Power Stability Expert

Microgrid Solution

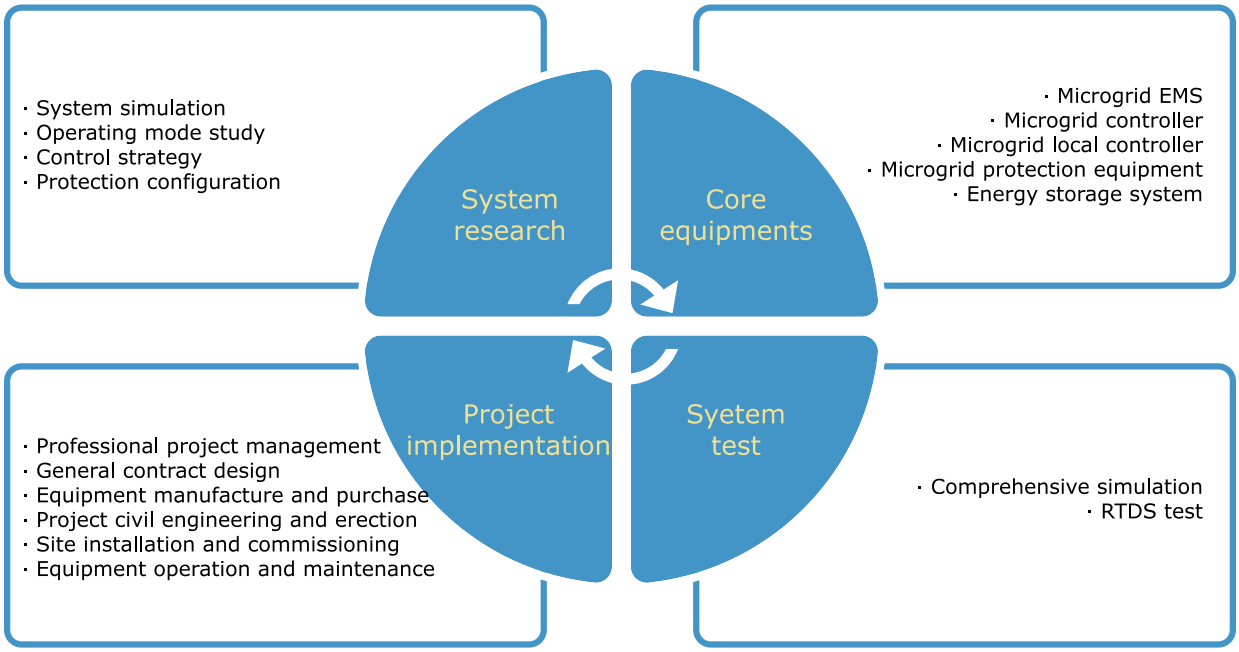

One-stop Solution
for Sustainable Power Supply

1 Overview

Microgrids are electricity generation and distribution systems containing loads and distributed energy resources, (such as distributed generators (DG), storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded. With its autonomous control, protection and management, it provides multiple advantages including higher energy utilization rate, higher power supply safety & reliability, less power transmission loss, low environmental impact.

The microgrid (MG) consists of two types, namely grid-connected microgrid and permanently islanded microgrid. The grid-connected microgrid is synchronized with the external power grid and generally applied in industrial parks and enterprises, communities,hospitals, schools, etc. It operates in parallel with the distribution network to realize the bidirectional energy exchange. During the external grid outage, it operates in the islanded mode to enhance the power supply reliability. The permanently islanded microgrid is a stand alone network, normally applied in the remote districts not covered by the large power grids, such as countryside, island, etc. It operates independently to meet the load demand by the DGs or Energy Storage System (ESS) within microgrids.

NR's all in one microgrid solution covers the overall planning, design, manufacturing, system simulation and test,site implementation, and provides a complete service for the customers.



System Research

NR Electric is a comprehensive enterprise integrated with research and analysis of steady-state, transient-state, operating modes, control strategy and protection configuration for microgrid. NR has also undertaken comprehensive research in multiple domains including power system analysis, stability control, FACTS application, AC/DC hybrid transmission system, analysis for grid applications, etc. At present NR is fully capable of proving the core technologies for microgrid with high end system research and analysis facilities.

Core Equipment

NR can cover all the high-end equipment to build your microgrid system including microgrid EMS, microgrid controller, microgrid local controller, microgrid protection IEDs, microgrid energy storage system, PV inverter, reactive-power compensator. This ensures a one-stop contact for a stable and economic microgrid system.

