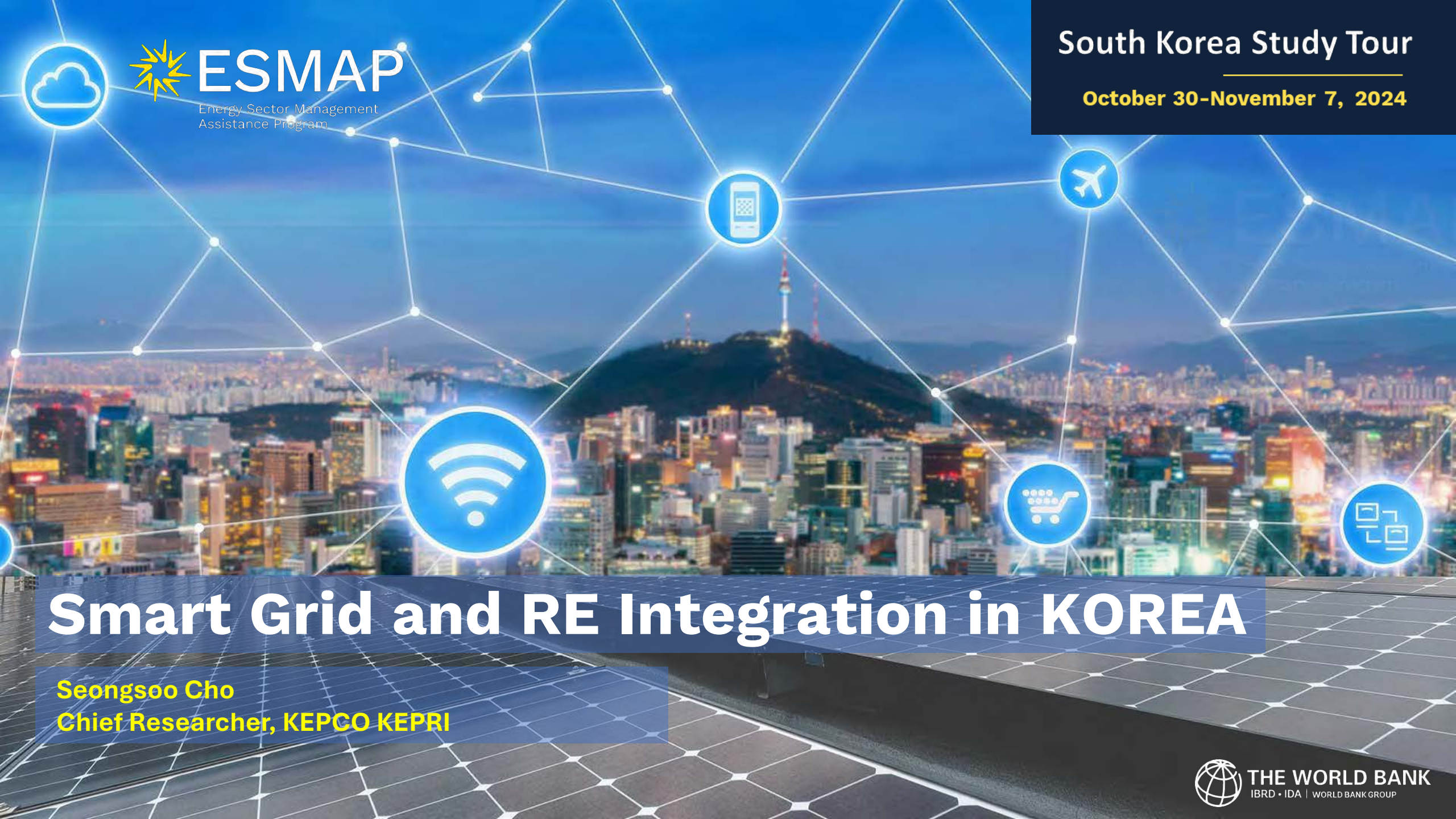

ESMAP
Energy Sector Management Assistance Program

South Korea Study Tour

October 30-November 7, 2024

Smart Grid and RE Integration in KOREA

Seongsoo Cho
Chief Researcher, KEPCO KEPRI

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2. RE Integration
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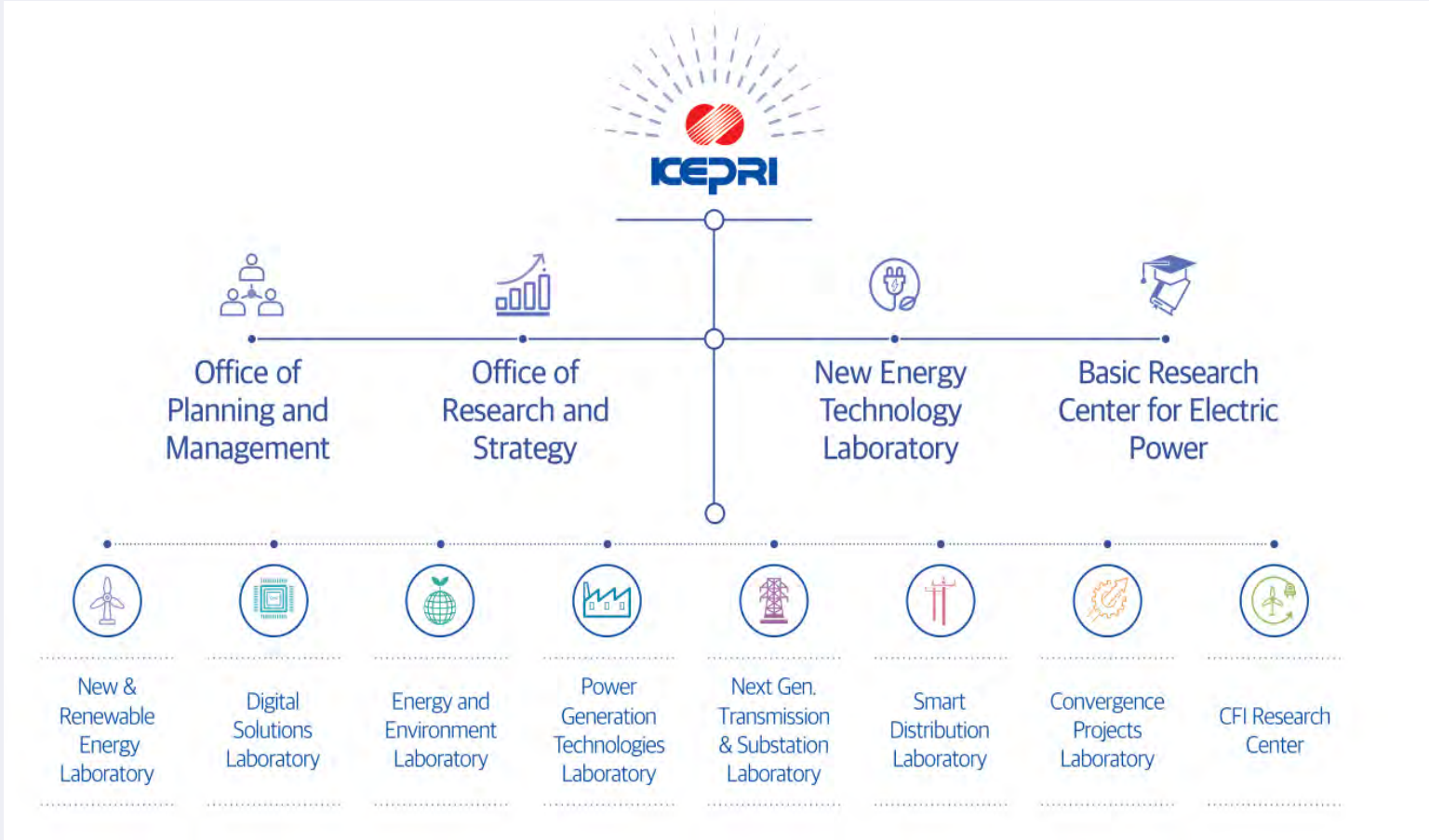
1. Introduction

* KEPRI = KEPCO Research Institute

Organization



Role

Personnel

(단위 : 명)

