Politics of Power in China: Institutional Bottlenecks to Reducing Wind Curtailment Through Improved Transmission

By Michael Davidson

Grid-connected wind capacity has increased thirty-fold in China in the six years since the Renewable Energy Law was passed. At the end of 2012, China led the world in cumulative wind installations with 63 gigawatts (GW), while approved projects planned or under construction exceeded 44 GW (He, 2013). Despite the lead in capacity, however, China generated 30% less electricity from wind than the United States, which was a close second in terms of total installations.

Reduced capacity factors have been attributed to high amounts of forced curtailment, which reached as high as 50% in some regions last year. The causes of curtailment are manifold: high penetrations of wind in provinces far from load centers, inflexibility of the coal-heavy generation mix, and institutional barriers owing to incomplete power deregulation. To address these shortfalls and other chronic power challenges, China's grid companies propose to significantly expand long-distance ultrahigh-voltage (UHV) interconnections as well as strengthen interprovincial and intraprovincial ties. These will reportedly double wind utilization by 2020 (State Grid, 2010). However, institutional hurdles to better integrating wind, ranging from an intense debate within China over the future structure of the grid to inflexible transmission operation and pricing, threaten to delay or derail benefits of interconnection.

Overview of Current and Proposed Transmission Network

China's transmission and distribution assets were restructured in 2002 into two large grid companies, State Grid and Southern Grid, as well as a handful of separately governed provincial grids. State Grid and Southern Grid encompass six multi-provincial regional grids with various degrees of interconnection, from 500 to 1000 kV. AC transmission ties between provinces within the same region were put in place in the 1980s and 1990s, which except for the northwest at 330/750 kV, are at 500 kV (Zhou et al., 2010). Both interprovincial and interregional ties are targets of ongoing grid planning efforts.

The power grid of the future is being designed around several emerging challenges: increasing wind penetration is but one of them. In its 12th Five-Year Energy Development Plan (2011-2015), China identified geographic barriers between all of its major energy resources – coal, hydro, wind, and solar – and demand centers as a priority area for work (State Council, 2013). In the case of transporting coal from west to east, congestion concerns on road and rail are particularly pressing. "Bundling" coal, hydro, wind and solar, transmission corridors would reduce the ratio of coal to electricity exports from 20:1 to 4:1 (State Grid, 2010). In addition, increasing energy demands, particularly varying residential loads, raise concerns about local grid stability.

State Grid

The East-West Transmission Project began during the 10th Five-Year Plan (2001-2005) sought to connect energy resource regions with load centers through three sets of UHV lines: two in State Grid's service area in the north and central, and a third in Southern Grid. The northern route connects coal-rich regions, upper Yellow River hydro resources and wind power bases in the northwest to North China Grid. Using AC lines up to 1000 km, these have strengthened the synchronous grid across northern China. Three Gorges hydroelectric dam, completed in 2012 at one end of the central route, is now connected via 500 kV DC lines ranging from 1000 – 2200 km to the East China Grid and Southern Grid (Pittman & Zhang, 2010).

In wind-rich northwest, several 750 kV interprovincial lines were added in the last decade to upgrade the existing 330 kV backbone. This region, home to Gansu and Xinjiang provinces, saw high wind curtailment in both 2011 and 2012. It is also home to the majority of China's grid-connected solar installations. Instantaneous UHV export capacity to the central and northern grids reached 8.1 GW in 2012 (NWCGC, 2013). Currently, an additional tie to Xinjiang is being tested and a 7.6 GW line to the eastern grid is being planned. See grid diagrm on next page.

