Development Path for Electricity Markets in the US

2018 Electricity Market Special Committee of Chinese Society for Electrical Engineering and National Electricity Exchange Institutions Forum

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Today I will do two things:

• Give some context regarding recent developments in US markets that will shed some light on policy discussion and market design debates.

• Discuss several US market design topics that may be particularly relevant to China.

今天我主要做两件事：

• 介绍近期美国市场发展情况，这将为政策讨论和市场设计提供一些启示；

• 讨论几个与中国相关的美国市场设计话题。
Introduction 介绍

- Why have electricity markets?
  - Efficient system operations
  - Rational market signals to guide investment in needed system resources (and retirement of unneeded resources)
  - Rational compensation for resource owners

- 为什么要有电力市场？
  - 高效的系统运营；
  - 合理的市场信号，引导对所需系统资源的投资（以及不必要资源的退役）；
  - 对资源所有者的合理补偿。
What is an ISO/RTO?
ISO/RTO 是什么？

- **Independent System Operator**: 独立系统运营商，简称ISO
- **Regional Transmission Organization**: 区域输电组织，简称RTO
What is an ISO/RTO?

ISO/RTO 是什么？

- Independent organizations that operate:
  - Intraday energy markets;
  - Day-ahead energy markets;
  - Ancillary services markets and mechanisms; and
  - Sometimes capacity markets.

- 独立的组织负责运营：
  - 日内能源市场；
  - 日前能源市场；
  - 辅助服务市场和机制；
  - 有时也会有容量市场。
What is an ISO/RTO?

ISO/RTO 是什么？

- Functional/operational control of the transmission system
- ISOs/RTOs do not own generation or transmission assets.
- Ensure real-time coordination of electricity supply with demand.
- System planning.

- 输电系统的功能 / 运行控制；
- ISOs/RTOs 并不拥有发电或输电资产；
- 确保电力供应与需求的实时协调；
- 系统规划。
US Market Trends

美国电力市场发展趋势
Slowing Demand Growth 降低需求增长

Annual change in retail electricity sales by sector (1975-2015)
percent change (five-year rolling average)

Source: EIA
Utility End-Use Energy Efficiency Investment 电力公司终端能效投资

Source: ACEEE Annual Report 2016
Strong Wind Deployment

Strong Solar Deployment

Yearly U.S. Solar Installations

Source: Greentech Media, SEIA
Declining Natural Gas Prices
天然气价格降低

Monthly and annual average natural gas spot price at Henry Hub (1997-2017)
dollars per million British thermal units

monthly average annual average

$3.01
Declining ISO/RTO Energy Market Prices

ISO/RTO 能源市场价格降低

Source: PJM SOM Report 2016
Coal Generation Declining

U.S. electricity generation by fuel, all sectors
thousand megawatthours per day

Forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Natural gas</th>
<th>Petroleum</th>
<th>Nuclear</th>
<th>Hydropower</th>
<th>Non-hydro renewables</th>
<th>Other sources</th>
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<tbody>
<tr>
<td>2010</td>
<td>44.8%</td>
<td>23.9%</td>
<td>30.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>2011</td>
<td>42.3%</td>
<td>24.7%</td>
<td>30.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>2012</td>
<td>37.4%</td>
<td>30.3%</td>
<td>27.7%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2013</td>
<td>38.9%</td>
<td>27.7%</td>
<td>27.5%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>2014</td>
<td>38.6%</td>
<td>27.7%</td>
<td>27.5%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2015</td>
<td>33.2%</td>
<td>32.7%</td>
<td>33.8%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2016</td>
<td>30.4%</td>
<td>31.7%</td>
<td>31.7%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2017</td>
<td>30.1%</td>
<td>33.1%</td>
<td>34.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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</tr>
<tr>
<td>2018</td>
<td>29.6%</td>
<td>34.3%</td>
<td>34.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2019</td>
<td>28.1%</td>
<td>34.3%</td>
<td>34.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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</tbody>
</table>

Note: Labels show percentage share of total generation provided by coal and natural gas.
Selected Topics in Market Design
电力市场设计相关议题
1. Regionalization 区域化
2. Competition 竞争
3. Contracts 合同
4. Generator Compensation 发电补偿
5. DERs in Wholesale Markets 批发市场中的分布式能源资源
Topic 1: Regionalization of Markets

议题1：区域化市场

Source: ISO/RTO Council
38 Separate Balancing Areas
38个单独的平衡区

- Each Balancing Area (BA) is responsible for assuring *resource adequacy* (reliability in the longer term) 每个平衡区负责确保资源充足性（长期可靠性）
  - Each BA must have sufficient resources to meet need in every hour over the planning horizon 每个平衡区必须有充足的资源满足规划期间每小时的需求

- Each BA is responsible for *system security* (reliability in real-time—i.e., balancing) 每个平衡区负责系统安全性（实时可靠性，比如，平衡区）
  - Each BA must have adequate resources to ensure that real-time (within hour) imbalances can be resolved 每个平衡区必须有足够的资源来确保可以解决实时（小时内）不平衡问题

- Trading between BA is possible but limited 平衡区之间的电力交易有限制
Consequences of Individual Operation of Small Balancing Areas
小型平衡区单独运营的结果

- Each BA invests separately
  - Each **plans** and **invests** to meet adequacy and balancing needs

Consequences
- Each BA acquires more resources than necessary
- Costs are higher than necessary
- Curtailment of variable generation is higher than necessary
- Reliability could be more robust & less costly

- 每个平衡区都单独投资
  - 每个**规划和投资**用以实现资源充足性以及平衡区需求。

结果
- 每个平衡区获得的资源超过实际所需；
- 成本高于实际所需；
- 波动性发电的弃电高于必然；
- 稳定性可以更强大&成本更低。
## Benefits of Regional Power Markets

<table>
<thead>
<tr>
<th>Category</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>More efficient capacity</td>
<td><strong>Lower need for total generation</strong> capacity when peak demands occur at different times** 当峰值需求在不同时间发生时，对总发电容量的需求较低</td>
</tr>
<tr>
<td>utilization</td>
<td></td>
</tr>
<tr>
<td>更高效的容量利用</td>
<td></td>
</tr>
<tr>
<td>More efficient interregional</td>
<td><strong>Lower production costs from centralized, security constrained</strong></td>
</tr>
<tr>
<td>dispatch</td>
<td><strong>economic dispatch</strong> across control areas** 通过控制区域内的集中化、安全约束经济调度，降低生产成本</td>
</tr>
<tr>
<td>更高效的跨区调度</td>
<td></td>
</tr>
<tr>
<td>Lower ancillary services</td>
<td><strong>Lower costs for frequency regulation and operating reserves from</strong></td>
</tr>
<tr>
<td>(A/S) costs</td>
<td><strong>reserve sharing and optimization</strong> 降低频率调节和运营储备的成本</td>
</tr>
<tr>
<td>更低的辅助服务成本</td>
<td></td>
</tr>
<tr>
<td>More efficient integration</td>
<td><strong>Fuel cost savings and lower reserve requirements from regional</strong></td>
</tr>
<tr>
<td>of wind &amp; solar</td>
<td><strong>economic dispatch of wind/solar</strong> 风能/太阳能的区域经济调度节省燃料成本并降低储备要求</td>
</tr>
<tr>
<td>更高效的风能&amp;太阳能并网</td>
<td></td>
</tr>
<tr>
<td>Lower emissions</td>
<td><strong>Lower pollution and CO₂ emissions from</strong></td>
</tr>
<tr>
<td>更低的排放</td>
<td><strong>more efficient dispatch and reduced curtailment</strong> 通过更有效的调度和减少限电来降低污染和二氧化碳排放</td>
</tr>
<tr>
<td>Improved reliability</td>
<td><strong>Improved system reliability from</strong></td>
</tr>
<tr>
<td>更高的稳定性</td>
<td><strong>improved visibility and response capability</strong> via centralized dispatch 通过集中调度提高可视性和响应能力，提高系统可靠性</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Expanding Regional Markets: Examples

Entergy (blue) joins MISO (green) in 2013

Western EIM created in 2014

EU market coupling

Initial (2/14) market coupling

5/14 expansion

2/15 expansion
Topic 2: Ensuring Sufficient Competition
议题2：确保充足的竞争性

- When markets are working well, competitive pressure generally incentivizes generators to reveal their operating costs and capabilities, facilitating efficient system operations and rational signals for investment.

- However, ensuring adequate competition is not simple.

- Electricity markets can be susceptible to market power.

- 当市场运作良好时，竞争压力通常会激励发电商披露其运营成本和能力，促进高效系统运营和合理的投资信号。

- 然而，确保充足的竞争性并不简单。

- 电力市场容易受到市场力的影响。
In US & global experience, a competitive market requires:

- collection of data on each generator’s operating costs,
- an independent market monitor,
- market rules,
- penalties and enforcement.

美国和全球其他地区经验表明，一个具备竞争力的市场需要：

- 每家发电商运营成本的数据收集；
- 一个独立的市场监督者；
- 市场规则；
- 惩罚和执行。
Topic 2: Ensuring Sufficient Competition
议题2：确保充足的竞争性

- Market manipulation: Cost to consumers and to overall efficiency; can undermine confidence in markets.
  - California crisis of 2000–01.
- Independent Market Monitors are now typical
- 市场操纵：对消费者以及整体效率产生的成本；会破坏对市场的信心。
  - 加州2000–01年危机
- 独立的市场监督者如今很典型
Topic 2: Ensuring Sufficient Competition
议题2：确保充足的竞争性

- FERC, ISO/RTOs, and market monitor units design and implement a range of methods to test for and counteract market power.
  - Assessment of generator operating costs
  - Tests for whether actual market outcomes reflect the presence of market power
  - Tests for the potential for market power
  - Measures to correct for market power

- FERC, ISO/RTOs 和市场监督机构设计并实施一系列方法来测试和抵消市场力：
  - 评估发电商运营成本；
  - 测试实际市场结果是否反映了市场力的存在；
  - 测试潜在市场力；
  - 纠正市场力的措施。
Topic 2: Ensuring Sufficient Competition
议题2：确保充足的竞争性

- Each ISO/RTO has established market monitoring units
  - Some are independent even from the ISO itself
  - Monitoring units do not have any financial interest in the market
  - Market participants are not members

- 每个ISO/RTO都成立了市场监督机构：
  - 有些是独立的，甚至来自ISO自身；
  - 监督机构在市场上没有任何经济利益；
  - 市场参与者不是监督机构的成员
Topic 2: Ensuring Sufficient Competition
议题2：确保充足的竞争性

- Market monitoring units have important roles, including:
  - Compliance;
  - Data collection
  - Developing “reference levels” for market behavior;
  - Penalties on market participants for market manipulation;
  - Reporting to promote transparency and market understanding;
  - Improvements.

- 市场监督机构起着重要的角色：
  - 合规；
  - 数据收集；
  - 为市场行为制定“参考水平”；
  - 惩罚实施市场操纵的参与者；
  - 促进市场理解和透明度的报告；
  - 完善。
ISOs/RTOs evolved from “power pools” established to facilitate trade between vertically-integrated utilities.

- In these pools, utilities dispatched shared resources according to reported operating costs.
- Pools were successful at increasing the efficiency of operations over broader areas, increasing reliability, and reducing costs.

ISO / RTO是从旨在促进垂直一体化电力公司之间交易而成立的“电力库”演变而来:

- 在这些“电力库”中，电力公司根据运营成本调度共享资源;
- “电力库”成功地提高了更广泛区域的运营效率，提高了可靠性并降低了成本。
Topic 2: Ensuring Sufficient Competition
议题2: 确保充足的竞争性

• A suggestion for China’s markets: consider a practical initial market design based on reported costs, e.g.:
  • operating cost (including emissions costs and opportunity costs) data associated with each generation unit are collected, subject to verification;
  • the system operator uses these estimates to establish a merit order and set a market-clearing price in a “spot market”.

• 对中国电力市场的建议：考虑基于成本报告设计一个具备实操性的初始市场，例如：
  • 收集与每个发电机组相关的运行成本（包括排放成本和机会成本）数据，并进行验证；
  • 系统运营商使用这些预估来建立优先顺序并在“现货市场”中设定市场清算价格。
Topic 3: Long-term Contracts are Mostly Financial (not physical)
议题3：长期合同大部分是金融合同（不是物理合同）

- US does not have a China-style “medium-long term” market (or annual generation output planning)
- Long-term contracts are mostly financial (e.g., contracts for difference)
- In a well-designed market, the system operator largely does not need to know details about these long-term financial contracts
- System operator focus on dispatch according to monthly/annual contracts can contribute to inflexibility and inefficiency.
- 美国没有中国式的中长期市场（或者年度发电产品规划）
- 长期合同大多数为金融合同（比如，差价合同）
- 在设计良好的市场中，系统运营商在很大程度上不需要了解这些长期金融合同的细节
- 系统运营商根据月度/年度合同关注调度可能导致缺乏灵活性和低效率。
ISO/RTOs were first implemented in the 1990s, but there is still much controversy over market design.

Ongoing debates about how best to:
- send the right signals for the investment in (and efficient operation of) flexible resources;
- fairly and adequately compensate resources that are economic and needed for reliability;
- encourage those generators that are not to retire;
- offer a level playing field to all resources, including distributed resources.

ISO / RTO 最初是在20世纪90年代实施的，但市场设计仍存在很多争议。

正在进行的关于如何最好地实施以下方面的辩论：
- 为灵活资源的投资（和有效运作）发出正确的信号；
- 公平和充分地补偿提供稳定性所需的具备经济性的资源；
- 鼓励那些不退休的发电机组；
- 为所有资源提供公平的竞争环境，包括分布式资源。
• Capacity payments have been highly controversial in the United States (and Europe).
• Some US markets have capacity payments; some do not (“energy only” markets).
• In practice, capacity payments have often supported high-emitting and inflexible resources, with costs for consumers and society.

在美国（和欧洲），容量费用一直备受争议。
美国一些市场有容量费用；一些没有（“单一电量”市场）；
在实践中，容量费用往往支持高排放和不灵活的资源，为消费者和社会带来成本。
Topic 4: Generator Compensation and Capacity Payments
议题4：发电补偿和容量费用

- We suggest: be cautious about giving generators capacity payments (“compensation for fixed costs”).
- If capacity payments are implemented, this should be done strictly.
- Only generators that are economic, meet environmental standards, and are actually needed for reliability or flexibility services should receive a capacity payment.
- Need improved planning and approval processes to guide any capacity payment.

- 我们建议：谨慎提供发电机容量费用（“固定成本补偿”）。
- 如果实施了容量费用，则应严格执行。
- 只有符合经济性，环境标准且实际上需要其提供可靠性或灵活性服务的发电机才能获得容量费用。
- 需要改进规划和审批流程以指导容量费用。
Topic 5: Distributed Energy Resources Participation in ISO/RTO Markets
议题5：分布式能源资源参与ISO/RTO市场

- How can DERs earn appropriate revenue from services provided to both distribution network and transmission grid?
- How best to aggregate DERs so that they can participate in ISO/RTO markets (energy and ancillary services)?
- How to increase ‘visibility’ of DERs to ISO/RTO system operator?
- Who should operate resources on the distribution system and how should these resources be ensured non-discriminatory interconnection and operation?
- 分布式能源资源如何从提供给配电网和输电网的服务中获得适当的收入？
- 如何最好地聚合分布式能源资源，以便他们可以参与ISO / RTO市场（能源和辅助服务）？
- 如何提高分布式能源资源对ISO / RTO系统运营商的“可见度”？
- 谁应该在配电系统上运营资源？如何确保这些资源的非歧视性并网和运营？
Conclusions 总结

• Wholesale market maturity, as with people, takes decades, and may never really be done
• Underlying trends are changing original expectations and demand attention and respect
• Evolving market rules should lead to sound planning and to efficient operation and investment for grid scale and local scale resources

与人一样，批发市场的成熟需要数十年，而且可能永远不会真正完成；
潜在的趋势正在改变原有的期望，需求关注和相关；
不断发展的市场规则应导向良好的规划，以及电网范围和当地范围资源的高效运营和投资。
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