7th Solar Integration Workshop
SESSION 4A – INTERNATIONAL STUDIES AND EXPERIENCE

Impact of waterworks pumps demand response to increase maximum photovoltaic integration capacity

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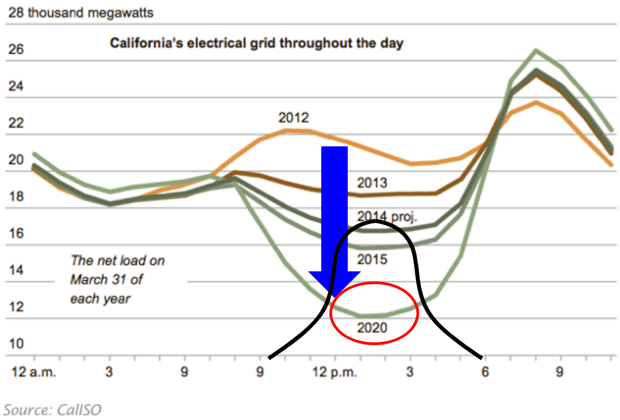
This research is supported by “**Miyako-city island type smart community evaluation project**”.

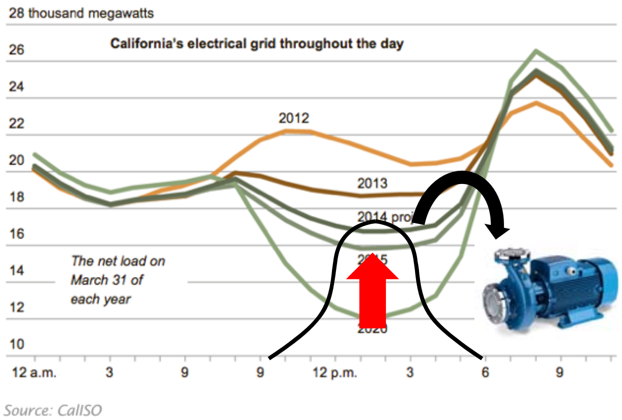
PV Influence to supply-demand balance

Net demand curve change by increasing PV penetration



Demand is under minimum output of total power generations
->PV will be curtailed.

Solution? Demand response of Waterworks pumps!



By **demand response (DR) of waterworks pumps**, increase daytime demand and reduce curtailment.

Target: Miyako island

- Sub-tropical, Isolated grid, Population: 55000
- Electrical demand: 18MW~55MW
- PV:**22.2MW**, Wind:4.8MW, Battery:4.0MW
- Additional PV installation is restricted because of “power surplus”.
- **Waterworks pumps: 5MW!**
- Pump DR tests has done to reduce peak and mitigate surplus.

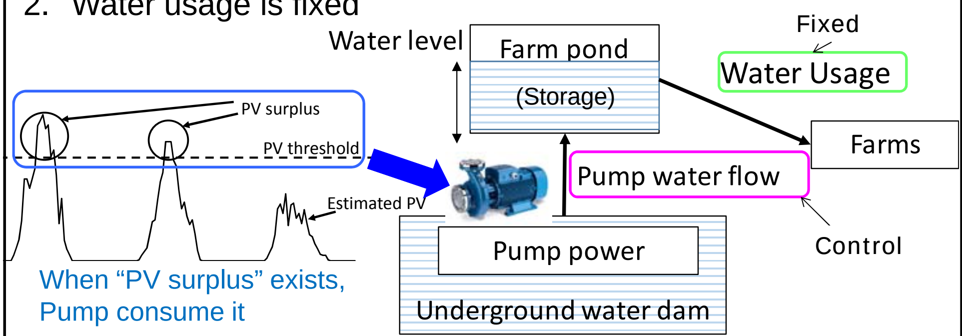
http://www.city.miyakojima.lg.jp/kanko/annai/beach.html

Research object

Evaluate the impact of demand response (DR) of waterworks pumps by shifting the time of pump operation

Constraint conditions

1. Tank water level is under 100%
2. Water usage is fixed



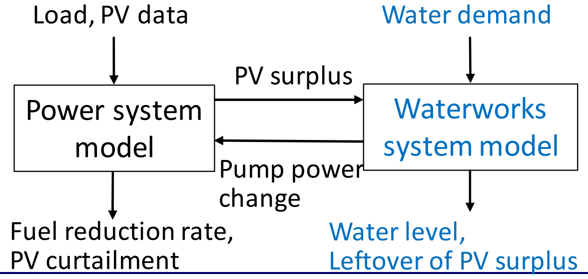
Overview of simulation

Suppose that there is **no** real-time signal from power system operator to waterworks system operator.

