EMS ENERGY Management SYSTEM

HARPS

Project Members

As of October 2016, 132 members (including 53 Graduate and Undergraduate students)

Adviser		
Yutaka Iino	Chief Specialist	Toshiba Corporation Infrastructure Systems & Solutions Company

Imura Group		
Jun-ichi Imura	Professor	Tokyo Institute of Technology
Takayuki Ishizaki	Assistant Professor	Tokyo Institute of Technology
Tomonori Sadamoto	Adjunct Assistant Professor	Tokyo Institute of Technology
Xin-Zhi Zheng	Research Director/ Researcher	Advanced Science, Technology & Management Research Institute of KYOTO/Tokyo Institute of Technology
Gou Nishida	Associate Professor	Nihon University
Masakazu Koike	Assistant Professor	Tokyo University of Marine Science and Technology
Masaki Inoue	Assistant Professor	Keio University
Karl H. Johansson	Professor	KTH Royal Instiue of Technology
Henrik Sandberg	Professor	KTH Royal Instiue of Technology
Nacim Ramdan	Professor	Universite d'Orleans
Akiho Setoguchi	Technical Assistant	Tokyo Institute of Technology
Noriko Sugimoto	Secretary	Tokyo Institute of Technology

Azuma Group		
Shun-ichi Azuma	Associate Professor	Kyoto University
Ichiro Maruta	Assistant Professor	Kyoto University
Kazuhiro Sato	Program-Specific Researcher	Kyoto University
Chihiro Inamoto	Assistant Technical Staff	Kyoto University
Yuki Minami	Assistant Professor	Nara Institute of Science and Technology
Shinsaku Izumi	Assistant Professor	Okayama Prefectural University
Koichi Kobayashi	Associate Professor	Hokkaido University
Kazunori Sakurama	Associate Professor	Tottori University
Masashi Miura	Assistant Professor	Tottori University

Ueda Group		
Yuzuru Ueda	Junior Associate Professor	Tokyo University of Science
Kosuke Uchida	Assistant Professor	Tokyo University of Science
Jindan Cui	Project Researcher	Tokyo University of Science
Ryota Watanabe	Research Assistant	Tokyo University of Science
Takahiro Sasaki	Research Assistant	Tokyo University of Science

Ohta Group		
Yoshito Ohta	Professor	Kyoto University
Kenji Kashima	Associate Professor	Kyoto University
Kentaro Ohki	Assistant Professor	Kyoto University
Kiyotsugu Takaba	Professor	Ritsumeikan University
Nobuyuki Hattori	General Manager	DAIHEN Corporation
Akihiro Ohori	Chief Engineer	DAIHEN Corporation
Kenji Hirata	Associate Professor	Nagaoka University of Technology

Kojima Group		
Akira Kojima	Professor	Tokyo Metropolitan University
Kotaro Hashikura	Specially Appointed Assistant Professor	Tokyo Metropolitan University

Sugihara Group		
Hideharu Sugihara	Associate Professor	Osaka University
Tsuyoshi Funaki	Professor	Osaka University
Toshiyuki Miyamoto	Associate Professor	Osaka University

Suzuki Group		
Hideyuki Suzuki	Associate Professor	Osaka University
Kazuyuki Aihara	Professor	The University of Tokyo
Yoshito Hirata	Project Associate Professor	The University of Tokyo
Gouhei Tanaka	Project Associate Professor	The University of Tokyo
Naoya Fujiwara	Assistant Professor	The University of Tokyo
Bing Wang	Associate Professor	Shanghai University

Zoka Group		
Yoshifumi Zoka	Associate Professor	Hiroshima University
Masataka Miyake	Associate Professor	Hiroshima University
Yutaka Sasaki	Assistant Professor	Hiroshima University
Hans Jürgen Mattausch	Professor	Hiroshima University
Michiko Miura	Specially-appointed Professor	Hiroshima University
Naoto Yorino	Professor	Hiroshima University
Shinya Sekizaki	Assistant Professor	Hiroshima University
Fumio Watanabe	Technical Staff	Hiroshima University

