



Grid-Forming Solutions for Renewable Energy Dominated Electric Power Systems

Dr Changjiang Zhan, February 2025

NR ELECTRIC CO., LTD.

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NR Introduction

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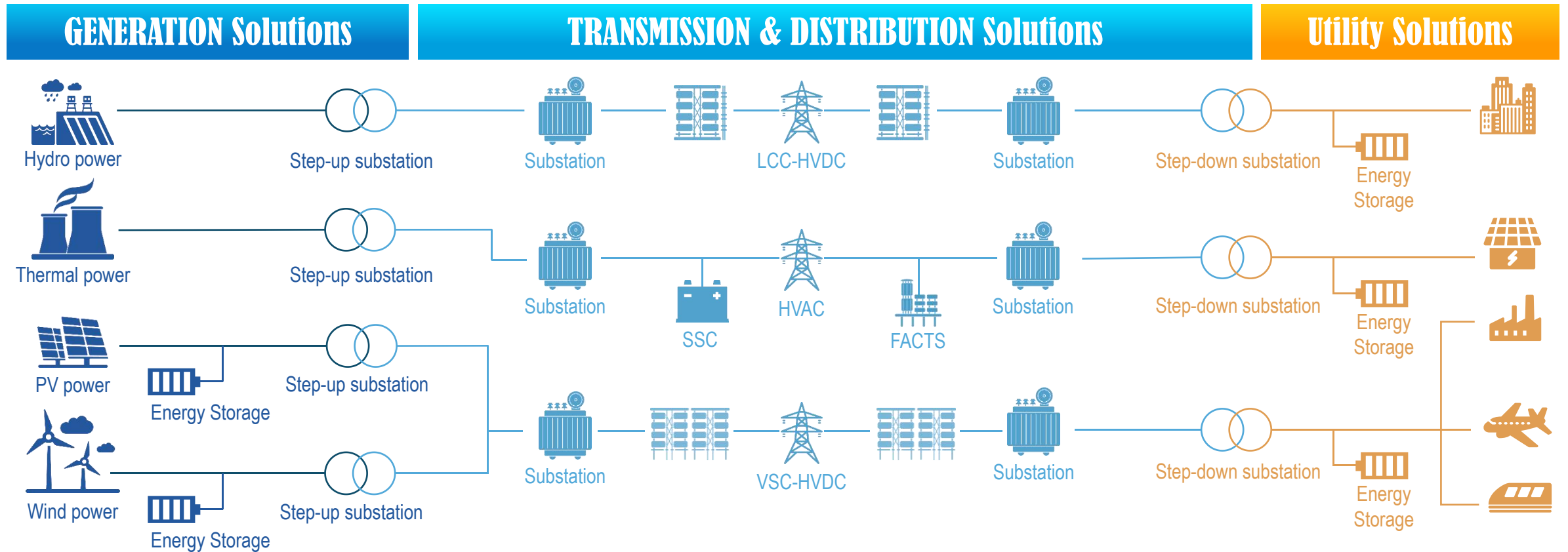
NR Engineering Practices

PART 04

Summary



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

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Inverter Based Resources: General System Needs



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



Conventional fossil energy as the dominated source in the past

Stability & Power Quality

Synchronization	Voltage Control
Frequency 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-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.

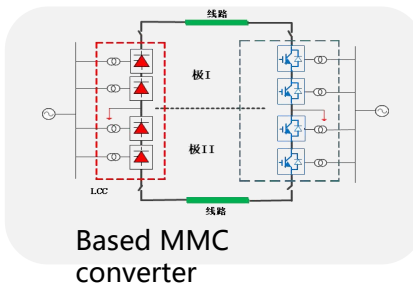
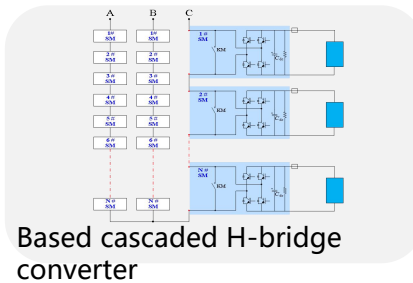
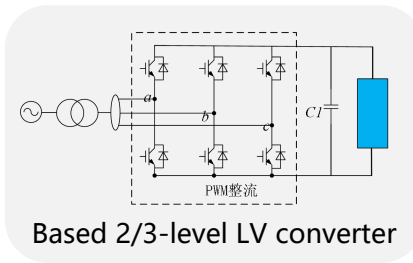


