OPTIMIZATION ENABLER FOR A VOLTAGE AND REACTIVE POWER MANAGEMENT (OPEN-VQ) SYSTEM FOR SMART OPERATION

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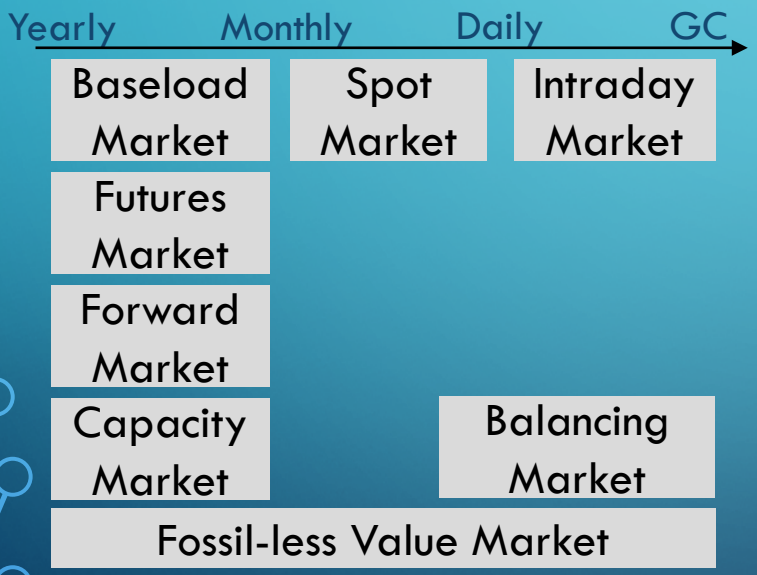
1-1. BACKGROUND

Electricity system reform and RESs implementation will increase uncertainties in Japan

Electricity system reform

: Market mechanism

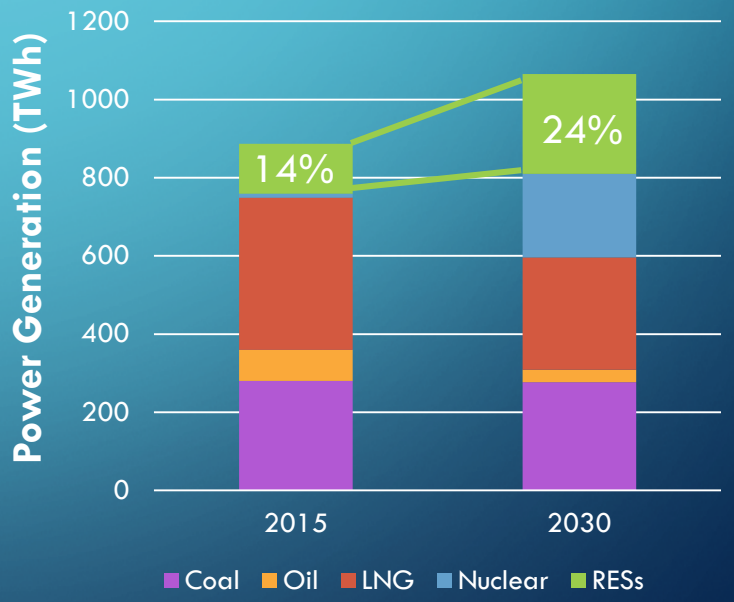
⇒Procurement uncertainties



RESs implementation

: Photovoltaic and wind generation

⇒Generation uncertainties



Facility expansion for the uncertainties requires a huge cost

RESs: Renewable Energy Sources

1-2. BENEFIT OF VOLTAGE OPTIMIZATION

Conventionally;

- voltage and reactive power has been managed manually and controlled locally.

Online optimization of voltage profile will reduce;

- OPEX by loss reduction, and
- CAPEX by enhancement of network security,

under the uncertainties caused by market and RESs.

