Optimization Problem of PV's Allocation Based on The Game Theoretic Cooperative Control

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Background

<Political Background>

- Development of a micro grid concept [2]
- Spread of renewable energy [3,4]
- Abolition of a nuclear power plant

<Technical Background>

- Stable energy supply in the microgrid
- Suppress volatility of PV's output (FOCUS)
- Application to a micro grid (FOCUS)

Objective & Outline

<Objective of Research>

Determination of PV's allocation in the inside of a microgrid

<Outline>

It checks there is no change by years

<From Result>

- Suppress volatility of PV's output efficiently
- Stabilization of an electric power system

Problem Setting 1

Player Set : $v = \{i | \ 1 \le i \le 100 \, , i \in \mathbb{N}\}$

Action Set : $\mathcal{A}_i = \{a_i | \ 1 \le a_i \le 630 \, , a_i \in \mathbb{N}\}$

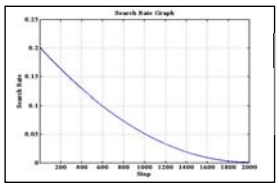
Power Spectrum Density (PSD) : $R(a_i)$

Power : $P(a_i)$

Utility Function : $U(a) = -\sum_j R(a_i) + w_1 \sum_k P(a_i)$

Learning Algorithm : PIPIP [1]

Data (1 Year) → PSD → Utility



$a = (a_1, \cdots, a_{30})$

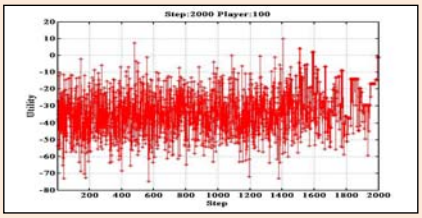
$f = 0.3\text{Hz} \sim 0.4\text{Hz}$

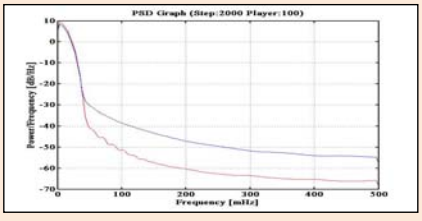
j, k is element of R, P

w is weighting factor

・Each player selects a solar panel

Result of Simulation (1/7)





<Assumption>

Step : **2000**

Player : **100**

Data : **1 year**

Utility : **PSD, Power**

<Result>

Effect : **94%**

Time Required : **4 Days**

Problem Setting 2

Player Set : $v = \{i | \ 1 \le i \le 30 \, , i \in \mathbb{N}\}$

Action Set : $\mathcal{A}_i = \{a_i | \ 1 \le a_i \le 480 \, , a_i \in \mathbb{N}\}$

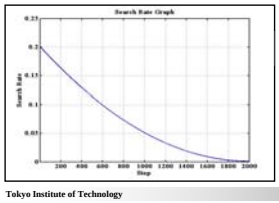
Fourier Spectrum (FS) : $Y(a_i)$

Power Spectrum (PS) : $G(a) = |\sum_{i \in v} Y(a_i)|^2$

Utility Function : $U(a) = -\sum_f G(a)$

Learning Algorithm : PIPIP [1]

Data (3 Month) → FS $Y_i(a_i)$ → FS $\sum Y_i(a_i)$ → PS $|\sum Y_i(a_i)|^2$ → Utility



$a = (a_1, \cdots, a_{100})$

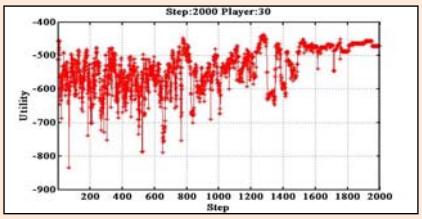
$f = 0.3\text{Hz} \sim 0.5\text{Hz}$

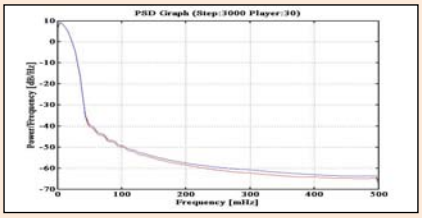
・Remove the broken solar panel

・PS is used instead of PSD

・The player was reduced

Result of Simulation (2/7)





