



国家电网
STATE GRID

中国电力科学研究院

CHINA ELECTRIC POWER RESEARCH INSTITUTE

中国区域内虚拟电厂发展现状

Virtual Power Plant in China : State of the Art

中国电力科学研究院

2023.9

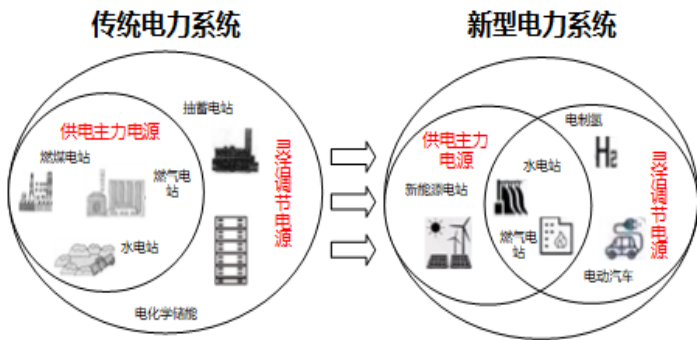
一 发展背景

I Development Background

“双碳”目标推动系统电源结构与负荷特性加速转变，电网尖峰负荷屡创新高、峰谷差持续拉大，给电网平衡、电力保供和带来巨大挑战，**据测算到2025年电力系统调节资源将达5.6亿千瓦**。分布式资源以聚合虚拟电厂形式参与电网互动调节是发展新型电力系统的必然选择，也是国家“十四五”现代能源体系规划的重要内容。

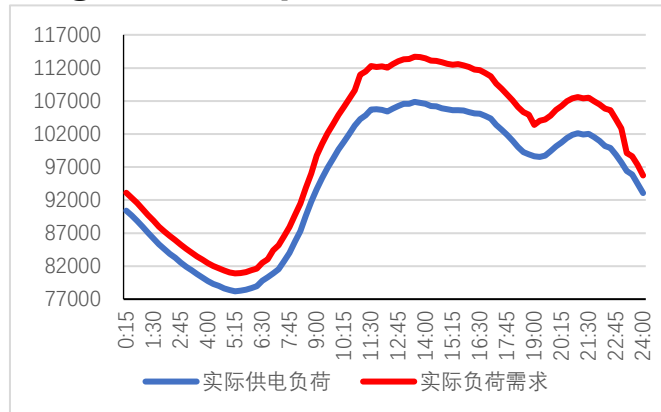
The "Dual-carbon" goals are driving a rapid transformation in the power supply structure and load characteristics of the system, leading to frequent peaks in electricity demand and a widening gap between peak and off-peak periods in the power grid. This poses significant challenges for grid balance and ensuring a reliable power supply. **According to estimates, the regulatory resources of the power system will reach 560 GW by 2025.** Involving distributed resources in the form of aggregated virtual power plants in grid interaction and regulation is not only an inevitable choice for developing a new type of power system but also a crucial component of China's "14th Five-Year Plan" for modernizing the energy system.

1 落实国家双碳目标要求，支撑新型电力系统建设
To implement the national dual-carbon objectives and support the construction of a new type of power system.



电力系统形态演变

2 丰富电网灵活性调节资源，提高电网平衡调节能力。
Enhancing the flexibility of the power grid regulation resources to improve grid balance and regulation capabilities.



2022年公司迎峰度夏期间全网负荷情况

3 缓解局部电网供需矛盾，保障清洁能源安全有序消纳
Mitigate local grid supply-demand conflicts and ensure the safe and orderly integration of clean energy sources.

单位:亿千瓦		2020	2025	2030	2050
传统调节手段	波动性可再生能源发电规模	5	10	15	40
	灵活煤电机组	1	2	3	4
	天然气发电机组	1	1.5	1.8	2.3
	抽水蓄能	0.32	0.68	1.2	1.7
	电化学储能	0.03	0.2	2	6.1
可再生能源功率调节缺口		2.65	5.62	7	25.9

电网灵活性调节资源需求预测

一 发展背景-政策要求

I Development Background-Policy requirements

为深入贯彻党中央“双碳”重大战略部署，国务院会同各部委陆续颁布了相关规划方案，要求以**数字化、智能化技术助力源网荷储智慧融合发展**。“云大物移智链边”等数智化技术在源网荷储各侧逐步融合应用，推动传统电力配置方式由**部分感知、单向控制、计划为主**向**高度感知、双向互动、智能高效**转变。

In order to further implement the major "dual-carbon" strategic deployment of the Central Committee of the Communist Party of China, the State Council, in conjunction with various ministries and commissions, has successively issued related planning schemes, requiring the use of **digital and intelligent technologies to support the smart integration of energy sources, grids, loads, and storage**. Digital technologies such as "cloud computing, big data, Internet of Things, artificial intelligence, and blockchain" are gradually being integrated and applied across the entire energy supply chain, promoting the transformation of the traditional power configuration from **partial perception, one-way control, and planning-oriented** to **highly perceptual, bidirectional interactive, and intelligent efficiency-oriented**.



《关于印发2030年前碳达峰行动方案的通知》(国发〔2021〕23号)

2021.10

大力提升电力系统综合调节能力。引导自备电厂、传统高载能工业负荷、**虚拟电厂**等参与系统调节。省级电网基本具备**5%**以上的尖峰负荷响应能力。

《关于印发“十四五”现代能源体系规划的通知》(发改能源〔2022〕210号)

2022.1.29

大力提升电力负荷弹性。整合分散需求响应资源，高比例释放居民、一般工商业用电负荷的弹性。争到2025年，电力需求侧响应能力达到最大负荷的**3%~5%**。

《关于完善能源绿色低碳转型体制机制和政策措施的意见》(发改能源〔2022〕206号)

2022.1.30

推动将需求侧可调节资源纳入电力电量平衡，探索建立以市场为主的补偿机制，全面调查评价需求响应资源并建立分级分类清单，形成动态的需求响应资源库。

《关于推进新型电力负荷管理系统建设的通知》(发改办运行〔2022〕471号)

