JST-NSF-DFG-RCN

Workshop on Distributed Energy Management Systems

-Future Power System Architectures and Control Paradigms-

Power System Operation with Battery Energy Storage System Based on Forecasted Photovoltaic Power Output

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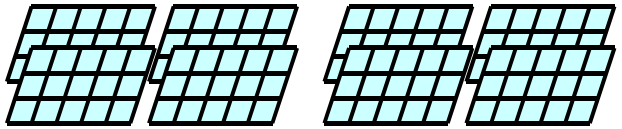
Apr. 21, 2015

Research objective

Supply and demand operation in future power systems (2030-2050)

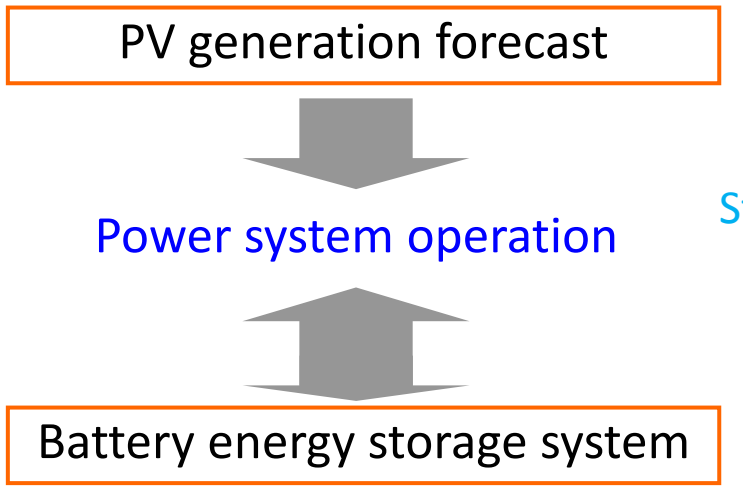
To utilize as much PV energy as possible

