

The Role of LVDC/MVDC Networks in Green Cities

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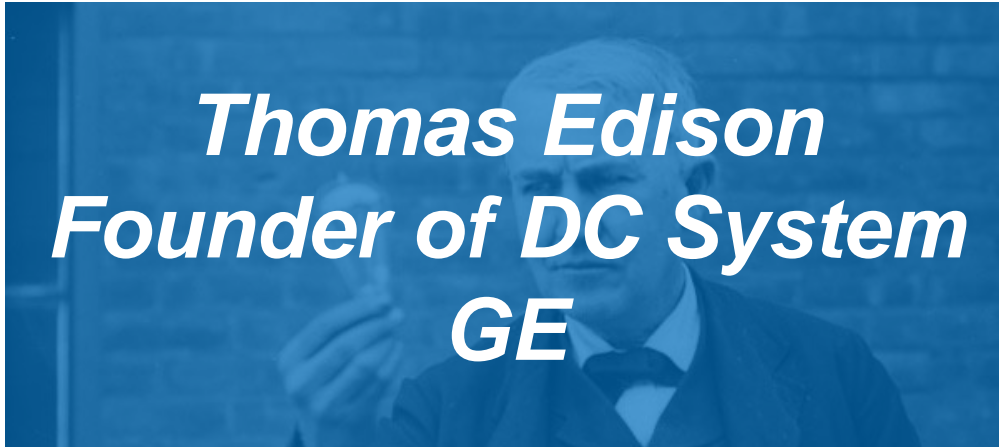
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Secretary, IEC TC8/SC 8A Grid Integration of RE Generation**

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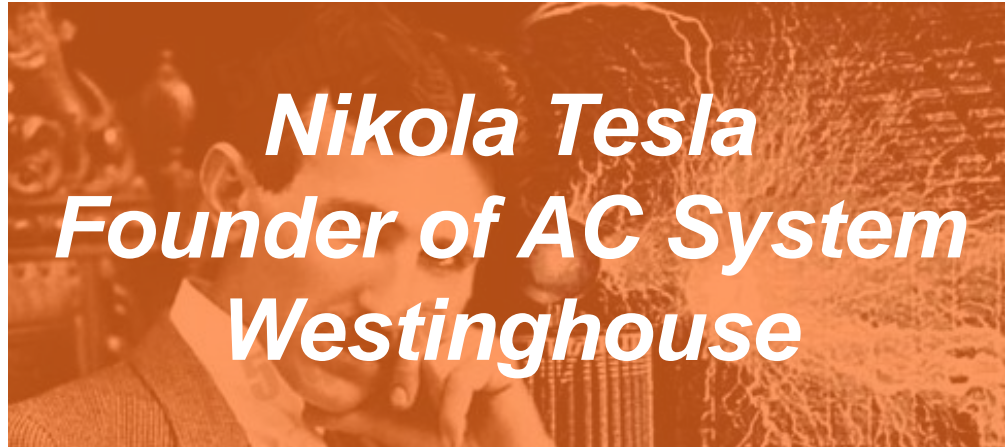
From “War of the Currents” to the Revival of “DC”

“War of the Currents” 100 Years Ago, AC vs. DC Power



Thomas Edison
Founder of DC System
GE

VS



Nikola Tesla
Founder of AC System
Westinghouse

- ☹ Hard to realize voltage conversion.
- ☹ Hard for arc distinction.

- ☺ Convert voltage easily with transformer.
- ☺ Easy for arc distinction when current crosses zero.

Since then, AC dominates in power system, including city distribution network.

What is Happening in Present-day City?



Increased green power

- Distributed PV, Wind Turbine
- Energy Storage System



Growing power demands

- More Economic Activities
- Bigger and Smarter Cities



Emergence of DC loads

- DC Household Appliance
- Electric Vehicle
- Data center

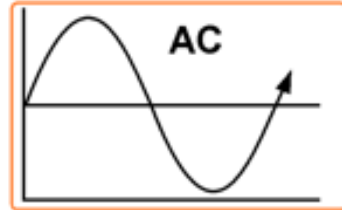
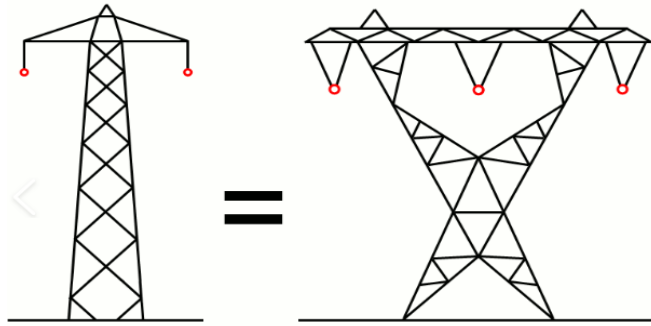


