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2010.12.7-8日，北京

Sino-US Wind Power Interconnection Seminar
Dec.7-8, 2010 Beijing

风电发展及并网相关问题

Related Issues about Wind Power Development and Integration

国网能源研究院 蒋莉萍

State Grid Energy Research Institute (SGERI)

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一、中国电力系统现状及未来发展趋势

1、Current status and development tendency of China's power system

（一）2009年现状
The status of power grid in 2009

全国发电装机容量：

8.74亿千瓦，比上年增长10.2%；

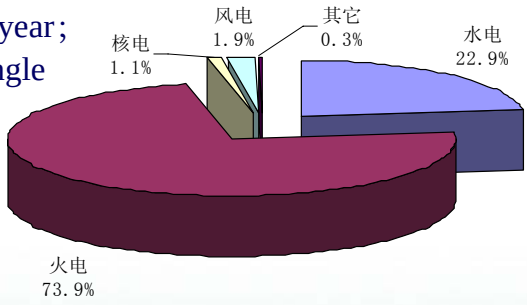
新增装机8970万千瓦（6000千瓦以上机组）

The installed capacity of generator:

87400GW，increased by 10.2% compared last year;

The new installed capacity is 89700MW（single generator capacity >6MW）

2009年全国发电装机构成



6000千瓦及以上电厂累计平均设备利用小时数为4527小时，同比降低121小时

Annual average utilization hours of the plant with installed capacity above 6MW is 4527h,decreased by 121h on year-on-year basis

电网发展现状

2010年11月3日，新疆-西北主网联网750千伏输变电工程正式投运。
Xinjiang—Northwest 750kV transmission project was operated on Nov 3, 2010

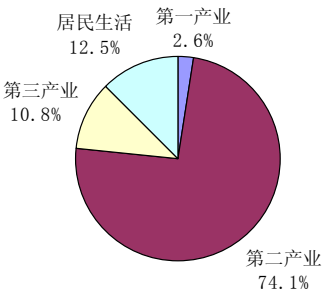
→除西藏、台湾外，全国各大区域电网之间已实现交直流互联（青海—西藏750千伏／±400千伏交直流联网工程7月底开工，计划2012年底建成）
→Except Tibet and Taiwan, the Nation-wide interconnection has completed （ Qinghai –Tibet AC 750 kV／DC ±400kV interconnection project began construct at the end of July and will be completed in 2012 ）

全国全社会用电量36430亿千瓦时，同比增长5.96%。
人均用电量2741千瓦时，相当于2007年世界平均水平。

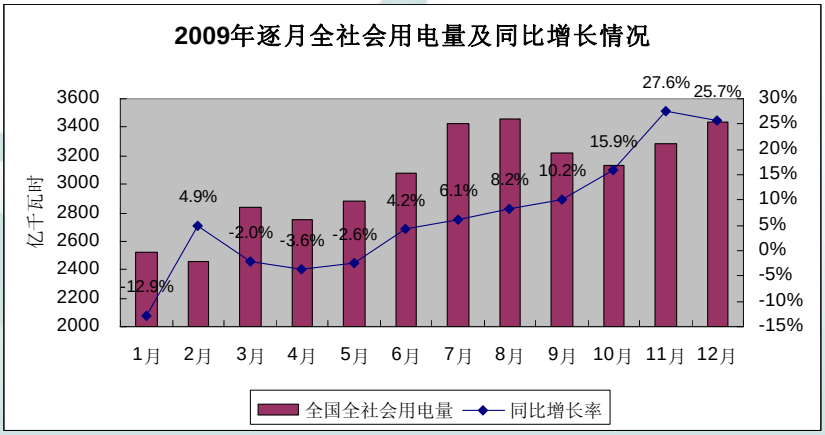
Total electricity consumption is 36430GkW.h, increased by 5.96% on year-on-year basis.

Electricity consumption per capita is 2741kW.h, which is global average level in 2007.

2009年全社会用电构成



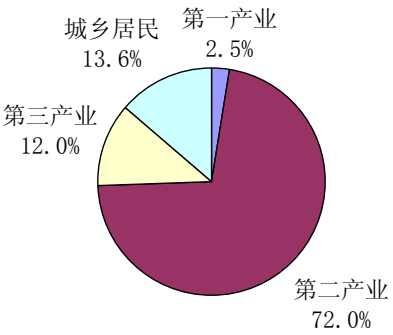
2009年逐月全社会用电量及同比增长情况



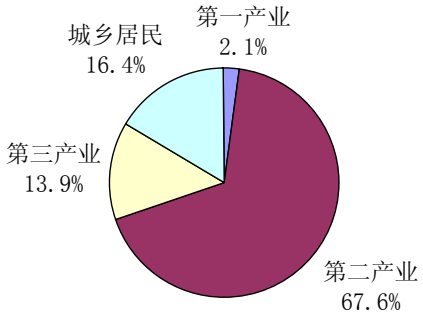
(二) 未来发展趋势
The development tendency

	全社会用电需求 Electricity demand	五年年均增长 Average annual growth	人均用电量 Per capita consumption	电力消费弹性系数 Power consumption flexible coefficient
2015年	5.65 ~ 6.20TkW.h	7.4 ~ 9.0%	4000 ~ 4450kW.h	0.94 ~ 0.99
2020年	6.99 ~ 7.98TkW.h	4.3 ~ 5.2%	4800 ~ 5500kW.h	0.69 ~ 0.79

