

Sendai Microgrid

- Introduction and Use Case

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Outline

■ Today's topic - Sendai Microgrid

- Constructed for the purpose of demonstration project
- Still in operation after finishing demonstration project
- Has two aspects
 - MPQM (Multiple Power Quality Microgrid)
 - Microgrid which supplies electricity in islanded mode – “Earthquake”

■ Contents

- Introduction of Sendai Microgrid
- Use Case
 - What is MPQM, and how it works
- Change in configuration after the demonstration project
- Earthquake experience of Sendai Microgrid
 - To be presented by Dr. Hirose after this presentation

By Me

By
Dr. Hirose

Sendai Microgrid Overview

Sendai Microgrid

- Constructed as a 4-year demonstration project (FY 2004 – 2007)
- Entrusted by NEDO
- Technical feature = MPQM (Multiple Power Quality Microgrid)
 - Desired power quality varies by customer in the Microgrid.
 - MPQM enables power supply with different levels of power quality for each customer within the area.



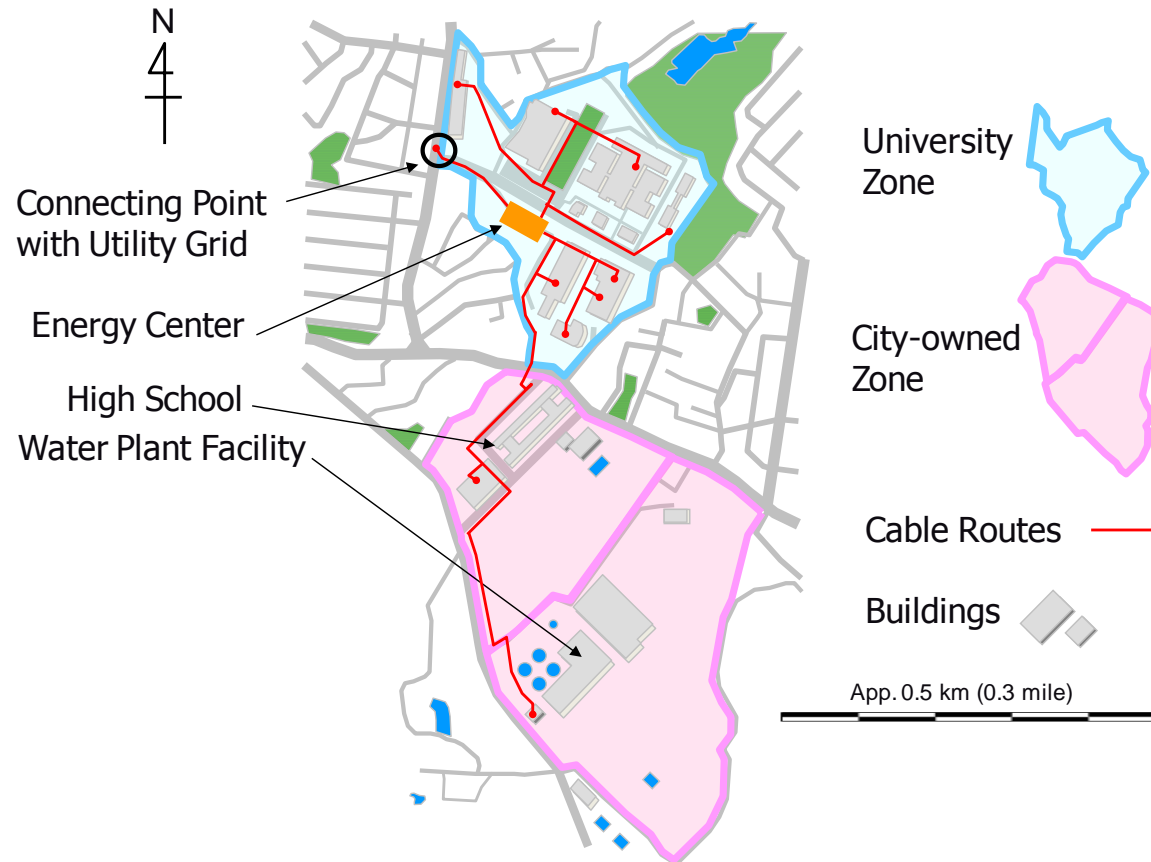
Overview of Sendai Microgrid



Geographical location of Sendai City

Coverage Area

- One connecting point (PCC) with Utility Grid
- Divided into 2 areas:
 - University area
 - City-owned area



Power Quality Definition and the Loads

■ Different classes of power quality

- In the Sendai Microgrid, five classes of power quality (DC Supply, A, B1, B2 & B3) have been defined according to each consumer's needs.

