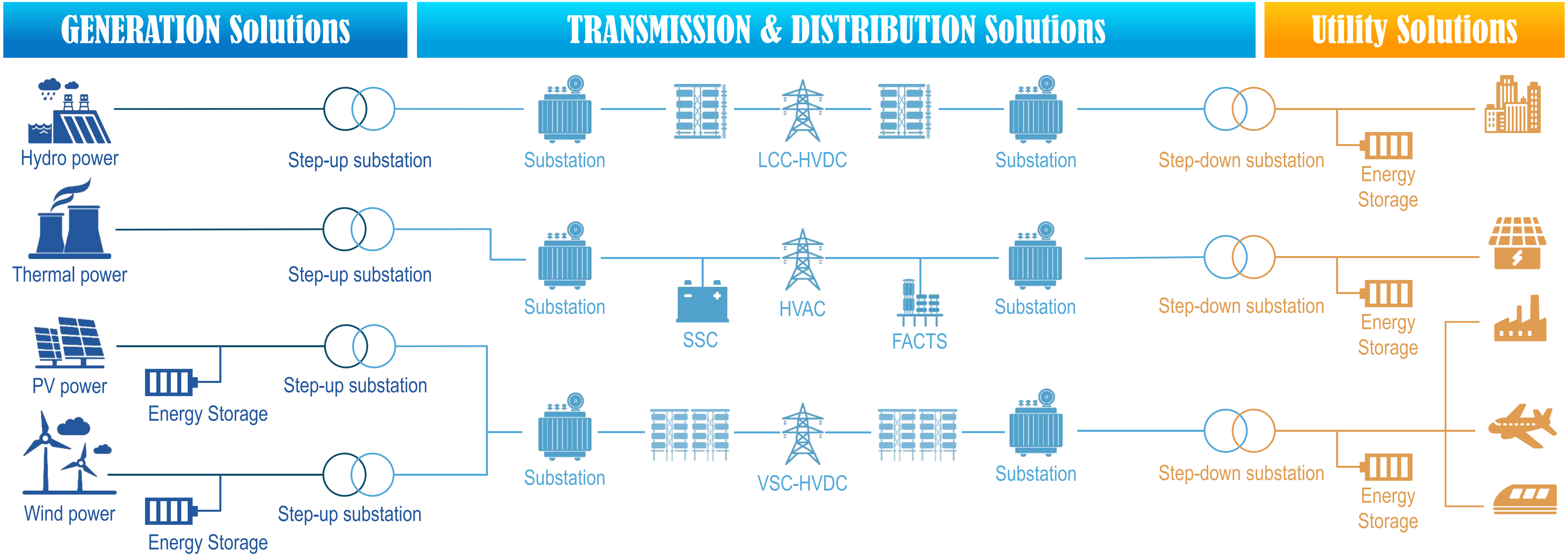
Grid-Forming Solutions for Renewable Energy Dominated Electric Power Systems

Dr Changjiang Zhan, February 2025

NR ELECTRIC CO., LTD.

Contents

NR ideal & Synchronous Grid (NR-iSGrid) SOLUTIONS



NR offer the whole power grid solutions:

HVDC & FACTS, Substation Automation, Protection & Control, Substation & Electrification;

Power Plant Automation/Excitation, Renewable Power Conversion;

Energy Storage System(ESS): NR-iSGrid ESS, NR-iSGrid Converter/Inverter, Energy Management System (EMS)

NR BESS Projects Worldwide

BESS 800MW in UK

BESS 500MW in Saudi

Headquarter: Nanjing
BESS 10GW+ in China

BESS 200MW in Chile

BESS 300MW in South Africa

1995
Foundation Date

2.8Billion $
Sales Volume

Top 3
P&C Manufacturer

Contents

Inverter Based Resources: General System Needs

High penetration of IBR based renewables as a trend for the future

Conventional fossil energy as the the dominated source in the past

Stability & Power Quality
- Synchronization
- Frequency Control
- Voltage Control
- Oscillation Damping

Security & Service Quality
- Relay Protection
- Black Start & System Restoration

Resource Adequacy
- Energy Requirement
- Power Requirement

Physical Limitations
- System Strength Shortage
- Absence of Short-Term Overload Ratings

NR ideal & Synchronous Grid （NR-iSGrid)

NR-iSGrid GFM control with the core characteristics of Natural Response & Robust Grid Supporting

NR Definition: **NR-iSGrid GFM control** of a converter/inverter means that it builds the grid-forming functions, via a power electronic conversion control algorithm /method, to create/ generate a nearly constant self-synchronizing internal-voltage-source behind an impedance, with a defined output characteristics within the sub-transient/ transient time scale, under its physical limits and constraints, such as voltage, current, power and energy.