2022.6.24

做好“双碳”背景下的电力安全保供工作，深化电力负荷管理，2025年，系统负荷控制能力达到本地区最大负荷20%以上，负荷监测能力达到本地区最大负荷70%以上。

国家能源局《关于公开征求电力现货市场基本规则、电力现货市场监管办法意见的通知》

2022.11.25

推动电力用户、售电企业和储能、分布式发电、负荷聚合商、虚拟电厂和新能源微电网等新兴市场主体参与电力现货交易，充分激发和释放用户侧灵活调节能力。

《关于加快推进能源数字化智能化发展的若干意见》(发改能源)

2023.3.31

以数字化智能化电网支撑新型电力系统建设，提高负荷预测精度和智能管理水平，推动负荷侧资源分层分级分类聚合及协同优化，加快推动负荷侧资源参与系统调节。

国家能源局《新型电力系统发展蓝皮书(征求意见稿)》

2023.6.2

数字化、智能化技术助力源网荷储智慧融合发展。推动传统电力配置方式由**部分感知、单向控制、计划为主**向**高度感知、双向互动、智能高效**转变。

一 发展背景-国内发展历程

I Development Background- Domestic Development

政策方面，国家层面尚未出台虚拟电厂专项政策，省市层面，山西、上海、宁夏、山东济南、广东广州、广东深圳出台了虚拟电厂专项政策，对虚拟电厂设计建设、参与交易、资金支持等多方面进行了引导和规范。

In terms of policy, there hasn't been a specific national policy for VPP yet. At the provincial and municipal levels, however, provinces and cities such as Shanxi, Shanghai, Ningxia, Jinan in Shandong, Guangzhou in Guangdong, and Shenzhen in Guangdong have introduced dedicated policies for VPP. These policies provide guidance and regulations on various aspects of VPP design, construction, participation in transactions, and financial support.

市场机制方面，虚拟电厂作为新兴市场主体纳入规划，可参与现货市场交易、辅助服务市场交易及需求响应市场交易，参与不同市场时按照具体市场规则执行。

In terms of market mechanisms, VPP as emerging market entities, are included in the planning and can participate in spot market trading, ancillary services market trading, and demand response market trading. When participating in different markets, they are subject to specific market rules and regulations.



虚拟电厂标准获国际电工委员会 (IEC) 批准立项。

国家发改委批复上海黄浦商业建筑需求侧管理示范项目。

国网上海电力启动“城市公共建筑群虚拟电厂聚合调控关键技术研究及应用”项目。

国家发改委、能源局印发《“十四五”现代能源体系规划》，提出开展虚拟电厂示范。

2015

2016

2017

2018

2019

2020

2021

2022

2023

上海黄浦区启动需求响应型虚拟电厂试点工作。

上海建成黄浦区商业建筑虚拟电厂示范工程。

国网冀北公司启动“能源互联网环境下的多主体多能虚拟电厂关键技术与示范应用”项目。

中国电科院牵头的国家重点研发计划项目“规模化灵活资源虚拟电厂聚合互动调控关键技术”获批立项。

国标开展编制政策推陈出新

一 发展背景-国内研究进展与案例

I Development Background- Domestic Research Progress and Case Studies

盈利模式 Profit Model

目前以参与需求响应邀约、调峰、调频、容量备用辅助服务交易为主要收益来源，部分虚拟电厂具备峰谷套利能力，还可作为综合能源服务商通过为用户提供能源托管等服务获益。

The primary sources of revenue for VPP include participation in demand response invitations, peak shaving, frequency regulation, and capacity reserve ancillary service transactions. Some VPPs also have peak-off-peak arbitrage capabilities and can serve as integrated energy service providers by offering services such as energy aggregation for users to generate income.

标准制定与应用 Standard Development and Application

目前虚拟电厂国内外在编标准6项，其中IEC在编标准2项，国内在编标准4项（推荐性标准）。虚拟电厂还可按需采用需求侧管理、储能、分布式电源并网相关标准。

There are six standards being developed for VPP both domestically and internationally, including two standards in progress by the International Electrotechnical Commission (IEC) and four domestic standards under development (recommended standards). VPPs can also choose to adopt standards related to demand-side management, energy storage, and the integration of distributed energy resources as needed.

实施模式 Implementation Model

尚未形成成熟的成套解决方案，虚拟电厂项目基本处于前期试点研究阶段。近年来，江苏、上海、河北、广东等地相继开展了虚拟电厂的试点，聚合资源主要偏重于可调节负荷。

Mature comprehensive solutions have not yet been established, and VPP projects are primarily in the early pilot research phase. In recent years, provinces such as Jiangsu, Shanghai, Hebei, and Guangdong have successively initiated pilots for VPP, with resource aggregation primarily focusing on adjustable loads.

试点建设 Pilot Construction

现存虚拟电厂项目与电力现货交易试点区域几乎重合，除河北冀北外，开展试点省份均在两批电力交易试点省份名单中。广东、江浙沪等经济发达地区电力交易试点较为成熟，业务基础良好。

Existing VPP projects are almost entirely overlapping with the regions where power spot pilot region are implemented. Except for northern Hebei, all the provinces conducting pilots are included in the two batches of provinces designated for power trading pilots. Regions with strong economies such as Guangdong, Jiangsu, Zhejiang, and Shanghai have more mature electricity trading pilots with a solid business foundation.

深圳虚拟电厂实践情况

The situation of VPP implementation in Shenzhen.

2022年4月16日, 广东电力交易中心印发《广东省市场化需求响应实施细则(试行)》(广东交易〔2022〕54号)文件, 规定虚拟电厂调节能力与需求响应机制。

- **非直控虚拟电厂调节能力:** 响应能力不低于0.3MW, 单次响应持续时间不低于2小时;
- **直控虚拟电厂调节能力:** 上下调节不低于10MW, 单次响应持续时间不低于2小时;
- **需求响应机制:** 响应时段为所发布的需求响应时段, 响应价格为单段报价, 具备条件后可启用多段报价。

On April 16, 2022, the Guangdong Power Exchange Center issued the "*Guangdong Province Market-Based Demand Response Implementation Rules (Trial)*" (Guangdong Trading [2022] No. 54), which stipulates the regulation capacity and demand response mechanisms for VPP.

- **For non-direct control VPP,** the regulation capacity should not be less than 0.3 MW, with a single response duration of not less than 2 hours.
- **For direct control VPP,** the regulation capacity for both upward and downward adjustments should not be less than 10 MW, with a single response duration of not less than 2 hours.
- **The demand response mechanism** includes response periods as defined in the demand response schedule and single-segment pricing. Multiple-segment pricing can be enabled when certain conditions are met.

政策机制

Policy Mechanisms

2022年6月13日, 深圳市发改委发布《深圳市虚拟电厂落地工作方案(2022-2025)》, 对下阶段深圳虚拟电厂建设实施指明了方向。

- **重点发展智能有序充电技术及相应商业模式,** 新能源汽车与电网双向能量互动商业模式取得突破;
- **建成100万千瓦级可调能力,** 逐步形成年度最大负荷5%左右的稳定调节能力;
- **不断完善虚拟电厂市场化交易机制,** 孵化培育一批国内领先的负荷聚合商和核心零部件研发制造企业。

On June 13, 2022, the Development and Reform Commission of Shenzhen Municipality issued the "*Shenzhen Virtual Power Plant Implementation Plan (2022-2025)*," which provides clear directions for the next stage of VPP construction in Shenzhen.

- **The key focus is on the development of intelligent and orderly charging technologies and corresponding business models,** as well as achieving breakthroughs in the bi-directional energy interaction business models between new energy vehicles and the grid.
- **The plan aims to establish adjustable capacity of up to 1 GW,** gradually forming stable regulation capacity of around 5% of the annual maximum load.
- **Continuous improvements will be made in the market-oriented trading mechanisms for VPP,** nurturing and incubating a group of leading domestic load aggregation businesses and core component research and manufacturing enterprises.

深圳虚拟电厂实践情况

The situation of VPP implementation in Shenzhen.

市场激励机制

Market Incentive Mechanism

接入深圳虚拟电厂平台的市场主体可以通过以下三个来源获得激励：

Market entities connecting to the Shenzhen VPP platform can obtain incentives from the following three sources:

广东省市场化需求响应补贴

Guangdong Province Market-Based Demand Response Subsidies

- 日前邀约，价格上限3.5元/kWh
Day-ahead invitation, the price ceiling was set at ¥3.5/kWh
- 周内中标时段、日内提前两小时，价格上限5元/kWh
Bid by week and being scheduled two hours in advance: price ceiling is ¥5/kWh

深圳市政府建立的本地固定补贴

The local fixed subsidy established by the Shenzhen Municipal Government

- 分布式光伏上网电量0.3元/kWh
Distributed PV: 0.3 ¥/kWh (electricity sent to grid)
- 直流充电桩并网容量300元/kW、交流充电桩并网容量150元/kW。
DC charging pile grid-connected capacity: 300 ¥/kW;
AC charging pile grid-connected capacity: 150 ¥/kW

南方电网区域两个细则规定的调峰、调频等辅助服务固定价格补贴

The fixed price subsidies for peak shaving, frequency regulation, and other ancillary services

- 独立储能0.792 元/ kWh;
Independent Energy Storage 0.792 ¥/kWh
- 直控型可调节负荷，填谷0.132-0.792元/kWh,削峰，0.264-1.584元/kWh。
Dispatch-center-controlled Adjustable Load, Off-Peak 0.132-0.792 ¥/kWh, Peak-Shaving 0.264-1.584 ¥/kWh

一 发展背景-国内研究进展与案例

I Development Background- Domestic Research Progress and Case Studies

深圳虚拟电厂实践情况

The situation of VPP implementation in Shenzhen.

建设情况

Construction Status

截至目前，平台已接入**聚合商12家**，接入**装机容量约71万千瓦**，其中**可调节负荷50万千瓦**（相当于约9万户家庭的用电报装容量），**分布式光伏容量21万千瓦**。

As of now, the platform has onboarded **12 aggregator companies** with a combined **installed capacity of approximately 710MW**. Among them, **the adjustable load capacity is 500MW** (equivalent to the installed capacity of about 90,000 households), and the distributed PV capacity is 210MW.

平台接入资源类型



电动汽车运营商



大型商业综合体



分布式储能



集中供冷站



大型写字楼



工业园区



数据中心



工业负荷



预计2025年，将建成具备**100万千瓦级可调能力的虚拟电厂**，逐步形成**年最大负荷5%左右**的稳定调节能力。

It is projected that by 2025, the **VPP with an adjustable capacity of 1 GW** will be established, gradually forming a stable regulation capacity of around **5% of the annual maximum load**.

深圳虚拟电厂实践情况

The situation of VPP implementation in Shenzhen.

建设情况

Construction Status

➤ 平台建设亮点 Highlights of the platform construction :

实时准确响应调度指令

Real-time and Accurate Response to Dispatch Instructions

实现了系统的闭环、实时在线、全自动运行，可在**1秒钟内**快速完成优化计算和指令下达。

The system has achieved closed-loop, real-time online, and fully automatic operation, with the ability to complete optimization calculations and issue instructions **within 1 second**.

通用性强、功能易扩展

High versatility and easy expandability of functions

智能终端采用模块化设计，具备通用接口，可适应不同类型分布式能源资源接入，**可集成更多应用功能**。

The intelligent terminal adopts a modular design with universal interfaces, making it adaptable to various types of distributed energy resource connections and **capable of integrating additional application functions**.

