Development of Methodologies for Cooperative Energy Management System Using Simulation Model and Distribution NW Simulator

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ACROSS: **A**dvanced **C**ollaborative **R**esearch **O**rganization for **S**mart **S**ociety

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ACROSS: Advanced Collaborative Research Organization for Smart Society

7 Research Institutes
in WASEDA Univ.

Yasuhiro HAYASHI
Chairperson of ACROSS
Research Institute for Advanced Network Technology (RIANT)

Yoshiharu AMANO
Research Institute for Power and Energy Systems

Shin-ichi TANABE
Research Institute for Building Environmental Design

Shinji WAKAO
Research Institute for Photovoltaic Power Generation System

Toshiyuki OKANO
The Smart Life Science Institute

Yushi KAMIYA
Research Institute of Electric-driven Vehicles

Ayu WASHIZU
Institute for Economic Analysis of Next-generation Science and Technology

PA-SST **17 companies**
(Promotion Association for Smart Society Technology)
Infrastructure companies

AsahiKASEI | NTTグループ | 大阪ガス
Daigas | 関西電力 | 九州電力
KDDI | JX Nippon Oil & Energy | 住友林業
SEKISUI | | 中部電力
TOKYO GAS | 東京電力 | 東北電力
野村不動産 | 三井不動産

SG-SST **18 companies**
(Study Group for Smart Society Technology)
Manufacturing companies with various development technology

アドソル日進 | OMRON | KYOCERA
住友電工 | DAIKIN | DENSO
東光高岳 | TOSHIBA Leading Innovation >>> | TOYOTA
NEC | Panasonic | HITACHI Inspire the Next
FUJITSU | 富士電機 | 三菱電機
明電舎 | OSAKI | azbil

Advanced research at university

Social Framework

Technology, Products

Innovation of technology fusion ···· **Shinjuku EMS R&D Center**

Implementation to Society, National projects, etc.

Creating the NEW social value from the view point of energy consumers/customers and global market

➢ **Changing Role of Smart Grid after The Great East Japan Earthquake**

➢ **Development of EMS method cooperated with grid EMS and HEMS by simulation model and distribution NW simulator**

➢ **Waseda University Shinjuku EMS R&D center**

➢ **JST R&D Project of Advanced EMS by Japanese Universities Team**

Before "3.11"
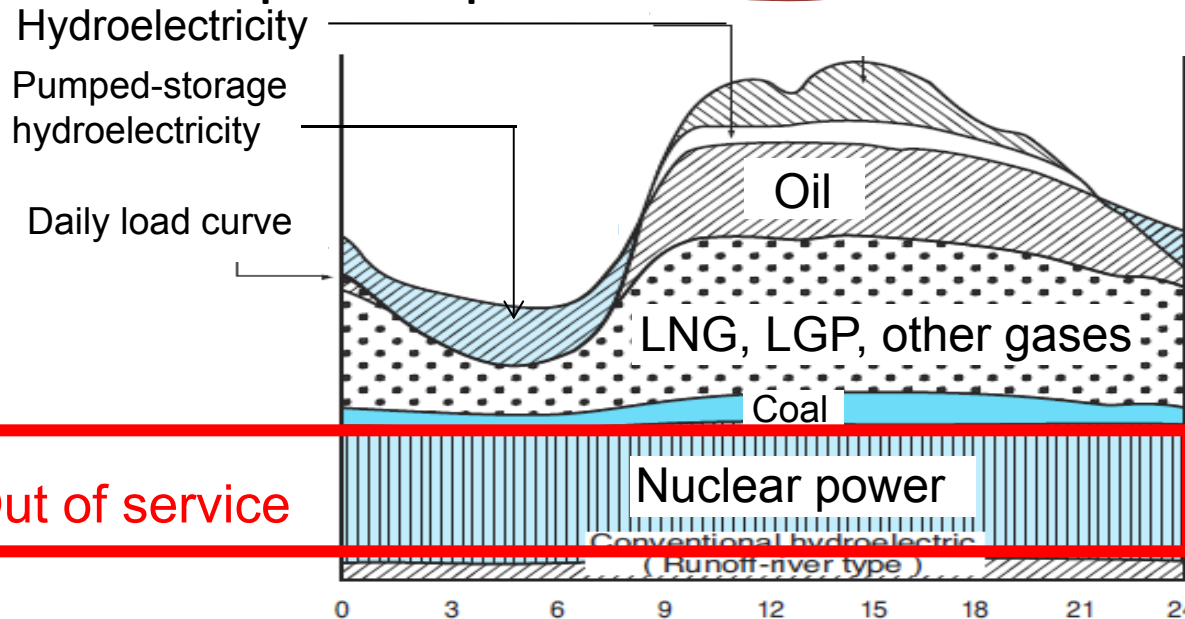
For low carbon society

- ✓ **Installation of high-efficiency of equipment & appliances**
- ✓ **Integration of renewable energy and EV/PHV**
- ✓ **Balancing demand-supply for electricity & gas** etc.

