自然エネルギー利用電源および蓄電システムを含む分散電源の運用・制 御

実験室用電力系統を用いたマルチエージェントシステムの実験的検証

檜山　隆
電力システム研究室
熊本大学大学院自然科学研究科

Intelligent Systems Application to Power Systems

1. Expert System (Rule Base System)
2. Fuzzy Inference & Fuzzy Reasoning
3. Fuzzy Logic Control
3. Artificial Neural Network
4. Heuristic Approach
   (Genetic Algorithm, Tabu Search, SA)
5. Multi-Agent System (Intelligent Agent)

International Conferences

ESAP(Expert System Application to Power Systems)

ANNPS(Application of Neural Network to Power Systems)

Now, ISAP(Intelligent Systems Application to Power Systems)

Research Topics

1. Real Time Wide Area Stability Monitoring System
2. Real Time Stability Margin Control of Electric Power Systems
3. Operation, Control and Management of Dispersed Power Sources including Renewable Energy Power Sources and Energy Storage Device
4. Artificial Neural Network Based Identification of Fault Location
5. Application of Energy Capacitor System to Power System Control
6. Multi-Agent Based Wide Area Operation, Control and Management of Electric Power Systems
7. Multi-Agent Based Hierarchical Stabilization Control of Power Systems
8. Multi-Agent Based AGC for Isolated Power Systems including Renewable Energy Power Sources and Energy Storage Device
9. Rule Based Voltage and Power Flow Management
10. Remote Tuning of Power System Controllers through Computer Network
11. Artificial Neural Network Based Estimation of Power Demand and Electricity Cost
12. Artificial Neural Network Based Diagnosis of Induction Machines
13. Development of Real Time PV System Simulator and MPPT Control under Partially Shaded Condition

Kumamoto University

Electric Power Systems Laboratory (Prof. Hiyama's Laboratory) October 2009

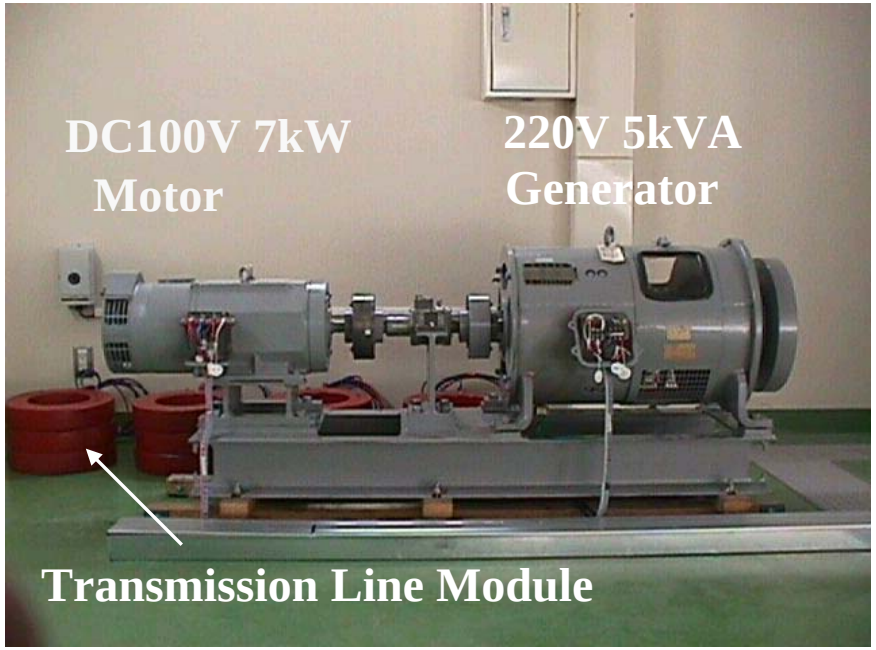
Facilities for Experimental Studies

1. **5kVA Laboratory One Machine Power System:**
   - 5kVA Synchronous Generator
   - 7kW DC Motor
   - Transmission Line Modules
   - Load Modules
2. **70Wh New Energy Storage Device(ECS):**
   - Electrical Double Layer Capacitors
   - **Maximum Charging/Discharging Power: 7kW**
3. **AC/DC Conversion Unit for Real Power Control**
4. **AC/DC Conversion Unit:**
   - Active/Reactive Power Control
5. **Wind Turbine Generators: 600W**
6. **PV System: 400W**
7. **VPN: Virtual Private Network**

Analog Power System Simulator at the Research Laboratory of Kyushu Electric Power Co. for Joint Research Projects: 10 to 14 weeks a year

Experimental Facilities (1)

MG Set



ECS and AC/DC Conversion Unit

ECS: Energy Capacitor System

Electrical Double-Layer Capacitors

We have several AC/DC conversion units for PV and WTG system and also for different control purposes.

Experimental Facilities (2)

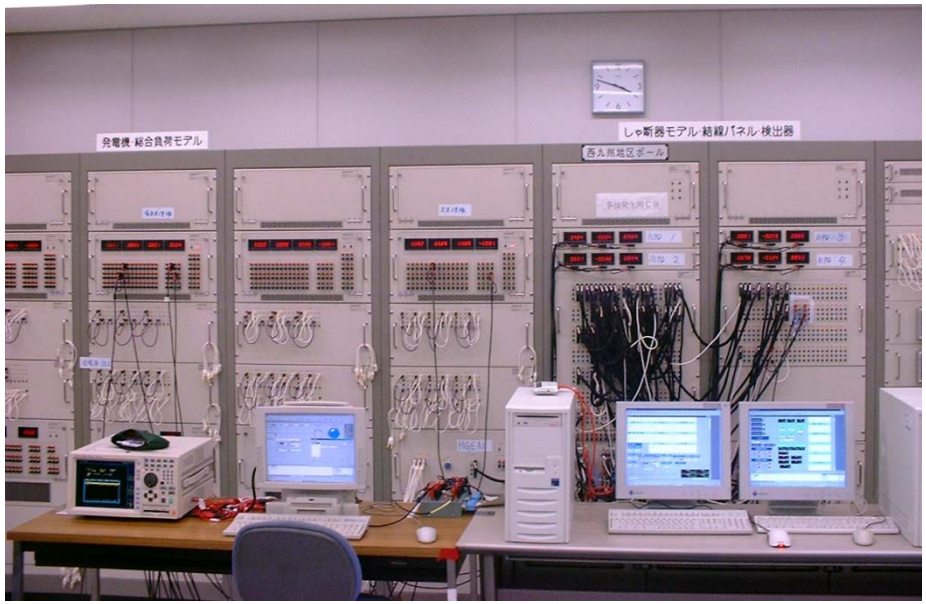
Small Sized Wind Turbine Generating Units

Photo-Voltaic Generating Units

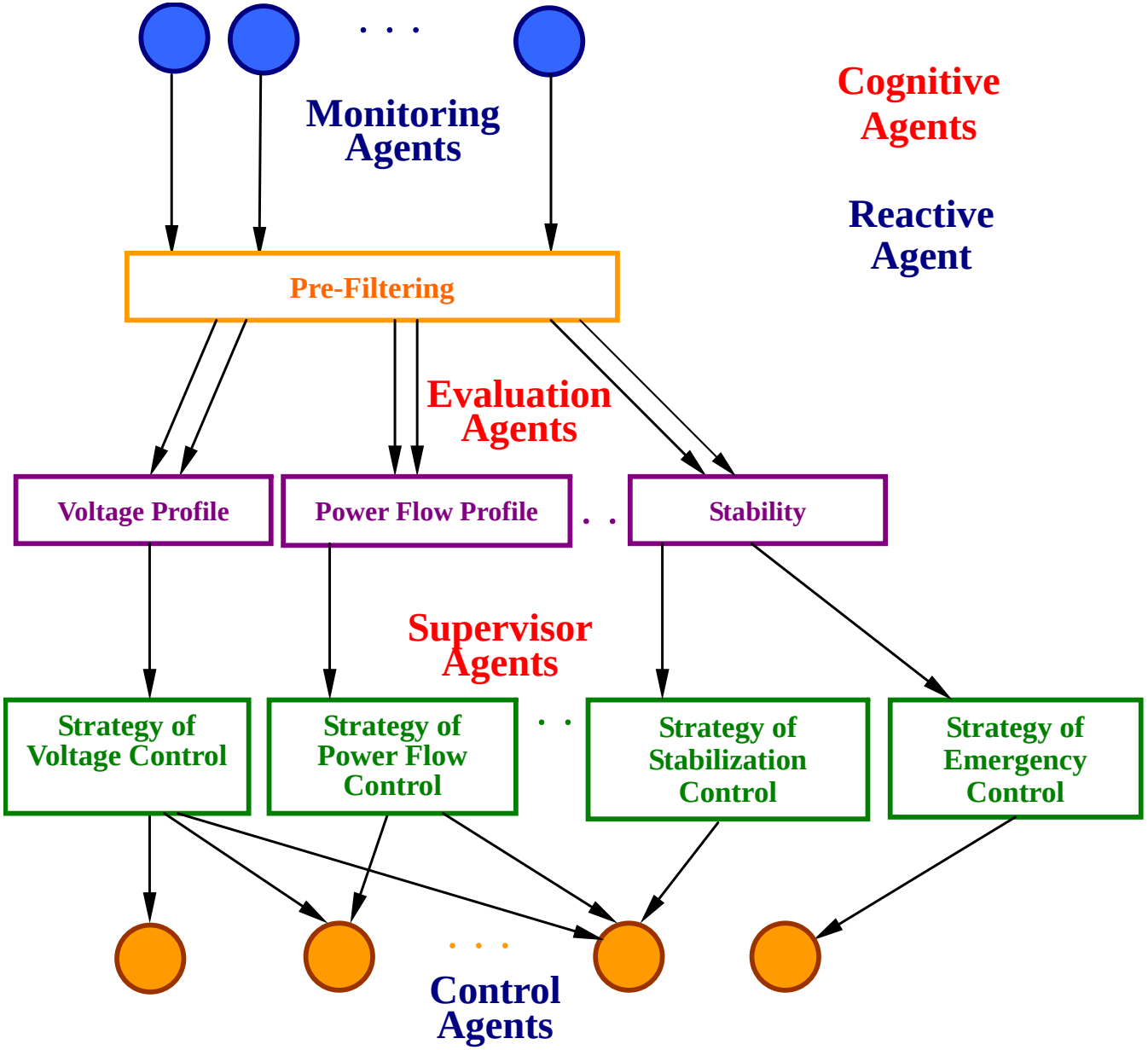
Analog Power System Simulator at the Research Laboratory of Kyushu Electric Power Co. (10 to 15 weeks per year)

Preparation of Simulator Test

Overview of Analog Power System Simulator



Multi-Agent Based Control System for Electric Power Systems



マルチエージェントシステムの適用による負荷平準化制御

Introduction

Renewable Energy Power Sources:

Photo-Voltaic Generation & Wind Turbine Generation

Conventional Power Sources:

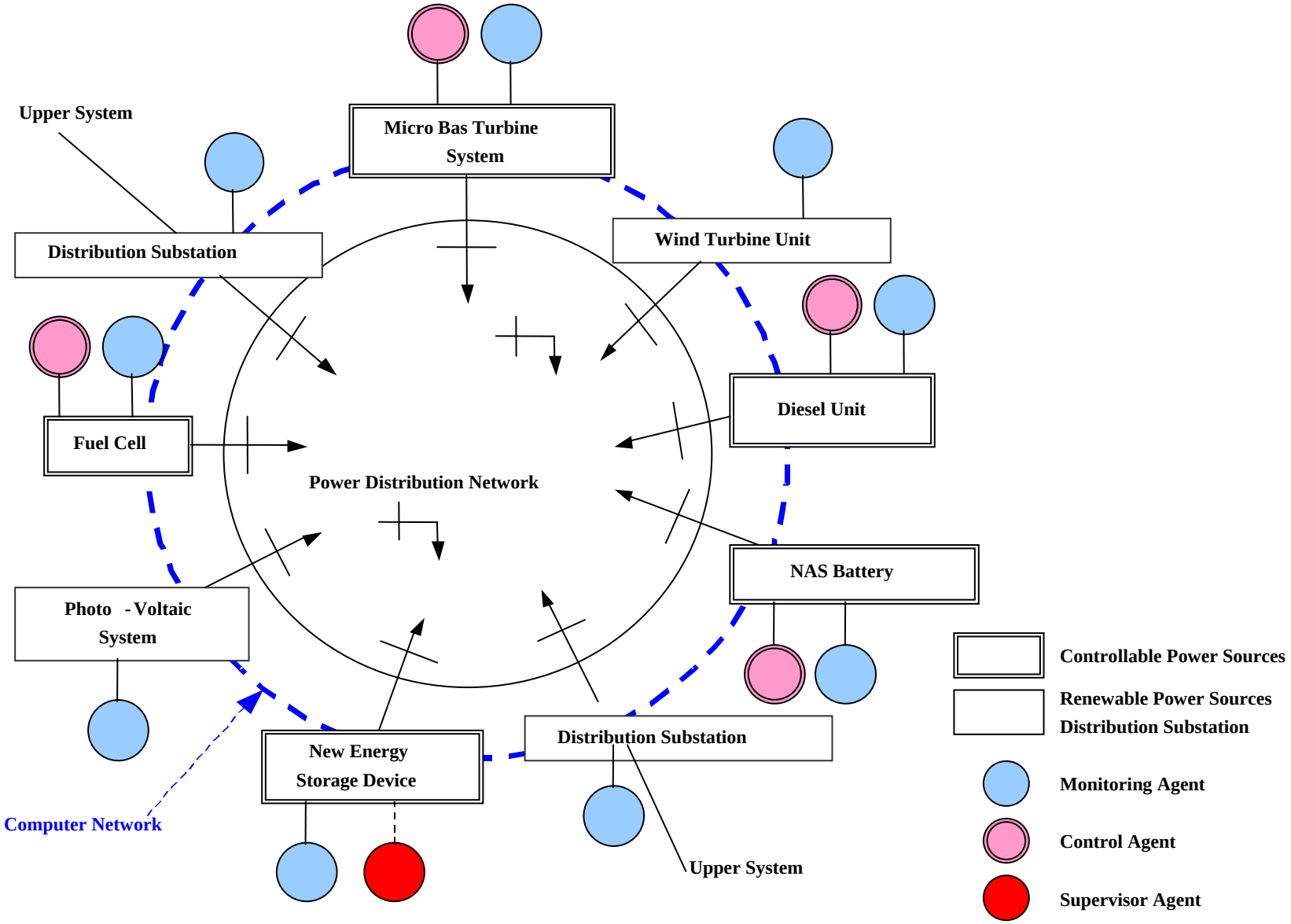
Diesel Generation & Gas Turbine Generation

Energy Storage Devices:

Energy Capacitor System (Electrical Double Layer Capacitors)

A number of new distributed power generation technologies are currently available to offer integrated performance and flexibility for the power consumers.

Multi-Agent Based Coordinated Operation of Dispersed Power Sources



Multi-Agent System

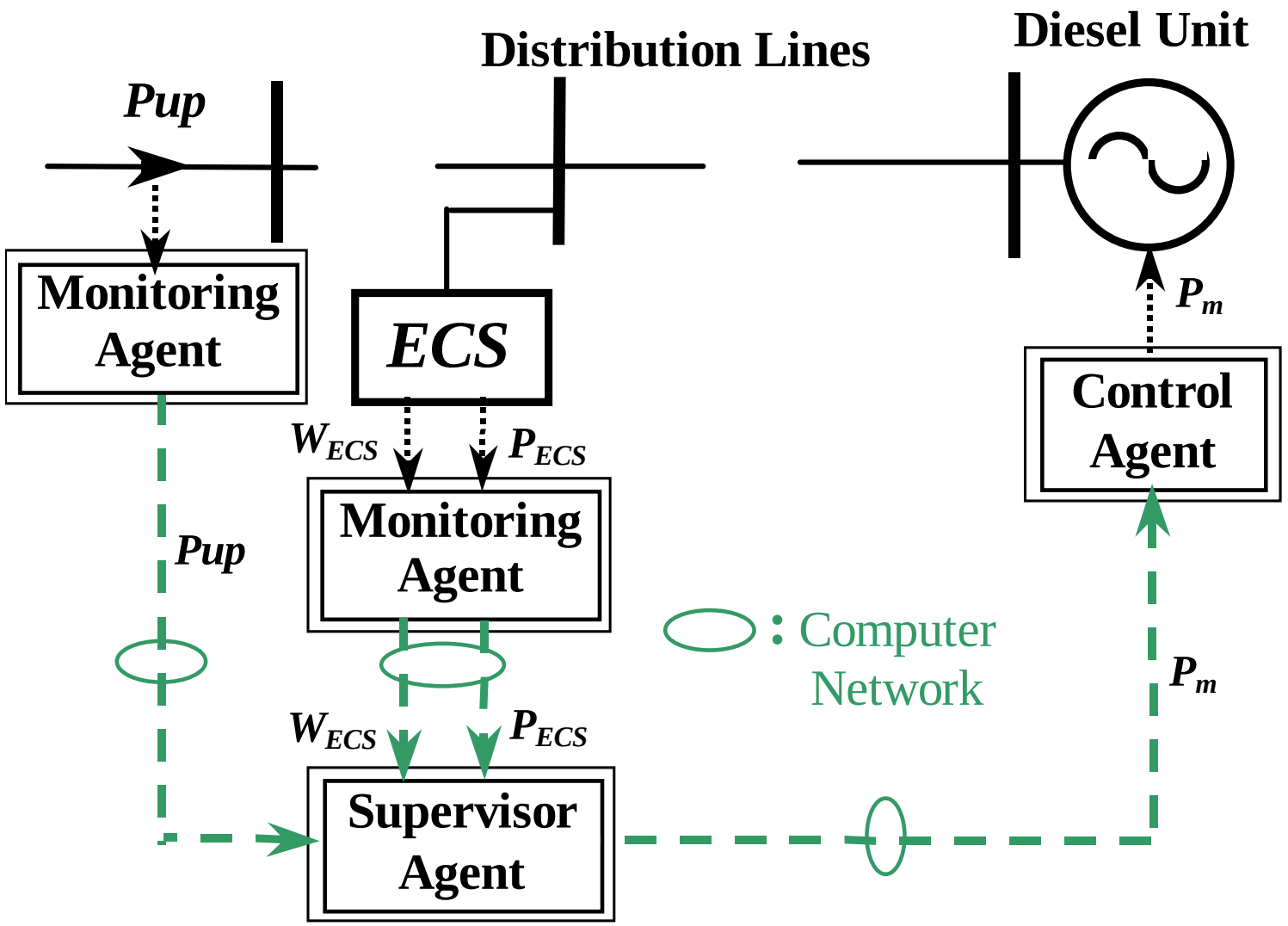
Three Types of Agents:

Monitoring Agents for the distribution of required information through the computer network (Reactive Agent)

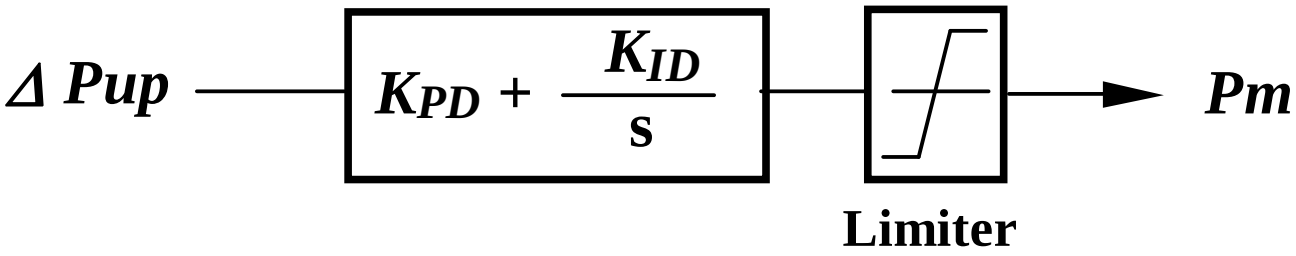
Control Agents for the charging/discharging operation on the ECS and also for the power regulation on the diesel units (Reactive Agent)

Supervisor Agent for the coordination between the ECS and the diesel units (Cognitive Agent)

Multi-Agent Based Load Leveling of Distribution System



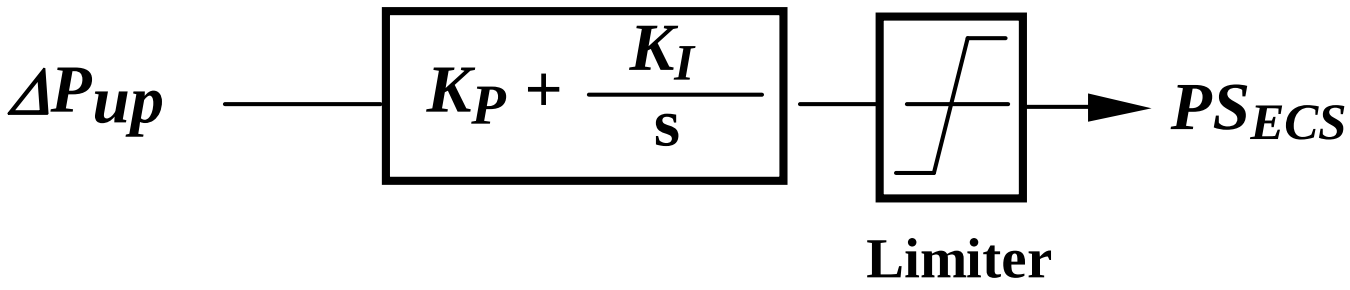
Conventional Load Leveling Control on Diesel Unit



***Δ Pup*:Deviation of Power Flow from Upper System**

***Pm*: Output Setting of Diesel Unit**

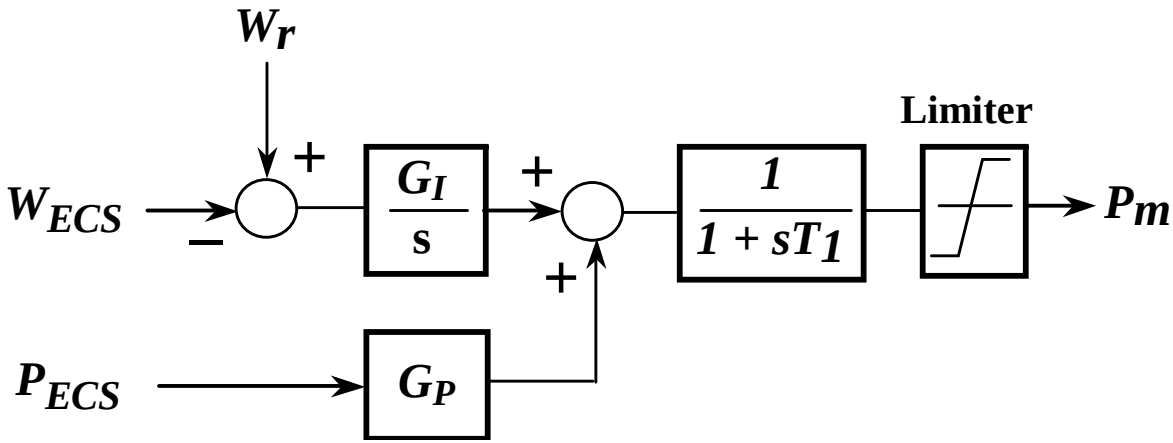
Proposed Load Leveling Control (Supervisor Agent)



***Δ Pup*: Power Flow Deviation from Upper System**
***PSECS*: Output Setting of ECS**

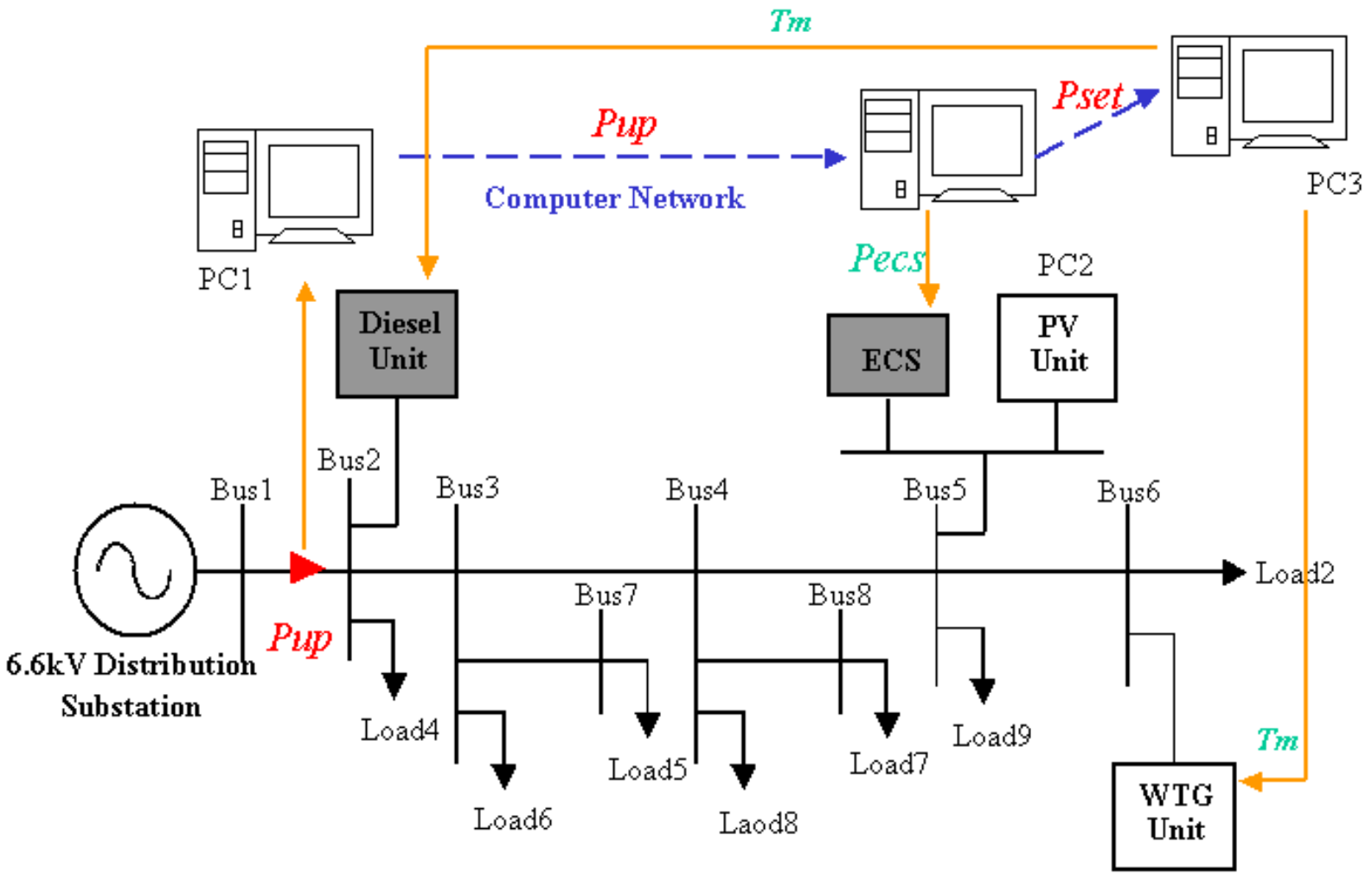
Coordination between ECS and Diesel Unit (Supervisor Agent)

1. A small sized ECS is considered in this study, therefore, the regulation of the output from the diesel unit is required to keep the stored energy level of the ECS in a proper range.
2. The ECS provides the main function of load leveling control and the diesel unit provides its supplementary function to support the load leveling control on the ECS.

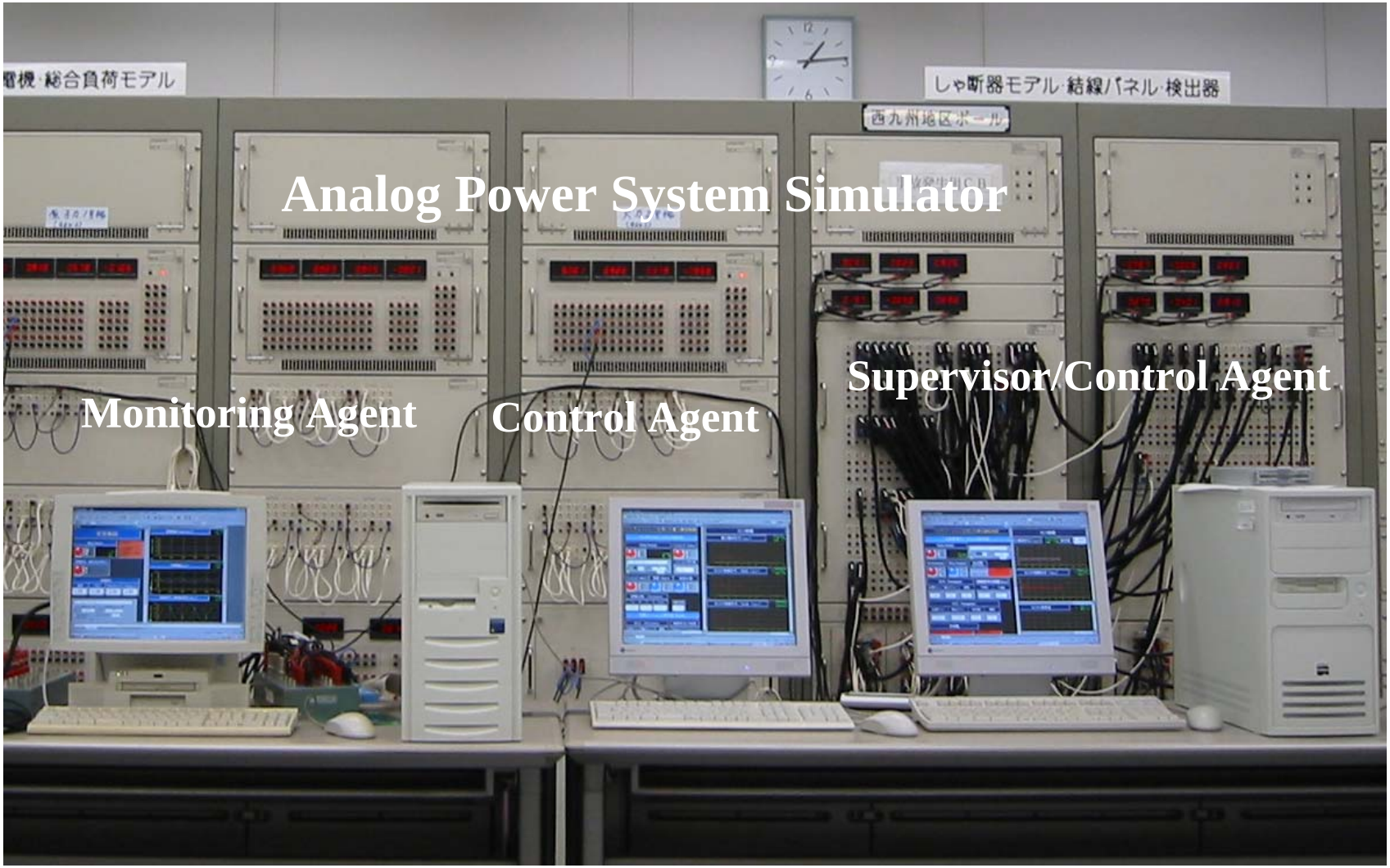


Wr : Target Stored Energy, *WECS* : Current Stored Energy
PECS : Power from ECS
Pm : Power Regulation on Diesel Unit for Coordination with ECS

