Photovoltaic Power Generation in China

Viewpoint from utility

China Electric Power Research Institute
Sep. 3 2015, Bangkok Thailand
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1. **Overview of Photovoltaic power Generation in China**

2. **Challenges of Power System with Photovoltaic Power Integration**

3. **Activities for Photovoltaic Power Grid Integration by SGCC.**
1.1 Resource and Development Plan

**Solar Resources**

Mainly located in west and north China

- Tibet
- Qinghai
- Gansu,
- Ningxia,
- Xinjiang,
- Inner Mongolia.

**Developing Plan**

<table>
<thead>
<tr>
<th>Year</th>
<th>PV generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>35 GW</td>
</tr>
<tr>
<td>2020</td>
<td>100 GW</td>
</tr>
</tbody>
</table>

Distribution of solar energy resources (MJ/m²·year)
1.2 Typical mode

**Typical Mode of photovoltaic power generation in china**

- **Large scale PV Stations**
  - Qinghai Germu 500MW PV power station
  - BIPV (<1MW)
  - BAPV (<6MW for single building)
  - PV in fishpond

- **PV on Vegetable greenhouse**
# 1.3 Generation capacity of recent years

## Photovoltaic Generation Development of 2014

<table>
<thead>
<tr>
<th></th>
<th>Annual Installation</th>
<th>Total capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large scale stations</td>
<td>8.55 GW</td>
<td>23.38 GW</td>
</tr>
<tr>
<td>Distributed systems</td>
<td>2.05 GW</td>
<td>4.67 GW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.60 GW</strong></td>
<td><strong>28.05 GW</strong></td>
</tr>
</tbody>
</table>

**Total Electricity** 25Twh

**Largest Station** 500MW

<table>
<thead>
<tr>
<th>No</th>
<th>Province</th>
<th>PV Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gansu</td>
<td>5.17 GW</td>
</tr>
<tr>
<td>2</td>
<td>Qinghai</td>
<td>4.13 GW</td>
</tr>
<tr>
<td>3</td>
<td>Xinjiang</td>
<td>3.56 GW</td>
</tr>
<tr>
<td>4</td>
<td>Inner Mongolia</td>
<td>3.02 GW</td>
</tr>
<tr>
<td>5</td>
<td>Jiangsu</td>
<td>2.75 GW</td>
</tr>
</tbody>
</table>

### PV generation capacity 2007-2014 (GW)

- Year 2007: 0.14 GW
- Year 2008: 0.28 GW
- Year 2009: 0.83 GW
- Year 2010: 2.8 GW
- Year 2011: 8 GW
- Year 2012: 17.93 GW
- Year 2013: 28.05 GW
- Year 2014: 30.06 GW
### 1.4 Price policy

<table>
<thead>
<tr>
<th>Solar Resource Area</th>
<th>PV Stations</th>
<th>Equivalent FIT of distributed PV system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>FIT (RMB/kWh)</strong></td>
<td><strong>Electricity used by the owner</strong></td>
</tr>
<tr>
<td>I</td>
<td>0.90</td>
<td>End user Price + 0.42 RMB/kWh</td>
</tr>
<tr>
<td>II</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

#### Notes:
- **FIT (RMB/kWh)**: Feeder Integration Tariff (RMB per kWh).
- **Electricity used by the owner**: End user price + additional RMB/kWh.
- **Electricity feed to grid**: Rated coal power price + additional RMB/kWh.
1. Overview of Photovoltaic Generation in China

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2.1 Characteristics of Power System in China

Distribution of Energy Resource and Load in China

- **Wind:** Northeast, North and Northwest
- **Solar:** Northwest and North
- **Load:** East and Central

Over 2/3 of the power demand concentrates in East and Central China.

4/5 of the hydro power resources is located in Southwest.

2/3 of coal resources, wind power, solar power is located in North and Northwest.
2.1 Characteristics of Power System in China

Distribution of Energy and Load in Some Area

Jiuquan wind power and photovoltaic power base in Gansu Province

Photovoltaic power base in Qinghai Province

Regions with rich wind resource

Regions with rich solar resource

Load center
2.2 Stability Problems

**Characteristics of PV power generation**

Inverter based grid interface lead to

- Cannot bearing under voltage and over voltage.
- Cannot contribute large short circuit current as synchronous generators.
- No inertial and damping as synchronous generators do.
- Small capacity, thus a PV power station is consists of hundreds of generation units, which brings great complexity of control.
- PWM modulation brings harmonics.

Large scale trip-off of wind power in 2011

<table>
<thead>
<tr>
<th>No</th>
<th>Time</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2011-02-24</td>
<td>Gansu</td>
<td>16 Wind farms, 598 Wind Turbines, 840MW</td>
</tr>
<tr>
<td>2</td>
<td>2011-04-03</td>
<td>Gansu</td>
<td>400 wind turbines, 568MW</td>
</tr>
<tr>
<td>3</td>
<td>2011-04-17</td>
<td>Gansu</td>
<td>16 Wind farms, 699 wind turbines, 1006MW</td>
</tr>
<tr>
<td>4</td>
<td>2011-04-17</td>
<td>Hebei</td>
<td>9 Wind farms, 644 wind turbines, 854MW</td>
</tr>
<tr>
<td>5</td>
<td>2011-04-25</td>
<td>Gansu</td>
<td>1278 wind turbines, 1535MW</td>
</tr>
<tr>
<td>6</td>
<td>2011-11-16</td>
<td>Hebei</td>
<td>15 wind farms, 790 wind turbines, 1016MW</td>
</tr>
</tbody>
</table>
2.1 Electricity Curtailment Problems

Why Electricity Curtailment?