Step1: Calculate hourly PV surplus by "Power system model"

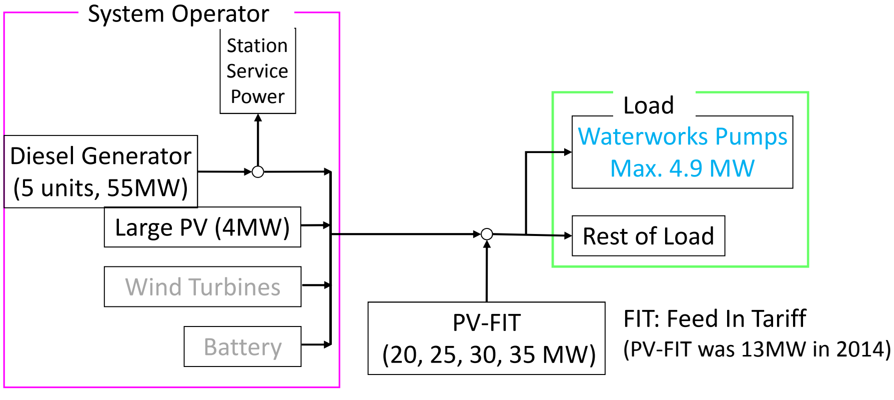
Step2: Calculate hourly PV surplus consumption and pump power change by "Waterworks system model"

Step3: Calculate the impact of Pump DR to Power System by "Power system model"



Step1:Power system model of the island

- Time resolution: 1 hour
- Time span:2014/10~2015/3



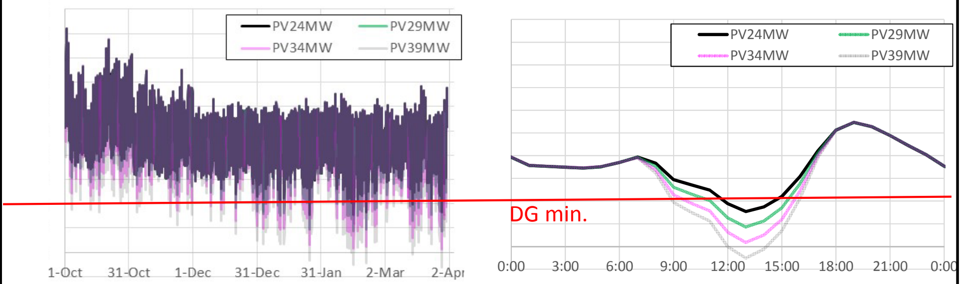
Step1: Estimate actual load

0. Hourly Large PV output and net load data are got
1. Estimate *existing FIT-PV* output using Large PV data
2. Estimate "actual load"

   Actual load = Net load + Large PV + FIT-PV

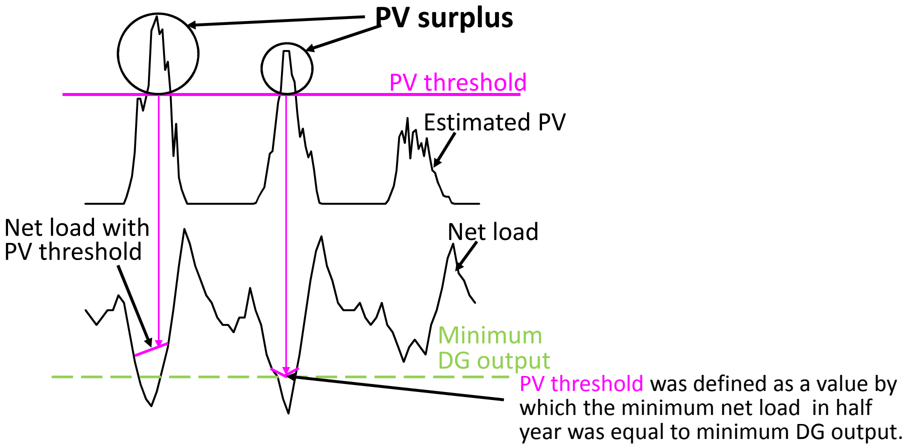
3. Calculate net load with larger PV installation scinarios