구분	Research Personnel						Support Personnel						Total
	Research		Exchange		Subtotal		General		Skill/Special		Subtotal		
Quota	508	73%	68	10%	576	83%	79	12%	36.63	5%	115.63	17%	691.63
Current personnel	496	72%	71	10%	567	82%	92	13%	34.63	5%	126.63	18%	693.63

※ Decimal: Short-term workers (in the cafeteria)

1. Introduction

Role of KEPCO for Carbon Neutrality Era

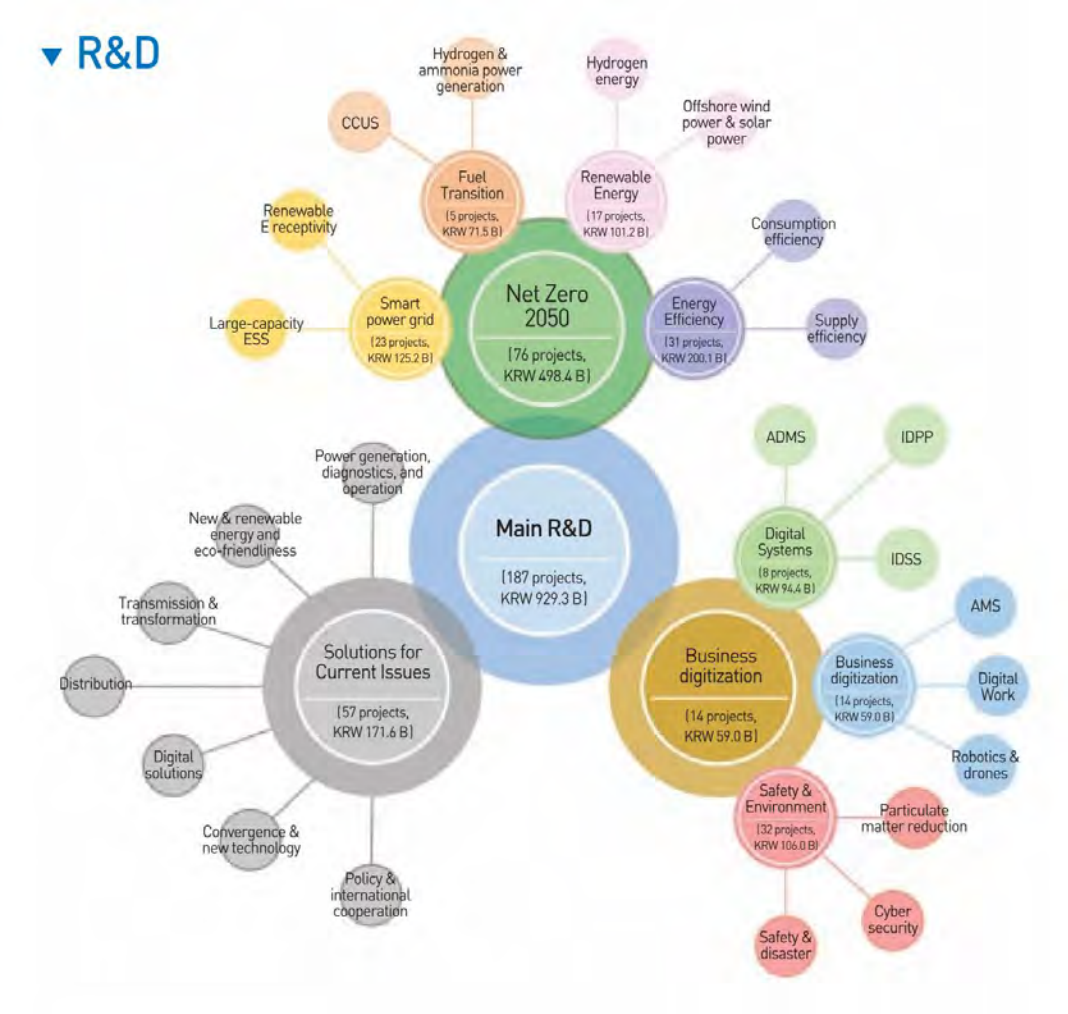
Leading the transition sector decarbonization

- Preemptive transmission and distribution network construction
- Leading the R&D to achieve carbon neutrality
- Promoting energy consumption efficiency and developing new business platforms
- Leading the decentralization with the “Special Act on the Promotion of Distributed Energy”
- Rational improvement of market system
- Establishing a reasonable cost sharing-system

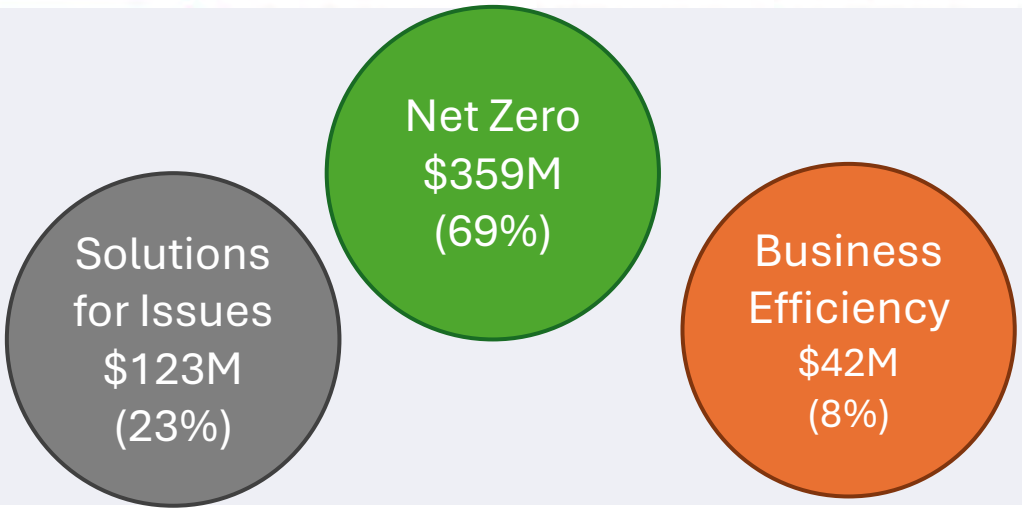
ⓘ Reference: KEPCO homepage , https://home.kepco.co.kr/

1. Introduction

R&D Portfolio



Lead Net-Zero Efforts	1. Energy Efficiency	1-1. Supply Efficiency	1-2. Consumption Efficiency
	2. Renewable Energy	2-1. Wind Power and Solar Power	2-2. Hydrogen Production, Storage, and Utilization
	3. Fuel Transition	3-1. Hydrogen and Ammonia Power Generation	3-2. CCUS
	4. Smart Grid	4-1. Renewable Energy Receptivity	4-2. Large-Capacity ESS
Improve Management Efficiency	5. Digital Systems	5-1. IDPP	5-2. IDSS	5-3. ADMS
	6. Business Digitization	6-1. AMS	6-2. Digital Work	6-3. Robotics and Drones
	7. Safety and Environment	7-1. Safety and Disaster	7-2. Cyber Security	7-3. Particulate Matter Reduction
Resolve Current Issues	8. Current Issues	8-1. Power Generation, Diagnosis, Operation	8-2. New and Renewable Energy and Eco-Friendliness	8-1. Transmission and Transformation
		8-4. Distribution	8-5. Digital Solutions	8-6. Convergence and New Technology



2. RE Integration

Korea's renewables energy policy goals

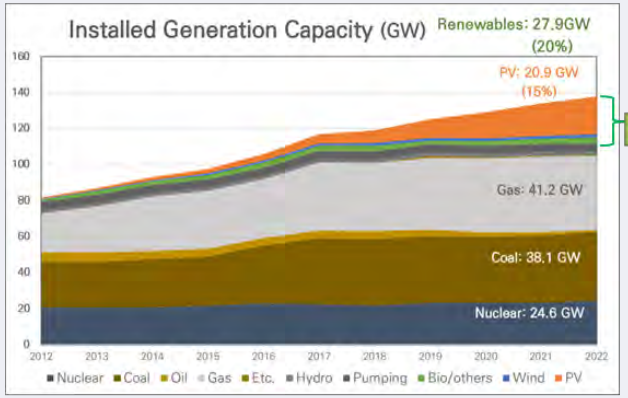
- Energy Transition & 2050 Carbon Neutrality Policy
- Share of renewables in generation: 7.6% (2019) → 20% (2030) → 30~35% (2040) → 60~70% (2050)