↔

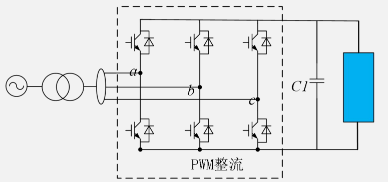
NR-iSGrid Grid-forming (GFM) Converter/ Inverter Functions/Capabilities:

1. Establish synchronous internal voltage;
2. Instantaneous phase jump response;
3. Instantaneous voltage support;
4. Flexible inertia support;
5. Fast frequency/voltage regulation;
6. Oscillation suppression & damping;
7. Adaptive fault current control;
8. Fast black start & stable islanding operation

NR-iSGrid GFM Solutions

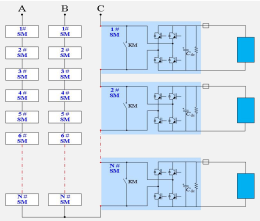
Three different NR-iSGrid grid-forming(GFM) Solutions based on 2/3-level, cascaded H-bridge, and MMC converters, with meeting the requirements of different scenarios.

NR-iSGrid GFM Solutions



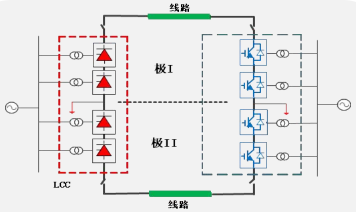
Based 2/3-level LV converter

- NR-iSGrid Centralized PCS GFM BESS
- NR-iSGrid String PCS GFM BESS
- NR-iSGrid PV and BESS integrated synchronous generator



Based cascaded H-bridge converter

- NR-iSGrid HV Direct-connected GFM BESS
- NR-iSGrid Static Synchronous Condenser (SSC)
- NR-iSGrid GFM STATCOM



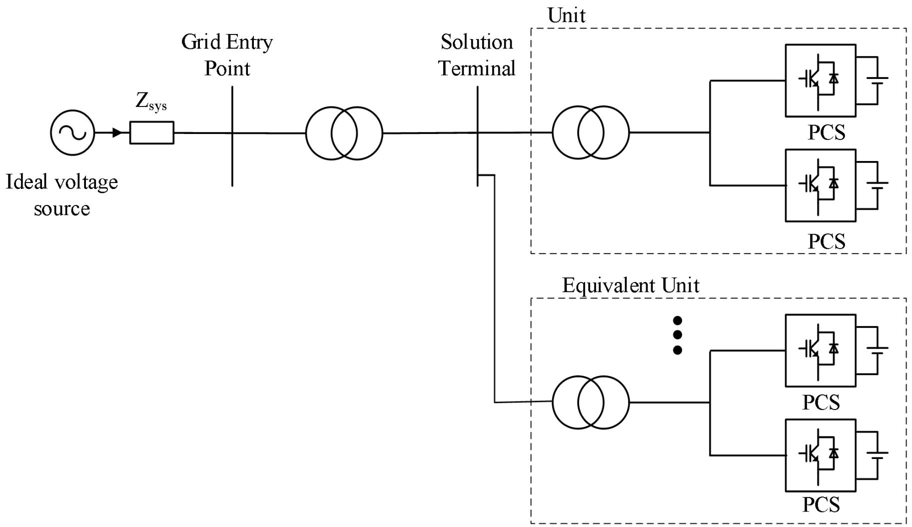
Based MMC converter

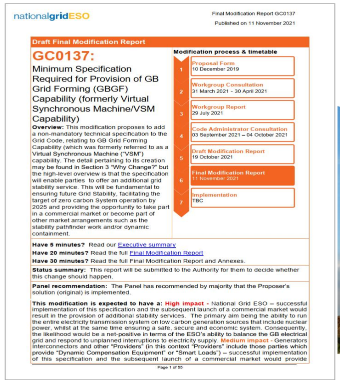
- NR-iSGrid GFM HVDC
- NR-iSGrid GFM HVDC with BESS
- NR-iSGrid GFM MMC based SSC with DC side Super Capacitor

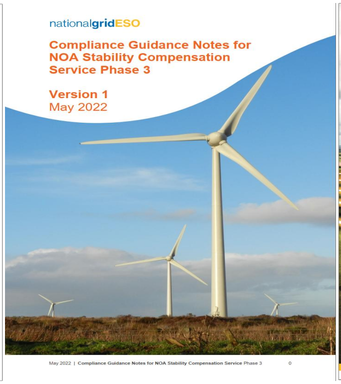
Grid Compliance Study-Model & Verification

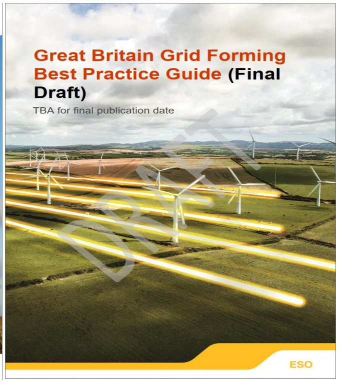
EMTDC and RMS models are ready according to NESO Grid Code and Compliance Guidance.

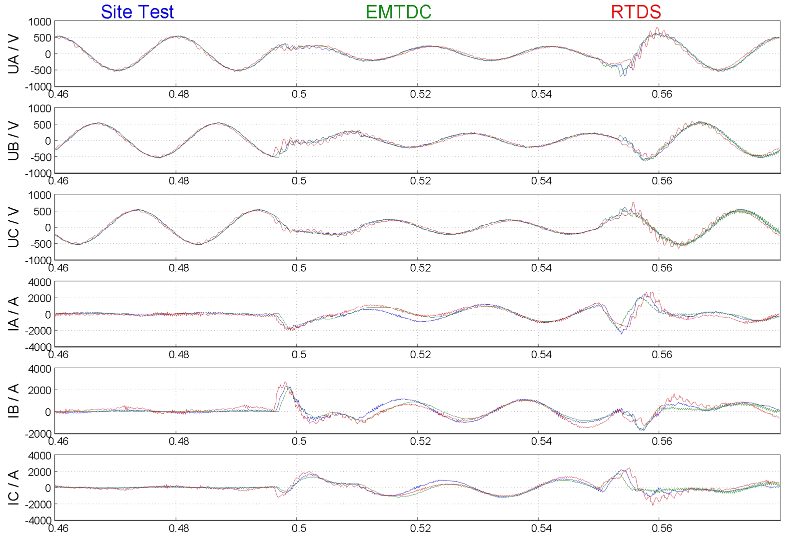
Model results are verified with the real site test results.







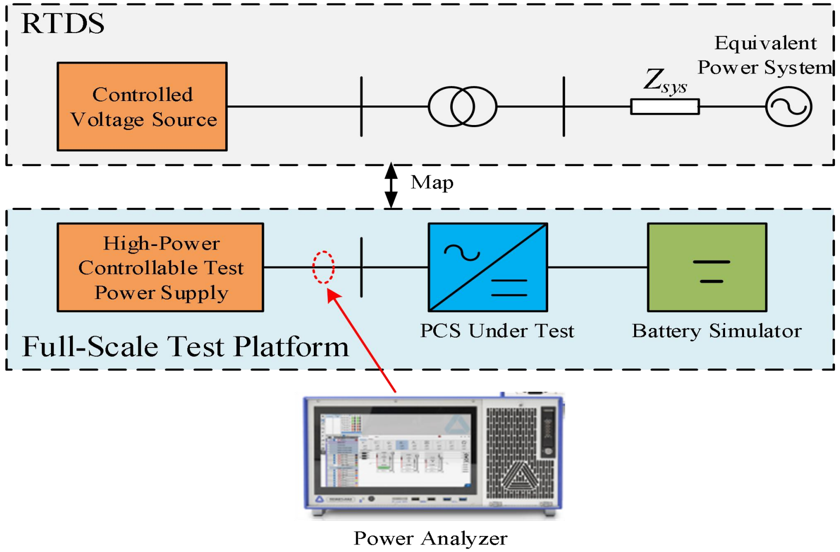




Physical Testing Systems

An Architecture of Full Power-Hardware-in-Loop Testing System

- Full-Scale Test Platform
  - ✓ Controllable high-power testing power supply
  - ✓ Battery simulator
  - ✓ PCS under test
- RTDS Platform
  - ✓ Flexible system modelling
  - ✓ Accurate simulation of new energy grid characteristics