Example:

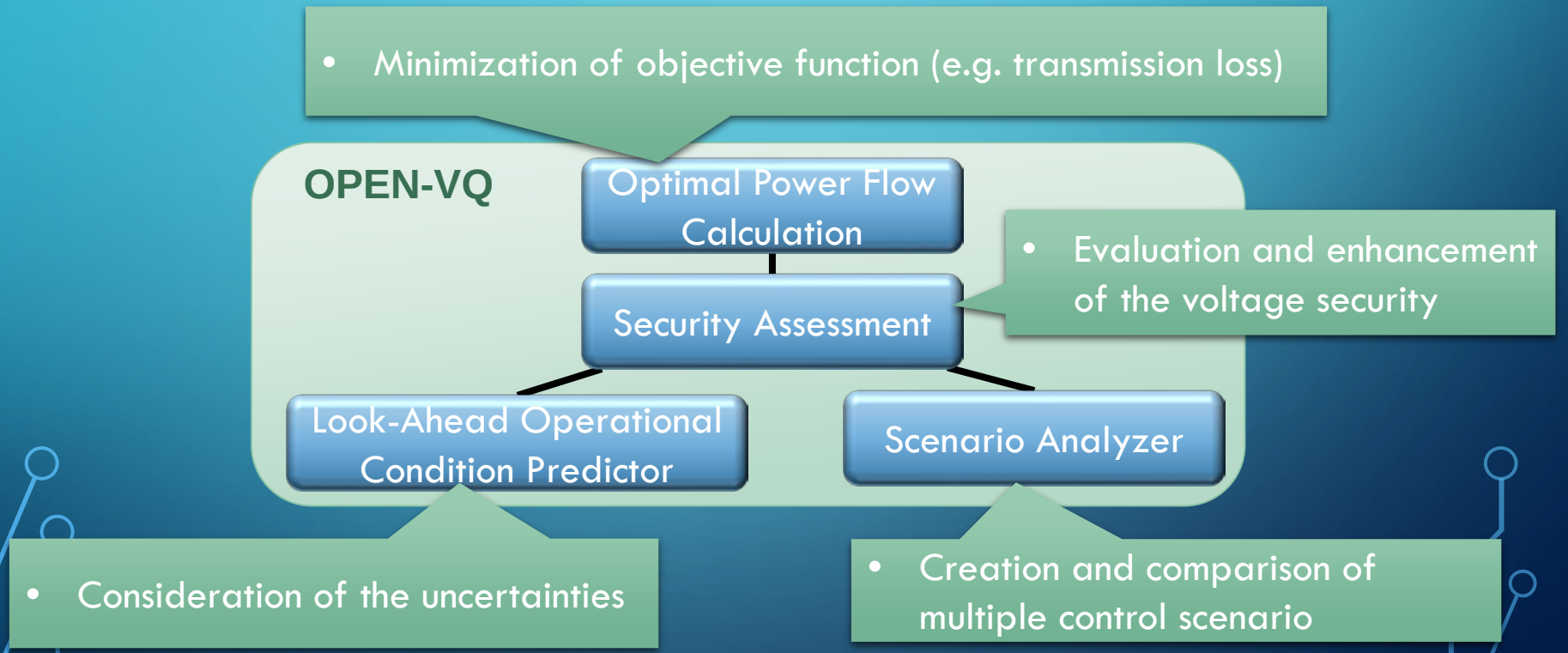
2% reduction of transmission loss (about 3%) has $18M cost impact with $30B fuel cost.

