Title: **MEP Design Challenges**

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MEP Design Challenges
机电设计的挑战

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The Suzhou Zhongnan Center is a megatall building of a mixed-used nature, including international Grade-A offices, a seven-star hotel, an observation deck, deluxe apartments, small-office home-offices (SOHOs), conference facilities, and retail. The design challenges from an MEP perspective include providing for a safe, reliable, high-tech, first-class, green, sustainable, and user-friendly building. These include the design of two (2) high-efficiency energy centers, district steam supply, ice storage system, 20kV power supply, high-voltage emergency generator, greywater and rainwater recycling, solar photovoltaic panels, advanced technological intelligent systems, the most reliable full-gravitational and dual-source fire services water tank protection available, and supplementary elevator evacuation with enhanced MEP protection.

本文讨论了中国高楼——苏州中南中心在机电设计方面的重大挑战。该项目集国际甲级办公楼、六星级酒店、高空观景台、豪华公寓、小型办公室/家庭办公室 (SOHO) 、会议设施及商场于一体。该建筑机电方面的主要挑战来自于如何提供安全可靠、技术一流、顶级配置、绿色环保、可持续发展以及人性化的机电系统。本文将讨论机电系统中最突出的设计挑战，包括: 两个高效的能源中心、区域蒸汽供应、冰蓄冷系统、20千伏供电系统、高压应急发电机、中水和雨水回收系统、太阳能光伏电板、先进的智能化系统、最可靠的全重力及双重消防水箱保护系统、配有机电增强保护措施的电梯辅助疏散系统。

Design Challenges for Attaining a Safe and Reliable Building

Certain design challenges have been encountered for this megatall building in ensuring that the tower is safe and reliable. The first consideration is the critical issues for its fire and life safety (Tse, 2012). A fire and life safety performance-based analysis was performed for special features, which include the fire and life safety for the 16-meter-high, 4,000 square-meter ground floor lobby, fire safety and evacuation for the podium grand ballroom (Level 7), and the fire and life safety for the sunken plaza at the basement level under the podium. Beyond complying with the fire codes, enhanced fire and life safety measures are also adopted.

From the architectural standpoint, a supplementary elevator evacuation system (by means of shuttle elevators) with enhanced design provisions and operational procedures is included. For example, the evacuation elevator lobbies are smoke-proofed with pressurization. The number of firefighting elevators has also been increased, while the separation between refuge levels has been reduced. As for the structural solutions, several designs have been adopted to enhance the fire resistance of the building core and supercolumns, the belt and outrigger trusses, and the slabs of refuge/MEP and typical floors.

The mentioned provisions are also supplemented with other active firefighting measures, should a fire disaster occur, which includes fire equipment power cables being fire retardant for three hours under a temperature of 950°C while low-voltage supply cables (other than those of fire equipment) are of Low Smoke Zero Halogen (LSOH) type. Moreover, fully gravitational fire services tanks that contain 540 cubic meters of water are strategically situated at the uppermost level of the megatall building (see Figure 2.8). These water tanks complement the Tuned Mass Damper (TMD) system and eliminate the need for pumps, which would require maintenance and be prone to failure. For a more reliable water supply system, pressure-break fire services tanks located on MEP floors are utilized instead of pressure-reducing valves; and a dual-water source is available due to the 630 cubic-meter fire services tank in the basement, in addition to the tank on the top level.

