Economic Operation of Battery Energy Storage System in Industrial Park Based on the Power Load Characteristics

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Content

Situation of power system in China

What is BESS from the perspective of power system

Electric load of Industrial Park

The economic operation of BESS
Situation of power system in China

<table>
<thead>
<tr>
<th>Type</th>
<th>Installed Capacity</th>
<th>Generating Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>0.99021 billion KW (65.6%)</td>
<td>4210.2 billion KWh (74.9%)</td>
</tr>
<tr>
<td>Water</td>
<td>0.31937 billion KW (21.2%)</td>
<td>996 billion KWh (17.7%)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.02608 billion KW (1.7%)</td>
<td>168.99 billion KWh (3.01%)</td>
</tr>
<tr>
<td>Wind</td>
<td>0.12934 billion KW (8.6%)</td>
<td>186.3 billion KWh (3.31%)</td>
</tr>
<tr>
<td>Solar</td>
<td>0.04318 billion KW (2.9%)</td>
<td>40 billion KWh (0.7%)</td>
</tr>
</tbody>
</table>

Primary energy and load are in reverse distribution.

80% supply

70% demand
In 2015, Total industrial electricity consumption is 3.93 trillions kWh. Growth rate has dropped, but the proportion is still great.

Industrial and commercial users in China bear cross subsidies to residents and agriculture. Energy savings through the installation of energy storage systems are more attractive for them.
Until the end of 2014, China had 485 national industrial parks, the total industrial output value made up more than 1/3 of the total industrial output value.

The outstanding problems of power supply:
- Local area distribution network overload
- Unreasonable structure, Poor reliability
- High loss, Low voltage at the end of the line
- Drop voltage transient, Power quality problems

The access of distributed power supply has advantages and disadvantages to the power supply in industrial parks. But it will be an inevitable trend for the development of power system to establish a new type of power grid with distributed power supply.
What is BESS

Transmission line
Real time, dynamic balance
Strong interconnected power grid

Transmission line
Energy body increases, dispersed
How to reach a new balance between multiple nodes?

Lowest possible cost  Supply reliability  Fluctuating demand

Power System
What is BESS

Combinatorial optimization

Purchasing power

Storage

Controllable process

Demand

Optimal quality

Supply

Residual power

Inverter

Rectifier

AC

DC
Electric load of Industrial Park

Source: Zhejiang University

Long time scale: capacity challenge

Climbing challenge

Peak shaving

Power quality, operation spare

Source: Zhejiang University
Step 1: clear requirements, load type

Several typical scenarios of industrial park using battery energy storage systems (sustainable?):

- **Electricity saving**, emergency power supply, power quality, virtual power plant, energy management, renewable energy smoothing

### AC LOAD

<table>
<thead>
<tr>
<th>Mechanical Type 1</th>
<th>Mechanical press</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metal lathe drive</td>
</tr>
<tr>
<td></td>
<td>Driller drive</td>
</tr>
<tr>
<td></td>
<td>Planning machine drive</td>
</tr>
<tr>
<td></td>
<td>Shaper drive</td>
</tr>
<tr>
<td></td>
<td>Hammer drive</td>
</tr>
<tr>
<td></td>
<td>Metal shear drive</td>
</tr>
<tr>
<td></td>
<td>Hydraulic press</td>
</tr>
<tr>
<td></td>
<td>Forging press</td>
</tr>
<tr>
<td></td>
<td>Grinder/raw-mill drive</td>
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<tr>
<td></td>
<td>Chipper drive</td>
</tr>
<tr>
<td></td>
<td>Crusher drive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical Type 2</th>
<th>Pump drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fan drive</td>
</tr>
<tr>
<td></td>
<td>Blower drive</td>
</tr>
<tr>
<td></td>
<td>Air compressor drive</td>
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<tr>
<td></td>
<td>Conveyor drive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HVAC</th>
<th>Chiller motor drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cooling water fan drive</td>
</tr>
<tr>
<td></td>
<td>Condenser pump drive</td>
</tr>
<tr>
<td></td>
<td>Air handler motor drive</td>
</tr>
</tbody>
</table>