+

After "3.11"

- ☐ **Renewable energy (FIT in 2012)**
- ☐ **Electricity saving and peak cut**
- ☐ **Demand Response**
- ☐ **Energy Management Systems**

***The Great East Japan Earthquake**

Hydroelectricity

Pumped-storage hydroelectricity

Daily load curve

Oil

LNG, LGP, other gases

Coal

Nuclear power

Conventional hydroelectric (Runoff-river type)

Out of service

Missing significant amount of base load supply

0   3   6   9   12   15   18   21   24

	FY2015	FY2020	FY2030
PV penetration (2012 FIT)	Operating capacity 10GW Certificated capacity 70GW Suppress 360 hours/y rule	Target: 28 GW	Target: 53 GW
Smart meter	Now Installing	**2020** TEPCO 27M	**2023** All 77M
DR	**2015** Nega-watt trading guideline		
Electricity System Reform	**2015 OCCTO** Organization for Cross-regional Coordination of Transmission Operators	**2016** Electricity full liberalization of retail market **2020** Unbundling of Generation and T&D Network sectors	
EV/PHEV diffusion		15-20% of sales	20-30% of sales
CGS diffusion		17.1 GW 81 billion kWh	31.4GW 154 billion kWh

Pumped-up Hydro Power

Hydro Power

Thermal Power

Electric Power NW (Power Grid)

③ Upgrading TD-network

① Expansion of Renewables

Control by ICT

Smart Community

Smart Building

Buildings with PV
CGS   Battery

② Demand Response

Smart House

PV

HP Water Heater

HEMS   AC

Battery   EV   Fuel Cell

Energy storage

Substation

Smart meter

PV Power Station

Wind Farm

Renewable Energy Sources

Environmental Impact

Impact of Smart Grid

Evaluation value

Energy Cost

Power Quality Issue (frequency, voltage)

Scheme for electricity saving With incentive

ICT Measurement & Control

【Optimal cooperation of distributed EMSs】
Energy Management System EMS

ICT Measurement & Control

GEMS   Grid

BEMS   Building

HEMS   Home

CEMS   Community

Advanced GEMS

6.6kV   **LRT, SVR**   **LVR**

PV

100/200V

Upper limit

Voltage

Pricing

P flow

Lower limit

Line length

Cooperative EMS Method of GEMS & HEMS

Smart meter

Next Day NW Load and PV Forecast
Next Hour V control Parameters Plan
Real Time Voltage Control
Expansion of PV installation

Advanced HEMS

Peak shift by DR based on TOU and FIT

Reverse PV power flow

PV

INV   **AC**   [W]

HEMS

HWHP

EV   **BESS**

E V
A E
C V
H
P

time

Next Day Load and PV Forecast
Next Day Operational Plan
Real time Equipment Control
Expansion of demand suppression

PV, Demand [MW]

Demand suppression

+

PV introduction

0   3   6   9   12   15   18   21   24

EMS
ENERGY
Management
SYSTEM

Propose of cooperative EMS method by GEMS and HEMS

| Forecast model GEMS/HEMS | → | Planning model GEMS/HEMS | → | Control model GEMS/HEMS |
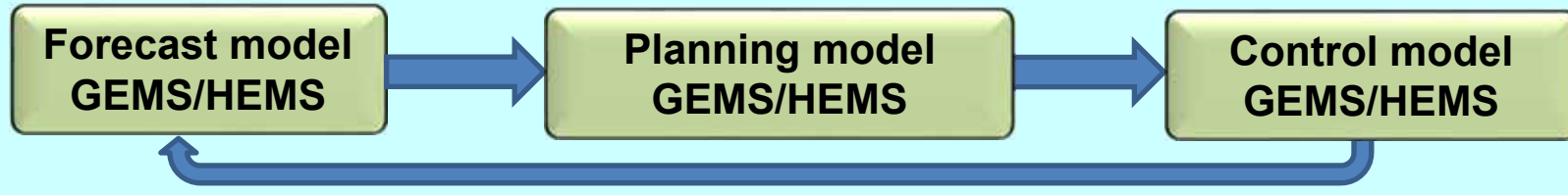
Introduction

Test Platform of cooperative EMS method

Integrated simulation model

Grid EMS model
✚
Home EMS model

System Link

Distribution NW simulator

Real time voltage control by GEMS/HEMS
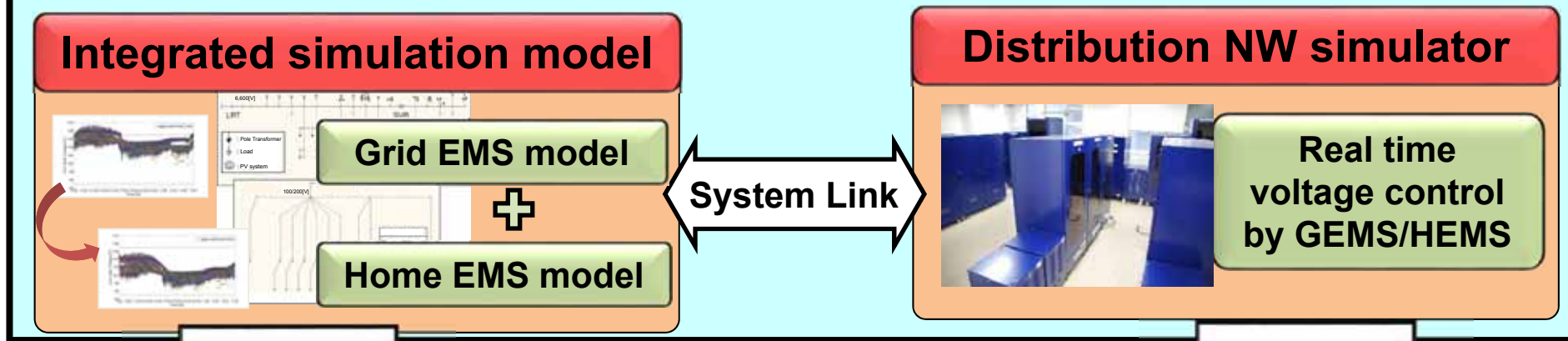
Evaluation