As for the mechanical, ventilation, and air conditioning system, the general intake is provided with air filtration, whereas the kitchen exhaust is provided with electrostatic precipitators and

安全可靠楼宇的设计挑战

为确保这座超高层大厦的安全与可靠，设计团队需要战胜诸多挑战。首要挑战便是消防与生命安全 (谢锦泉，2012) 。设计团队为此进行了消防与生命安全的性能化分析，分析区域包括: 高16米、面积4,000平方米的首层大堂、裙楼宴会厅 (7楼) ，以及裙楼地库下沉式广场。此外，为符合消防规范之要求，还采用了增强型的消防与生命安全措施。

从建筑学的角度考虑，本大厦采用了包含增强型设计与操作程序的穿梭电梯辅助疏散系统。疏散电梯的前室设计采用空气加压，可有效防止烟雾进入。当避难层数量减少时，消防电梯的数量相应增加。从建筑结构的角度出发，大厦采用了多种设计技术，以增强楼宇核心筒及巨型柱、腰桁架和伸臂桁架、避难层楼板/机电楼层和标准层的防火能力。

除上述防火设计，大厦还将运用其他的防火措施，其中包括可耐摄氏950度高温长达3小时的消防设备电源线，以及低烟无卤阻燃的弱电电源线 (除消防设备外) 。此外，540立方米的全重力消防水箱巧妙地安装在大厦的最高处 (图2.8) 。这些水箱可弥补调谐质量阻尼器 (TMD) 系统的不足，而且无需配备维护成本巨大且极易出现故障的水泵。采用设于机电层的减压消防水箱

UV odor removal units located prior to the discharge level to the ambient air. Intake and exhaust points are separated at th ground level and oriented toward different façades on the MEP floors within the tower to prevent air from short-circuiting. Another safety precaution involves the cooling towers being remotely located from the fresh-air intake to preclude the dissemination of Legionnaire's disease.

Other challenges such as gas leakage and the presence of dangerous goods and equipment pose additional threats to achieving a safe building. Early gas leakage detection and emergency (incident) ventilation are implemented for gas-supply pipe ducts within the tower core, with the ventilation rate double what the code requires to further enhance the life-safety provision. In addition, dangerous goods and equipment like generators, underground diesel tanks, gas pressure-reducing stations, and gas-fired backup boilers are located away from the tower and podium footprint. For the achievement of system reliability, one of the actions is to furnish the emergency lighting system with a centralized Emergency Power Supply (EPS) system connected to an emergency generator power backup, with a continuous power supply for at least three hours.

Design Challenges for Attaining a High-Tech and First-Class Building

The Suzhou Zhongnan Center is considered a high-tech performance structure due to the utilization of upgraded intelligent control, monitoring, surveillance, and communication systems (see Figure 2.9). In other words, advanced technology with Building Management Systems (BMS) is adopted to allow automatic control and monitoring of MEP systems via Direct Digital Control (DDC) controllers, which are able to continue to operate independently in case of network malfunctioning. Up-to-date technology has been integrated throughout to permit network interface with open protocol for monitoring of readings, interfaces with various systems and connections to control consoles for various users.

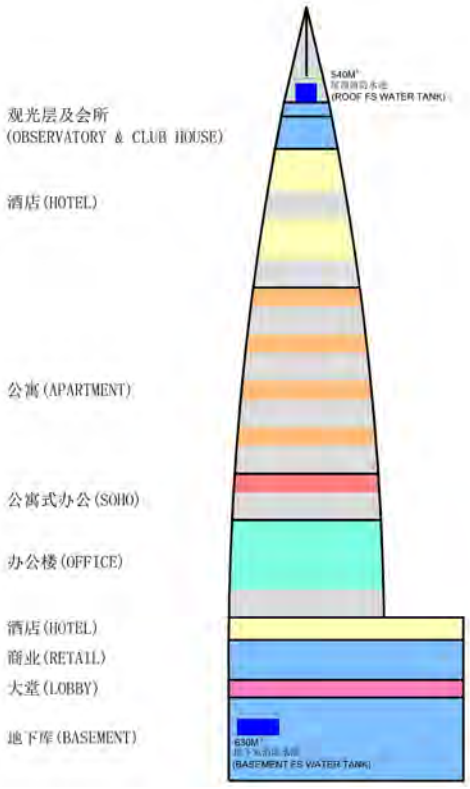

Figure 2.8. Location of fire services main water tanks (Source: PB)
图2.8. 消防主水箱位置 (来源: PB)