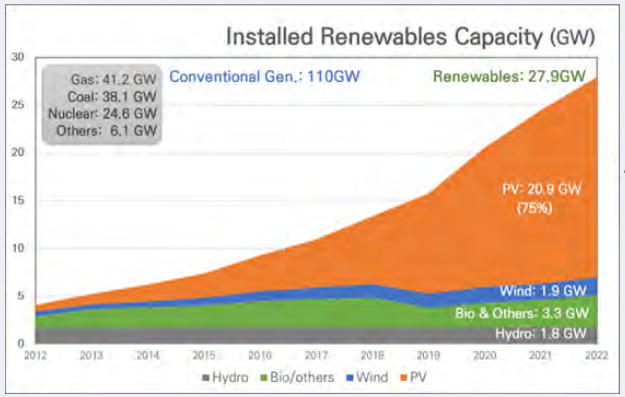
Policy	Target yrs.	Share of renewables in generation	Installation Capacity of renewables	Remark
RE 3020	2030	20.8%	58GW	PV: 34GW Wind : 18GW
9th National Plan	2034	26.1%	78GW	PV: 46GW Wind : 24GW
NDC Revision	2030	30.2%	–	
10th National Plan	2030	21.5%	72.7GW	
2050 Carbon Neutrality	2050	Plan A: 70.8% Plan B: 60.9%	–	A: completely phasing out fossil fuel power generation B: retaining some LNG power plants and actively utilizing CCUS

2. RE Integration

Korea's renewables efforts predominantly focused on solar power

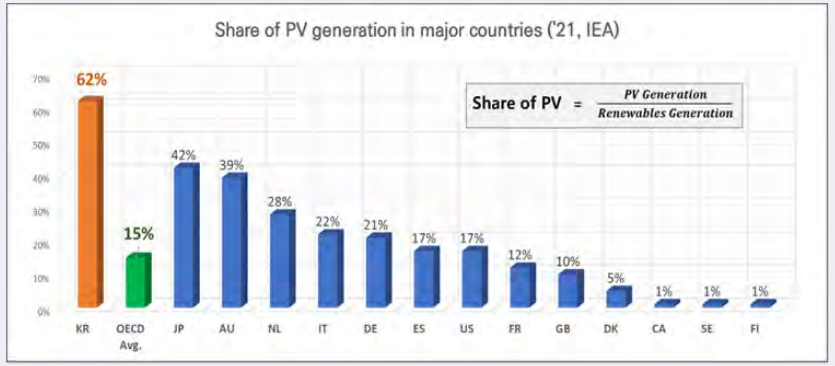
- 15% of generation capacity (20.9GW/137.9GW), 75% of renewables (20.9GW/27.9GW)
- 94% of distribution system (LV 63%, MV 31%), 6% of transmission system

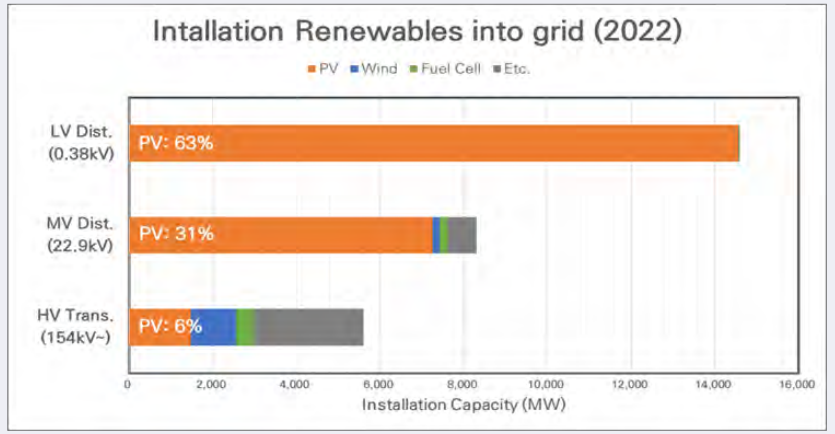




Renewables 20%
(27.9/137.9GW)
PV 15%
(20.9/137.9GW)

PV 75%
(20.9/27.9GW)

