unique validated high resolution dataset in the new domain and laying the ground work for other interested researchers.

The first part of the analysis consists of two ambitious baseline scenarios for the far future, in 2050, where the overall cost composition of the Chinese power system with a 100% wind-solar penetration is discussed in Section 5 before Section 6 concludes the paper. Sensitivity analysis and the issue of curtailment is discussed in Section 5 before Section 6 concludes the paper.

2. Data and methods

A simplified model of the Chinese electricity network is used for the study. Here, each province is aggregated into a single node located at its geometric center, and the connecting links represent the combined transmission capacity between neighboring provinces. Fig. 1 shows the network topology and the average loads of the individual provinces.

The hourly renewable power generation in node $n$ is composed of wind $C_{GW}^n$ and solar PV $C_{GS}^n$ generation:

$$C_n^p(t) = C_{GW}^n(t) + C_{GS}^n(t).$$

This renewable generation, shown in Fig. 2, is modeled using hourly weather data covering 2005–2012 with spatial resolution of $40 \times 40$ km$^2$. Details can be found in the supplementary material. The hourly load $L_n$ time series modeling is also described there.

The penetration $\gamma_n$ of renewable power generation for each node is defined as the ratio between average renewable generation, ignoring curtailment, and average load $L_n$:

$$\gamma_n = \frac{C_n^p}{L_n}.$$  

Furthermore, the wind-solar mix $0 \leq \alpha_n \leq 1$ is defined as

$$\alpha_n = \frac{C_{GW}^n}{C_n^p}.$$
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات