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From Strong to Smart: the Chinese Smart Grid and its relation with the Globe

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Abstract

Since 2004, electricity consumption in China has been growing at an unprecedented rate due to the rapid growth of industrial sectors. Serious supply shortage during 2005 had impacted the operation of many Chinese companies. Since then, China has very aggressively invested in electricity supply in order to fulfill the demand from industries and hence secure economic growth. In addition to increase generation capacity, it is equally important to improve delivery and utilization. In the last few years, the country has focused to expand T&D capacity and reduce loss by (1) uplifting transmission voltage and (2) installing high efficiency distribution transformer. Complementary to these physics-based technological improvements, Smart Grid offers the possibility to very effectively manage utilization and lead to very substantial energy saving. After US and Europe, China has also announced an aggressive framework for Smart Grid deployment. By reviewing the recent advancements of the Chinese grid system and contrasting the differences in the Smart Grid ideologies and physical constraints in US, Europe and China, this article discusses the role of Chinese electricity industry in the changing world.

Introduction: developmental issues in China

For decades, GDP growth of China remains as very remarkable. Since 2003, the Chinese economy has continuous to grow, in real GDP terms, at a rate higher than 10% (ADB 2008). Although the recent financial tsunami has negatively impacted the economic activities in the country, it is generally believed China will be the first major economy to start emerging from this global crisis (Lardy 2009).

The industrial structure of China has been evolving significantly since the 1980s. Figure 1 shows the GDP contribution of each production sector. Moving along the Industrialization path, contribution of primary production in China has decreased rapidly and that of tertiary production has picked up quickly. In addition, weight of the secondary sector has shown an upward trend in the last few years.

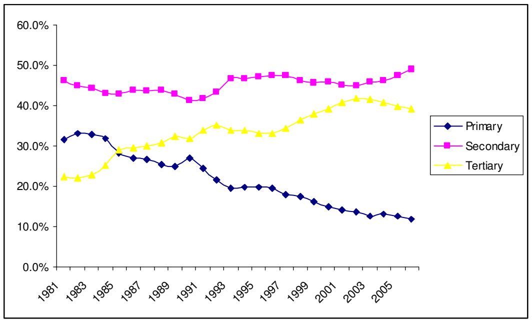

Figure 1 China's GDP composition by sector

If one further examines the components of secondary production, it is not difficult to realize that the percentage contribution of heavy industries is getting higher and higher: while the product values of heavy and light industries remained roughly as 50:50 from 1987 to 1997, the ratio moved up sharply to 70:30 in 2006 (data available from China National Statistics Bureau, www.stats.gov.cn). As such, the heavy industrial sector has become an increasingly important driver for Chinese GDP growth in recent years. Extensive production of ferrous and

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Questions and comments can be directed to the author at jerry.li@alumni.ucd.ie non-ferrous metallurgies, chemicals, non-metallic minerals and clement are instant examples.

As well as leading to extraordinary GDP growth for China, the energy intensive nature of these industries has also led to serious sustainability challenges to the country. At the first place, added values of these industries are, in general, not high. In other words, much energy is consumed to produce a relatively low GDP increment. The immediate challenge is, therefore, the availability of energy sources to sustain China's aggressive economic growth plan. Depending on the mode of development and the adoption of improvement measures, bottleneck could occur in foreseeable future (Li 2005). Besides the economic growth aspect, the environmental problems associated with heavy industries are well known – as of today, China's heavy industrial sector is one of the biggest sources of CO_2 and SO_2 in the Globe (Zhang & Liu 2007).

Mitigating these problems is extremely complex: deploying clean energies, improving energy efficiency, changing economic structure, etc are partial but crucial components of the solution. While a versatile solution is yet to identified, it is very certain that an efficiency electric grid will be an essential element of the any vital mitigation plan. This article briefly reviews some of the notable energy efficiency movements of the Chinese electric grid, followed by a discussion about the recent announcement of the "Strengthened Smart Grid"[1] plan. By contrasting with the "Unified Smart Grid" in US and the "SuperSmart Grid" in Europe, this article also explore potential collaboration across continents.

