Introduction to Power Supply Reliability Enhancement of CSG

Jian-Guo Yu

September, 2014
1. Overview of China Southern Power Grid

2. Actions for Power Supply Reliability Enhancement of CSG

3. Further Solutions for Power Supply Reliability Enhancement of CSG
Part I
Overview of China Southern Power Grid
China Southern Power Grid Co. Ltd (CSG) was established on 29th December, 2002.
The business of CSG covers five provinces, i.e. Guangdong, Guangxi, Yunnan, Guizhou and Hainan. Also it is interconnected with Three Gorge hydropower station, Hong Kong, Macao and other areas related. It supply electricity to 230 million people over 1.02 million square kilometers.

CSG has been one of the global top 500 enterprises for 9 years successively. It ranked the 115th in 2014.
By the end of 2013

- Total installed capacity: **225.39GW**
  - Thermal: 52.8%
  - Nuclear: 2.8%
  - Wind: 0.7%
  - Others: 0.1%
  - Hydro: 42.1%
  - Pump & Storage: 1.5%

- The voltage of 110kV and the above transmission line: **18,267km**
- The voltage of 110kV and the above number of substations: **3,842**

- ±800kV DC:
  - 2787km, 2%
- ±500kV DC:
  - 5,498km, 3%
- ±500kV (including ±500kV):
  - 118, 3.07%
- 500kV:
  - 33,849km, 19%
- 220kV:
  - 59,216km, 32%
= 110kV:
  - 81,331km, 45%

Peak Load of CSG and Each Province by the end of Aug, 2014, (GW)

- CSG Total: **136.14**
- Guizhou: **17.1**
- Yunnan: **16.57**
- Hainan: **3.44**
- Guangxi: **16.36**
- Guangdong: **90.73**

Number of Customers

- Guangzhou: **5.17E+06**
- Shenzhen: **2.64E+06**
- Hainan: **2.20E+06**
- Guizhou: **2.50E+06**
- Yunnan: **2.01E+06**
- Guangxi: **2.81E+06**
- Guangdong: **1.63E+07**
- CSG Total: **3.35E+07**
8 AC + 8 DC from West to East

- Long Distance
- Ultra High Voltage
- Bulk Capacity
- Hybrid Operation of AC/DC

Data: Until Aug., 2014

Incoming side total: 35.3GW

Three Gorge

Guangdong

Guangxi

Guizhou

Yunnan

Hainan

8.9GW

18.8GW
Assets of distribution network accounts for 32% of CSG.

(CSG Total original value of assets : 700 Billion RMB)
## Overview of CSG Distribution Network

(Total equipment quantity + electricity quantity by the end of 2013)

<table>
<thead>
<tr>
<th>Province</th>
<th>Number of feeder</th>
<th>Length of line/km</th>
<th>Number of transformer</th>
<th>Total capacity of transformer /MW</th>
<th>Electricity /billion kWh</th>
<th>Load/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangdong</td>
<td>23665</td>
<td>219622</td>
<td>455562</td>
<td>175829</td>
<td>473</td>
<td>84073</td>
</tr>
<tr>
<td>Guangxi</td>
<td>5589</td>
<td>103353</td>
<td>164326</td>
<td>34127</td>
<td>100.2</td>
<td>16535</td>
</tr>
<tr>
<td>Yunnan</td>
<td>8253</td>
<td>157858</td>
<td>243326</td>
<td>40414</td>
<td>109.3</td>
<td>17524</td>
</tr>
<tr>
<td>Guizhou</td>
<td>6058</td>
<td>139453</td>
<td>195338</td>
<td>32113</td>
<td>100.9</td>
<td>17318</td>
</tr>
<tr>
<td>Hainan</td>
<td>1687</td>
<td>27277</td>
<td>43098</td>
<td>10367</td>
<td>19.7</td>
<td>3164</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>5127</td>
<td>30737</td>
<td>77856</td>
<td>47517</td>
<td>67.3</td>
<td>13117</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>5979</td>
<td>25653</td>
<td>74725</td>
<td>41887</td>
<td>71.3</td>
<td>13867</td>
</tr>
<tr>
<td><strong>CSG Total</strong></td>
<td><strong>56358</strong></td>
<td><strong>703953</strong></td>
<td><strong>1254231</strong></td>
<td><strong>382253</strong></td>
<td><strong>809.2</strong></td>
<td><strong>165598</strong></td>
</tr>
</tbody>
</table>
Part II
Actions for Power Supply Reliability Enhancement of CSG
(1) Evolution of CSG Power Supply Reliability

The ice disaster reduced the reliability at 2008.