Requirements	CLASS				
	DC Power	AC Power			
		A	B1	B2	B3
<i>Interruption</i>	NI	NI	< 15 ms	< 15 ms	< 15 ms
<i>Voltage Dip</i>	Y	Y	Y	Y	Y
<i>Outage</i>	Y	Y	Y	Y*	-
<i>Voltage Fluctuations</i>	Y	Y	-	-	-
<i>Voltage Harmonics</i>	Y	Y	-	-	-
<i>Voltage Unbalance</i>	N/A	Y	-	-	-
<i>Frequency Variation</i>	N/A	Y	-	-	-

Note. NI: No Interruption, Y: With compensation--: Without compensation,
*: When Gas engine sets generated

CLASS	Capacity	Consumers (Load)
A	200 kVA	Clinic (MRIs) Laboratory (servers)
B1	20 kVA	Nursing Care Facilities (lighting, PCs)
B2	600 kVA	High School (lighting, PCs, elevators) Water plant (induction motors)
B3	200 kVA	Nursing Care Facilities (lighting, clinic equipment)
DC	20 kW	Energy Center (servers, lighting, fans)
Normal	N/A	Nursing Care Facilities Training Center Dormitories

Power quality classes of the Sendai Microgrid

Power quality classes and Loads

System Configuration

■ Generation Facility

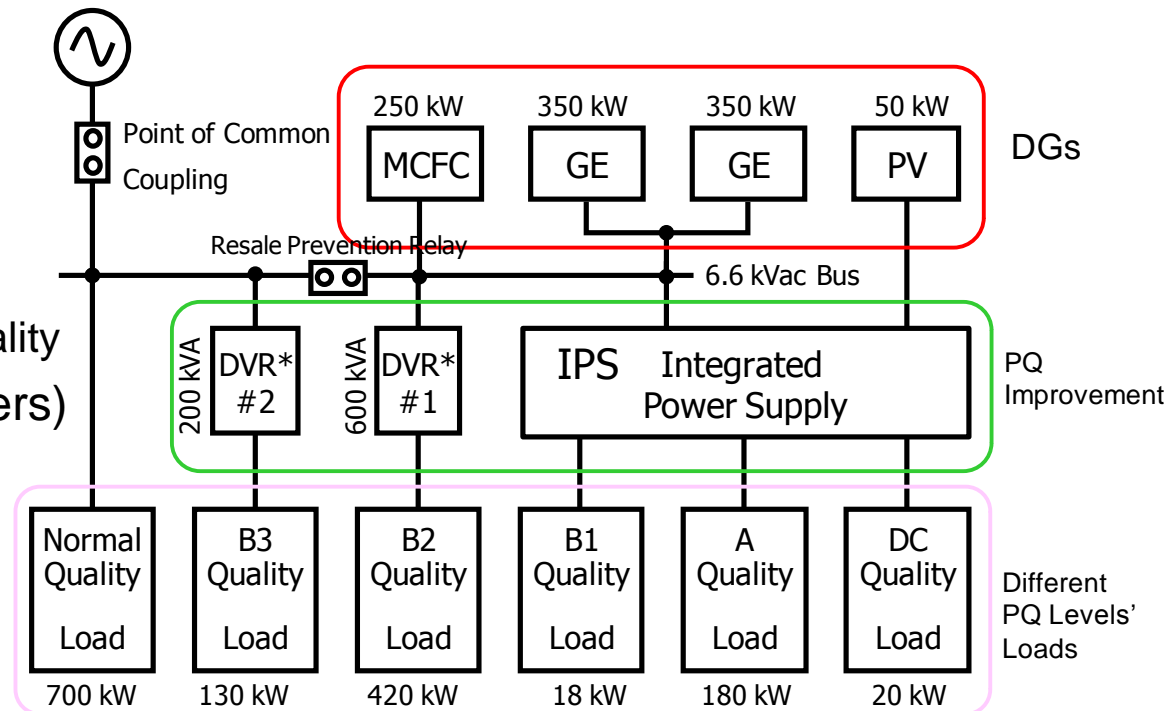
- Integrates generation facilities in coordination with power from area EPS
- Generation Facilities inside the Microgrid
 - Two Gas Engines (350kW × 2)
 - Photovoltaic Generation (50kW)
 - Fuel Cell (250kW)

■ Key Energy Devices

- IPS (Integrated Power Supply)
 - Provides the highest level of quality
- DVR (Dynamic Voltage Restorers)
 - Compensates Voltage Dip

■ 2 Switches

- Point of Common Coupling
- Resale Prevention Relay
- Manages islanding operation of the Microgrid by changing the switch status to Open or Close in the event of power outage/recovery.



Configuration of Sendai Microgrid

Use Case

- What is MPQM and
How it works

Definition of MPQM and Model Simplification

■ Definition

- . The Multi Power Quality Microgrid (MPQM) enables the supply of power to critical loads at multiple levels of power quality at higher levels than are supplied normally by the distribution utility.
- The Microgrid does this by utilizing Distributed Energy Resources (DER) and power from the distribution utility (grid) in a mutually complementary manner

■ Functions

- The MPQM can continue to supply power at a high power quality level, when grid connected, when the DER is grid-connected, or when the grid suffers from an outage and the DER is in an islanding operation mode.

■ Simplified Model MPQM”:

- Focuses on the functionality of “Multiple Power Quality Supply”
- Describes the supply of three classes of power quality, as follows:

Class	Voltage Dip Compensation	Waveform Compensation	Power-failure Compensation
A-Class	Compensation by IPS	Compensation of waveform.	In case of power outage in grid: DER shifts to islanding operation. In case of power outage of DER: Power continues to be supplied from the UPS (battery) embedded in the IPS.
B-Class	Compensation by DVR	No waveform compensation	In case of power outage in grid: DER shifts to islanding operation. In case of power outage of DER: No compensation for outage.
Normal Class	No voltage dip compensation	No waveform compensation	No compensation or back up for outage.