Development of sophisticated voltage and reactive power management is focused

OPEX: Operating Expenditure, CAPEX: Capital Expenditure

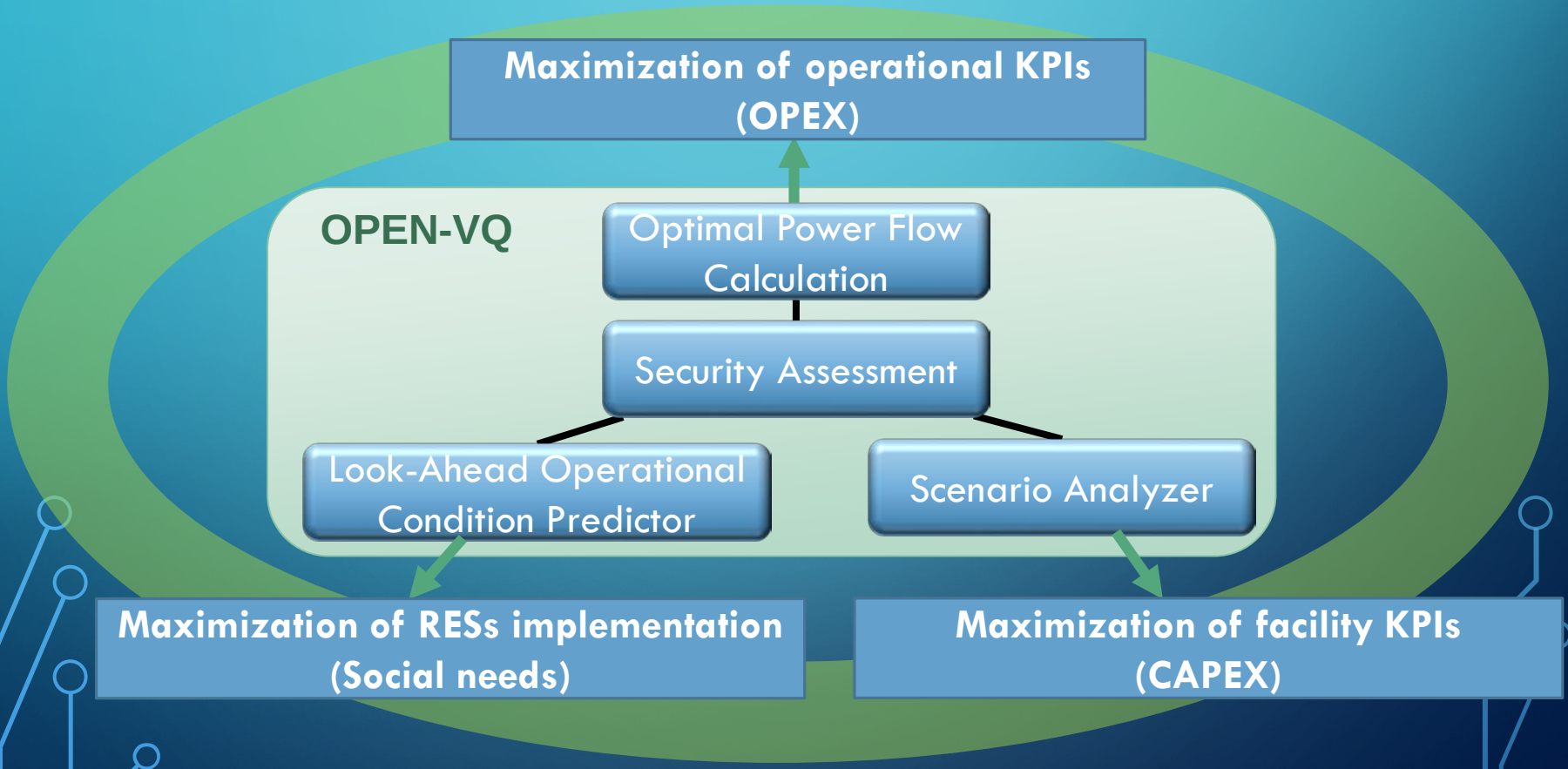
2-1. OPEN-VQ CONCEPT

OPEN-VQ consists of multiple functions for various viewpoints



2-1. OPEN-VQ CONCEPT

OPEN-VQ provides feasible management plan by coordination of optimization results in various viewpoint



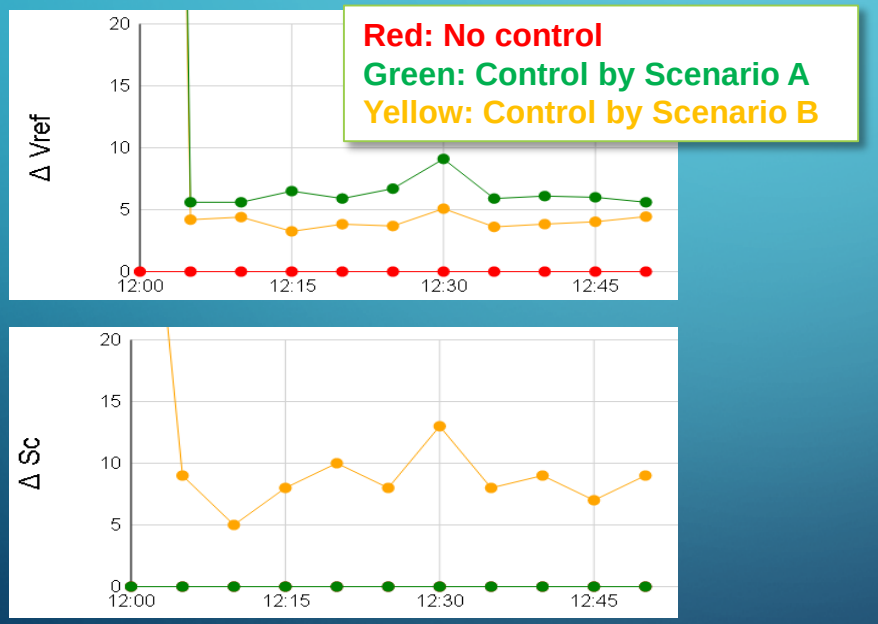
2-2. VALIDATION OF CONCEPT

Preliminary evaluation shows possibility for coordination of voltage and reactive power management plan

