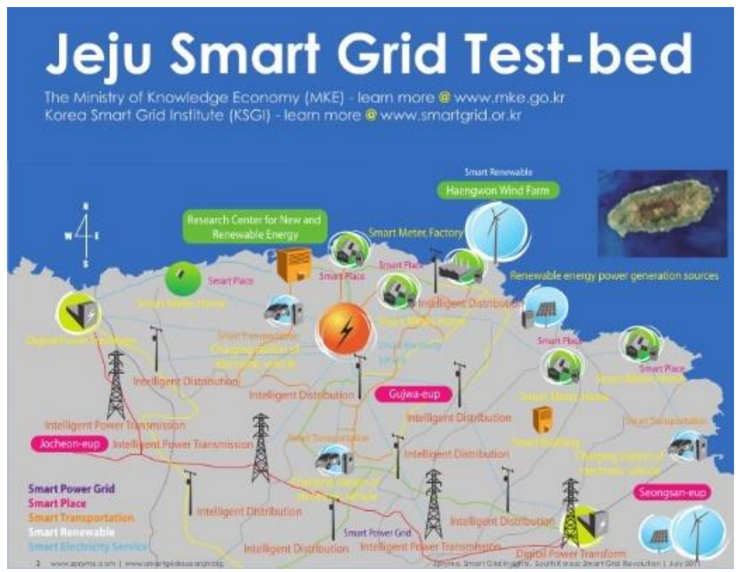
CITIES 5th General Consortium Meeting
Fredericia, 20-21 Sep 2018

Control Issues in Smart Grids



Young IL Lee

Seoul National University of Science and Technology

Energy Transition

◆ Decarbonization

- *Fossil Fuels → ~~Nuclear fuel~~ and Renewable energy sources*

◆ Decentralization

- Centeralized sources → Distributed Sources

Need **Smarter** Protection and Operation of Power Grid

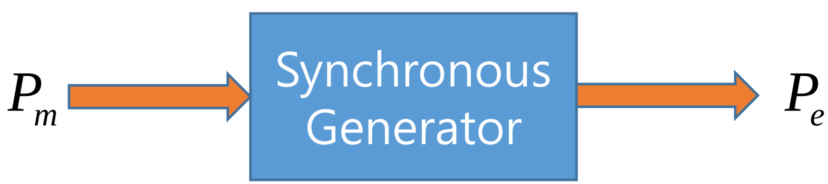
Power Grid

◆ **Reciprocally interdependent system**

- Production and Consumption of Electricity should be balanced

→ $\sum P_g = \sum P_c$

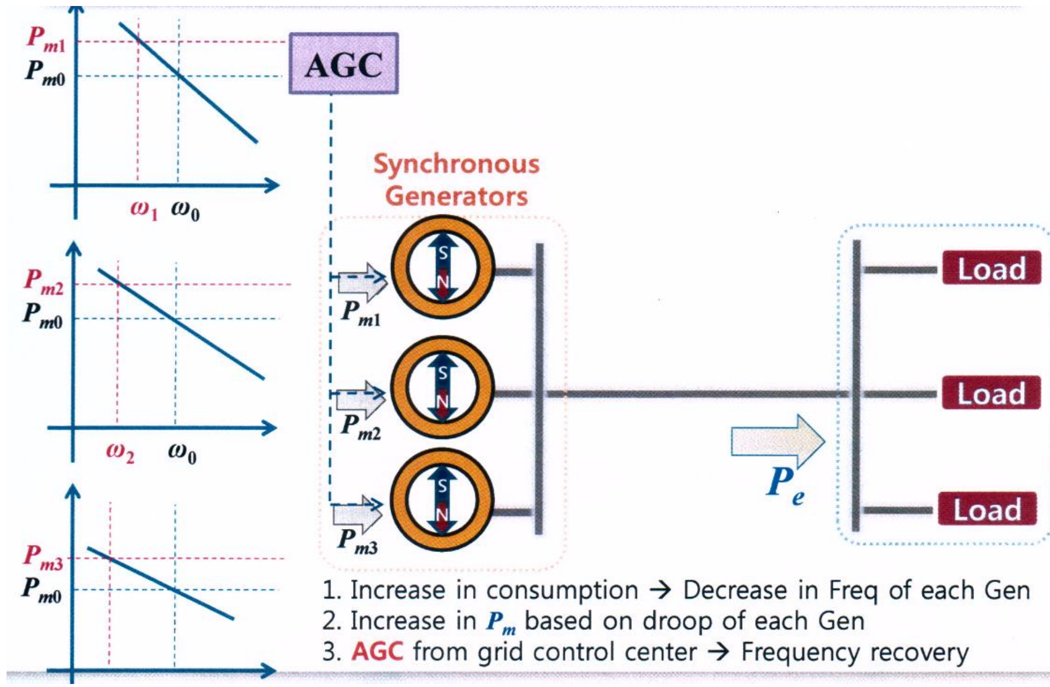
- Otherwise frequency changes → May leads to breakdown