Evaluation

Evaluation of EMS method

Theoretical aspect

Amounts of
• PV introduction
• Peak demand suppression

Consumer's demand

Total demand   Target value

PV introduction

0 3 6 9 12 15 18 21   Time
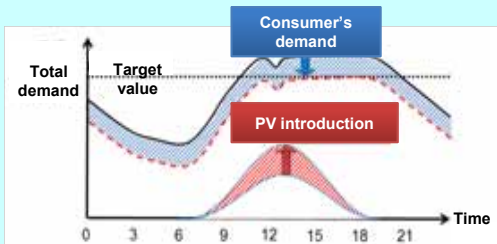
Practical aspect

Control possibility of
• PV introduction
• Peak demand suppression

Proposed GEMS method

Proposed HEMS method

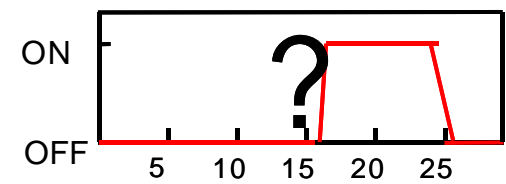Introduction

Introduction

Integrated simulation model

MV-network

Residential area

Pole trans 6750/105V

Pole trans 6600/105V

N21

N1 N2 N3 N4 N5 N6 N7 N8 N9 N10 N11 N12 N13 N14 N15

N16 N18 N20 N22 N24 N25

LRT N17 N19 N23 SVR N26

N27

N28

GEMS

LV-network

LVR

Unit : m

29.7 43 19.7 12.6 27.8 46.2 25 50 43.2 30.2

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

15 min. intervals data

Smart House
with HEMS, PV, FC and AC

AC

HEMS

PV

FC

Smart meter

Output

Output

Total load : 2971 kVA
- ✓ **MV-customers : 14**
- ✓ **LV- smart house customers : 479**
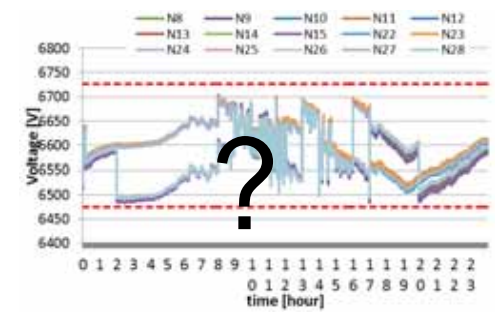
Daily voltage profile

Daily primary energy consumption
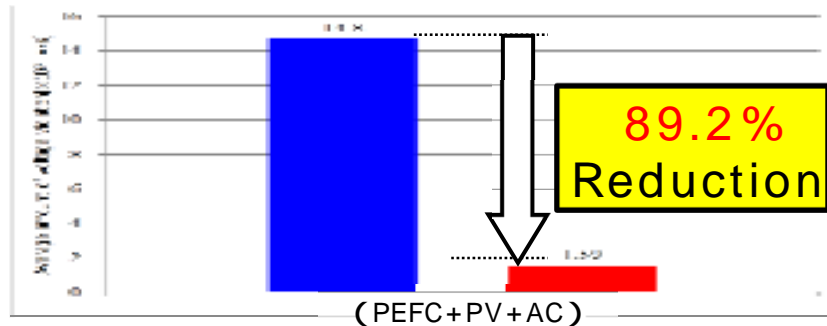

FC state

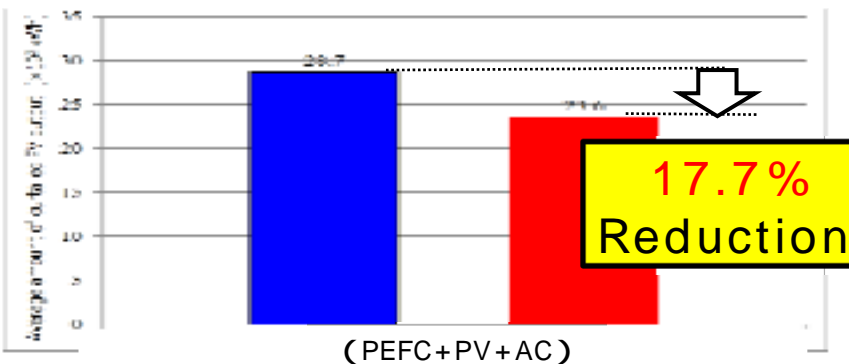## Introduction effects of GEMS for one month (January)
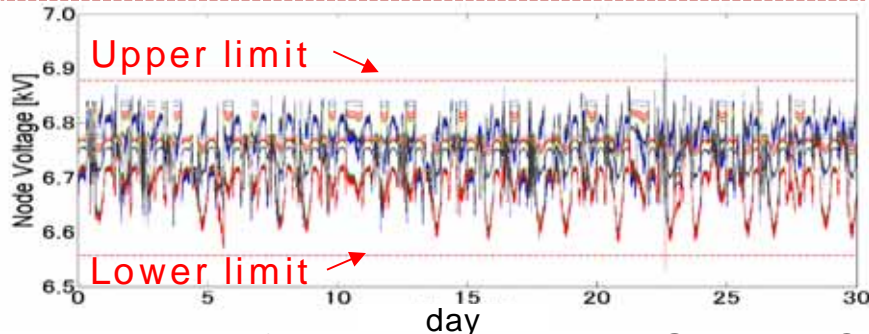
Voltage profiles by proposed Grid EMS