Hara Group		
Shinji Hara	Professor	The University of Tokyo
Koji Tsumura	Associate Professor	The University of Tokyo
Chiaki Kojima	Assistant Professor	The University of Tokyo
Binh Minh Nguyen	Researcher	The University of Tokyo
Yoshihiko Susuki	Associate Professor	Osaka Prefecture University
Xin Xin	Professor	Okayama Prefectural University
Daisuke Tsubakino	Associate Professor	Nagoya University

Masuta Group		
Taisuke Masuta	Associate Professor	Meijo University
Masahiro Ishihara	Chief Researcher	The Institute of Applied Energy
Kenichiro Usui	Chief Researcher	The Institute of Applied Energy
Kazutaka Kawase	Chief Researcher	The Institute of Applied Energy
Takeshi Kishishita	Chief Researcher	The Institute of Applied Energy
Takuya Fukumi	Researcher	The Institute of Applied Energy

Murata Group		
Akinobu Murata	Group Leader	National Institute of Advanced Industrial Science and Technology
Takashi Oozeki	Group Leader	National Institute of Advanced Industrial Science and Technology
Susumu Shimada	Researcher	National Institute of Advanced Industrial Science and Technology
Hideaki Ohtake	Researcher	National Institute of Advanced Industrial Science and Technology
Fumichika Uno	Researcher	National Institute of Advanced Industrial Science and Technology
Yuya Takane	Researcher	National Institute of Advanced Industrial Science and Technology
Yoshinori Yamada	Head of the 1st Laboratory	Forecast Research Department
Kenichi Shimose	Researcher	National Research Institute for Earth Scienece and Disaster Prevention
Joao Fonseca	Project Assistant Professor	The University of Tokyo
Yukihiro Kikegawa	Professor	Meisei University

Yamaguchi Group		
Nobuyuki Yamaguchi	Junior Associate Professor	Tokyo University of Science
Takeshi Murata	Managing Director	National Institute of Information and Communications Technology
Michiko Ishizuka	Technician	Tokyo University of Science

Inquiry

Imura Laboratory
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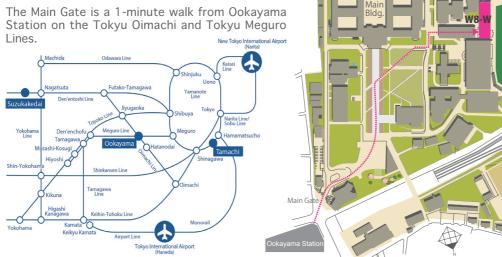
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Web site

For more information on our research, please see the following website.
http://harps-crest.jpn.org/

Access

Tokyo Institute of Technology Ookayama Campus

The Main Gate is a 1-minute walk from Ookayama Station on the Tokyu Oimachi and Tokyu Meguro Lines.

Main Bldg.
W8-W
Main Gate
Ookayama Station

New Tokyo International Airport (Narita)
Machida
Odawara Line
Nagatsuta
Suzukakedai
Den'entoshi Line
Futako-Tamagawa
Keisei Line
Shinjuku
Ueno
Yamanote Line
Tokyu Toyoko Line
Jiyugaoka
Shibuya
Tokyo
Narita Line/ Sobu Line
Yokohama Line
Den'enchofu Line
Tamagawa
Meguro Line
Meguro
Hamamatsucho
Ookayama
Hatanodai
Tamachi
Musashi-Kosugi
Hiyoshi
Shinagawa
Shin-Yokohama
Shinkansen Line
Kikuna
Tamagawa Line
Oimachi
Higashi Kanagawa
Keihin-Tohoku Line
Monorail
Yokohama
Kamata
Keikyu Kamata
Airport Line
Tokyo International Airport (Haneda)

System Theory
for Harmonized Power System Control
Based on Photovoltaic Power Prediction