Advancements of the Chinese Electric Grid

Owing to energy-based nature of the present GDP growth, China's energy demand in the recent years has increased very substantially. As a result, China's electricity industry has been growing at the fastest rate in human history. Installed generation capacity has run from 443GW at end of 2004 to 793GW at the end of 2008. Increment in these merely four years is equivalent to approximately one-third of the total capacity of US, or 1.4 times of the total capacity of Japan. During the same period of time, power consumption has also raised from 2,197TWh to 3,426TWh.

Being the medium for delivering electricity to users, this rapidly increasing demand presents a serious challenge to the capacity, reliability and efficiency of the grid system. The problem is further complicated by the fact that generation resources and load centers in the country are far apart – majority of hydropower resources are in west, coal in northwest, but huge loadings are in east and south. It has been estimated that 100-200GW transmission capacity will be required for delivering electricity over long distance from west to east and from north to south in the next 15 years. The existing grid structure in China, which is primarily based on 500KV AC and ±500KV DC backbones, is insufficient for serving the purpose (Du 2008). Furthermore, overall T&D loss consideration is also critical because the net growth of electricity consumption will be at the magnitude of 2,000-3,000TWh in this period of time (CAE_UHV 2009). To satisfy the needs, therefore, it is necessary to establish (i) reliable transmission circuits that can deliver electric energy across extremely long distance at low loss, and (ii) an extra efficient distribution system.

Moving towards this direction, two major developments have taken place:

(a) Ultra High Voltage (UHV) Transmission

The energy demand surge in 2004 has led to numerous discussions among leaders of the electricity industry, officials, academies and even general public regarding the limitations of the existing grid. As a technology capable of carrying large amount of electric energy over long distance, UHV has been in China's scope of interest since 1986 (SGCC 2006). The dramatic increase in energy demand has served as a trigger point for rapid deployment. After vigorous investigations and verifications, it has

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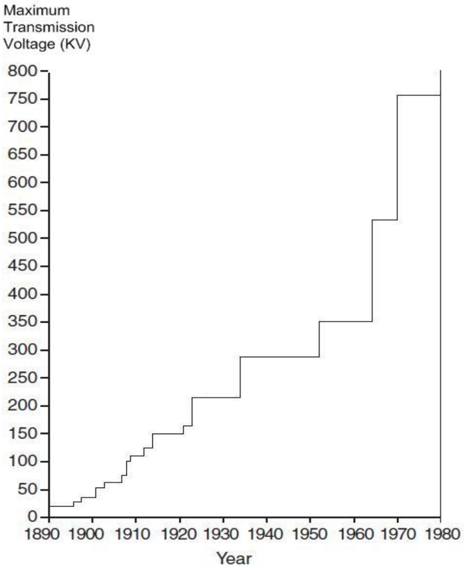
[1] Author's translation, official English translation is not available yet.

come to the consensus that developing and deploying UHV technologies are mandatory for the country (Liu 2005; Shu 2005; CAE_UHV 2009). Subsequently, the government approved a number of pioneering transmission projects using Ultra High Voltage Alternating Current (UHVAC, refers to 1,000KV) and Ultra High Voltage Direct Current (UHVDC, refers to ±800KV) technologies.

High voltage transmission is, of course, not a new idea. Since the establishment of AC transmission system in the late 18th Century, there have been continuous efforts to deploy higher transmission voltage in order to increase capacity and reduce loss (Figure 2).



Source: Casazza & Delea (2003)

Figure 2 Change in transmission voltage

In a loose sense, the electric industry entered into the High Voltage AC (HVAC) Era in the 1930s when the AC transmission voltage was approaching the 300KV mark. In about the same period of time, researchers had demonstrated the feasibility of an alternative to HVAC – High Voltage DC (HVDC) transmission. The world's first HVDC transmission line, operating at ±200KV, was built between the mainland of Sweden and Gotland Island in 1954 (ABB 2008). As of today, there are over hundred HVDC circuits installed all over the world. In case of China, seven ±500KV HVDC circuits have been installed and are currently operating. The total length of these circuits in China is approximately 7,000km.

