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深圳市建筑科学研究院股份有限公司
Shenzhen Institute of Building Research Co.,Ltd.

民用建筑低压直流配电工程设计标准研编及行业推广

Design Standard Research and Dissemination for LVDC in Civil Buildings

深圳市建筑科学研究院股份有限公司

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关于作者

郝 斌　陆元元　康 靖　李雨桐　李叶茂　童亦斌　李 娅　李婉溢
Hao Bin　Lu Yuanyuan　Kang Jing　Li Yutong　Li Yemao　Tong Yibin
Li Ya　Li Wanyi

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关于项目单位/关于能源基金会

深圳市建筑科学研究院股份有限公司（简称“建科院”）是国家级高新技术企业、全国博士后科研工作站、全国绿色建筑先锋单位、国家绿色建筑华南基地、全国科普教育基地，以中国绿色城市价值创造者为使命，2000 年以来专注于持续探索中国特色新型城镇化之路。建科院的愿景是平视城市，共享生命精彩。

能源基金会是在美国加利福尼亚州注册的专业性非营利公益慈善组织，于 1999 年开始在中国开展工作，致力于中国可持续能源发展。能源基金会的愿景是通过推进可持续能源促进中国和世界的繁荣发展和气候安全。

执行摘要

■ 建筑电气化开始关注零碳电力转型

- **建筑电气化将成为未来减排和清洁能源转型的道路上扮演重要的一环。**建筑电气化主要解决的是直接碳排放的问题，电气化后我们面临的主要问题是未来电网呈现的“双高”、“双随机”特征。“双高”即高比例可再生能源接入与高比例电力电子设备应用，“双随机”即供给侧随机性和需求侧随机性。零碳电力的实现在很大程度上取决于电力供给与电力需求的实时匹配，理想情况是我们能够按照高比例风光的发电规律而用电，即“荷随源动”。

- **以新能源为主的新型电力系统正在构建**。可再生能源规模化应用的瓶颈问题之一是其波动性与随机性，能否有效消纳风电光电，决定了风电光电的发展进程。这在本质上就需要将目前“源随荷变”模式转变为“荷随源动”模式。事实上，解决风电光电消纳问题的关键节点并非风电光电的输送，而是供给侧和需求侧的不同步。“源随荷动”模式是指目前电力生产侧要随时根据用电侧的变化而变化，而风电光电不可调控，就要求用电侧随着风电光电的变化而改变其用电量，实现“荷随源动”的柔性用电模式。

- **建筑电力交互势在必行**。在“荷随源动”的新模式中，对于建筑而言，包含三方面变革：第一，建筑用电方式转变为“供给导向-需求响应”的用电模式；第二，发展建筑内部蓄电系统，电力供给量大于用电需求时蓄电，而电力供给量小于电力需求量时则由蓄电池发电，满足电力的不足；第三，利用电动汽车储电能力，将电动汽车充电桩与建筑配电系统有机整合实现动态平衡，以灵活满足建筑用电需求。由此，建筑光伏发电-储电-直流配电-柔性用电模式，就构成了光储直柔建筑新型能源系统，其中“柔”是最终的目的，使建筑用电由目前的刚性负载转变为柔性负载，即建筑电力交互，可通过建筑整体用电柔性改变建筑电力消费模式，从而实现供给侧与需求侧的动态平衡。

- **光储直柔新型建筑能源系统是电力交互的有效解决方案之一。**随着可再生电力高比例渗透、传统火电比例降低，灵活性将成为电网系统的稀缺资源。而建筑用能恰恰是很好的可调节负荷，采用光储直柔技术，建筑用电与供给的关系逐渐从过去的“源随荷动”转变为“荷随源动”，破解电源侧大比例的风电光电导致电网上源与荷瞬间不平衡问题，为大规模的风电光电有效消纳给出新的途径。