Higher energy efficiency requirements

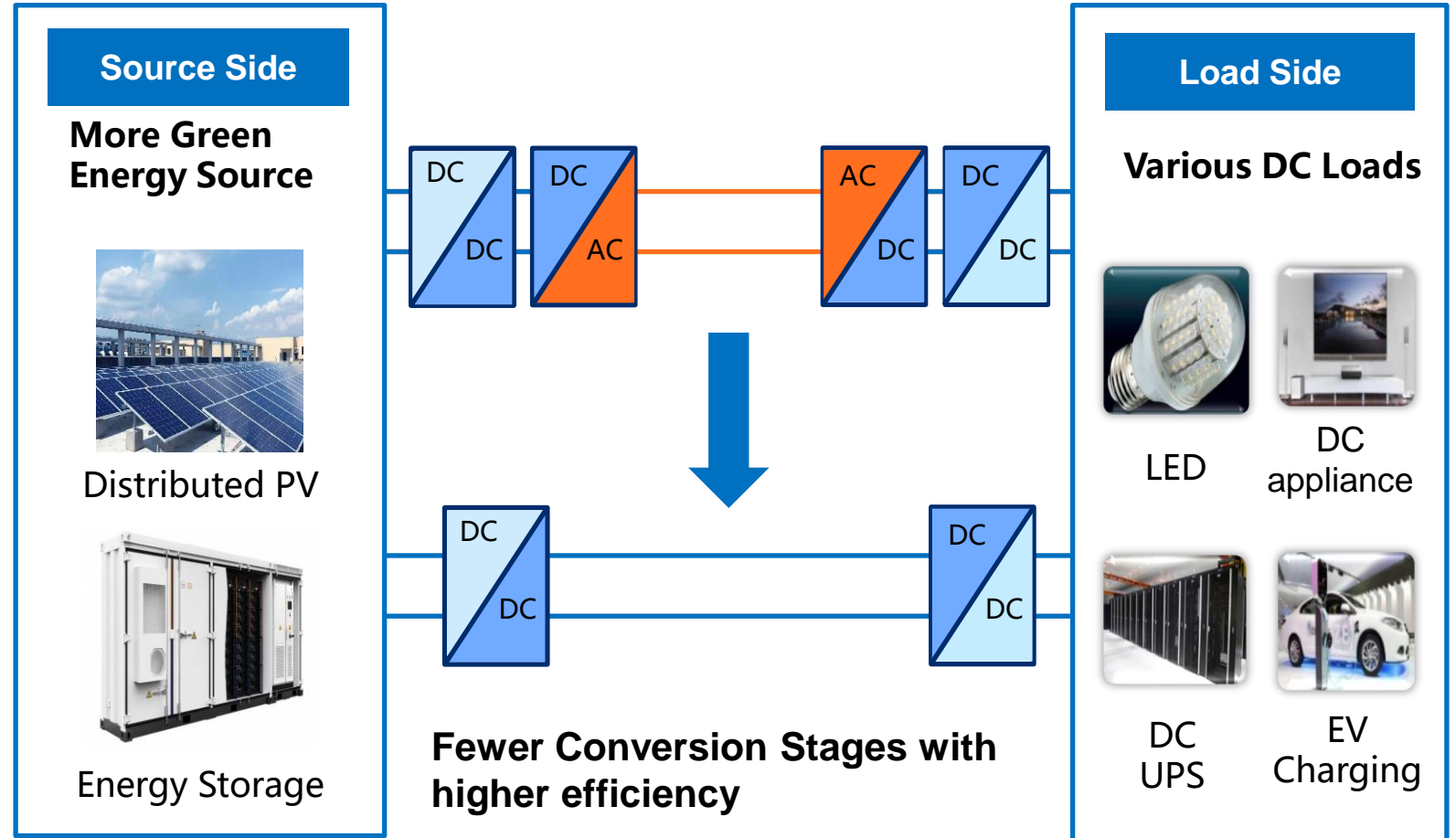
- Higher Reliability & Efficiency
- Uninterruptible Power Supply

City distribution networks attempt to develop into a new stage of hybrid AC/DC.

