Smart Grid and Power Quality Development in China

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Monday May 19th, 2014
Chiang Mai, Thailand
Power Grids in China

Key Statistics
- Generation capacity: ~1,145GW
- Peak load: ~669GW
- Annual energy consumption: 4,959TWh
- Ultra-High Voltage transmission: ±800kV/±1100kV DC, 1000kV AC
- Distribution max voltage: 110kV
- Two large trans. owers: SGCC and CSG

Challenges
- Rapid economic growth
- Imbalanced generation/demand distribution
- Pressures over sustainability and environment
State Grid Corporation of China Profile

Geographic coverage
• 88% of China’s territory

Customers
• Over 1.1 billion (83%) of China’s population

Core business
• Power grid construction and operation

Overseas business
• National Grid Corporation of the Philippines
• National Energy Network of Portugal
• SG Brazil Holdings
• South Australia’s ElectraNet

Fortune Global 500
• 7th in 2013
Overview of CSG

Date of Establishment
• December 29, 2002

Services
• Power transmission, distribution, and supply in Guangdong, Guangxi, Yunnan, Guizhou, and Hainan, a total area of 1.02 million square kilometers

Population Served
• A total population of 230 million, accounting for 17.8% of the national population

Assets
• As of the end of 2013, 562.9 billion yuan, ranked 134 in Fortune Global 500
Strong & Smart Grid

- Smart grid is a highly integration of strong network and smart technologies
- Large scale access of clean energy such as wind power and solar power, etc.
- Realize two way interaction with users
- Enhance flexibility and security of power grid

A New Modernized Power Grid
Strong & Smart Grid Initiative

UHV AC & DC Transmission Projects:
- Highest operating voltage
- Longest transmission distance
- Largest transmission capacity

Smart Grid:
- Automated, ICT-based, interactive
- Covering Generation, Transmission, Transformation, Distribution, Consumption and Dispatching

UHV AC & DC projects in operation

National Wind/Solar/ Energy Storage/ Smart Grid Demonstration Project
Smart Grid Pilot Projects

- Since 2009, launched 313 pilot projects
- 269 pilot projects completed so far
- 32.6 billion Yuan invested totally

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (mil. Yuan)</td>
<td>3,900</td>
<td>13,230</td>
<td>8,470</td>
<td>10,330</td>
<td>230</td>
</tr>
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</table>
Development of Renewable Energy

Wind Energy Distribution

Wind Power Planning

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-scale wind power bases</td>
<td>80GW</td>
<td>140GW</td>
</tr>
<tr>
<td>Offshore wind power</td>
<td>5GW</td>
<td>30GW</td>
</tr>
<tr>
<td>Distributed wind power</td>
<td>5GW</td>
<td>15GW</td>
</tr>
</tbody>
</table>

Solar Energy Distribution

Solar Power Planning

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-scale PV power</td>
<td>10GW</td>
<td>20GW</td>
</tr>
<tr>
<td>Distributed PV power</td>
<td>10GW</td>
<td>27GW</td>
</tr>
<tr>
<td>Solar thermal power</td>
<td>1GW</td>
<td>3GW</td>
</tr>
</tbody>
</table>
Why Ultra-High Voltage Transmission in China?

- The imbalanced allocation of generation resources and consumption centers
- **North China & West China:** 2/3 coal, wind, solar energy
- **Southwest China:** 4/5 hydro energy
- **East China & Central China:** 2/3 energy demand
- Distance: 1,500-3,000km
- Forming large scale, long distance, large capacity transmission pattern
UHV DC Technology

- Cost efficient and technically mature
- Capable of long distance delivery of renewable energy
- Effective backup for energy security
- Environmentally friendly
Southern Hami-Zhengzhou UHV DC Project

- World’s largest and longest UHV DC project
- The first “Xinjiang power transmission” UHV DC project, transmits thermal power bundled with wind power
- Providing an effective solution for hazy weather in China

Main Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>±800kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>5,000A</td>
</tr>
<tr>
<td>Rated capacity</td>
<td>8000MW</td>
</tr>
<tr>
<td>Transmission distance</td>
<td>2,210km (1,373 miles)</td>
</tr>
<tr>
<td>Commercial operation</td>
<td>Jan 27, 2014</td>
</tr>
</tbody>
</table>
Europe:
Energy challenges
(Stem from emission reduction, nuclear phasing out and sustainable growth)

Central Asia:
Energy resources
(Coal, gas, hydro, wind, solar)

EHV/UHV AC to bring together energy sources, UHV DC for Asia-Europe intercontinental transmission:
Technical feasibility
Economic feasibility
Direct transmission

