China's UHV Grid: Exporting Power in an Age of Overcapacity

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Since the publication of our previous ***UHV Lines: Shaping the Future of China's Power Sector Landscape*** in January 2016, China has made significant progress constructing and commissioning Ultra High Voltage (UHV) projects approved in 2015 and 2016. However, China has granted no new approvals to date in 2017.

In this edition of ***TLG on***, we update our views on China's expanding UHV grid, comment on more recent developments, including the current pause, and suggest possible new directions for future UHV projects.

Key Points

- As of March 2017, China's UHV network stretched across 18,000km; a further seven projects currently under construction will extend this out to 30,000km. The 13th Five Year Plan has overseen a major expansion of the network, but the grid still lags original plans.

- The recent apparent pause in further UHV approvals reflects several factors. First, the technical challenge of interconnecting China's vast power system cannot be underestimated. Second, UHV expansion is likely producing less benefit than originally expected due to slowing growth in electricity consumption and the near ubiquitous problem of overcapacity. Finding a suitable province that can receive surplus power has become harder as almost all provinces now have some degree of oversupply or prefer to build their own capacity to meet expected future demand in order to retain both tax revenue and employment opportunities. Ambitious renewable targets have only exacerbated this oversupply.

- Development plans for coal, hydro and renewable capacity additions all affect the prospects for new UHV projects. The cancellation of new coal capacity will likely delay associated UHV projects while renewable generation capacity may not be reliable enough to support UHV lines unaided. Further, while Sichuan and Yunnan provinces are both capable of substantial hydro additions, there appears to have been little appetite to approve new UHV lines out of these provinces. At least part of the problem lies in poor national and regional coordination. Power planning lies with different levels of authorities, and this exacerbates the problems of coordinating successful inter-provincial power flows as each province independently seeks to build out its own new capacity, reducing any need for power imports or the UHV lines that would carry it.

At the end of March 2017, China's total UHV transmission route length was roughly 19,000km, with a capacity of 94GW. Projects currently under construction will boost this to over 30,000km and 155GW.

The Build-Out Has Continued

In total, China had commissioned fourteen UHV projects by the end of March 2017. Six of these were alternative current (AC), with a total route length of about 4,000km and a combined transmission capacity of nearly 39GW. The other eight were direct current (DC) projects with a combined route length of 14,750km and a total capacity of 55.6GW. Together, these new lines had, as of the end of March 2017, brought China's total UHV transmission route length close to 19,000km, with a nationwide capacity of 94GW.

An additional seven other UHV projects are under construction.[1] Six of these (with a combined length of 10,331km and capacity of 55GW) use DC technology, and all but one are expected to be completed by the end of 2017. The DC project connecting Dianxibei (in Yunnan province) to Shenzhen will be commissioned first on a monopolar [2] basis in 2017 and will achieve bipolar status in 2018. The seventh project is an AC line connecting Yuheng in Shaanxi to Weifang in Shandong; it will be China's longest UHV AC project to date.

When all these UHV projects are commissioned, China's overall UHV transmission route length will reach over 30,000km, and total capacity will exceed 155GW. This marks a significant increase in both length and capacity over the current UHV grid (see Table 1 for a list of past and current UHV grid expansion projects). Of this total, 98GW was either commissioned after 2015 or remains under construction. This represents three quarters of the 130GW of inter-provincial and inter-regional transmission capacity planned for in the 13th FYP Electric Power Development Plan (covering 2016 to 2020).[3] Clearly China has stepped up its UHV development activity to an extraordinary degree.