NR-iSGrid Grid-forming (GFM) Converter/ Inverter Functions/Capabilities:

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

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



NR-iSGrid Centralized PCS GFM BESS

NR-iSGrid String PCS GFM BESS

NR-iSGrid PV and BESS integrated synchronous generator

NR-iSGrid HV Direct-connected GFM BESS

NR-iSGrid Static Synchronous Condenser (SSC)

NR-iSGrid GFM STATCOM

NR-iSGrid GFM HVDC

NR-iSGrid GFM HVDC with BESS

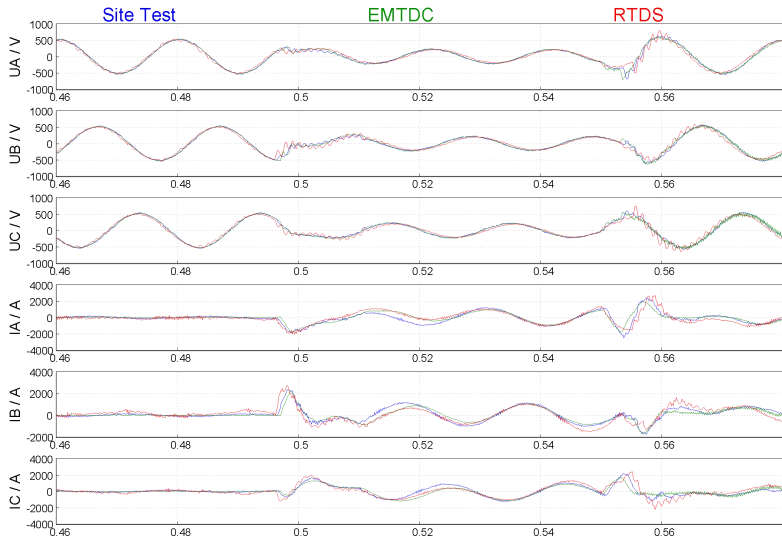
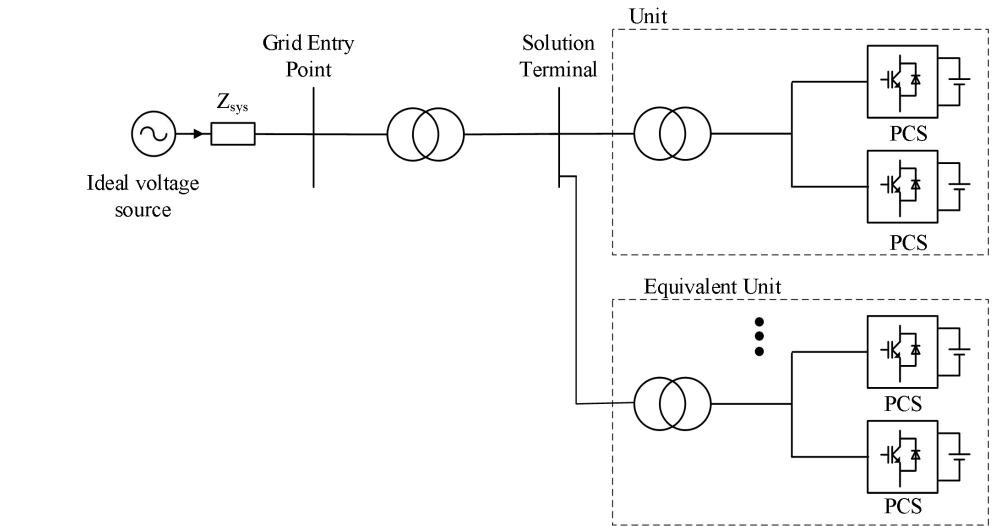
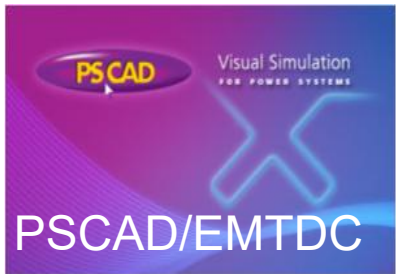
NR-iSGrid GFM MMC based SSC with DC side Super Capacitor