Hourly net load in the half year — example of net load in a day (Feb. 15)



Step1: PV surplus and PV threshold

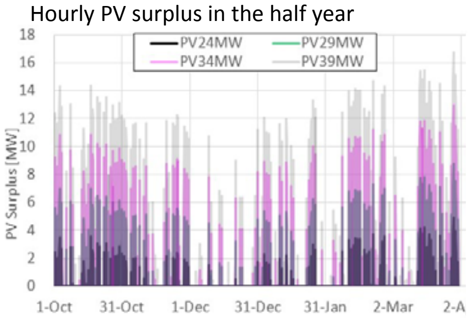
- **"PV surplus"** was defined as hourly PV output minus constant PV threshold.
  - **Not** calculated by hourly net load itself



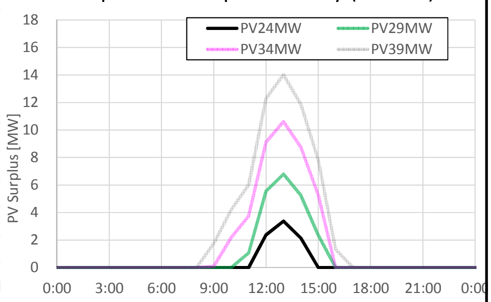
Step1: Calculation result of PV surplus

- The amount of PV surplus increased dramatically when total capacity of PV increased.
  - PV surplus was relatively small and less-frequent in Dec. and Jan..

Hourly PV surplus in the half year



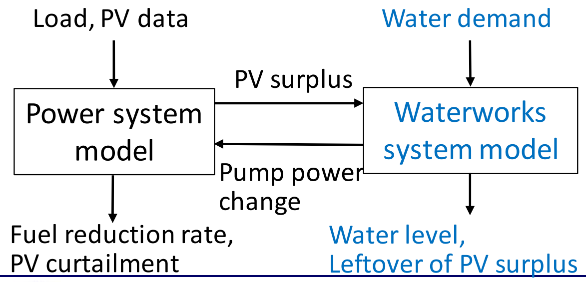
example of PV surplus in a day (Feb. 15)



Next: Step2

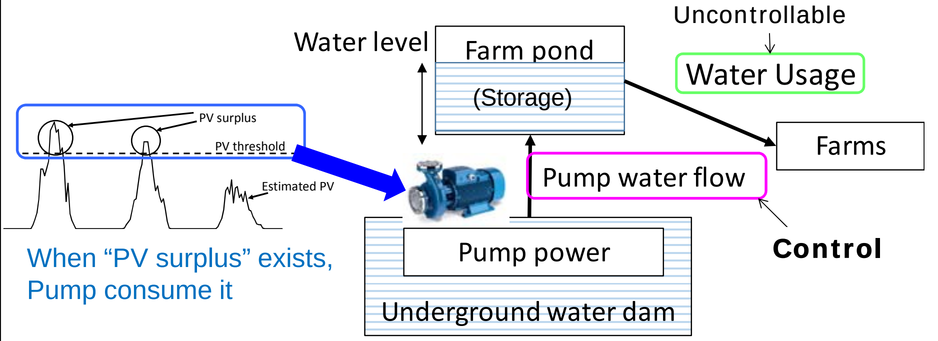
Suppose that there is **no** real-time signal from power system operator to waterworks system operator.