<Assumption>

Step : **2000**

Player : **30**

Data : **Mar - May**

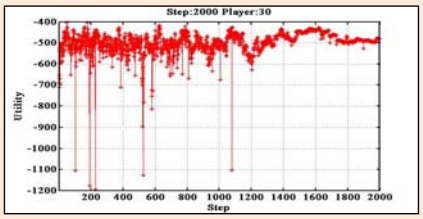
Utility : **PS**

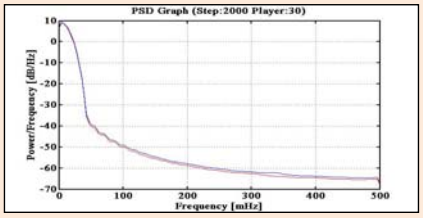
<Result>

Effect : **19%**

Time Required : **4H**

Result of Simulation (3/7)





<Assumption>

Step : **2000**

Player : **30**

Data : **Jun - Aug**

Utility : **PS**

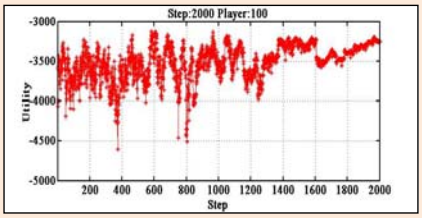
<Result>

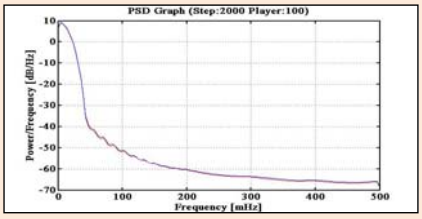
Effect : **26%**

Match Rate : **16%**

Time Required : **4H**

Result of Simulation (4/7)





<Assumption>

Step : **2000**

Player : **100**

Data : **Mar - May**

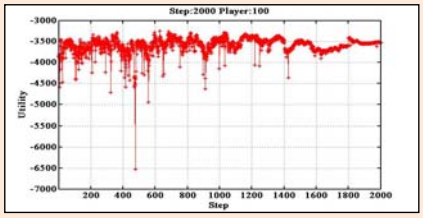
Utility : **PS**

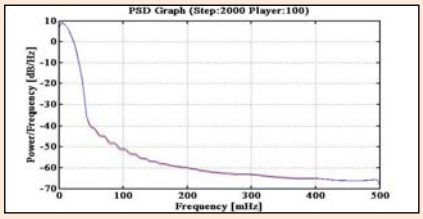
<Result>

Effect : **15%**

Time Required : **12H**

Result of Simulation (5/7)





<Assumption>

Step : **2000**

Player : **100**

Data : **Jun - Aug**

Utility : **PS**

<Result>

Effect : **3%**

Match Rate : **20%**

Time Required : **12H**

Problem Setting 3

Player Set : $v = \{i | \ 1 \leq i \leq 50 \ , i \in \mathbb{N}\}$

Action Set : $\mathcal{A}_i = \{a_i | \ 1 \leq a_i \leq 480 \ , a_i \in \mathbb{N}\}$

Fourier Spectrum (FS) : $Y(a_i)$

Power Spectrum (PS) : $G(a) = |\sum_{i \in v} Y(a_i)|^2$

Utility Function : $U(a) = -\sum_f G(a)$

Learning Algorithm : PIPIP [1]

Data (3 Month)