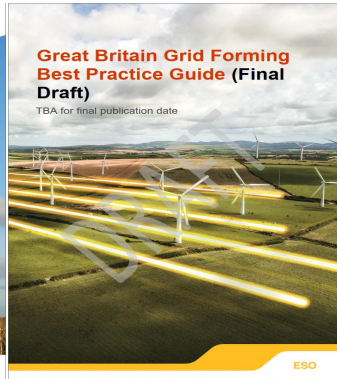
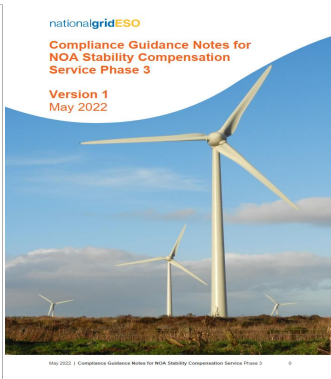
Grid Compliance Study-Model & Verification



EMTDC and RMS models are ready according to NESO Grid Code and Compliance Guidance.
Model results are verified with the real site test results.

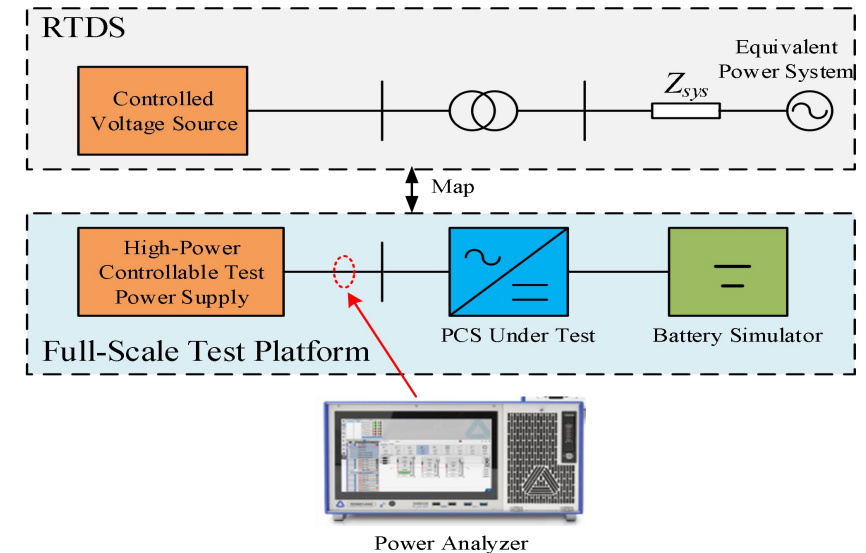


nationalgridESO	Final Modification Report 000137 Published on 11 November 2021
Draft Final Modification Report	Modification process and timeline
GC0137: Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability)	Proposed Change: 10 December 2019
Overview: This modification proposes to add a non-mandatory technical specification to the Grid Code, relating to GB Grid Forming Capability (which was formerly referred to as a Virtual Synchronous Machine (VSM)) capability. The intent of this specification is to ensure that the high-voltage converter in the converter may be used in a 'grid-forming' mode, which is a capability that is not currently specified in the Grid Code. This will be implemented by ensuring that the converter is able to provide a target of zero current system operation by 2025 and providing the opportunity to take part in a commercial market or become part of other market arrangements such as the electricity purchaser work and/or dynamic compensation.	Revised Change: 20 March 2021 - 26 April 2021
Have 20 minutes? Read the full Final Modification Report.	Revised Change: 26 April 2021
Have 30 minutes? Read the full Final Modification Report and Annexes.	Revised Change: 26 April 2021
Status summary: This report will be submitted to the Authority for them to decide whether this change should happen.	Revised Change: 26 April 2021
Panel recommendation: The Panel has recommended by majority that the Proposed's solution (original) is implemented.	Revised Change: 26 April 2021
This modification is expected to have a high impact. - National Grid ESO - successful implementation of this specification and the subsequent launch of a commercial market would require the provision of additional stability services. The primary aim being the ability to run the GB electricity transmission system in low-carbon generation modes that can provide power, whilst at the same time ensuring a safe, secure and economic system. Consequently, the likelihood exists for a non-provision in terms of the ESO's ability to balance the GB electrical grid and respond to unplanned transitions to electricity supply. Therefore, the Generation (renewables and other 'flexible' or 'dispatchable' generation) and the Grid Code (which provides a framework for the operation of the GB electrical grid) are both impacted by this specification and the subsequent launch of a commercial market would provide a high impact.	Revised Change: 26 April 2021