替代常见的减压阀，设于地库的630立方米消防水箱则与楼顶的消防水箱共同构成双重消防水箱系统。

暖通空调系统方面，进风口配备有滤网，厨房出风口配有静电除尘器，并在室外排风层前方安装UV除臭装置。入风口和出风口在地面位置相互隔开，并在大楼内朝向机电层的不同外立面，以防止空气循环短路。冷却塔设于远离新风入口的位置，从而防止军团病菌的传播。

此外，若发生燃气泄漏或存在危险物品和设备，都将威胁到大楼用户的安全。为此，大厦核心筒内采用高于设计标准排风量二倍的事故排风设计，其燃气输送管道运用早期气体泄漏检测和紧急 (事故) 通风。发电机、地下柴油罐、燃气调压站以及燃气锅炉等危险物品与设备则设置于远离大楼及裙楼的位置。为实现系统可靠性，其中一个做法是将中央应急照明电源系统连接至备用的应急发电机，使应急照明系统的持续照明时间达到三小时以上。

为实现高科技、超一流大厦而面临的设计挑战

苏州中南中心使用高级智能控制、监测、监视和通信系统 (图2.9)，从而被认为是具有高科技性能的建筑。其楼宇设备自控管理系统为分布智能式系统结构，在通信网络失效时，各直接数字控制器 (DDC) 均能独立继续其正常工作。

除了利用DDC控制及监察部分机电系统的设备外，透过高阶接口，更可与其他独立运作的机电系统 (如: 中央制冷系统、锅炉系统、高压系统、弱电系统等) 连接及联动，形成一个完整、先进、友善使用的"智能化楼宇管理系统"，对大楼所有公用空间实施畅顺的中央管理，最终达到节能以及有效的能源管理之目的。背景音乐及火灾应急广播系统采用IP式系统，使用网络结构技术，作实时/预录广播至所选择的广播分区，包括大堂、电梯厅、电梯轿厢、卫生间、客房等。部份广播分区的扬声器，平时可兼作播放背景音乐，当发生火灾事故情况时，系统可强行切换扬声器至火灾紧急广播状态。IP网络结构技术可弹性地容许更改/增加广播分区，避免增加大量主干线缆。

In addition, integrated security systems with full digital security surveillance systems and access control systems are provided for the entire development. Security alarms, on the other hand, are exclusively provided for critical areas. Each functional area has an independent integrated security system with equipment and control consoles under individual areas for easy operation and good management. The seven-star hotel has additional room control units which centrally and remotely control all lighting, curtains, and air-conditioning within the guest room. Another system that has been enhanced is the emergency broadcast alarm system, which serves public areas, elevators, and lobbies according to different fire compartments. The innovative feature of this system is that it permits the emission of background music during normal scenarios and emergency broadcasts during fire breakouts. Furthermore, fiber optic networks that have a full backbone for network and communication, and video access control and communication systems are provided to the luxury apartments and SOHO office areas.

The office spaces are designed to international Grade A specifications. For example, Variable Air Volume (VAV) air conditioning systems are adopted to avoid the installation of water pipes in tenant areas and to minimize the noise and maintenance nuisance with the use of fan coil units. Variable air-flow rate is adjusted based on tenant-cooling load requirements to achieve maximum energy efficiency. The grade-A office facilities also contain two Air Handling Units (AHU), Electricity (EL), and Extra-Low Voltage (ELV) rooms on each typical office floor with the highest reliability. To suit flexible office-floor planning, raised floors are also adopted for the cables and electrical trunking.