Configuration of the Simplified Model

■ Simplified Configuration

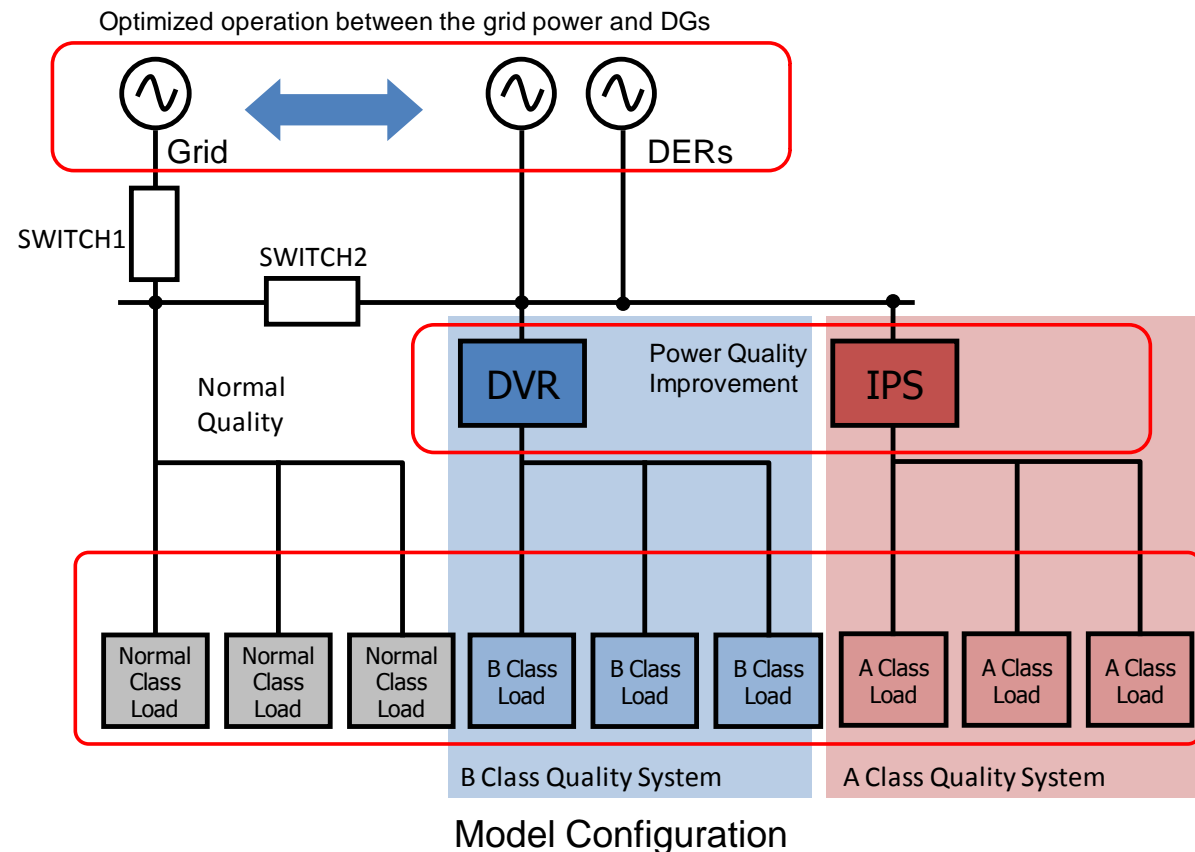
- The below diagram shows a configuration of the Microgrid offering three classes of power quality shown in the previous page.

■ Generation Facility

- Microgrid has DERs
- Two operational modes
 - Grid Connection Mode
 - Islanding Mode

■ Two Switches

- Switch 1
 - PCC between MPQM and commercial grid
- Switch 2
 - Boundary point of the microgrid's Islanding Operation



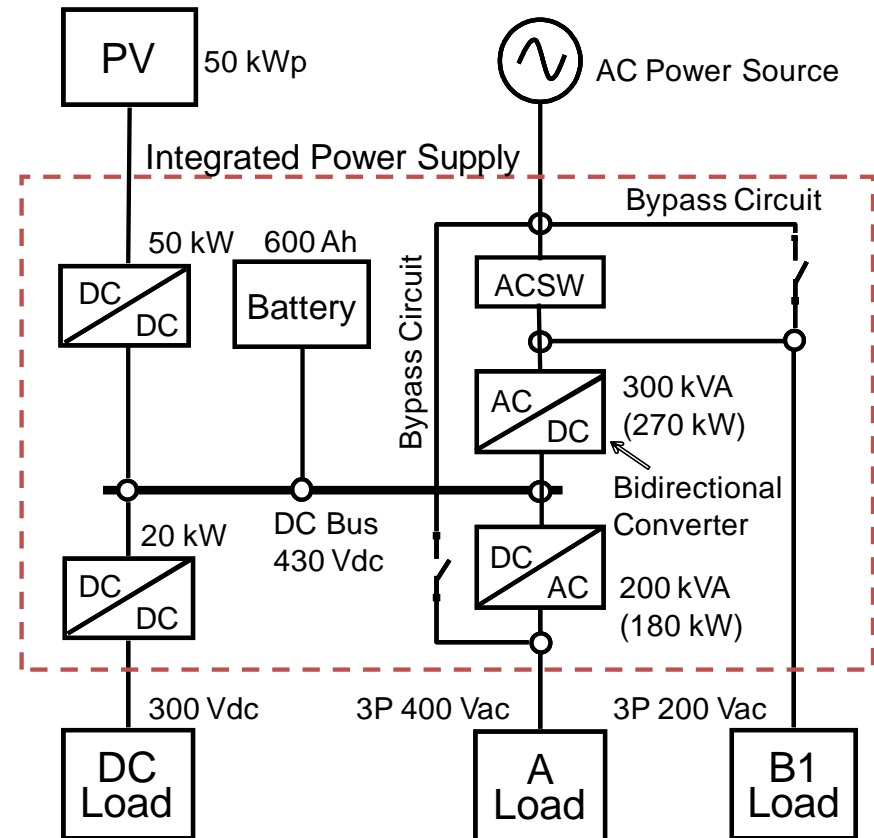
Configuration of the Simplified Model (Cont.)