Table 1: The Building of China's UHV Grid - UHV Projects Commissioned or Under Construction as of March 2017

UHV Project	Approval Date	Construction Start Date	Commission Date	AC/DC	Voltage (kV)	Length (km)	Capacity (MW)	Dominant Fuel at Source
Jindongnan-Nanyang-Jingmen	Aug-06	Dec-06	Jan-09	AC	1000	650	5000	Coal
Yunnan-Guangdong	Dec-06	Dec-06	Jun-10	DC	±800	1374	5000	Hydro
Xiangjiaba-Shanghai	Apr-07	Dec-07	Jul-10	DC	±800	1907	6400	Hydro
Jinping-Sunan	Nov-08	Dec-09	Dec-12	DC	±800	2059	7200	Hydro
Nuozhadu-Guangdong	Jul-11	Dec-11	Sep-13	DC	±800	1413	5000	Hydro
Huainan-Zhebei-Shanghai	Sep-11	Oct-11	Sep-13	AC	1000	650	6000	Coal
Southern Hami-Zhengzhou	May-12	May-12	Jan-14	DC	±800	2210	8000	Coal + Wind + Solar
Xiluodu-Zhejiang	Jul-12	Jul-12	Jul-14	DC	±800	1680	8000	Hydro
Fuzhou-Zhejiang North	Mar-13	Apr-13	Dec-14	AC	1000	603	6800	Nuclear
Huainan-Nanjing-Shanghai	Apr-14	Nov-14	Dec-16	AC	1000	780	6000	Coal
Ximeng-Jinan	Jul-14	Nov-14	Jul-16	AC	1000	730	9000	Coal + Wind
Ningdong-Zhejiang	Aug-14	Nov-14	Aug-16	DC	±800	1720	8000	Coal + Solar
Mengxi-South Tianjin	Jan-15	Mar-15	Nov-16	AC	1000	608	6000	Coal + Wind + Solar
Yuheng-Weifang	May-15	May-15	expected Jun-17	AC	1000	1049	6000	Coal
Jiuquan-Hunan	May-15	Jun-15	Mar-17	DC	±800	2388	8000	Coal + Wind + Solar

1 A further project (approved in January 2016; construction started in April 2016; expected start date in June 2017) is unusual iin being wholly within a single province, linking seven power stations to the Ximeng substation, which goes on to feed the Ximeng-Jinan UHV AC and Ximeng-Taizhou UHV DC lines. The UHV link is not used for long-distance transmission and is excluded from our discussion.

2 This means that the transmission capacity will be half of the designed capacity initially.

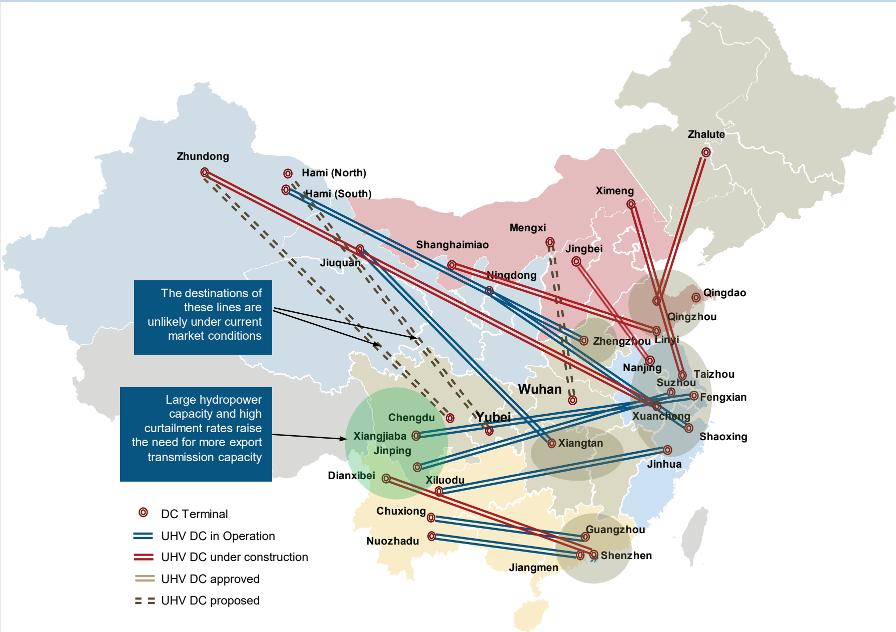
3 See NDRC and NEA, The 13th Electric Power Development Plan of China, 2016.