Figure 2.9. Intelligent systems design (Source: PB)
图2.9. 智能化系统设计 (来源: PB)

办公区域按国际甲级办公楼的标准进行设计，例如，采用变风量空调系统 (VAV) 以避免在租户区域安装水管，消除由于使用风机盘管而导致的噪音和繁琐的维护工作。可基于租户空调冷量要求对空调风量进行调节，实现最大化的能源效益。此外，每个办公楼层配备两间空调处理机、电气和弱电机房，以达到最高程度的系统可靠性。活动地板的应用可满足管线及线槽的布置需求，从而实现灵活的办公楼层规划。

综上所述，苏州中南中心通过采用自动化及能源节约措施，促进大厦的灵活适应性及功能多样性，并使得国际甲级办公楼空间满足租户的要求 (谢锦泉及林龙伟，2013)。

绿色及可持续楼宇设计的挑战

节约能源不仅能使大厦获得一流的声誉，还能使其成为绿色、可持续发展的楼宇 (林龙伟，2013)。该大厦已取得LEED (美国能源与环境设计先锋) 金级预认证以及中国绿色三星级预认证。减少能源消耗的措施已融入工程设计中，以达到上述绿色节能目标 (图2.10)。

首先，大厦拥有两个高效的空调系统能源中心 (图2.11)，这有助于减少整栋塔楼之间能源传输及冷却水热交换所产生的能源损耗，不仅满足了节省能源的操作要求，还使得管道工程在保持高可靠性的同时，进行低负荷运转。高区的独立能源中心使得六星级酒店能够进行独立的系统操作; 地库能源中心则服务于裙楼、零售和办公区域。此外，苏州工业园的区域蒸汽所产生的废热将进行循环再利用; 蒸汽直接供应到整座大楼，以减少加热水而产生的热气传输与交换。