Since 1970s, countries including US, Former USSR, Japan, Italy, Canada, have made in-depth investigations about going for even higher voltage - UHV transmission. To verify the practicality, a number of UHV circuits have been constructed. For UHVAC, 2,362km of 1,150KV circuits have been built in Former USSR, 427km of 1,000KV AC circuits have been developed in Japan. Experimental lines of various scales are also found in different parts of the world (Du 2008; SGCC 2006). However, most of these lines are currently operating at lower voltage due to insufficient power demand or other reasons (Shu 2005; Zhao & Niu 2007a; Zhao & Niu 2007b). There are fewer examples for UHVDC – although there are plenty ±500KV (or below) circuits around the world, the only operative circuit above this threshold is the Itaipu ±600KV project in Brazil.

Based on the needs to (a) efficiently transmit huge amount of electrical energy over long distance from point to point, i.e. from remote energy sources to load centers, and (b) to effectively improve grid connectivity and expand capacity, China is heavily investing into both UHVDC and UHVAC transmission. Table 1 provides a summary of the on-going projects.

Table 1 On-going UHV projects in China, 2009

	Location	**Technology**	**Capacity**	**Circuit Length**
JNJ	Jindongnan-Nanyang-Jingmen	UHVAC, 1000KV	6000 MVA	654 km
YG	Yunnan-Guangdong	UHVDC, ±800KV 12 pulses, bipole	5000 MW	1438 km
XS	Xianjiaba-Shanghai	UHVDC, ±800KV 12 pulses, bipole	6400 MW	1907 km
JS	Jinping-Sunan	UHVDC, ±800KV 12 pulses, bipole	7200 MW	2096 km

JNJ: Construction started in November 2006 and completed in December 2008. Trial run completed on January 6, 2009. The circuit is currently under normal operation.

YG: Construction started in December 2006. The lower -400kV pole test operation completed in July 2009. By the end of 2009, monopole operation is expected. Bipole operation will likely be in 2010.

XS: Construction started in December 2007. Test and commissioning target is March 2010. Bipole operation is expected to be within 2010. Commissioning panel has been established in August 2009.

JS: construction will start within 2009, expected completion is 2012.

China is serious about further deploying UHV transmission. During the 2009 International Conference on UHV Power Transmission in Beijing, it was officially announced that China will invest RMB 600 Billion (approx. USD 88 Billion) into UHV development between now and 2020. It is not an easy task to accurately quantify the benefits of this plan. For reference purposes, Du, Niu & Zhao (2007) have estimated the direct benefit of grid interconnection via UHVAC will be a saving of 100TWh per year by 2020. This will be equivalent to 20GW generation investment. Further benefits are, among others, reduction of operating cost, right-of-way need and coal consumption.

While this heavy investment in UHV could be a vital solution for China's electricity supply bottleneck, the other very important benefits for the country are comprehensively upgrade of the country's capability to design and implement the most sophisticated transmission systems, plus the acquisition of the ability to produce the most high-end electric equipment.

As far as technology availability is concerned, ABB and Siemens indeed remain as the two major suppliers of UHV components and systems. In fact, some critical parts are only available from these two vendors. This is especially true for UHVDC. To a significant degree, XS and JS circuits are based on ABB's technology framework and YG circuit is based on the Siemens' framework. In the process of developing these gigantic UHV applications, however, China has acquired unique experiences and knowledge in the system engineering perspectives – deployment plan, simulation, fault tolerance, electromagnetic environment analysis, effects of altitude, precipitation & other environmental factors, cost control, and many others. In the last few years, 321 UHV-related key technology researches have been initiated in State Grid and vast amount of research results are reported (Example: www.aeps-info.com).

The deployment of these large UHV projects has also led to remarkable advancements in UHV and HV equipment manufacturing in China. Some Chinese manufacturers are now able to supply a good range of UHV transformers, reactors, cables, circuit breakers, switchgears, bushings & insulators, converter valves, thyristors, etc. (Shu 2006; SGCC 2006; Zhang 2009). It has been reported that 91% of the equipment used in the JNJ UHVAC circuit is designed and produced locally by Chinese manufacturers (Zhang 2009). For UHVDC, the reliance on foreign supplier is higher – the target for of locally designed and produced equipment in YG circuit is 60% or higher (CSG 2007). For HVDC (i.e. ±500KV level), however, the percentage is generally higher than 70%. The deployment of UHV in China has strategically driven the Chinese equipment manufacturers to a new level of competence and competitiveness at international level. As president F. Li of XJ Electric mentioned during an interview, *"UHV deployment has provided a great opportunity for Chinese electric equipment manufacturers to raise their standard and enhance their core competence. At the time we hadn't involved in UHV, we felt that ±500KV protect control equipment and converter valves were difficult to make. After working on UHV, however, making those "regular" products has become much easier. It is not only XJ feels this way. Other manufacturers involving in UHV deployment feel the same."* (Zhang 2009).