System Test

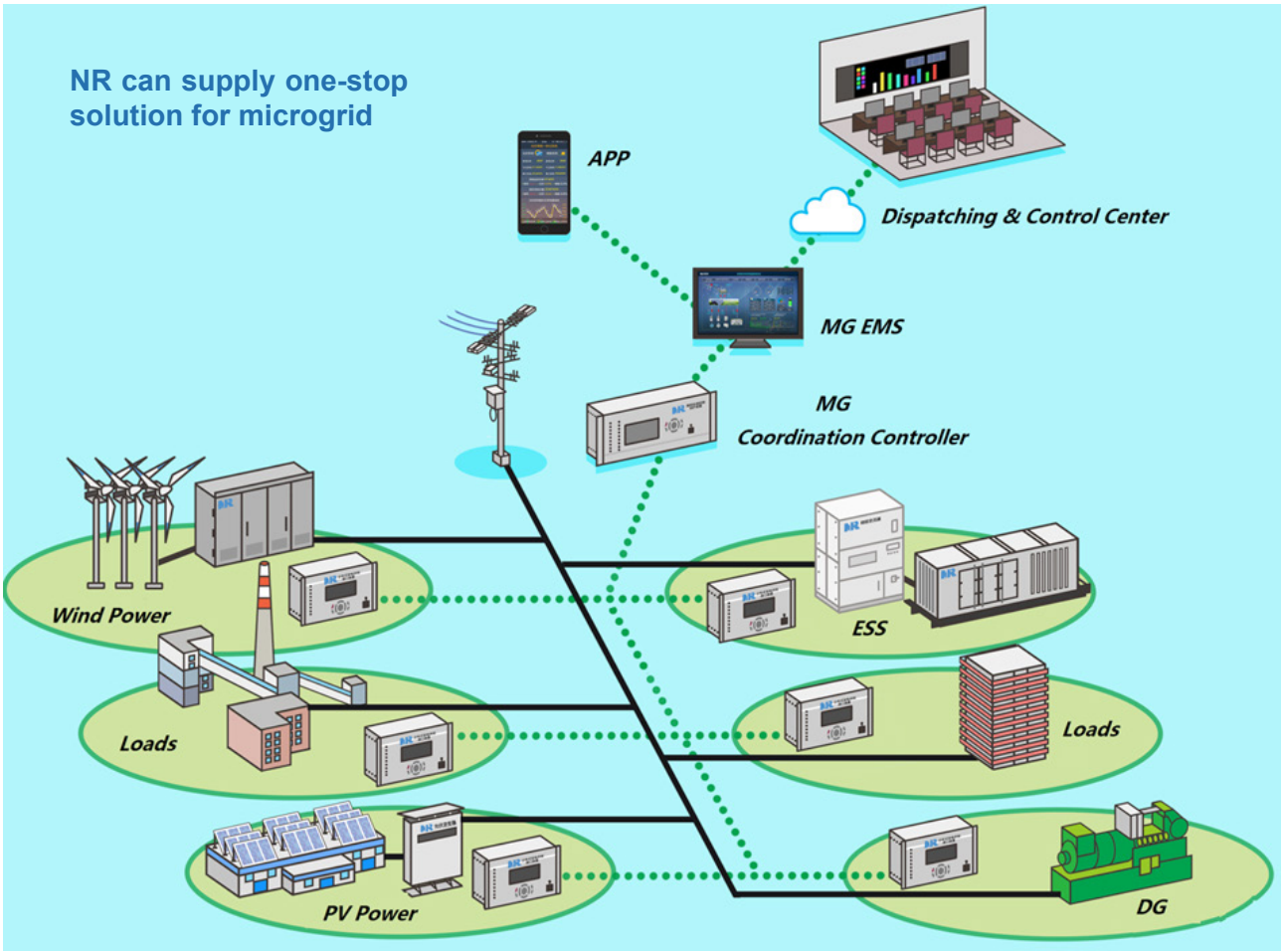
NR has established RTDS test facility, RT-LAB test facility, dynamic analog simulation test facility and synthetic test loops to simulate site application scenarios and to verify the control & protection system, guarantee the correctness of control and protection logics, and cut down the site commissioning work.