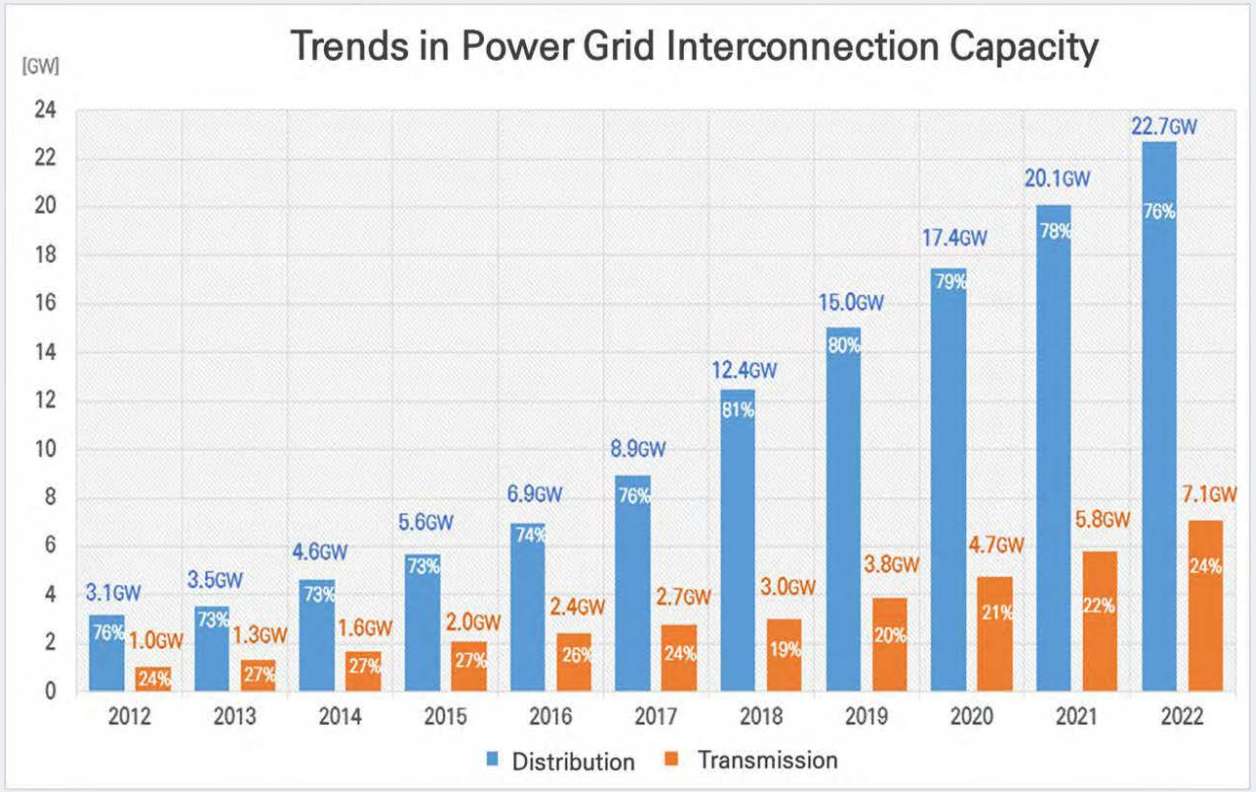


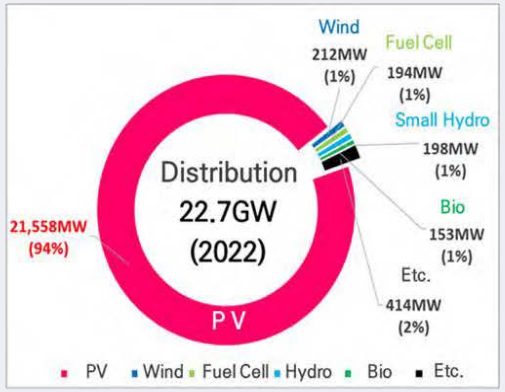


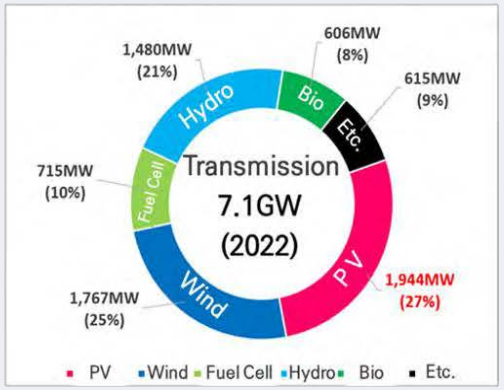
2. RE Integration

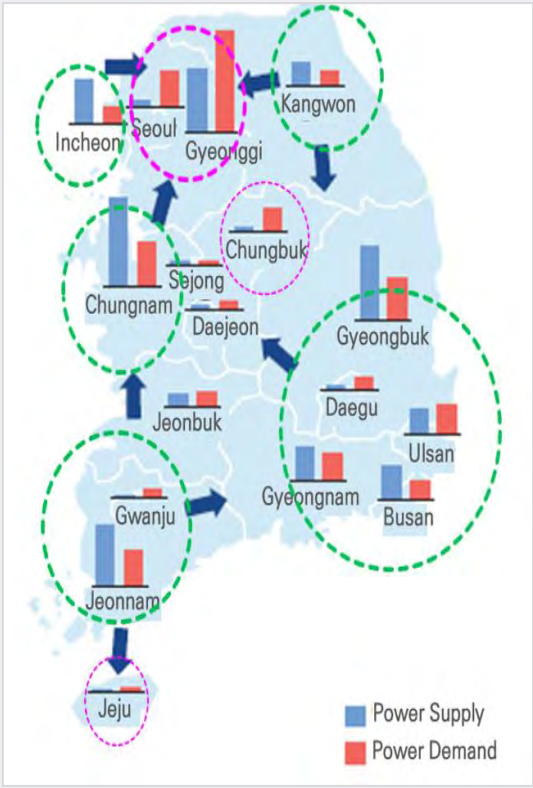
Guaranteed grid access by policy for renewable energies under 1MW (2016–2024)

- Power utility bears the cost of grid reinforcement for grid interconnection (financial burden).
- Promote local production and consumption to avoid the construction of power plant & transmission grid









3. Grid Issues

Grid Issues from the rapid increase of RE integration

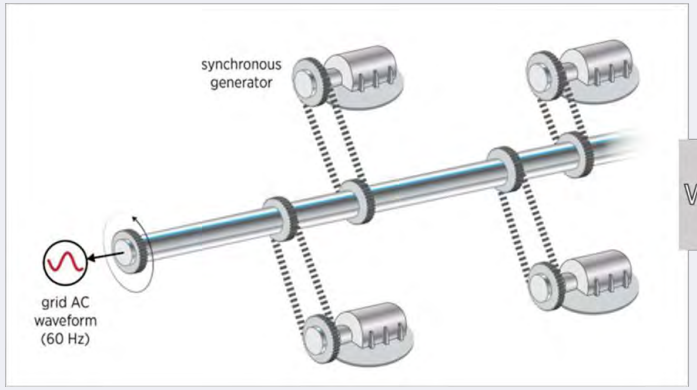
- **Grid Stability Issues** (Mainly Transmission Systems)
  - Frequency Instability ← Increase grid inertia : Launching 700MWs FSC(Flywheel Synchronous Condenser) and GFM(Grid Forming) Inverter demonstration R&D project in Jeju-island
  - Power Demand & Generation Imbalance ← Power Curtailment : On going projects to install RE control infrastructures and monitoring systems (RMS + LRMS + ADMS) with RE output forecasting
- **Voltage Quality Issues** (Mainly Distribution Systems)
  - Over-voltage at PCC (Point of Common Coupling) ← Reactive Power Control by Smart Inverter
- **RE Interconnection Delay** (Both)
  - Lack of power facilities for grid connection ← Introduction of Flexible Interconnection (flexible curtail.)
- **RE Monitoring & Control Issues** (Mainly Distribution Systems)
  - Cyber Security Policy : Require physical separation from the each communication network
  - Small Scale REs (under 100kW) are not required by law or regulation to install monitoring devices

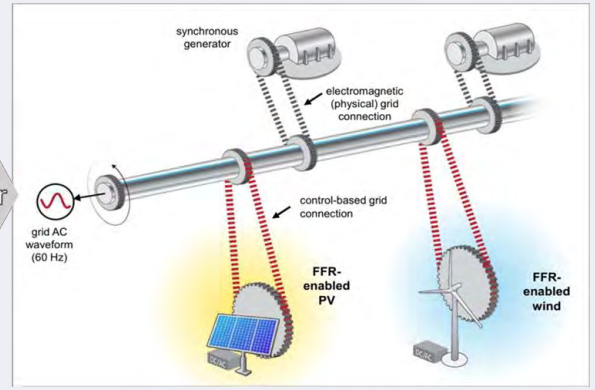
3. Grid Issues

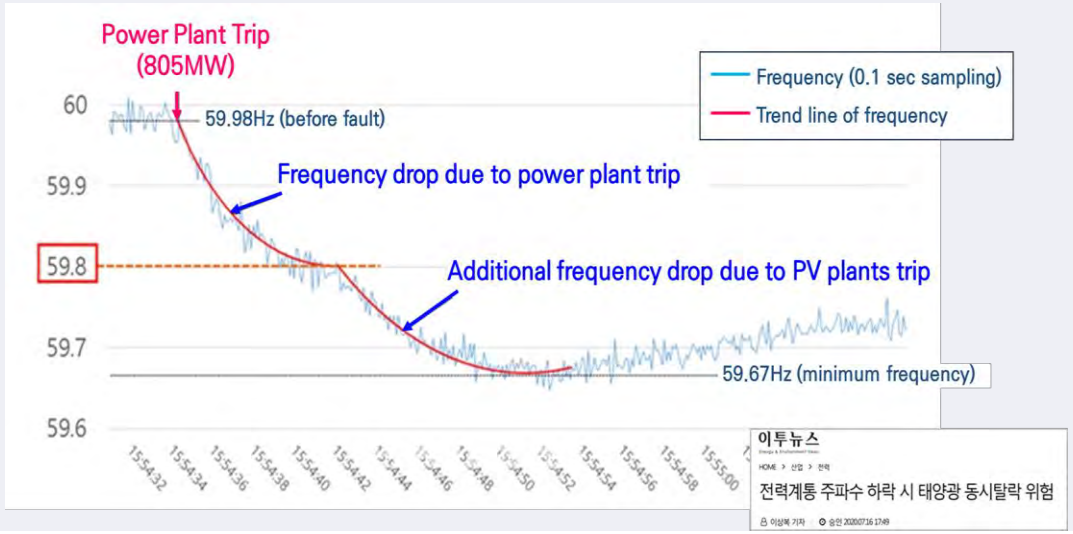
– Grid Stability –

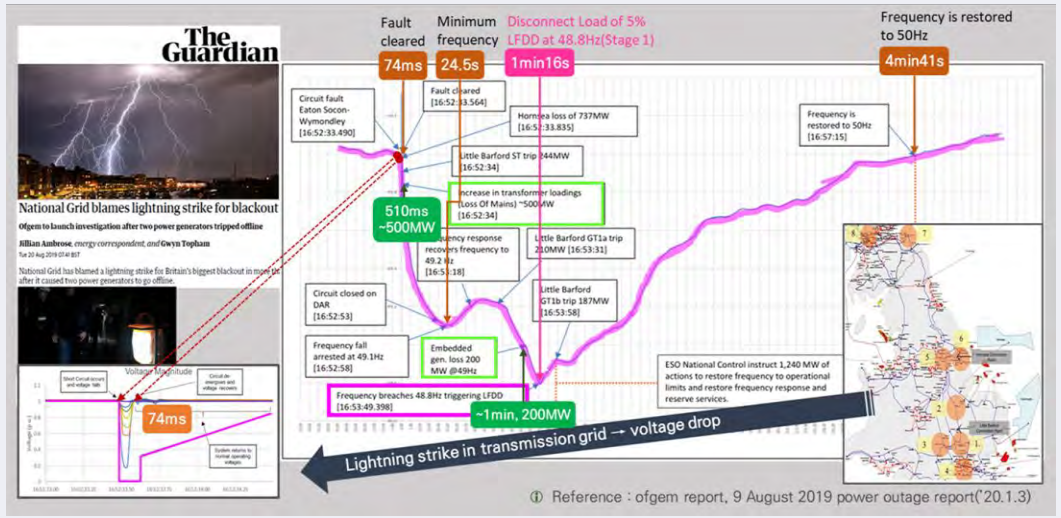
Frequency Instability due to lack of inertia