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



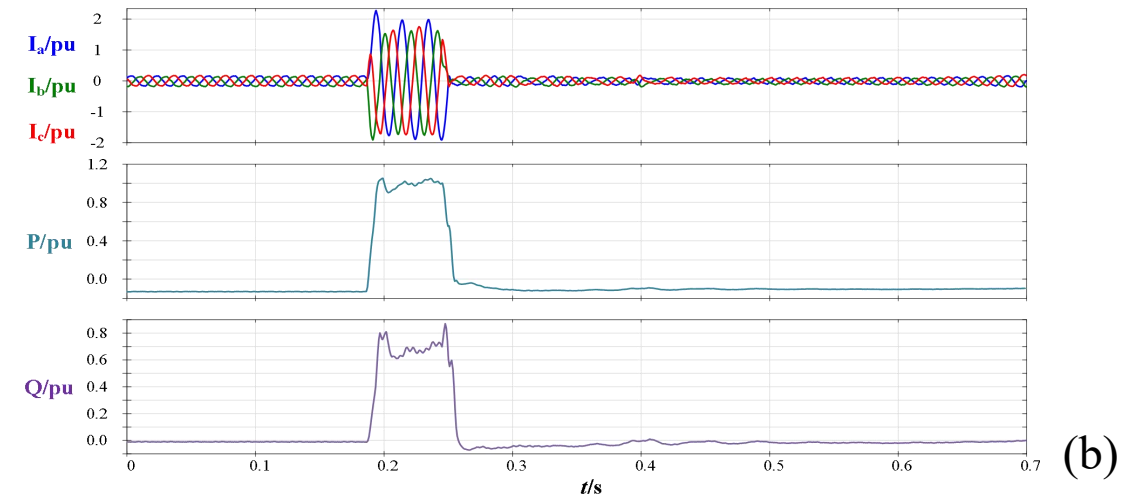
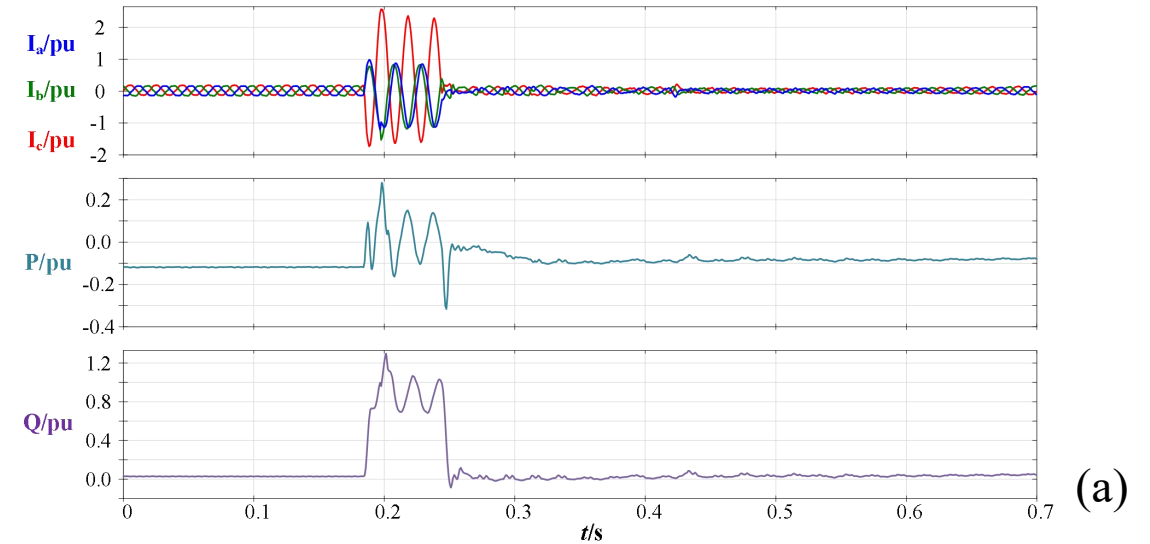
DNV Endorsement