Project Implementation

NR has the professional project management system with project managers certified by the international Project Management Professional (PMP) . The general contract design covers the projects of primary electrical engineering, secondary electrical engineering, civil engineering as well as the design capabilities of the conventional substation, DC transmission, FACTS, renewable energy generation, etc. The manufacturing of core equipment, the purchase management of auxiliary devices and the operation & maintenance management of operating equipment also are included in the complete microgrid solution.

2 Microgrid Solutions

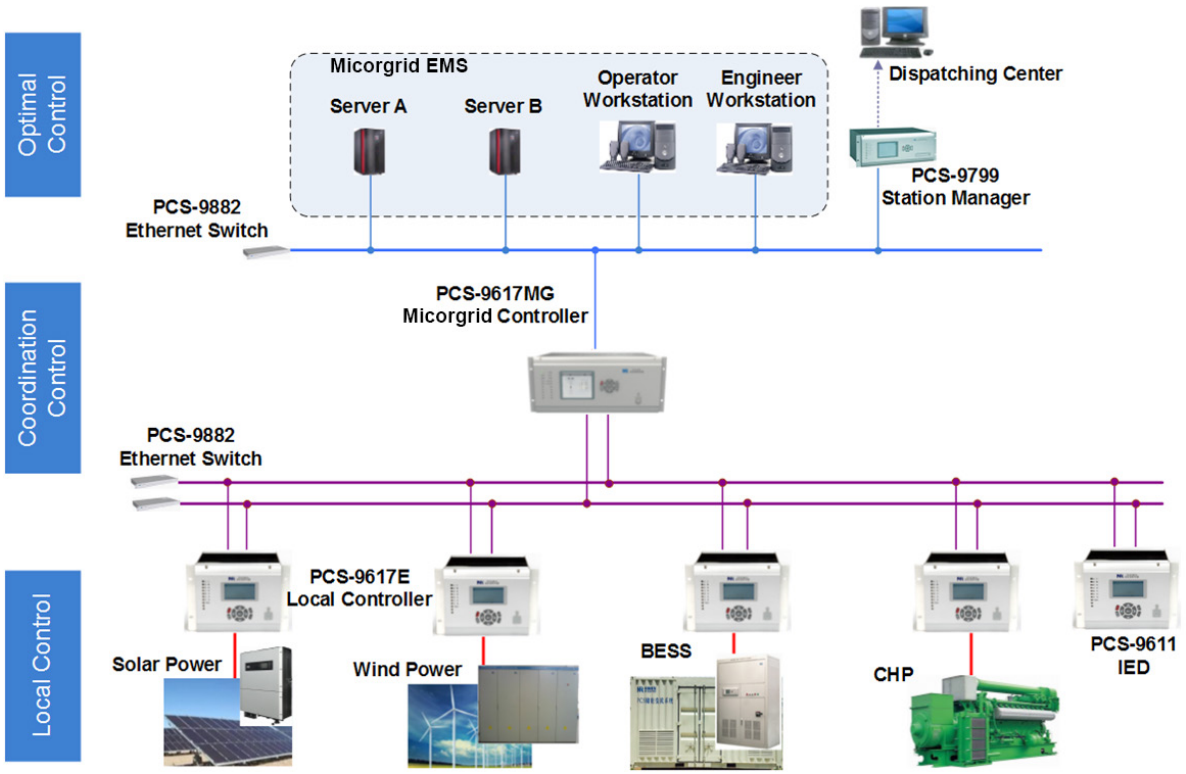
NR provides a safe, stable and reliable solution to both grid-connected and islanded type microgrid, which adopts the design of layered and distributed control system, inherits the technology of smart substation and carries out the coordination of control & protection among different layers to realize the stable and economic operation of microgrid system. This system greatly increases the proportion of grid-connected renewable DGs in the distributed power grids.



No.	Equipment name	Type	Description
1	Microgrid EMS	PCS-9000	Microgrid dispatching automation system for data acquisition, supervisory control, optimization and management.
2	Microgrid Controller	PCS-9617MG	Controller has the functions of control, protection, measuring, monitoring, communication, etc. and carries out the coordinative control of DG, energy storage, diesel generator and controllable load to realize the safe, stable and economic operation of the microgrid.
3	Microgrid Local Controller *	PCS-9617E	Controller will be installed at the sides of DG, energy storage, diesel generator and load for realizing the local information acquisition, monitoring and control, etc.
4	PCS	PCS-9567	The PCS (power conversion system) supports multiple operating modes, such as PQ, VF, droop control, VSG, black start, constant-DC voltage, constant-DC current, etc.
5	PV Inverter	PCS-9563	Rated capacity: 33kW~1000kW
6	Hydropower Station SCADA System	PCS-9150	This system carries out the monitoring and control of hydroelectric generating unit.
7	Microgrid Protection Equipment	PCS-9600 Series	Protections for mid-/low-voltage line, transformer, capacitor, etc.
8	Reactive-power Compensator (SVC, STACOM) *	PCS-9580 PCS-9583	The system supplies dynamic reactive-power compensation for the large-capacity microgrid.
9	Battery		lead-acid, lead-carbon, lithium-ion, zinc-bromine,vanadium flow battery and sodium-sulfur, etc.