During the course of development, China has filed for 139 key invention patents and 144 other patents in the UHV area. Combining the system engineering know-how and the advancements in equipment design and manufacturing, it is expected that China will become an increasingly active participant of international UHV projects (AEPFM 2009).

(b) Amorphous Metals Distribution Transformer

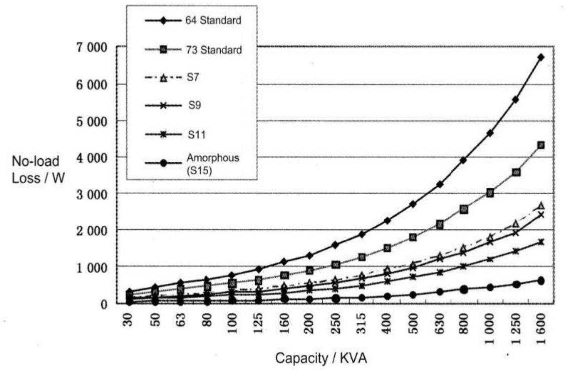
To improve the overall efficiency of the grid, distribution network is another critical area that needs to be addressed. Distribution transformer core loss, or no-load loss, is a very major component of the total T&D loss. Literatures (ECI 1999; Casazza & Delea 2003; Targosz 2005; Hu & Zhao 2007) pointed out that the loss due to distribution transformer can be over 40% of the total T&D loss in a typical modern grid, or about 3% of the total electricity generated. For the 3,426TWh consumed in China in 2008, distribution transformer loss could be close to 100TWh. The magnitude of this loss has attracted significant attentions and major economies including China, Europe, US, Japan, etc. have put more stringent requirements on distribution transformer loss in recent years (Obama, Shibata et al. 2001; Li 2001; Targosz 2005; US_DOE 2007; Topalis, Irrek et al. 2008). From efficiency standpoint, Table 2 provides a snapshot of some important standards.

Table 2 Distribution Transformer Efficiency

Size (KVA)	Japan Top-runner Scheme	US DoE	China	
			S11	S15
75	-	98.91%	-	-
100	99.16%	-	98.86%	99.10%
1000	99.55%	99.29%	99.25%	99.39%

Source: Irrek , Topalis et al. (2008)

Figure 3 shows the evolution of the Chinese distribution transformer standard. While S11 is currently the country's minimum standard for new installations, China is very aggressive in using transformers with higher efficiency.



Source: Hu & Zhao (2007)

Figure 3 Evolution of the China Distribution Transformer No-load Loss Specification

In 2005, an experimental program deploying the S15 level transformer – i.e. amorphous metal distribution transformer (AMDT), had been kicked off in Jiangsu Province. The core of AMDT is made with amorphous metal, which is a soft magnetic material with very low hysteresis loss. In a general sense, AMDT can reduce the transformer no-load loss by about 70% with respect to conventional transformer. The Jiangsu experiment has successfully verified the AMDT performance, and the technology is being recommended for large scale adoption (SGCC 2007; Li 2008).

Deploying AMDT is a relatively simple approach to significantly improve grid loss. With a simplistic assumption that load loss and no-load come in with a rough ratio of 40:60 (Irrek, Topalis, et al. 2008; Hu & Zhao 2007), about 24% of the T&D loss is contributed by distribution transformer no-load loss. As AMDT could reduce this loss by 70%, 17% of total T&D loss could be saved. For China's 2008 consumption, this saving potential would approximately equal to 40TWh, or, equivalently, the annual capacity of 8GW generation facilities.