2015年全社会用电构成



2020年全社会用电构成

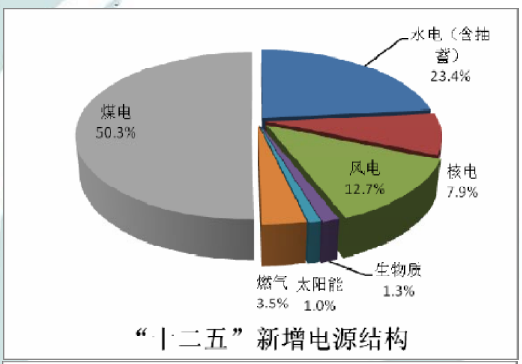


→未来相当长时期内，电力需求呈刚性增长趋势….

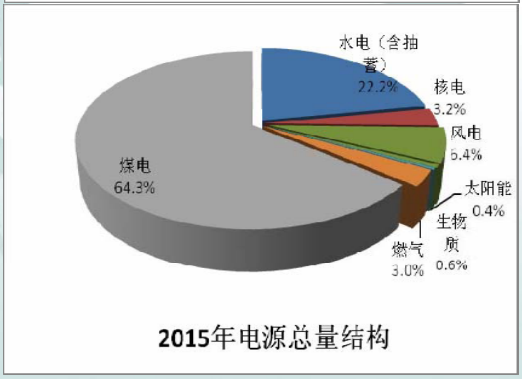
→In a long period, growth trend of electricity demand was rigid …

根据用电需求预计，到2020年，全国发电装机容量将超过15亿千瓦，甚至达到17-18亿千瓦。

Based on forecast of electricity demand, it is expected that the total power-generating installed capacity will be more than 1500 GW, and even to 1700 and 1800 GW by 2020 .

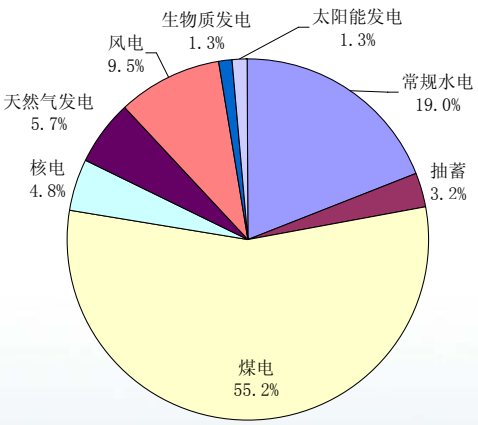


“十二五”新增电源结构



2015年电源总量结构

2020年发电装机构成

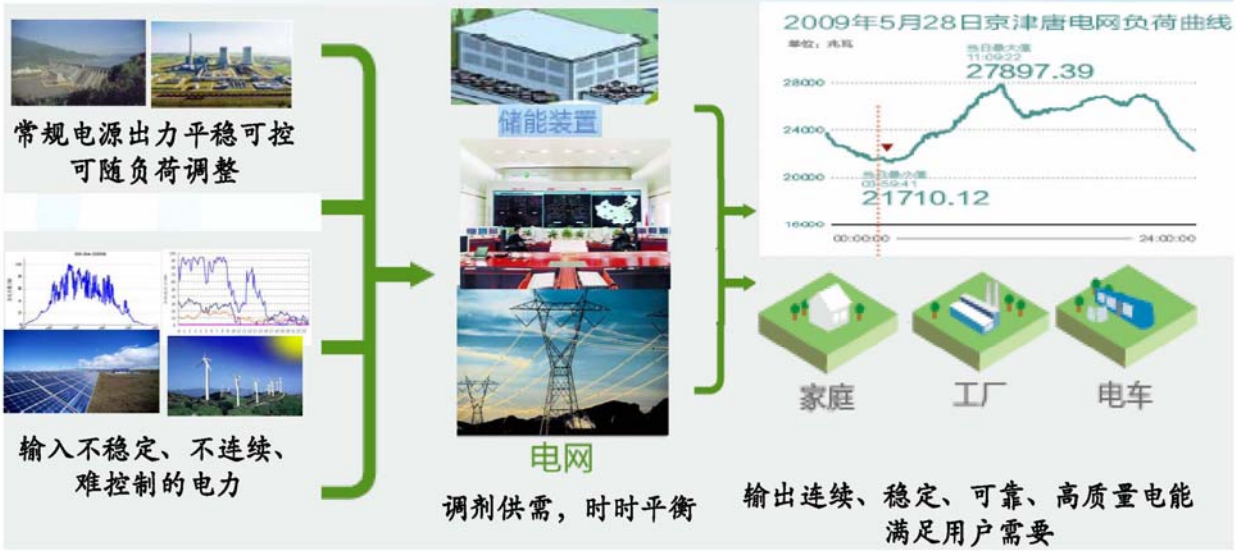


- 非化石能源发电装机达到约35%
- Non-fossil energy power generation installed capacity reached about 35%
- 燃煤发电装机比重下降到55%左右。
- The precentage of Coal-fired power generation installed capacity will dropped to 55%

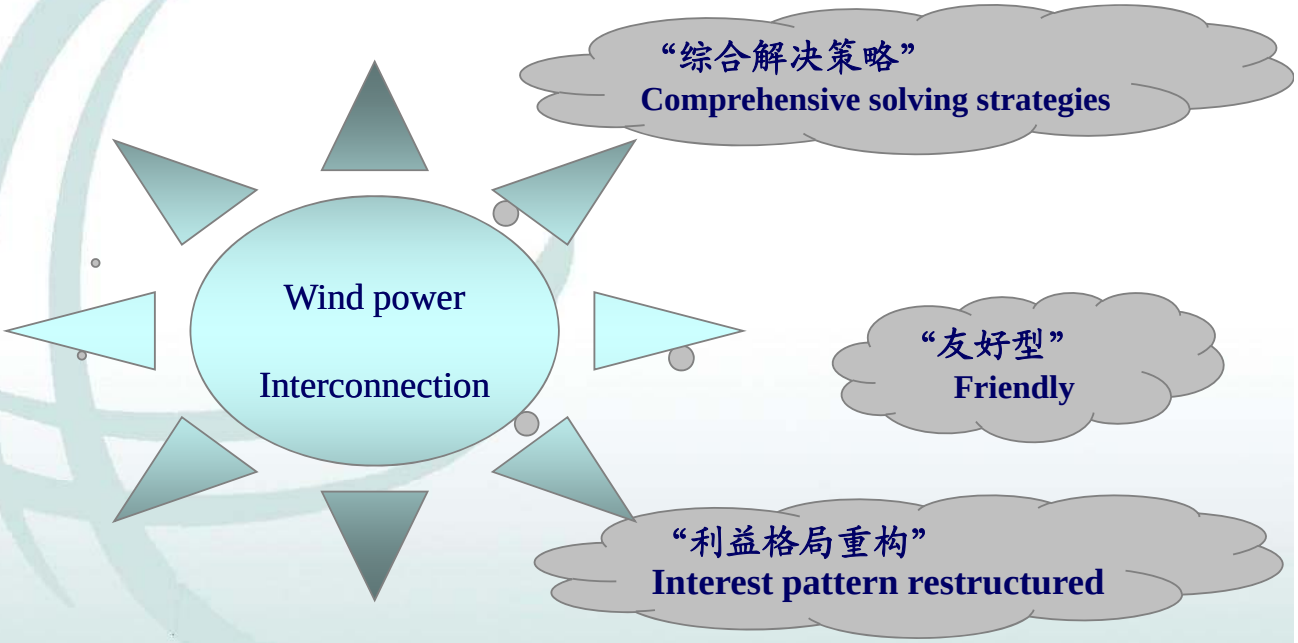
二、对风电并网发展的几点看法
Comments on wind power interconnection and development

并入大电网是实现风电、太阳能等大规模开发利用最有效、最主要的途径
Integrating into strong power grid is the most effective and important way to develop large-scale wind power\ solar power

风电、太阳能等清洁能源发电出力具有间歇性、波动性、不可控和难预测等特点，只有通过电网实现不同分布清洁能源间、不同类型电源间的调剂，才能实现其规模化有效利用。



（一）实现大规模风电并网的三个关键词
Three key words for large-scale wind power integration



“综合解决策略”：技术+管理
Comprehensive solving strategies: Technique+Management

- 发展规划、项目审批、项目建设、运行…… → 发展成本
- Development plan\project examining\construction\ operation…… → cost
  - 发展规模及布局与电网和电源建设发展统一规划、统筹协调
  - The development scale \ layout and network \power sources construction should be under unified planning and overall coordination
  - 项目核准及建设进度安排要衔接
  - Approval and project construction schedule should be connected
  - 阶段性规划目标 vs 年度发展规模：均衡
  - Balance between period planning and annual development