Note: * labeled equipment is normally applied in the large-capacity microgrids (MW-level).

2.1 Layered and distributed microgrid control & protection system



NR's microgrid control & protection system adopts the layered and distributed design, which is divided into local control level, coordinative control level and optimal control level.

• Local control level

The Local control level includes DGs, PCS, local controller and protection IEDs. The automated local control system generally not dependent on communication system can provide fast response speed during disturbances or short-circuit faults, and stabilize power-supply by the self-regulation of converter or the fast action of protection equipment.

• Coordinative control level

The coordinative control level includes the microgrid controller, which acquires the information of DGs, energy storage, diesel generators and important load via the control communication network. When microgrid operates in the islanded mode and large disturbance occurs (such as non-scheduled grid outage, large-capacity DG tripping, etc.), the microgrid controller coordinates the operating modes of energy storage and diesel generator as well as the output power of DGs to maintain the voltage and frequency within the allowable ranges and guarantee the stable and safe operation of microgrid system.

• Optimal control level

The optimal control level includes the microgrid EMS and depends on the data supplied by SCADA system, dispatching & schedule system, load forecast system, etc. It realizes the functions of data analysis, energy prediction, load management, optimal operation, economic dispatching to maximize the comprehensive utilization of the DGs within microgrid.

Features

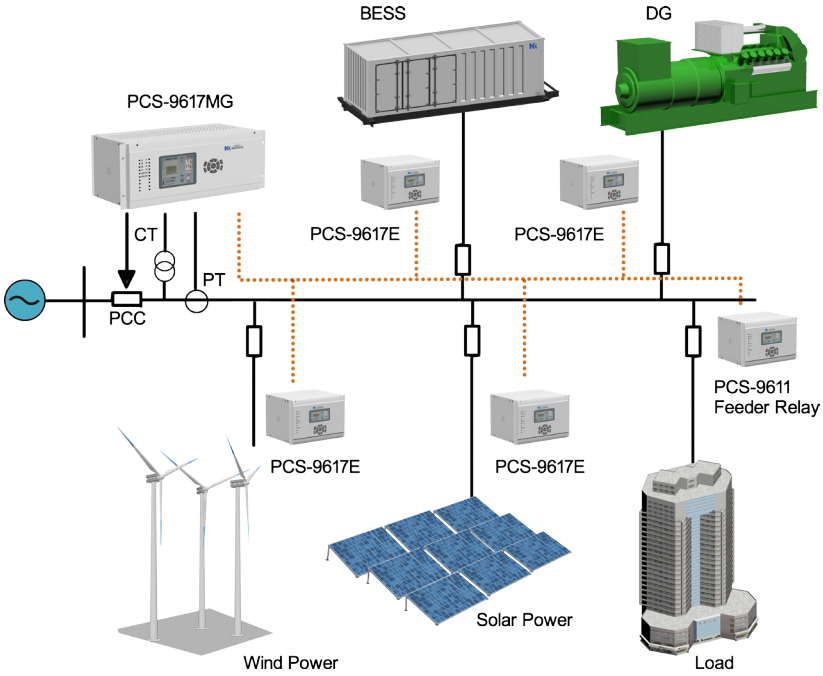
• The effective coordination of control and protection among different layers with both centralized and distributed features is very helpful to realize the stable and economic operation of microgrid.

• The control-layer networks can be redundantly designed and configured independently with high reliability and safety.

• The high-performance and ms-level response speed of the microgrid controller enables the seamless switch between different operation modes of microgrid.

2.2 Microgrid Controller

PCS-9617MG is a coordination control equipment specifically designed for microgrid (both grid-connected and islanded). It has the function of control, protection, measuring, monitoring, communication, etc. and carries out the coordinative control of DG, energy storage, diesel generator and controllable load to realize the safe, stable and economic operation of microgrid. This helps to increase the economic benefit for customers and enhance the penetration and utilization of DG and renewable energy.