↓

FS $Y_i(a_i)$

↓

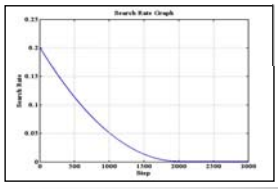
FS $\sum Y_i(a_i)$

↓

PS $|\sum Y_i(a_i)|^2$

↓

Utility

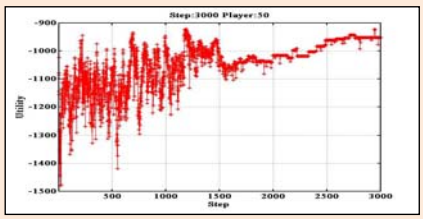


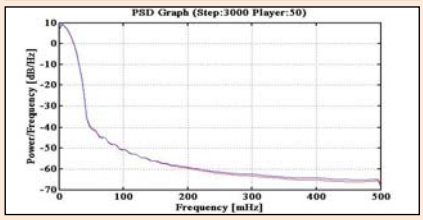
$a = (a_1, \cdots, a_{100})$

$f = 0.3\text{Hz} \sim 0.5\text{Hz}$

- The step was increased
- PS is used instead of PSD
- The player was increased

Result of Simulation (6/7)





<Assumption>

Step : **3000**

Player : **50**

Data : **Mar - May**

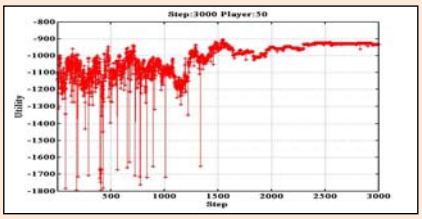
Utility : **PS**

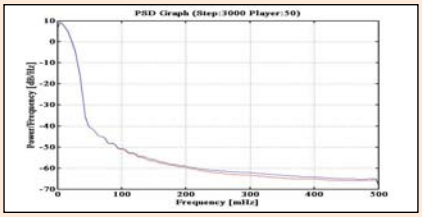
<Result>

Effect : **17%**

Time Required : **8H**

Result of Simulation (7/7)





<Assumption>

Step : **3000**

Player : **50**

Data : **Jun - Aug**

Utility : **PS**

<Result>

Effect : **20%**

Match Rate : **22%**

Time Required : **8H**

Consideration

- It is difficult only for PS to estimate (Except Sim 1)
- The difference of PS is small when there are many players (Except Sim 1)
- Each match rate is low (Except Sim 1)
- It is good to do Step by 3000 (Sim 6,7)
- The judgment by a season may be difficult (Except Sim 1)
- It takes time too much
- Since there are too many data rows, a memory is lacking
- It may improve by change of Utility Function

Future Work

- The check of the effect by the following situations

<Situation 1>
Player : **100**
Step : **2000**
Utility : **PSD + Power**
Data : **1 Year (2006)**
◇Comparison
with simulation 1

<Situation 2>
Player : **100**
Step : **3000**
Utility : **PS + Power**
Data : **3 Month**
◇The check of the
effect by a season

<Situation 3>
Player : **100**
Step : **3000**
Utility : **PSD + Power**
Data : **3 Month**
◇ Comparison
with situation 2

<Situation 4>
Player : **100**
Step : **3000**
Utility : **PS + Power**
Data : **1 Year**
◇Comparison
with situation 1

Reference

[1] T. Goto, T. Hatanaka and M. Fujita, "Payoff-based Inhomogeneous Partially Irrational Play for Potential Game Theoretic Cooperative Control: Convergence Analysis," *Proc. of 2012 American Control Conference*, pp. 2380-2387, 2012.

[2] T. Hatanaka, Y. Wasa and M. Fujita, "Game Theoretic Cooperative Energy Network Management for Distributed Microgrids: Variability Reduction of Photovoltaic Generation," *Proc. of the 2013 American Control Conference*, submitted.

[3] NEDO, "太陽光発電ロードマップ," 2009.

[4] 資源エネルギー庁, "我が国における再生可能エネルギー," 2012.