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PERSPECTIVE

Low-altitude economy is coming: How to develop new-type power system

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Low-altitude economy (LAE), as a representative of new productive forces, is rapidly expanding worldwide. Driven by low-altitude aircraft, the LAE can improve mobility efficiency, advance logistics intelligence, and foster the low-altitude industrial supply chain, thereby contributing to sustainable economic and social development. However, limited energy storage and flight range of these aircraft pose significant barriers to the growth of the LAE. The "LAE + Power System" presents a promising solution to address this challenge. This paper explores how the power system can embrace this emerging economic form to support its development, focusing on aspects of power system planning, operation, and resilience enhancement. Finally, the Guangdong-Hong Kong-Macao Greater Bay Area is taken as an example to prospect the new opportunities in the LAE era.

THE EMERGING LOW-ALTITUDE ECONOMY

The low-altitude economy (LAE) refers to a comprehensive economic form that encompasses a wide range of low-altitude flight activities below 1000 meters, such as flight sightseeing, urban air mobility, drone logistics, and more, fostering integration and advancement across related fields, as shown on the left part of Figure 1.

The LAE is experiencing unstoppable growth worldwide. For example, China has released the "Implementation Plan on Innovative Application of General Aviation Equipment (2024-2030)" to develop the LAE, with a clear outline to form a trillion-yuan market scale.[1] In the United States, the Federal Aviation Administration has issued numerous policies for accommodating wide-scale advanced air mobility operations in the LAE.[2] In Europe and Japan, companies such as Volocopter and Toyota are also actively positioning themselves in the LAE.

The carrier of the LAE is low-altitude aircraft (LAA), including drones, electric vertical take-off and landing (eVTOL) aircraft, helicopters, and traditional fixed-wing aircraft. The limited energy storage and flight range of LAA represent major barriers to the development of the LAE. To this end, electric-powered aircraft with fast-charging facilities and hydrogen-powered aircraft with hydrogen storage stations are two feasible solutions. Electric-powered aircraft are promising technologies with substantial potential for further market share growth.[3]