Note: When the microgrid capacity is small, the local controller could not be configured and the microgrid controller communicates directly with DG, energy storage and diesel engine.

PCS-9617MG is developed based on high-performance Unified Advanced Platform for Protection and Control (UAPC) independently developed by NR Electric with high speed control response and thousands of applications. This guarantees the stable and safe operation of microgrid with seamless operation. In addition, it adopts the advanced optimal control algorithm to ensure the highly efficient and economic operation of various energy sources within microgrid, such as DG, CHP, solar generation, wind generation, etc. Its control logic can be flexibly configured according to the various microgrid application scenarios.Besides of the advanced control functions, it also integrates the functions of microgrid Interface protection.

PCS-9617MG includes the following functions:

1) Control

a) Control Strategy for grid-connected Mode

• Interface tie-line power control

In order to avoid the impact of large tie-line power variation, the output of energy storage systems and DGs should be under control to guarantee the power flow of the point of common coupling (PCC) within the acceptable range.This makes the microgrid operate as a controllable source/load for a friendly grid-connected distributed system.

• Ancillary Services

For higher operation reliability and power quality, the output of ESS and DGs can be controlled to supply the ancillary services, such as frequency and voltage regulation, for power grid based on dispatch enter commands or real-time system operation condition.

• Energy storage management

Fluctuation suppression: The intermittent feature of wind generation and solar generation impact the power quality and stability of microgrid greatly. However, the energy storage system has the capability to dynamically absorb or release the power depending upon grid needs. Special strategy is set in the controller to suppress the power output fluctuation of wind generation and solar generation and realize the smooth power output of wind generation and solar generation.

Peak shaving: When microgrid operates in the grid-connected mode, it injects power into the distribution system during the peak-load period and absorbs power from the distribution system during the valley-load period. The peak-valley schedule curve function is set in the controller, which receives the schedule curve issued by the dispatching center and controls the power output to make the microgrid an excellent solution for the distribution system. A peak-valley power output curve can also be set locally to generate power during the peak-price period and absorb power during the valley-price period to obtain the benefit of peak-valley price difference which ultimately enhance the economic efficiency of the microgrid.

b) Control Strategy for Islanded mode

• Frequency & voltage emergency control

In islanded mode, the power deficiency or excess may lead to the sharp variation of frequency and voltage. This severely impacts the normal operation of microgrid and causes the system breakdown. The frequency & voltage emergency control is set to balance the power demand within microgrid and to recover the voltage and frequency within the allowable operating ranges by the energy storage output control, fast load shedding and DG disconnection.

• PV power limit control

In order to avoid the automatic shutdown or damage of generator (diesel generator, gas engine) due to its too low power output, the PV power output is limited by the automatic generation control to maintain the power output of generator within an allowable range.

c) Transient process control

• Switching between grid-connected and islanded

Switchover from grid-connected mode to islanded mode: When the grid is de-energized due to fault, overhaul, etc., the controller quickly detects the islanded condition, trips the circuit-breaker of PCC and sends the islanded signal to the energy storage and DGs for the switching between microgrid's two operating modes.

• Synchronous grid-connection

Switchover from islanded mode to grid-connected mode: The controller provides automatic synchronous switching-on function for a safe and reliable grid inter-connection of microgrid.

2) Protection

All the major protection functions according to grid codes needed including over-current protection, under/over voltage protection and under/over frequency protection are all inbuilt in the controller.

3) Monitoring and Measuring

a) Voltage, current, frequency, active power, reactive power, power factor and kilowatt-hour at PCC

b) Monitoring of circuit-breaker position, CT-wire disconnection, PT-wire disconnection, etc.

c) Up to 64 fault & action logs, 64 fault wave records, 1024 self-check reports and 1024 COS (Change-of-state) logs

d) The synch interface supports several GPS synchronization modes, including IRIG-B, SNTP, etc., as well as IEEE1588 V2 high-precision net synchronization mode

4) Communication

a) Up to 6 10/100Mbps electronic Ethernet ports, one 1000Mbps electronic Ethernet port and 6 RS-485/RS-232 serial ports are equipped for communicating with DGs and SCADA system. Additionally, it supports IEC60870-5-103, IEC60870-5-104, DNP3.0 and MODBUS (Master and Slave).

b) Up to 8 100Base-FX optical Ethernet ports are equipped for the fast communication with PCSs and supportsIEC`61850-8-1 GOOSE.

c) Hundreds of communication protocols are supported for communicating with subordinate DGs and other intelligent devices. The protocol module is easy and flexible for configuration and extension.