■ IPS

- Able to supply A-Class
- Power quality compensation system with battery storage
- Three operational modes:
 - Grid-Connection Mode
 - DER-Islanding Mode
 - Battery-Supply Mode

■ DVR

- Able to supply B-Class
- Compensates Voltage dip
- Implemented in STATCOM

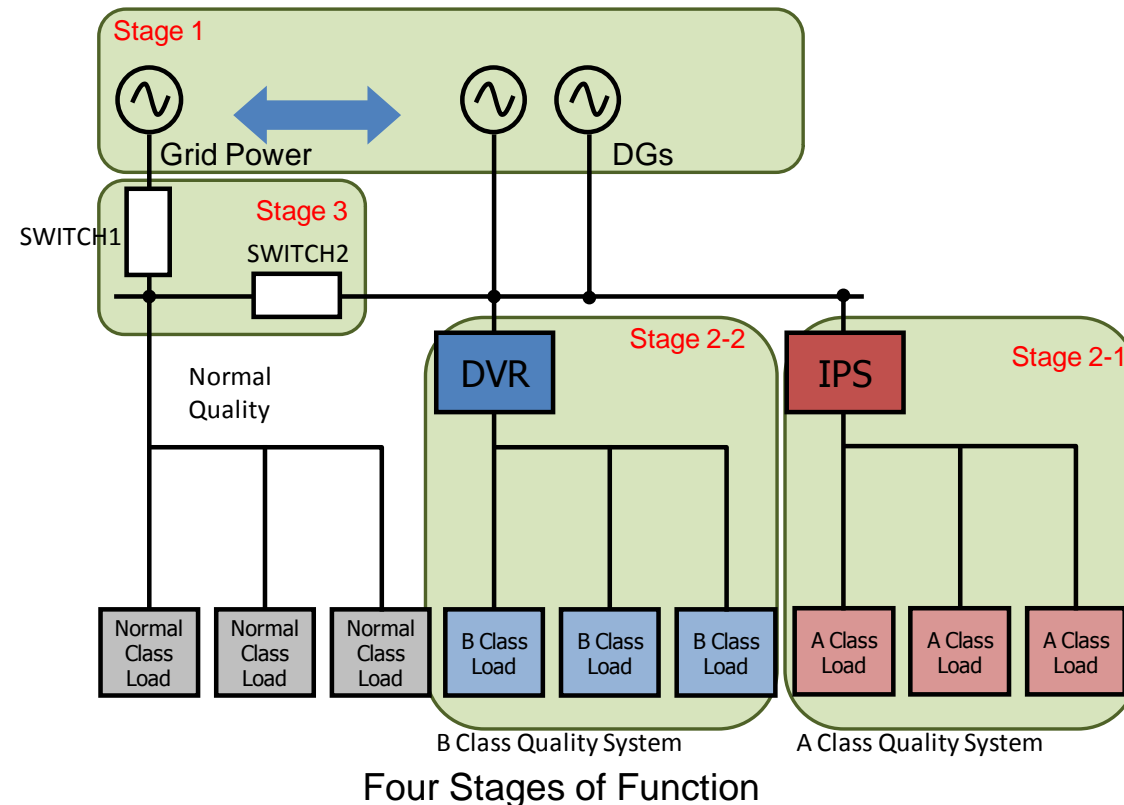


IPS System used in Sendai Microgrid

MPQM's Behavior – Four Stages

■ Four Stages Comprising MPQM's Behavior

- Stage 1: Demand and generation forecast, generation scheduling and on-the-day review
 - Develop generation schedule of the Microgrid
 - Monitor supply-demand status
- Stage 2-1: A-CLASS POWER QUALITY SUPPLY
 - Supply A-Class loads with A-Class quality of power.
- Stage 2-2: B-CLASS POWER QUALITY SUPPLY
 - Supply B-Class loads with B-Class quality of power.
- Stage 3: Automatic shift to connected operation at grid restoration
 - Manage the grid's outage/restoration with two switches



Stage 1:

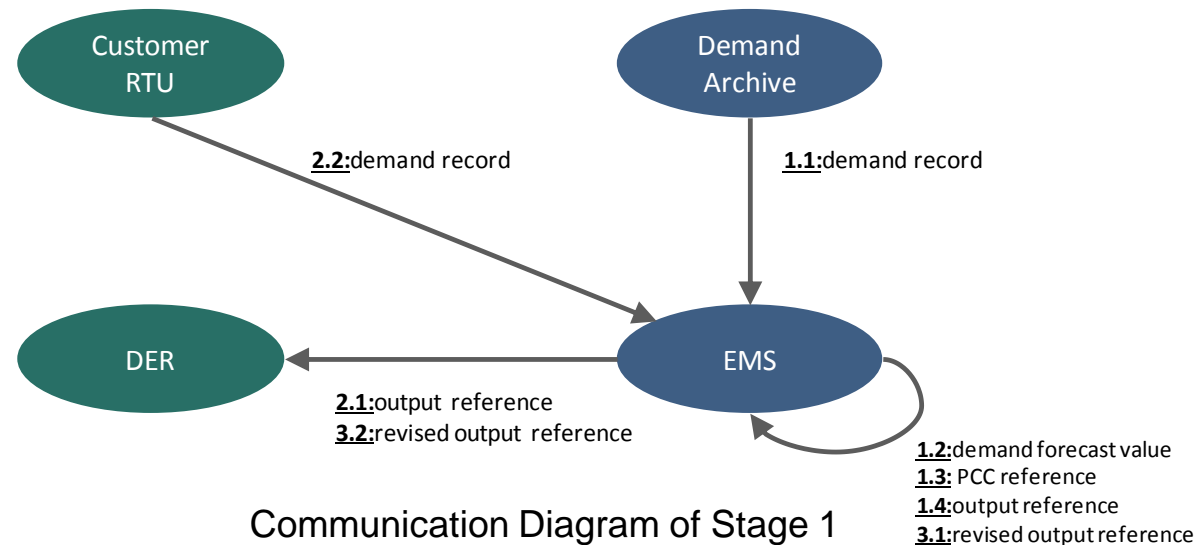
Demand and generation forecast, generation scheduling and on-the-day review

■ Precondition

- Reverse flow from MPQM to Grid is prohibited according to the grid connection agreement between MPQM owner/operator and the electric utilities.
- Therefore, it is required for the Microgrid to set a target for the power flow at the PCC and incorporate it into the operational plan of DER.

■ Flow of DER Dispatch

- Flow1: Development of generation schedule
 - Develop generation schedule based on the past demand data, demand forecast and PCC flow target value.
- Flow2: Command and monitoring
 - Send commands to DER and also monitor demand data
- Flow3: Correction of discrepancy
 - Change the planned value in case there is a discrepancy between supply & demand.



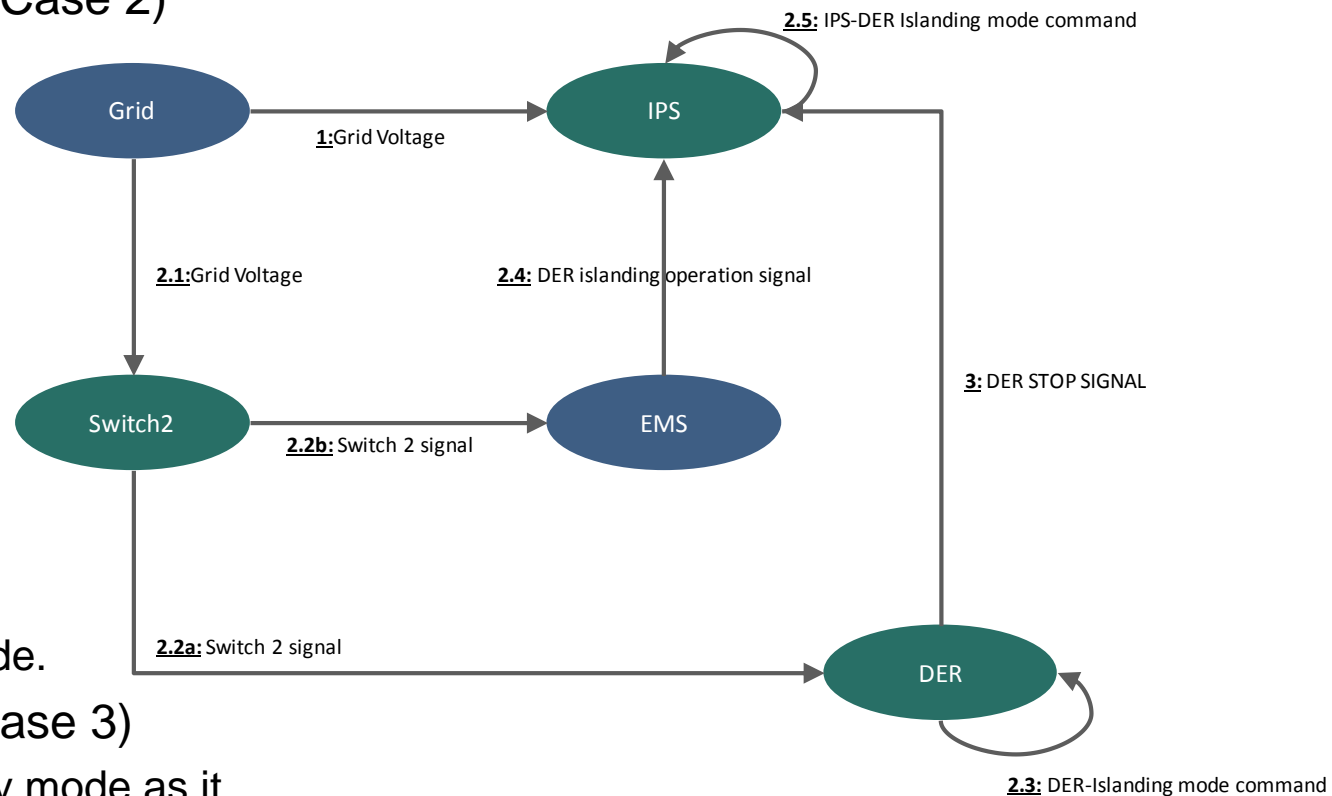
Communication Diagram of Stage 1

Stage 2-1 : A-CLASS POWER QUALITY SUPPLY

- In the Event of Instantaneous Voltage Dip (Case 1)
 - IPS shifts into Battery-Supply Mode as it detects an occurrence of instantaneous voltage dip from the grid voltage.