Reasons of DC Revival – Connecting DC Source & Load



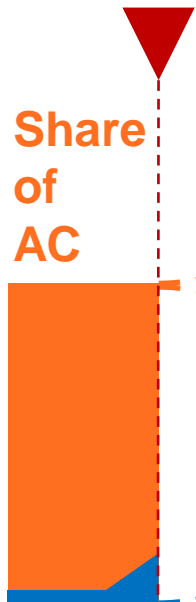
DC distribution requires fewer lines to transmit the same amount of energy compared to AC.



DC distribution networks is compatible with DC sources connection and DC loads.

Transforming from AC to DC is a process, the efforts made today will benefit us in the future.

We are here.



Share of AC

Share of DC

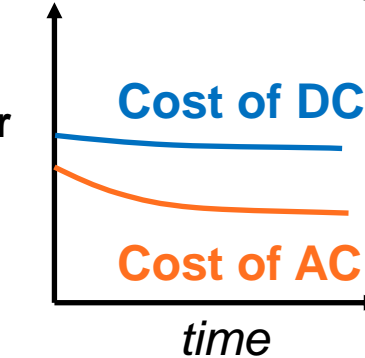
IF: **Stopped** by high initial investment on DC at the present.



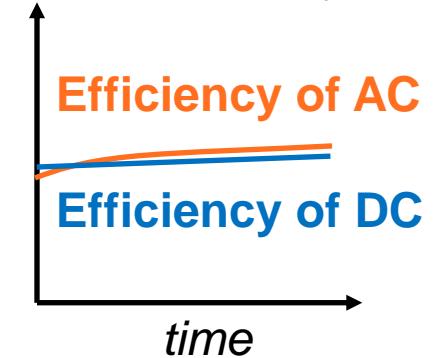
☹ MVDC/LVDC Perish



Cost remains high.



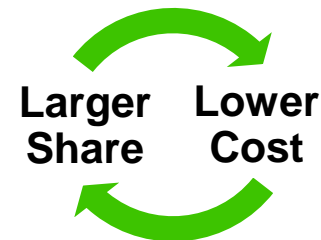
Lose efficiency merit.



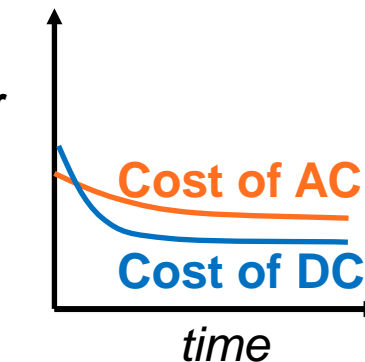
IF: **Overcome** the market inertia of AC.