  主题词：协调 Keywords: Coordination
- 并网技术标准及管理规范 →系统运行的安全稳定性和电力供应的可靠性
- Grid code → Stability and Reliability

  主题词：强制（门槛、地板） + 引导（方向）

  Keywords: compulsion + guide

Comprehensive technology strategies

【综合技术策略】

风电站：先进的风机设备+电站级控制技术+风电出力预测技术+储能技术……

Wind farm: advanced wind turbine + wind farm control+ wind power forecast + energy storage

电网/电力系统：充裕的输电能力+先进调度+充足的调节能力……

Grid/power system: enough transmission capability + advanced dispatch + sufficient adjustment capacity

友好型
“friendly”

系统友好型风电站 Grid-friendly wind farm
+
风电友好型电力系统 Wind power-friendly grid

生产优质能源（电量）
Produce quality energy

生产优质电量及优质电力
Produce quality electricity and power

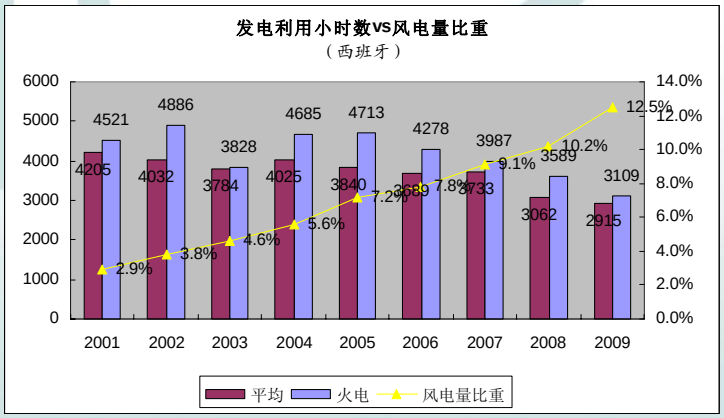
- “电网友好型”：实现“风电场”向“风电厂○（站）”的转型
- **Grid-friendly wind farm: from windfarm○to wind plant(like normal plant)**
  - 先进的发展理念+技术手段
  - Advanced ideas+technique
  - 储能?
  - Energy storage?

  先进的风机设备advanced wind turbine
  电站级控制技术wind farm control
  更加准确的风电出力预测技术more accurate wind power forecast……
- **电网/电力系统：如何实现“风电友好型”**
- **Grid/ Power system: How to realize “wind power friendly”**

充裕的输电能力+先进调度+充足的调节能力……
Sufficient transmission capacity +advanced dispatch+ sufficient adjustment capacity
→ 更坚强、更智能的电网；更灵活、更可调的系统
→ Stronger and smarter grid; more flexible and controllable system

“利益格局重构”— by 政策法规/市场
Interest pattern restructured-by policy/market

- 传统电源投资者：发电市场份额减少、调峰调频要求提高（应对RE出力的波动性等）
- Traditional power investors: electricity market share reduced, higher request of regulating ability（ to deal with the fluctuation of RE）
- 跨区消纳的利益分配/成本分担：地区之间
- Cross-regions consumption benefits distribution /cost sharing: between regions
- 系统发展成本 ：电网？用户？
- System development cost: Power grid? User?
- ……



初步分析表明:

相对于2020年风电装机规模为1亿千瓦的发展情景而言，风电装机规模达到1.5亿千瓦的发展情景下，电力系统的全系统综合运行成本将提高1.1%。

Preliminary analysis shows that:

The total installed capacitor of wind power will rise from 1 billion kW to 1.5 billion kW in 2020 , the whole operation cost of power system will rise by 1.1%

政府作用（尤其是在快速发展阶段及市场培育初期）：

Government function（ especially in the early time of development ）

- 制定规划并有序实施：总体目标+分阶段目标 –协调性、均衡性
- **Planning and orderly implementation：General target-+Stage goal - coordination, balance**
- 采取“大棒+胡萝卜+锣鼓”的一揽子政策措施
- The package of policies and measures which is called "Big stick + carrot+drum"

核心(Core)：

- 以最低的社会成本实现最好的发展成效
- Obtain best development by lowest cost
- 保持利益格局的均衡，确保能源行业发展的稳定性、可持续性 – by 市场化或适当的政策调整
- Keeping Interest pattern’s balance, ensure the stability and sustainability of the energy sector development-by marketing or appropriate policies adjustment

（二）风电开发规模与消纳问题

The wind power development scale and consumption

基本认识：

Basic knowledge:

对一特定电网/电力系统而言，其可再生能源的接纳能力（比例），主要取决于该系统的电网充裕度，以及系统调峰能力（与电源结构及负荷特性有关）；

For a special grid/power system, the accommendation of renewable energy is depend on the grid adequacy and the regulating balancing ability(which is related with the power source structure and the load charactristics);

对一特定地区而言，其可再生能源资源的开发利用规模，主要取决于消纳范围（亦即所在电网的覆盖范围）

For a special region, the renewable energy development scale is depend on the consumption range (that is the grid area);

→“基地式”与“分散式”相结合的开发模式

→**The development model combined “big base style” with “dispersed style”**

	消纳市场 consumption market
甘肃 Gansu	西北主网、三华Northwest China \North China\East China\Central China power grid
新疆 Xinjiang	新疆、三华Xinjiang \North China\East China\Central China power grid
蒙西 West Inner Mongolia	蒙西、三华West Inner Mongolia\North China\East China\Central China power grid
蒙东 West Inner Mongolia	东北、三华Northeast China \North China\East China\Central China power grid
吉林Jilin	东北Northeast China
河北Hebei	三华North China\East China\Central China power grid
江苏Jiangsu	华东East China power grid

七大风电基地的开发规模约占规划开发总规模的80%；北部六大基地的规模比例接近3/4.

The seven base’s scale is account for 80% of the total planning scale, the six base in the north china is 75%.

初步分析结论：通过加强调峰电源及跨省区电网建设，全国风电开发规模可以提高一倍以上。

Primary conclusion: By strengthening balancing power and the grid construction, the total wind power development scale in China can double.

（三）风电大规模开发的经济性问题

The economical problems of large-scale development of wind power

（1）借助煤电基地外运通道实现风电外送，有利于扩大风电的消纳范围和规模，降低大规模风电开发成本。

Transmit wind power with the coal-power bases transmission lines， it is useful for enlarging the wind power **consumptive scope and scale ,** reducing the development cost

主要风电基地的能源外送流向与输煤输电并举的煤电流向正好相吻合!

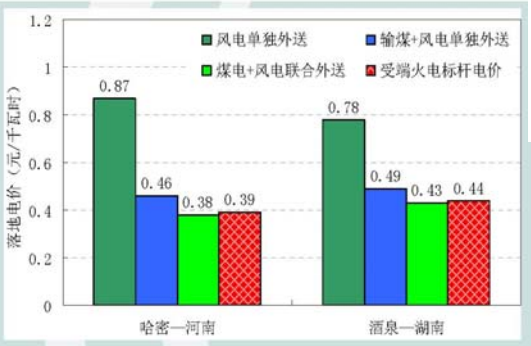
The major outbound flows of wind power base coincides exactly with the coal power flow.

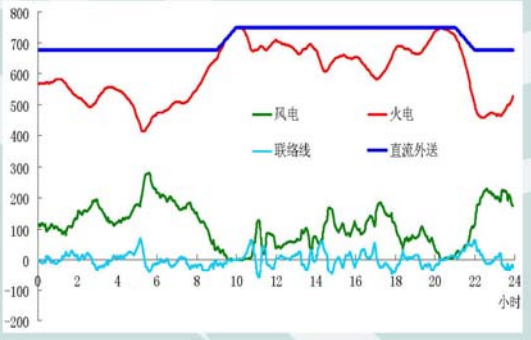
初步测算:

preliminary measurement：

借助煤电外送通道外送风电，通过综合协调风电、火电（及其他电源）、电网、用户之间的关系，至受端电网的落地电价可不高于当地的火电标杆电价（输电线路的利用小时数达到6500小时以上，火电5000小时以上）。

By coal-power bases transmission lines to transmit wind power and the regulating relationship among wind power, thermal power (and other kinds of power), grid and customers, the electricity price of receiving-side grid is not more than the benchmark price of the local thermal power (the utilization hours of transmission lines is more than 6500h and more than 5000h are for thermal power).