As of today, many energy intensive provinces/cities including Jiangsu, Shanxi, Fujian, Shandong, Henan and Shanghai are massively deploying AMDT. In 2007 and 2008, about 20,000,000KVA of AMDTs have been installed in China each year, making China the world's largest user of amorphous metal materials. On August 27, State Grid and World

Bank entered into an MOU for a distribution transformer upgrade project. In this proposal, World Bank will buy the carbon credits generated by replacing 166,000 pieces of low efficiency distribution transformers in the State Grid system (SPIN 2009). Upon finalization, it is expected that this project will further boost the adoption of AMDT in China.

Similar to the UHV program, the adoption of AMDT has led to important advancements in the Chinese industry. A good number of Chinese transformer manufacturers are now equipped with the best knowledge for AMDT design and manufacturing. This is reflected by the compact size and low noise level that have been achieved. Their AMDTs have been exported to many countries and are operating on technically demanding grids.

Besides electric equipment sector, Chinese material companies have also been benefited: while Hitachi Metals is the most dominant supplier of amorphous metal, Chinese material company AT&M is catching up and will likely become another important driving force for global AMDT growth in the near future.

The "Strengthened Smart Grid"

Smart Grid has become a hot topic not only among practitioners of electricity industry but also the general public. Like UHV and AMDT, it will help to enhance reliability, supply capacity and also save loss. The principles, however, are different. In a nutshell, while UHV and AMDT are physics-based technologies that improve the components of the grid, Smart Grid can be viewed as a sophisticated control system for better managing resources and consumptions.

After US's "Unified Smart Grid" and Europe's "SuperSmart Grid", China has also announced the "Strengthened Smart Grid" plan. The announcement was made on May 21, 2009 during the 2009 International Conference on UHV Power Transmission. According to Liu, President of State Grid of China Corporation, China's Smart Grid plan can be divided into three stages (CBN 2009):

2009-2010: Planning and Testing

Major tasks at this initial stage are establishing developmental plan, setting up technical and operational standards, developing technologies and equipment, performing trial tests;

2011-2015: Construction and Development

This second stage focuses on accelerating UHV, urban and rural grids construction, establishing the basic framework for smart grid operation control and interaction, achieving the projected advancements in technology and equipment production, mass deployment;

2016-2020: Upgrading

The final stage is the completion of the whole Strengthened Smart Grid with most advanced technology and equipment.

At any standard, this plan is a very aggressive one.

While further details are yet to be announced, it is of interest to point out that the Chinese smart grid framework could be quite different from the rest of the world. This is due to the relatively primitive structure at the distribution ends, the extensive development of UHV transmission in recent years, and also the unique asset ownership and management structure in China. The next section reviews the drive forces for Unified Smart Grid and SuperSmart Grid development, followed by an exploration of the role of Strengthened Smart Grid in the new regime of electricity industry.

Diversity and Collaboration: where does it go from here?

In an interview with Chinese media, George Arnold, US National Coordinator for Smart Grid Interoperability at NIST, pointed out that even though US, Europe and China give different names to their smart grids, the contents would be the same. His further comment is that the definition for smart grid is global (EMN 2009). From the operation control perspective, Arnold's comment is sound. The actual deployment plan, however, would likely vary significantly based on the country or the region's own particular circumstances. In case of US, while the conceptual model presented in the most recent report to NIST (EPRI 2009) is generic and universal, the depth of discussions about different domains varies significantly. For example, while the user-end discussions are comprehensive, analysis about transmission is relatively light. A possible explanation is that the US system is more mature and the design orientation focuses more heavily on users and services integration (metering, renewables, electric transportation, etc.). Also, it could be affected by the fact that the US grids are operated by many individual players so it is difficult to enforce unified changes. For China, both the focal problems and the asset structure and management are different from US. Thus, the smart grid plan design could be different from several perspectives – as mentioned earlier, the very serious geographical mismatch between energy resources and load centers in China has led to the decision to deploy a highly interconnected UHV grid system. While interaction and services integration at user level are desirable, it is at least equally important to have a smart grid plan that can, in a harmonize way, fully realize the potential of UHV transmission. Furthermore, the end-users and distribution networks in China are not as mature as most developed countries, and the penetration rate of small-scale renewables are relatively low at the moment. In fact, growth of renewable energy in the country is primarily driven by large-scale projects that do not directly connected to end-users. Given these conditions, it is expected that initial stages of the Chinese smart grid plan will focus on the ability of controlling bulk electricity transfer efficiently, and then moves towards end-users and services integration in the next stages when the users are becoming more ready. In other words, it will likely start with transmission-centric control that effectively manage connectivity, and gradually enhance itself by adding discrete control and services capabilities at distribution and end-user levels. Hence, deployment plan and technology roadmap for the Chinese Strengthened Smart Grid will likely show considerable dissimilarities in relation to the US Unified Smart Grid. More details will be announced by State Grid in the near future (SGCC 2009a).