其他的节能设计元素包括提供一个20千伏的高压供电系统 (图2.12)，以减少在传输

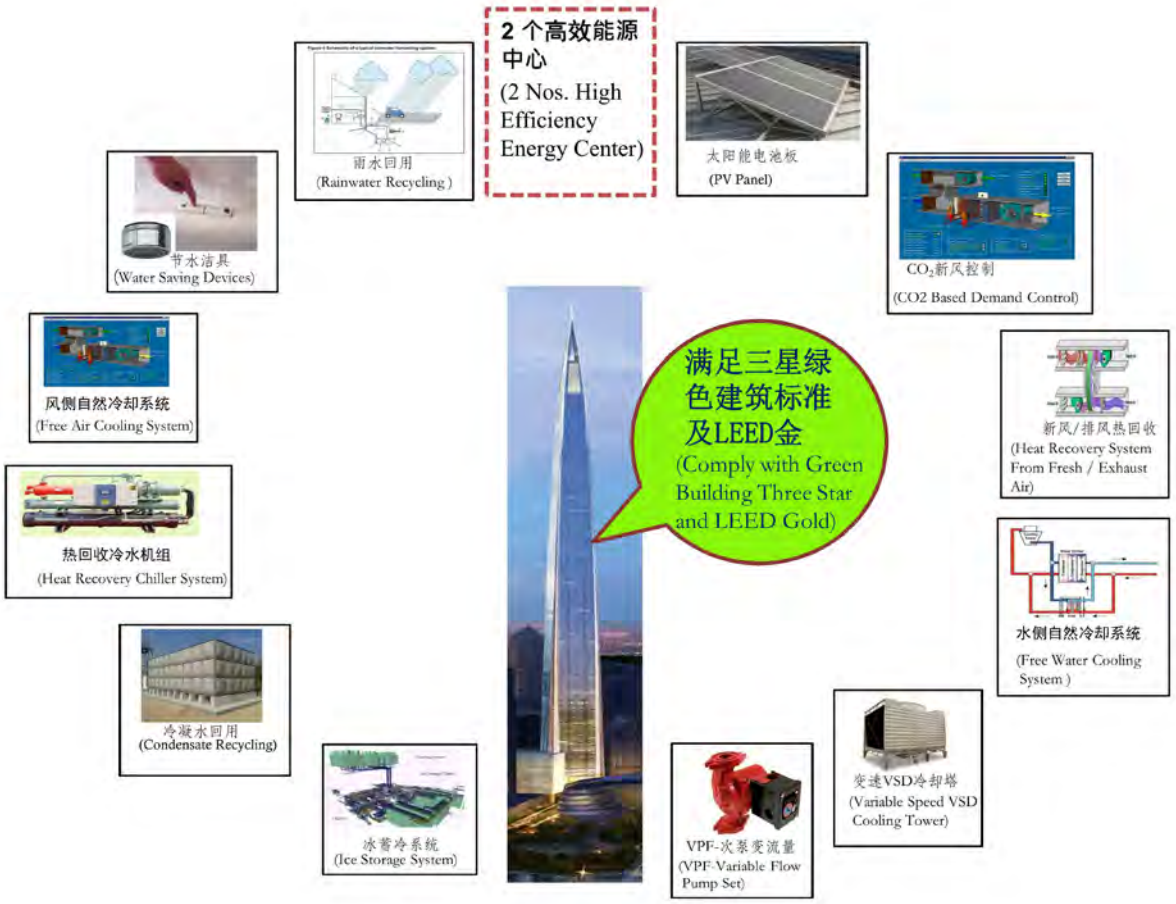

Figure 2.10. Green and sustainable design strategies (Source: PB)
图2.10. 绿色及可持续发展设计 (来源: PB)

Overall, these design features are aimed to facilitate the flexible adaptation of the building and diversify the building use by means of automation, as well as conserve and save energy where possible, and to make the international Grade-A office area suitable for tenant use (Tse & Lam, 2013).

Design Challenges for Attaining a Green and Sustainable Building

Energy-saving not only leads to a first-class designation but also to a green and sustainable one (Lam, 2013). A LEED Gold certification and a China Green Star Three-star rating have been pre-determined for the megatall tower. Energy-loss reduction solutions have been engineered for achieving the aforementioned goals (see Figure 2.10).

Firstly, the tower has two high-efficiency energy centers (see Figure 2.11) for air conditioning systems that enable the reduction of energy loss through transmission and heat exchange of chilled water through the tower height. This will not only provide energy-efficient operation, but also the pipework will be subjected to a lower working pressure with higher system reliability. A high-zone independent energy center is also provided for the individual operation of the seven-star hotel, whereas a basement energy center serves the podium, retail, and office areas. In addition, the waste heat generated by the district steam from Suzhou Industrial Zone is recycled for heating purposes; steam is directly supplied throughout the building height to minimize energy loss through transmission and heat exchange of heating water.

Other energy-saving design elements include the supply of 20kV high-voltage power (see Figure 2.12) to diminish the energy loss during its transmission and to save space for cable installations. High-voltage generators are also integrated for the power supply to high zones for the same energy-efficient purpose. The consumption of electricity during peak usage along with the tariff in Suzhou is decreased by implementing an ice-storage system and solar photovoltaic panels. Additionally, greywater and rainwater recycling are implemented to reduce water usage and to improve the environment throughout the building.

过程中造成的能源损耗，并留出空间用于管线安装。高压发电机则能提供高区的电源供应。冰蓄冷系统及太阳能光伏板的采用可降低用电高峰期的电量消耗及电费支出。此外，中水和雨水回收系统的实施可降低用水量并改善大厦环境。

用户便利性楼宇的设计挑战

楼宇的用户便利性是不容忽视的一部分。中南中心拥有一个备用的燃气蒸汽锅炉，以便能够一年四季向六星级酒店供暖/提供热水。不同区域的自来水供应可以独立运行，并由不同用户进行操作与维护。此外，为不同功能区域提供独立系统以使其易于操作和管理，满足将来可能发生的修改或更新需求。对于将来的空间扩张而言，该大厦已配备了充足的技术系统及控制/监控系统。

闭路电视监控系统为一个配置专用局域网的IP数码摄像机系统，配置高清IP数码摄像机、POE网络交换机、光纤主干及水平六类非屏蔽双绞线、数码管理录像及录像系统、RAID存储系统、监视器及电脑控制台等设备对重要公共场所进行闭路电视监控。此系统架构提供最新的技术及最大的弹性可供将来扩展系统容量。

