



China's UHV Highway Revisited

State Grid Corporation of China (SGCC) has long championed an integrated, ultra-high voltage (UHV) transmission grid. Yet, SGCC's specific plans have been delayed and changed many times. For a country that has built the near equivalent of the entire UK power system almost ten timesⁱ in the past decade, it is notable that planned UHV grid development is now three or more years behind expectations.

Keeping track of China's UHV system development is difficult because public information is limited. Also, the underlying issues and challenges are complex, technically, economically and politically, so that even an "official" plan will change frequently.

Last year, at the request of Macquarie Securities, we analysed China's UHV transmission plans, timetables, and expectations. Following the release, on 1 January 2013, of China's *12th Five-Year Plan for Energy Development* we take another look in this update. We revisit the key forces shaping grid plan development priorities. We also review the status, as best we can tell, of the major proposed UHV grid elements. We have not fully factored in the recent tragic earthquake in Ya'an, though that may well delay or alter some plans going forward.ⁱⁱ

The Key Forces

The best way to make sense of the many versions of, and frequent variations to, China's UHV grid plans is to track the key drivers and impediments that influence development of China's UHV power grid. Since publishing our earlier report:

- The drivers remain unchanged:
 - An unambiguous need for long-distance large-scale transfer of power in China between fuel sources and load centres; and
 - SGCC's overall vision, which reveals itself in its transmission system design choices.
- The impediments have become clearer:
 - High cost and complexity;
 - Challenges to maintaining system security as the system expands and becomes more tightly integrated;
 - Limited experience with large-scale, integrated UHV systems;
 - Challenges within the process of evaluating and approving projects; and
 - Unresolved implications for overall regulatory structure.

Reinforcing the drivers are reports and statistics that focus on the trapped wind resources in provinces/regions such as Jilin, Inner Mongolia, Gansu and Xinjiang. Some wind generation resources in these regions are unable to export their full generation output due to transmission constraints.ⁱⁱⁱ

Existing trapped wind resources are, quite possibly, a less potent driver than one might first think. If China's total reported *national* trapped wind generation of about 20,000 GWh in 2012^{iv} could magically be gathered to a single point for transfer to major load centres, it could be served by a typical 6,400 MW UHV interconnector loaded to less than 36%^v utilization annually under favourable assumptions. In fact, China's Northeast, North, and Northwest regions accounted for only 12,300 GWh of China's total

trapped wind generation in 2011^{vi}; so the resulting loading would have been closer to 22% utilization, or less. Viewed in this light, the existing trapped wind problem is more one of overbuilding wind generation in regions without adequate transmission than underbuilding transmission to serve the wind that exists. The coordination of generation and grid planning should have been strengthened and enforced when generation was separated from the power grid back in 2002 – these issues have only more recently been addressed.

Furthermore, the risks to operational system security when integrating and augmenting the UHV grid remains one of the strongest and most persistent technical impediments to overall UHV network development. As China puts more focus on non-hydro-based renewable generation options China will face the challenge of integrating *intermittent* generation resources. When it comes to prioritising possible UHV network expansion projects, SGCC is almost certain to favour UHV elements that increase or protect system security by delivering more predictable or more easily controlled power flows.

China's complex and cumbersome grid planning and approval processes remain a major source of impediment to UHV grid expansion. Getting a UHV project through these processes requires detailed coordination between project proposers and grid operators^{vii}, local and central governments^{viii}, and local governments and grid companies^{ix}. A problem at any stage can lead to further changes in plans.

Finally, two further factors appear to be emerging as new impediments:

- First, the slow-down in China's economic growth, and its acceleration of nuclear power and other renewable projects in the eastern provinces have reduced the urgency of long-distance power transfers across China; and
- Second, the enhanced prospect of eventual on-grid pricing reform, which is needed if China is to shift more aggressively to natural gas-fired generation technologies in the future^x makes

choosing the right UHV configuration for the future problematic.

Indeed, on-grid tariff reforms could dramatically strengthen the case for gas resource development and pipeline system expansion. With further pipeline development, more gas-fired generation capacity could be located directly in the eastern and central regions, within environmental targets, further reducing the urgency for long distance power transfers to serve load in the eastern provinces.

The 12th Five Year Plan for Energy Development

China released the 12th Five-Year Plan for Energy Development (FYP-ED) at the beginning of 2013. We note that the FYP-ED was released in the *middle* of the plan period (2011-2015)—an indication of the extent of the delays that have arisen in formulating and gaining approval for the plans.