The customer average interruption duration within CSG has decreased by 77.8% from 2006 to 2013!
(2) Comparison Among Main Cities in China

The comprehensive evaluation of 2013 power supply reliability demonstrates that the Top 4 nationwide Level-A Power Supply Companies are from CSG!

Source: Conclusion from National Energy Administration of China

Fig. 2013 AIHC Comparison Between Level-A Power Supply Companies of CSG and Other Main Cities

Note: AIHC-1: Customer Average Interruption Duration Index

5 out of 10 2013 nationwide Level-A power supply companies are from CSG!
(3) Comparison Between Main Cities within CSG and Other Cities in Advanced Countries

CSG is committed to power supply reliability enhancement!

(4) CSG Made Benchmarking with Other Companies in Advanced Countries

Conclusion:
CSG is committed to power supply reliability enhancement!
(5) Main Idea

By Technology!

Reduce fault outage frequency and duration,

Reduce planned outage frequency and duration

By Management!

Major Objective

Improve Power Supply Reliability of Distribution System
(6) What We Have Done.

- Classification of Load and Areas
- Optimization of network structure
- Standard Design
- Distribution Automation
- New Equipments and Systems
- Integrated Overhaul Management
- Live-Wire Operation
- Differentiated O&M
- Demand Side Management
- Electricity Utilization Service
- Information Integration of Distribution and Marketing
- Emergency Management
• **Dividing Regions into Four Grades**

<table>
<thead>
<tr>
<th>Grades</th>
<th>Ultra grade</th>
<th>First grade</th>
<th>Second grade</th>
<th>Third grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>International city</td>
<td>Capital of provinces and other major city</td>
<td>Other city, where the state government located</td>
<td>County</td>
</tr>
</tbody>
</table>

**Note:**
1. International city: Guangzhou, Shenzhen.
3. Other city can develop to international city or major city.

• **Dividing Areas into Six Classes**

<table>
<thead>
<tr>
<th>Grades</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
<th>Class E</th>
<th>Class F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra grade</td>
<td>Central area or ≥30MW/km²</td>
<td>General urban area or 20-30MW/km²</td>
<td>Suburbs and towns and 10-20MW/km²</td>
<td>Suburbs and towns and 5-10MW/km²</td>
<td>Town or 1-5MW/km²</td>
<td>County</td>
</tr>
<tr>
<td>First grade</td>
<td>≥ 30MW/km²</td>
<td>Central area or 20-30MW/km²</td>
<td>General urban area or 10-20MW/km²</td>
<td>Suburbs and towns and 5-10MW/km²</td>
<td>Town or 1-5MW/km²</td>
<td>County</td>
</tr>
<tr>
<td>Second grade</td>
<td>---</td>
<td>20-30MW/km²</td>
<td>Central area or 10-20MW/km²</td>
<td>General urban area or 5-10MW/km²</td>
<td>Suburbs and towns or 1-5MW/km²</td>
<td>County</td>
</tr>
<tr>
<td>Third grade</td>
<td>---</td>
<td>---</td>
<td>10-20MW/km²</td>
<td>County town or 5-10MW/km²</td>
<td>Town or 1-5MW/km²</td>
<td>County</td>
</tr>
</tbody>
</table>

Different grades and classes, different reliability planning
• Optimization of network structure

- The network structure is simplified
- Load transfer scheme is flexible
- Operation is reliable

Fig. Structure optimization by typical wire-connection in Guangzhou

• Distribution network meshed design

- Possible load transfer ratio increased
- Schedule power outage time: 2min
- Recovery time of non-fault zone: 60min

Fig. Meshed grid in Luohu district of Shenzhen
(1) Standard Design Frame G4

- Establish unified construction standards
- Copy homogeneous construction projects
- Construction period is shortened
- Project quality is guaranteed
- Interruption Duration is reduced and reliability is improved
(2) Project Management

