Optimal Allocation of Angles of Panels for Reducing The Volatility

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Introduction: Background

<Instability>

Daily power generations of PV have volatility.
It's difficult to keep the power demand and supply balance.
Power Supply Large ⇒ Equipment Damage
Power Supply Small ⇒ Power Outage

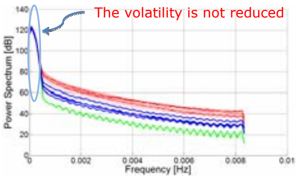
<Smoothing>

The total power generation of multiple PVs is smoothed.
⇒Possible Stable Power Supply
⇒Smoothing as much as possible

Introduction: Background

<Problem>

The Volatility is not reduced at low frequencies (Less Than 0.4mHz-0.5mHz)

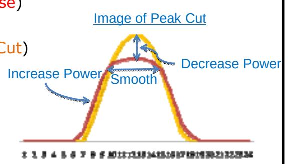


<Cause>

Morning or Evening:
Power Generation is Large
Noon:
Power Generation is Small
⇒ Daily Power Fluctuation is Large (Cause)

<Solution>

Cut The Peak Power Generation (Peak Cut)



<Effects of Peak Cut>

⇒ Daily Power Fluctuation will be small
⇒ The volatility will be reduced at low frequencies

Introduction: Objective

<How to Peak Cut>

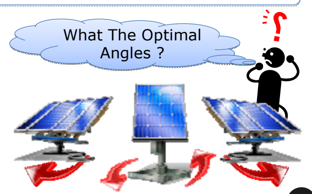
Set up panels directed in various directions
⇩
Time shift of maximum power generation
⇩
Instead decrease the maximum power generation at noon, increase power generation at other times

<Objective>

Optimal Allocation of Angles of Panels For Smoothing

<Approach>

- Apply "PIPIP" (Payoff-based Inhomogeneous Partially Irrational Play) for The Solution (Unnecessary Model)
- Spectral Analysis Using The Optimal Values by PIPIP (Evaluation of Smoothing)



Outline

- Introduction
- Apply PIPIP for Optimal Allocation of Angles
  - Problem Settings
- Simulation Results
  - Comparison of Sunny and Cloudy
  - Future Works

Problem Settings For PIPIP

<Agents i>

28 Cities:Tokyo,Oume,Fuchu,Hachioji,Nerima,
Ogouchi,Chichibu,Hatoyama,Koshigaya,
Kuki,Kumagaya,Saitama,Tokorozawa,
Yorii,Abiko,Chiba,Choshi,Funabashi,
kamogawa,Katsura,Kisaradu,Mobara,
Sahara,Sakahata,Sakura,Tateyama,
Ushiku,Yokoshiba

<Action>

$a_i(k)$:Angle θ_i of Agent i at Time k
$a_i \in A, i \in V, 0^\circ \le \theta_i \le 360^\circ$

<Utility Function>

$U_i(a_i(k))$:Variance of Power Generation
$\Pi_i(a) - \Pi_i(a') < 1, \forall a, a'$

<Search Rate ε>

$\varepsilon = 0.05$ (Constant)

<Parameters κ>

$\kappa = 0.5$ (Constant)

<Formula of Power Generation>

(Solar Radiation[$^{MJ}/_{m^2}$]) $\cdot$ (1 − Temperature Loss) $\cdot$ (1 − Loss) $\cdot$ (Installed Capacity)[kW]

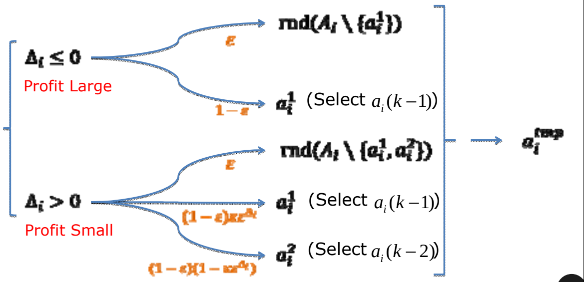
PIPIP

<Memory>

$U_i(a_i(k-2))$, $U(a_i(k-1))$, $a_i(k-2)$, $a_i(k-1)$

<Definition>

Δ_i : $U_i(a_i(k-2)) - U(a_i(k-1))$



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Simulation Results

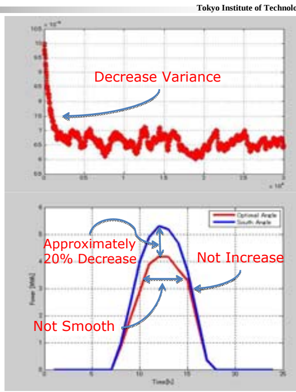
<Situation>

Weather: Sunny
Direction of Panels:
South (Blue Line)
Optimal Direction (Red Line)

- Peak Cut is Made
  - The peak power generation was decreased approximately 20%
- Not Increase Power
  - Power generation must increase other than peak time
- Not Smooth Around Peak

<Result>

Only total power generation was decrease.
No smoothing effects.



Simulation Results

<Situation>

Weather: Cloudy
Direction of Panels:
South (Blue Line)
Optimal Direction (Red Line)

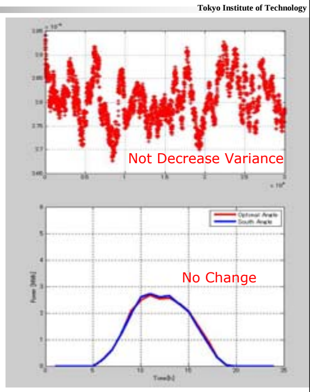
- Peak Cut is Not Made
- Not Decrease Variance
- There is Almost No Change

<Result>

No Change

<Cause of Simulation>

・Utility function is not well.
・Program of PIPIP is wrong.
・When weather is cloudy, strategy is less.
・When weather is cloudy, there is no peak.



Future Works

- Improve Utility Function
  - Could Not Peak Cut (if using only variance)
  - Constraint of Amount of Total Power Generation
- Analysis Using 1 Minute Value Data
  - PIPIP, Spectrum, …etc.
- Spectral Analysis
  - Evaluation and Analysis of Angles
- Apply The Learning Algorithm (Non-PIPIP) and Compare
  - Optimal Simple Experimentation Dynamics
  - Fictitious Play
  - Joint Strategy Fictitious Play
  - Joint Strategy Fictitious Play With Inertia
  - Regret Matching …etc.

References

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[2] 和佐,後藤,畑中,藤田,"ポテンシャルゲームに対する非合理的選択を含む学習アルゴリズムの設計と被覆制御問題への適用",計測自動制御学会第12回制御部門大会, 奈良,16th,Mar.,P0155,2012

[3] 七原,"大量導入時における太陽光、風力発電の出力変動特性",オペレーションズリサーチ,Vol.56,No.7,pp.375-380,2011.

[4] 畑中,藤田,"ゲーム理論的学習アルゴリズムに基づく最適再生可能エネルギー管理に関する考察",2012年度第1回高信頼制御通信研究会,岐阜,6th,June (to be presented)