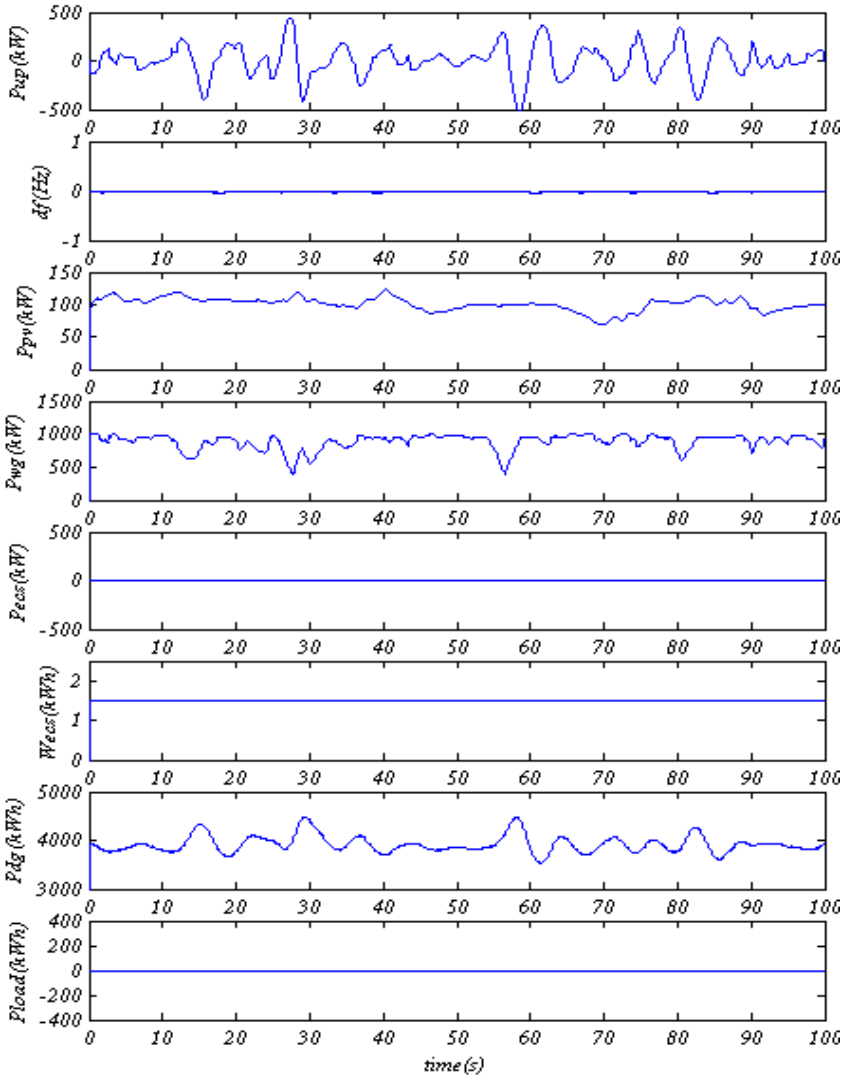
6.6kV Distribution System on Analog Power System Simulator



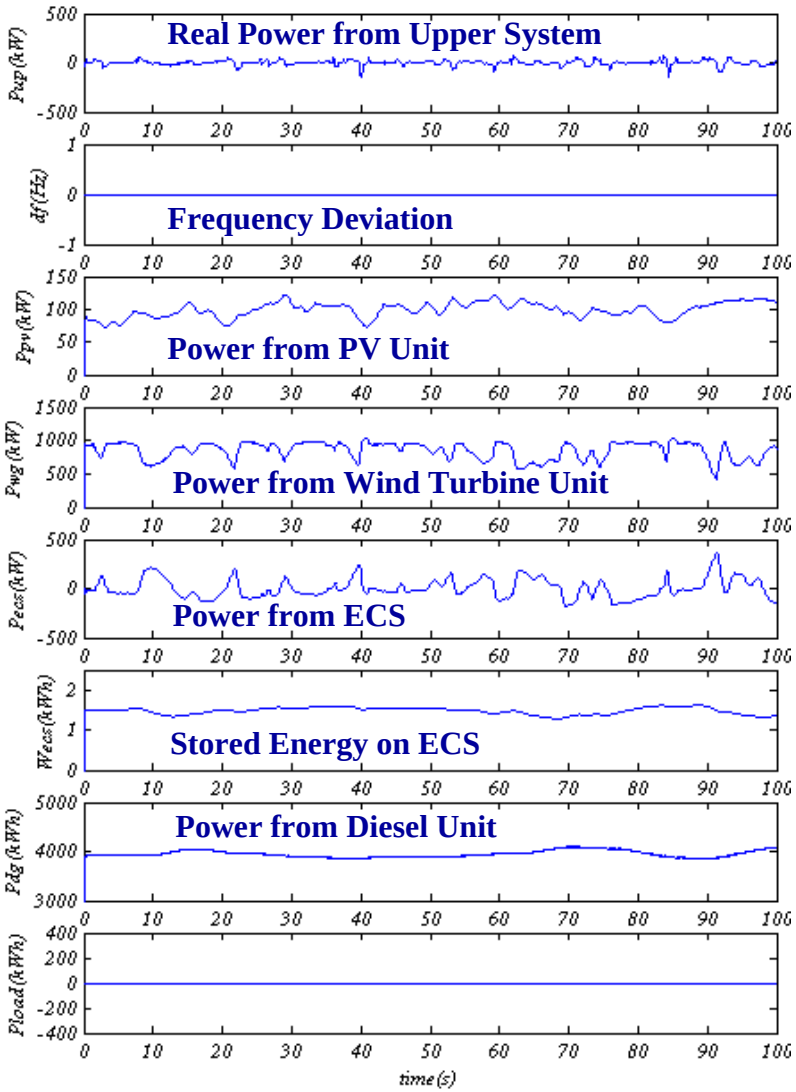
Overview of Analog Power System Simulator at the Research Laboratory of Kyushu Electric Power Co.



Load Leveling Control (Fixed Load)

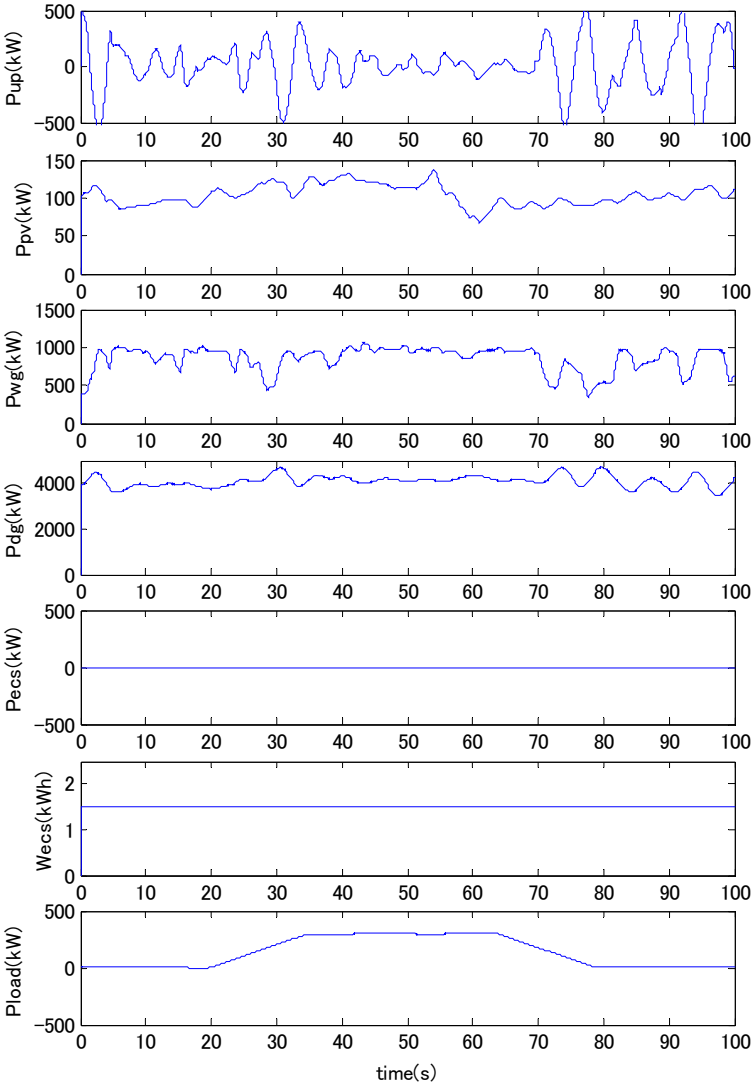


With Diesel Unit

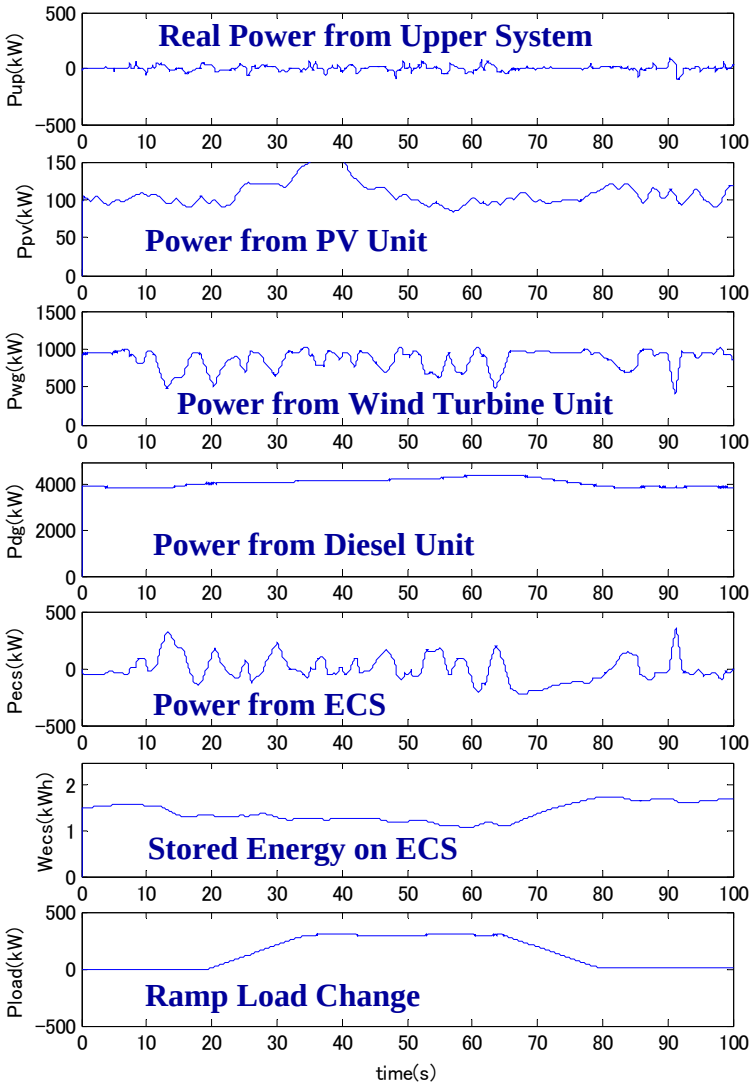


With Diesel & ECS Units

Load Leveling Control (Ramp Load Change)

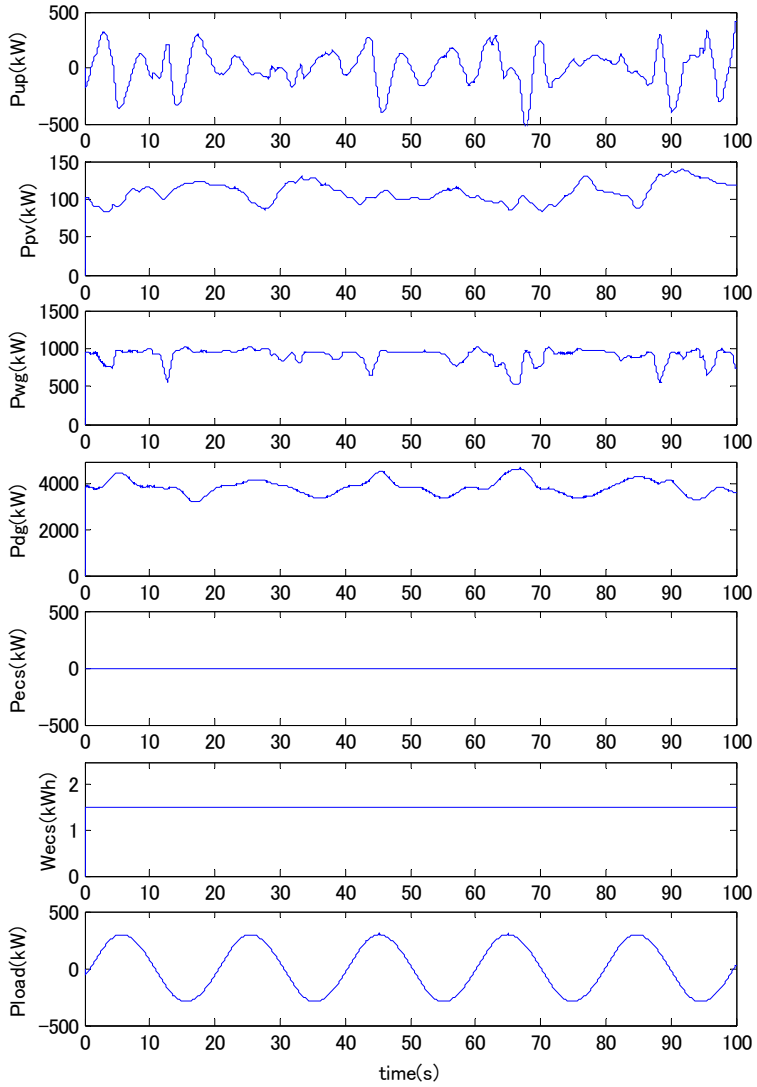


With Diesel Unit

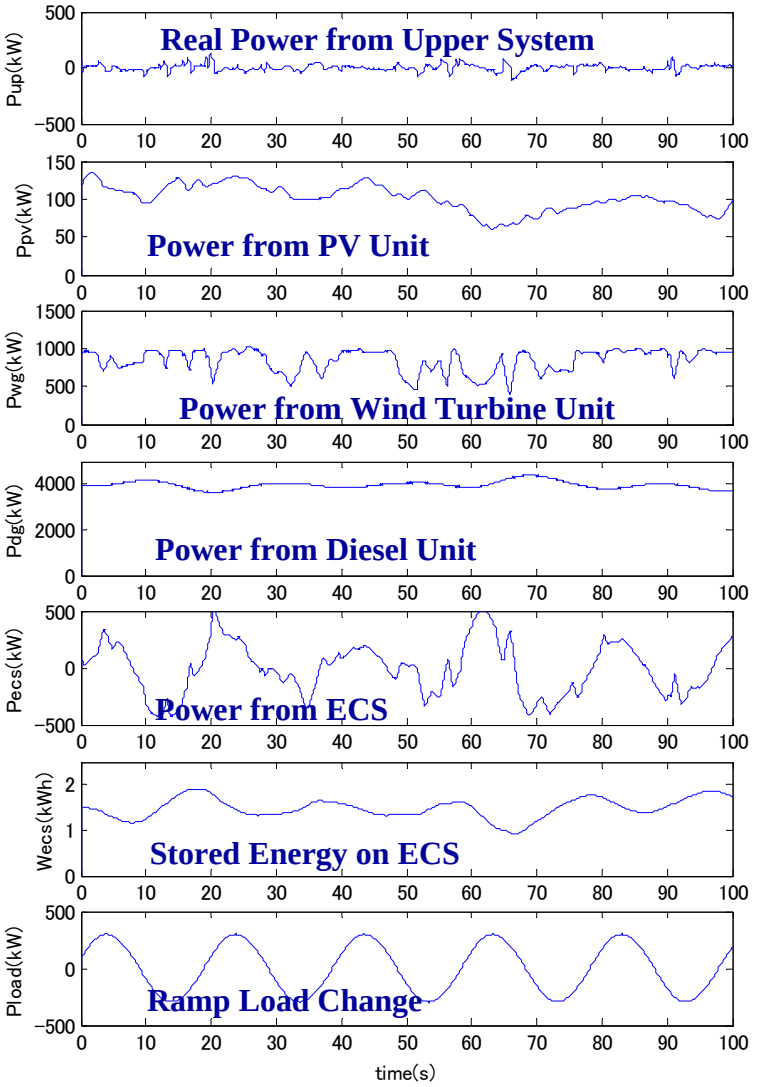


With Diesel & ECS Units

Load Leveling Control (Periodical Load)