• WHS operation standards
  W: Witness Point
  H: Hold Point
  S: Standby Point

Improve project quality
(3) Material procurement

a. Materials category optimization

<table>
<thead>
<tr>
<th>No.</th>
<th>Materials category</th>
<th>Number of types</th>
<th>Original quantity</th>
<th>Optimized quantity</th>
<th>The Optimized ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lines: $\geq 110$kV</td>
<td>6</td>
<td>152</td>
<td>65</td>
<td>42.8%</td>
</tr>
<tr>
<td>2</td>
<td>Lines &amp; Cables: 10-35kV</td>
<td>4</td>
<td>385</td>
<td>45</td>
<td>11.7%</td>
</tr>
<tr>
<td>3</td>
<td>LV lines</td>
<td>4</td>
<td>977</td>
<td>96</td>
<td>9.8%</td>
</tr>
<tr>
<td>4</td>
<td>10kV switches</td>
<td>6</td>
<td>378</td>
<td>95</td>
<td>25.1%</td>
</tr>
<tr>
<td>5</td>
<td>10kV-35kV transformers</td>
<td>7</td>
<td>242</td>
<td>111</td>
<td>45.9%</td>
</tr>
<tr>
<td>6</td>
<td>total</td>
<td>27</td>
<td>2134</td>
<td>412</td>
<td>19.3%</td>
</tr>
</tbody>
</table>

Materials category optimization results

b. Quality control of the entire process

Case: Key point control strategy of GIS manufacturing in Guangzhou utility

<table>
<thead>
<tr>
<th>No.</th>
<th>Key point control strategy</th>
<th>Discovered problems</th>
<th>Benefit Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1. At least 200 times operation test on breakers, isolation switches and ground switches in factory</td>
<td>1. 64 items equipment manufacturing problems in first half year of 2013</td>
<td>1. Saving cost of 23 million RMB.</td>
</tr>
<tr>
<td></td>
<td>2. Replace the defective parts of the GIS after the voltage withstand test</td>
<td>2. 12 items of serious problems</td>
<td>2. Saving the possible loss of electricity 312MWh</td>
</tr>
<tr>
<td></td>
<td>3. At least 3 times lightning impulse test if the rated voltage is great than 252kV</td>
<td>3. The significant defect may cause 13 accidents</td>
<td></td>
</tr>
</tbody>
</table>

10kV-35kV XLPE cables types

<table>
<thead>
<tr>
<th>No.</th>
<th>types</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>YJV22</td>
<td>3X70</td>
</tr>
<tr>
<td>2</td>
<td>YJV22</td>
<td>3X120</td>
</tr>
<tr>
<td>3</td>
<td>YJV22</td>
<td>3X240</td>
</tr>
<tr>
<td>4</td>
<td>YJV22</td>
<td>3X300</td>
</tr>
<tr>
<td>5</td>
<td>YJV22</td>
<td>3X400</td>
</tr>
</tbody>
</table>
(4) Technology Roadmap of Distribution Automation

Primary Target

Enhance Power Supply Reliability

Construction Thoughts

- Concise
- Practical
- Economy

Implementation Approach

1. Fast fault isolation
2. Reduce fault influenced areas
3. Auto-restore the non-fault areas
4. Remote control and reduce on-site operation time

Achievements

1. Extended to 39 Cities.
2. Covered 8555 distribution lines.
3. Used 64000 distribution automation terminals
(4) Effects of Distribution Automation

Case 1: Reduce average time for fault location.

- **Hours per fault**
  - **Before DA Reform**
    - Shenzhen: 1.2 hours
    - Foshan: 2 hours
    - Dongguan: 2.5 hours
    - Zhongshan: 3 hours
    - Zhuhai: 3 hours
    - Maoming: 3 hours
    - Shaoguan: 2.5 hours
    - Zhaoqing: 2.5 hours
    - Guiyang: 3 hours
    - Zunyi: 1.43 hours
    - Kunming: 1.2 hours
  - **After DA Reform**
    - Shenzhen: 0.48 hours
    - Foshan: 0.5 hours
    - Dongguan: 0.5 hours
    - Zhongshan: 0.58 hours
    - Zhuhai: 0.3 hours
    - Maoming: 0.58 hours
    - Shaoguan: 0.65 hours
    - Zhaoqing: 0.65 hours
    - Guiyang: 0.5 hours
    - Zunyi: 0.5 hours
    - Kunming: 0.38 hours

Case 2: Reduce average time for load transfer on 10kV feeders.