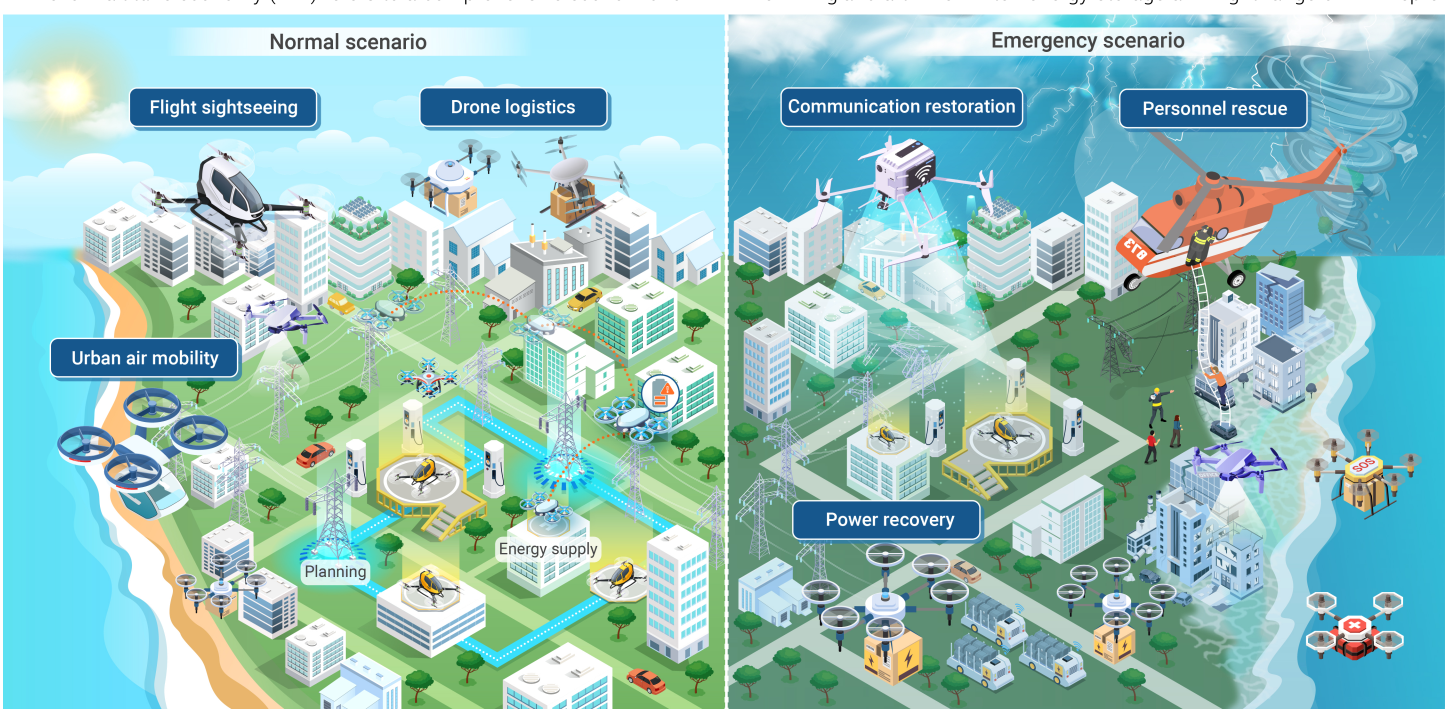

Figure 1. Urban low-altitude economy in normal scenario and emergency scenario

Due to the high reliance of LAA on electricity, the LAE is closely coupled with the power system, presenting unprecedented challenges and opportunities for it. The power system must proactively evolve to adapt to this evolution and support the sustainable development of the LAE.

POWER SYSTEM PLANNING FOR THE LOW-ALTITUDE ECONOMY

Power system capacity planning for LAE: To support the growth of the LAE in the coming years, power system capacity planning must extend beyond traditional residential and industrial electricity consumption to consider the electricity demands arising from various LAE activities. These include the power requirements for the construction of low-altitude cyber-physical infrastructure, the operation of the low-altitude transportation networks, data centers for LAE, and communication facilities for LAE, as well as the charging demands of LAA, among others. In addition, the planning should incorporate a more three-dimensional spatial network, consider the potential construction of dedicated power grid for the LAE, and include redundant power lines for LAE emergencies. Determining the capacity expansion requirements at different locations is essential to ensure the stable operation of the LAE.

LAA charging station siting: Planning fast-charging networks and properly siting LAA charging stations is essential to ensure efficient power supply for the LAE.[4] Facility siting should take into account factors such as power accessibility, ground traffic connectivity, charging demands of LAA, flight route distribution, flight frequency, flight duration, and take-off/landing locations, while also considering power system balance to prevent overloads and instability caused by simultaneous charging.

POWER SYSTEM OPERATION FOR THE LOW-ALTITUDE ECONOMY

Operational optimization of LAA: Optimizing the operation of LAA is essential to ensure effective coordination among various types of LAA across diverse mission scenarios, which supports the LAE's efficient and sustainable operation. When optimizing operational strategies, key factors should be considered, including the urgency of flight missions (e.g., rescue, manned, inspection, logistics, agriculture), charging station locations, charging capacity requirements of different-sized LAA, and power system operational constraints (e.g., power flow).

Power system dispatch optimization: In the LAE era, the power system requires dispatch optimization to accommodate the frequent and dynamic power demands generated by LAE activities, including LAA charging.[5] Optimization strategies involves coordinating flexible resources, such as solar photovoltaics, wind power, energy storage, electric vehicles, and temperature-controlled loads, in conjunction with LAE activities. This enables the power system to minimize the impacts caused by LAE, including reducing overload risks and maintaining supply-demand power balance. Notably, the LAA themselves can also serve as ideal flexible resources to support power system operations.

Coordinated operation of power network and low-altitude transport network: The power network and low-altitude transport network are interdependent systems. Charging demands of LAA directly affect the load of the power network, while the energy supply capacity of power network affects the operational efficiency of the low-altitude transport network. Therefore, optimizing the coordination between the power network and the low-altitude transport network can improve the overall performance of both systems.[6] Specifically, based on the information from the low-altitude transport network, the power network can obtain the charging schedules and demands of aircraft. Combining these with the power network's dynamic supply-demand status, charging prices at different locations can be adjusted in a market-driven manner. Subsequently, aircraft can adjust their flight schedules and routes motivated by economic incentives, meanwhile, the power network can dynamically reallocate flexible resources to accommodate fluctuating power demands of the low-altitude transport network.