Challenge : Grid gets weakened as the share of renewables increases







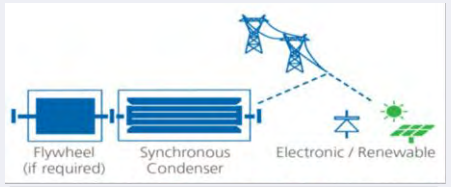


3. Grid Issues

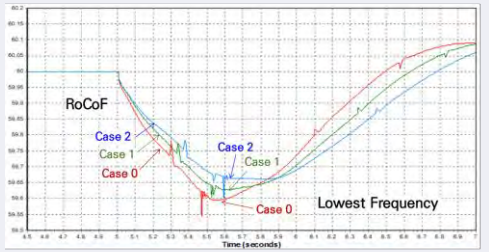
– Grid Stability –

Improvement of frequency stability

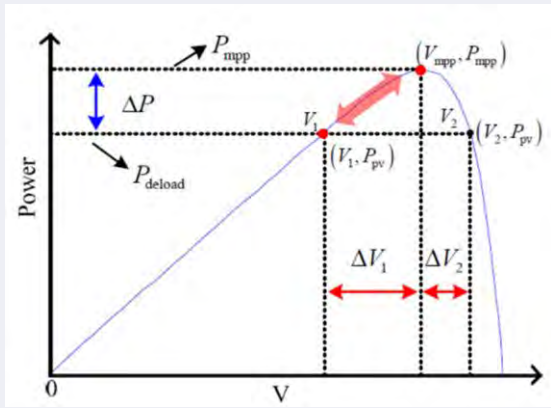
Introduction of Flywheel Synchronous Condenser & Grid Forming Inverter

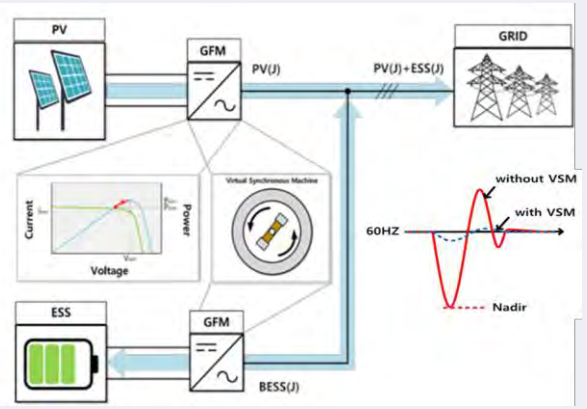


〈 Frequency stability simulation results (110MW Power Plant Trip) 〉

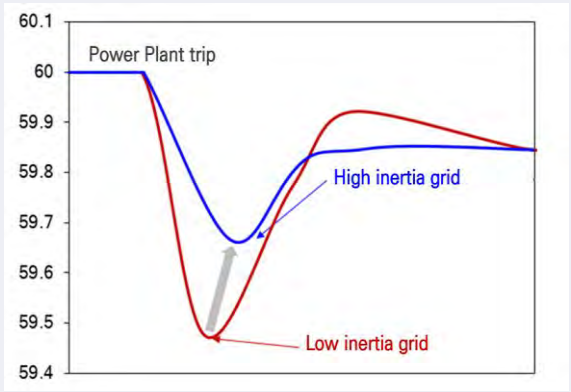


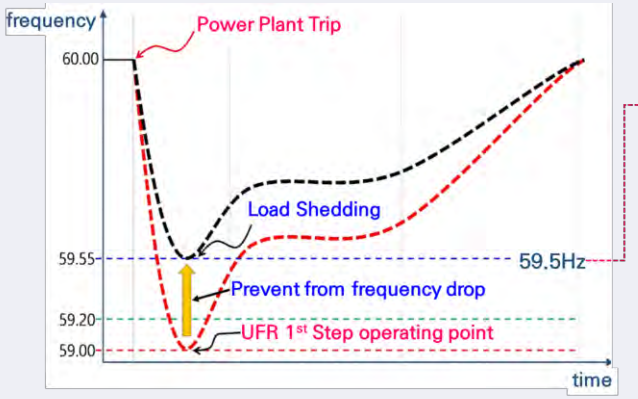
Case	Case 0 No SC	Case 1 SC 500MWs	Case 2 SC 1,000MWs
RoCoF (200msec)	1.05Hz/s	0.85Hz/s	0.75Hz/s
Lowest Frq.	59.60Hz	59.63Hz (+0.03)	59.66Hz (+0.06)
Time to reach	5.56s	5.61s (+0.05)	5.82s (+0.26)

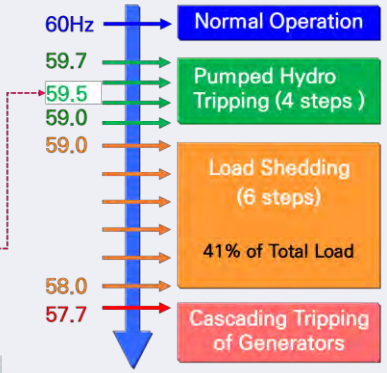




Customer Participation Load Shedding Scheme







- Pre-planned emergency load shedding for customers
- Minimum 1 operation of 10 min.
- Capacity cost: 1$/kW (KRW 1,320)
- Operation cost: 71.5$/kW/1 oper. (KRW 98,400)