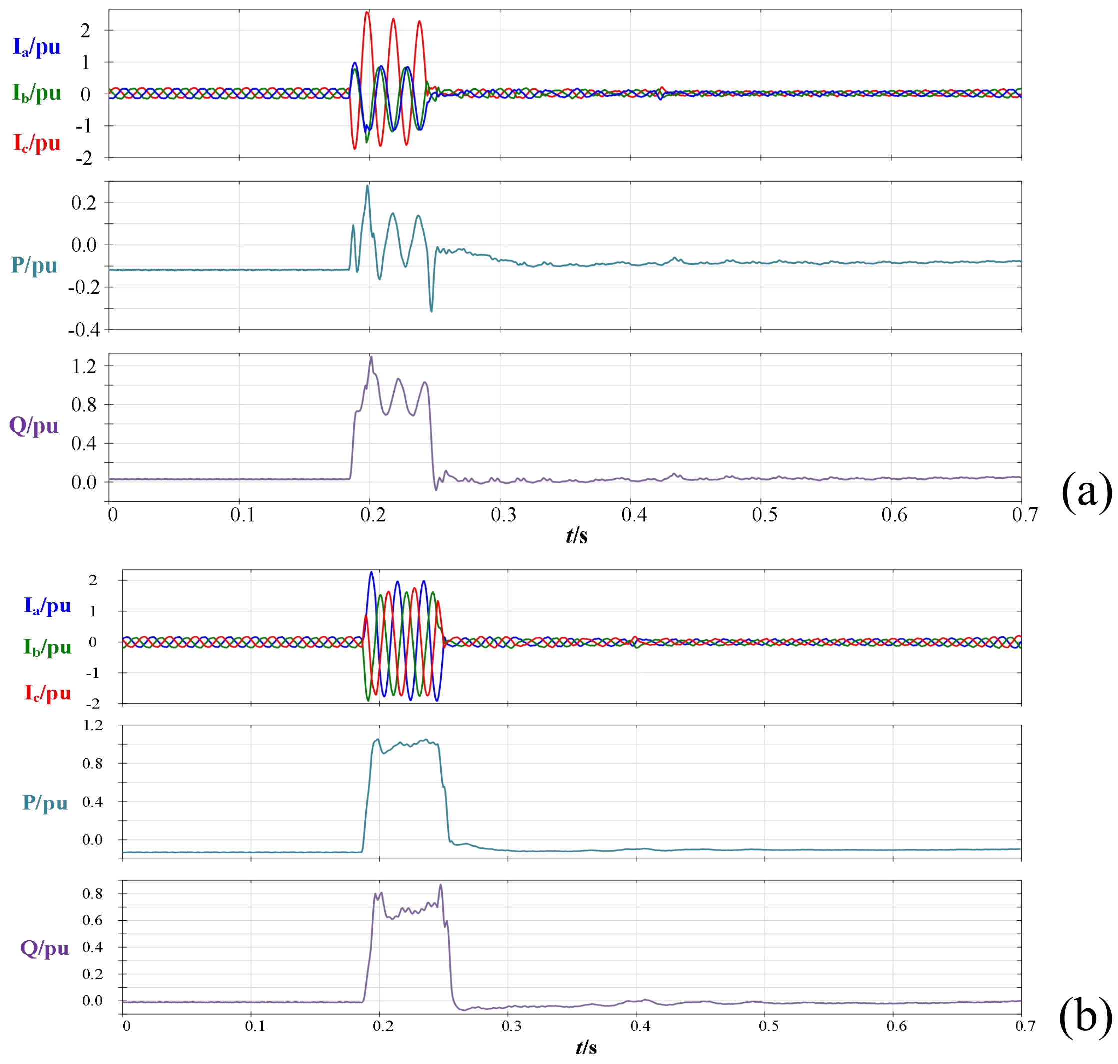


DNV Endorsement

GFM PCS physical test based on GC0137 and UK NESO GFM guidance notes， witnessed by DNV

Testing Contents of an Example in China

- ✓ Active ROCOF Response Test
- ✓ Phase Jump Test
- ✓ Short Circuit Test
- ✓ Temporary Over Voltage Test
- ✓ Power Oscillation Damping
- ✓ Frequency Regulation Test
- ✓ Mode Switching Test
- ✓ Black Start Test
- ✓ System Stability Test
- ✓ Grid Adaptability Test
- ✓ Multiple Fault Ride Through



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NR Grid-Forming Energy Storage Projects

NR has rapidly promoted a number of applications of the grid-forming technologies and solutions, with gaining the industry confidence through those successful engineering projects, and accelerating the process of the future grid-forming applications, particularly in large-scale power grids.