RESILIENCE ENHANCEMENT IN EMERGENCY SCENARIOS UNDER THE LOW-ALTITUDE ECONOMY

Early warning for disasters: LAA, equipped with high-precision sensors and lightweight edge computing, is capable of monitoring hydrological, meteorological, and other emergencies in three-dimensions, as well as performing edge-end hazard risk analysis. This facilitates the immediate transmission of early warning information to relevant authorities, so that emergency responses can be deployed quickly.

Post-disaster search and rescue: LAA offer significant advantages in post-disaster search and rescue operations due to their mobility, reconnaissance capabilities, and payload capacity. LAA can quickly reach disaster-stricken areas to conduct a comprehensive search and damage assessments, deliver emergency supplies such as medical equipment, and facilitate personnel rescue and evacuation, as shown on the right part of Figure 1. This greatly improves the efficiency of disaster relief efforts, contributing to the protection of lives and property.

LAA-based communication restoration: In situations where the original communication network cannot be available after a disaster, LAA can be rapidly deployed to reconstruct relay networks.[7] This enables emergency notifications to be broadcast and ensures that communications between the disaster-stricken area and the outside world are restored in a timely manner. Moreover, it promotes the smooth recovery of power services by ensuring the rapid restoration of power dispatch information transmission.

Aerospace energy storage for power recovery: In the event of ground transportation obstruction, LAA can deliver mobile energy storage devices to disaster-stricken areas with damaged power infrastructure in the earliest moments. This enables rapid recovery of local power supplies, enhancing the resilience of the power system. Aerospace mobile energy storage provides a promising solution for post-disaster power recovery.

PROSPECT THE LOW-ALTITUDE ECONOMY, AN EXAMPLE IN THE GUANGDONG-HONG KONG-MACAO GREATER BAY AREA

Emerging economic growth engines: The Guangdong-Hong Kong-Macao Greater Bay Area (GBA), as one of the most dynamic economic regions in the world, hosts international metropolises like Guangzhou, Shenzhen, Hong Kong, and Macao. Given the already highly developed economy of the GBA, the LAE stands out as one of its most dynamic and promising growth engines. Through activities such as flight sightseeing, urban air mobility, and drone logistics, it can boost production efficiency, stimulate consumption, and accelerate the growth of related industries in the GBA. Notably, the GBA has a solid foundation for the LAE. For example, XPeng AeroHT's "land aircraft carrier", developed by a company in the GBA, recently completed its first global public flight at China International Airshow, demonstrating the huge potential of urban air mobility.[8] Meanwhile, DJI, another company in the GBA, is revolutionizing aerial delivery and takeaway services with its advanced drone technology, significantly contributing to the development of the LAE.[9]

Urban connectivity enhancement: The GBA is characterized by its distinct geographical features, where cities are separated by the sea. The LEA can effectively bridge this gap, enhancing connectivity between these cities. Through the low-altitude transportation system, the efficiency of inter-city transportation and logistics is greatly improved, creating a "one-hour living circle" in the GBA. For example, EHang Intelligent successfully achieved the world's first public cross-sea, cross-city eVTOL flight (an air taxi from Zhuhai to Shenzhen), saving nearly 80% of travel time.[10] Moreover, the LAE contributes to cross-regional power system dispatch and resource integration, thereby improving resource allocation efficiency, managing power variations across cities, and enhancing the stability and coordination of regional power grid.

Infrastructure investment reduction: In the GBA, traditional infrastructure such as cross-sea bridges and congested highways incur high construction and maintenance costs. LAA, by flying directly to their destinations, reduce dependence on the infrastructure, leading to significant savings in investment.

Carbon reduction potential of the LAE: The GBA is one of the world's most energy-consuming regions and plays a key role in China's efforts to achieve carbon dioxide peaking and carbon neutrality. The LAE can contribute to carbon emission reduction by alleviating energy waste caused by traffic congestion and inadequate coordination of resources between cities.

It is important to note that, while this section uses the GBA as an example for specificity, the LAE, as a global concept, offers advantages that are applicable to other regions around the world.

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AUTHOR CONTRIBUTIONS

All authors contributed to the manuscript and approved the final version.

DECLARATION OF INTERESTS

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