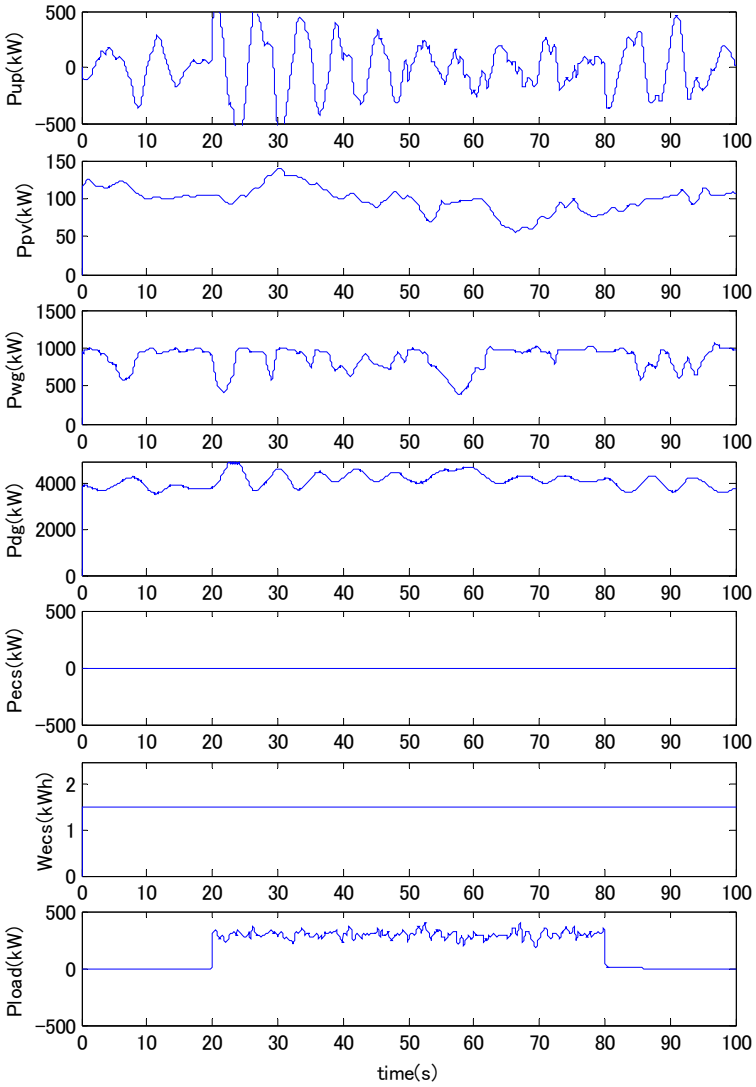


With Diesel Unit

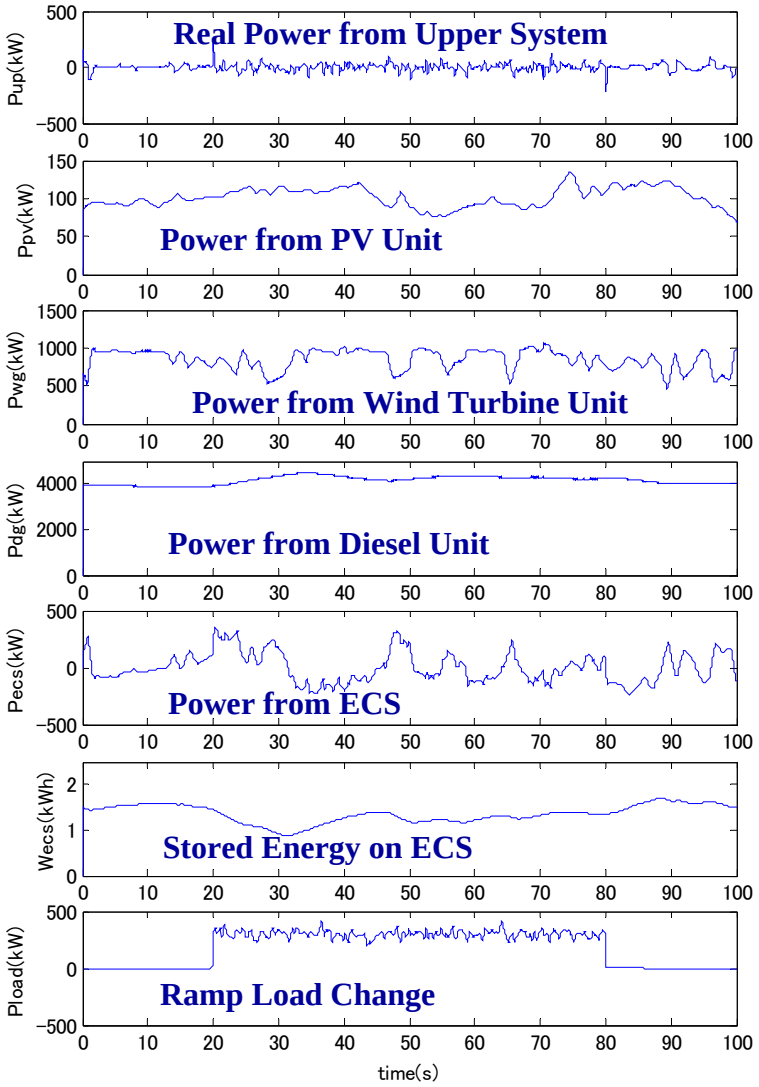


With Diesel & ECS Units

Load Leveling Control (Step & Random Load Change)

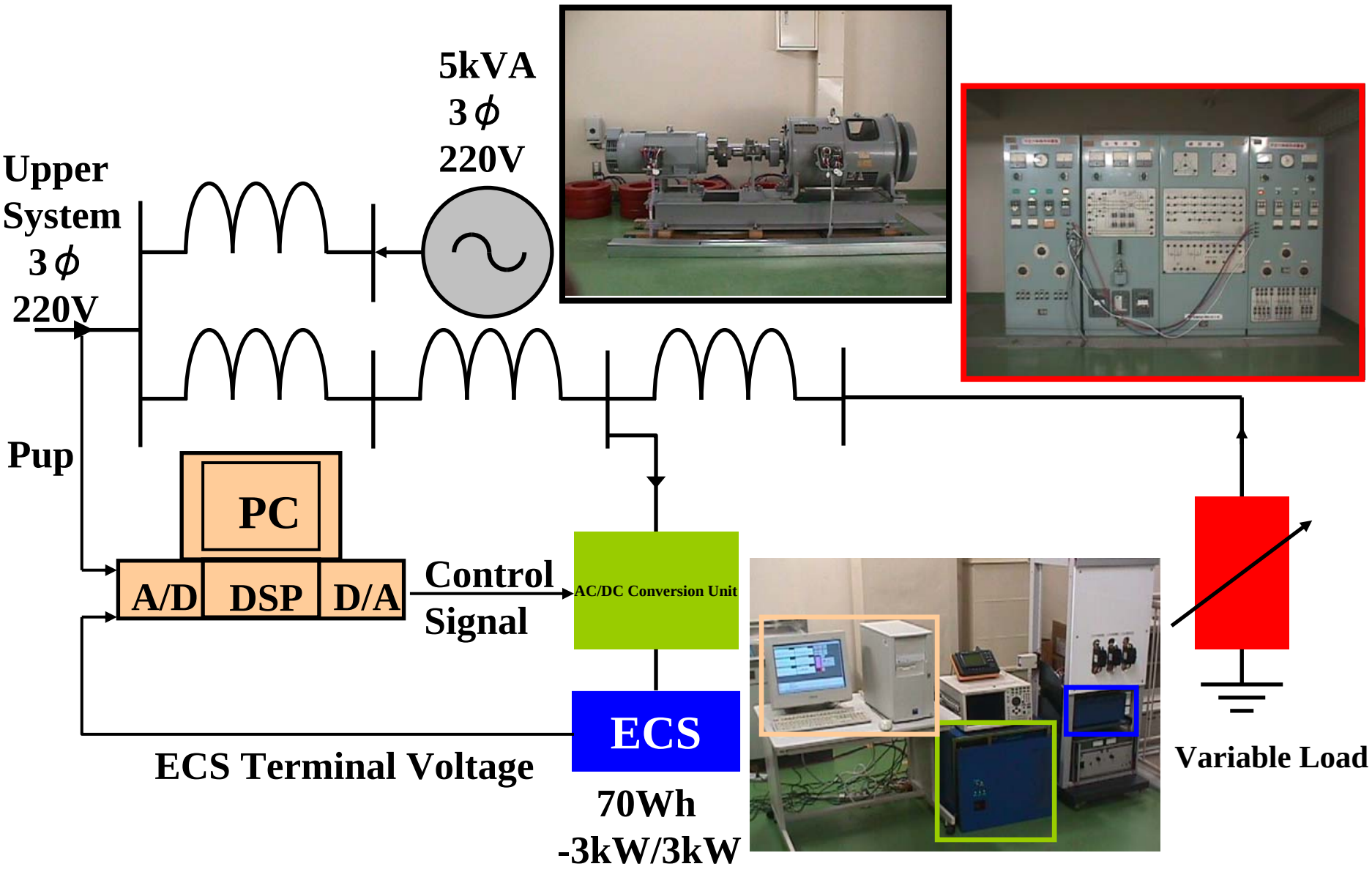


With Diesel Unit



With Diesel & ECS Units

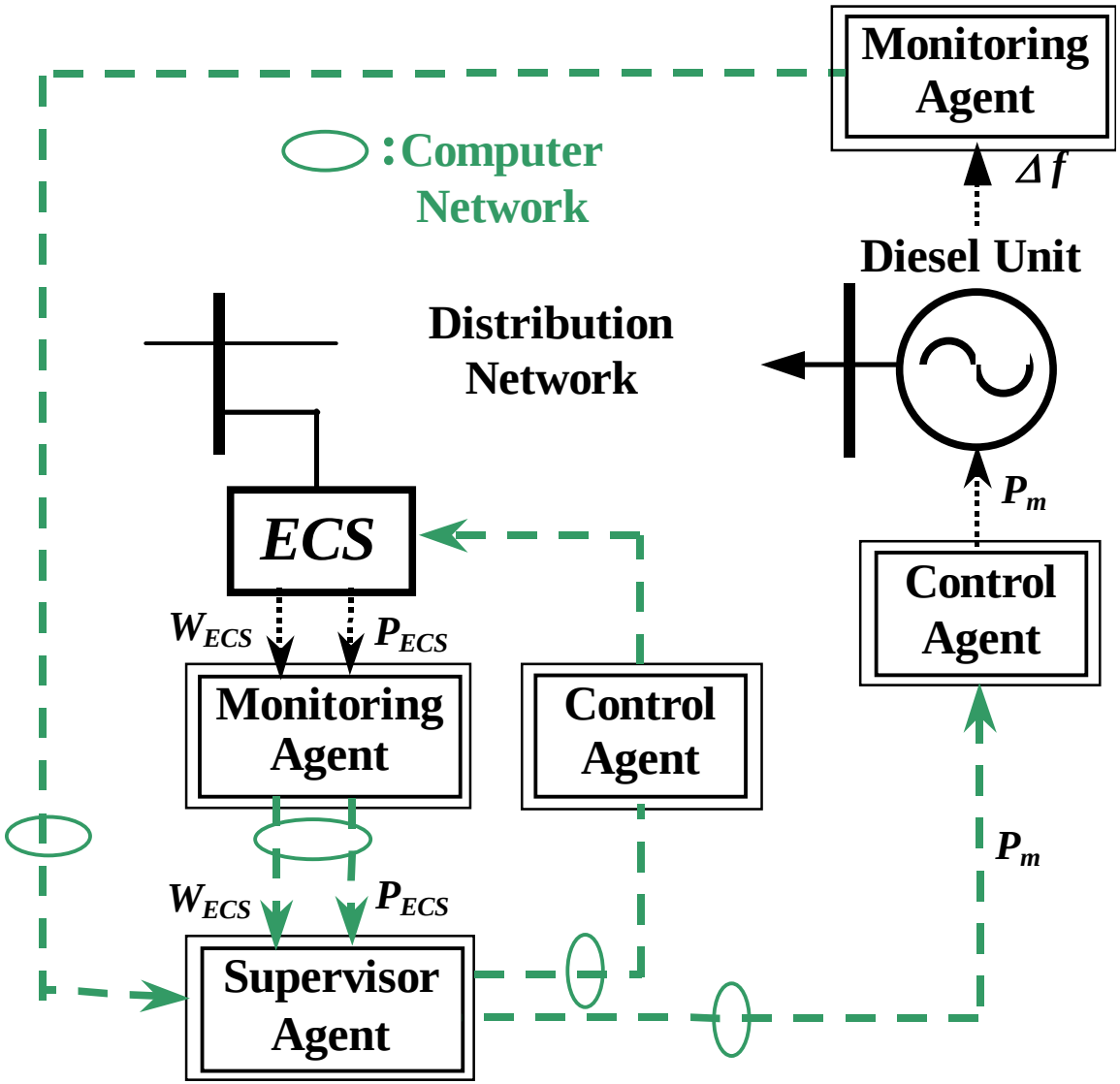
Laboratory System for Load Leveling Control