Research Area : Creation of Fundamental Theory and Technology to Establish a Cooperative Distributed Energy Management System and Integration of Technologies Across Broad Disciplines Toward Social Application

Project Duration : April 2015 - March 2020

System Theory for Harmonized Power System Control Based on Photovoltaic Power Prediction

Principal Investigator Jun-ichi Imura

OUTLINE OF RESEARCH PROJECT

The main purpose of this research project is to **develop a system theory of next generation power system control** in order to **achieve a harmonized power supply under large penetration of photovoltaic (PV) power systems**. In particular, this project aims to develop a power system control framework and methodology, fully exploiting **PV/demand power prediction**, and focusing on, in addition to both system operation and user layers, **functions and properties of a middle layer** (called as a harmonized aggregator) consisting of various kinds of power aggregators such as demand-response aggregators, electricity-trade balancing groups, and cooperative electric power converters. This research is performed from **the following five viewpoints**: PV power prediction, supply and demand control, consumer-side control, control of power transmission and distribution systems, and basic system theory.

GOAL

The goal of this research project is to develop <u>a basic theory to realize electric power system control that harmonizes the entire system</u> in terms of economy, environmental friendliness, resilience, fairness, and comfort to users, <u>even under uncertainty in PV generation predictions</u>. This provides a fundamental framework for a future power control system that allows us to continuously introduce <u>PV power up to 102 GW</u> (50% of the current consumption power of Japan), where a target of PV 64 GW set by the Japanese government for the year 2030 is regarded as a checkpoint, and that can be further developed for achieving a stable supply against PV power that is more than 102 GW. The specific targets of this project are to develop the following:

- Electric Power System Design: <u>A system design theory</u> composed of <u>system operation, middle, and user layers</u>.
- Prediction Technology: <u>A PV power prediction technology</u> adapted for power system control techniques that achieve a stable power supply.
- Control Technology: <u>A power system control theory and technology to realize a harmonized stable power supply</u> by fully exploiting PV power prediction.

APPROACH

To accomplish the goal of this research, we perform researches centered on the following two main topics, as shown in Fig. 1:

(A) <u>(Harmonized electric power system control using PV power prediction)</u>
Development of electric power system control theory and technology based on PV power prediction including large errors, to achieve a harmonized stable power supply from the perspective of economy, environmental friendliness, resilience, fairness, and comfort.

(B) <u>(Electric power system design including a middler layer)</u>
Development of system design theory to optimize the entire electric power system by focusing on the role of various aggregators in the middle layer, which is created as the third function neither included in the system operation layer nor the user layer with reference to changes in electric system structures such as large penetration of PV generators and batteries, the electricity deregulation, and the unbundling of electricity generation and transmission.

By developing a collaboration room that realizes powerful collaborative research through electric power simulations, we can offer a new collaborative research method for developing new cooperative control techniques of electric power systems, as shown in Fig. 2.
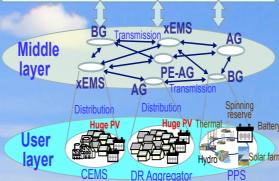

Fig. 1 Framework of next generation electric power system control

To achieve the research target according to the above two topics, the research is exaecuted according to the following five unit groups, as shown in Fig. 3.

PV Prediction Unit
Develops high precision PV generation forecasting and estimation technology for the entire spatial-temporal scale, merging large-scale generation data, and variety of weather resources.

Supply and Demand Control Unit:
Clarifies the roles of conventional power sources under the next generation supply and demand control/operation, and <u>realizes cooperative control techniques with the conventional and other regulating power resources</u>.

Demand-Side Control Unit:
Develops basic theory and technology for <u>cooperatively utilizing the flexibilities of power consumption of consumers having PV generators and batteries</u> under ensured comfort and fairness. This achieves the demand-side control in order to balance the system supply and demand.

Control of Transmission and Distribution Grids Unit:
Develops theory and technology to solve the stable operation problem of transmission and distribution grids (synchronized stability, overload, voltage, etc.), taking into account the spatial output fluctuation characteristics of PV generation and its power prediction capability.