[Map showing direct transmission route between countries, marked as 5,365km and ±1100kV DC Converter Station]
Future Outlook

- With European Supergrid:
  Renewable Electricity → UHV Power Grid → European Supergrid → Countries in Europe
- With breakthroughs in energy efficiency, new materials and energy storage:
  Transmit massive renewable power from Central Asia, Middle East, and North Africa to Europe
Microgrid Pilot Project

Project Overview
• Location: Beihai city, Guangxi province
• Supported by National High-Tech R&D Program (863 Program)
• Power supply using microturbines, rate capacity is 8MW
• Peak load in 2009 is 2.1MW, and more than 15MW in 2013

Main Objectives
• Construct a pilot project of island microgrid with multiple types of distributed energy
• Develop isolated island microgrid demo system
• Develop the integrated energy utilization mode including wind, solar, natural gas and marine energy
• Improve the reliability of power supply of islands
Microgrid Pilot Project (Cont’d)

Sketch map of the new power system in Weizhou Island
Multi-terminal VSC-HVDC for wind farms integration

Wind farms in Nan’ao island
- By 2011, total capacity is 143MW
- In 2013, more than 25MW;
- In 2015, offshore 50MW(Tayu)

Multi-terminal VSC-HDVC
- Three sending converter stations, one receiving inverter station
- Rated DC voltage: ±160kV
- Rated capacity: 200MW
- Distance: 20km
- Commissioning: 2013
For the Pearl River Delta region, CSG has constructed many HVDC transmission grid. Therefore, dynamic reactive power demand and voltage stability are paramount to ensuring the supply of electrical energy to this region.

The STATCOM can enhance transmission system control, reliability and operation, and improve system power quality.

Connected to the 35kV bus instead of the 10kV bus to reduce the output current required and the losses.

The construction and operation of the ±200Mvar STATCOM project has resulted in remarkable and comprehensive benefits.
STATCOM operation curve after lightning fault
EV Charging and Battery-swap Service Networks

- At the end of 2013, SGCC has built 400 charging and battery-swap stations and 19,000 charging spots
- By 2012, CSG has built 18 charging station and 3,229 charging spots

Intercity interconnection project between Suzhou, Shanghai and Hangzhou
Tesla in China

- Delivered the first cars in China at customer events in Beijing and Shanghai last month
- Shanghai government's announcement that Model S drivers in the city will be entitled to free license plates
- Tesla plans are to install a large supercharger network in China
Tesla’s Supercharger Network in China

Open now

Coming soon
SMEPC PQ Monitoring and Management System

Shanghai Municipal Electric Power Company (SMEPC) at a glance

- SMEPC is a branch company of SGCC
- SMEPC provides transmission and distribution in Shanghai
- Generation capacity: 12GW
- Number of substations: 941
- Shanghai population: 16 million
- Peak load (2013): 29,400MW
- Customer number: over 8.5 million
Overview of PQMS

- PQ Monitor installation begun in 2007
- PQMS extent as of December 2013
  - PQ monitors: 368
  - Other sensors including SCADA and smart meter: 3,770
- Monitored Voltages:
  - 380V to 500kV
- Monitor Locations include the Shanghai Expo park and Disney resort
上海市电力公司

上海电网电能质量监测简报

2009. 02

1. 监测点

根据系统在监测中心，监测报告如图所示。共接入86个监测点，下表为部分监测点列表。

<table>
<thead>
<tr>
<th>监测点</th>
<th>城区</th>
<th>农村</th>
<th>工业</th>
<th>商业</th>
<th>住宅</th>
<th>交通</th>
<th>城市</th>
<th>乡村</th>
<th>住宅</th>
<th>商业</th>
<th>工业</th>
<th>城市</th>
<th>乡村</th>
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<th>城市</th>
<th>乡村</th>
<th>住宅</th>
<th>商业</th>
<th>工业</th>
</tr>
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<tbody>
<tr>
<td>基准点</td>
<td>178</td>
<td>134</td>
<td>94</td>
<td>172</td>
<td>74</td>
<td>48</td>
<td>35</td>
<td>26</td>
<td>126</td>
<td>24</td>
<td>53</td>
<td>3</td>
<td>208</td>
<td></td>
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</tr>
</tbody>
</table>

2. 电能质量监测

电能质量监测点如图所示。根据系统在监测点监测结果，系统需进行相关调整。监测点分为如下类型：

- 监测点：
  - 监测点1: 城区
  - 监测点2: 农村
  - 监测点3: 工业
  - 监测点4: 商业
  - 监测点5: 住宅
  - 监测点6: 交通
  - 监测点7: 城市
  - 监测点8: 乡村
  - 监测点9: 住宅
  - 监测点10: 商业
  - 监测点11: 工业