UHV expansion features prominently in the Plan, which goes on to support “two approaches to transportation of energy: coal transportation and electricity transmission, gradually relying more on electricity transmission.” Ultimately the Plan targets the use of “large capacity, high efficiency and long-distance transmission technologies to steadily improve the electricity transmission corridors from southwest energy bases to East China, Central China and Guangdong; from Ordos Basin, Shanxi, and Ximeng in Inner Mongolia to North China, Central China and East China...”

The focus on coal transportation as a key approach, particularly in the near term, makes economic sense, as we stressed in our original report. Coal transportation has been limited by available railway capacity for many years, especially in the inland provinces such as Hubei, Hunan, Sichuan and Jiangxi. Although UHV transmission of electricity is an alternative to transporting coal, rail transport of coal is both potentially less expensive over longer distances and also creates additional value because rail infrastructure supports other uses. For example, the planned Mengxi-Huazhong railway^{xi} can serve the

existing and new coal-fired plants while also supporting economic and social development along the route. So whether it is better to prioritise railway or UHV development depends on factors well beyond those pertinent to the electricity sector alone. Such complexity constitutes one of the impediments to faster UHV development.

UHV AC Projects

In March this year, SGCC set out a revised working plan for its UHV AC projects in 2013^{xii}. We comment on key elements below:

- Huainan-Zhebei-Shanghai UHV AC Project:
 - The construction of this Project has progressed well, with commissioning expected in late 2013.
- Huainan-Nanjing-Shanghai (the north part of the Loop), Zhebei-Fuzhou, Ya'an-Wuhan, and Mengxi-Changsha:
 - The Huainan-Nanjing-Shanghai project has obtained all supporting documents and approvals from the Ministries of Land and Resources, Environmental Protection, and Water Resources^{xiii}. It remains a top priority amongst potential UHV projects. Construction should start in 2013, with commissioning in 2015;
 - The Zhebei-Fuzhou UHV Project (1000kV AC) was not a top priority project last June. The change in priority for this project is linked to the rapid progress in commission and construction of the Ningde and Fuqing Nuclear Power Stations in Fujian Province. It received NDRC approval on 18 March 2013 and started construction on 11 April 2013.^{xiv} This project is projected to cost around RMB 20 billion and has a capacity of 6,800 MW in the near future and expected to be completed in March 2015;
 - The Ya'an-Wuhan UHV AC Project (the southern line of the three horizontal UHV AC lines in SGCC's long-term vision of a 3-

vertical and 3-horizontal UHV AC system) is in advanced project status and it is hoped to commence operation by 2015. This project fits with China's "National Priority" of tapping hydro resources in Sichuan and the Southwest region and with SGCC's vision of optimizing hydropower generation in Central China and coal and wind resources in North China. It also fits with targeted development of more hydropower generation capacity in Sichuan and Ya'an by 2015 (assuming no delays caused by the recent earthquake in Ya'an); and

- Mengxi-Changsha does not have advanced status yet. However, it has risen to be among SGCC's top priorities due to its role as a key part of the overall UHV AC frame grid. It will become the west vertical line, connecting the wind/coal power base with Hunan Province, of SGCC's 3-vertical and 3-horizontal UHV AC frame grid. The existing Jindongnan-Jingmen is already part of this route.

UHV AC projects that are in an advanced status of approval (such as having obtained all necessary approvals from the Ministries of Land and Resources, Environmental Protection, and Water Resources^{xiii} are marked in Figure 1 in yellow. We conclude these are the most likely projects for final approval in 2013. Additional projects for which SGCC has indicated it is seeking final approval are marked in black, though we can find no evidence that such approval can reasonably be expected in 2013. Those projects currently under construction are marked in green. Those that are in operation are marked in red.

SGCC's latest proposals reflect a number of mostly minor changes since last June, highlighting the on-going challenges of planning the overall grid architecture. For example, the proposed north horizontal transmission pathway has shifted. It is now proposed to run from Jingbian in Ningxia to Weifang, rather than from Mengxi in Inner Mongolia to Weifang. The middle horizontal line from Jindongnan to Xuzhou

had previously been planned to originate from Jinzhong in Shanxi.

Figure 1: UHV AC System under operation, construction and planned



Figure 2: UHV DC Systems under Operation, Construction and Planned



UHV DC Projects

To date, three UHV DC projects are in operation, two run by SGCC, including the recently commissioned line from Jinping in Sichuan Province to Sunan in Jiangsu Province, and one run by China Southern Power Grid. A further three UHV DC projects are under construction, including SGCC's Hami-Zhengzhou and Xiluodu-Zhexi projects and CSPG's Nuozhadu-Jiangmen project.