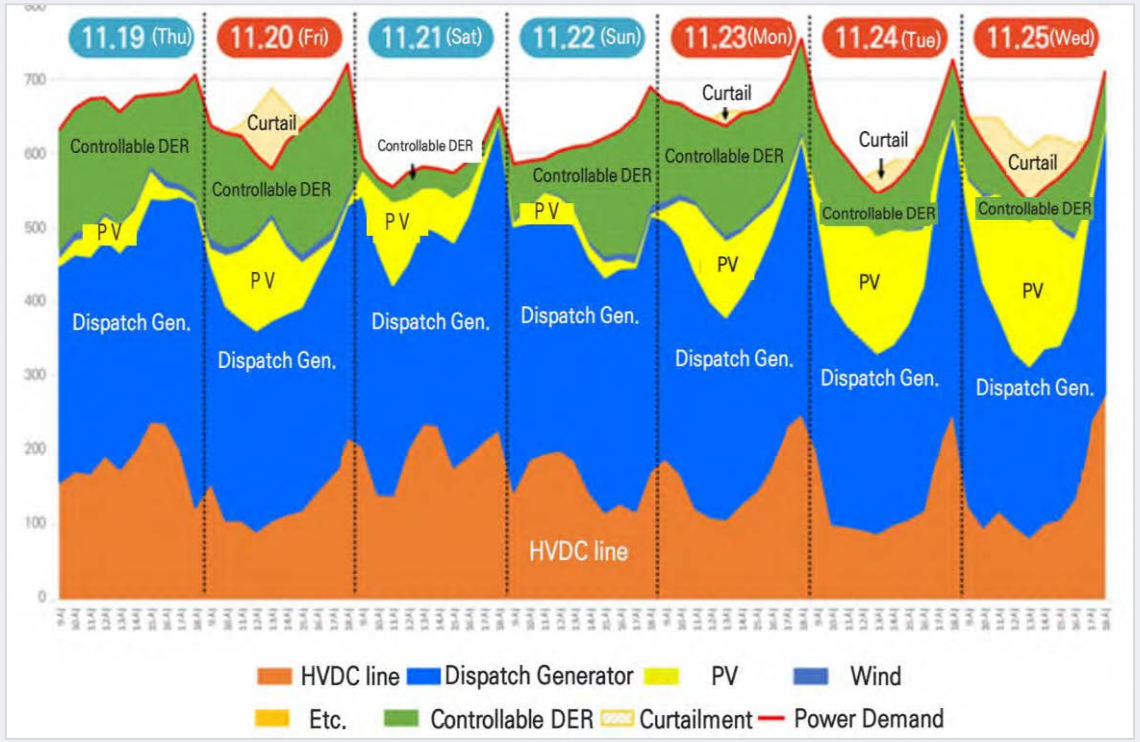
3. Grid Issues

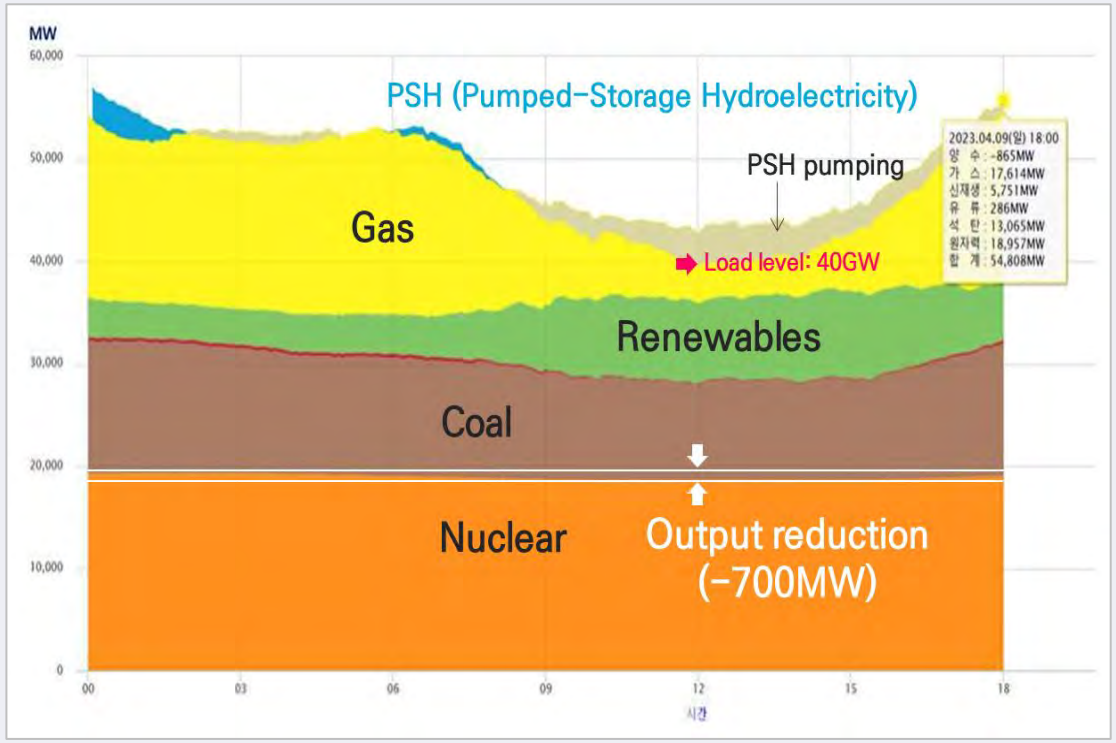
– Grid Stability –

Power Demand & Supply Imbalance

Challenge : Over-generation from renewable energies

- Frequent wind-farm curtailment due to increase of PV generation in Jeju-island
- Unprecedented reduction of nuclear power output (~700MW) in mainland





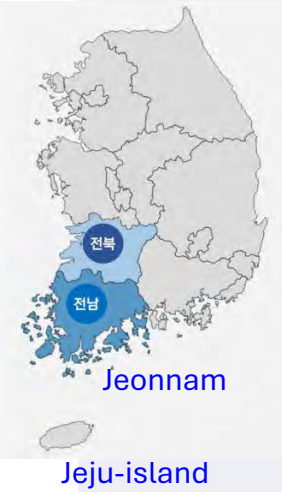
3. Grid Issues

– Grid Stability –

Online RE Generation & Demand Control

Local Renewable Management System (Monitoring & Control, Ongoing project)

- Jeonnam LRMS



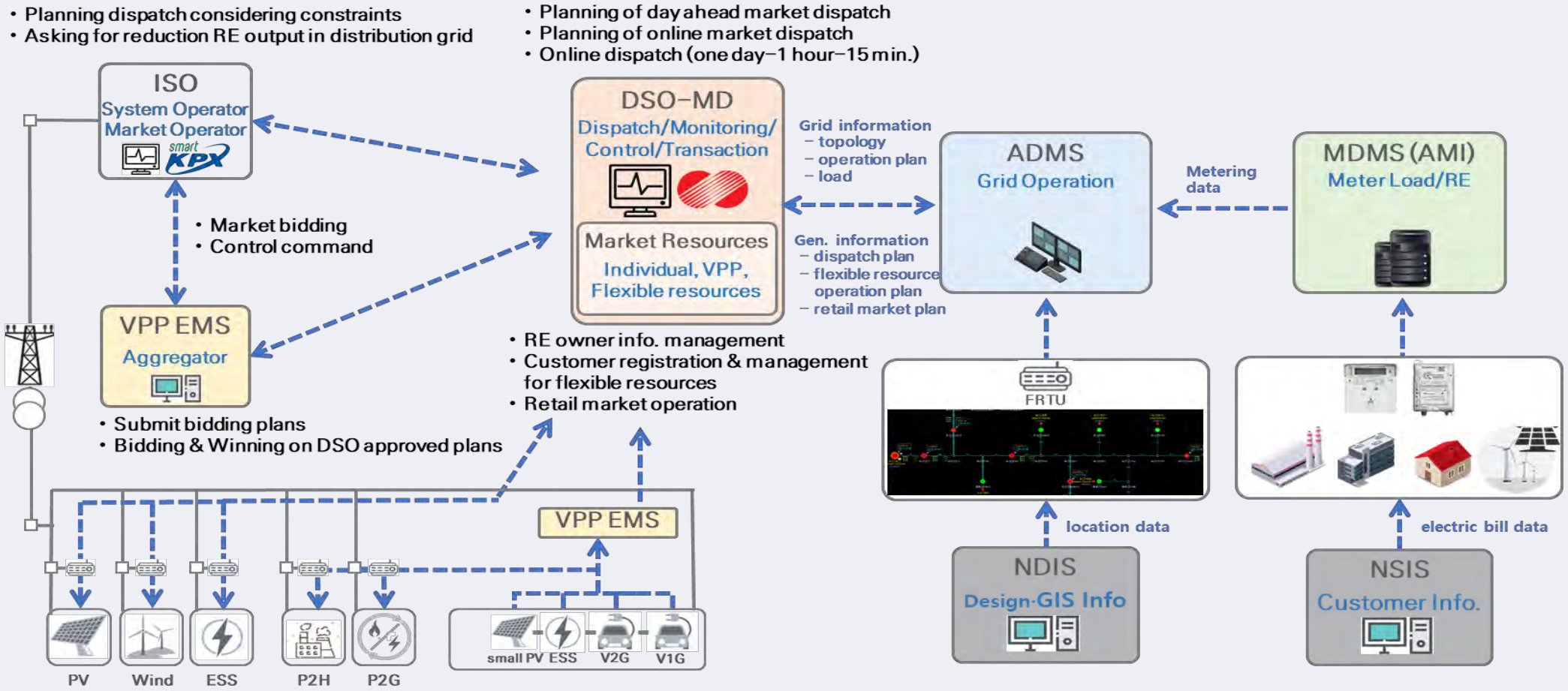
- Jeju LRMS

3. Grid Issues

– Grid Stability –

Online RE Generation & Demand Control

DSO–MD (Market management & Dispatch, Ongoing project)