防盗报警系统透过各报警点，包括门磁感应器、手动报警按钮、防水型紧急报警按钮及漏水感应器等，经数据采集器及网状

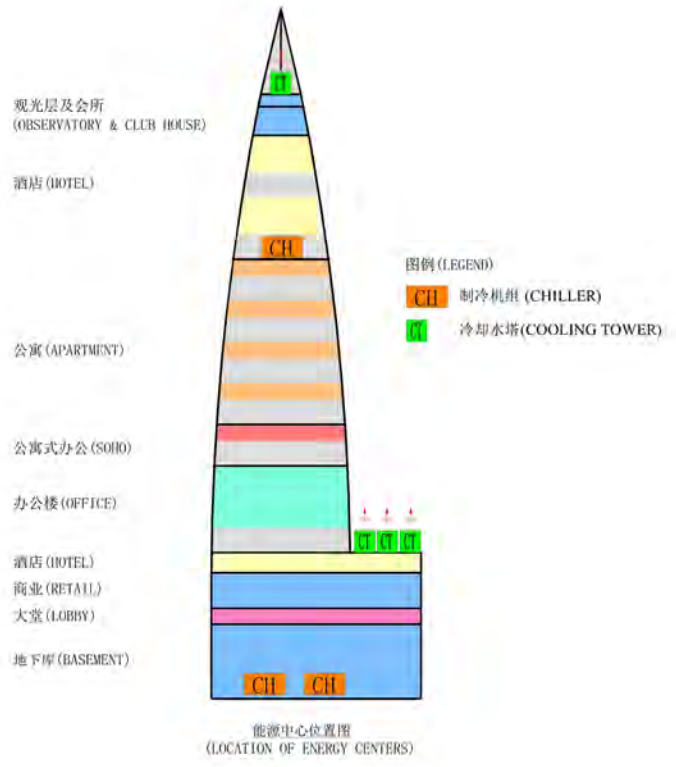

Figure 2.11. Location of energy centers (Source: PB)
图2.11. 能源中心的位置 (来源: PB)

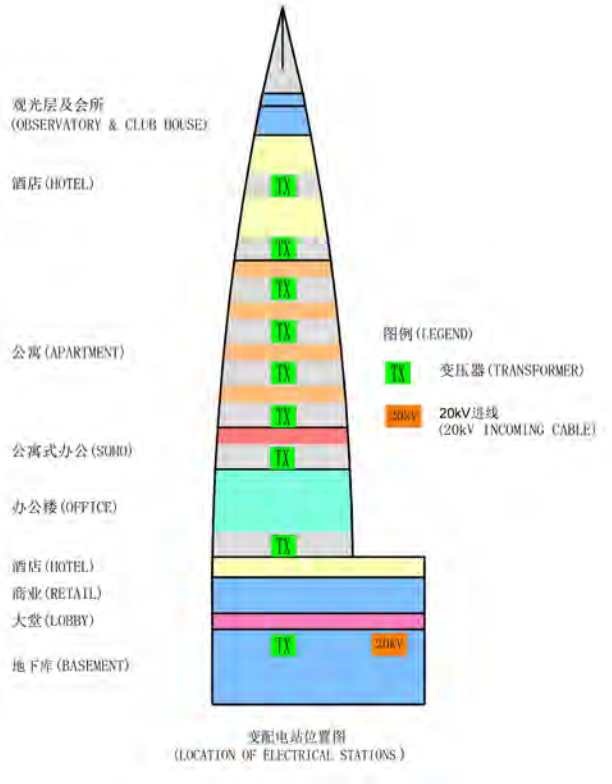

Figure 2.12. Location of electrical stations (Source: PB)
图2.12.电气机房位置 (来源: PB)

Design Challenges for Attaining a User-Friendly Building

The user-friendliness of a building is an element that cannot be overlooked. In this sense, the building has a backup gas-fired steam boiler to maintain a year-round heating operations for the hotel. Potable water supply serves different zones to allow individual operation and maintenance by different users. In addition, individual systems are provided for various functional areas for easy operation and management and to facilitate any future alterations and/or renovations. If these include future expansion with spare capacities, the complex development is already equipped with adequate technological and control/monitoring systems.