技术可行

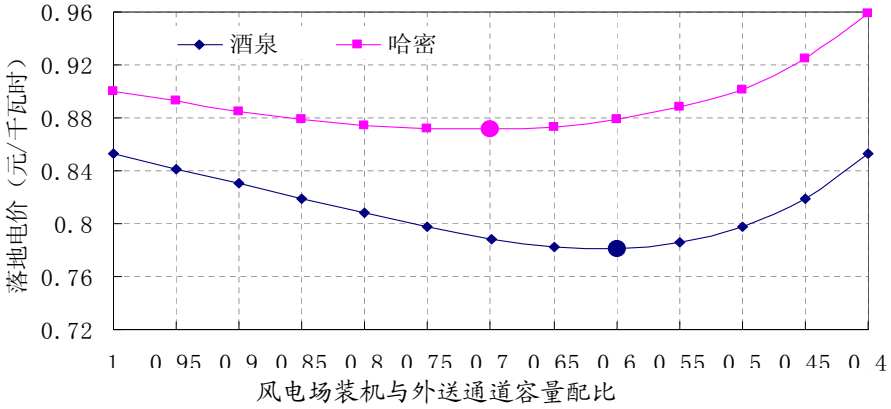
Technical Feasibility

网对网输送方式，可调用系统内的水电、抽蓄等资源，参与风电功率波动的调节，保障系统安全稳定运行。

以甘肃酒泉风电基地为例，在大多数情况下，酒泉打捆火电能及时跟踪风电波动；为提高系统整体经济性，以及在风电出力快速变化的时段，可借助坚强的750千伏电网，调用西北电网的水电、火电、抽蓄等系统资源，参与风电功率波动的跟踪，保持系统安全稳定运行。

（2）风电基地单独外送：核心是合理配置输电容量

(2) Wind power alone transmission : the core is the reasonable transmission capacity



The ratio between wind farm's installation capacity and transmission capacity

（1）对于风电单独外送，从涵盖发电和输电环节的综合经济性来看，输电通道容量按风电装机容量的60%～70%配置较为合理（特高压直流）。

Wind power alone transmission, according to the comprehensive economic aspects of power generation and transmission, it is reasonable if the transmission capacity is about 60%～70% wind farm's installation capacity (extra-HVDC) .

（2）即便如此，由于输电线路的利用率低，到达受端电网的落地电价为受端火电标杆电价的2倍左右，且远远高于当地风电标杆电价。

Even so, because of the low utilization rate of transmission line, the electrical price of receiving-side grid is twice of the local benchmark price, it is far more than the benchmark price of the local wind power .

（3）为适应大规模风电等可再生能源开发，电力系统的综合运行成本将会上升

In order to adapt to the large-scale development of wind power and other renewable energy, the power system comprehensive operation cost will rise.

分析表明：2020年风电装机总规模从1亿千瓦提高到1.5亿千瓦情况下，整个电力系统的运行成本将提高1.1%。其中：

Analysis shows: in 2020 the scale of the wind power is rise from 100 GW to 150 GW, the whole operation cost of power system will rise by1.1%. In which:

- 电网投资需要增加4.8%
- The investment of power grid will increase 4.8%
- 抽蓄、燃气发电等提高系统调峰及运行灵活性的电源投资需要相应增加8.5%和11.4%。
- The investment of power sources including pump storage generator and gas-fuel power generator requires a corresponding increase of 8.5% and 11.4% in order to improve the grid's balancing capability and the operation flexibility.

（四）更加灵活、可控的发电技术组合

(4) The combination of more flexible and controllable power generation technology

各种发电技术构成及其运行方式需要加强优化

The composition and operation mode of various power generation technologies need strengthen and optimize.

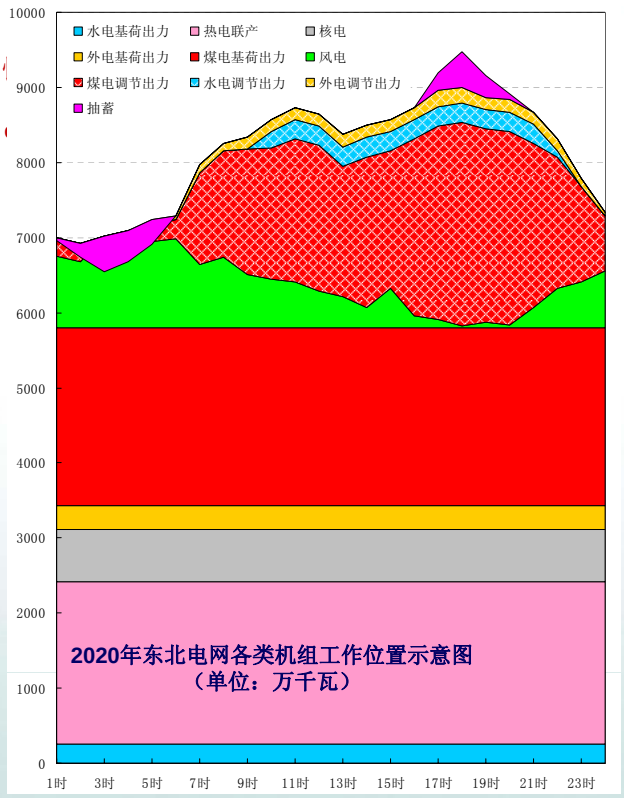
尤其是需要加强投入有利于提高系统调峰能力及运行灵活性的发电技术

Especially, strengthen the power generation technology which can improve the system balancing capacity and operational flexibility.