Figure 2 highlights the very long, point-to-point application of UHV DC technology. Each injection and

off-take point on an UHV DC line requires investment to convert AC to DC power and back again. These conversion-related costs dictate the minimum economic segment length of UHV DC technology. UHV DC technology is only economic over very long distances (over about 600 kilometres at prevailing generation costs).

The other key factor is that DC technology does not cause two otherwise separate electrical regions to become as deeply electrically integrated as does AC technology. In practical terms, DC technology allows a weaker, less secure, electrical region to connect to a stronger, more secure, electrical region, with much less risk of compromising the overall security of the stronger electrical region.

SGCC's proposed UHV DC project from Mengxi to Wuhan has received more attention recently, which may reflect projected power shortages in Hubei Province (9 GW in the dry season by 2015^{xv}) and higher GDP growth than the national average (11.3%^{xvi} in Hubei, the 9th largest provincial economy in China, versus 7.8%^{xvii} nationally) in 2012.

On the other hand, SGCC has also included a proposed UHV AC route from Mengxi to Changsha^{xviii} (not that far away from Wuhan). The UHV AC project has more interconnections along its path, and would more likely be driven by the need to strengthen the core grid. The DC project—being point-to-point—would have a similar impact as putting a local power station in Wuhan, and thus is linked to plans for further development of remote generation power resources in Inner Mongolia.

Another set of potentially competing AC and DC projects is proposed to originate in Ximeng and then head south. Such intensive development in one relatively small area raises questions of whether both of these proposed AC and DC projects can be supported simultaneously, or whether the choice will reflect an assessment of the potential risk to system security of integrating an electrically weaker region into the core grid around Beijing and Shanghai. If the UHV AC grid and the HV AC grid that supports are

still too weak, then UHV DC proposals could gain an advantage in terms of lower risks to overall system security. Alternatively, the UHV AC project could be built but then possibly not operated at full capacity until the overall transmission network is more robust – a question of overall cost-effectiveness and the timing of other UHV and HV projects.

Summary

Table 1 summarises the progress of the UHV AC and DC projects, and compares this with those projected to be commissioned by 2015 in the June 2012 Report. If SGCC's aggressive UHV AC plans^{xxix} proceed more or less on schedule from this point forward, then SGCC could complete a relatively modest "2-vertical and 2-horizontal UHV AC frame grid" by 2015 – a delay of three years and a reduction in scope from the "3-vertical and 3 horizontal" UHV core grid that SGCC ultimately seeks.

SGCC has intensified its propaganda favouring its UHV AC vision via its regional branch platforms^{xxx} and during China's 18th Congress^{xxxi}, and also through the announcements of awards achieved for its newest UHV AC technologies^{xxxii}. However, system security remains a paramount concern and significant impediment to faster UHV AC development and a relative driver of further UHV DC development.

In our view, however, further delays are likely. In addition to the rather substantial costs of each new project and the technical challenges of integrating new UHV projects into the existing grid, the scale of construction and the requirements for associated infrastructure development, relevant manufacturing capacity, and qualified human resources constitute very significant impediments.

Table 1: Updated development schedule (new developments shaded)

UHV Projects	UHV Type	June 2012 Projected Commission Year	Updated Projected Commission Year	Latest Status as of Early April 2013
Jinping-Sunan	DC	2012	2012	Commissioned
Nuozhadu-Jiangmen	DC	2013	2013	Under construction, on schedule
Xiluodu-Zhexi	DC	2014	2014	Under construction, on schedule
Hami-Zhengzhou	DC	2014	2013	Under construction, ahead of schedule
Hami-Chongqing	DC	2015	2015	No new developments
Mengxi-Wuhan	DC	n/a	n/a	New Project Appears to substantially duplicate the Mengxi-Changsha AC project
Ximeng-Nanjing	AC	2015	2016	Delayed approvals
Mengxi-Changsha	AC	2015	2016	On track for approval from NDRC in 2013, but appears to "compete" with a newly proposed Mengxi – Wuhan UHV DC project.
Ya'an-Wannan	AC	2015	2015	Ya'an-Wuhan section is advanced- but may be delayed by earthquake in Ya'an
Huainan-Zhebei-Shanghai	AC	2013	2013	Under construction, on schedule
Huainan-Nanjing-Shanghai	AC	2014	2015	Appears to be progressing through approvals, but more slowly than expected.
Fuzhou-Zhebei	AC	n/a	2015	New Project Approved on 18 March 2013 and started construction on 11 April 2013.