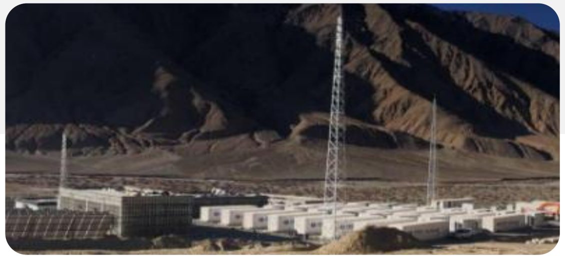
70+
GFM BESS

6
Fully-Integrated Power System Projects

10
Static Synchronous Compensator(SSC)

7
GFM STATCOM

1
GFM VSC-HVDC








Application Scenarios

1. Enable Stable & Secure Operations of a Weak Power System

Main Requirements: Support the stability and operation of renewable energy power systems with arbitrary proportions and capacities of VRE:

- Support voltage and frequency stability, ensuring grid strength
- Provide frequency and voltage regulation and control
- Provide power flow regulation and control

Typical projects:

- Inner Mongolia Ejina Project (25MW/25MWh)
- Laguocuo (65MW/130MWh) and Zabuye (20MW/40MWh) Project
- Zhangbei DC-grid with renewables and GFM functions (3+1.5GW)
- ……

2. Enable Reliable & Secure Operations of an Off-Grid System or Islanded Power Grid

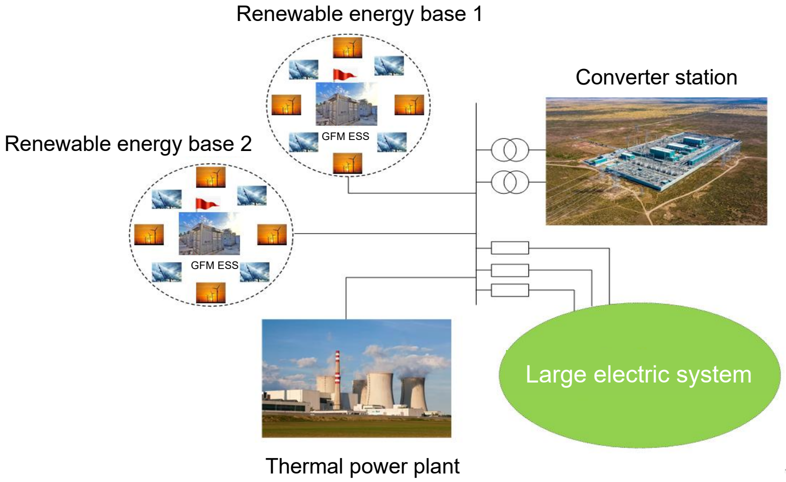
For the special regions of “high plateau, island, and uninhabited” without a strong network, the grid-forming energy storage system can build the necessary voltage source to achieve both islanded or/and on-grid operations, in order to improve overall system reliability, stability and security.

Typical projects:

- Laguocuo Project (65MW/130MWh)
- Zabuye Project (20MW/40MWh)
- Ronghe Project (16MW/28MWh)
- ……

3. Enhancing System Strength of a Remote Power Grid Fed with high VRE

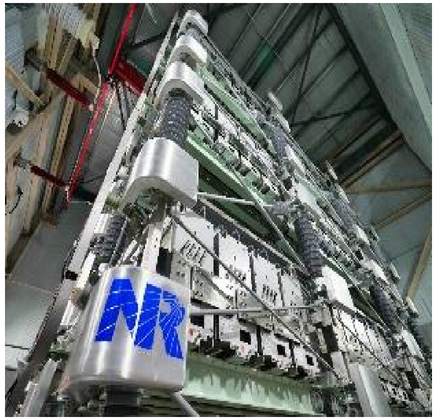
Those renewable-rich regions with high renewable energy fed in the long ending of the power grid, often have issues with the low short-circuit ratio. This can be addressed by using the GFM BESS, static synchronous compensators (SSC), or grid-forming STATCOM.