Step1: Calculate hourly PV surplus by “Power system model”
Step2: Calculate hourly PV surplus consumption and pump power change by “Waterworks system model”
Step3: Calculate the impact of Pump DR to Power System by “Power system model”

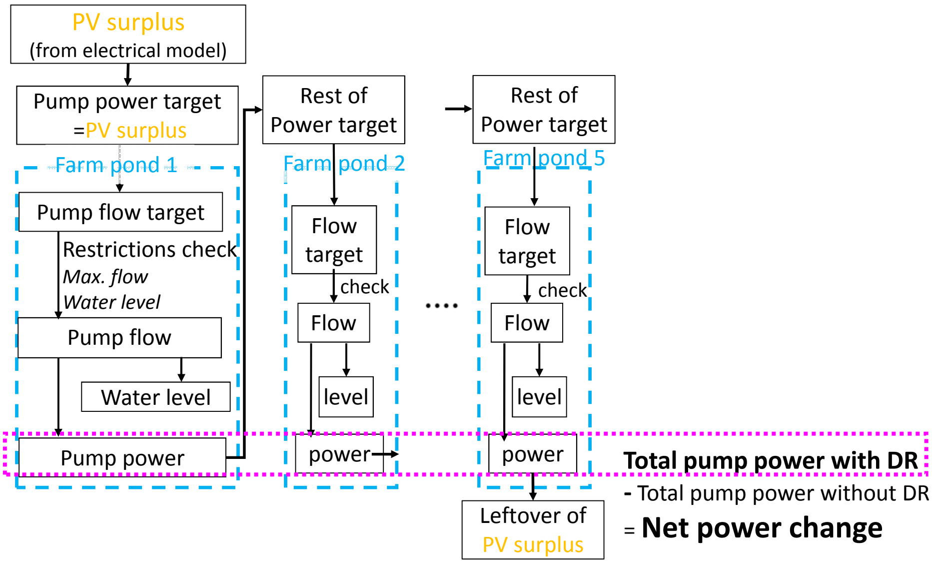


Step2: Waterworks pump system model

- There are 5 farmponds and each water level is calculated.
- PV surplus is used as target of the total pump power.
- Water level of the farmpond is calculated using actual water usage data.



Step2: Determination sequence of pump power



Step2: Results in half year

- The ratio of the leftover became higher in proportion to increase of PV installation,
  - In PV24MW case, almost all of PV surplus was consumed by pumps.
  - Even in the PV34MW scenario, half of PV surplus was consumed by pumps.

PV scenario	**24MW**	**29MW**	**34MW**	**39MW**
PV surplus [GWh]	0.46	1.49	3.04	4.59
Leftover [GWh]	0.002	0.38	1.48	2.79
Leftover/ surplus	0.005	0.25	0.49	0.61

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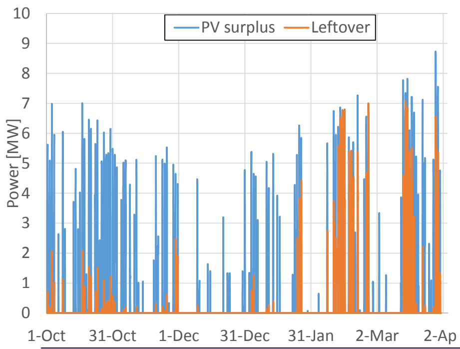
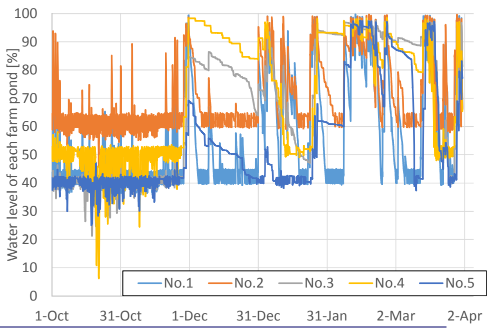
Step2: Result when total PV was 29MW

- From Oct. to Jan., most of the PV surplus was consumed because the PV surplus itself was relatively small.
- The PV surplus remained in February and March.
  - The water level reaches 100% frequently.