### DC LOAD

<table>
<thead>
<tr>
<th>Mechanical Type 1</th>
<th>Mixer drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crane</td>
</tr>
<tr>
<td></td>
<td>Hoist</td>
</tr>
<tr>
<td></td>
<td>Freight elevator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical Type 2</th>
<th>Kiln drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variable-speed fan drive</td>
</tr>
<tr>
<td></td>
<td>Variable-speed blower drive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal</th>
<th>Smelter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arc furnace</td>
</tr>
<tr>
<td></td>
<td>Electrolytic cell</td>
</tr>
<tr>
<td></td>
<td>Induction furnace</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lighting</th>
<th>LED lamps</th>
</tr>
</thead>
</table>

### Load Types

- **Friendly**
- **Adjustable**
- **Neutral**
- **Interruptible**
- **Unfriendly**
- **Important and sensitive**
Step 2: battery selection

- Battery type selection
  - Safety
  - Performance guarantee
  - Performance requirements
  - Operation and maintenance cost
  - Effect cost
  - Module cost
  - Power grid requirements
  - Discharge depth / length

- Test record
- Environment condition
- Infrastructure
- Space restriction
- Energy density
- Application
- Work efficiency
- Cycle life
- Policy
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Step 3: capacity planning for BESS

Maximum annual income = Distribution station capacity ↓ + Basic electricity ↓ + **Electricity purchase cost** ↓ + Transformer loss ↓ + **Outage loss** ↓ - Investment cost ↑ - Operation cost ↑

Source: Shanghai Jiao Tong University

\[
\text{max } E_{\text{year}} = E_1 + E_2 + E_3 + E_4 + E_5 - C_1 - C_2
\]

\[
E_1 = \begin{cases} 
\gamma_d C_d P_{\text{max}} & P_{\text{max}} \geq P_c \\
\gamma_d C_d (2P_c - P_{\text{max}}) & P_{\text{max}} < P_c 
\end{cases}
\]

\[
P_c = P_{\text{dmax}} - P_a
\]

\[
E_2 = \begin{cases} 
e_r P_{\text{max}} & P_{\text{max}} \leq P_c \\
e_r (2P_c - P_{\text{max}}) & P_{\text{max}} > P_c 
\end{cases}
\]

\[
E_3 = n \sum_{i=1}^{24} (P_i^+ - P_i^-) e_i
\]

\[
E_4 = n \sum_{i=1}^{24} \left[ \frac{P_i^2 - (P_i - P_i^+ + P_i^-)^2}{(S_N \cos \phi)^2} \right] P_k e_i
\]

\[
E_5 = R_{\text{IEA}} E_{\text{ENS}} \lambda_s (1 - P(W_i < E_{\text{ENS}})) + (\lambda_s - \lambda_s') E_{\lambda}
\]

**PSO+ Mult-SUMT**

- Operation strategy is mainly based on electricity price incentives.
- According to the Peak / Valley segment to determine usually.
- Most of the situation is a charge of a release.
- Suitable for friendly or neutral load.
Step 4: discuss the operation strategy

Peak hour: 19:00-21:00;
Rush hour: 8:00-11:00, 13:00-19:00, 21:00-22:00;
Trough hour: 11:00-13:00, 22:00-8:00
Step 5: BESS connected to the power grid

To ensure safety and reliability, Full set system redundancy.

Unit equipment charge and discharge conversion speed $< 100$ ms

Typical structure of BESS

PCS conversion efficiency $\geq 97\%$

Total life equivalent power cost $< 0.5$ YUAN/kWh

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Conclusion

1、The trend of BESS applied in power system is beyond doubt, but the power system is expected to further break through the relevant ontology technology, especially the long life, high security and reliability of the BESS.

2、High confidence interval of the strong power grid is not one day of work, the high confidence interval of the “Renewable energy + Energy storage” combination can not be one day of work.

3、In order to gain the profit of the business model is not sustainable, the maximum value of the energy storage can be used to improve the reliability of power supply.

4、The electrochemical cell system is the product of the depth fusion of physics and chemistry, but its dynamic model is difficult to build.

5、The full consideration of the load is not friendly causes the need to configure the hybrid energy storage system.
Thank You

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Intelligence to create a better future