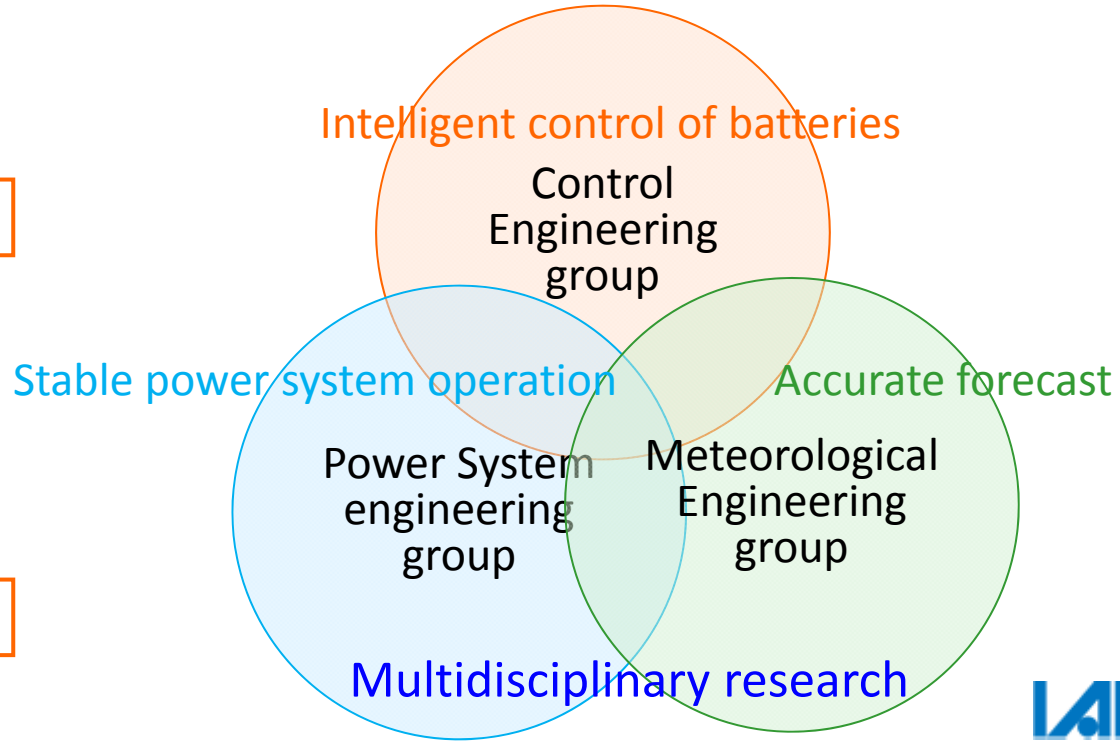


Government Target: 53 GW (25% of peak load, 5% of electric energy consumption)

Base Case: 102 GW (50% of peak load, 10% of electric energy consumption)

Extreme Case: 330 GW (150% of peak load, 33% of electric energy consumption)





Operation based on day-ahead forecasted PV power (1)

Previous day: Unit commitment based on forecasted PV power

Objective function: Minimize operational cost of generators

Constraint conditions

- Balance between supply and demand
- Upper and lower limits of output of generators
- Regulating capacity for load fluctuation (LFC capacity)
- Priority dispatch of PV generation

Given day: Optimal load dispatch

Output regulation of connected generators

- Power shortfall <- greater than the upward reserve capacity
- PV suppression <- less than the downward reserve capacity

Operation based on day-ahead forecasted PV power (2)

Simulation Condition

Power system model of Kanto area of Japan

Generation data

Constant output	Nuclear	12,000 MW
	Hydro	6,000 MW
Target for UC	Thermal	39,150 MW (94 units)
PV generation	PV	30,000 MW (≒102 GW in Japan)

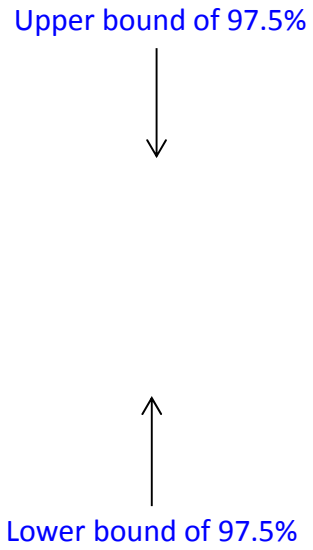
Load data: data of Tokyo-EPCO in May 2010

Irradiation data：actual data of Kanto area in May 2010

Forecast data：calculated data based on the actual data

Operation based on day-ahead forecasted PV power (3)