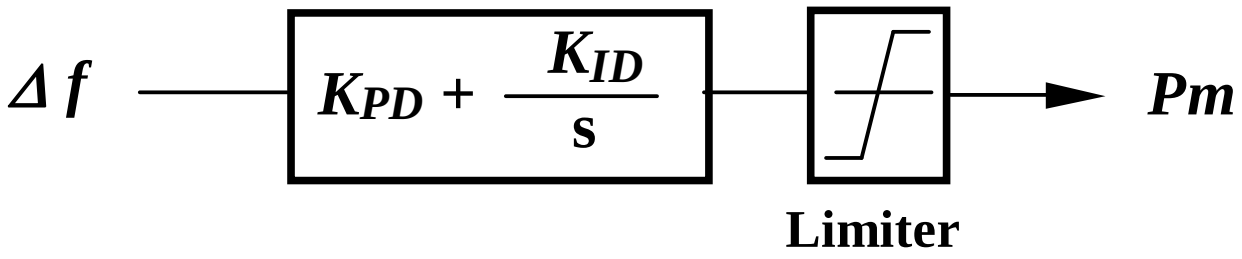
マルチエージェントシステムの適用による単独系統の自動発電制御

Journal of Engineering Intelligent Systems, Vol. 13, No. 2 (2005)

Configuration of Multi-Agent Based AGC System



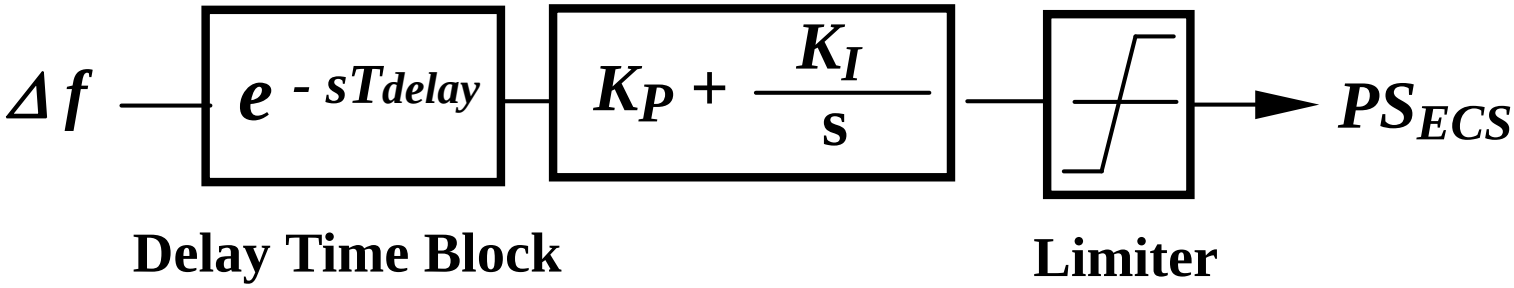
Conventional AGC on Diesel Unit



Δf: Frequency Deviation on Diesel Unit

***Pm*: Output Setting of Diesel Unit**

Proposed AGC (Supervisor Agent)



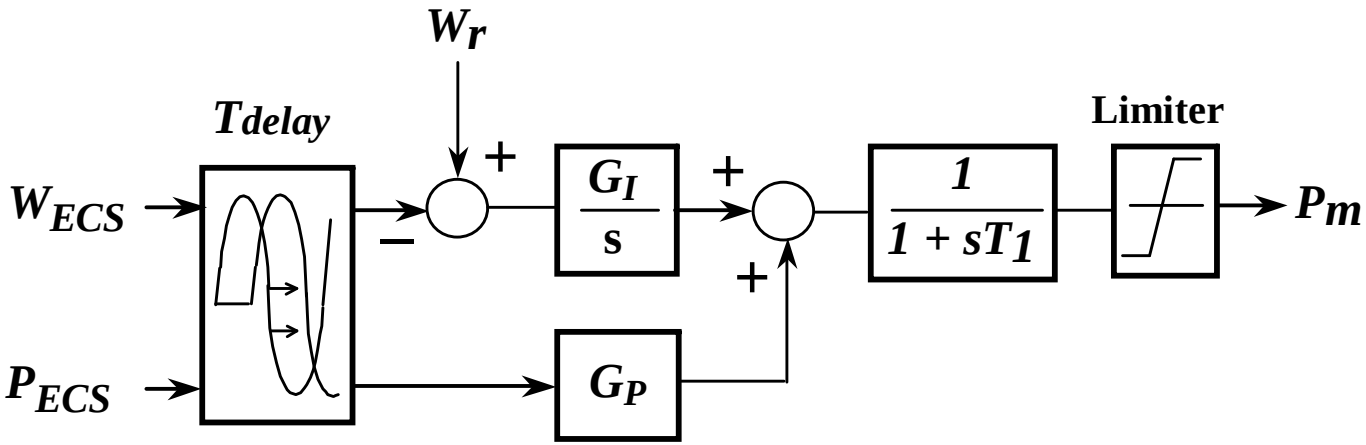
Δf: Frequency Deviation of Diesel Unit

PS_{ECS}: Output Setting of ECS

***Tdelay*: Communication Delay Time**

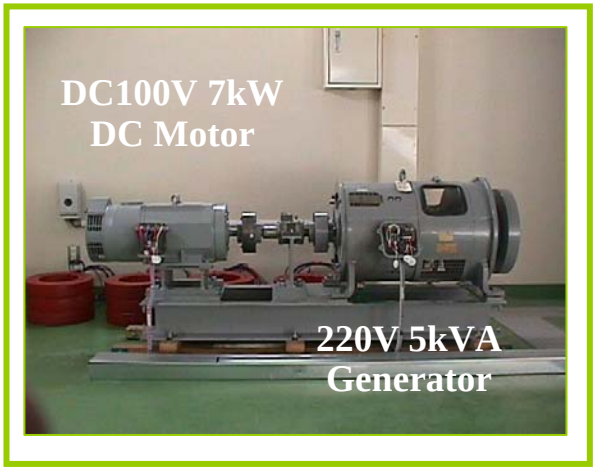
Coordination between ECS and Diesel Unit (Supervisor Agent)

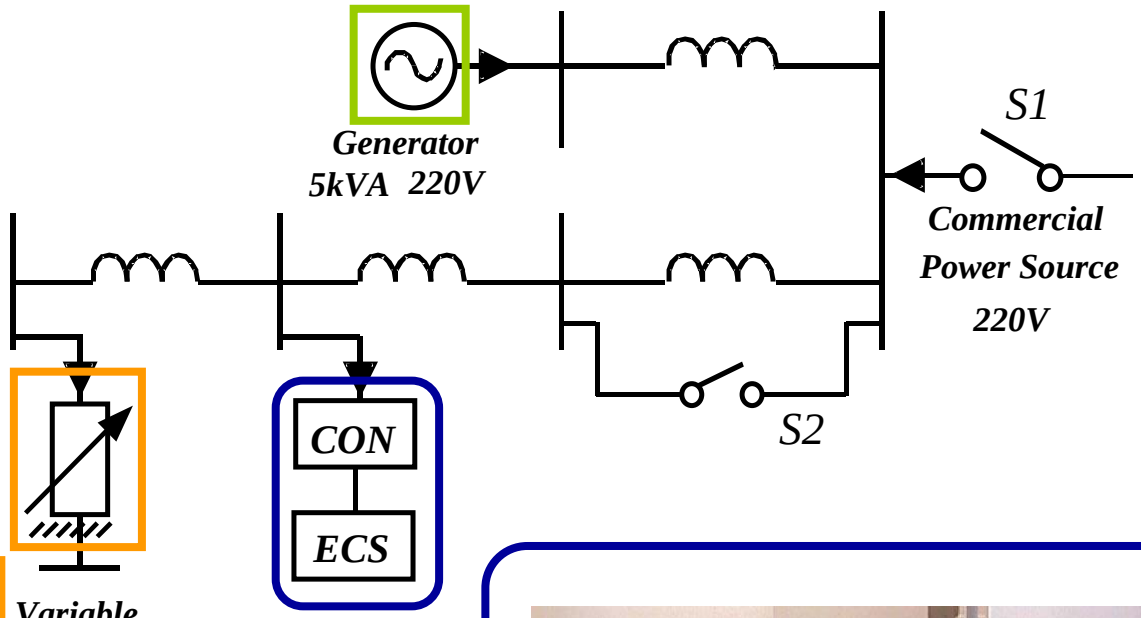
1. A small sized ECS is considered in this study, therefore, the regulation of the output from the diesel unit is required to keep the stored energy level of the ECS in a proper range.
2. The ECS provides the main function of AGC and the diesel unit provides a supplementary function to support the AGC on the ECS.

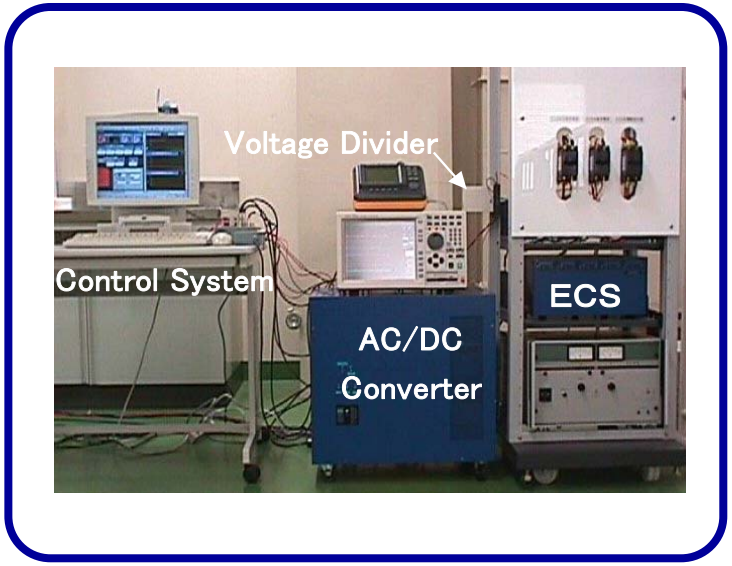


Wr : Target Stored Energy, *WECS* : Current Stored Energy
PECS : Power from ECS
Pm2 : Power Regulation on Diesel Unit for Coordination with ECS
Tdelay : Communication Delay Time

Laboratory System for AGC

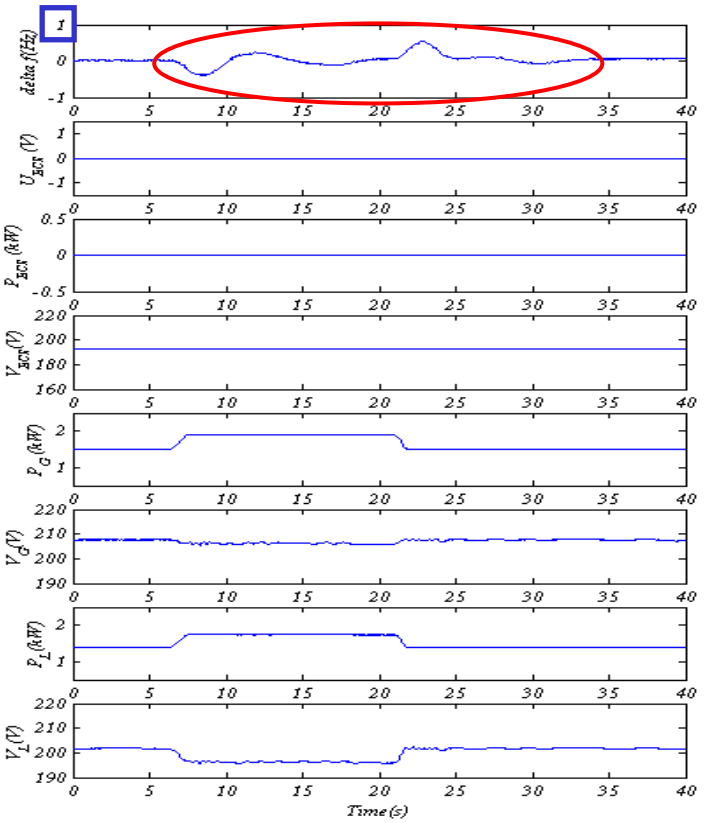




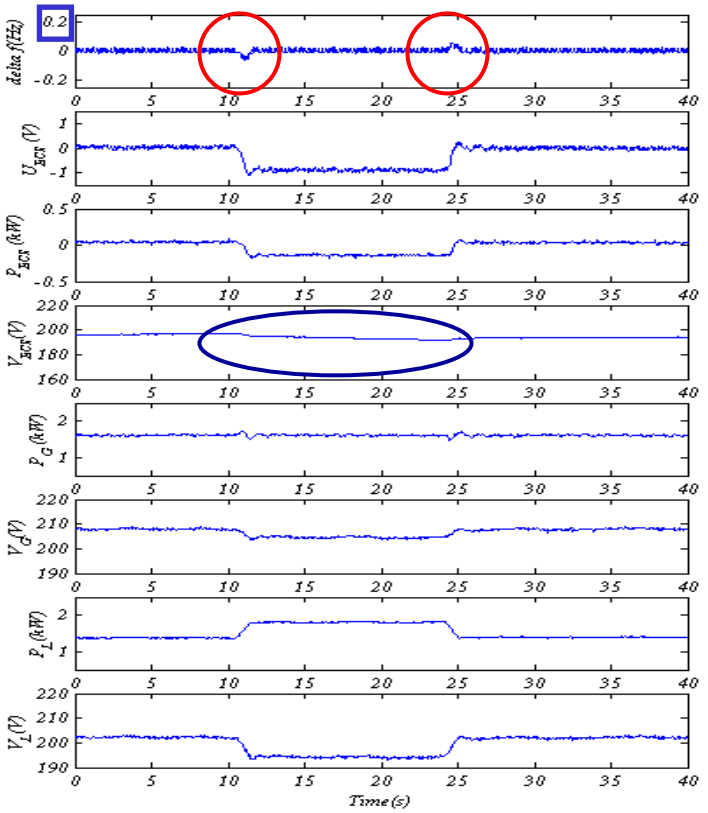


AGC for Step Load Change 1

Conventional Control



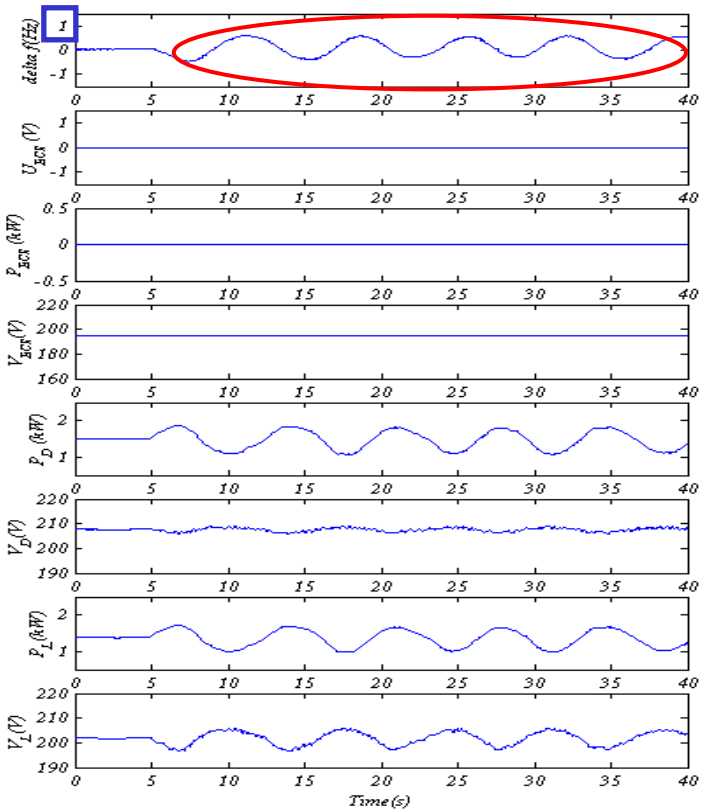
Proposed AGC



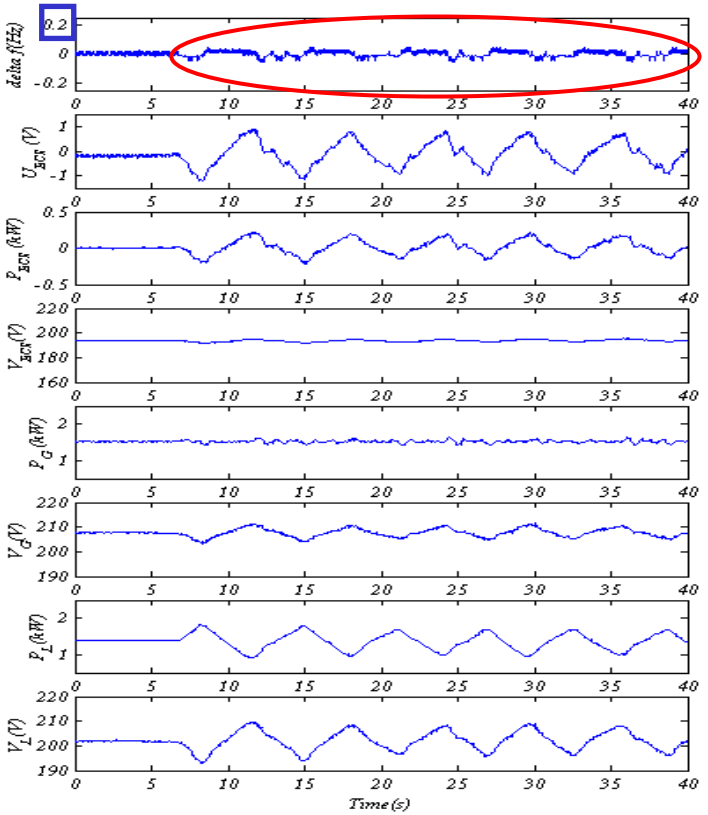
	Δfmax	*Δfave*
Conventional	**0.802**	**0.263**
Proposed	**0.068**	**0.011**