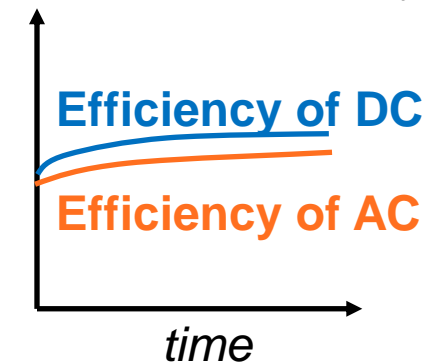
☺ MVDC/LVDC Flourish



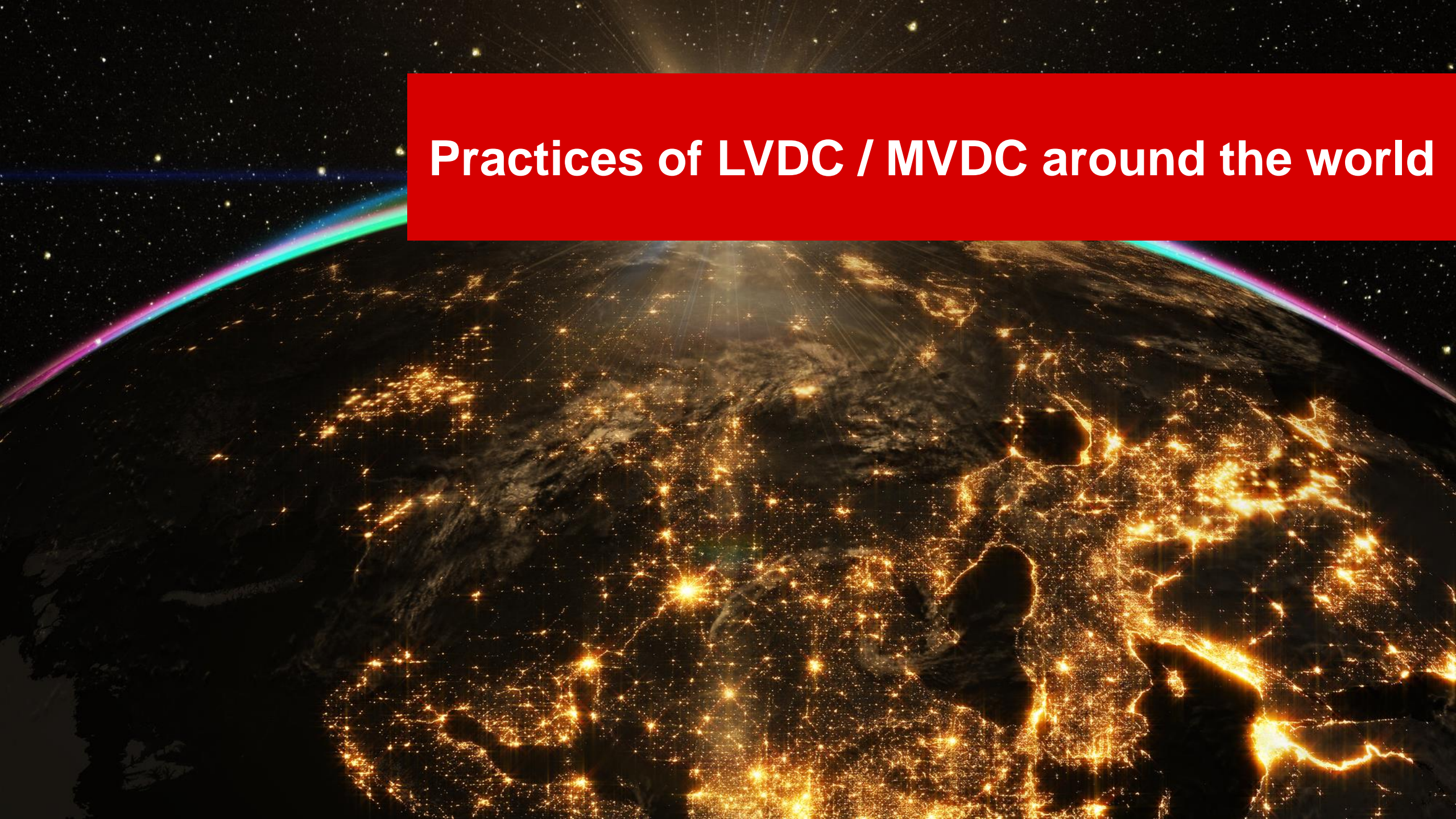
Cost becomes lower.



Maintain efficiency merit.