UHV Project	Approval Date	Construction Start Date	Commission Date	AC/ DC	Voltage (kV)	Length (km)	Capacity (MW)	Dominant Fuel at Source
Jinbei-Nanjing	Jun-15	Jun-15	expected 2017	DC	±800	1100	8000	Coal
Ximeng-Taizhou	Oct-15	Dec-15	expected 2017	DC	±800	1641	10000	Coal + Wind
Shanghaimiao-Shandong	Dec-15	Dec-15	expected 2017	DC	±800	1238	10000	Coal + Wind + Solar
Zhundong-Huainan	Dec-15	Jan-16	expected end of 2017	DC	±1100	3324	12000	Coal + Solar
Dianxibei-Shenzhen	Dec-15	Feb-16	expected bipolar 2018	DC	±800	1828	5000	Hydro
Zhalute-Shandong	Aug-16	Aug-16	expected 2017	DC	±800	1200	10000	Coal + Wind
TOTAL						30,152	155,400	

Source: TLG based on various government publishes and media reports.

The latest development of China's UHV systems is shown in Figure 1.

Figure 1: China's UHV Systems Completed, Under Construction and Proposed



Source: Government and press releases, TLG analysis.

Note: Provincial colours denote regional grids. Taupe ellipses denote major power demand load centres.

The UHV grid's rapid development still lags original 2020 targets. The problem lies in finding destination markets willing to accept the additional power.

Despite this apparent progress, however, the overall development still lags State Grid's original UHV targets for 2020.[4] Moreover, it is clearer now that several UHV projects which previously appeared highly likely to gain approvals are no longer being actively considered. For example, the NEA's approval of the third 500kV transmission corridor between Sichuan and Chongqing as a solution to Sichuan's hydropower surplus has led to the cancellation of the UHV AC line from Ya'an (Sichuan) to Wuhan (Hubei). Neither Sichuan nor Chongqing is short of power, even in the dry season. With its substantial hydropower, Sichuan is looking for export destinations, especially for during the wet season. This means that while, further to the west, Xinjiang's large generation surplus still clearly also needs export transmission, it is unlikely that Sichuan or Chongqing are the right destinations. The demand centres lie further to the east. The central challenge for UHV investment now lies in matching origins and destinations that have compatible power surplus/deficit characteristics. Given China's massive and near ubiquitous overcapacity, this matching-up process has become much more difficult.

In its project approvals, the NEA has also shown clearer intentions to avoid UHV AC projects that connect any of the six regional grids given the increased risk of cascading grid failures. The UHV AC projects previously proposed by the State Grid that connected the three regional grids of the North China Grid, East China Grid and Central China Grid have each been deferred indefinitely.

But Everything Has Changed

As noted, the biggest new challenge is to find export destinations for power from regions with surplus. As China's economic growth has slowed to a 'New Normal', overall power demand growth has also slowed. Unfortunately, the country's power system planning practices have yet to adapt to this 'New Normal', apparently sticking with its past 'Mega Project' ideology.[5]

China's GDP growth is slowing, as is the growth rate of electricity demand.