全资源整合、闭环优化调控

Comprehensive Resource Integration and Closed-Loop Optimization Control

全面包含典型**源、荷、储**可控资源，均可参与调度调控，打通中小型分布式能源与调度的通信及调控壁垒。

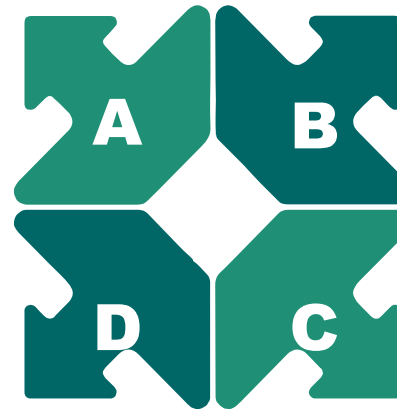
Comprehensively encompassing typical controllable resources in **generation, load, and storage**, all of which can participate in dispatch and control

配套终端功能灵活定制

Customizable Terminal Functions

智能终端RTU模块有强可编程能力，可灵活实现用户所需定制化**逻辑控制功能**，保证**现场运行稳定可靠**。

The smart terminal RTU module possesses strong programmable capabilities, allowing for flexible implementation of customized **logic control functions** as required by users, ensuring **stable and reliable on-site operation**.



深圳虚拟电厂实践情况

The situation of VPP implementation in Shenzhen.

□ **试点运行成效1:** 2021年11月8日, 深圳能源售电公司代理的深圳地铁集团站点、深圳水务集团笔架山水厂参与响应。在正常安全生产前提下, **按计划调节负荷共3000kW**。负荷侧资源在接到紧急调控需求后, **10分钟内**负荷功率即下调至目标值。

Pilot Operation Effect 1: On November 8, 2021, demand response adjusted the load as planned, totaling 3 MW. Upon receiving the emergency control request, the demand-side resources reduced the load power to the target value **within 10 minutes**.

□ **试点运行成效2:** 2022年4月28日, 提前向平台下发10000kW向下调节需求, **一天内7家聚合商在指定区域最大削减负荷5344kW**。

Pilot Operation Effect 2: On April 28, 2022, an advance request to reduce demand by 10MW was sent to the platform. **Within one day, seven aggregator companies reduced the maximum load by 5,344 kW in the designated area.**

运行效果

Operational Performance

□ **试点运行成效3:** 2022年4月29日下午14时30分, 深圳龙华区民兴苑的V2G充电站**自收到指令1分钟内**, 充电功率降为零, 并将车载电能返送电网, **实现了电动汽车与电网互动的迅速调节**。

Pilot Operation Effect 3: On April 29, 2022, at 14:30 in the afternoon, the V2G charging station rapidly reduced the charging power to zero **within 1 minute** upon receiving the command, **achieving swift regulation through the interaction between electric vehicles and the grid.**



深圳虚拟电厂平台 Shenzhen VPP Platform

一 发展背景-国内外研究进展对比分析

I Development Background- Comparative analysis

从国内外虚拟电厂实践对比看，有较大差别，总结如下。

Comparing VPP practices between domestic and international contexts, there are significant differences, summarized as follows.

国内外 对比项	国外 Overseas	国内 Domestic
聚合资源类型 Aggregated Resource Types	<p>类型丰富，含源、荷、储等各类资源。欧洲以分布式可再生能源为主，负荷侧资源占比小。</p> <p>Diverse in type, encompassing various resources such as generation, load, and storage. Europe primarily focuses on distributed renewable energy, with a smaller share of demand-side resources</p>	<p>以负荷侧资源调节为主。未发挥国内可再生能源资源富足优势，难以实现规模效益。</p> <p>Mainly focused on load-side resource regulation. It has not fully leveraged the abundant domestic renewable energy resources, making it challenging to achieve economies of scale.</p>
政策及市场成熟度 Policy and Market Maturity	<p>辅助服务市场和电力现货市场机制完善，尤其是电力现货市场更加成熟。</p> <p>The ancillary services market and electricity spot market mechanisms are well-developed, with the electricity spot market, in particular, being more mature.</p>	<p>两类市场尚不成熟，大部分省份以试点方式推进。</p> <p>Both types of markets are not yet mature, and most provinces are promoting them through pilot programs.</p>
技术成熟度 Technological Maturity	<p>协调控制技术等技术更加成熟，可实现对各种可再生能源及负荷的灵活控制。</p> <p>Core technologies such as coordinated control have become more mature, enabling flexible control of various renewable energy sources and loads.</p>	<p>分布式可再生能源尚不可控，且协调控制策略有待完善。</p> <p>Distributed renewable energy sources are still uncontrollable, and coordinated control strategies need further improvement</p>
商业模式 Business Model	<p>已实现商业化，主要通过电力市场交易、参与调峰调频、配置储能参与辅助服务获益。</p> <p>It has achieved commercialization, primarily by participating in electricity market transactions, peak shaving, frequency regulation, and engaging in energy storage to benefit.</p>	<p>商业模式尚不清晰，以参与需求响应、提供节能及用电监控等服务为主，参与辅助服务市场为辅，参与电力现货仍在探索中。</p> <p>The business model is not yet well-defined, primarily focusing on participation in demand response, providing energy-saving and power consumption monitoring services, with auxiliary services markets as secondary, and participation in the electricity spot market still in the exploratory phase.</p>

二 研究现状-基于不同区域资源的VPP分析

II Status-quo research – VPP analysis based on different regional advantages

基于相关国家和行业政策下VPP在电力市场的潜在参与前景

VPP目前仍处于试点阶段，实践中以负荷管理的一种形态参与需求响应市场收益和补贴不足以支持用户持续投入。因此，**虚拟电厂参与市场化交易，尤其是现货交易，为用户获取足够的利益，是破局的关键。**

受全国统一电力市场体系建设等利好政策驱动，能源行业各发电集团、电网公司积极开展研究试点，VPP市场机制衔接、技术规格标准化、商业模式多样化等工作快速推进，“十四五”期间，VPP有望在供需紧张地区快速发展。

Potential VPP applications in the power market under relevant national and industry policies

VPP is still in the pilot stage, with its application in demand response as load managing entity. However, given inadequate profit margins and subsidies, investments are shy to sustain. **Market-based transactions, especially spot transactions, to obtain sufficient benefits for VPP investors is the key to break the ice.**

Driven the construction of a unified national power market, various power generation groups and power grid companies are actively conducting research and pilots. VPP market mechanisms, technical standards, and business model developments are rapidly advancing. During the 14th Five-Year Plan period, VPP is expected to develop rapidly in power supply-scarce areas.