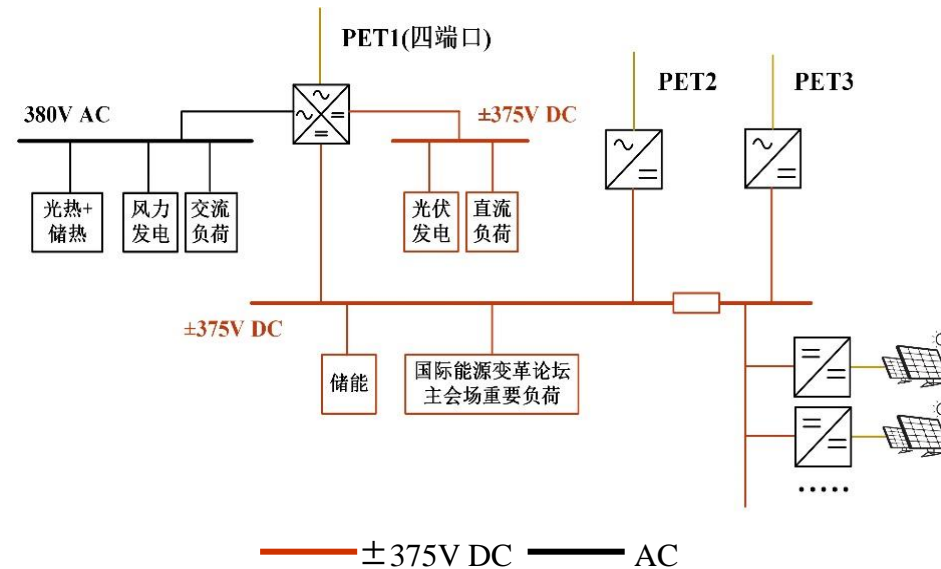
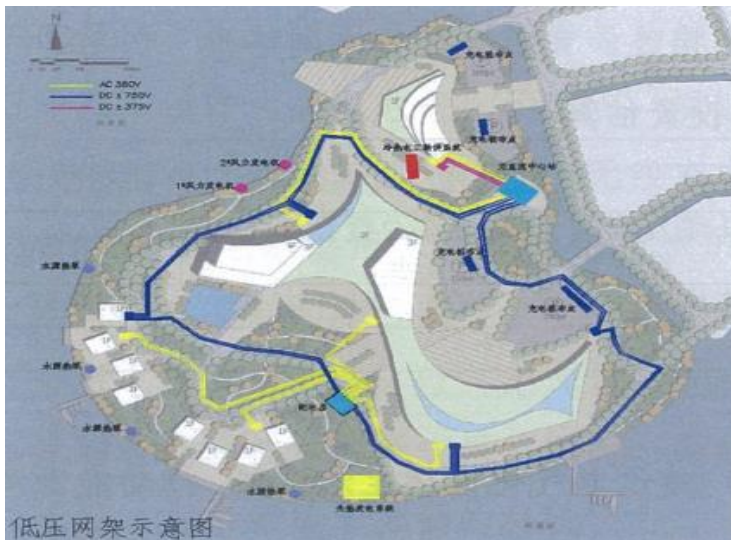
Practices of LVDC / MVDC around the world



MVDC/LVDC Demo Project with The Most DER Types

Project “Smart Renewable Energy Town of Tongli, Suzhou City” (2017~2020)

- An AC/DC hybrid system in which there is a $\pm 375\text{V}/\pm 750\text{V}$ LVDC networks.
- Distributed **PV, wind power and energy storage** are interconnected into **$\pm 375\text{V}$ DC Bus** via DC-DC converters to demonstrate the RE utilization.



AC-DC
Power-electronics Transformer



国家电网
STATE GRID

DER-Based DC Data Center

Date Center @ Alibaba, Qiandao Lake ([Thousand-Island Lake](#))

- Multi-channel + 240V full DC power supply, with diesel generator backup
- **DC integration of roof top PV**, powering the devices directly
- Overall efficiency $\geq 97\%$, close to the highest level of power supply reliability
- Annual average energy efficiency (PUE: Power Usage Effectiveness) ≤ 1.3 , 1.17 at a minimum



DER-Based DC Building

Future Building, Shenzhen City

- Shenzhen Research Institute of Architecture Design
- U.S.-China Clean Energy Research Center