Annual GDP growth rates ranged from 9.1 percent to 14.2 percent over the ten years from 2002 to 2011, with an average of 10.7 percent. Since 2011, growth has slowed, reaching 6.7 percent in 2016: the lowest since 1991. According to China's '13th Five-Year Plan for National Economic and Social Development'[6], the GDP target for 2016 to 2020 is at least 6.5 percent. Beyond these official numbers, there is little consensus over whether the economy will continue to slow long-term, or whether it will show a mid-term recovery. For example, half of the twelve economists surveyed by Bloomberg in December 2015 projected some form of recovery in 2018; the other half did not.[7] In mid-2016, the IMF projected China's annual GDP growth would average 6.08 percent over 2016 to 2020, with growth falling to 5.9 percent in 2020.[8]

The growth of China's electricity consumption is closely correlated with its GDP growth. Electricity elasticity averaged 1.02 for the period from 2000 to 2015, but differences between years were high. Efforts to reduce China's energy intensity have seen a downward trend in elasticity over recent years, hitting 0.07 in 2015, as China continues to curb production from energy intensive industries. Demand growth fell significantly to less than 1 percent in 2015, and picked up to 5.0 percent in 2016. This compares with

4 See *TLG China Focus: China's UHV Highway Revisited*, June 2013, and *TLG on China: UHV,* January 2016, for example.

5 "Big coal power bases, big hydropower bases, big nuclear power bases, big renewable power bases", implying "big transmission projects".

6 http://www.sdpc.gov.cn/zcfb/zcfbghwb/201603/P020160318573830195512.pdf.

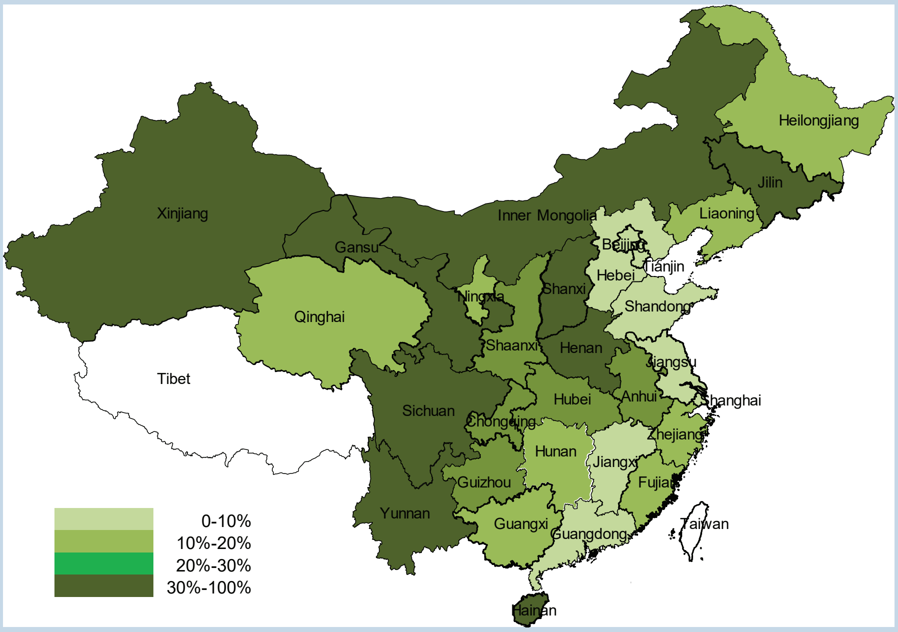
7 https://www.bloomberg.com/news/articles/2015-12-15/china-s-economic-growth-rate-is-seen-falling-until-at-least-2018.

8 http://www.scmp.com/news/china/economy/article/2003075/china-economic-growth-may-slow-59-cent-2020-imf-report.

an average of 9.6 percent over the fifteen years from 2002 to 2016. In the 13th FYP[9], annual electricity demand for 2016-20 is expected to grow at a slower pace at between 3.6 and 4.8 percent.

At this point, nearly all provinces are in a condition of oversupply (see Figure 2), a situation that will likely persist for several years given the slower demand growth outlook. In fact, we expect this oversupply situation to worsen before improving, as several large generation units are still being constructed. The most optimistic scenarios would require China to further limit new capacity additions and speed up the retirement of older thermal generating capacity, neither of which is certain. Figure 2 shows provincial supply adequacy in 2015.[10]

Figure 2: Assessment of Provincial Power Surplus Rate in 2015



Source: National Energy Administration (NEA), China Energy Yearbook and TLG research from news reports (Tibet's data are not available).