发布时间	文号	政策名称	发布单位	Announced time	Document id	Policy name	Department
2022年7月	/	《电力需求侧管理办法（征求意见稿）》	国家发展改革委	2022 Jul	/	Demand Side Management Measures (Draft)	NDRC
2022年11月	/	《电力现货市场基本规则（征求意见稿）》	国家能源局	2022 Nov	/	Power Spot Market Ground Rules (Draft)	NEA
2022年1月	发改能源〔2022〕210号	《“十四五”现代能源体系规划》	国家发展改革委、国家能源局	2022 Jan	发改能源〔2022〕210号	14 th Five-Year-Plan Modern Energy System Planning	NDRC, NEA
2022年1月	发改能源〔2022〕206号	《关于完善能源绿色低碳转型体制机制和政策措施的意见》	国家发展改革委、国家能源局	2022 Jan	发改能源〔2022〕206号	Opinions on Improving the Institutional Mechanisms and Policy Measures for Green and Low-Carbon Energy Transition	NDRC, NEA
2022年1月	发改体改〔2022〕118号	《关于加快建设全国统一电力市场体系的指导意见》	国家发展改革委、国家能源局	2022 Jan	发改体改〔2022〕118号	Guidance on Accelerating the Construction of a Nationally Unified Power Market	NDRC, NEA
2021年7月	发改能源规〔2021〕1051号	《关于加快推动新型储能发展的指导意见》	国家发展改革委、国家能源局	2021 Jul	发改能源规〔2021〕1051号	Guidance on Accelerating the Development of Novel Energy Storages	NDRC, NEA
2021年2月	发改能源规〔2021〕280号	《关于推进电力源网荷储一体化和多能互补发展的指导意见》	国家发展改革委、国家能源局	2021 Feb	发改能源规〔2021〕280号	Guidance on Promoting the Integration of Generator, Grid, Load and Storage and the Development of Multi-energy Complementarity	NDRC, NEA

二 研究现状-基于不同区域资源的VPP分析

II Status-quo research – VPP analysis based on different regional advantages

多种电网交互场景下的VPP需求和资源供需匹配

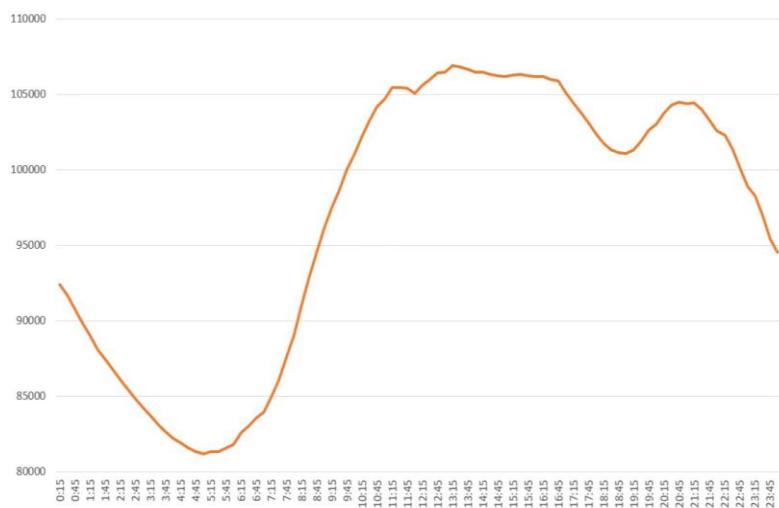
VPP demand and supply coupling in multiple grid interaction scenarios

城市虚拟电厂缓解极端天气下电力供需矛盾 Urban VPP can ease power shortage during extreme weather conditions

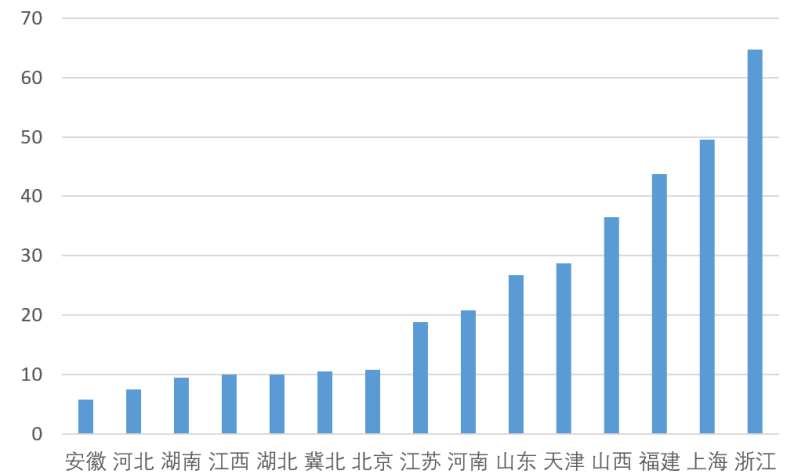
- 城市虚拟电厂主要集中了居民、商业建筑的空调负荷和照明负荷。在上海、北京、杭州等受端电网，城市虚拟电厂是缓解供需矛盾的有效工具，同时可以减少电力通道扩容占地和建设改装碳排总量。
- Urban VPP mainly aggregates AC and lighting loads of residential and commercial buildings. In the recipient grids of Shanghai, Beijing and Hangzhou, urban VPP are effective tools to alleviate the tense between supply and demand, and reduce the total amount of carbon emissions from the expansion of transmission and distribution capacity.