IEEE-118 model case

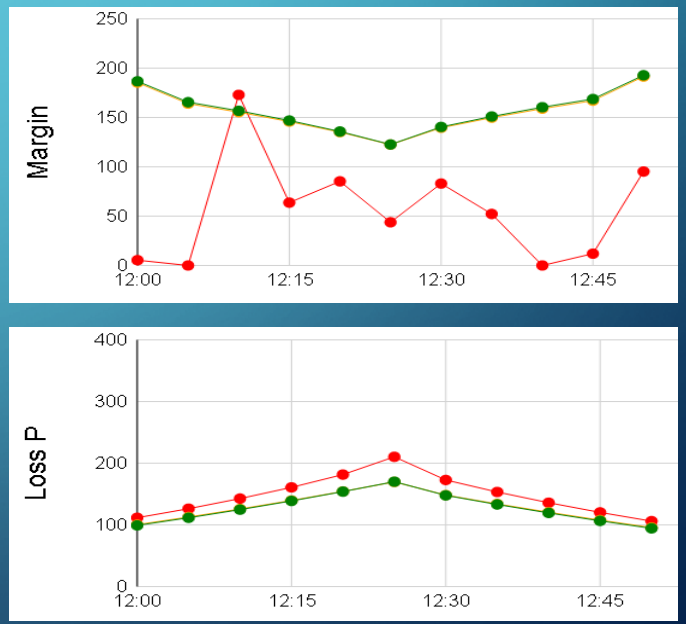
Optimization results:

Different control schemes depend on scenarios



KPIs:

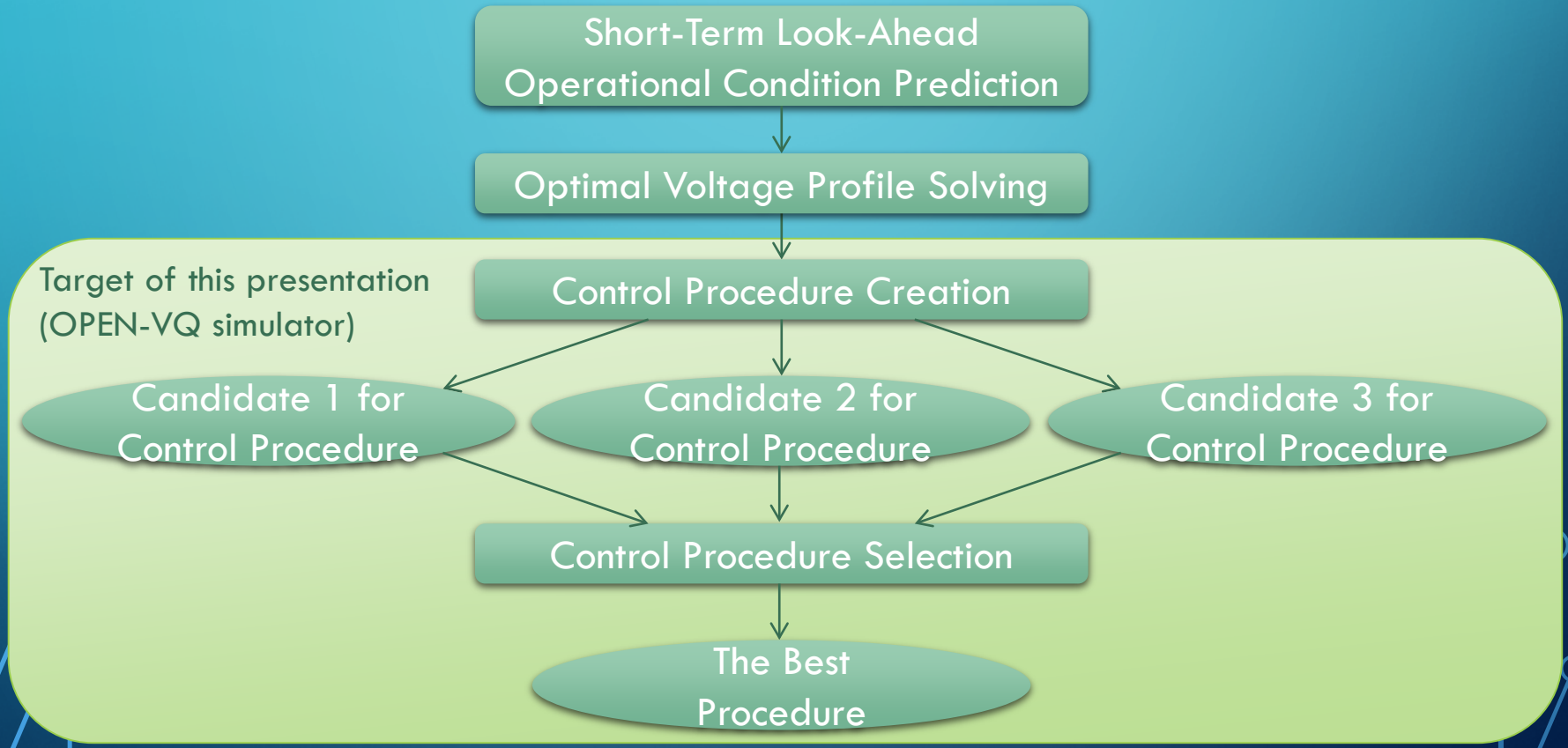
Almost same values between scenario A and B