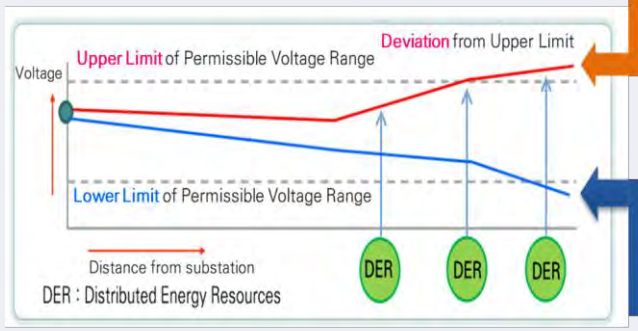


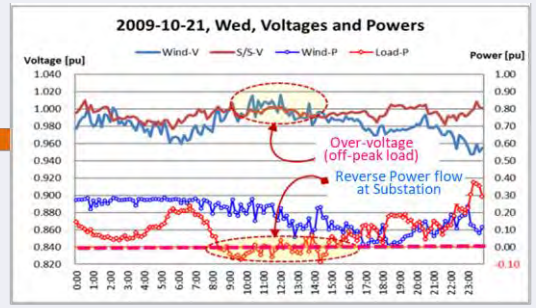
3. Grid Issues

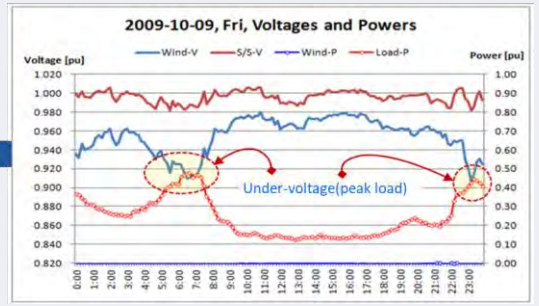
– Hosting Capacity –

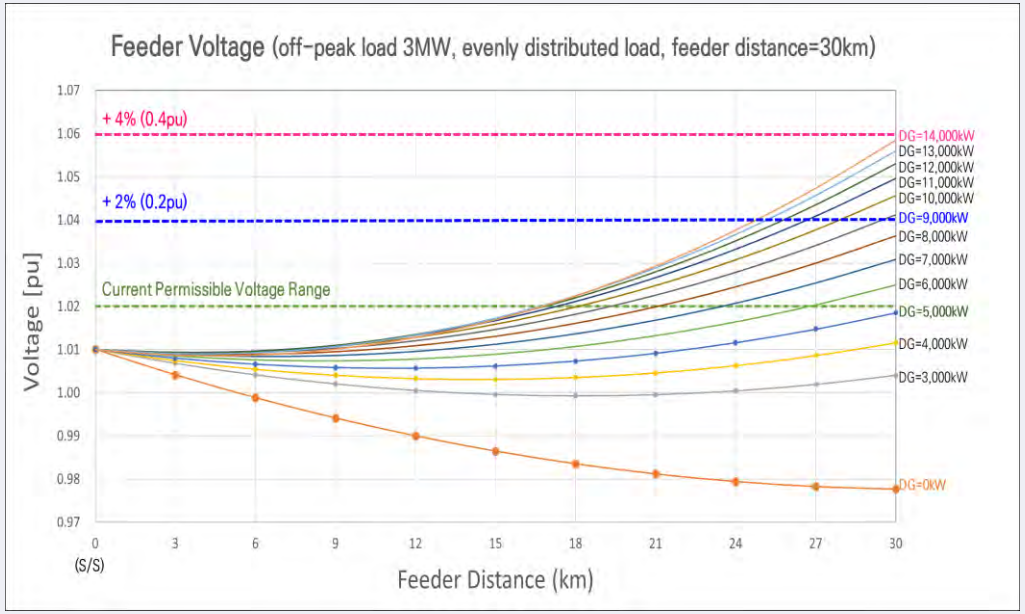
Voltage Quality Degradation

- **Voltage Rise** due to reverse power flow from DERs, **Voltage Drop** due to power flow into Loads
- To keep the voltage quality, DER hosting capacity of feeder should be limited.









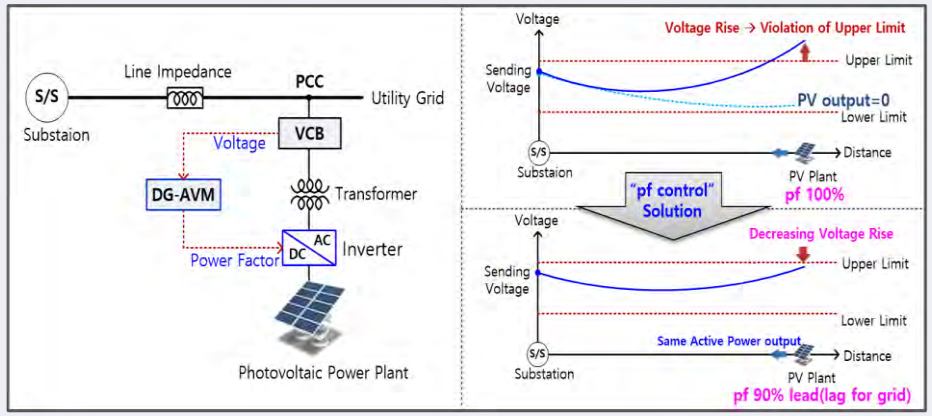
3. Grid Issues

– Hosting Capacity –

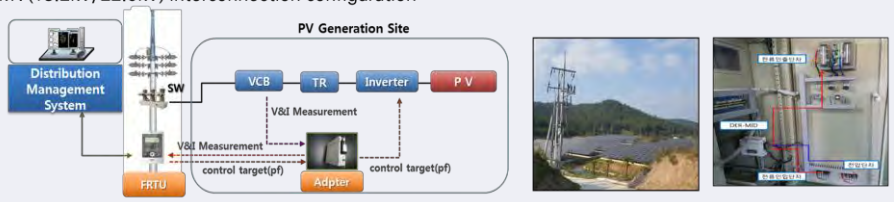
South Korea Study Tour

Active Voltage Management using Reactive Power Control

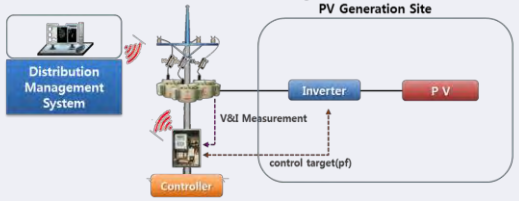
Mitigation of voltage issue can increase RE hosting capacity of feeder.



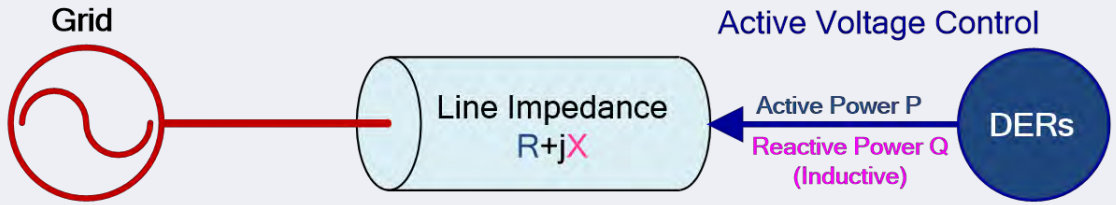
- MV(13.2kV/22.9kV) interconnection configuration