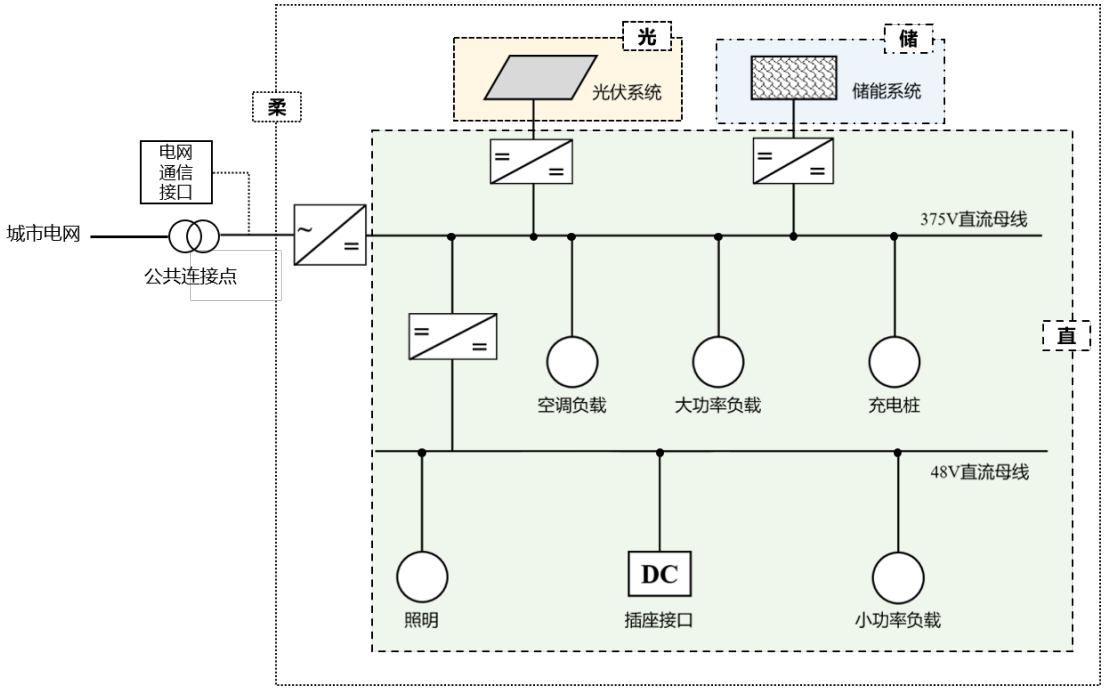

图 | 光储直柔系统示意图

■ 民用建筑直流配电设计标准即将发布

- **建筑直流供配电好处多。**直流建筑在安全、效率、可靠性与分布式电源协同以及实现恒功率供电等方面具有明显优势。建筑领域若采用直流供配电，一是可以直接利用光伏等分布式能源产生的直流电源，就地消纳可再生能源、提高能源利用效率外；二是相比与交流电，直流电的用电安全性更高；三是采用直流电气系统的柔性建筑，可以协调光伏发电与建筑用电的不同步、缓解建筑用电峰谷变化对电网的冲击，平衡供需矛盾，实现建筑电力交互，有效提高城市能源系统综合效率。

- **直流配电应用日趋广泛。**光储直柔涉及的产业均在“直流化”：一是我国光伏产业的快速发展和技术迭代，光伏成本愈发具有竞争力，使得“源”在直流化；二是储能技术日新月异，电池的安全性、能量密度、寿命、成本等老百姓关注的指标正在并将继续得到显著的改善，这就使得分布式电化学储能在建筑中应用逐渐成为可能，甚至是标配，使得“储”在直流化；三是建筑终端用电设备发展和技术进步方向均是由交流驱动转为直流驱动，使得“用”在直流化；四是未来大规模发展风电光电所面对的光电安装空间和风电光电调控这两大难题，需要通过柔性负载实现“荷随源动”，使得建筑用电系统由目前的刚性负载变为柔性负载，可以根据电力系统的供需关系随时调整用电功率，即“柔”在直流化。

- **民用建筑直流配电设计标准即将发布。**这一标准创新性地提出了建筑光储直柔配电概念和具体实施方法，结合示范工程和相关研究，确定了建筑直流配电系统的设计要求和量化指标，填补了民用建筑直流配电系统

相关标准的空白，对直流配电技术和光储直柔技术在建筑中的推广应用具有重要的指导和促进作用。标准章节内容与顺序兼顾建筑电气设计专业的习惯和直流电气的特点，主要技术内容包括：1. 总则；2. 术语和缩略语；3. 基本规定；4. 系统设计；5. 建筑储能；6. 主要设备与线缆；7. 保护与防护；8. 系统性能；9. 监测与控制。