Hourly PV surplus and leftover



Hourly water level



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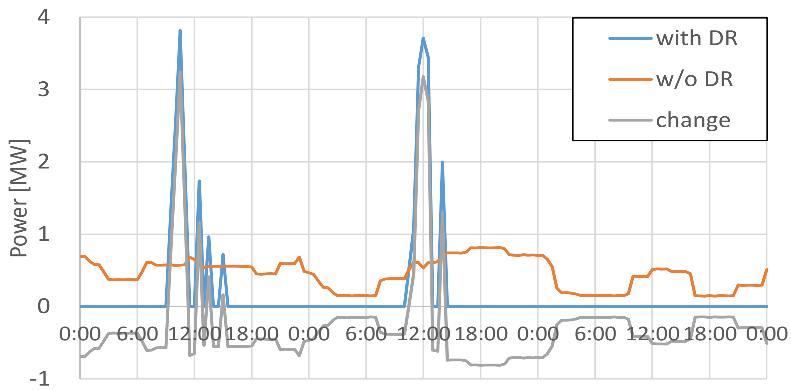
Step2: Example of pump power with and without DR

- Without DR, pump power is relatively flat.
- When there is large PV surplus, the pump power increases dramatically.



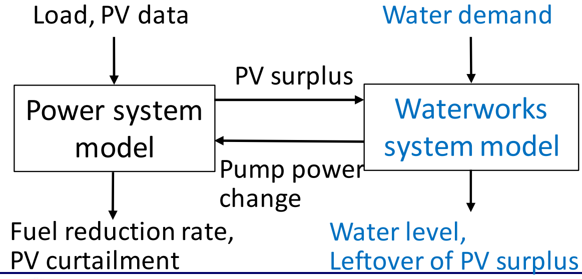
Next: Step3(only result)

Suppose that there is **no** real-time signal from power system operator to waterworks system operator.

Step1: Calculate hourly PV surplus by “Power system model”

Step2: Calculate hourly PV surplus consumption and pump power change by “Waterworks system model”

Step3: Calculate the impact of Pump DR to Power System by “Power system model”



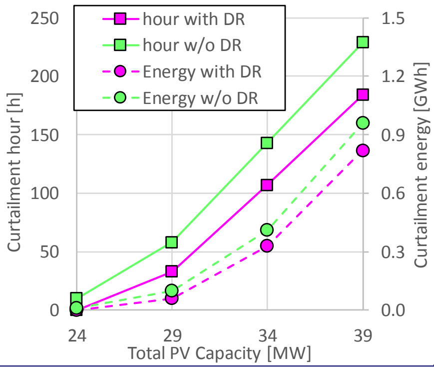
Step 3: Impact of Pump DR to Power System

- Fuel reduction by DR itself is not large.
- Curtailment reduction leads to more PV installation.

	PV scenario	24MW	29MW	34MW	39MW
Fuel reduction rate [%]	w/o DR	2.9	4.9	6.6	8.1
	With DR	3.0	4.9	6.7	8.3
Curtailment energy [GWh]	w/o DR	0.01	0.10	0.41	0.96
	With DR	0.00	0.06	0.33	0.82
Curtailment time [hour]	w/o DR	10	58	143	229
	With DR	0	33	107	184

Step3: Curtailment hour and energy

- When the PV installation was relatively small, most of the PV surplus could be consumed by the pumps.
- When PV installation became larger, the waterworks pumps could not consume all of the PV surplus power.
- About 2 MW PV can be installed additionally with same extent curtailment.



Summary

- This paper evaluated impact of DR of waterworks pumps to consume the PV surplus.
- Seasonal characteristics of water usage and PV surplus is important for analysis of pump DR.
- Fuel reduction by DR itself is not large, but the curtailment reduction leads to more PV installation.

Future work

- Forecast of PV generation and water usage and more sophisticated water level control.
- IoT sprinklers can control the water usage itself.

Thank you

- Please give me questions or comments!

http://www.city.miyakojima.lg.jp/kanko/annai/beach.html