89.2% Reduction

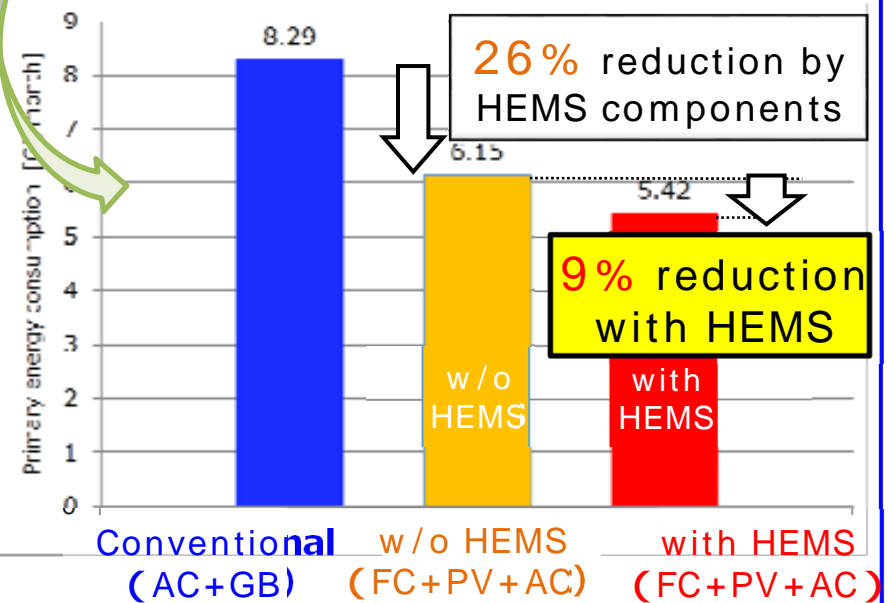Average amount of voltage violation[V s]

17.7% Reduction

Average amount of curtailed PV output[kWh]

Introduction effects of HEMS for one month (January)

Power consumption [kW]

26% reduction by HEMS components

9% reduction with HEMS

Conventional AC+GB) — w/o HEMS FC+PV+AC) — with HEMS FC+PV+AC

Primary energy consumption [GJ]

Development EMS method

Implement

Evaluate

NO
Directly implement

Impossible to directly install

Actual power network

Practical use
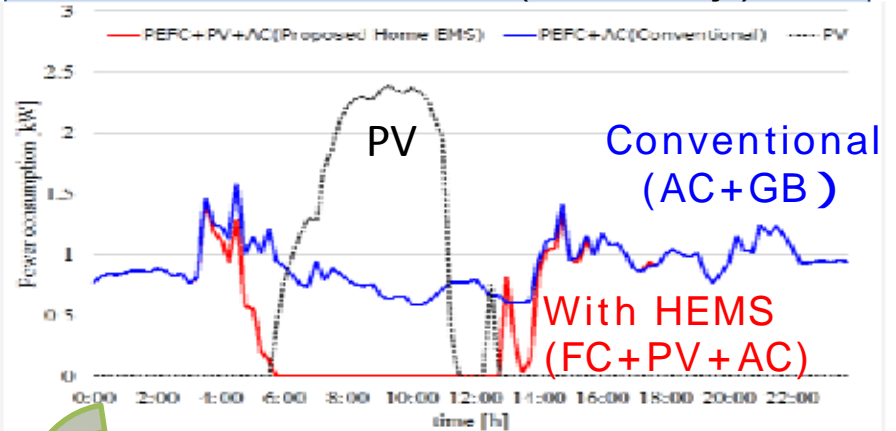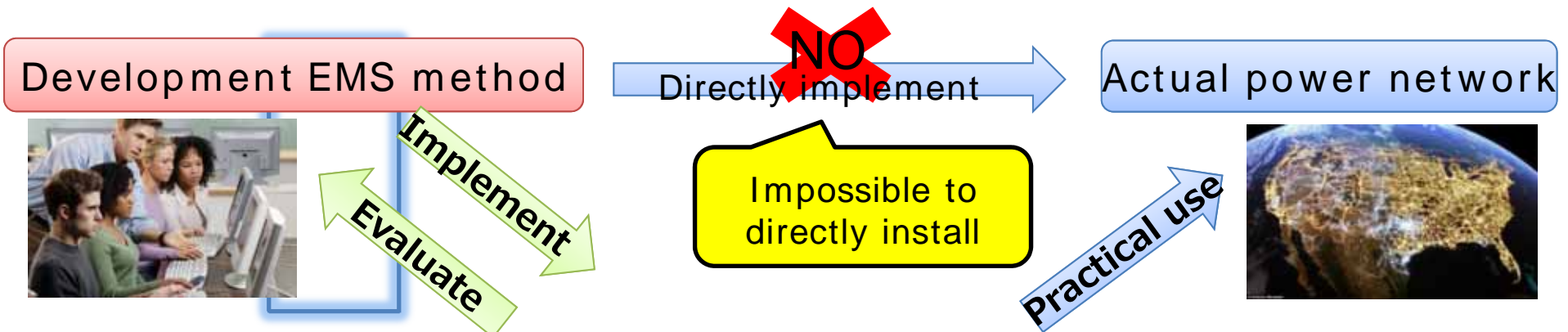
Distribution NW simulator "ANSWER"
Active **N**etwork **S**imulator **W**ith **E**nergy **R**esources

Inverter for Load/PV

Auto voltage regulator (AVR)

Step Voltage regulator (SVR)

Low voltage regulator (LVR)