Note: The import and export of a province are based on their historical levels and existing inter-province transmission capacities. The provincial supply surplus is defined as:
Surplus rate = Theoretical local generation - Local demand + Import -Export / Local demand

Power demand and (over)supply are crucially relevant to the fate and effectiveness of China's UHV strategy.

To highlight this relevance, we considered a simple scenario in which:

- National electricity consumption in 2020 reaches 7,200TWh, an increment of 1,280TWh on 2016's 5,920TWh. This implies a compound annual growth rate (CAGR) of about 5 percent for 2016-20 (matching the 5 percent growth rate recorded for 2016).
- 13th FYP Electric Power Development Plan targets are met.
- Wind generation in 2020 is 420TWh, compared to 241TWh in 2016, and solar in 2020 is 150TWh (up from 2016's 66TWh).

We anticipate continued generation capacity additions, which will exacerbate oversupply and reduce average utilisation yet further. This may continue to undermine UHV expansion plans.

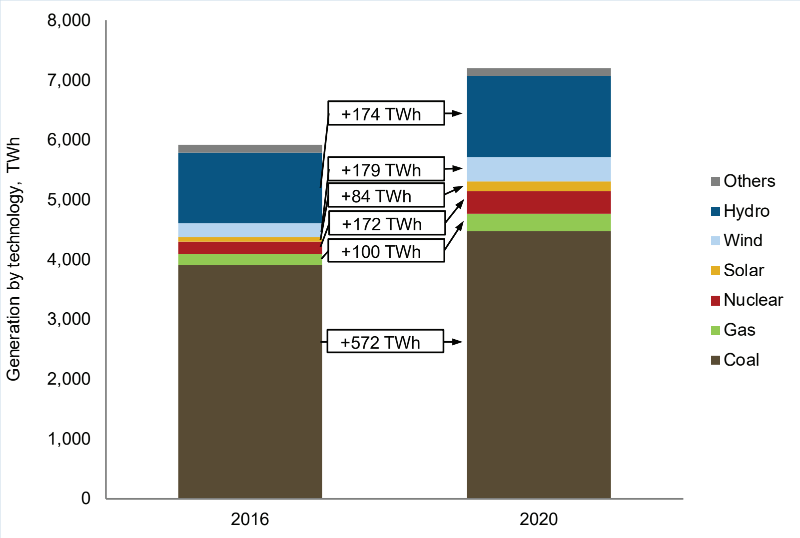
9 Specifically, this is the 13th FYP for Electric Power Development.

10 We assume the annual utilisation hours as follows: coal plants from 4200 to 5800 depending on locations and historical utilisations; gas-fired plants from 2500 to 3500 depending on gas supply sources and prices, hydro plants based on the corresponding average of historical utilisation from 2013 to 2015, wind and solar power plants based on historical utilisation and resources, and nuclear plants of 7500.

- Utilisation levels for hydro and nuclear remain at 2016 levels, while gas plants run at their historical average of 2500 hours.

Figure 3 shows the expected allocation of incremental generation by fuel type in 2020 under the assumption that the average annual demand growth is 5 percent in the period from 2017 to 2020. Coal fired generation accounts for about 47 percent: the largest share among all generation technologies. Even if coal capacity is capped at the 2020 target of 1100GW,[11] average utilisation for this new capacity will be only 3,633 hours, much worse than the already bad figure of 4165 hours for 2016.

Figure 3: Changes in Generation by Fuel Types from 2016 to 2020



Source: TLG estimates based on new generation capacities from the 13th FYP Plan for Power Industry and historical utilisation levels of generation types. The wind and solar numbers are the 2020 generation target from the 13th FYP Plan for Power Industry; other numbers (except coal) are calculated based on 2020 capacity targets and 2016 national average utilisation hours (gas is assumed to be 2500 hours and nuclear 6500 hours).