State Grid's UHV grid expansion plans do not end here. As early as 2004, State Grid began envisioning a massively expanded backbone network consisting of several high capacity 1000 kV AC lines crisscrossing the country. The "three-by-three" pattern of north-south and west-east lines was designed primarily as an AC grid, establishing a large synchronous grid over the entire country except the northwest. Two of the lines could help allevi-

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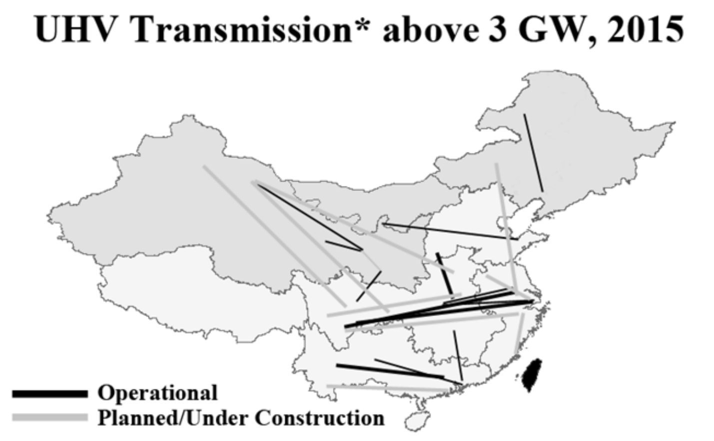
ate congestion in high wind curtailment areas to the north and northeast. State Grid promoted this "electricity superhighway" as the key solution to solve the geographic mismatch between energy resource and demand regions (21CBH, 2013). Yet wider plans of a "five-by-six" grid connecting neighboring Russia, Mongolia and Kazakhstan is proposed for 2020 (CEC, 2012).



Source: State Grid 12th Five-Year Plan, State Grid Yearbook 2011, Electricity Reliability Report 2011, Lei (2011)

Southern Grid

The southern route of the East-West Transmission Project, beginning in hydropower-rich Yunnan and coal-rich Guangxi provinces, has been built to meet surging demand in coastal Guangdong province. These lines – a mixture of AC and DC – may deliver power from west to east up to 27 GW by 2015, 58 GW by 2020, and 73 GW by 2030 (Zeng et al., 2013). Though not mentioned explicitly, these interconnections may also help integrate wind. In 2012, owing to large rainfall, wind in Yunnan was curtailed significantly for the first time (Lu, 2013).

Institutional barriers to increased transmission

AC vs. DC

The extensive remaking of China's power grid has sparked considerable controversy. As a powerful state-owned enterprise, State Grid's proposed broader synchronization through 1000 kV AC lines has rekindled concerns of overreach, adding to voices calling for further competition in the power sector. Most of the debate, however, centers on fundamental disagreements on the engineering and economic merits of a centuries-old debate: AC vs. DC.

Models put forward by the Chinese Academy of Engineering (CAE) and the Electric Power Planning & Engineering Institute (EPPEI), a government advisory body, disagree on the stability of UHV-AC lines over long distances. Experts have also attacked the UHV-AC proposal on cost grounds. For example, a handful of current and former electricity officials claimed that at more than 1500 km, sending coal is cheaper than sending electricity, undermining a key claim by State Grid (21CBH, 2013). There is, unfortunately, little to back up either claim: China's experience with 1000 kV AC is limited to a single 640 km line in operation since December 2009. The result has been delay in line construction: State Grid now expects the "three-by-three" to be completed by 2017 (Wang, 2013).

Fragmented Transmission Authorities

Assuming a vast, synchronous grid is eventually put in place, China's idiosyncratic regulatory structure would complicate attempts to utilize it properly. Regional grids are composed of provincial grids, where most dispatch decisions are made on the basis of balancing production and consumption inside borders. Provinces must craft bilateral contracts (typically, annually) stipulating how much electricity can be transmitted across each boundary; except where specific consideration for large energy or transmission projects is given by the central government, these often must net to close to zero at the end of the year. These are relics from the era of the Ministry of Electric Power, and ensure that all power companies in the province achieve their minimum generation quota.

The primary reason for creating a wide, interconnected grid is the ability to flexibly smooth out generation and load over a large number of units, but this kind of optimization is nigh impossible without centralization of dispatch and transmission. Even with the currently well-integrated northern grids and extensive long distance ties, the effective balancing area of wind may not be much larger than in their absence.