Multiple procedures exist to maximize specific KPIs

2-3. OPEN-VQ SYSTEM PROCESS

Sequential process is adopted to achieve coordination of multiple requirements



The best control procedure can be selected out of the multiple procedures

3-1. SIMULATION CONDITION

OPEN-VQ system was simulated on TEPCO 1500-bus model for validation

Operational KPIs

- Transmission loss
- Load margin

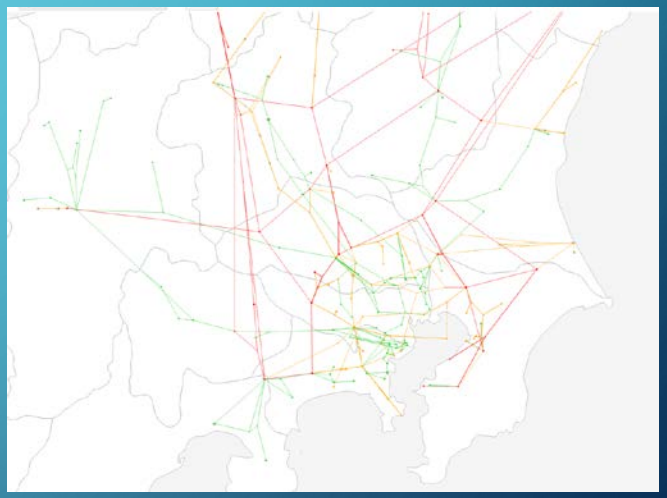
Facility KPIs

- Control number of switchable devices (shunt equipment, on load tap changer)

Optimal power flow condition

- Objective function:
  minimization of transmission loss
- Constraints:
  voltage range,
  maximum reactive power output of generators,
  Capacity and discretized available value of switchable devices

TEPCO 1500-bus model



3-2. CONTROL PROCEDURE CREATION

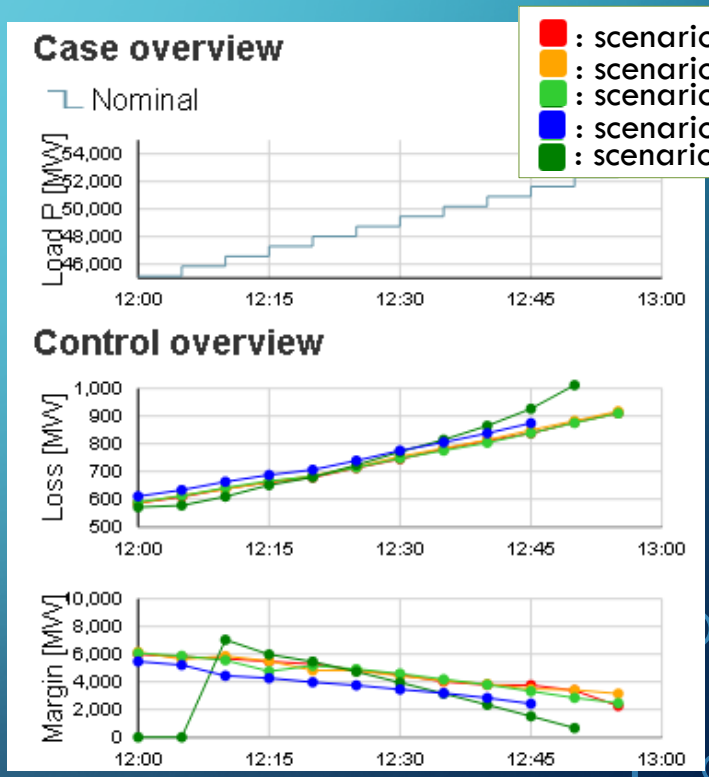
Control amount of regulators and KPIs can be checked in this process