Line impedance device
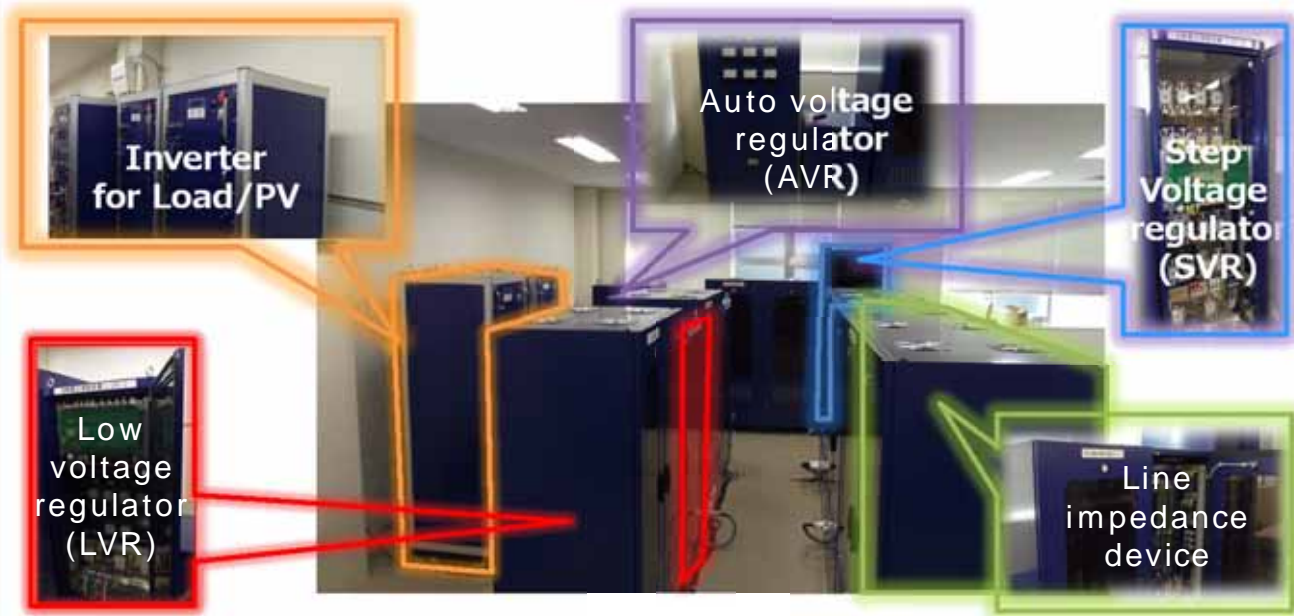
		Simulator
MV:	6600V	**400V**
LV:	200V	**200V**

Free selection
Freely choose the components

Free connection
- Freely connect components electrically on information communication environment

Free testing
- Freely test EMS method in freely built network

■ **Enable to implement control model built by MATLAB Simulink on simulator**
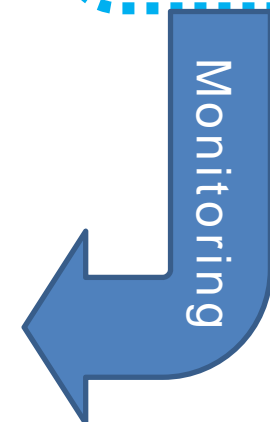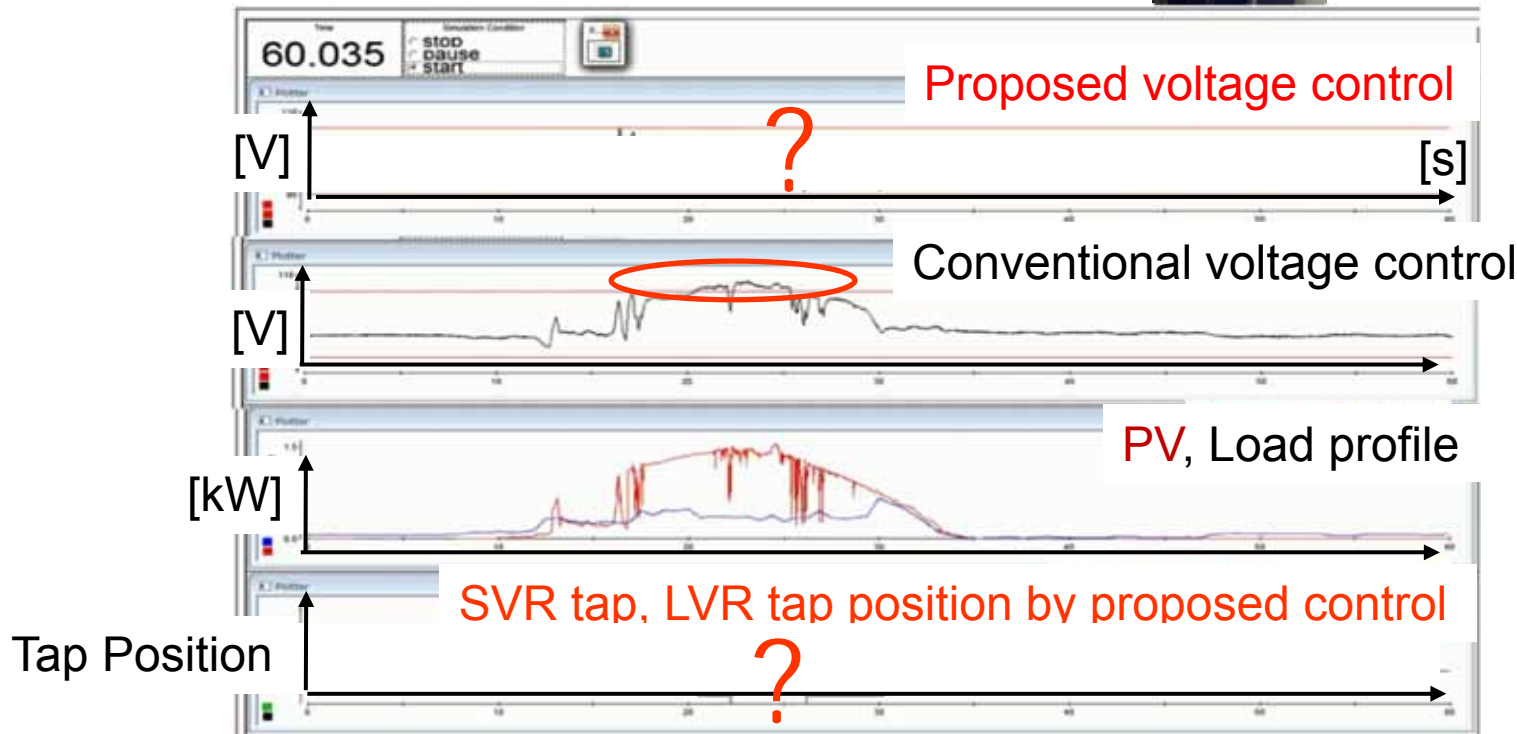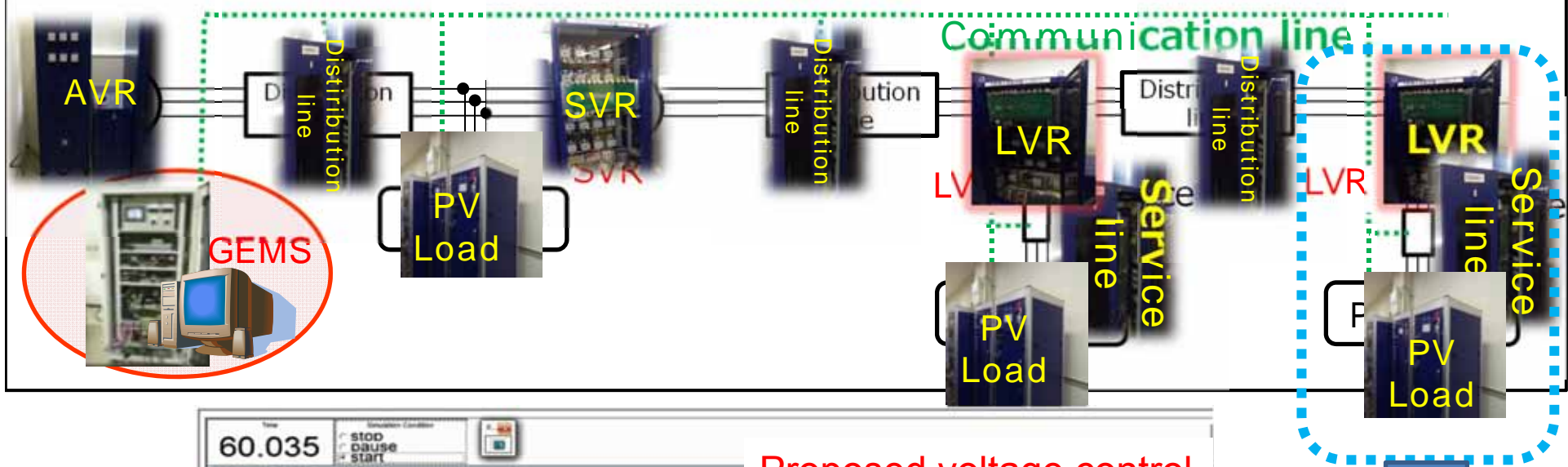
Distribution NW Simulator
"ANSWER"