■ In the event of grid outage (Case 2)

- Switch 2 automatically opens as it detects an outage.
- DER shifts to Islanding mode as it detects the opening of Switch 2.
- EMS sends IPS a command to shift to Islanding mode as it detects the opening of Switch 2.
- IPS shifts into Islanding mode.



Communication Diagram of Stage 2-1

- In the event of DER stop (Case 3)
 - IPS shifts into battery supply mode as it detects the stop of DER.

Stage 2-2: B-CLASS POWER QUALITY SUPPLY

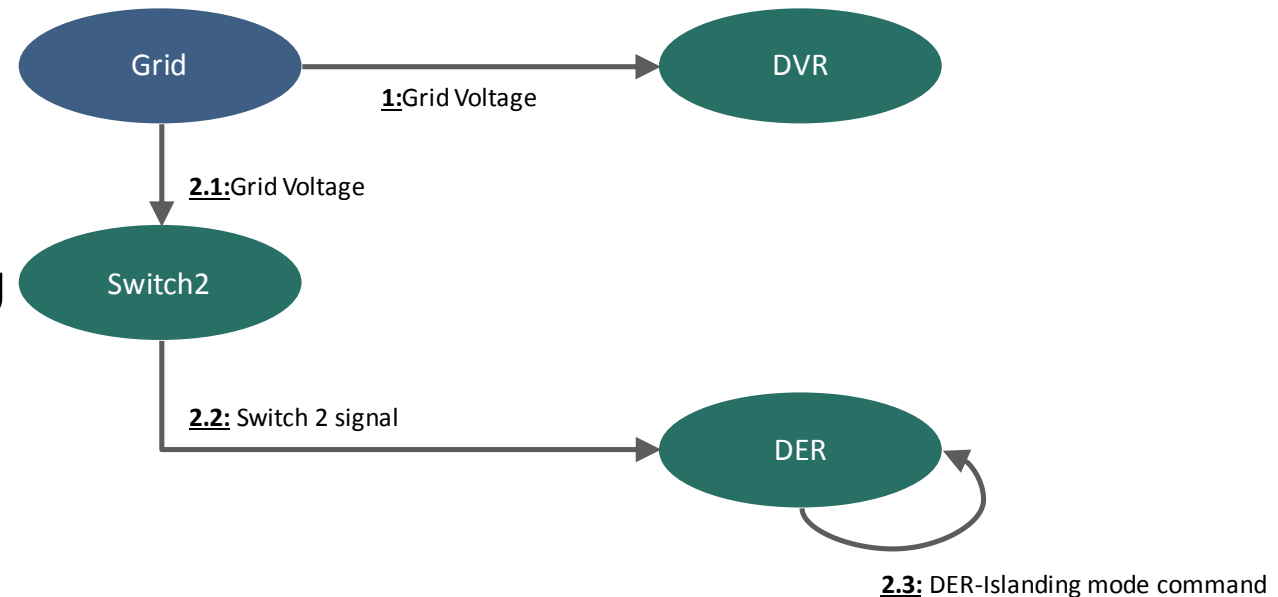
- B-Class power quality cannot be supplied when DER is no longer available.

- In the event of Instantaneous Voltage Dip (Case 1)

- DVR compensates the voltage as it detects an occurrence of instantaneous voltage dip from the grid voltage.

- In the event of grid outage (Case 2)

- Switch 2 automatically opens as it detects an outage
- DER shifts to Islanding mode as it detects the opening of Switch 2.



Communication Diagram of Stage 2-2

Stage 3:

Automatic shift to connected operation at grid restoration

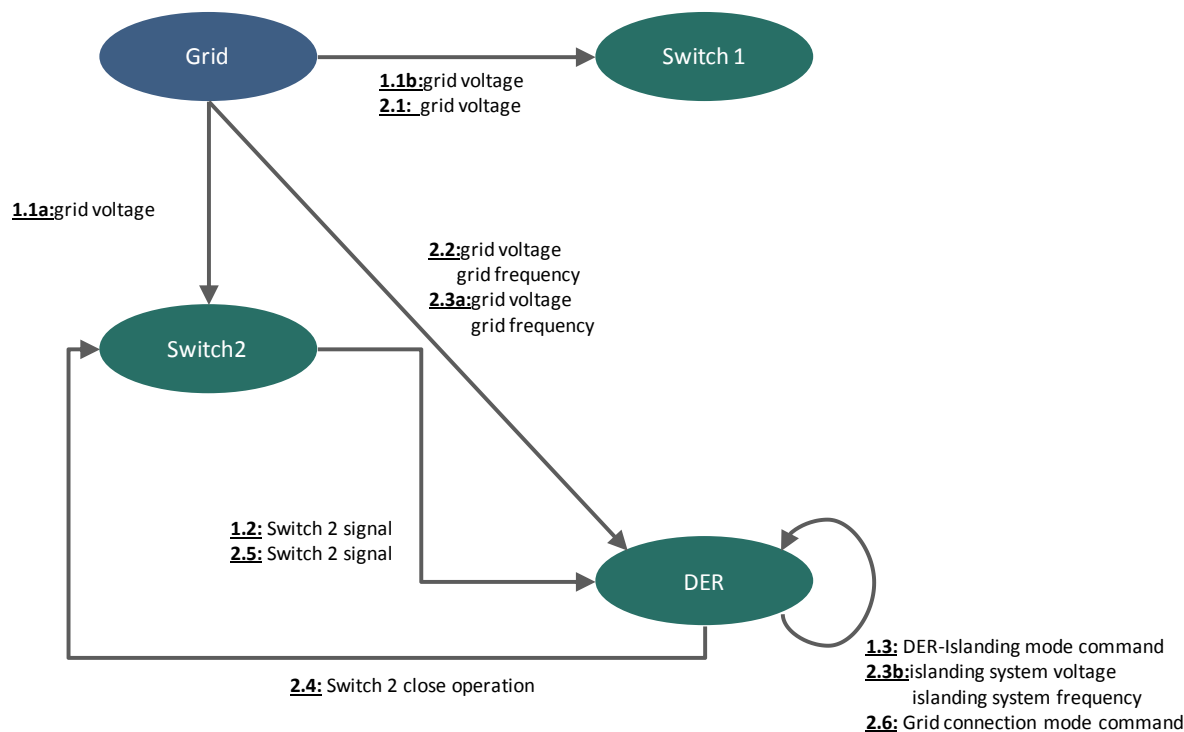
- Microgrid automatically shifts to islanding operation at time of grid outage.
- Microgrid automatically shifts to grid connected operation at time of grid restoration.

■ At time of grid outage (Case 1)

- Switch 2 opens as it immediately detects an outage from the grid voltage information.
- Simultaneously, Switch 1 opens.
- DER shifts to Islanding mode as it detects the opening of Switch 2.

■ At time of grid restoration (Case 2)

- Switch 1 closes as it detects power restoration from the grid voltage information.
- DER synchronizes the voltage and frequency of the islanding system with the grid's voltage and frequency.
- DER closes Switch 2 as soon as it detects the synchronization.

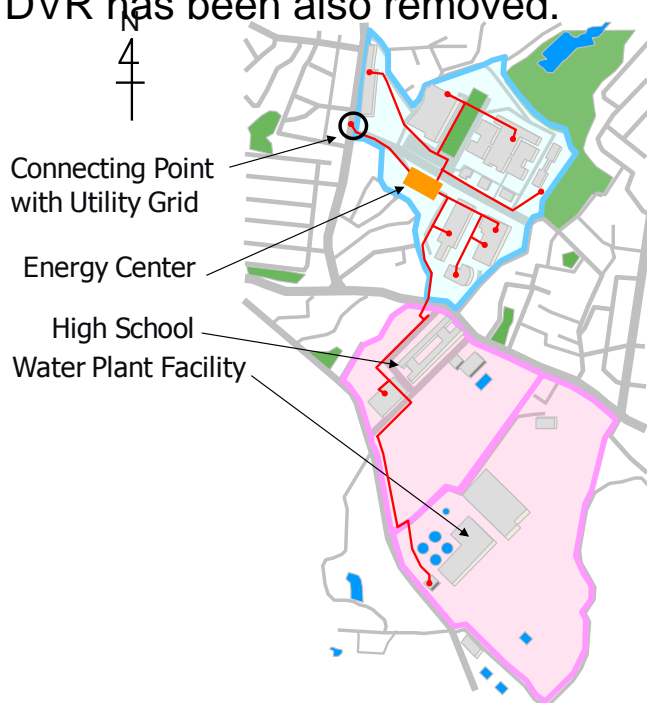


Communication Diagram of Stage 3

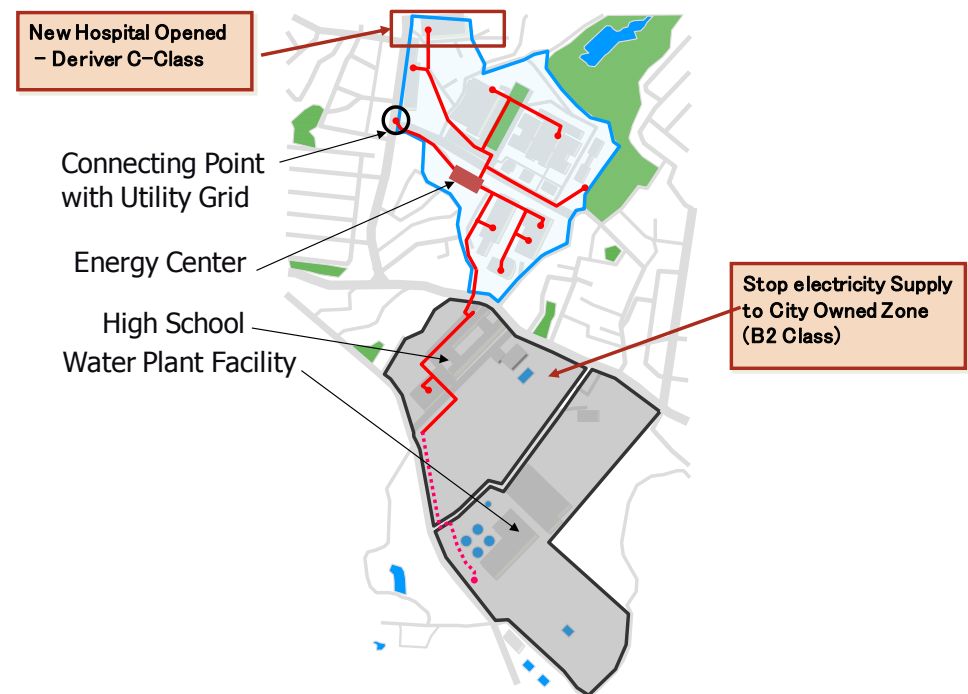
Configuration Update After the Demonstration (Introduction to Hirose-san's Presentation)