- ➢抽蓄、燃气机组
- ➢pump storage units and gas turbine
- ➢煤电机组的运行灵活性
- ➢the operation flexible of coal-fired units
- ➢核电、风电等技术的出力调节能力
- ➢The balancing ability of nuclear power, wind power etc.

对应2020年风电开发规模达到1.5亿千瓦，除需加强风电基地所在省级电网的网架结构外，还需要在受端“三华”电网新增抽水蓄能装机约1200万千瓦，燃气电站增加约800万千瓦。

In order to match the wind power scale in 2020, it is needed not only to strengthen the provincial grid structure, but also to increase the installed capacity of pumped storage units to 12000MW and installed capacity of gas turbine to 8000MW in the receiving-side grid which is “Three Regional power grid of China”.



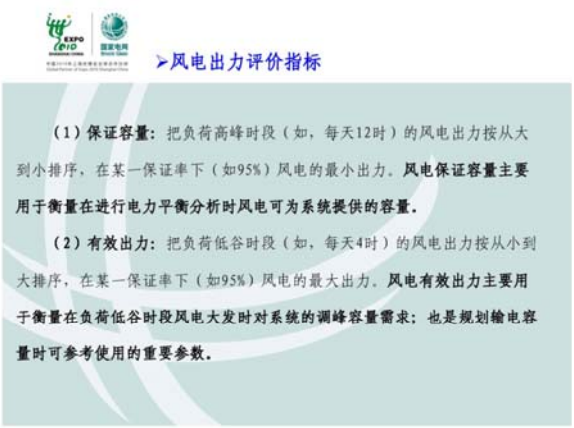
2020年东北电网各类机组工作位置示意图
（单位：万千瓦）

（五）建立科学、合理的研究分析理论及方法体系

(5) Establish scientific, rational study and deduce theory and methods system

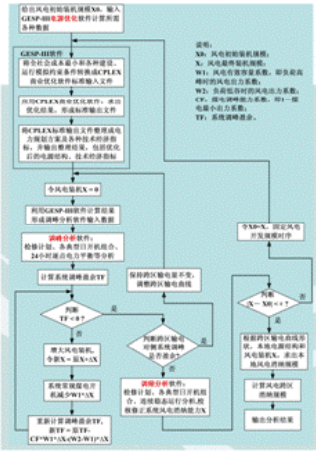
- ◘ 规划研究层面
- ◘ The aspect of planning research
- ◘ 系统运行分析层面
- ◘ The aspect of system operation and analysis
- ◘ 评价分析层面
- ◘ The aspect of evaluation and analysis
- ◘ ……

- －立足于整个系统综合效率及效益最优
- －Depending on comprehensive efficiency and optimal efficiency of the whole system
- －结合/反映电力系统特性
- －Combining/reflecting the power system characteristic


➢风电出力评价指标

（1）保证容量：把负荷高峰时段（如，每天12时）的风电出力按从大到小排序，在某一保证率下（如95%）风电的最小出力。**风电保证容量主要用于衡量在进行电力平衡分析时风电可为系统提供的容量。**

（2）有效出力：把负荷低谷时段（如，每天4时）的风电出力按从小到大排序，在某一保证率下（如95%）风电的最大出力。**风电有效出力主要用于衡量在负荷低谷时段风电大发时对系统的调峰容量需求；也是规划输电容量时可参考使用的重要参数。**