- 监测点类型：
  - 监测点类型1: 高压
  - 监测点类型2: 低压
  - 监测点类型3: 雷电
  - 监测点类型4: 火灾

- 监测点数据：
  - 监测点数据1: 电能质量数据
  - 监测点数据2: 电能质量数据
  - 监测点数据3: 电能质量数据

- 监测点列表：
  - 监测点列表1: 电能质量数据
  - 监测点列表2: 电能质量数据
  - 监测点列表3: 电能质量数据

- 监测点结果：
  - 监测点结果1: 电能质量数据
  - 监测点结果2: 电能质量数据
  - 监测点结果3: 电能质量数据
Expo 2010 Shanghai China

- From May 1 to October 31, Shanghai World Expo was the largest World's Fair site ever at 5.28 square km
- Participant countries: 192 countries
- Participating International Organizations: 50
- By the end of the expo, over 73 million people had visited
PQ Monitoring and Analysis at Shanghai Expo Park

- Monitoring Shanghai Expo Park substation using 76 PQ monitors
  - Monitored Voltages: 10kV to 220kV
- Employing visual display monitoring center
- Providing steady-state and transient PQ measurement, statistics and analysis

Monitored locations at expo site

<table>
<thead>
<tr>
<th>Name</th>
<th>EHV</th>
<th>Urban</th>
<th>City East</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitors</td>
<td>37</td>
<td>13</td>
<td>28</td>
<td>78</td>
</tr>
<tr>
<td>Substations</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>19</td>
</tr>
</tbody>
</table>
Power Quality Visualization Analysis Software
Specific Problem after Expo Opened

- **Harmonic Distortion**
  - The Ruijin 110kV bus station in May 2010 showed a voltage total harmonic distortion voltage passing rate of 72.11%. The 11th harmonic voltage was 83.76% compliant.

- **Voltage Fluctuation Plt**
  - The Puminglu 10kV substation in May 2010 showed Plt compliance rate of 66.67%.
The 11\textsuperscript{th} Voltage Harmonic at Ruijin Substation

![Graph showing voltage harmonic levels at Ruijin Substation from 2010-6-25 to 2010-6-29]
Solar Power Monitoring at 10kV Substation

Puminglu 10kV substation Plt trends
Voltage Sag Propagation

<table>
<thead>
<tr>
<th>Voltage Level</th>
<th>Events</th>
<th>Sag mag</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4kV</td>
<td>1</td>
<td>85.7%</td>
</tr>
<tr>
<td>10kV</td>
<td>45</td>
<td>70.8%~89.4%</td>
</tr>
<tr>
<td>35kV</td>
<td>46</td>
<td>65.9%~89.2%</td>
</tr>
<tr>
<td>110kV</td>
<td>21</td>
<td>62.7%~87.4%</td>
</tr>
<tr>
<td>220kV</td>
<td>39</td>
<td>57.1%~85.8%</td>
</tr>
</tbody>
</table>

Events Time: March 27, 2011 11:49:02
Cause: 960 meters away from the Yanghang substation, Gaohang 5109 transmission line phase A foreign short leading to discharge
PQView Users in China

SGCC
- Beijing Electric Power Company
- Hebei Electric Power Company
- Henan Electric Power Company
- Shanxi Electric Power Company
- Shandong Electric Power Company
- Shanghai Municipal Electric Power Company
- Fujian Electric Power Co., Ltd.
- Jibei Electric Power Company

CSG
- China Southern Power Grid
- Guangdong Power Grid
- Guangxi Power Grid
- Yunnan Power Grid

CLP Power Hong Kong

Macau Electric Company (CEM)
The Key Technologies of Smart Substation

- Data collection, transmission, sharing and utilization through high speed communication
- Equipment life cycle management: condition monitoring → fault diagnosis → condition based maintenance
- Advanced applications: Automatic control, smart regulation, co-operation...

Smart substation: Digital substation + Condition monitoring + Advanced applications
Power Quality Monitoring for Smart Substation

**HIGHLIGHTS**

- ECT/EVT, MU and PQ monitor sampling: 512 samples/cycle
- PQ Monitor modeling based on IEC 61850 standard:
  - Real-time measurements: MMS/Logical Nodes
  - Historical data (Trend) and Event data: IEEE Std 1159.3 PQDIF/IEC 61850 file services
Thank you for your attention!