For instance, a dedicated Internet Protocol (IP)-based network CCTV system, comprising IP CCTV high-definition cameras, Power Over Ethernet (PoE) switches, fiber backbone with horizontal Category 6 Cable, video management server, video recording server, network video recorders, storage RAID, CCTV monitors, and control workstation. This system configuration allows maximum flexibility for future expansion and with the latest technology.

Another ELV provision is a Security Alarm System, which operates by means of alarm sensors such as magnetic door contacts, panic alarm buttons, water-proof panic alarm buttons and water detectors for central monitoring and control, and event logging of system operations. In addition, an Access Control System has been integrated for the use of card reading for restricted/authorized controlled areas. The central equipment and workstations for these two systems are located inside the Security Control Room and will be high-level interfaced with the CCTV system, providing an overall "Intelligent Security System" to protect the premises and the people inside.

Additionally, a Structured Cabling System (SCS) is designed to provide an open and reliable platform for telecommunication services. For vertical risers, multi-mode fiber cables are used for data transmission, and multi-pair Category 5E cables are used for voice transmission; while all horizontal distribution uses Category 6 UTP cables. These cabling provisions are able to serve all required telecommunication services (i.e. voice, data, and Wi-Fi).

For the hotel portion (see Figure 2.13), a Single Master Antenna Television (SMATV) system is provided; this will also integrate foreign channels in conjunction with Cable television, which distributes the local television programs. The overall combined signal will be distributed to the television outlets through a single-backbone wiring network, which in turn will include

系统，将信号处理并联结监控主机作监察、处理、记录系统之运作。另外，门禁管理系统 (主要利用读卡器) 对需要限制人员进出的区域进行出入口控制。此两个系统的中央设备及电脑控制台均设置于安保控制中心内，再与闭路电视监控系统透过高阶接口，实现一个"智能化安保系统"，以全面保障整座建筑及在内各人员的安全。

综合布线系统为智能建筑建立一个开放、高速、可靠的大容量信息平台，以供传输各类信息。供数据部分的垂直主干线缆为多模光纤，语音部分则采用超五类大对数电缆; 水平布线则不论供语音或数据，全部采用六类非屏蔽双绞线。这些线缆形成一个综合传输信息的布线网络系统，足够提供予各类信息服务，包括语音、数据及无线网络。

SMATV卫星电视接收系统将提供予酒店部分 (图2.13)，当卫星电视接收天线接收境外频道后，将与有线电视公司提供的当地电视频道讯源合并。再加上酒店自设的资讯频道，一并透过单一的传输主干至电视插座。另外，已于裙楼顶层预留空间及相关线槽供办公楼租户将来自行安装VSAT卫星通信系统。