总体方法
和分析流程

包括电源优化、生产模拟和调峰分析、调频校核等多种专业分析方法。

第一步 设定边界条件
（电力需求，已有和备选的电源、跨区输电，及其技术经济条件）

第二步 优化电源结构和布局
（确定火电、清洁电源、调峰电源等各类电源的规模、时序、布局和流向）

第三步 确定清洁能源消纳规模
（通过系统详细生产模拟和调峰平衡分析，调频平衡校核，修正清洁能源消纳规模）

第四步 收敛判断、迭代计算

第五步 输出结果
（包括电源结构、布局、跨区电力流、污染物和温室气体排放，系统总成本、典型日运行方式等）

三、关于风电的“波动性”管理

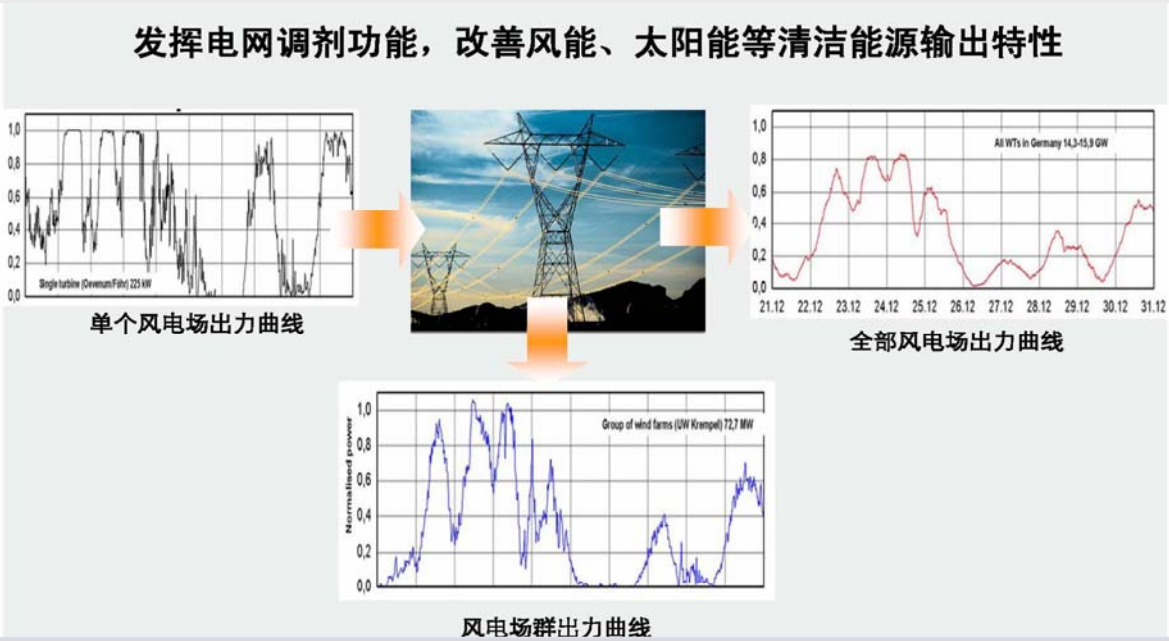
The management of wind power’s “fluctuation”

（一）风电站出力的波动性管理

(1) The management of wind power’s fluctuating output

（1）借助电网平台，改善风能、太阳能等清洁能源的综合输出特性

1) With grid platform to improve the integrated output characteristics the of wind, solar and other clean energy.



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- 对系统而言，风电出力的不稳定随着规模的增加而增大；
- For system, the instability of wind power output increases with the size of the wind power.
- 由于分散分布的风电资源之间存在互补性，不稳定并非按比例增大。
- Because the dispersed wind resources are mutually complementary , the instability is not increased in proportion

（2）借助电网平台，发挥电力系统综合调度的优越性，实现不同电源技术间的优势互补
2) Based on grid, realizing the advantage of power system's comprehensive dispatching, implementing the complementary advantages of different power technologies

- 风电：提高风电出力预测的准确性（扮演好电源角色）
- Wind power : improving the predictive veracity of the output(be a good power source)
- 调度：适应风电等新发电技术的调度管理策略和技术
- Dispatch: adapting the dispatching management and technology of the new generation technology (wind power etc.)
- 传统电源：进一步提高运行灵活性
- traditional power source: improving operation flexibility
- 加强电网输配电能力
- Improving the capacity of transmission and distribution
- 增加运行更加灵活的发电技术：燃机、水电/抽蓄等
- Improving the more flexible generation technology: gas, hydropower / pumped storage etc.

每个风电、太阳能等项目均通过储能手段来实现平滑出力，未必是系统效率和效益最优的策略！-- 需要而且有必要结合开发规模、电源构成、负荷特性等对各系统作具体的分析和论证，在此基础上提出相应的解决策略和技术方案。

To each project of wind power , solar energy etc. smoothing output by storage may not be the optimal method to improve system efficiency and benefit. Depending on the analysis of the developing scale, the structure of source, the load characteristics etc., it is possible to present relevant methods and technical scenarios.

（3）配网侧分散接入的分布式风电，可采用“负荷”式管理方式
3) “load” management method can be usedon the distributed wind power in distribution grid .

（二）风电项目开发的波动性管理
(2) The management of the wind farm's development fluctuation

核心：实现风电开发与电网及其它电源建设之间的协调发展；促进风电技术研发及设备制造产业的健康、可持续发展；减少发展代价，降低系统供电的综合成本。

Core: realizing the harmonious development among the wind farm, grid and other sources; promoting health and sustainable development of the wind power 's technical research and equipment manufacturing industry; decreasing the development cost, reducing the comprehensive cost of the system power supply.

- ✓ 明确的发展规划目标（总目标及阶段目标）
- ✓ Specific development plan and goal (general goal and stage goal)
- ✓ 完善、稳定的政策措施
- ✓ Perfect and steady policy and measures
- ✓ 规范的项目审批程序
- ✓ Standardized procedures for project approval
- ✓ 明确的技术及管理要求
- ✓ Specific technology and management requirement
- ✓ 理性、合格的市场参与者
- ✓ Rational, qualified market participants

谢谢！

欢迎讨论！

Thanks!

Welcome to the discussion！