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

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)
-



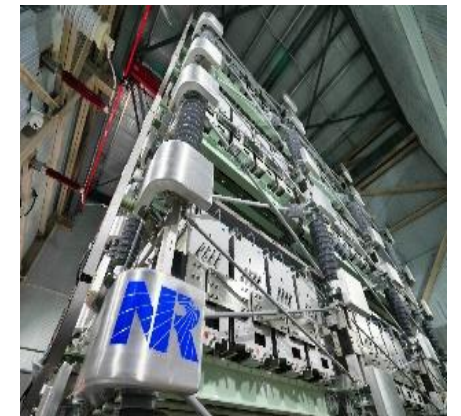
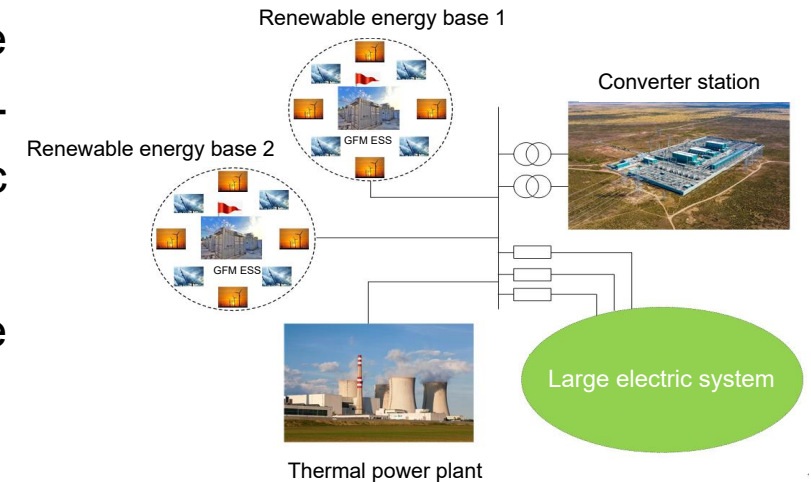
3. Enhancing System Strength of a Remote Power Grid Fed with high VRE

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

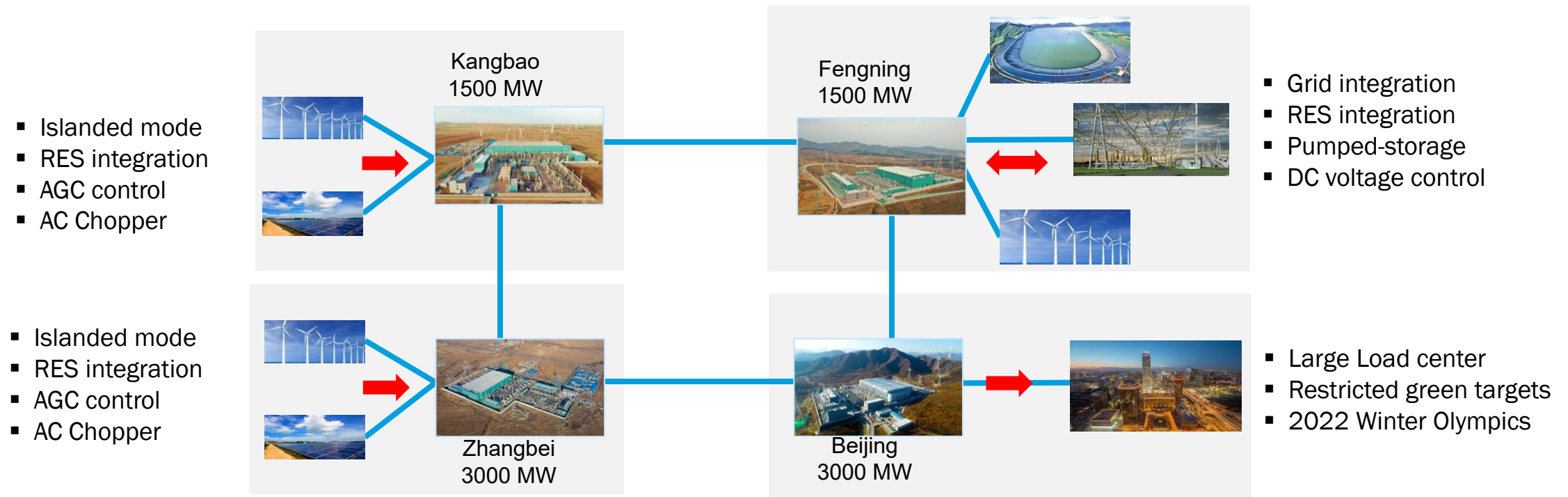
Typical projects:

- Ningxia Longyuan 320MW GFM energy storage
- Dangxiong MMC static synchronous compensator ($\pm 50\text{Mvar}$)
- Jilin Bamian static synchronous compensator ($50\text{Mvar}/340\text{MJ}$)
- Mulei and Chengdu Grid-Forming STATCOM($5\times 60\text{Mvar}$)
-



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



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

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- 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.

An aerial photograph of a vast solar farm with rows of solar panels stretching towards the horizon. The sun is low on the right side, creating a warm, golden glow and long, diagonal shadows across the panels. The sky transitions from a pale blue to a bright yellow near the sun.

Thanks for your Attention!

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