虚拟电厂聚合海量异构资源，提取资源响应速度、时长、容量等特征参数。在极端场景下，组织用户主动参与需求响应市场邀约、调峰辅助服务交易，最大程度支撑电网安全稳定运行和电力可靠供应。

VPP aggregates massive heterogeneous resources and extracts advantages of various resources such as fast response speed, long duration and large capacity. In extreme scenarios, it organizes users to actively participate in demand response and peaking ancillary services to maximally support the safe and stable operation of the power grid and the reliable supply of electricity.



某区域典型日用电负荷曲线
Typical inter-day load curve



某地区95%以上尖峰负荷持续时间
Typical peak load ($\geq 95\%$) durations by area

二 研究现状-基于不同区域资源的VPP分析

II Status-quo research – VPP analysis based on different regional advantages

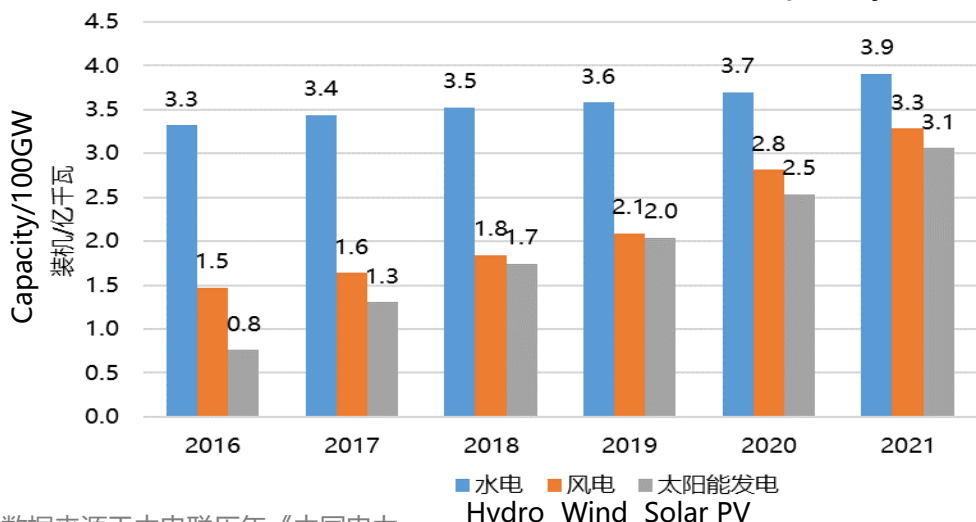
多种电网交互场景下的VPP需求和资源供需匹配

VPP demand and supply coupling in multiple grid interaction scenarios

工业调峰虚拟电厂提升新型电力系统灵活调节能力 Industrial VPP enhances flexibility of the New Power System

- 《中华人民共和国节约能源法》和《工业节能监察办法》要求严格能效约束，推动重点行业节能降碳、降本增效；工信部2023年对钢铁、焦化、铁合金等17个行业开展强制性能耗限额标准专项监察。
- The People's Republic of China Energy Conservation Law and Industrial Energy Conservation Supervision Measures* require industry to comply strict energy-efficiency standards to promote energy conservation, carbon reduction, cost reduction and efficiency improvements in key industries; the Ministry of Industry and Information Technology (MIIT) carried out mandatory energy-consumption quota standards for 17 industries in 2023, such as iron and steel, coking, ferroalloys, etc.
- 工业调峰虚拟电厂位于能耗强度高的工业园区。在辽宁鞍山，虚拟电厂可以优化工艺流程与执行时段，实现调峰，提高碳效率。
- Industrial VPPs are in industrial parks with high energy intensity. In Anshan, Liaoning province, the VPP optimizes process flows and production periods to enable peaking and improve carbon efficiency.

各类可再生能源累计装机规模¹ VRE Capacity¹



系统调节需求预测² System flexibility demand projection²

单位:亿千瓦		Unit: 100GW		2020	2025	2030	2050
波动性可再生能源发电规模		VRE Capacity		5	10	15	40
传统调节手段	灵活煤电机组	Traditional Dispatchable Units	Coal	1	2	3	4
	天然气发电机组		Gas	1	1.5	1.8	2.3
	抽水蓄能		Pump hydro	0.32	0.68	1.2	1.7
	电化学储能		Battery Storage	0.03	0.2	2	6.1
可再生能源功率调节缺口		VRE Power Ramping Gap		2.65	5.62	7	25.9

¹数据来源于中电联历年《中国电力行业年度发展报告》

²依据《“十四五”现代能源体系规划》等预测 ¹ China Power Industry Annual Report, CEC ² 14th Five-Year-Plan Modern Energy System Planning, NDRC & NEA

二 研究现状-基于不同区域资源的VPP分析

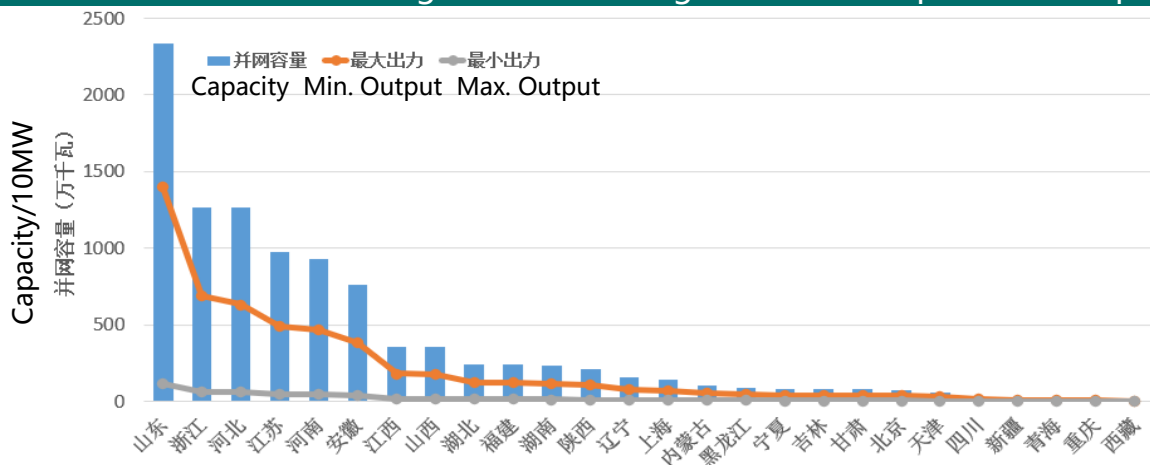
II Status-quo research – VPP analysis based on different regional advantages