25 companies

WASEDA University　経済産業省

AsahiKASEI　Ad-Sol NissIn　大阪ガス　OMRON　関西電力

KDDI　九州電力　SHARP　住友電工　DAIKIN

中部電力　DENSO　東京電力　TOKYO GAS　TOSHIBA Leading Innovation

TOYOTA　NISSAN　NTT　NEC　Panasonic

HITACHI Inspire the Next　FUJITSU　MITSUBISHI MOTORS　MRI　MITSUBISHI Changes for the Better

Waseda University Shinjuku EMS R&D Center
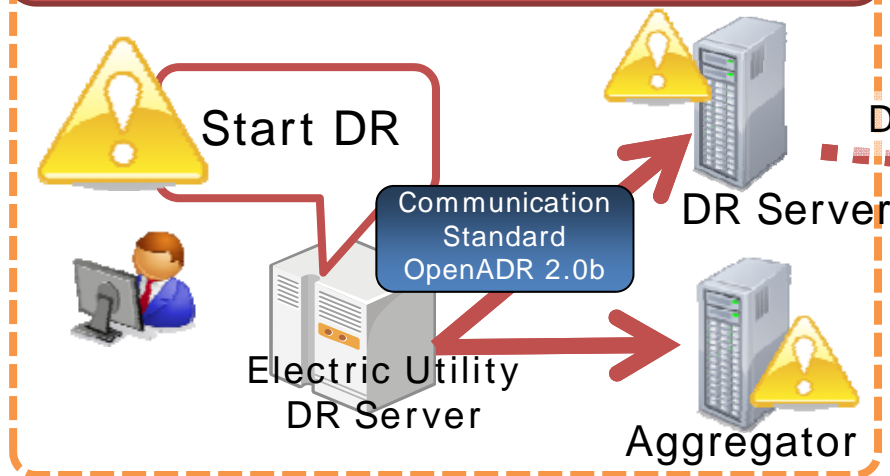
DR servers

Four Smart Houses

Research, development, experimental demonstration and technical assistance for the aiming Demand Response technology with the global standard communication

DR communication and control with electric utility company OpenADR2.0b)