AGC for Periodic Load Change

Conventional Control



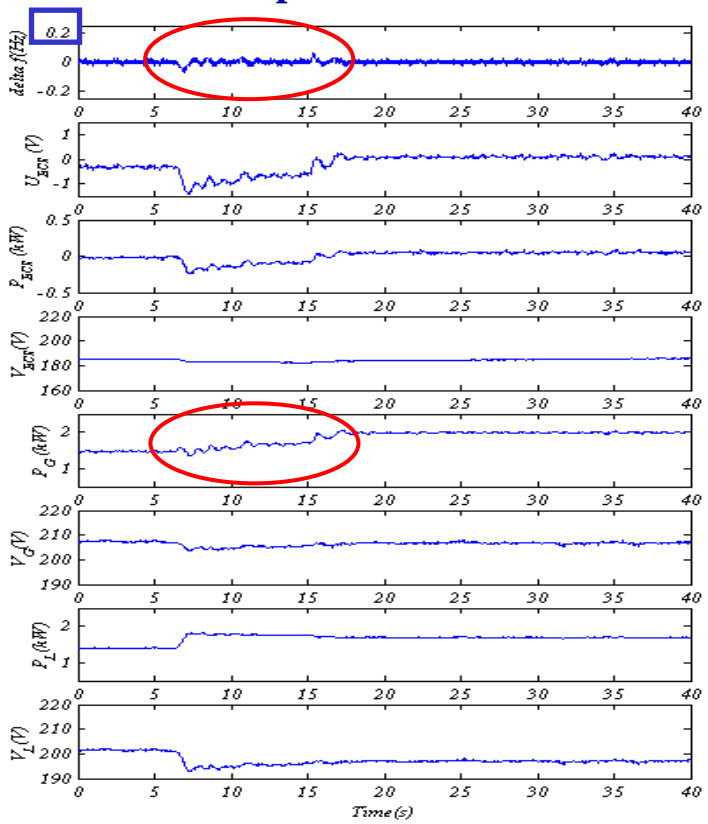
Proposed AGC



	Δfmax (Hz)	*Δfave* (Hz)
Conventional	**0.702**	**0.257**
Proposed	**0.056**	**0.016**

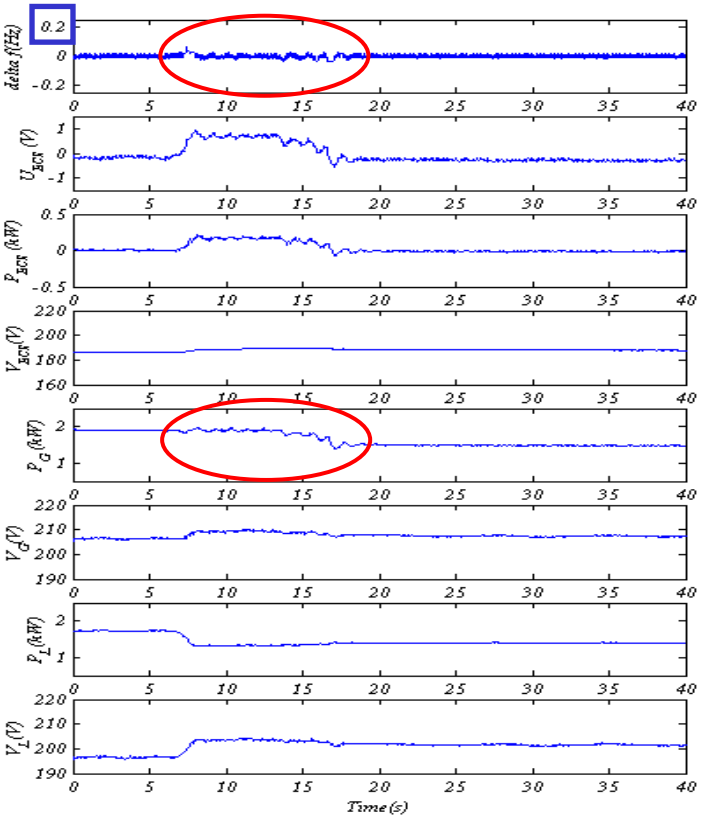
AGC for Step Load Change 2 & 3

Proposed AGC



	Δfmax (Hz)	*Δfave* (Hz)
Conventional	**0.396**	**0.052**
Proposed	**0.070**	**0.009**

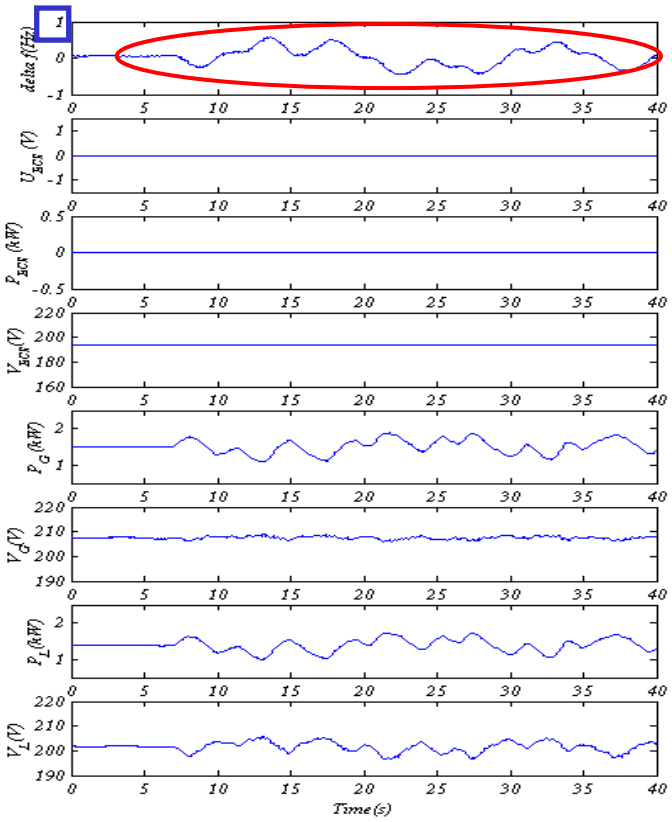
Proposed AGC



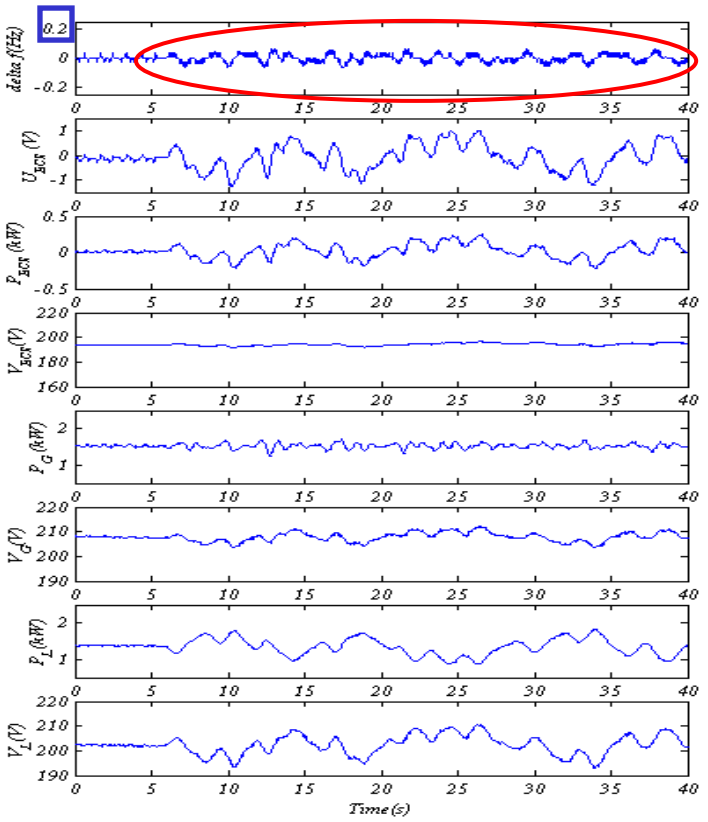
	Δfmax (Hz)	*Δfave* (Hz)
Conventional	**0.477**	**0.062**
Proposed	**0.061**	**0.009**

AGC for Random Load Change

without AGC



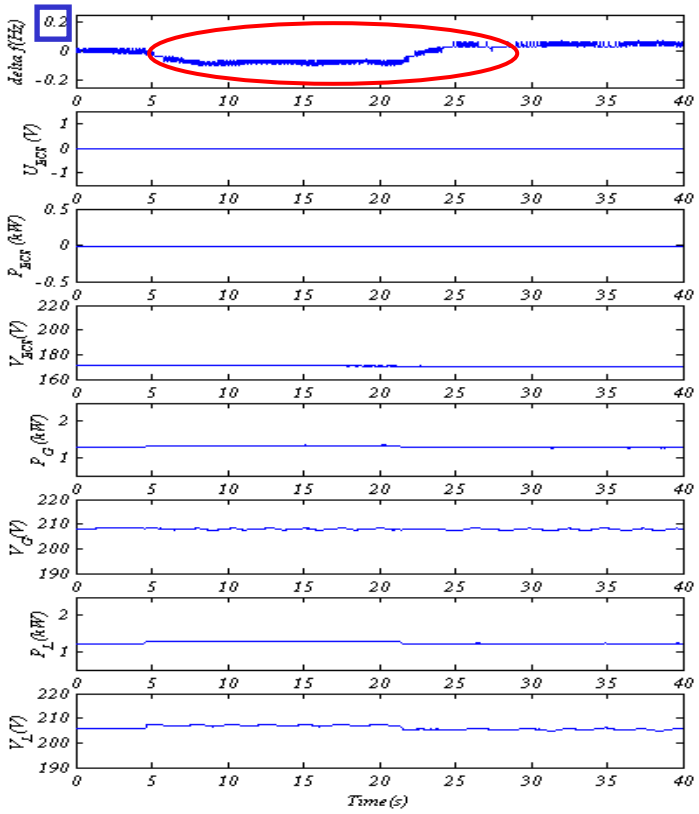
Proposed AGC



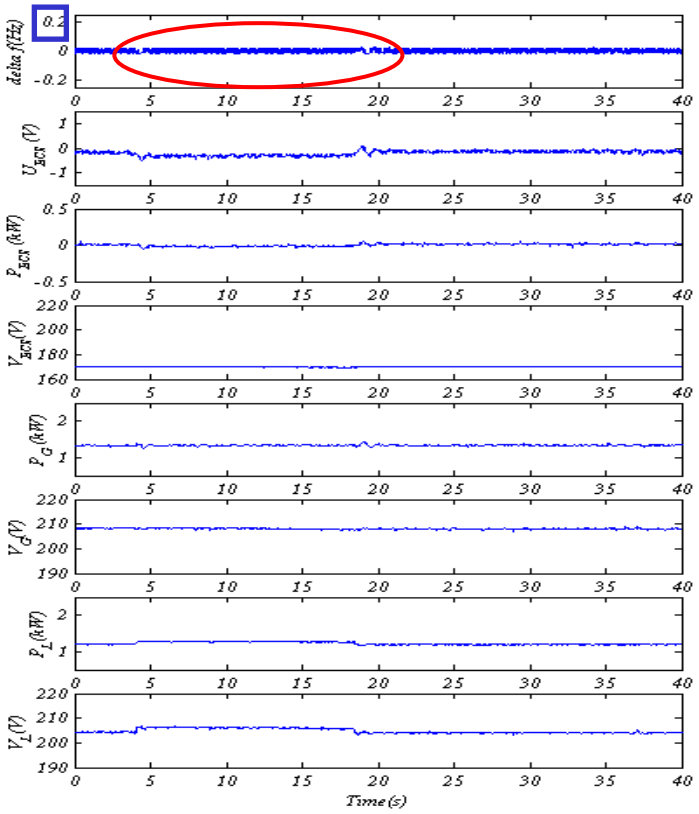
	Δfmax (Hz)	*Δfave* (Hz)
without AGC	**0.568**	**0.200**
Proposed	**0.067**	**0.019**

AGC under Large Disturbance

without AGC



Proposed AGC

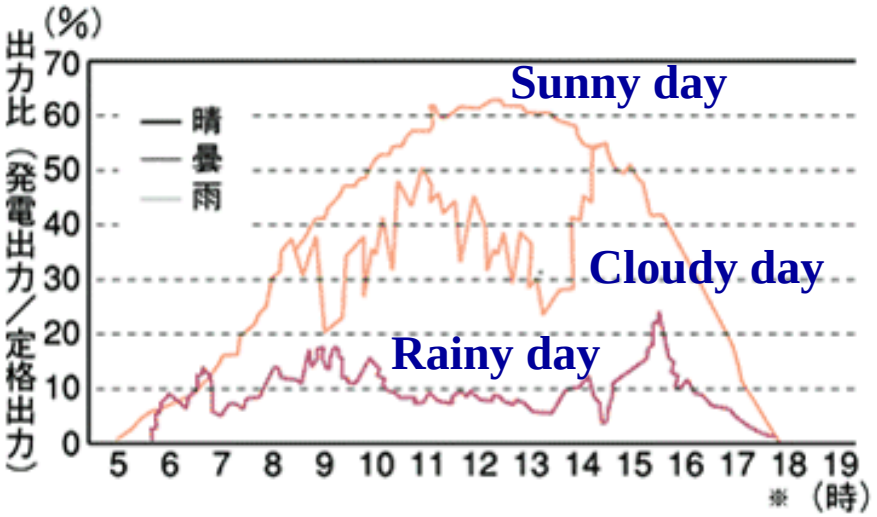


	Δfmax (Hz)	*Δfave* (Hz)
without AGC	**0.101**	**0.050**
Proposed	**0.028**	**0.009**