The development of smart grid in Europe is driven by multiple factors, of which some are generic and some are unique to Europe.

As in most of the developed economies, many HV grids in Europe were built a long time ago. Obsolete design and aging issues have put limitations for these grids to serve the energy needs today (EU_DGR_SES 2006).

Another remarkable factor in Europe is energy security. As a matter of fact, Europe is relatively deficient in traditional fossil energy resources and therefore has high reliance on import. In 2006, 83% of oil, 55% of natural gas, and 58% of hard coal consumed by EU were imported (Eurostat 2009). Russia is a very major supplier, and countries in Middle East and Africa are also playing various roles. When political conflicts or instabilities arise from time to time, energy supply in Europe could be seriously disturbed. In order to reduce the risk, Europe has a specific need to develop complementary energy supply. This partially explains why Europe has been running ahead of the world in terms of renewable energy deployment. The other well recognized driver is climate change. To mitigate the issue, EU has made strong commitment to reduce CO_2 emission – the European Parliament has proposed the targets of reducing EU's CO_2 emission by 30% for 2020 and 60-80% for 2050. (European Commission 2007; Battaglini, Komendantova, et al. 2008). To reach these targets, the European grid indeed needs to be "reinvented" to prepare for 100% renewable electricity in 2050 (Battaglini et al. 2009).

In response to the energy security concerns, the ENCOURAGED (Energy corridor optimisation for European markets of gas, electricity and hydrogen) project has been launched in the beginning of 2005 (EU_DGR_SES 2007). For electricity sector, the project has outlined a plan for (i) enhancing interconnectivity and hence cross-border transmission capacity within Europe, and (ii) building strong connectivity with neighbouring countries/regions including Turkey, Cyprus and Northern Africa. From both developmental and risk management perspectives, this plan is very beneficial. At the first place, good connectivity reduces the possibility of supply interruption due to particular incidents. In addition, connectivity is also crucial for tackling the intermittency of renewable generations, and effectively utilizes those large-scale installations in Europe (Battaglini, Komendantova, et al. 2008). The Northern Africa connection, on the other hand, will enable Europe to tap the huge renewable energy resources in the region. It is recommended that the transmission capacity of this Europe-Northern Africa link should reach 5GW by 2030. This conceptual framework of centralized large-scale transmission is commonly known as Super Grid in Europe.

Battaglini et al. (2009) argued that the Super Grid concept is complementary to the small-scale decentralized smart grid approach and coined the name "SuperSmart Grid" to represent the European vision of grid development.

It is interesting to point out that the vision for the smart grids in Europe and China have quite some similarities – a large capacity, highly interconnected backbone as reliable carrier, added on with decentralized interactive blocks that could conveniently serve users. Due to the difference in historical development, the sequences of deployment are different. As of today, Europe has already installed with large capacity of renewable generation, whereas China is starting off with both UHVAC and UHVDC. Despite the differences, it is clear that there are many areas of common interest including but not limited to technology development, system engineering, best practices in operation.

The global movement towards smart grid is a milestone in the history of electricity industry. While the conceptual framework of smart grid is universal, implementation plans for different regions will show certain diversities because of unique regional challenges and priorities. These diversities, on the other hand, provide the opportunity for the regions to share a wide spectrum of experiences and results, and eventually lead to an optimization at global scale. During their July visit to China, the US Energy Secretary Steven Chu and Commerce Secretary Gary Locke have stopped by State Grid and exchanged opinions about UHV grid development, smart grid cooperation, and many others (SGCC 2009b). Equally good, if not better, collaboration potential exists between Europe and China due to the similarities discussed earlier. In particular, if both Europe and China work closely together to synergize from the knowledge and experiences in high voltage / ultra high voltage transmission, technological breakthrough and economy of scale could be achieved much faster. Real large scale deployment and hence enormous energy saving and superior interconnectivity would then become feasible in Europe, Asia, and the rest of the world.