Main Requirements: Increase the short-circuit ratios (SCR) at the weak connection points

Typical projects:

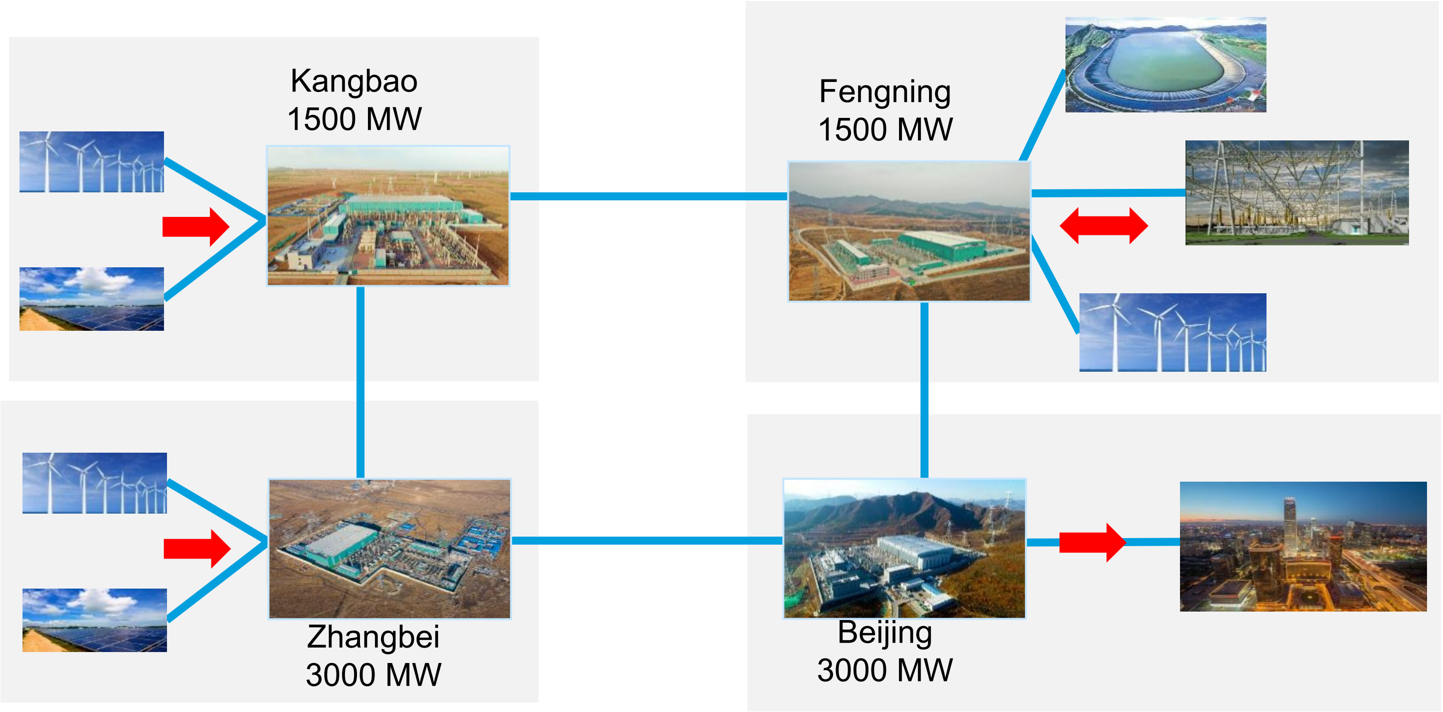
- Ningxia Longyuan 320MW GFM energy storage
- Dangxiong MMC static synchronous compensator (±50Mvar)
- Jilin Bamian static synchronous compensator (50Mvar/340MJ)
- Mulei and Chengdu Grid-Forming STATCOM(5x60Mvar)
- ……



4. Bulk Renewable Energy Transmission with Grid-forming HVDC Applications

The existing local AC power grid in Zhangbei area is very weak and it's very challenging to meet the demand for large-scale renewable energy integration and transmission

- Islanded mode
- RES integration
- AGC control
- AC Chopper



- Grid integration
- RES integration
- Pumped-storage
- DC voltage control

- Islanded mode
- RES integration
- AGC control
- AC Chopper

- Large Load center
- Restricted green targets
- 2022 Winter Olympics

100% renewable energy integration, Grid-forming Control in an islanded Zhangbei local grid

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Summary

- The GFM technologies assisted with Full X-in-Loop Testing Systems are expected to be applied significantly to improve the stability, reliability and security of the bulk power systems, dominated by renewable energy sources such as solar and wind energy.

- The success of NR iSGrid GFM BESS engineering projects such as Ejina and Laguocuo in China, has demonstrated that the GFM-based solutions can be fully capable of guaranteeing the secure and stable operation for the future power grid without any reliance on synchronous generators.

Thanks for your Attention!

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