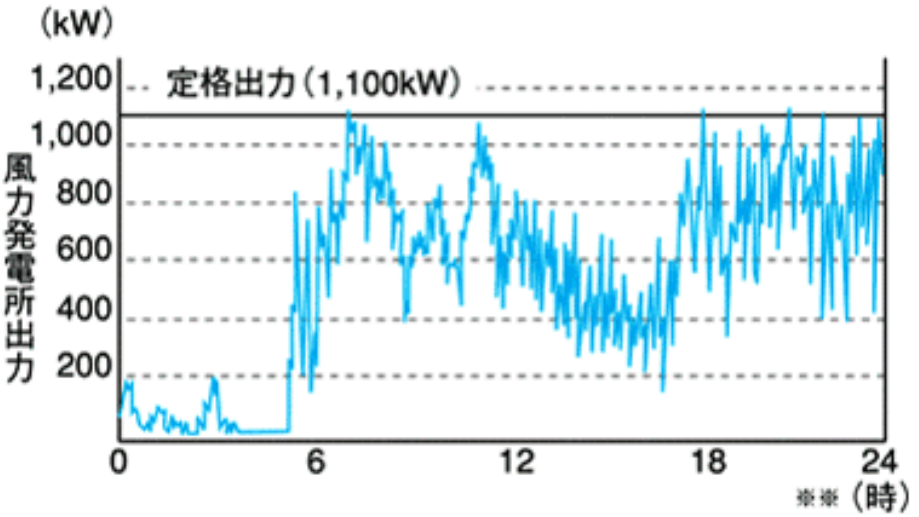
自然エネルギー利用電源を含むハイブリッド電源の出力平準化

Fluctuation of Power Output

Output from PV System

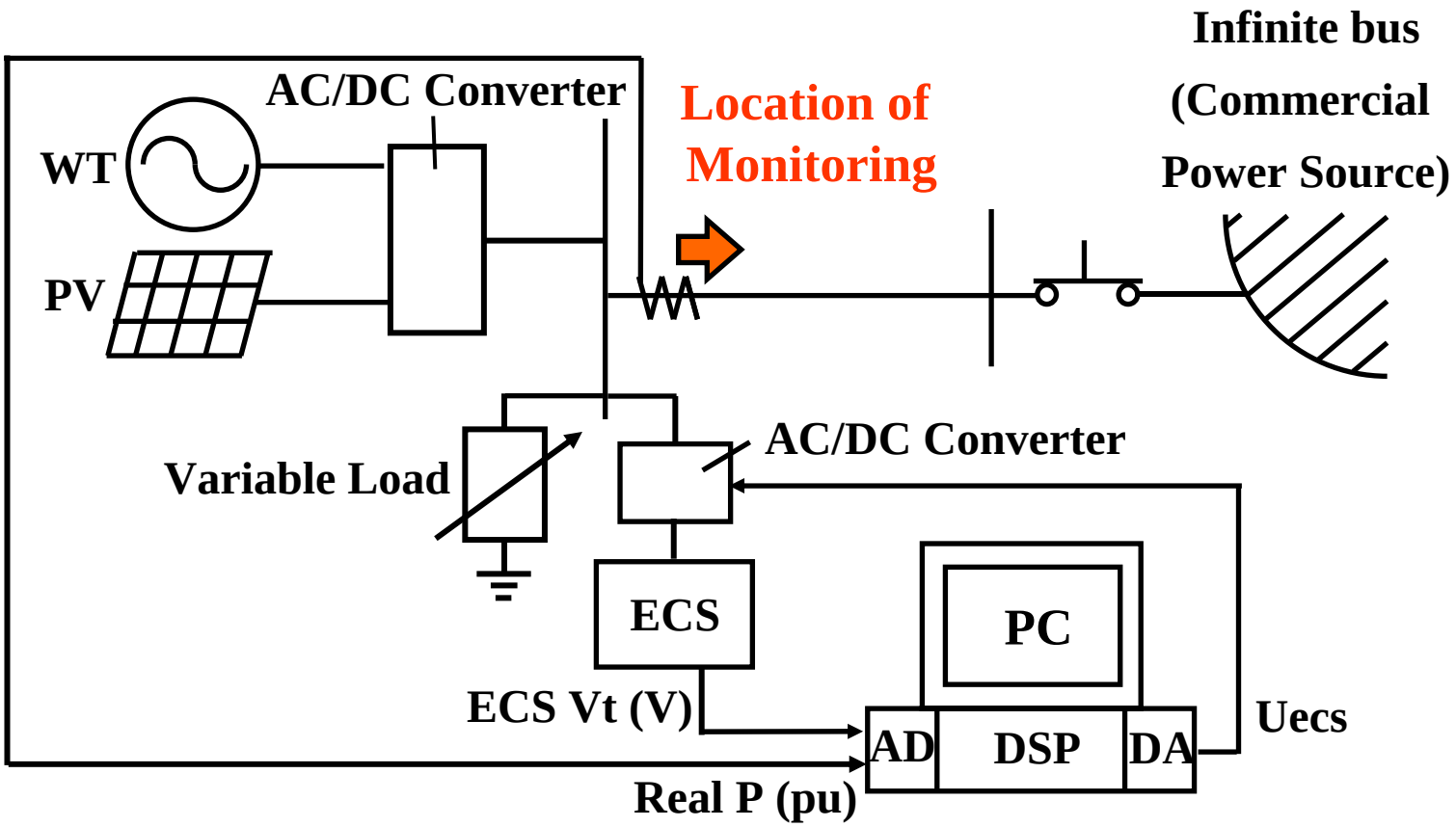


Output from Wind Generation System



出典：※第3回総合エネルギー調査会　新エネルギー部会資料
※※北海道電力ほりかっぷ発電所

Configuration of Laboratory System



PC Based Controller

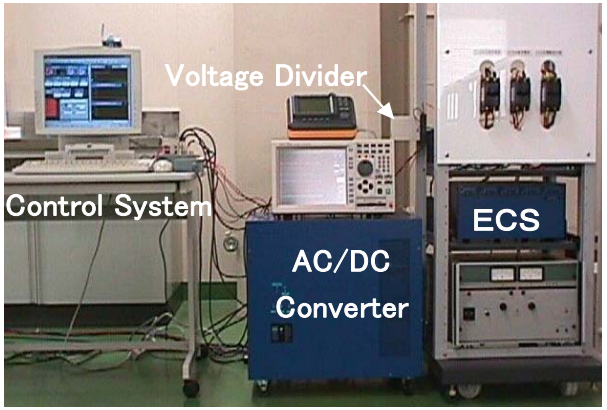
Estimation of Stored Energy

Stored Energy in *Wh*

$$Wh = \frac{1}{2} CV^2 * \frac{1}{3600}$$

C : Capacitance (F)

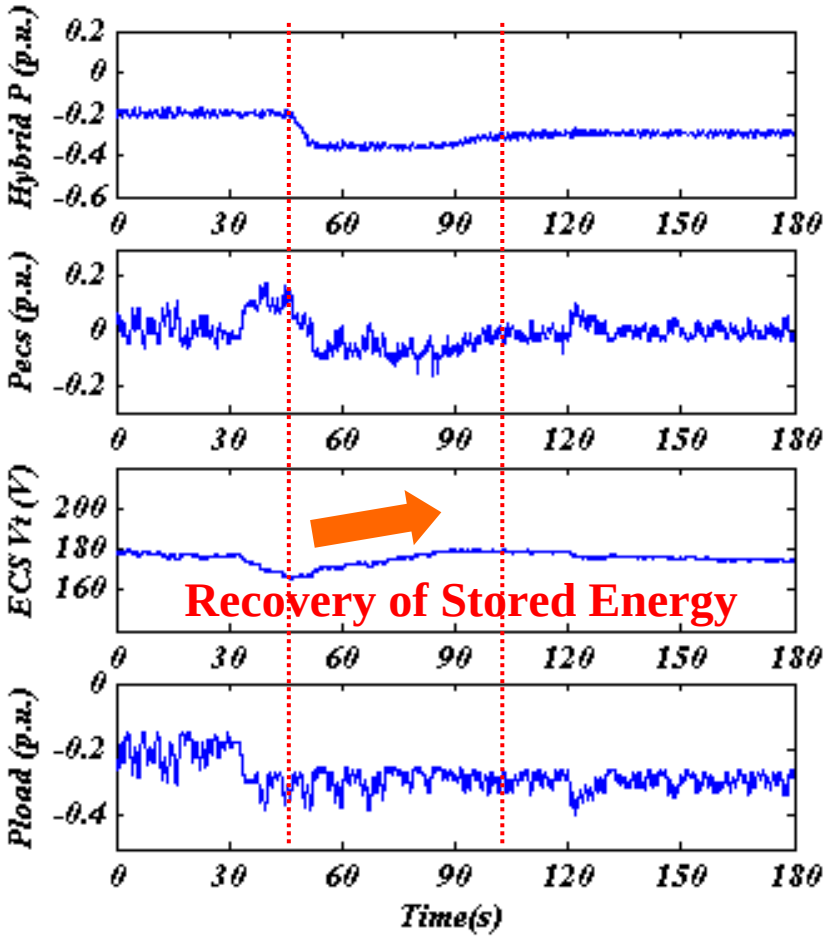
V : DC side terminal voltage



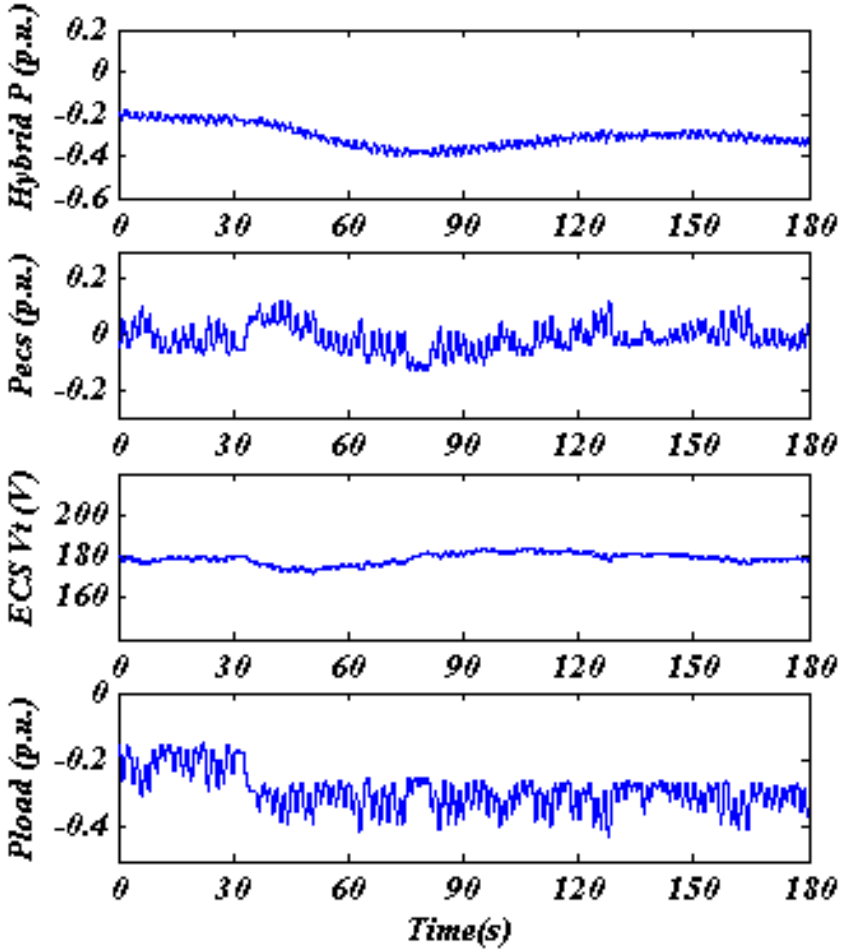
Monitoring of DC side voltage

Experimental Results (1)

Rule-based Regulation

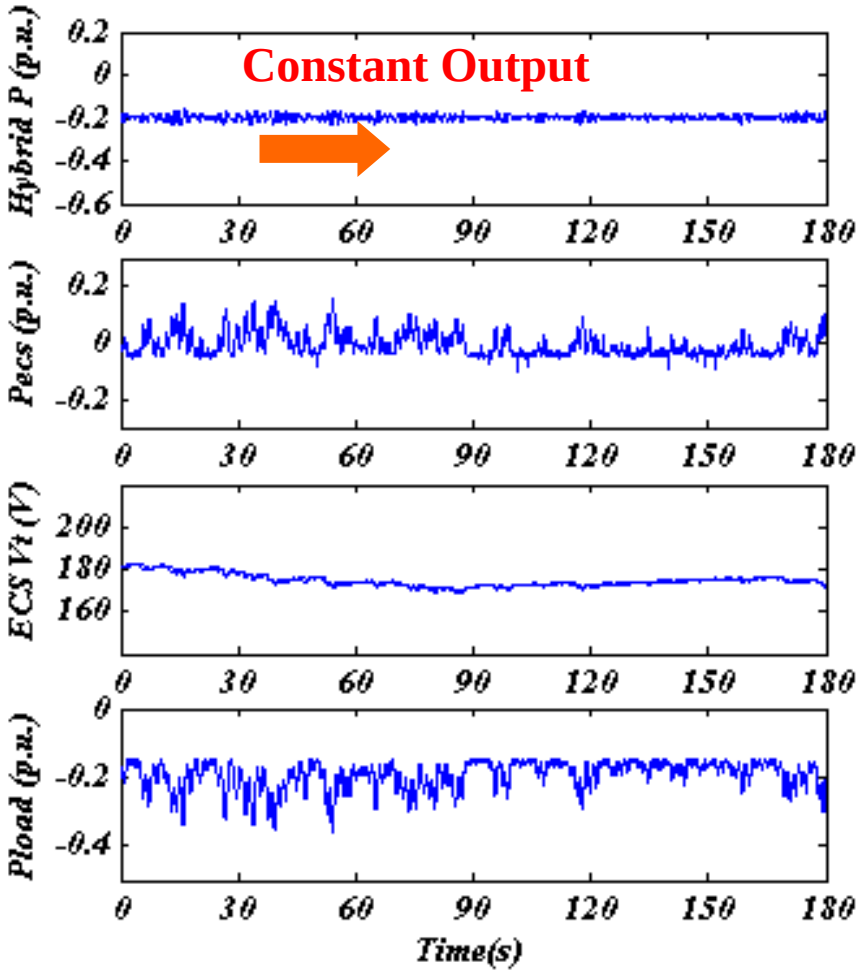


PI-type Regulation

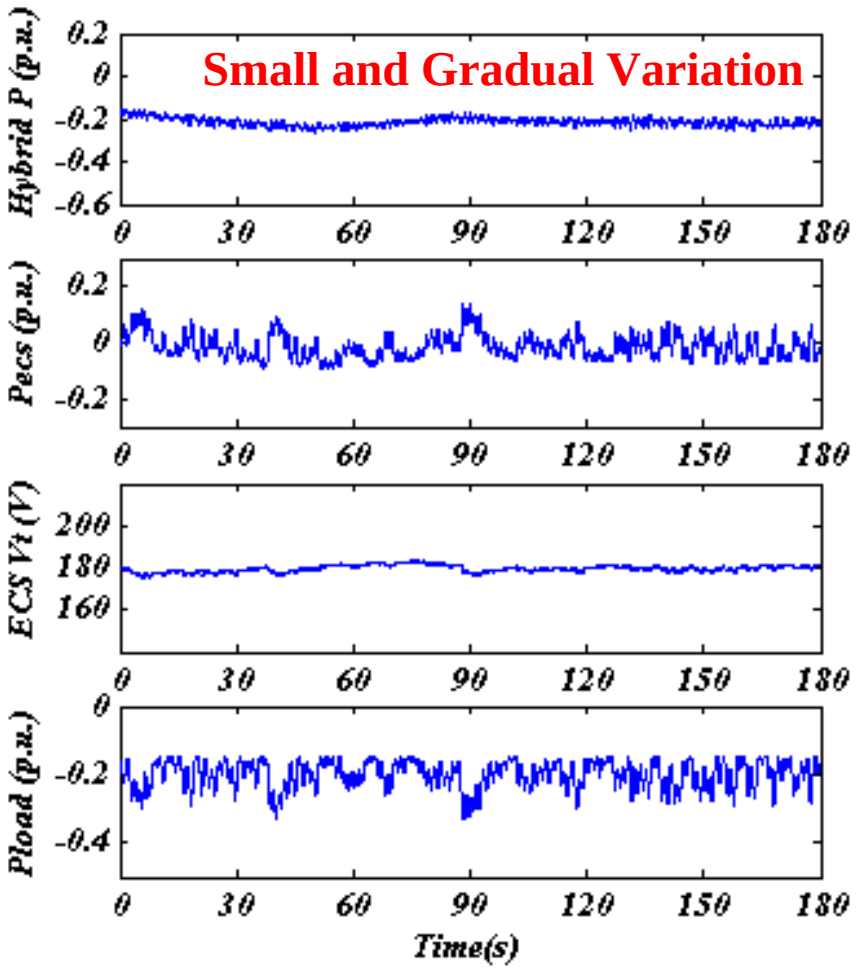


Experimental Results (2)