Features of Microgrid Controller

• Based on the mature platform of UAPC, with relay-level reponse speed and reliability,capable of seamless switchover between different microgrid operation modes.

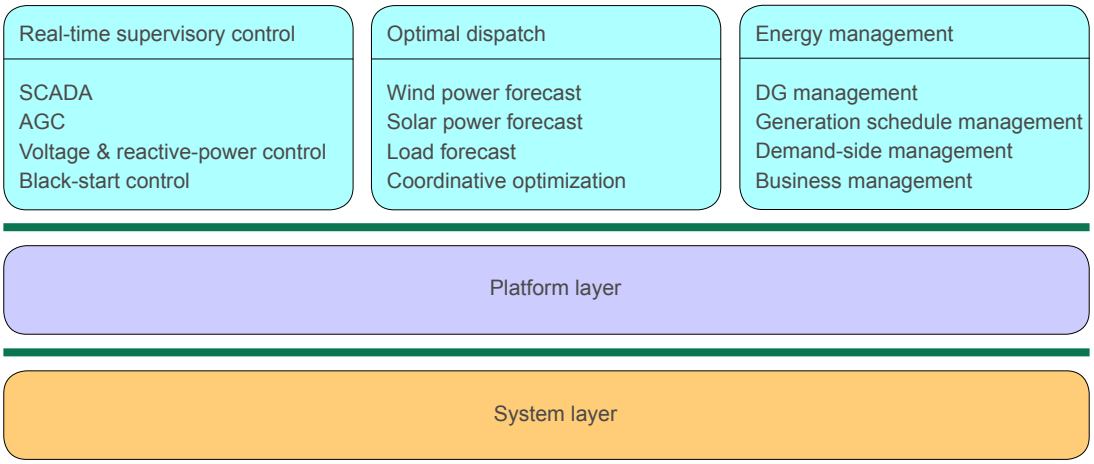
• The control logic can be flexibly configured.

• Sufficient communication ports and protocols are supplied to realize the communication access of converters and inverters of different equipment and different manufacturers.

• The communication card and I/O module can be flexibly and optionally configured to meet the requirements of different microgrid capacities.

2.3 Microgrid energy management system

The microgrid energy management system (MEMS) is a dispatching automation system for the data acquisition, supervisory control, optimization and management of microgrid. The system coordinates and dispatches the microgrid for its efficient, economic, safe and reliable operation. The architecture of MEMS is shown as the following diagram.



The application functions of MEMS include three subsystems:

1) The real-time control subsystem includes the data acquisition & supervisory control (SCADA), automatic generation control (AGC), voltage & reactive-power control, and black-start control.

• The data acquisition & supervisory control is the basis of MEMS. It acquires the data of source, network and load within microgrid and carries out the supervisory control. It also integrates the meteorological data to provide the basis for the optimal dispatching of microgrid.

• The automatic generation control realizes the tie-line active-power control in the grid-connected mode and the frequency control in the islanded mode. It eliminates the negative influence of the output power's uncertainty of renewable energy sources and guarantees the stability of microgrid active-power and frequency.

• The voltage & reactive power control exploits the reactive-power control capability of the control equipment and DGs within microgrid and carries out the coordinated reactive-power control to realize the fast and continuous regulation of microgrid voltage.

• When the microgrid enters into complete black-out condition, the black-start control generally only starts up the micro-sources in microgrid to gradually expand the recovery scope of system for realizing the efficient and stable recovery of microgrid.

2) The optimal dispatching subsystem includes the wind power forecast, solar power forecast, load forecast and coordinative optimization.

• The wind power forecast and solar power forecast predicts the power of wind generation and solar generation respectively. It provides the basic data for the dispatching and decision-making of microgrid for understanding and analyzing the bad influences of the intermittency on the grid.

• The load forecast analyzes the information, such as historical microgrid load, weather, festival & holiday, special event, etc., to dig the law of load variation, establish the forecast model and predict the future variation of system load.

• The coordinative optimization establishes the multi-objective source-net-load optimization model based on the forecasts of DGs, flexible loads and the real time operation condition of microgrid. This helps to carry out the optimal dispatching of the coordination for realizing the implementation and comprehensive utilization of energy sources.