Scenario

0: no control
1: all regulators are controlled
2: some switchable devices are locked
3: some switchable devices are locked
4: all switchable devices are locked

Candidates for control procedure

- Scenario 1, 2, 3, and 4 result almost same transmission loss and load margin.



Different candidates for control procedure result almost same operational KPIs

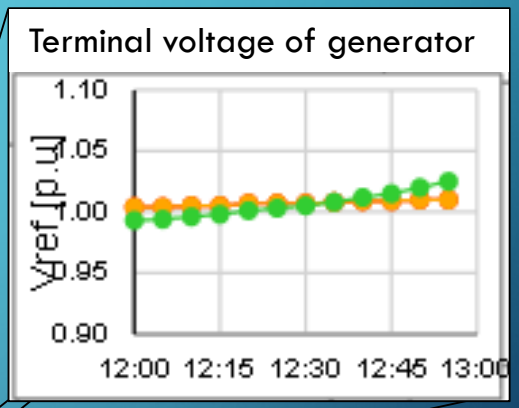
3-3. CONTROL PROCEDURE CREATION

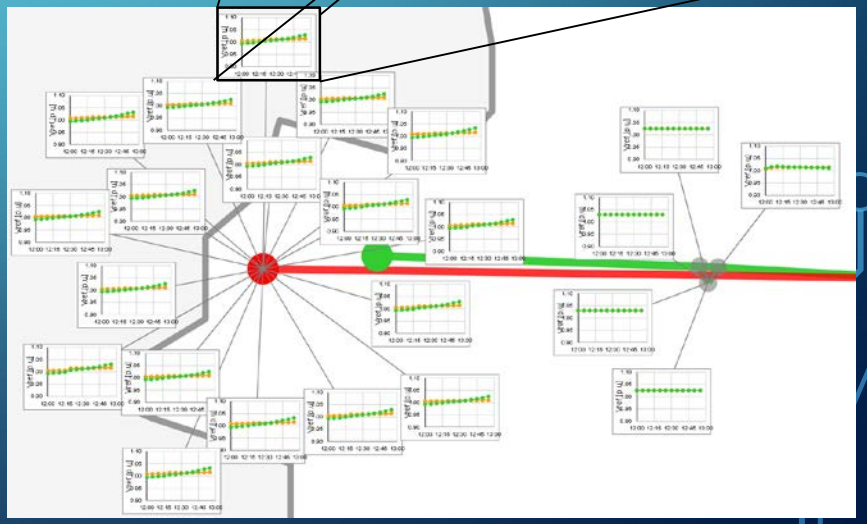
Chronological control state of each regulator also can be checked on the map viewer

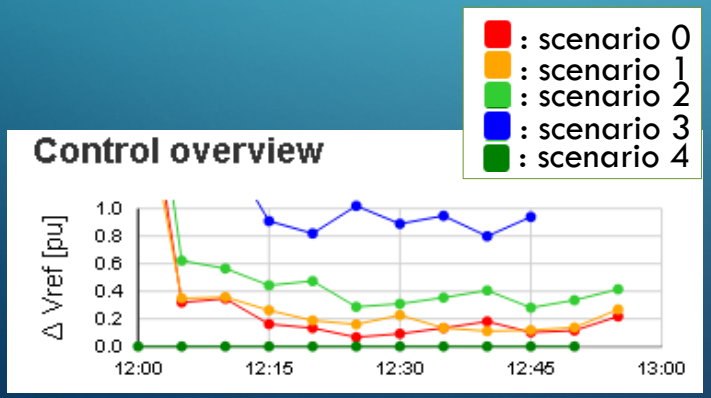
Chronological control state

- Terminal voltage of generator
- Tap position of on load tap changer
- Number of shunt devices switched in

The change of control state from a previous time is also calculated.