多种电网交互场景下的VPP需求和资源供需匹配

VPP demand and supply coupling in multiple grid interaction scenarios

可再生能源消纳虚拟电厂促进分布式新能源并网消纳 VPP for renewable energy consumption reduces renewables curtailment

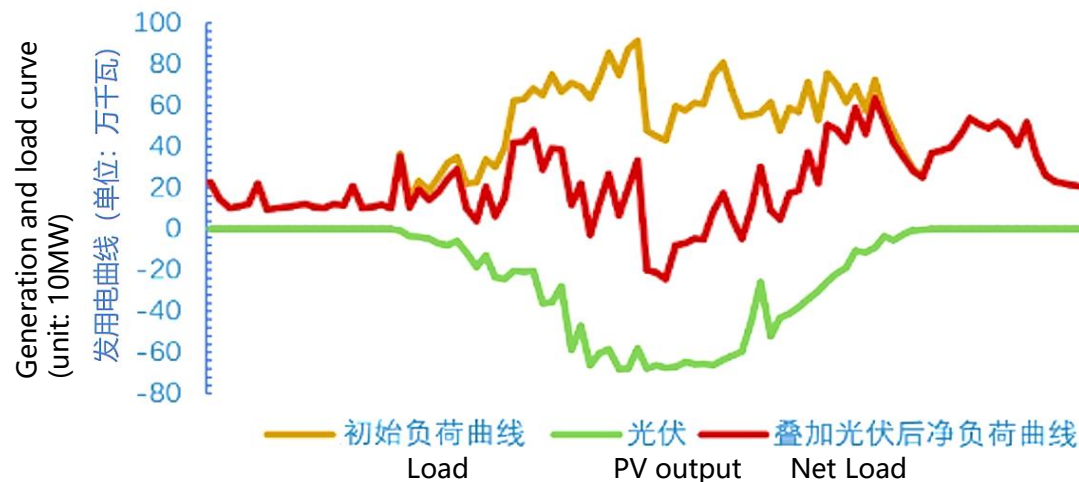
- 分布式新能源出力存在不确定性，低电压等级电源信息接入率低，规模化发展后影响负荷预测精度，叠加集中式新能源电站影响，导致局部地区日间负荷低谷时段调峰难度加大。
- Distributed VRE has variable output, poor low voltage power information access rate. Large scale distributed VRE deployment would impact load forecasting accuracy, adding on the impact of centralized renewables, significantly increasing the difficulty in daytime ramping during low load periods.
- 可再生能源消纳虚拟电厂位于可再生能源丰富的地区，可在甘肃、河北、东北等地，通过评估可控负荷消纳能力，应用于附近可再生能源发电大发时段，促进可再生能源就地消纳。
- Renewables curtailment prevention VPP is in renewable energy-rich areas, such as Gansu, Hebei and Northeastern China. Through load and output forecasting, these VPPs and utilize VRE generation during maximum output hours to promote the local renewables consumption.



截至2021年底国网经营区分布式光伏累计并网容量及出力情况

State Grid owned distributed PV capacity and output summary in 2021

虚拟电厂可实现各类分布式发电资源间的高效连接与实时监测，通过先进的自动响应控制技术、灵活的商业模式，开展分布式新能源本地交易，并依托现货市场进行集中交易，最大限度提升分布式新能源的消纳能力。



2021年江苏省某县光伏出力及负荷用电曲线

Load and PV's output curve in a county in Jiangsu

VPP can establish efficient connection and real-time monitoring between various types of distributed resources, carrying out trading of distributed renewables through advanced automatic response control technology and flexible business model. VPP can also conduct centralized trading in spot market, to maximize the renewables consumption.

二 研究现状-基于不同区域资源的VPP分析

II Status-quo research – VPP analysis based on different regional advantages

多种电网交互场景下的VPP需求和资源供需匹配

VPP demand and supply coupling in multiple grid interaction scenarios

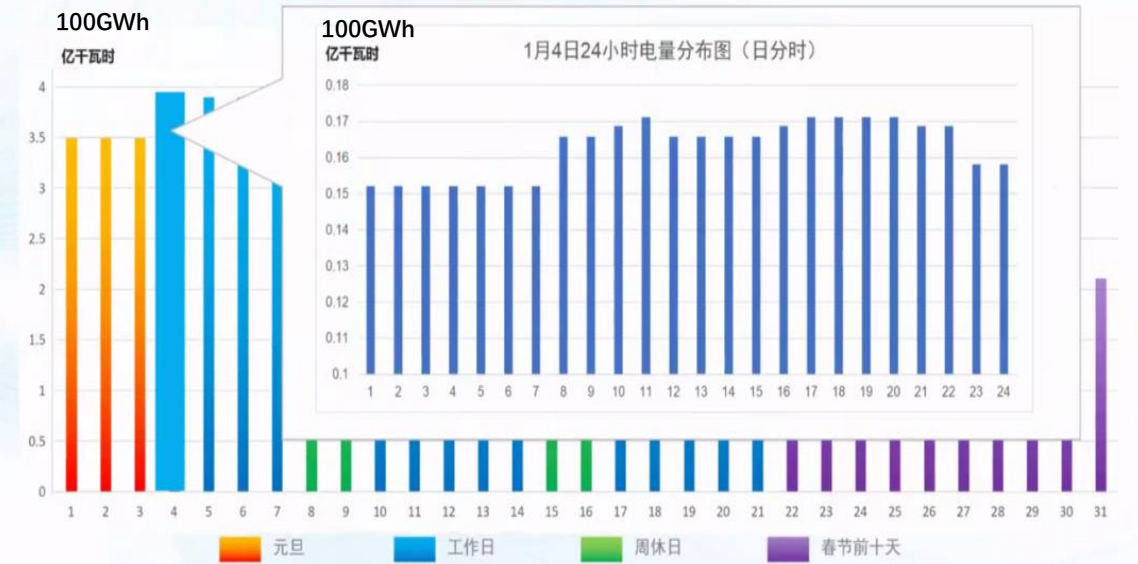
服务用户开展多元化用能服务 Diversified energy services for consumers