The geographical distribution of the new generation capacity also has implications for UHV planning. If 50 percent of the incremental coal generation comes from capacity built in designated coal power bases, 50 percent of incremental wind generation from the wind power bases, and 30 percent of incremental solar from the solar rich regions, then in 2020 about 413TWh will be generated in these regions, far in excess of local requirements. And yet, the problem of finding suitable and willing destination markets remains.

The combined capacity of UHV projects serving these regions commissioned by the end of March 2017 was 93GW (see Table 1).[12] If they are utilized at a reasonable capacity factor of 51 percent, or 4500 hours, then they can transfer 418TWh. To some extent, this implies that no new UHV projects for long-distance transmission are needed to accommodate likely incremental 2020 power demand. China's plan to shift coal-based generation to less developed provinces also meets resistance from coal-fired generating units located close to demand centres. Competition amongst coal generators at the sending and receiving ends of proposed lines amounts mainly to a value transfer battle between each location, as the total generation potentially available is simply not needed.

Hydropower brings an additional dimension to the outlook for UHV projects. Our scenario contains about 178TWh of incremental hydro-generation by 2020. China's untapped hydropower resources are largely located in the Southwest and Tibet, but only one (from Dianxibei to Shenzhen) of the currently under-construction UHV lines

11 At the end of 2016, the coal fired generation capacity was about 921GW.

12 Excluding the Dianxibei to Shenzhen line, which originates from a hydropower region.

A lack of proper nationally coordinated planning is hampering the effectiveness of UHV lines and of efforts to reduce overcapacity. Local governments continue to prefer to build their own capacity rather than import power through UHV lines.

targets these exporting regions, with an estimated annual transfer of 20TWh.[13] Looking forward, for environmental and developmental reasons, the best opportunities for new UHV projects are likely to be linked to hydro-electricity generation optimisation, not coal. Furthermore, with the apparent limited ability of UHV expansion to moderate the curtailment problem, the Government appears to have shifted focus on supporting newwind and solar projects nearer the eastern and central load centres, including a focus on distributed solar generation. In effect, curtailment in the most renewable resource rich regions may last longer and be worse than expected.[14]

China needs to coordinate planning at the national level to optimise generation capacity additions and grid expansion. While resource-rich locations hope to develop their local economies by investing in large infrastructure projects such as power plants and UHV lines[15], locations with only mild or occasional shortages are also better off if they attract more local generation capacity and so retain tax revenue and employment.

The example of Jiangxi in the Southeast is instructive. Jiangxi has experienced relatively fast growth in GDP and electricity demand. In 2016, Jiangxi experienced peak demand of nearly 18GW and total consumption of 118TWh. At the end of 2015, total installed capacity reached 25.3GW, of which 19GW was centrally dispatched: a tighter local supply margin than many other provinces. By 2016, a further 10GW of coal-fired capacity was under construction,[16] of which eight units were 1000MW each! These projects are to be commissioned in 2017 or early 2018. Despite available import capacity, the preferred strategy has been to develop local supply, even to the point of exacerbating the overall excess supply situation. Lack of coordinated cross-province planning and mis-aligned local vs national incentives continues to frustrate more rational power system development.

Other Shift Factors

Curbing Coal Power Will Further Reduce the Prospects for UHV Projects

In response to massive thermal overcapacity, the NEA has cancelled some projects. This may delay associated UHV lines.

China's coal fired generation capacity reached 921GW by the end of 2016, up from 880GW in 2015. National average utilisation levels for thermal capacities have been declining since 2011, falling from 5294 hours to 4165 hours by 2016.[17] According to Professor Jiahai Yuan of North China Electric Power University, about 346GW of coal power generation capacity were under construction as of September 2016.[18] This suggests that utilisation levels will continue to drop, even if demand grows at 5 percent annually out to 2020.