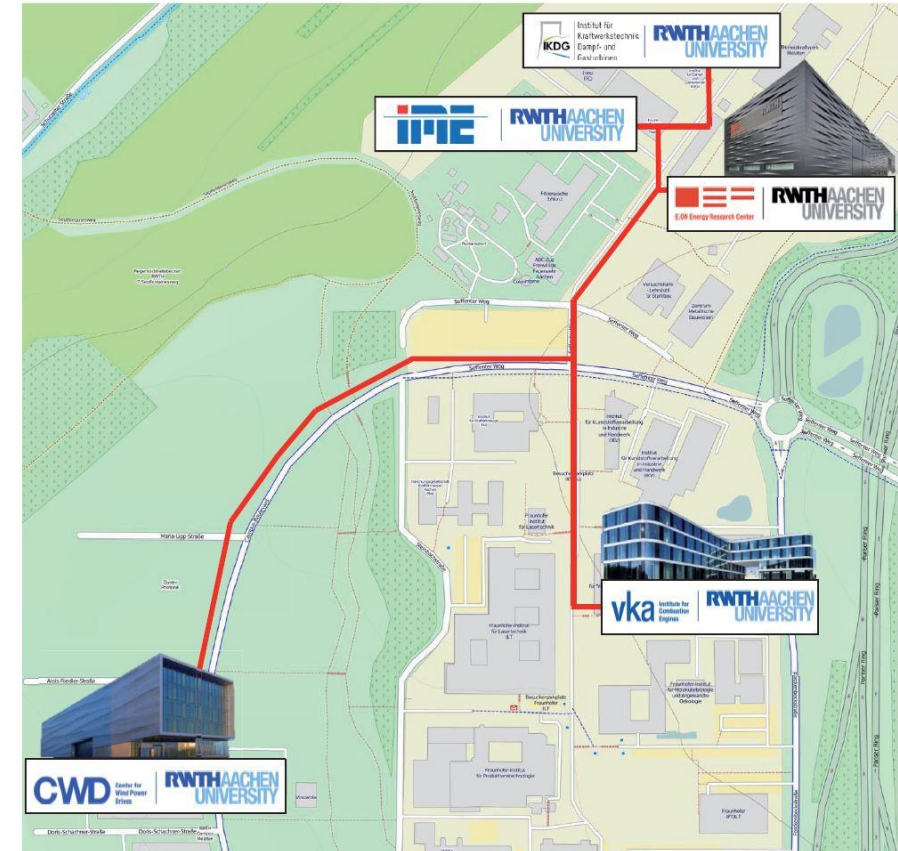
- Building area: 5000m²
- DC voltage level: $\pm 375V$, 48V
- Load capacity: 345 kW
- **150 kW PV directly connected to $\pm 375V$ DC**
- Energy storage: 480Ah



University Campus MVDC Distribution System

Campus Melaten, RWTH Aachen University, Germany

- Integrated into a MVDC distribution system for university campus.
- Including a 4MW test bench as the interface for DC integration of wind turbines, a 5MW high-speed test bench for testing of high-speed drive trains and power electronic converters.
- DC voltage level: ± 5 kV.