3) The energy management subsystem includes the DG management, generation schedule management, demand-side management and business management.

• The DG management includes managements of safety,operation,equipment and data of DGs and realizes the asset management in their whole lives.

• The generation schedule management lays down the balance of electric power, and arranges the electricity quantity, generator unit on-off and power supply schedules for different DGs according to the overhaul plan.

Meanwhile, the generation schedule management also makes the statistics and checks the execution.

• The demand-side management applies the effective incentive and guiding measure to improve the electricity utilization pattern of microgrid users, increase the electricity utilization efficiency, optimize the resource allocation, protect the environment, and cut down the power-supply service cost.

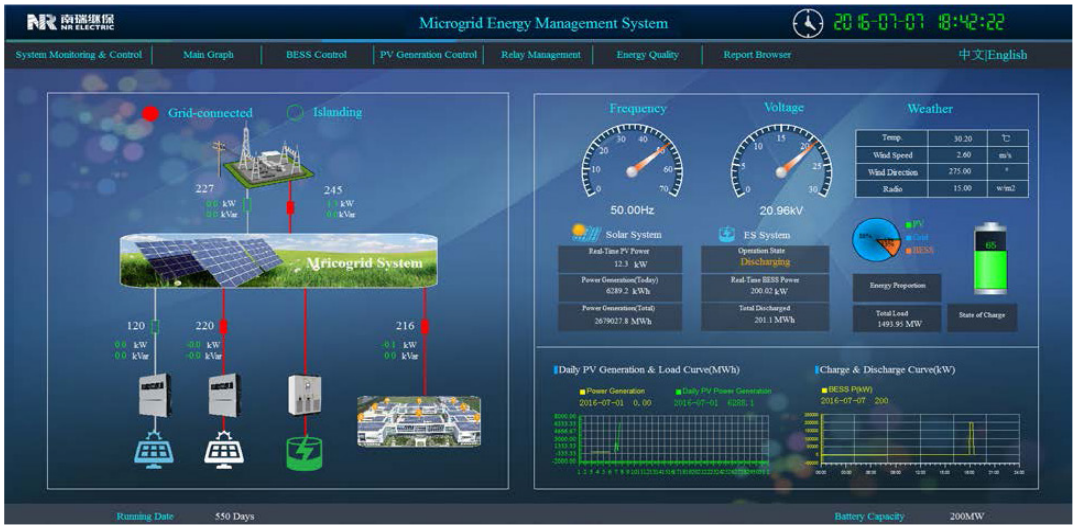
• The business management manages the electricity trade between microgrid and distribution network according to the contracts of microgrid users with the power distribution company and the actual operational conditions of microgrid.

Microgrid EMS Features

• MEMS integrates data of different subsystems seamlessly to provide a unified interface for easy realization of the flexible interaction among different application functions.

• MEMS senses in the real time situation of microgrid and responses quickly to the variation of source, network and load. This ensures the microgrid to be an effective, economic, safe and reliable operating condition at any time.

• There are various built-in DG models in MEMS to support the quick access and participation in the optimal dispatching management for different DG.



2.4 PCS for ESS

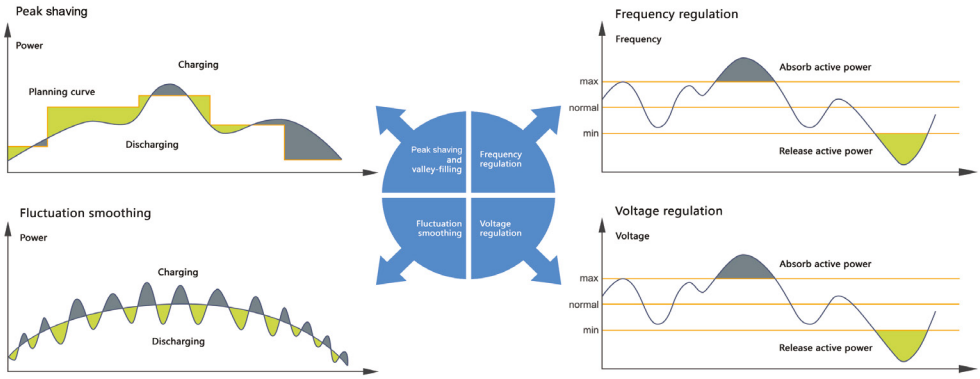
The Power Conversion System (PCS) of ESS has the features of bidirectional power flow and flexible control during much needed situations. The advantages of ESS in microgrid are as follows :

• Peak shaving: Promote the application of renewable energy in microgrid, increase the penetration rate of DG accommodation and lessen the impact on microgrid.