In January 2017, in response to this burgeoning imbalance, NEA announced the cancellation or delay (to after 2020) of about 107GW of coal power capacity across eleven provinces, including some projects currently under construction. Among those cancelled or delayed, there were 22.6GW dedicated to UHV projects in Xinjiang, Shaanxi, Inner Mongolia, Ningxia and Gansu. At the same time, China is also taking measures to limit coal consumption. China's 13th FYP Development Plan for Energy

13 http://www.cec.org.cn/yaowenkuaidi/2016-02-04/148848.html.

14 For example, according to the SGCC the UHV DC line from Hami South in Xinjiang to Zhenzhou (commissioned in January 2014) transmitted just 1.97TWh of wind and solar power in 2015, against a nameplate capacity of 35TWh at 50 percent utilisation. In the same year Xinjiang curtailed 8.8TWh of wind and solar power.

15 They often wish to continue to build coal-fired, wind and solar plants.

16 http://www.jxdpc.gov.cn/departmentsite/zdb/zdxm_3737/zdgcjsjd/201601/t20160125_154428.htm.

17 Equivalent capacity factor of 47.5 percent.

18 http://opinion.caixin.com/2017-01-17/101044847.html.

caps total national coal consumption at 4.1 billion tonnes of raw coal in 2020.[19] The central emerging challenge will be the battle for who gets allocated dispatch hours to use the available coal under the cap. The UHV grid capability is a key part of that potential calculus.

Consequently, cancellation of coal capacity additions in the remote coal resource bases will lead to associated UHV projects also being either cancelled or delayed. UHV projects for wind and solar in the North or Northwest may also be limited because UHV lines for wind and solar power alone are not nearly as cost-effective given the low availability factor and intermittent nature of the associated power available to be transmitted.

Improved Hydropower Resource Use Will Require More UHV

As noted above, hydropower has been a development priority for China's top planners, and, after coal, has been the second largest source of electricity for the country. Hydropower has played important roles in China's energy transition and poverty alleviation.

The potential for additional hydropower in China remains large but rests on projects in remote regions far from load centres. According to China's latest estimation, total exploitable hydropower in China is 660GW; by the end of 2015 just 297GW of conventional hydropower capacity had been developed. The untapped hydropower potential is mainly in Yunnan, Sichuan and Tibet, though at a much smaller scale upstream of the Yellow River in Qinghai Province could also be developed.

Hydropower is set to expand considerably out to 2020, but existing capacity is already suffering curtailment. This will likely worsen with the new capacity, and there are no firm UHV plans to help export the additional electricity.

In the 13th FYP Development Plan for Hydropower, China set out plans to commission another 43.5GW of conventional hydropower between 2016 and 2020. More than one third of this is in Yunnan and Sichuan. Yet these two provinces have experienced high rates of hydropower curtailment that have worsened in recent years. For example, Sichuan's installed capacity at the end of 2015 was 87GW, yet in 2016 peak demand was only about 29GW. In 2016 alone, 14TWh of hydropower were lost to curtailment.[20] The curtailment situation in Yunnan is even worse. Both Yunnan and Sichuan would benefit from significant export transmission capacities, yet the only UHV transmission project under construction in either province is the one from Dali (Dianxibei; Yunnan) to Shenzhen (Guangdong). No new UHV projects have been approved in Sichuan since July 2012.

There remain several potential UHV projects under bilateral discussion, initialized by Yunnan and Sichuan with NEA coordination. The major obstacle to these is finding provinces that are willing to receive the additional electricity. To a certain extent, over-capacity is ubiquitous across China's provinces and none is in need of substantial power imports.

Can China Fix the Planning Process?