Basic System Theory Unit:
Develops basic system theory and technology for optimally designing the entire <u>system composed of the system operation, middle, and user layers</u>, from various perspectives such as system, integrity, and stability.

Fig. 2 Collaboration room
Fig. 3 Five research units

ORGANIZATION STRUCTURE

Cross-disciplinarily connection of studies

MurataG
Suzuki G
Masuta G
Kojima G
Ueda G
Azuma G
Imura G
Sugihara G
Ohta G
Zoka G
Hara G
Yamaguchi G

G: Group
U: Unit

Post-Doctor Researchers
・Studies beyond the groups

PV Prediction U UL: A.Murata
Supply and Demand Control U UL: T.Masuta
Demand-Side Control U UL: Y.Ueda
Control of Transmission and Distribution Grids U UL: H.Sugihara
Basic System Theory U UL: S.Hara

Collaboration Room@TUS
As a cornerstone for fusion of different fields
Coordinators: Yamaguchi, Ueda
・Research meetings, Seminars, etc.

Management organization PI: J. Imura
Meetings for Unit Leaders, Meetings for Group Leaders, Research Policies, Promotions of Units Collaboration, Information Disclosure, Enlighten Research Activities etc.

Bridging the study and society

Office (Tokyo Tech)
・Meeting management
・Website maintenance
・Outreach(Publication etc.)

Towards practical implementation

Consortium
Comments from Companies and Specialists

Towards development of young researchers

Globalizing research collaboration

International Research Collaboration
・KTH(SW), COOPS(IT), Univ. of Orleans(FR) Clemson Univ.,CMU,MIT,NCSU,WSU(US)
・International WS etc.

Seminar, Workshop
Different field study groups for young researchers etc.

INTERNATIONAL COLLABORATION

Prof. N. Ramdani (Univ. of Orleans)
Prof. K. Johannson (KTH Royal Inst. of Tech.)
Dr. Roberto Tempo (CNR-IEIIT)
Prof. C.-C. Liu (Washington State Univ.)
Prof. M. Ilic (Carnegie Melon Univ.)
Prof. A. Annaswamy (MIT)
Prof G. K. Venayagamoorthy (Clemson Univ.)
Prof. A. Chakrabortty (NC State Univ.)

GROUP LEADERS

Jun-ichi Imura Tokyo Instute of Technology
(Principal Investigator)
Middle layer based power system control theory

Hideyuki Suzuki Osaka University
Nonlinear science of power grids and photovoltaic power prediction

Shun-ichi Azuma Kyoto University
Design principles of demand response

Yoshifumi Zoka Hiroshima University
Enabling improved electricity-supply flexibility of the grid by expanded and highly efficient utilization of power electronics
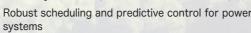
Yuzuru Ueda Tokyo University of Science
(Unit Leader on Demand-side Control, Collaboration Room Coordinator)
Development of the harmonized EMS by utilizing demand side diversity
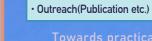
Shinji Hara The University of Tokyo
(Unit Leader on Basic System Theory)
Development of hierarchical decentralized aggregators

Yoshito Ohta Kyoto University
A study on efficient power transmission and distribution with high quality - theory and experimental verification

Taisuke Masuta Meijo University
(Unit Leader on Demand and Supply Control)
Advanced demand and supply control in future power systems

Akira Kojima Tokyo Metropolitan University
Robust scheduling and predictive control for power systems

Akinobu Murata AIST
(Unit Leader on PV Prevention)
High accuracy PV power monitoring and forecasting technologies for the whole spatio-temporal scale

Hideharu Sugihara Osaka University
(Unit Leader on Control of Transmission and Distribution Grids)
Methodologies for evaluating middle layer entities in T&D networks

Nobuyuki Yamaguchi Tokyo University of Science
(Collaboration Room Coordinator)
Technical and economical decision making on power systems through a middle layer