Start DR

Communication Standard OpenADR 2.0b

DR Server

DR Signal

Electric Utility DR Server

Aggregator

In-house DR communication with HEMS (ECHONET Lite

Lighting　PV

Air-con

Communication Standard ECHONET Lite

Home Energy Management System

Heat pump water heater

Fuel cell

Electric Vehicle　Battery

ECHONET (JPN)　SEP2.0(US)　KNX(EU)
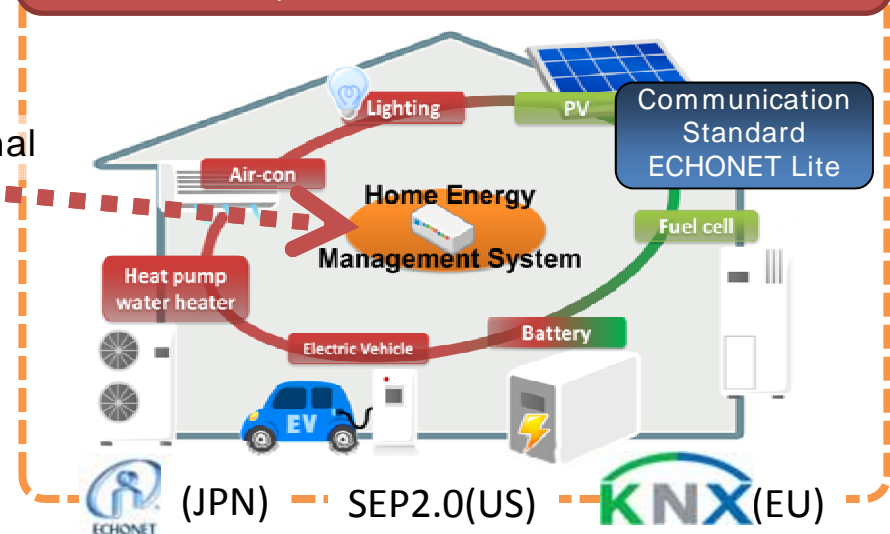
Demand Response Automation Servers (Open ADR 2.0b)

Distribution Network Simulator :ANSWER

Fuel Cell

Smart Houses

HEMS

Room AC

HP Water Heater

Smart Meters

TEPCO   KEPCO

CEPCO   KYUDEN

PHV/EV

Charger

Battery

Distribution Board

PV-inverter system
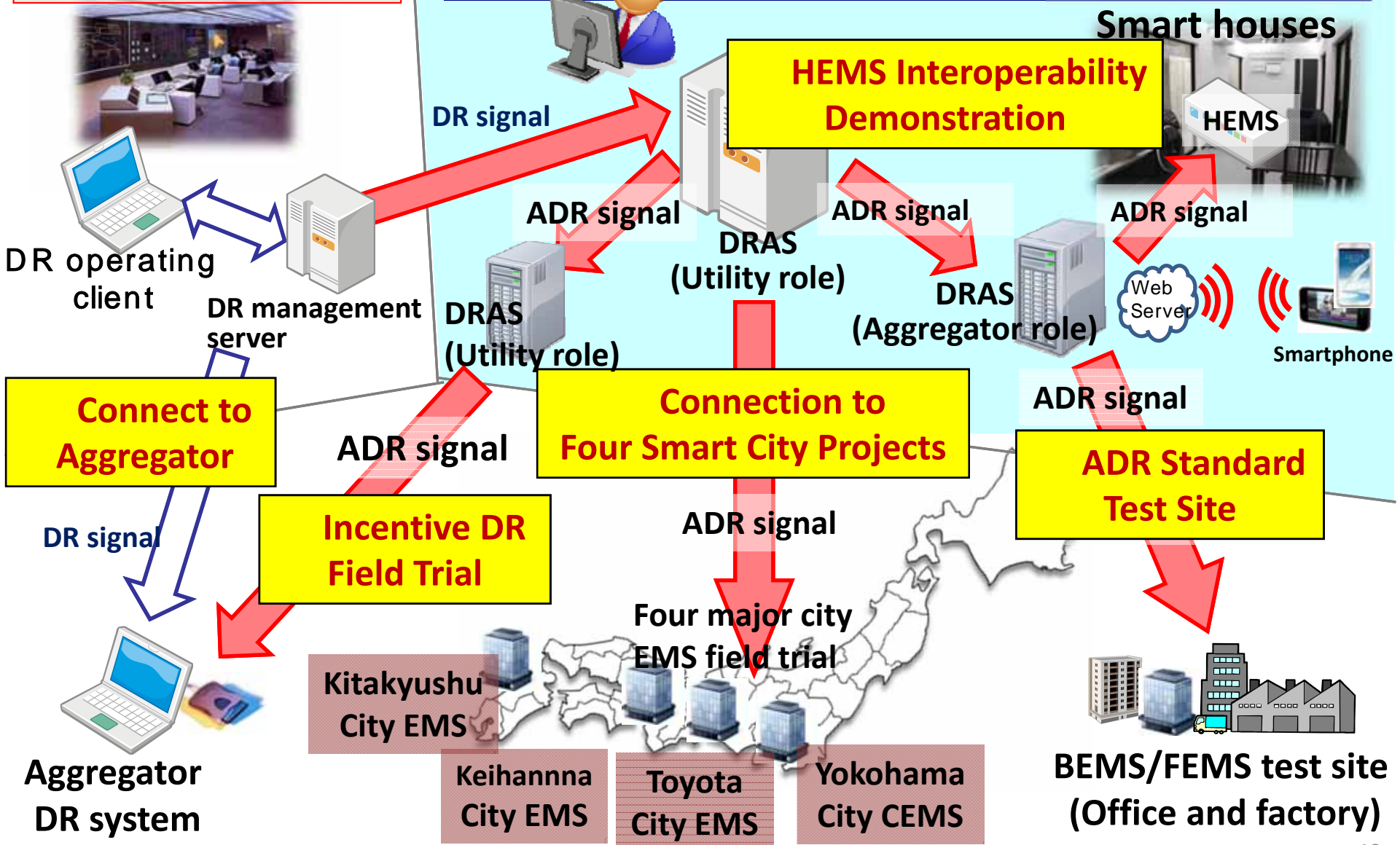
JST R&D Project of Advanced EMS by eight Japanese Universities Team (FY2015-2019)