Besides economical and technological factors, there are, of course, some more barriers to overcome. For example, EU member states have not yet agreed on a EU-wide energy policy, conflicts due to diversified asset ownerships and rights, etc. Nonetheless, the recent movements towards sustainable electricity systems in China, Europe and US are opening up a new horizon for energy conservation and climate change mitigation. Undoubtedly, extensive international cooperation is mandatory in order to make this bold evolution successful.

References

ABB (2008), *HVDC: ABB – from Pioneer to World Leader*, ABB Review, Vol. 2008-4, P.59-64

ADB (2008), *Asian Development Outlook 2008*, Asian Development Bank

AEPFM (2009), *Business Implications of the Ultra High Voltage Transmission Technology development in China*, Report # CN09021, Asia Energy Platform

Battaglini A, Komendantova N, Lilliestam J, Patt A (2008), *Linking North Africa's Renewable Energy Resources to Europe – Policy Challenges*, IIASA, background paper for a scientific workshop (November 24-26, 2008), Laxenburg, Austria

Battaglini A, Lilliestam J, Bals C, Haas A (2009), *Development of SuperSmart Grids for a more Efficient Utilization of Electricity from Renewable Sources*, Journal of Cleaner Production, Vol. 17, Issue 10, P.911-918

CAE_UHV (2009), *The Necessity and Feasibility of Developing UVH Technologies in China*, SGCC Journal, Issue 2009-3, P.32-34 (In Chinese)

CBN (2009), *Completing Strengthened Smart Grid by 2020*, China Business News– June 13, 2009 (In Chinese)

Casazza J, Delea F (2003), *Understanding Electric Power Systems*, IEEE Press

CSG (2007), *Yunan-Guangdong ±800KV UHV converter station major equipment contract*, http://www.csg.cn/news/compnewscon.aspx?id=10697&ItemCode=002002000000 (In Chinese)

Du Z, Niu L, Zhao J (2007), *Developing UHVAC Transmission and Constructing a Strong State Power Grid*, Electric Power Automation

Du Z (2008), *Study on Strategic Planning of Ultra High Voltage Grid Development in China*, Ph.D Thesis, Shangdong University (In Chinese)

ECI (1999), *The Scope for Energy Saving in EU Through the Use of Energy Efficient Electricity Distribution Transformers*, ENERGIE

EMN (2009), *The Necessity of a Unified International Standard in the Smart Grid Era*, Eastern Morning News (In Chinese)

EPRI (2009), *Report to NIST on the Smart Grid Interoperability Standards Roadmap (Contract No. SB1341-09-CN-0031 – Deliverable 10)*, Electric Power Research Institute

EU_DGR_SES (2006), *Smart Grids – European Technology Platform*, EUR22040, Directorate-General for Research, Sustainable Energy Systems, European Commission

EU_DGR_SES (2007), *Energy Corridors*, EUR22581, Directorate-General for Research, Sustainable Energy Systems, European Commission

European Commission (2007), *Limiting global climate change to 2 degrees Celsius – The way ahead for 2020 and beyond,* Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Brussels: European Commission; 2007.

Eurostat (2009), *Panorama of energy - Energy statistics to support EU policies and solutions*, 2009 Edition, Eurostat, European Commission

Hu J, Zhao Y (2007), *Implementation Guide for Distribution Transformer Energy Efficiency Standard*, Chinese Standard Publication (In Chinese)

Irrek W, Topalis F, Targosz R, Rialh A, Frau J (2008), *Policies and Measures Fostering Energy-Efficient Distribution Transformers*, Project No. EIE/05/056/SI2.419632, Intelligent Energy Europe

Lardy N (2009), *Keynote Speech*, Inaugural Chinese Economic Association (Europe) Conference (July 23, 2009), UCD, Ireland