■ 建筑电气化行业推广活动

在项目执行期间，结合国家低碳政策、国内外重大研究成果以及《民用建筑直流配电设计标准》研编工作进展，主要策划组织的行业推广活动包括：①组织建筑电气化的行业研讨会，针对直流建筑标准、建筑电气化政策和技术的关键问题或热点话题开展讨论，邀请知名企业和专家参与，并且对公众开放；②基于直流建筑联盟微信公众号平台，定期发布行业动态，发布新闻、解读政策、推广技术，让大家对建筑电气化的关键技术，例如光伏、储能、IoT、材料、电池、直流配电、柔性用电等有更深了解；③基于联盟机构下属的优秀案例，组织线下开展直流实验室体验开放日活动，增强公众参与度、感知度及接受度；④邀请国内知名专家，结合建筑电气化的热点话题，推出多个主题系列的宣传教育视频，普及建筑电气化的基础知识和核心技术。

- **直流线上讲堂宣传教育视频系列。**2020 年以来发布了 3 个主题系列建筑电气化宣传教育视频共 20 期，包括“直流童话”系列 7 期、“明辩直流”系列 11 期、“光储直柔”系列 2 期。可在直流建筑联盟微信公众号、B 站搜索访问。

- **“直流百问”科普问答系列。**由来自企业、高校、科研机构等近 40 名各界专家学者共同提问、解答、编写，形成《直流百问（上）》已于 2021 年 5 月在第十七届绿色建筑大会“光储直柔实现建筑零碳用电”论坛发布。会后通过微信公众平台每周发布一问，内容包括“1. 光储直柔是什么？”、“2. 建筑供电直流化可以带来什么好处？”、“22. 直流配电系统需要怎样的电压等级？”等。

- **《直流建筑发展路线图 2020-2030》中英文报告。**报告由清华大学江亿院士牵头主编，并由来自直流建筑联盟秘书处、深圳市建筑科学研究院股份有限公司、清华大学、国网能源研究院有限公司、深圳供电局有限公司、北京交通大学等 15 位行业专家、学者共同参与，完成了撰写工作。《直流建筑发展路线图 2020-2030》已在《建筑节能（中英文）》分三期进行连载。

- **学术论坛专家演讲报告分享系列。**在《民用建筑直流配电设计标准》研编过程中，组织了多次建筑电气化行业的公开研讨会，共同探讨建筑直流及能源利用相关的专题。经作者授权，会上专家研讨所发表的演讲报告及 PPT 均对公众开放，推动更多行业专家与建筑用户关注直流配电，关注光储直柔，共同参与到助力双碳目标实现的能源转型行列中来。

Executive Summary

■ Building electrification begins to focus on zero-carbon electricity transition

- **Building Electrification will play an important role in the road of emission reduction and clean energy transition in the future.** Building Electrification mainly solves the problem of direct carbon emissions, but the main problem we face after electrification is the "double high" and "double random" characteristics of the future power grid. The "double high" means a high proportion of renewable energy access and a high proportion of power electronics applications, and the "double random" means randomness on the supply side and randomness on the demand side. The realization of zero carbon power depends largely on the real-time matching of power supply and power demand. Ideally, we can use electricity according to the power generation law of high proportion of wind and solar energy, i.e. "load follows source".

- **A new type of power system focusing on new energy is being constructed.** One of the bottlenecks of renewable energy scale application is its volatility and randomness, whether it can effectively consume wind power, photovoltaic power determines the development process of wind power and photovoltaic power. This in essence needs to transform the current "source follows load" mode into "load follows source" mode. In fact, the key node to solve the wind power and photovoltaic power consumption problem is not the wind power and photovoltaic power transmission, but the unsynchronized supply side and demand side. The "source follows load" mode means that the current power production side should be changed at any time according to the change of the power consumption side. As the wind power and photovoltaic power are not adjustable, it requires the power consumption side to change its power consumption with the change of the wind power and photovoltaic power, to realize the flexible power consumption mode of "load follows source".

- **Grid-interactive building is an imperative.** In the new mode of "load follows source", for buildings, it includes three changes: first, the building power consumption mode is changed to "supply-oriented-demand response" power consumption mode; second, the building internal storage system is developed. When power supply is greater than power demand, power will be stored. When power supply is smaller than power demand, storage battery will generate power to make up for power shortage; third, electric vehicle storage capacity is used to achieve the organic integration of electric vehicle charging pile and building power distribution system to achieve dynamic balance, so as to flexibly meet the building electricity demand. Thus, building photovoltaic – energy storage - DC power distribution - flexibility mode, constitutes a new

energy system of PEDF, of which flexibility is the ultimate purpose, so that building electricity is transformed from the current rigid load into a flexible load, that is, grid-interactive to change building power consumption mode through overall power consumption flexibility so as to achieve dynamic balance of supply side and demand side.