Development of distributed cooperative EMS methodologies for multiple scenarios by using versatile demonstration platform

Proposal of integrated cooperative EMS methods for multiple scenarios

Forecast → Plan → Control ✚

Cyber security   Economics

Computer science   Satellite data

Introduction to simulator
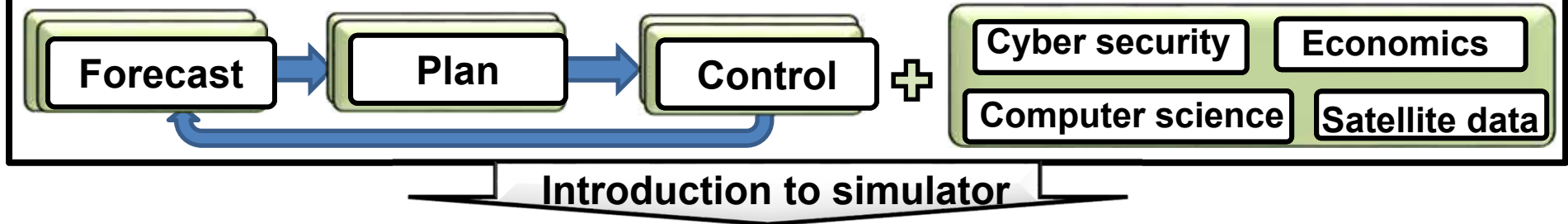
Open demonstration platform for integrated cooperative EMS methods

Open EMS Simulation Model

GEMS model ✚ HEMS model

✚

B/MEMS model

System Link

Open Distribution NW Simulator

GEMS model ✚ HEMS model ✚ B/MEMS model

Implementation to society
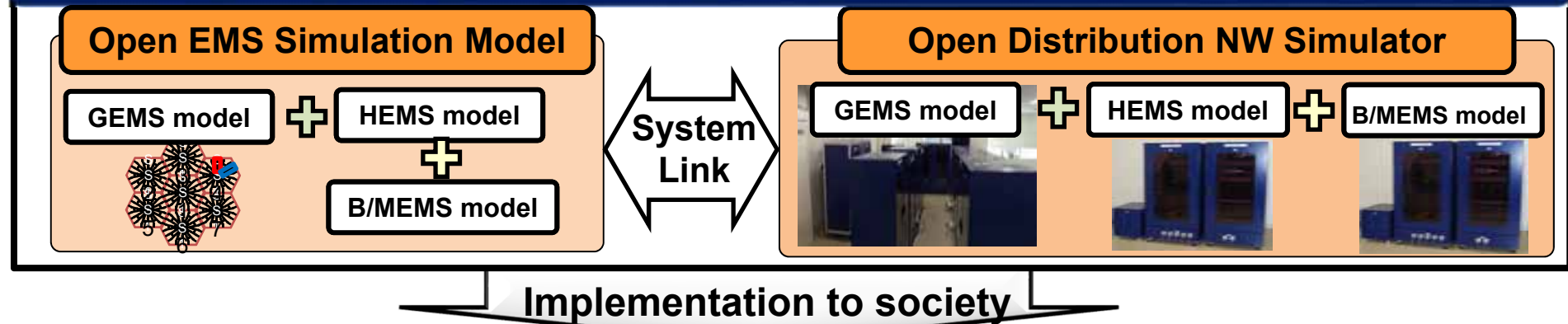
Embed integrated cooperative EMS methods to practical field

Shinjuku EMS R&D center

Auto EM and DR by EMS methods

Interoperability by xEMS

Support

35 companies

Outside test bed ↔ Practical ADR servers   Smart houses

HOKKAIDO UNIVERSITY

Prof. Minato (JST ERATO)

Discrete Structure Manipulation
- Determination of NW configuration by switches

THE UNIVERSITY OF TOKYO

Assoc. Prof. Baba

HPWH-HEMS Control
- HPWH model reflecting actual characteristic
- Feeder voltage control

NAGOYA UNIVERSITY

Prof. Suzuki

PHV-HEMS Control
- Operational charge-discharge plan for PHV-HEMS

TOKYO TECH

Prof. Ishii

Cyber Security
- Detection of cyber attacks against voltage control

WASEDA University

Prof. Hayashi (PI)

Development of Collaborative EMS

Prof. Amano
Operational planning for residential energy systems

Assoc. prof. Fujimoto
Multiple scenario Forecast

Prof. Tanabe   **Prof. Wakao**   **Prof. Murata**

Development of integrated cooperative EMS method

Open EMS Simulation Model

Open DNW Simulator

International collaboration

Universities (NSF, DFG, RCN)

THE UNIVERSITY OF TOKYO

Prof. Ohashi

Economic Analysis
- Simulation of demand change against DR based on electricity price

OSAKA UNIVERSITY

Prof. Shimoda

Demand profiles for EMS
- Generation of energy demands for EMS based on multi-agent model

TOKAI UNIVERSITY EUROPEAN CENTER

Prof. Nakajima

Solar Irradiance data
- Analysis and delivery of solar irradiance data using satellite (30 minutes intervals 1km^2)

Keio University

Prof. Ohmori

Robust Distributed Optimal Control
- Distributed collaborative control b/w BESS and PVs

Please collaborate with our team
on open EMS platform
to build international super team.

Thank you for your attention.