Prediction intervals -> possible ranges of the actual PV power outputs

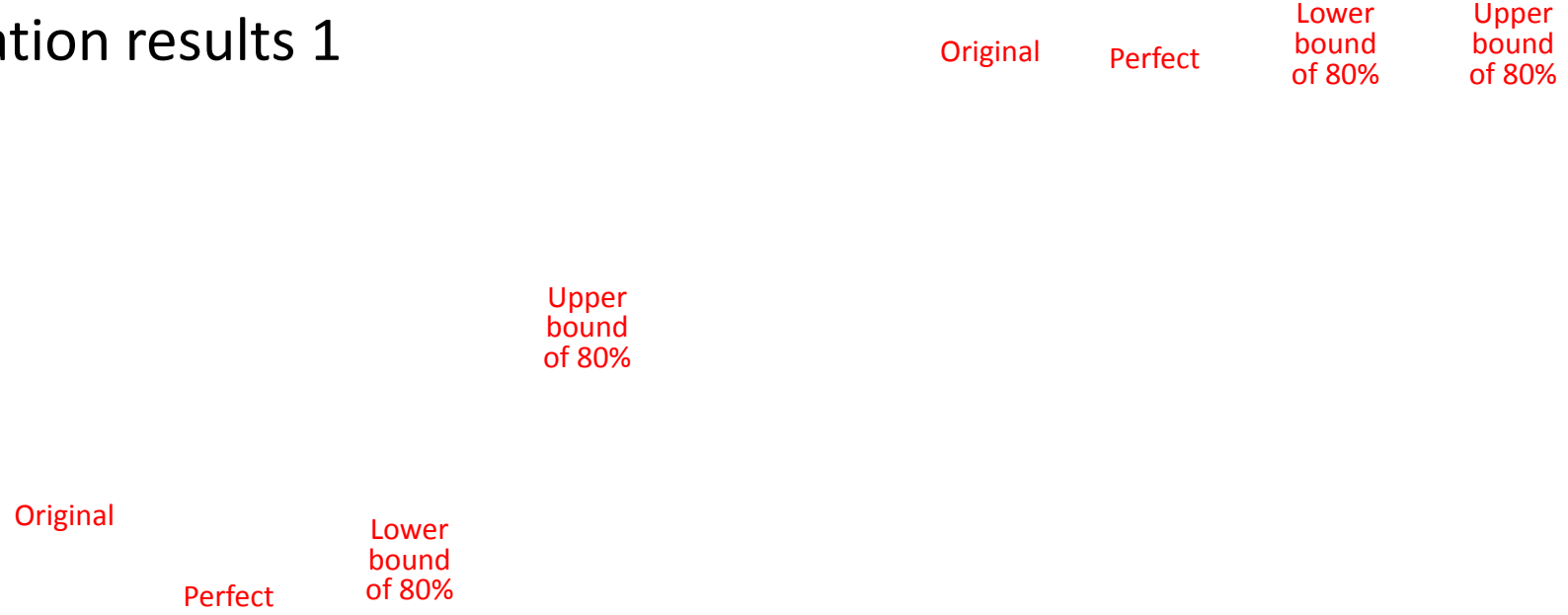


UCs are determined based on the original forecast, perfect forecast, or upper/lower bounds of prediction intervals with confidence of 80 %.

- Upper bound -> reduce surpluses
- Lower bound -> reduce outages

Operation based on day-ahead forecasted PV power (4)

Simulation results 1



Total energy shortfall (outage)

Total suppressed PV energy (surplus)

Possible total PV generation in May: 3,900 (GWh)

- Outage can be reduced close to zero.
- Surplus cannot be avoided even if the output is perfectly forecasted.
  - ➢ Improvement of forecast accuracy has a limitation.
  - ➢ Battery energy storage systems (BESSs) are necessary.

Application of battery energy storage system (BESS) (1)

- Difficult to determine both generator and BESS operations simultaneously considering…
  - PV generation forecast error
  - PV power output suppression
  - Starting/stopping scheduling of generators
  - Charge/discharge of BESS

Proposed operation method

1. Firstly determine charge/discharge schedule of BESS
2. Secondly determine UC of generators based on 1

Application of battery energy storage system (BESS) (2)

Interval analysis based on prediction intervals (80%) of PV generation

- Generation schedule of power plants
- Charge/discharge schedule of BESS

- There are an endless number of pathways.
- To find the upper pathway of power generation is important.
  - To secure reserve capacity as much as possible
  - Corresponding to the upper pathway of net load = the lower bound of PI
- A pathway of charge/discharge corresponding to the upper pathway of generation is selected.

Application of battery energy storage system (BESS) (3)

Simulation results 2

Impact of forecast errors

Total energy shortfall (outage)

Total suppressed PV energy (surplus)

- Suppressed energy becomes small for a larger value of BESS.
- Energy shortfall becomes large for a larger value of BESS.
  - BESS charges/discharges according to the day-ahead schedule.
  - BESS does not always discharge during shortage of supply.

Charge/discharge should be re-scheduled with more accurate forecast.

Application of battery energy storage system (BESS) (4)

Simulation results 3 (Re-scheduled case)

Total energy shortfall (outage)

Total suppressed PV energy (surplus)

- Charge/discharge of BESS is re-scheduled based on perfect forecast after determining UC.
- Energy shortfall becomes smaller than the case without BESS.
  - Improve the accuracy of the forecast
  - Change the operation method of BESS

Conclusion

Future power system operation

with extremely large capacity of PV generation.

- Difficult based only on the conventional power system engineering
- Necessary to apply
  - intelligent control methods
  - accurate forecasting methods