-PEDF, a new building energy system, is one of the effective solutions for power interaction. With the high penetration of renewable power and the reduction of traditional thermal power, flexibility will become a scarce resource for the power grid system. The building energy consumption is exactly a good adjustable load. With PEDF, the relationship between building power consumption and supply gradually changed from the past "source follows load" to "load follows source", solving the problem of the instant imbalanced source and load of power grid resulted from the large proportion of wind power and photovoltaic power on the power side, providing a new way for effective consumption of large-scale wind power and photovoltaic power.

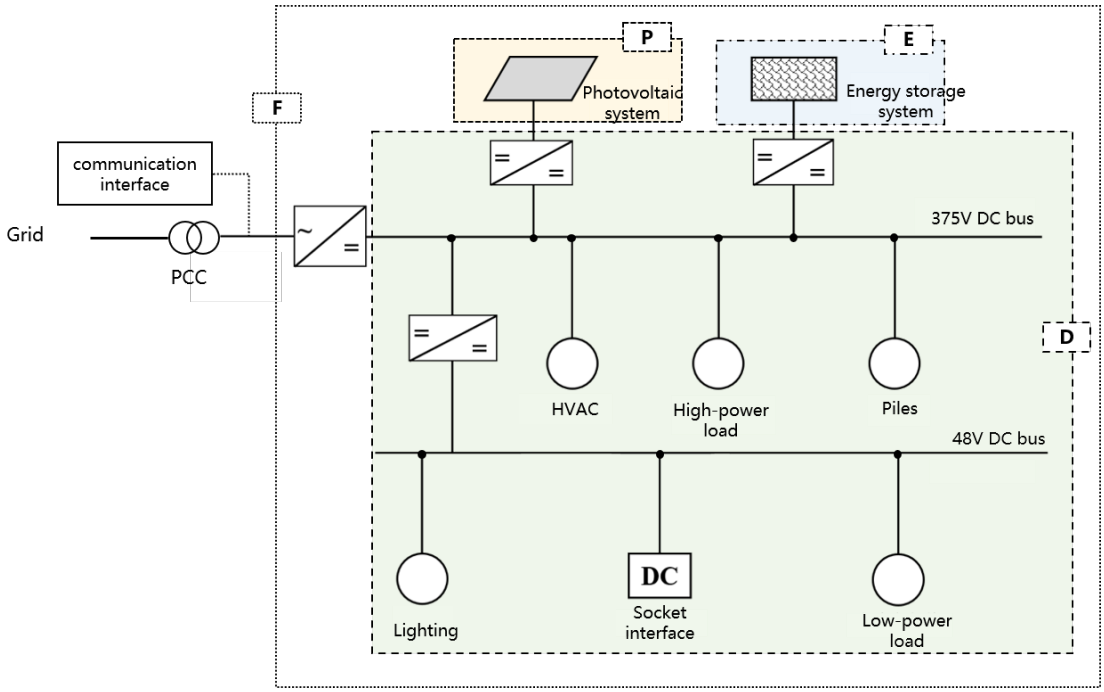

Figure I Schematic diagram of PEDF

■ Design Standard for Direct Current Power Distribution of Civil Buildings to be released soon

- **Building DC power supply and distribution has many benefits.** DC buildings have obvious advantages in terms of safety, efficiency, reliability and distributed power synergy as well as achieving constant power supply. If DC power supply and distribution is adopted in the building field, firstly, it can directly use DC power generated by distributed energy sources such as

photovoltaic to have local consumption of renewable energy and improve energy utilization efficiency; secondly, compared with AC power, DC power is safer; thirdly, a flexible building with DC electric power system can coordinate the unsynchronized power generation of photovoltaic and building electricity, alleviate the impact of peak and valley changes of building electricity on the power grid, balance the contradiction between supply and demand, realize building power interaction and effectively improve the comprehensive efficiency of urban energy system.