3-4. PROCEDURE SELECTION

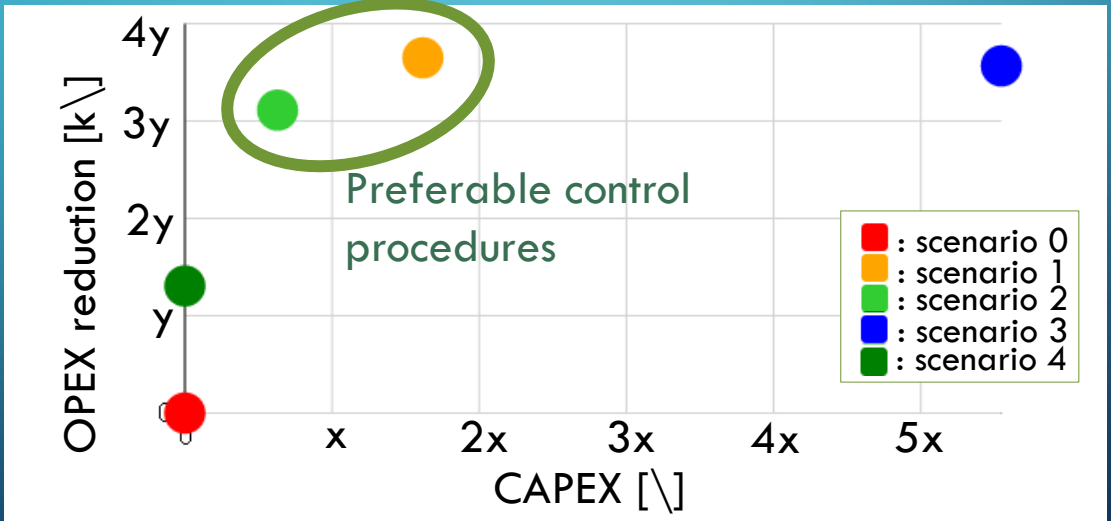
Operator can select the best control procedure in point of OPEX and CAPEX

Economical analysis for procedure selection

OPEX: generation cost of power plant (reduced by loss reduction)

CAPEX: estimated switching cost of switchable devices

$$\left(switching\ number \times \frac{maintenance\ cost}{acceptable\ switching\ number} \right)$$

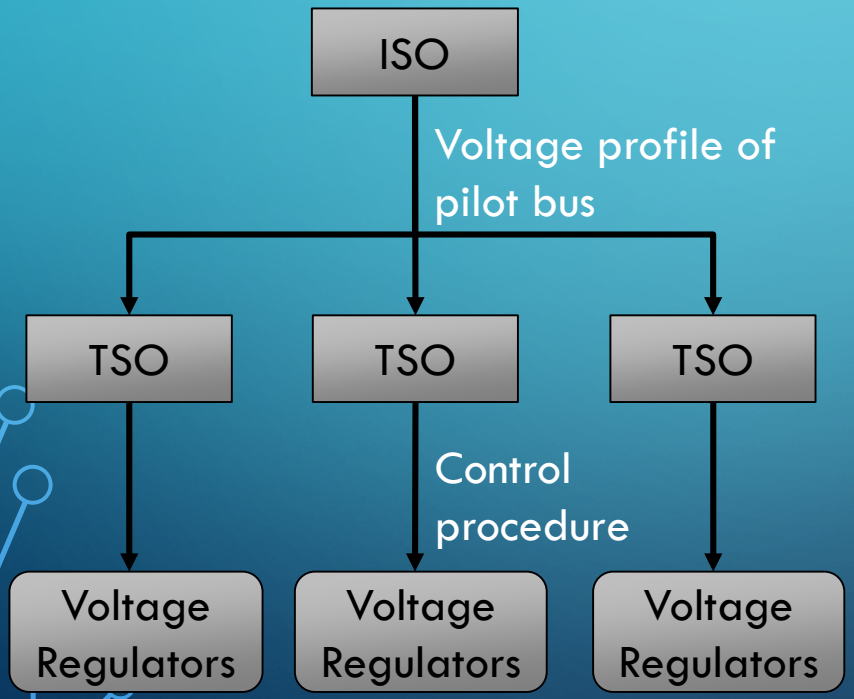


Scenario 1 and 2 are preferable control procedures in this simulation

4-1. POTENTIAL OF OPEN-VQ SYSTEM FOR DIFFERENT LAYER OF ENTITY

Each entity can choose required function for their voltage and reactive power management