• Frequency & voltage regulation: Participate in the frequency & voltage regulation of microgrid and provide active and reactive-power support, which enhances the stability of microgrid operation.

• Backup power-supply: Maintain the voltage and frequency of microgrid during its outage, which ensures the continuous power-supply for important devices to reduce the economic loss due to the outage.

• Black start: Used as the black-start power source of the islanded microgrid to set up the base voltage and frequency of microgrid to ensure its stable startup.



PCS is the interface between grid and storage system, which can store the electrical energy from grid into the energy storage device as well as release the energy into the grid from the storage.

PCS-9567 PCS supports various operating modes to meet the requirements of different microgrid application scenarios for peak shaving, frequency & voltage regulation, etc. By the mode selection, it can operate in either grid-connected mode or islanded mode. The advanced virtual synchronous generator (VSG) control strategy is applied to realize the fast and seamless switchover between grid-connected mode and islanded mode for avoiding the impact of sudden changed voltage and current due to the operation mode switchover.

• **PQ decoupling mode:** The decoupled control of active and reactive powers in the grid-connection condition, suitable for the peak shaving and the frequency & voltage regulation.

• **VF control mode:**The frequency & voltage control in the islanded condition, suitable for the reliable operation in islanded mode.

• **Droop control mode:** It has active power-frequency and reactive power-voltage droop controls, suitable for frequency & voltage regulation.

• **VSG mode:** Simulate the external characteristic of synchronous generator, suitable for the seamless switchover between grid-connected mode and islanded mode.

• **Black start mode:** Establish and stabilize the grid voltage and frequency, suitable for the black-start application in the islanded condition.

Features of PCS-9567 series PCS:

1) As the core part of energy storage system, the Power Conversion System (PCS) is developed based on high-performance and highly-reliable UAPC platform with features of dual-DSP design, independent management CPU, reliable protection and control functions, powerful communication, advanced event management and information storage, perfect fault recording, etc.

2) Support multiple isolated channels for binary and analog inputs including battery communication interfaces, such as CAN, net port, optical port, serial port, etc.

3) Support various communication protocols, such as CAN, MODBUS, IEC103, IEC61850, etc.

4) Meet the requirement of the fast response at ms-level and realize the flexible dispatching in the microgrid.

5) High safety and reliability realized based on modular and integrative system design with highest conversion efficiency up to more than 98.7%.

6) The product has been certified by UL and TUV.

7) The excellent high voltage and low voltage ride-through (LVRT) performance and better frequency adaptability provide the frequency and voltage supports to ensure the stable operation of microgrid.

2.5 Microgrid Protection

PCS-9600 series microgrid protective IEDs have the following advantages:

• High-performance CPU and DSP with reliable internal high-speed communication bus is adopted for reliably realizing outstanding functions.
• The modular designed board hardware is flexibly-configurable, very universal and easy to expand and maintain.
• Duplex design and duplicated sampling is applied for enhanced data collection reliability.
• The startup DSP and protection DSP are completely independent of each other to guarantee the reliability of protection actions.
• Easy to maintain and operate.
• Long equipment platform lifetime.
• The visual programming and commissioning software adopts the visualized, modularized, hierarchical and object-oriented programming mode.
• Support self-adaptation of protection settings for both grid-connected and islanded modes.

NR can supply whole series of protection devices for microgrid

3 Microgrid References

- The microgrid protection and control system of Yunnan science park
- The microgrid protection and monitoring system of Island Dawanshan
- The microgrid protection and monitoring system of Island Guishan
- The microgrid protection and monitoring system of Island Dong'ao
- The microgrid protection and monitoring system of Gonghe, CGNPC
- The protection and control system of Dynamic simulation microgrid, Zhejiang EPRI
- The protection and control system of the Changchun Institute of Technology
- The microgrid protection system of Yanqing, Beijing
- The microgrid project of Jiaze, Ningxia
- The PV-storage microgrid of Jiangning intelligent industrial park in Nanjing city
- The India's first 500kW Li-ion and 500kW Lead Acid Battery Energy Storage System of Power Grid Corporation of India
- The AC/DC hybrid-type microgrd turnkey project of State Power Economic Research Institute, Beijing city of China
- The PV&BESS microgrd turnkey project in Mozambique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PV GRID-CONNECTED INVERTER
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