- **1 hour** Before DA Reform
  - Maoming City
- **0.2 hour** After DA Reform
- **0.5 hour** Before DA Reform
  - Guiyang City
- **0.1 hour** After DA Reform
(5) Research and Applications of New Equipments and Systems

**Equipments**
- Smart ring main unit
- Solid state breaker
- STATCOM
- Electronic power transformer
- Multifunction smart meters
- ...

**Systems**
- Distribution Management System (DMS)
- Energy Management System (EMS)

**To improve reliability and reduce interruption time**
2.4 Distribution System Operation

(1) Integrated Management of Overhaul with Service Interruption

**Issues**
1. Outage plan is managed by different departments.
2. Many repeated service interruptions

**Two Principles**
1. Customer-Centric Management
2. Make load transfer as much as possible during scheduled outage

**Rolling Optimize**
Annual and monthly integrated plan of service interruption

**Targets**
1. Avoid unnecessary service interruption.
2. Decrease frequency and duration of service interruption.

---

2011-2013 Customer Average Planned Interruption Duration Analysis (Unit: Hours)

- **Power Rationing**: 2.54%
- **Main Grid Renewal**: 6.26%
- **Main Grid Equipment Repair**: 6.76%
- **Load Transfer**: 12.44%
- **Distribution Renewal**: 42.08%
- **Distribution Equipment Repair**: 29.92%

---

Yearly Analysis:
- **2011**:
  - Planned Interruption Duration: 6.34 hours
  - Interruption By Fault: 4.11 hours
- **2012**:
  - Planned Interruption Duration: 3.97 hours
  - Interruption By Fault: 2.53 hours
- **2013**:
  - Planned Interruption Duration: 1.81 hours
  - Interruption By Fault: 2.82 hours
2.4 Distribution System Operation

(2) Live-Wire Operation

3 categories
37 operation items

Targets
1. Reduce Interruption Frequency and Duration
2. Increase Power Supply Quantity

Case: By-Pass Operation

Table. Contribution of live-wire operation on AIHC of 15 key Cities in CSG

2013 Achievements
1. Increased 48% than 2013
2. Avoid power outage of 2.8725 million household
3. AIHC is reduced by 2.54 hours
(3) Differentiated Operation and Maintenance

**Targets**
1. Reduce interruption due to maintenance.
2. Reduce the impacts of equipment fault on power supply reliability.

**Differentiated**
1. 3 levels for risk management and control.
2. according to their importance and health

**Application**
Differentiated Cycles for inspection, maintenance, test and defect elimination.

**Case**
Conventional cycle of inspection: At least once per month for urban area

- **Cycle of Level-III equipment**: Once every 3-6 months
- **Cycle of Level-II equipment**: Once per month
- **Cycle of Level-I equipment**: Once every 1-2 weeks

**Fig. Procedures for risk management and control of distribution equipments**
(1) Demand Side Management & Orderly Electricity Utilization

- **Subsidy policy**
- **Price policy**

**Marketization Mechanism**

**Forced Control in Emergencies**

- **Industrial consumer**
  - Schedule the plan of electricity consumption of industry loads

**Targets**
- Guarantee the electricity utilization of residential customers
- Balance the load demand at the customer side
(2) Our Activities on Consumer

- Promote green action
- Customer service for energy-saving
- Ensure electricity utilization safety

- Introduce energy-saving technologies and products to consumers
- Spreading the idea of energy-saving and environment-protecting to the public.
- Encourage society participation.
- Normalization of Customers' Electricity Utilization.
- Intensify the Electricity Utilization Safety of Key Customers
(1) Mechanism of Fast Service Restoration

- Fault Monitoring
- Fault Alarm
- Fault Handling
- Repair Monitoring
- Evaluation