Hierarchical Layer of Entity

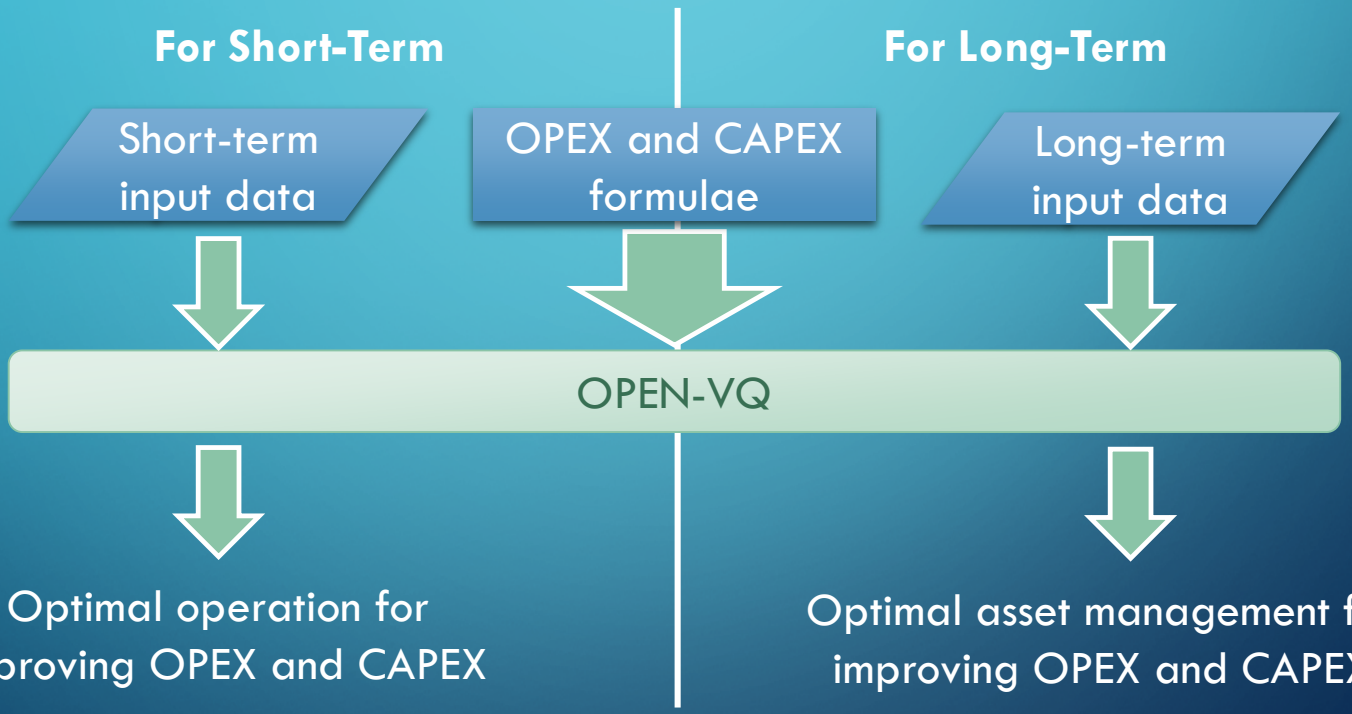


OPEN-VQ Function for each Entity

	ISO	TSO
Look-Ahead Operation Condition Prediction	◎	○
Optimal Voltage Profile Solving	◎	—
Control Procedure Creation	—	◎
Control Procedure Selection	—	◎

4-2. POTENTIAL OF OPEN-VQ SYSTEM FOR DIFFERENT TIME SCALE

OPEN-VQ can optimize asset management with long-term look-ahead operation condition



OPEN-VQ system can become a common platform for integration of power system planning and operation

SUMMARY

- OPEN-VQ system providing feasible management plan by coordination of optimization results in various viewpoint is proposed.
- Its process consists of;
  - ✓ a short-term look-ahead operational condition,
  - ✓ an optimal voltage profile solving,
  - ✓ a control procedure creation, and
  - ✓ a control procedure selection.
- Simulation of OPEN-VQ on the TEPCO 1500-bus model show that;
  - ✓ there are multiple procedures improving the specific KPIs, and
  - ✓ the best procedure can be selected in point of OPEX and CAPEX for multiple KPIs.

- As a future work,
  - ✓ comparison between the proposed and conventional system, and
  - ✓ development of additional functions for asset management

  are planned.