From the first edition of *TLG on China: UHV*, we have stressed the importance of establishing a more disciplined and coordinated power system planning process and associated incentives not only for UHV projects but also for other elements such as generation and grid expansion. The slow approval of UHV projects; curtailment of wind, solar and hydro power; low utilisation rates of UHV projects; debates on the economics of UHV projects; and the conflicts between local and national capacity build-out and utilisation decisions all stem from inconsistent power system planning.

19 2016 consumption was 3.77 billion tonnes of raw coal (which is not washed), 4.65 percent lower than 2015's according to China's National Bureau of Statistics.

20 http://www.in-en.com/article/html/energy-2259802.shtml. Note that there are different reports of curtailed hydropower. Some estimated the curtailed hydropower in Sichuan up to 26TWh in 2016.

Overcapacity is so widespread in China that it makes finding markets willing to import additional power much more difficult. This is reflected in the lack of a clear overall plan for UHV development.

One of the key drivers of UHV technologies and applications when the UHV projects were first planned is the need for long-distance bulk power transmission from the West to the East, from the North to central and eastern provinces, and from the Southwest to the South and East. As economic growth has slowed, so this need has lessened. As previously noted, it is now difficult to find destinations for power from the North, Northwest, or Southwest, no matter whether it is wind, solar, or hydro. The provinces in the east, south, or inland centre often either already have surplus supply or prefer to build local capacity.[21] The underlying issue is that power-development planning is a provincial matter, and, again as mentioned above, is not optimised across regions or nationally. Local and sector interests are put ahead of regional and national interests.

Even in the 13th FYP Electric Power Development Plan there is no clear plan for UHV development. The source locations of surplus power are clear, but the destinations are not. The Pearl River Delta, Yangtze River Delta and Shandong were the main receiving regions in previous rounds of UHV projects. These markets are now saturated. Other possible destinations could include the central provinces such as Jiangxi, Hunan, Hubei and Henan given their demand growth, lack of energy resources, and environmental capacities.

What Next?

UHV projects are all mega-projects costing tens of billion RMB and with capacities of least five gigawatts each. In the previous era of fast economic expansion and electricity demand growth, all the parties in the UHV chain, from both the supply and demand sides and from grid companies to governments, had incentives to support UHV development. As electricity demand growth has slowed, incremental power demand has shrunk (with negative numbers appearing in some provinces in the Northwest and Southwest) and generation side competition has intensified. This has resulted in destination regions displaying only lukewarm support, and even opposition, to UHV project proposals. There has been a breakdown in support from across the UHV chain.

The drivers for additional UHV projects under current market conditions are mainly the reduction of wind, solar and hydropower curtailment in the North, Northwest and Southwest, and more general support for China's transition to a low-carbon green economy. The key is to find provinces willing to accept the electricity delivered by any new UHV project, a challenge that has become increasingly difficult given China's extreme levels of excess capacity.

Demand growth is shrinking and support for UHV lines weakening. The economics of existing UHV lines has been poorer than expected and this is further reducing enthusiasm for expansion.

The performance and economics of already commissioned UHV projects may also have raised concerns with regulators. The reasons for the low utilisation of UHV projects and the fact the UHV projects have not improved the curtailment of wind and solar power are many. They have been linked to a number of factors such as power system planning for grid and generation, technologies, policies, and conflicts of interest among government departments and industrial groups.

Together, this leads us at TLG to expect that the potential for further UHV development is limited in the near future without the intervention of political power from top levels. It is also evident that the growing extent of power system imbalances is reaching a critical level in terms of financial viability, commercial risk, and the need for major reforms to bring the overall system under control. The biggest transitions we have seen in relation to infrastructure regulation and policy occur at the point where the focus shifts from supporting investment as much as possible due to rapid growth and continuous fear of shortage to the point of recognising the rising cost of underutilised resources or poorly coordinated decisions. At this critical point, a wide range of regulatory, policy, and commercial changes become imperative. China is at that point.

21 The investment would drive local GDP, helping both manufacturing industry and employment.

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