- “十三五”期间我国单位GDP能耗约为经合组织国家的3倍、世界平均水平的1.5倍；“十四五”规划《纲要》¹指出“十四五”期间要求单位GDP能源消耗降低13%~14%。
- China's energy consumption per GDP during the 13th FYP period is about three times that of OECD countries and 1.5 times the world average; the 14th FYP Outline¹ points out that during the 14th FYP period, energy consumption per GDP should be reduced by 13% to 14%.
- 住建部发布国标《建筑节能与可再生能源利用通用规范》自2022年4月实施，强制要求建筑实施碳排放计算。
- The Ministry of Housing and Construction (MOH&C) has issued a national standard: *General Standard for Energy Efficiency and Renewable Energy Utilization in Buildings* to be implemented since April 2022, making it mandatory for buildings to implement carbon emission accounting.
- 现货和辅助服务电力交易市场建设，对分析电力客户用电行为、负荷特性，提升负荷预测和电量预测水平，提出了更高要求。
- The establishment of the spot and ancillary services market has put forward higher requirements for analyzing the power consumption behavior, load characteristics, and load forecasting.

- 虚拟电厂基于异构资源互补特性，综合内部资源最优碳流计算与成本效益，为用户提供能效提升同时降低碳排放的经济运行策略。
- 虚拟电厂实时监测用户在线聚合容量与调控潜力，预测市场情况，支撑用户参与中长期和现货场景下的电能量、辅助服务及容量市场。

- Based on the complementary characteristics of heterogeneous resources, VPP integrates the optimal carbon flow calculation and cost-effectiveness of internal resources to provide users with an economic operation strategy that improves energy efficiency and reduces carbon emissions.
- VPP monitors users' aggregated capacity and regulation potential in real time, forecasts market demand, and supports users' participation in the energy, ancillary services and capacity markets in medium- to long-term and spot transactions.

1. 《中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要》 *Outline of the 14th FYP for the National Economic and Social Development of the People's Republic of China and 2035 Vision Planning*



某省2022年1月4日24小时日分时电量预测

Hourly energy demand forecast in a province on Jan. 4th

二 研究现状-基于不同区域资源的VPP分析

II Status-quo research – VPP analysis based on different regional advantages

不同场景下虚拟电厂资源供需匹配

VPP resources coupling under different scenarios

城市虚拟电厂 Urban VPP

城市虚拟电厂资源包括**空调负荷、电动汽车、移动基站、分布式电源、储能、充电站**等，具有建筑密集，核心区域用电强度大的特点。

随着经济水平提升与消费理念升级，可调负荷资源快速增长，对负荷灵活性的需求不断提高，**尖峰时段负荷调节能力增强**，削减电量无需移峰用电，直接减少碳排放。

Urban VPP resources include **AC loads, EVs, telecom stations, distributed power sources, energy storage, charging stations**, etc., which are characterized by dense buildings and high intensity of electricity consumption in the core area.

With the evolvement in economy and consumption preferences, adjustable loads are growing rapidly, the demand for load flexibility is increasing, **the load regulation ability during peak hours is enhanced**. Adjustable loads tend to shrink instead of shifting during peak hours, which directly reduces consumption and carbon emissions.

工业调峰虚拟电厂 Industrial VPP

高耗能工业一般利用低谷电价，夜间集中生产，造成局部电网白天利用率低、夜间负载率过高，威胁电网运行安全和电力供应。

工业调峰虚拟电厂需提前调查登记企业**具有错峰能力的设备和生产环节**，预先生成**安全、智能的调控策略**，帮助企业按需主动切除支持短时停电的生产线，避免拉闸限电造成的损失。

Energy intense industries generally take advantage of the valley power price and concentrate their production at night, resulting in low utilization of local power grids during the day and high load ratios at night, which threatens the safety of grid operation and power supply.

The industrial peaking VPP needs to research and register **the production load available for peaking capacity in advance**, and formulate **safe and intelligent strategies** to help enterprises proactively excise production lines supporting short-term power outages on demand, to avoid losses caused by unserved load and power shortage.

可再生能源消纳虚拟电厂 Renewables curtailment prevention VPP

与前文所述城市虚拟电厂、工业调峰虚拟电厂存在重叠或联动。

在西北、东北等风、光资源富足地区，企业依据市场出清和调度信息适时作出**增加生产计划**，消纳可再生能源发电，减少传统化石能源发电产生的碳排放；或由**储能设备**作为可再生能源消纳虚拟电厂资源，存储绿电并在用电高峰时段出力。

Renewables consumption VPP has overlap or linkage with the urban VPP and the industrial peaking VPP described in the previous section.

In the northwestern, northeastern China and other renewables-rich areas, enterprises can make **timely adjustment on production plans** according to market clearing and scheduling, thus better utilize renewables generation, reduce carbon emissions generated by traditional fossil energy generators. **Energy storages** can also be renewables consumption VPP, which store green power when renewables are outputting at their peak and discharge during peak hours.