- **Excessive Power generation source and small load**
- **Limitation of transmission capacity**

Power Structure of Gansu, Xinjiang and Qinghai Province of 2014 (GW)

<table>
<thead>
<tr>
<th>Province</th>
<th>Maxium Load</th>
<th>Total Generation</th>
<th>Wind Power</th>
<th>PV Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gansu</td>
<td>12.4</td>
<td>38.7</td>
<td>10.1</td>
<td>5.17</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>19.65</td>
<td>57.6</td>
<td>8.0</td>
<td>3.56</td>
</tr>
<tr>
<td>Qinghai</td>
<td>8.99</td>
<td>18.0</td>
<td>0.31</td>
<td>4.13</td>
</tr>
</tbody>
</table>

Electricity Curtailment of PV power generation from Jan to Jun 2015 (TWh)

<table>
<thead>
<tr>
<th></th>
<th>Gansu</th>
<th>Xinjiang</th>
<th>Qinghai</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.141</td>
<td>0.463</td>
<td>0.128</td>
</tr>
</tbody>
</table>


2.2 Grid Integration management

Mismatching of renewable energy and grid

Mismatching of planning

• How many renewable energy power generation will be built in the next few years?
• Where to build those renewable plants?
• How can I make a grid plan to connect those renewable plants?

Mismatching of construction

• For Photovoltaic power generation, the construction period is very short, which normally several month.
• The Investment and construction period of power grid is very slow limited to grid plan, capital plan, project approval and so on, normally takes more than one year.

The utility is the biggest barrier of renewable energy development?
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3.1 Grid Code

Grid Code for wind farm and photovoltaic stations

<table>
<thead>
<tr>
<th>GB/T 19964 2012</th>
<th>Technical requirements for connecting photovoltaic power station to power system</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 29319 2012</td>
<td>Technical requirements for connecting photovoltaic power system to distribution network</td>
</tr>
</tbody>
</table>

Some critical technique requirements are specified such as:

- **Active and reactive power control.**
- **Low voltage ride through and dynamic reactive power support**
- **Short and ultra short term power forecasting requirement.**
- **Model and Parameters requirement.**

![Graph showing different power levels over time](image)
3.2 Grid Compliance Test

Grid Compliance test for photovoltaic generations

National Energy Solar Center located in Nanjing, Jiangsu

1️⃣ Laboratory for grid compliance test of PV Inverters
2️⃣ Mobile grid compliance test equipment for distributed PV systems up to 300kW, 400V
3️⃣ Mobile grid compliance test equipment for PV stations up to 35kV, 1.5MW (Unit Test)
3.3 Power Forecast system

- **Short and ultra short term power forecast of photovoltaic power generations**

**Requirement for PV stations greater than 10MW**
- Short term power forecast:
  - 0 - 72h with 15min interval.
- Ultrashort term power forecast:
  - 0 - 4h with 15min interval.

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**Power forecast of renewable generation**
- Medium- and long-term power forecast
- Short-term power forecast
- Ultra short-term power forecast

**Optimal dispatching between renewable generation and conventional power**
- Power plan of renewable generation
- Operation mode and unit combination
- Tomorrow plan of renewable generation
- Day ahead plan of conventional power
- Real-time control of renewable generation
- Real-time control of conventional power
3.4 Transmission Capacity Enhancement by UHV Technique

Hami-Zhengzhou UHV DC Project
- Operation time: 2014.01.27
- Length: 2192km
- Voltage level: ±800kV
- Transmission capacity: 8000MW
More UHV Projects are will be build in the future.

2017年建成“三纵三横”特高压同步电网和13回特高压直流。
3.5 Greenway for distributed PV system grid integration

- **Simplification of grid integration procedures.**

  - **Apply for integration**
    - 20 days
  - **Make Integration scheme**
  - **Integration agreement issued**
  - **Apply for check and accept**
    - 5 days
  - **Installing electricity meter**
    - 10 days
  - **Grid integration check and accept**
    - 10 days

  **All are free !!!**

**Client Service Center**

- 13 typical integration schemes

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3.5 Greenway for distributed PV system grid integration

- **Take the responsibility for grid investment and construction**

<table>
<thead>
<tr>
<th>Integration point</th>
<th>Grid integration project</th>
<th>Upgrade or reform of public grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public grid</td>
<td>Utility</td>
<td>Utility</td>
</tr>
<tr>
<td>Grid inside the user</td>
<td>User</td>
<td>Utility</td>
</tr>
</tbody>
</table>

**Invest by utility**
- C1-C2

**Invest by user**
- A1-A2
- B1-B2

![Diagram showing grid integration and investment points](image-url)
4 Conclusion

1. Coordination between PV power generations and other power sources such as wind power or coal is very important. And also the transmission capacity must be considered while making development plan.

2. A suitable grid code is the basic approach to maintain the stability of power system with photovoltaic generations integrated.

3. Grid compliance test and evaluation is very helpful to ensure that the performance of PV generations can meet the requirement of grid code.

4. Power forecast system is vital when the penetration of photovoltaic power generation is unneglectable.

5. For utilities, to avoid too much blame from the PV generation investors and government, you’d better make some simplification to accelerate the process of grid integration of distributed PV system. And it will be great if you can cancel or reduce some fees such as power backup fees.
That’s all, Thanks!