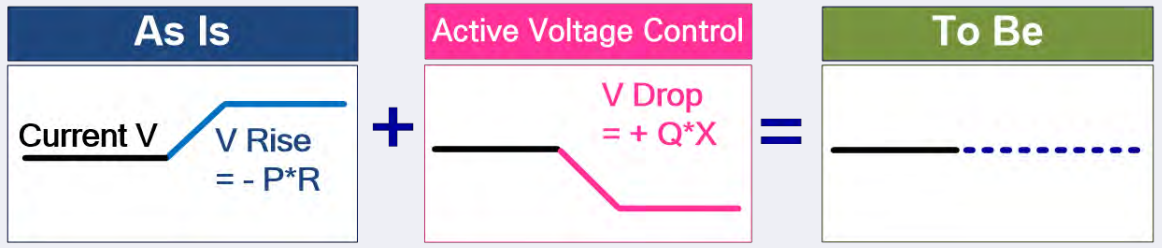


- LV(220V/380V) interconnection configuration



- ACSR 160㎟ : R 0.1835 ohm/km, X 0.4064 ohm/km, cosφ = 0.9114, operating power factor = ~ 0.9





Over voltage

Adjust Q(reactive power) so that '|R*P| = |X*Q|'

Stabilized Voltage

$$\Delta E = E_s - E_r \cong -I\cos\theta \cdot R + I\sin\theta \cdot X = \frac{-E_r I\cos\theta \cdot R + E_r I\sin\theta \cdot X}{E_r} = \frac{-P \cdot R + Q \cdot X}{E_r}$$

$$\cos\emptyset = \frac{X}{\sqrt{R^2 + X^2}}$$

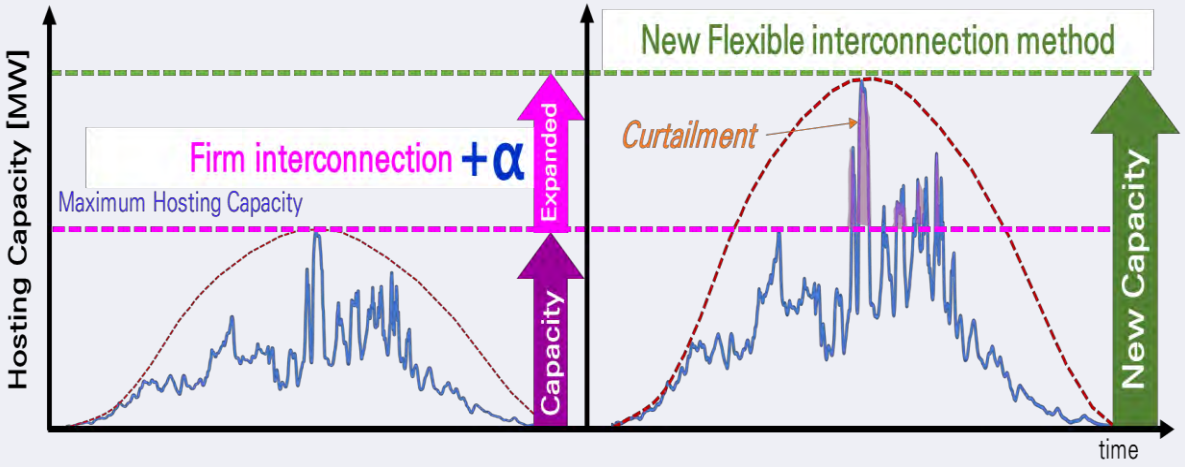
3. Grid Issues

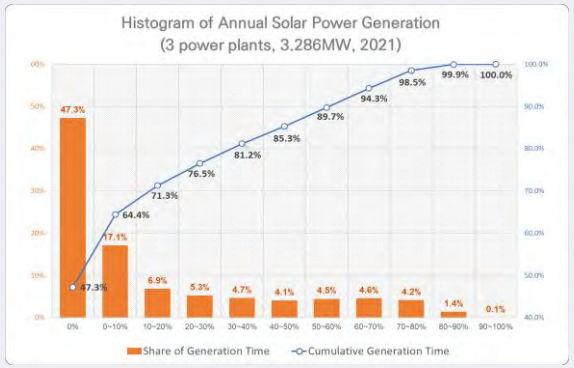
– Hosting Capacity –

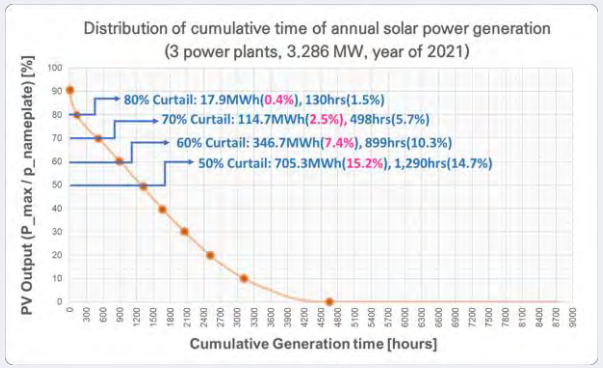
Resolving connection delay using Flexible Interconnection

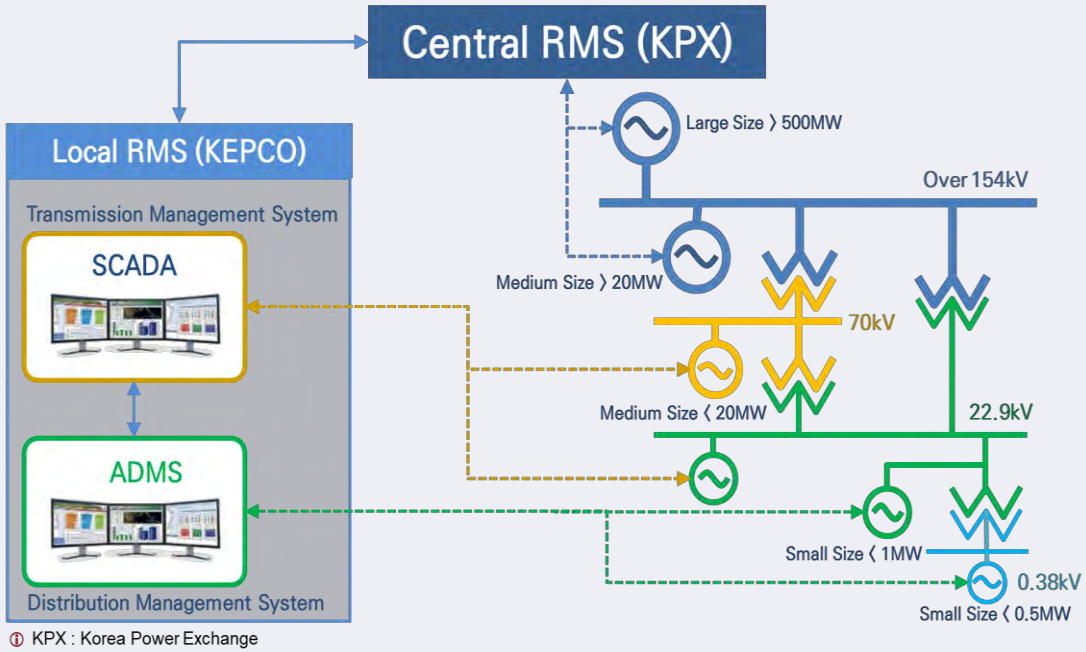
Flexible interconnection can also increase RE hosting capacity of feeder.

- [D−1] Forecasting DER output → limit maximum output, [D−0] Auto curtailment using smart inverter









4. Summary

– Lessons & Learned –

First of all, long term plan about standards, control–infrastructure, market rules

- Policy (laws, market rules, regulations, grid codes, and etc.) is the most important thing.
- Cyber security policy & strategy in utility for interoperability between different systems should be reviewed with a top priority.
- It will take 10 yrs for Smart Inverter deployment even after standardization of inverter performances.
- Upgrading to additional functions (LVRT, LFRT…) costs a lot money and time.
- In advance, preparing a way to be free from power curtailment for both utility and RE owners.

Upgrade power facility & operation standards in distribution system

- Voltage management in distribution system is the top priority task when renewables increase.
- Pole transformer's fixed tap changer scheme should be changed to OLTC scheme, such as SVR. (Reactive power control can cause additional issue when its amount is significant.)
- Keep in mind that the voltage fluctuations from renewable sources can be minimized to nearly zero by selecting the appropriate type of wire and operating power factor.
- Small scale PV plants (under 100kW) –〉 Integrated consignment operation of large scale plant

THANK YOU

Link to Agenda and Materials