Li J (2001), *Use of Energy Efficient Transformer in Asia*, Asian Energy Conference 2001 (August 17, 2001), Hong Kong

Li J (2005), *Climate Change and Energy – Opportunities in China*, presented in Climate Change: the Business Forecast Conference (October 6, 2005), London, UK

Li J (2008), *Deployment of Amorphous Metal Distribution Transformer in China*, China Electric Power Yearbook 2008, P.793-795, China Electric Power Press (In Chinese)

Liu Z (2005), *Ultra High Voltage Grid*, Chinese Economic Press (In Chinese)

Obama A, Shibata E, Mori A, Furuya K (2001), *Suggestion for Reduction of the Second Standby Power – No Load Loss*, presented in 3rd International Workshop on Standby Power, Paris, France

SGCC (2006), *UHV Showcase*, State Grid Corporation of China, materials available at http://www.sgcc.com.cn/uhv2006/2j-showcase.shtml (In Chinese)

SGCC (2007), *State Grid of China Corporation Key Technology Listing 2006 – Group 1*, China Electric Power Press (In Chinese)

SGCC (2009a), *Commencement of the First Stage of SGCC Strengthened Smart Construction,* State Grid Corporation of China, http://wwwsgcc.com.cn/xwzx/gsyw/2009/08/204816.shtml (In Chinese)

SGCC (2009b), *US Energy Secretary Steven Chu and Commerce Secretary Gary Locke visiting SGSS*, State Grid Corporation of China, http://www.sgcc.com.cn/xwzx/gsyw/2009/07/201703.shtml (In Chinese)

Shu Y (2005), *Development and execution of UHV power transmission in China*, China Power, Vol. 38, No. 3, P.12-16 (In Chinese)

Shu Y (2006), *Stimulating Electrical Equipment Manufacturing Industry via Developing UHV Grid*, China Industrial News – August 24, 2006 (In Chinese)

SPIN (2009), *State Grid Corporation of China and World Bank signed MOU for Grid CDM Project*, State Power information Network, http://www.sp.com.cn/dlyw/gndlyw/200908/t20090828_134822.htm (In Chinese)

Targosz R (2005), *The Potential for Global Energy Savings from High Efficiency Distribution Transformers,* European Copper Institute

Topalis F, Irrek W, Targosz R, Frau J (2008), *Potentials & Impacts of Energy Efficient DTs*, Intelligent Energy Europe (31st January, 2008), Brussels, Belgium

US_DOE (2007), *10 CFR Part 431 - Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule*, Department of Energy, USA

Zhang X (2009), *Riding on the UHV Express: advancements of the electrical equipment manufacturing industry*, SGCC Journal, Issue 2009-3, P.50-51 (In Chinese)

Zhang Y, Liu D (2007), *Study on city heavy modality problems caused by heavy industry*, Journal of Qingdao Technological University, Vol. 28, No. 3, P.118-121 (In Chinese)

Zhao J, Niu L (2007a), *Research and Application of UHVAC Transmission Technologies in Japan Part I*, Proceedings of CSU-EPSA, Vol. 19, No. 1, P. 28-33 (In Chinese)

Zhao J, Niu L (2007b), *Research and Application of UHVAC Transmission Technologies in Japan Part II*, Proceedings of CSU-EPSA, Vol. 19, No. 4, P. 1-6 (In Chinese)

Biography

Jerry Li graduated with B.Eng in electronic engineering from Hong Kong Polytechnic University and M.Sc in Finance from University College Dublin, National University of Ireland. His professional experiences cover engineering, marketing, corporate investments, mergers & acquisitions and general management in multinational companies including AlliedSignal / Honeywell, Groupe Schneider and National Semiconductor. Currently, he is the Asia Pacific Vice President of Hitachi (Metal Division) and is responsible for power sector business. Jerry has close working relationships with international organizations and government authorities related to energy policies. He also actively participates in non-profit oriented organizations in the sector. In addition to his professional exposures, he is working towards his doctoral degree on energy efficiency issues in University of Newcastle. Jerry is a certified Financial Risk Manager (FRM) and a member of Association of Energy Engineer (AEE).