- **DC power distribution applications are becoming increasingly extensive.** The industries involving PEDF are "DC-oriented": first, with the rapid development of China's photovoltaic industry and technology iteration, the cost of photovoltaic is becoming more and more competitive, making the "source" DC-oriented; second, with rapid changes in energy storage technology, battery safety, energy density, life, cost and other indicators of concern to the people are and will continue to be significantly improved. This makes the application of distributed electrochemical energy storage in buildings gradually become possible, and even standard, making "storage" DC-oriented; third, the direction of development and technological progress of building end-use equipment is from AC drive to DC drive, making "consumption" DC-oriented. fourth, the two challenges of photovoltaic power installation space and wind power and photovoltaic power regulation and control faced by future large-scale development of wind power and photovoltaic power need to achieve "load follows sources" through flexible load, so that the building electricity consumption system can be transformed from the current rigid load into a flexible load, adjust power rate according to the supply and demand relationship of power system at any time power, making "flexibility" DC-oriented.

- **The Design Standard for Direct Current Power Distribution of Civil Buildings will be released soon.** This standard innovatively puts forward the concept and specific implementation method of building PEDF and determines the design requirements and quantitative indexes of building DC power distribution system in combination with demonstration projects and related research, which fills the gap of relevant standards for DC power distribution system in civil buildings and has an important guiding and promoting role in the promotion and application of DC power distribution technology and PEDF technology in buildings. The content and order of the standard chapters take into account the habits of the building electrical design profession and the characteristics of DC electricity. The main technical content includes: 1. general provisions; 2. terms and abbreviations; 3. basic regulations; 4. system design; 5. building energy storage system; 6. facilities and cables; 7. protection; 8. system performance; 9. monitoring and control.

■ Promotion activities of building electrification industry

During the implementation of the project, the main industry promotion activities planned and organized in conjunction with the national low-carbon policy, major research results at home and abroad, and the progress of the research and compilation of the Design Standard for Direct Current Power Distribution of Civil Buildings include: ① Organize industry seminars on building electrification to discuss key issues or hot topics on DC building standards, building electrification policies and technologies, invite well-known enterprises and experts to participate, and open to the public; ② Based on the DC Building Alliance WeChat official account platform, regularly publish industry news, release news, interpret policies and promote technologies, so that people can have a deeper understanding of key technologies of building electrification, such as PV, energy storage, IoT, materials, batteries, DC power distribution, flexible electricity consumption, etc.; ③ Based on the excellent cases under the Alliance, organize offline DC lab experience open days to enhance public participation, perception and acceptance; ④Invite domestic famous experts, combined with the hot topics of building electrification, to launch a number of thematic series of promotional and educational videos to popularize the basic knowledge and core technologies of building electrification.

- **-DC online lecture educational video series.** Since 2020, we have released 20 issues of educational videos on 3 themes, including 7 issues of "DC talked by Tong" series, 11 issues of "DC debated by Ming" series, and 2 issues of "PEDF" series. The videos can be accessed on WeChat official account for Alliance of DC Building and Bilibili.

- **-"DC 100 Questions" educational Q&D series.** Nearly 40 experts and scholars from enterprises, universities and scientific research institutions have jointly asked, answered and compiled the DC 100 Questions(I), which was released in May 2021 at the 17th Green Building Conference "Zero Carbon Electricity for Buildings with PEDF" forum. After the conference, one question will be released every week through the WeChat official account platform, including "1. What is PEDF?", "2. What are the benefits of DC-oriented power supply for buildings?", "22. What voltage level is needed for DC power distribution system?", etc.

- **-*The Development Roadmap of Direct Current Buildings* (2020-2030).** The report is edited by Academician Jiang Yi from Tsinghua University and co-authored by 15 industry experts and scholars from DC Building Alliance Secretariat, Shenzhen Institute of Building Research Co., Ltd., Tsinghua University, State Grid Energy Research Institute Co., Ltd., Shenzhen Power Supply Bureau Limited, Beijing Jiaotong University. *The Development Roadmap of Direct Current Buildings* (2020-2030) has been serialized in three

issues of Building Energy Efficiency (Chinese and English).

- **-Academic Forum Expert Lecture Report Sharing Series.** During the research and compilation process of Design Standard for Direct Current Distribution of Civil Buildings, several public seminars in the building electrification industry were organized to jointly discuss topics related to DC and energy utilization in buildings. With the author's authorization, the presentations and PPTs delivered at the seminars are open to the public to promote more industry experts and building users to pay attention to DC power distribution and PEDF and to jointly participate in the energy transition for achieving "carbon neutrality and carbon emissions peaking".

直流建筑联盟公众号