Rule-based Regulation

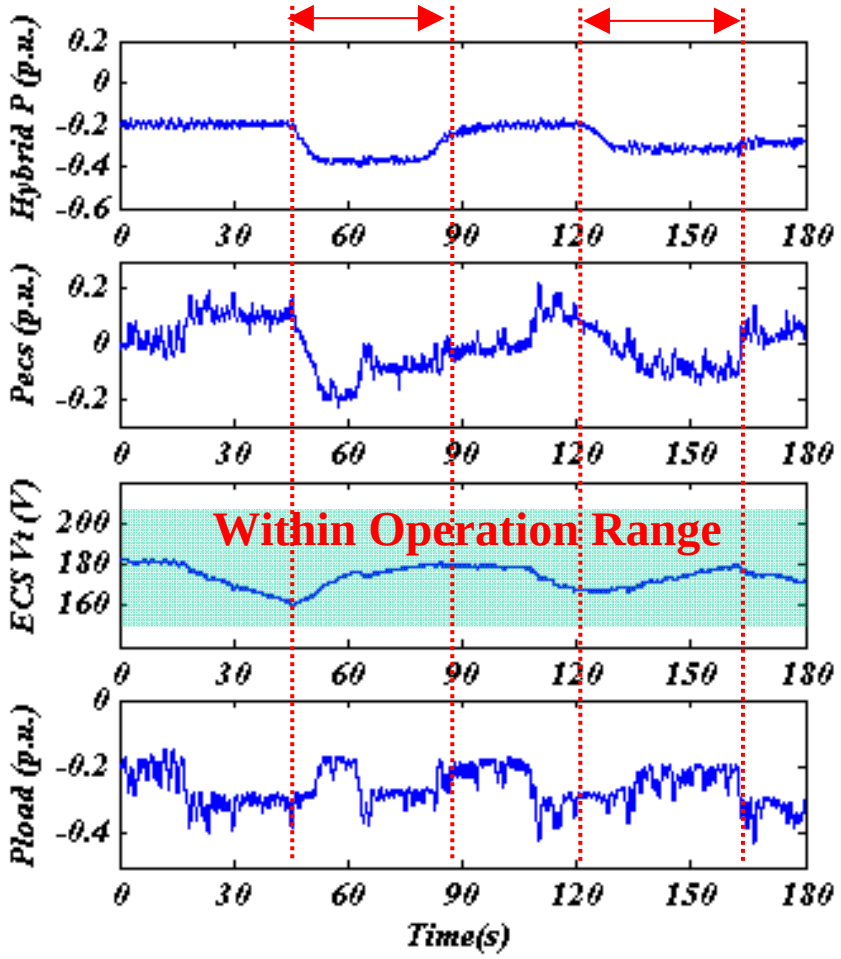


PI-type Regulation

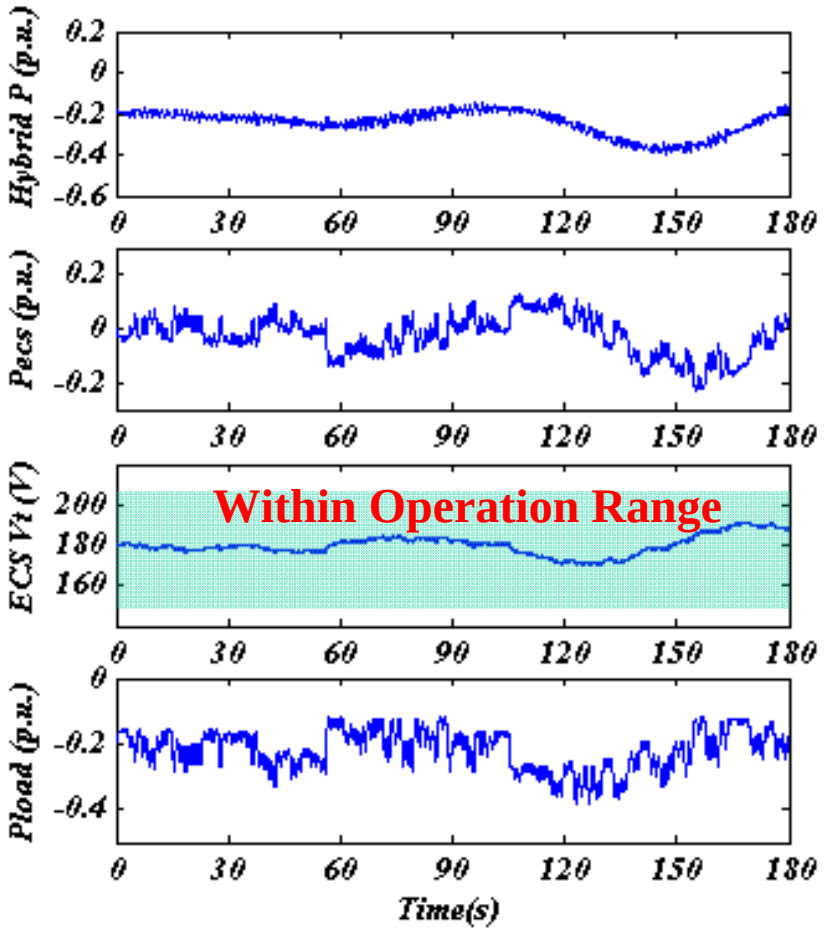


Experimental Results (3)

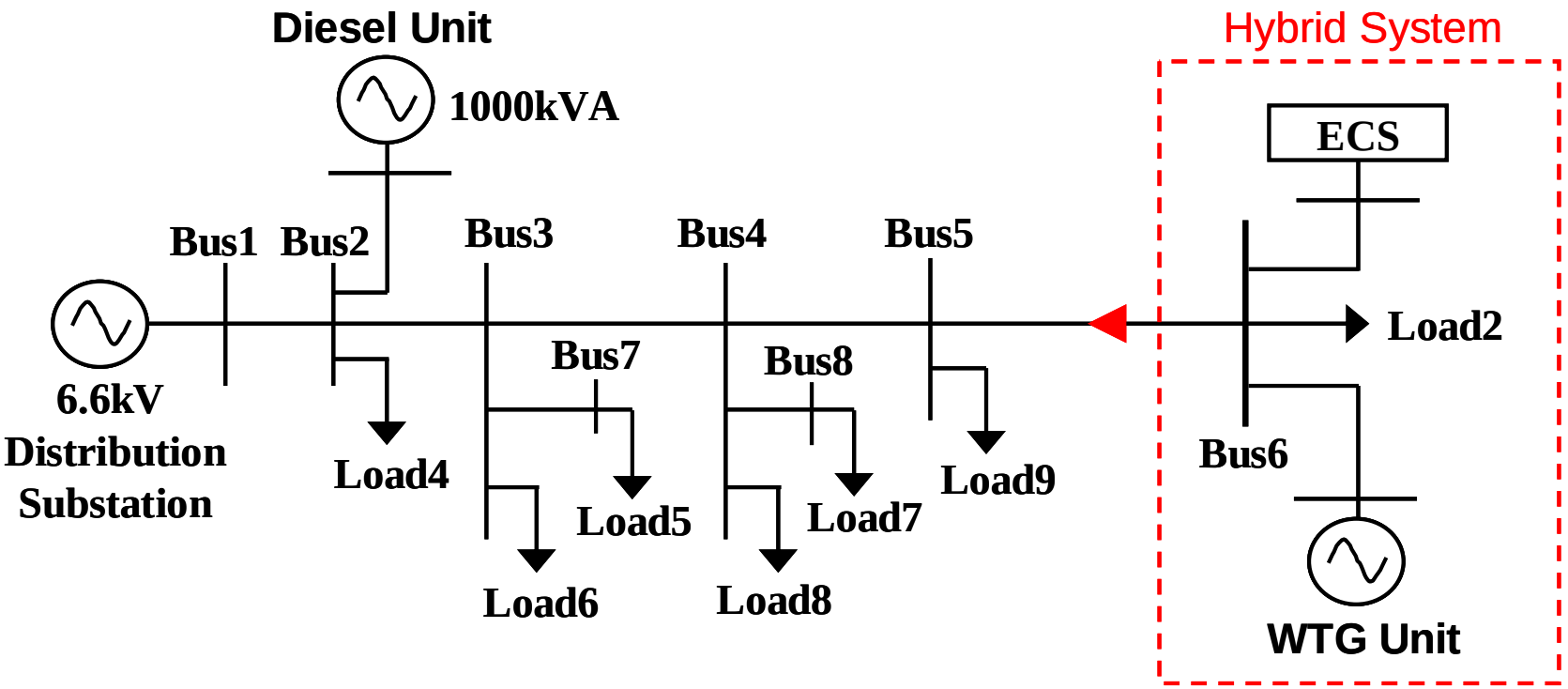
Rule-based Regulation



PI-type Regulation

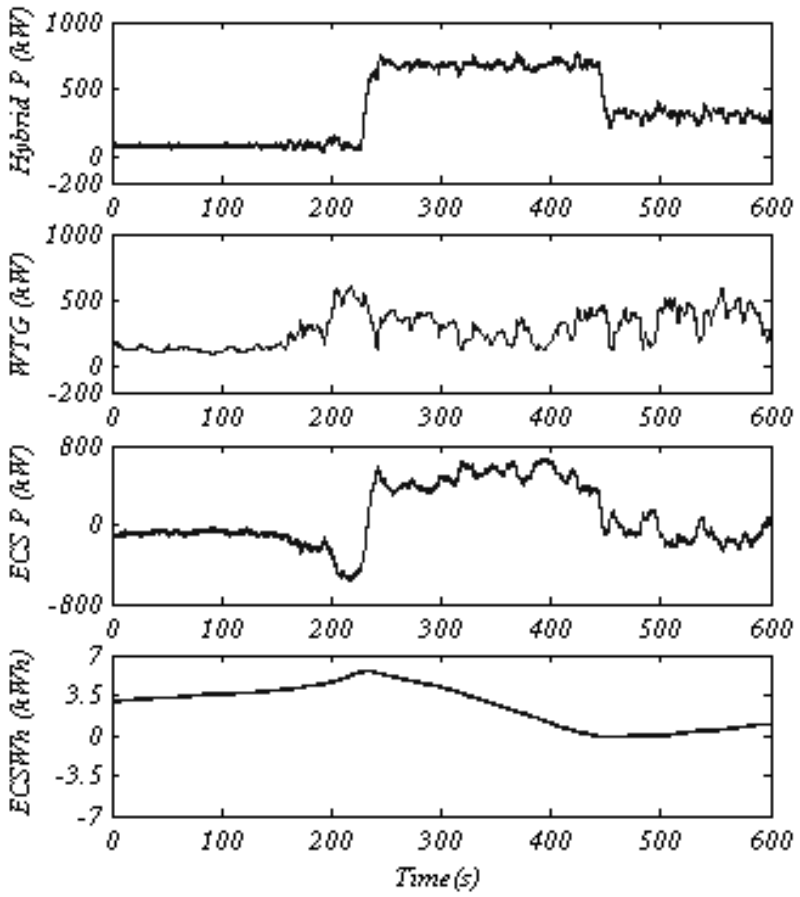


Analog Simulator Tests

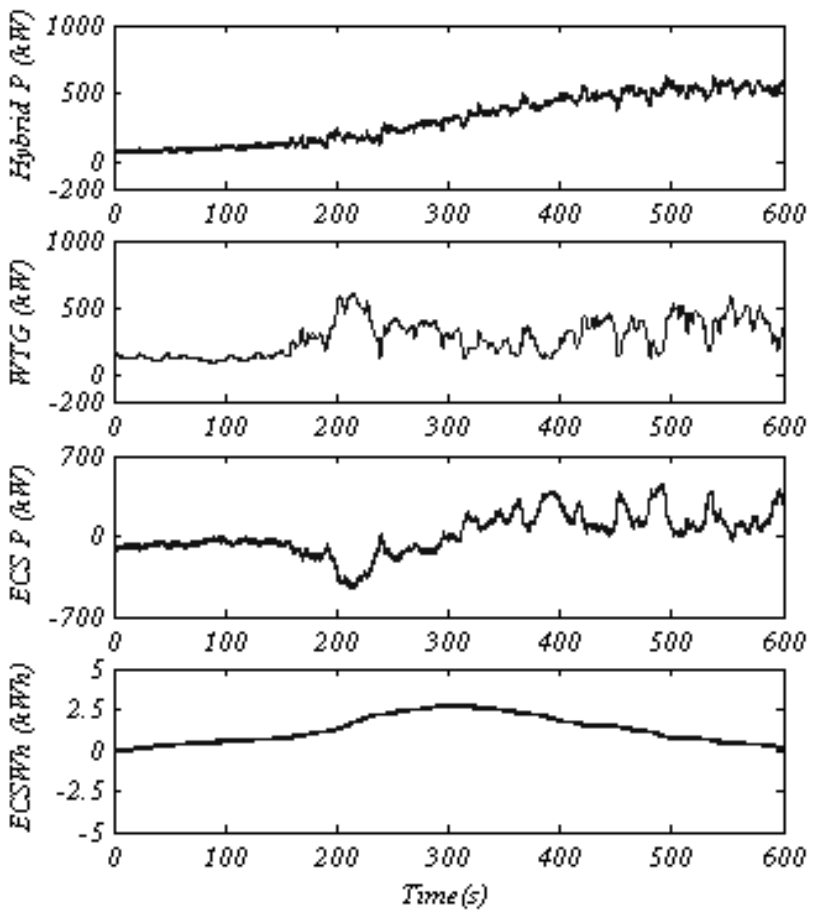


Typical Results in Analog Simulator Test

Rule-based Regulation



PI-type Regulation



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Thank you for your attention.