Pricing

Both investment and operation issues are compounded by non-market, semi-transparent transmission pricing principles. Grid companies are compensated mostly based on the residual between the retail and wholesale power prices, both regulated by the central government. Revenue is not subject to robust cost accounting. Between provinces, additional difficulties arise. Line losses are typically not reimbursed and neighboring provinces may have different FIT levels, complicating wind power trading (Zhao et al., 2012). Costs for large, interregional transmission projects are likely socialized as well, because the energy tariffs designed to cover them are insufficient, which may limit grid companies' willingness to make further investments on behalf of wind (Zeng et al., 2013).

Hard Road to Reform

Record curtailment in 2012 prompted a strong central government reaction, which strengthened existing regulations such as priority dispatch for renewable energy as well as laid out new reform agendas such as compensation schemes for ramping services. Together with increased pressure on grid companies to accommodate transmission requirements, these appear to have had an impact: all provinces except Hebei saw an increase in utilization hours in the first half of 2013 (CEC, 2013).

Ten years after China's power sector began deregulation, most of the challenges to reforming transmission policy are deep-seated but well understood: vested interests and centrally-administered pricing tend to dull the effectiveness of infrastructure investments. If China's central planners are to meet the 2020 target of generating 390 TWh of electricity from wind (roughly 5% of production under business-as-usual), they will have to come to a consensus on an appropriate grid structure and allocate sufficient investment. This may be much easier, however, than the difficult political reforms necessary to ensure the infrastructure is used efficiently and cost-effectively.

References

21st Century Business Herald (21CBH). (2013, June 18). "What kind of power grid will China build?" [*Zhongguo yaojian shenmeyangde dianwang*] http://www.chinasmartgrid.com.cn/news/20130618/440360-7.shtml

He, J. (2013, June 19). *China Energy News*. "Assessment of 2012 wind power construction." [*Fengdianjianshe qingkuang tongjipingjia*] http://www.ccchina.gov.cn/Detail.aspx?newsId=40513&TId=57

China Electricity Council (CEC). (2012, March 8). "Report on the electric power industry's 12th five-year plan." [*Dianligongye "shierwu" guihua gundongyanjiu zongshubaogao*] http://www.chinasmartgrid.com.cn/news/20120308/346630.shtml

CEC. (2013, July 18). "Overview of the Electric Power Industry (January – June 2013)." http://www.cec.org.cn/yaowenkuaidi/2013-07-19/106023.html

Lu, Y. (2013, Feb 4). *China Energy News*. "Idling wind turbines." [*Kongzhuang de fengji*] http://paper.people.com.cn/zgnyb/html/2013-02/04/content_1196625.htm

Northwest China Grid Company (NWCGC). (2013). "Review of State Grid northwest territory 2012 work." [*Guojiadianwanggongsi xibeibufen 2012 nian gongzuohuimou*] http://www.nw.sgcc.com.cn/new_list.jsp?pagetype=TPP_CONTENT&wbnewsid=125718&tree=3

Pittman, R. & Zhang, V. (2010). "Electricity restructuring in China: How competitive will generation markets be?" *The Singapore Economic Review*, 55 (**2**): 377-400.

State Council. (2013). *12th Five-Year Energy Development Plan*.

State Grid. (2010). *Green Development White Paper*.

Wang, M. (2013, April 11). "China's ultrahigh-voltage power grid enters expansion phase." [*Zhongguo tegaoyadianwang jinru guimohua jianshe jieduan*] http://news.xinhuanet.com/fortune/2013-04/11/c_115352242.htm

Zeng, M. et al. (2013). "Review on transaction status and relevant policies of southern route in China's West-East Power Transmission." *Renewable Energy* **60**: 454-461.

Zhao, X. et al. (2012). "Constraints on the effective utilization of wind power in China: An illustration from the northeast China grid." *Renewable and Sustainable Energy Reviews* **16**: 4508-4514.

Zhou, X. et al. (2010). "An overview of power transmission systems in China." *Energy* **35**: 4302-4312.