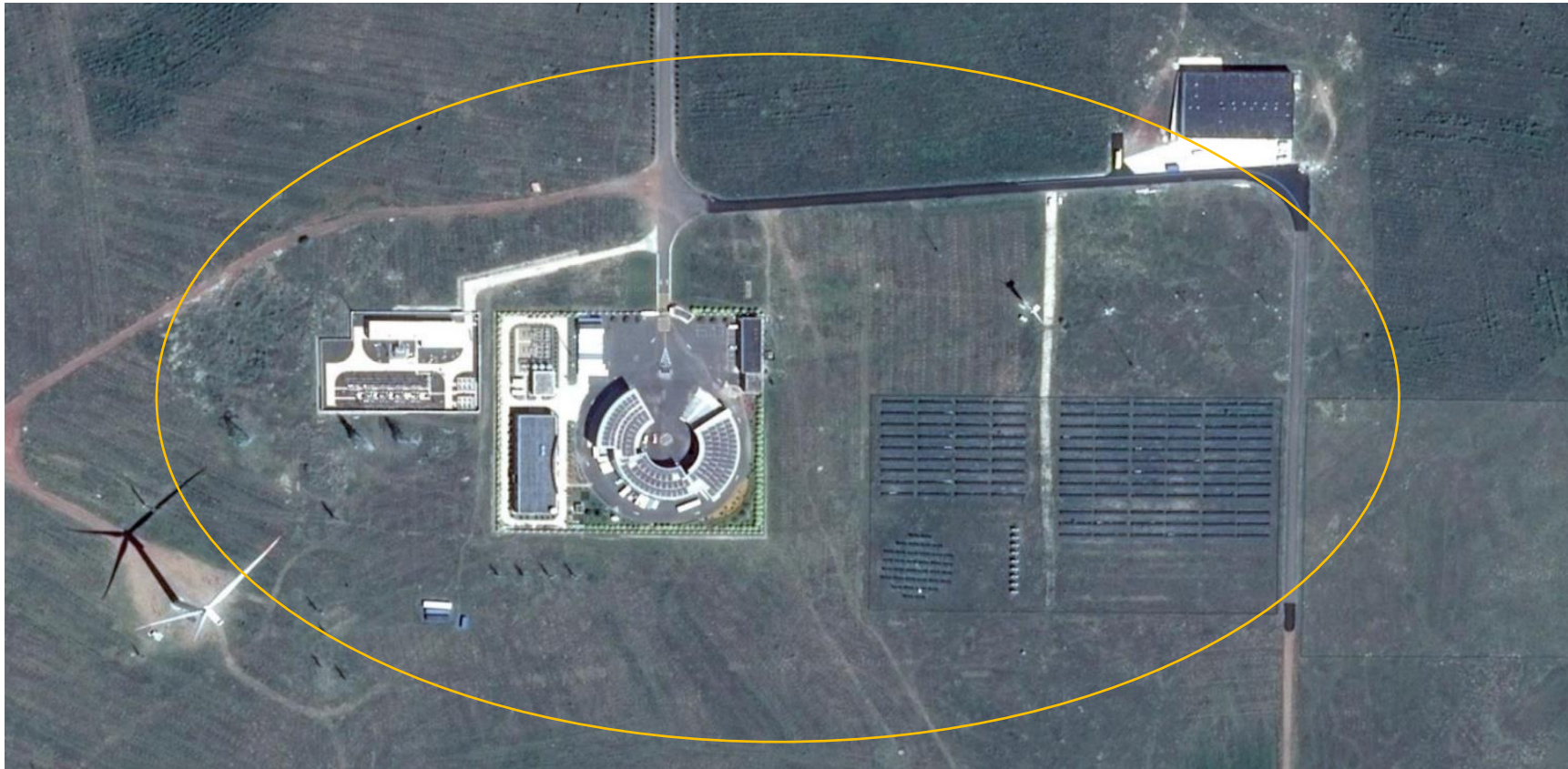
Source: Marco Stieneker, Jens Butz, Sedigheh Rabiee, Hanno Stagge and Rik W. De Doncker, 'Medium-Voltage DC Research Grid Aachen', International ETG Congress, 2015.



**Our Activities:
Integrate Distributed PV into LVDC/MVDC**

Experimental DC Network for MW-Level PV Integration

National Wind Power Integration Center (NWIC) – testing wind power plant
Zhangjiakou, Hebei Province, China. 114.53E, 41.13N