- System operation department
- Call Center
- Repair Crew
- System operation department
- Call Center

Production Equipment Management Department
Sales & Marketing Department
(2) Information Integration of Distribution Network and Electricity Marketing

Targets: 1. Supply Information for Fast Urgent Repair
2. Lean Management of CSG Power Supply

Break Through the Information Barrier of Four Key Links

Substation → Transmission Lines → Transformers → Customer

Fig. Information Management of power supply reliability based on Information Integration of Distribution Network and Electricity Marketing

Fig. Visualization of Outage Area Based on GIS System
2.6 Urgent Repair and Service Restoration

(2) Information Integration of Distribution Network and Electricity Marketing

- **95598**
  - Request for repair info.
  - Repair progress info.
  - Outage info.
  - Customer Record info.
- **System Operator**
  - Repair command info.
  - Operation monitoring info.
  - Fault location info.
- **Urgent Repair Crew**
  - Repair progress info.
  - Fault location info.
  - Remote Control info.
- **Marketing System**
  - Outage info.
  - Customer Record info.
  - Main Grid Model info.
- **Distribution and Utilization OS2 Master Station**
  - Real-time remote signaling info.
  - Real-time remote metering info.
  - Geographic map info.
  - One line diagram info.
  - Load control terminal info.
  - Distribution transformer monitoring info.
- **Main Grid OS2**
  - Main Grid switch info.
  - Main Grid alert info.
  - Remote Control info.
- **Fault indicator Auto-switch**
  - Data collection terminal
- **GIS**
  - Geographic map info.
  - One line diagram info.
(3) Emergency Management

Critical Focus Areas

Major Natural Disasters

Key Customers

Key Approaches

Complete emergency plan

Make emergency-handling exercises

Interconnect emergency platform

Targets: Ensure Power Supply under Emergency

序号 | 预案名称
--- | ---
1 | 总体应急预案
2 | 防风防汛应急预案
3 | 地震应急预案
4 | 大面停电应急预案
...... | ..........................
(3) Emergency Management

Case 1: Respond to Ice Disaster
① Ice monitoring system
② Ice melting and removing device

Case 2: Respond to Typhoon
① Material reserve and dispatch
② Emergency command center
③ Urgent repair and fast restoration
Part III
Further Solutions for Power Supply Reliability Enhancement of CSG
3.1 Key Role of Technology and Equipment

Our Focus

Advanced Technology, Network Structure, and Reliable Equipment has key effects

Conclusion: To further improve reliability, we need advanced technology, network structure, and reliable equipment.
Future Distribution System

Three Challenge

Customer’s Growing Demand for Power Supply Reliability

More Reliable

Energy Conservation and Emission Reduction

More Green

Distributed Generation and New Energy Integration

More Flexible
3.3 Optimizing Distribution Planning and Operation

Optimize Entire Process of Distribution Planning

- Detailed Load Forecast
- Meshing Network Structure
- Upgrade of Old Network
- Flexible Integration of DG

Optimize Entire Process of Distribution Operation

- Smart Meter and Demand Side Management
- Energy-Saving Economic Dispatch of Distribution Systems with DG
- Relay Protection under Bidirectional Power Flow
- Self-Healing of Smart Distribution Systems
Targets: Built the interaction bridge between CSG and Customers

Distribution Data Center

Data Analysis

Operation & Maintenance

Collect Equipment Information and Status

Collect Customer Demand and User Behavior

Respond to Customer Demand

Customer

Equipment
3.5 Research and Extension of Microgrid

- Experiment
- Summarize
- Copy
- Popularize

Yunnan Kunming: Science Park Microgrid

Guangxi Nanning: Microgrid Group Demonstration

Guangdong Foshan: Combined cooling and power supply microgrid

Guangdong Zhuhai: 1) Dong-Ao island microgrid, 2) Guishan island microgrid
3.6 Asset Lifecycle Management

- Optimization and management of the asset lifecycle.

**Key Future Work**

**Planning**
- Improve and refine distribution standards

**Construction**
- Start post-installation evaluation of equipments

**Procurement**

**Maintenance**

**Retirement**

**Targets:**
1. Enhance equipment reliability
2. Improve asset utilization efficiency
The End.
Thanks!