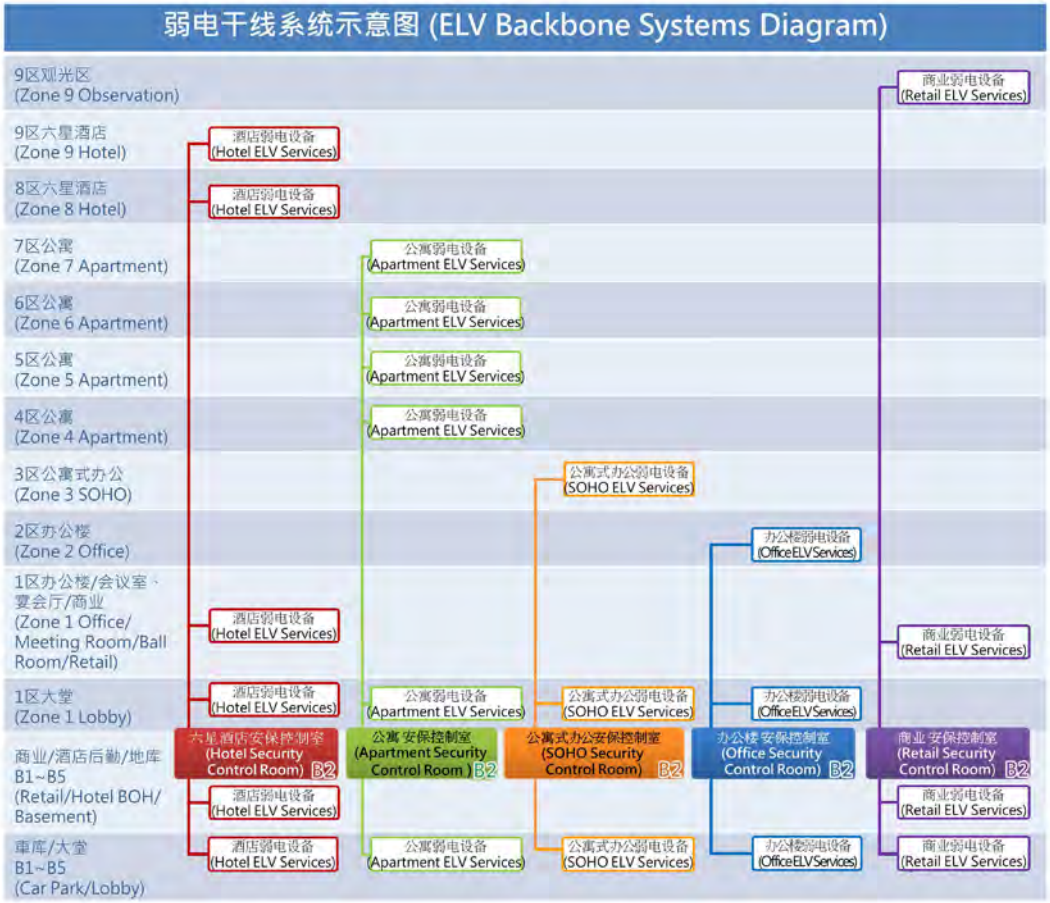

Figure 2.13. Extra-low voltage backbone systems diagram (Source: PB)
图2.13. 弱电主干系统图 (来源: PB)

information channels. Space allocation on the podium roof with associated trunking is also reserved for office tenants to install their own Very Small Aperture Terminal (VSAT) satellite dishes.

Summary

Designing one of China's tallest buildings may come with challenges, yet, the design team surpassed all expectations by delivering a first-tier MEP system for the building to represent a Safe, Reliable, Technologically-Advanced, Green, and Sustainable megatall tower. This is made possible by provisions such as two highly efficient energy centers, district steam supply, ice-storage system, 20kV power supply, high-voltage emergency generator, rainwater recycling, solar photovoltaic panels, advanced technological ELV systems, full-gravitational and dual-source fire services water tank protection, and supplementary elevator evacuation with pressurization to evacuation elevator lobbies. These key MEP design features and latest technologies available have contributed to the successful delivery of a sophisticated system for the tower.

结语

设计中国高楼面临巨大的挑战，但设计团队努力为中南中心打造顶级的机电系统，并超越了所有人的期待，使其成为安全、可靠、技术先进、绿色可持续发展的超高层建筑。机电设施包括两个高效的能源中心、区域蒸汽供应系统、冰蓄冷系统、20千伏供电系统、高压应急发电机、中水及雨水回收、太阳能光伏板、先进的弱电系统、全重力及采用双重消防水箱的保护系统、配备机电增强保护措施的电梯辅助疏散系统等。这些特色设计及最新技术为中南中心提供了尖端的机电系统。

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