Experimental DC Network for MW-Level PV Integration



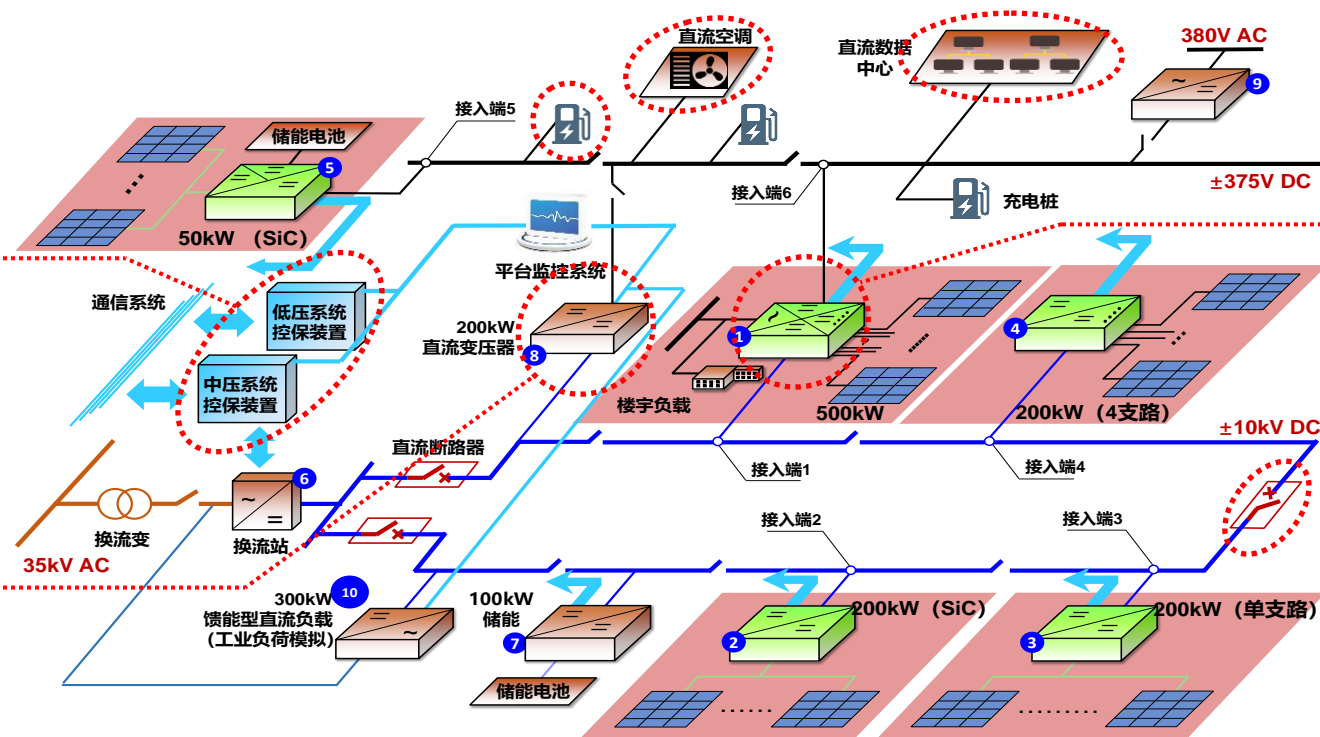
- ◆ DC loads:
data center, home appliance, EV charging pile...

- ◆ DC control and protection apparatus

- ◆ Multi-port converter (electric energy router)

- ◆ DC transformer

- ◆ DC breaker



- ◆ Multi-voltage level:
DC±10kV, DC±375V, AC 35kV, AC 380V

- ◆ PV total capacity: 1.2MW

Key Technological Aspects



Standardization

Control

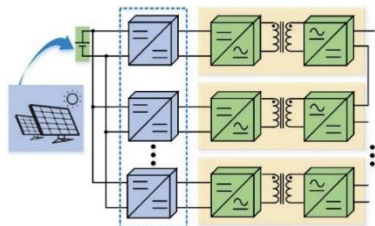
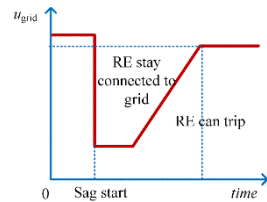
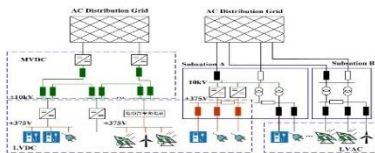
- Enable flexibility in supply and demand
- Provide efficient power management
- Allow reconfiguration of the system

Protection

- Fault detection and location
- New protection strategies
- Coordination with AC protection

Key Equipment

- DC-DC Converter
- DC Breaker
- Power Electronic Transformer
- Energy Router



Standardization

Platforms

- IEC
SyC - LVDC



- CIGRE
WG C6.31 - MVDC



- CEC
DC distribution
standardization committee



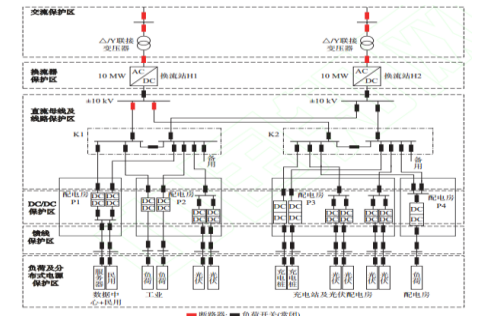
中国电力企业联合会
CHINA ELECTRICITY COUNCIL

Current Work

- **New Working Group within IEC SC 8A**
Integrating distributed PV into LVDC/MVDC systems and use cases



- **Design Manual**
Typical PV integration into LVDC networks considering equipment selection and protection & control



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Thank you!