China's grid development delays have implications for China's longer-term power sector development strategy, and for SGCC itself. Without full access to remote resources, China must find alternatives. Those alternatives include increased potential use of natural gas via pipeline, coal via rail or nuclear. Furthermore, given significant challenges and risks inherent in developing a secure, integrated AC transmission system, restructuring of SGCC would be problematic – creating more risk of greater system integration and planning complexities. Yet, SGCC's large size remains a concern to regulators and a potential impediment to future industry reforms.

We consider on-grid tariff reform to be a key element in helping China rebalance its system and reduce dependence on remote areas. First, on-grid tariff reform can help to fix the current problems that arise because tariffs do not support investment in gas-fired generation capacity for peaking or mid-merit dispatch. Gas pipeline development tends to closely align with power sector demand, as the power sector is potentially a significant user of natural gas. Depending on the timing and design of China's evolving gas pipeline network, on-grid tariff reform would support more localized generation within the energy intensive eastern and southern provinces, reducing pressure for long-distance power imports.

China's aggressive resumption of its nuclear programme also has the potential to influence UHV grid development, as we have seen with the prioritization of the UHV projects to support new nuclear capacity in Fujian province. And, finally, increased focus on distributed generation and energy efficiency have some potential to moderate the pace of growth, supporting more robust grid development, but also buying some time for decisions to be made regarding the need for, or timing of, development of remote primary fuel resources.

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Endnotes

- i The grid-connected generation capacity in the UK is 81.7 GW at the end of 2012, according to UK's Department of Energy & Climate Change
- ii The earthquake in Ya'an may affect two UHV projects, specifically. One is the UHV DC project (Xiangjiaba-Shanghai) currently in operation, as the sending power plant of the Project in Xiangjiaba is near to Ya'an. The other is the proposed Ya'an-Wuhan UHV AC project, which is reported to have all supporting documents/permits ready for NDRC's consideration of approval.
- iii <http://cppcc.people.com.cn/n/2013/0305/c34948-20674734.html>
- iv http://zfxqk.nea.gov.cn/auto87/201303/t20130319_1587.htm
- v 20,000 GWhs divided by (6,400 MW x 8,760 hours) = 36%
- vi State Electricity Regulatory Commission (July 2012). See, http://www.gov.cn/qzdt/2012-08/02/content_2196858.htm
- vii There are requirements that a generation project approval is conditioned on grid connection and power purchase agreements. There are loopholes for renewable energy projects.
- viii NEA approves projects of 50 MW or above. So there are a lot of 49.5 MW wind projects that have been approved by provincial DRCs. Also, project proponents wish a fast approval in order to acquire the highly-valued wind resources before someone else gets it.
- ix Local governments benefit from GDP growth, which is influenced by large investments such as power and grid infrastructure. Grid companies need the support of local governments in lobbying Central Government for their grid project approvals, and in receiving local approvals for land, water and environments as well.
- x Current on-grid pricing for natural gas-based generation does not cover the associated costs.
- xi Mengxi-Huazhong (Central China) Railway (coal transportation) started construction in October 2012 and it is expected to complete by 2017. See <http://www.hnfgw.gov.cn/site/jccqzdt/33430.html> and it was accounted in Hubei Province's 12th FYP Energy Development Plan for coal-fired generation planning. See http://qkml.hubei.gov.cn/auto5472/auto5473/201302/t20130201_432830.html
- xii http://sq.js.sgcc.com.cn/art/2013/3/4/art_617_79569.html
- xiii http://paper.people.com.cn/zgnyb/html/2013-02/25/content_1202720.htm
- xiv SGCC: <http://www.sgcc.com.cn/xwzx/gsyw/2013/04/290805.shtml>
- xv See http://www.serc.gov.cn/hysj/zhxx/201208/t20120817_26126.htm
- xvi Guangdong R&D Centre for Technological Economics, <http://www.gdte.cn/showpage.jsp?infold=201303282176>
- xvii National Bureau of Statistics of China, http://www.stats.gov.cn/english/newsandcomingevents/t20130222_402874607.htm
- xviii <http://www.cc.sgcc.com.cn/DisplayNews.jsp?url=page/201303/5845503.html>
- xix http://sq.js.sgcc.com.cn/art/2013/3/4/art_617_79569.html
- xx http://www.npc.gov.cn/npc/dbdhhy/12_1/2013-03/09/content_1773004.htm
- xxi <http://smepc.xinmin.cn/mtjj/2013/03/18/1152202.html> and http://big5.xinhuanet.com/gate/big5/www.sd.xinhuanet.com/ztjn/qqlh/2013-03/15/c_115033415.htm
- xxii <http://www.sgcc.com.cn/shouye/tbxw/286873.shtml>