Coverage Area of Sendai Microgrid after the Demonstration

- Coverage area and configuration of the Sendai Microgrid changed during and after the demonstration project.
 - GE is now also used for emergency power generation, starting to supply the C-Class power to emergency system in (newly-built) hospitals.
 - Fuel Cell (MCFC) has been removed.
 - Supply of B2-Class (Sendai High School Water Plant Facility) has been finished.
 - DVR has been also removed.



Coverage Area **During** Demonstration

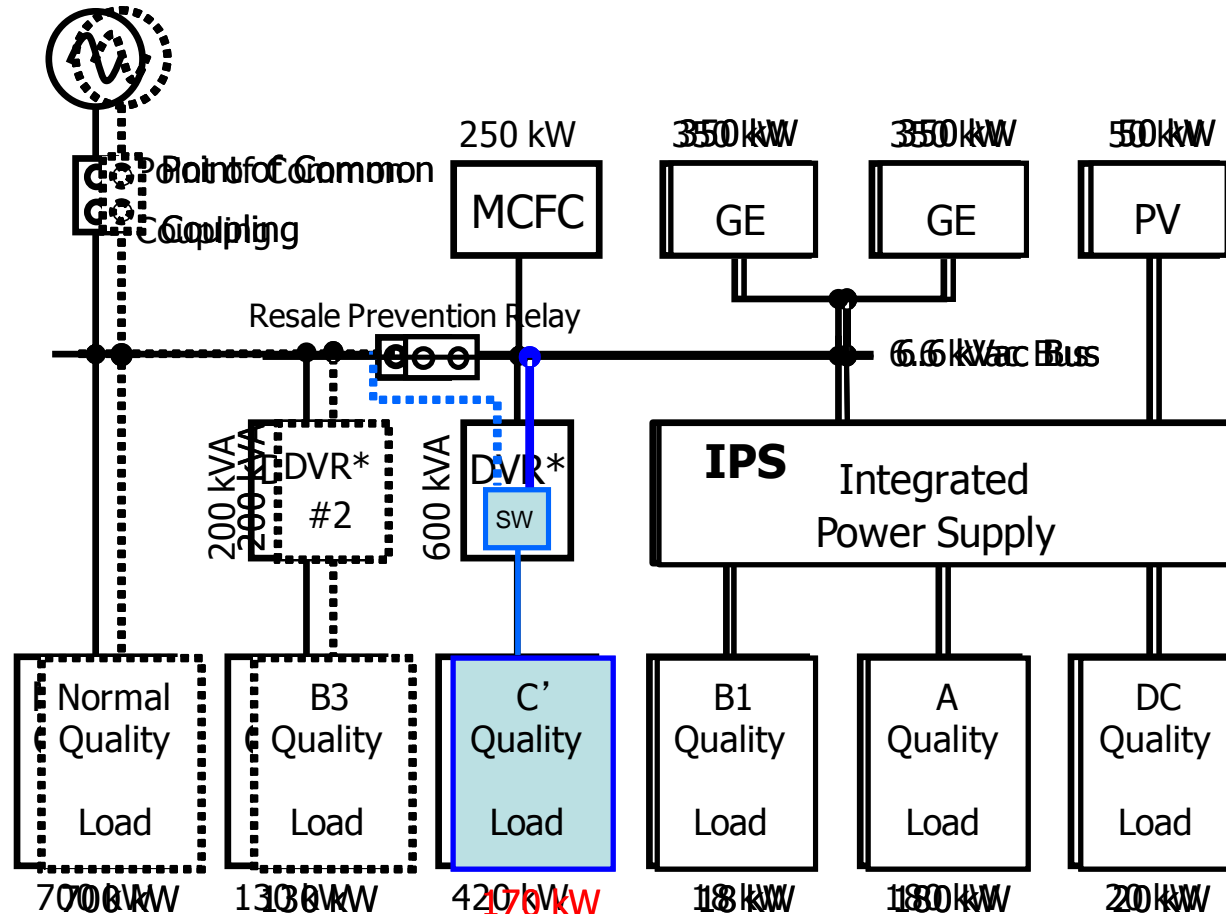


Coverage Area **After** Demonstration

Changes in Configuration

■ Configuration **after** the demonstration project

- There is more B2-Class load.
- C'-Class load (supply to new hospital) has been added, instead.



Thank you for your attention!
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