$$J\omega \frac{d\omega}{dt} = P_m - P_e$$

Frequency Control Strategy

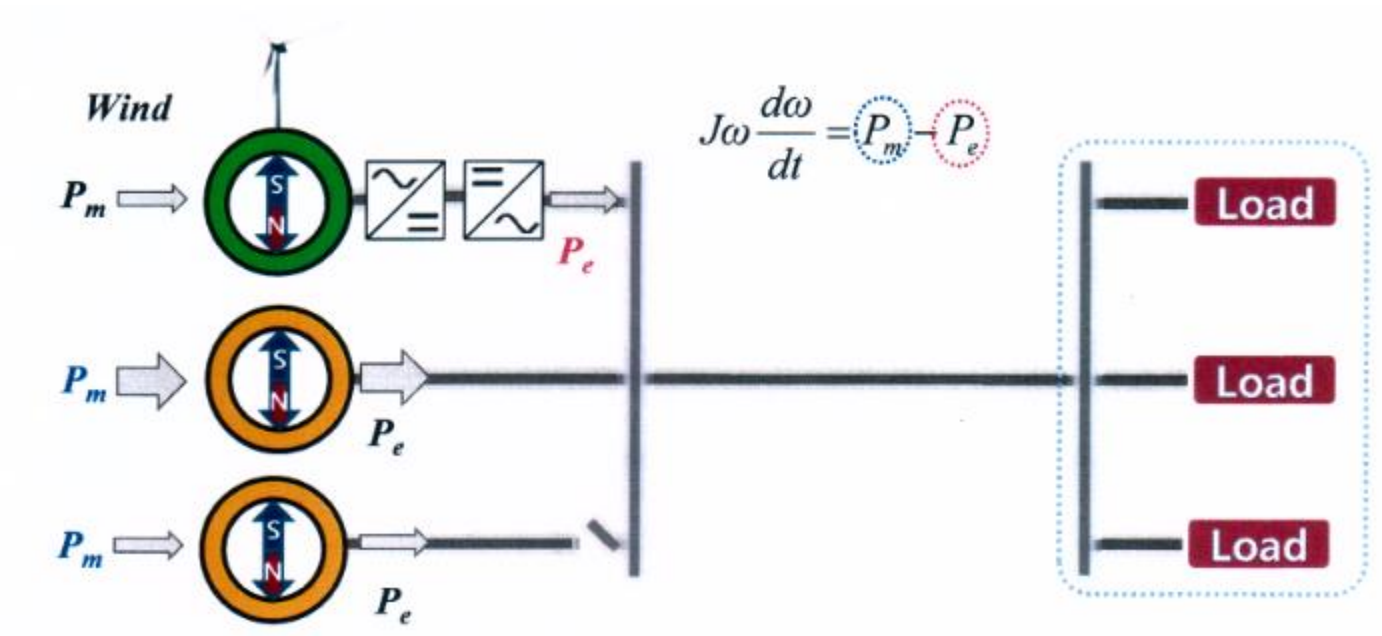
DROOP Control



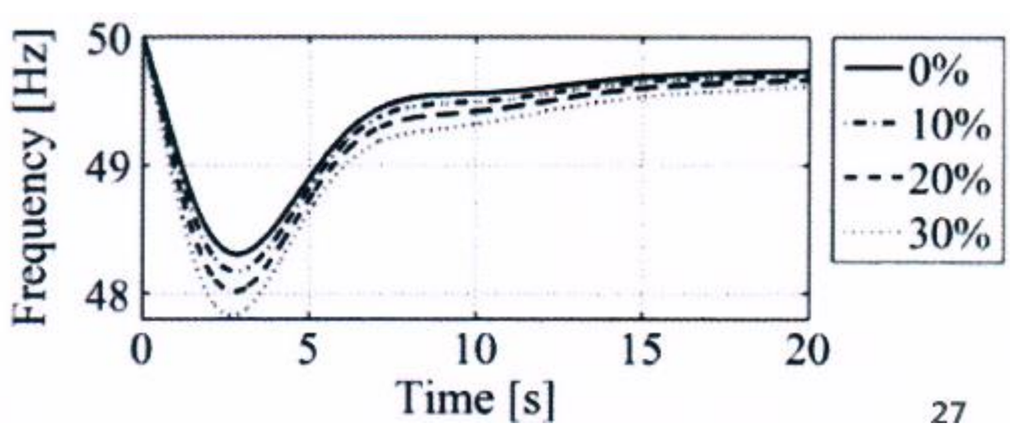
(AGC: Automatic Generation Control)

Frequency Control	Response Time	
Inertial response	2-3 sec	Uncontrollable
Droop Control	10-60 sec	Immediate supply capacity
AGC	1-10 min	

Effect of Renewable Energies



MPPT control reduces system inertia



How to Reduce the Effect

1. Provide More Immediate Supply Capacity

2. Increase ESS

3. Release the kinetic energy stored in the rotating masses in the WTG
   - Virtual inertia control
   - Emulated inertia control
   - Synthesized inertia control
   - Inertia-based fast frequency response

4. Virtual Power Plant using EVs

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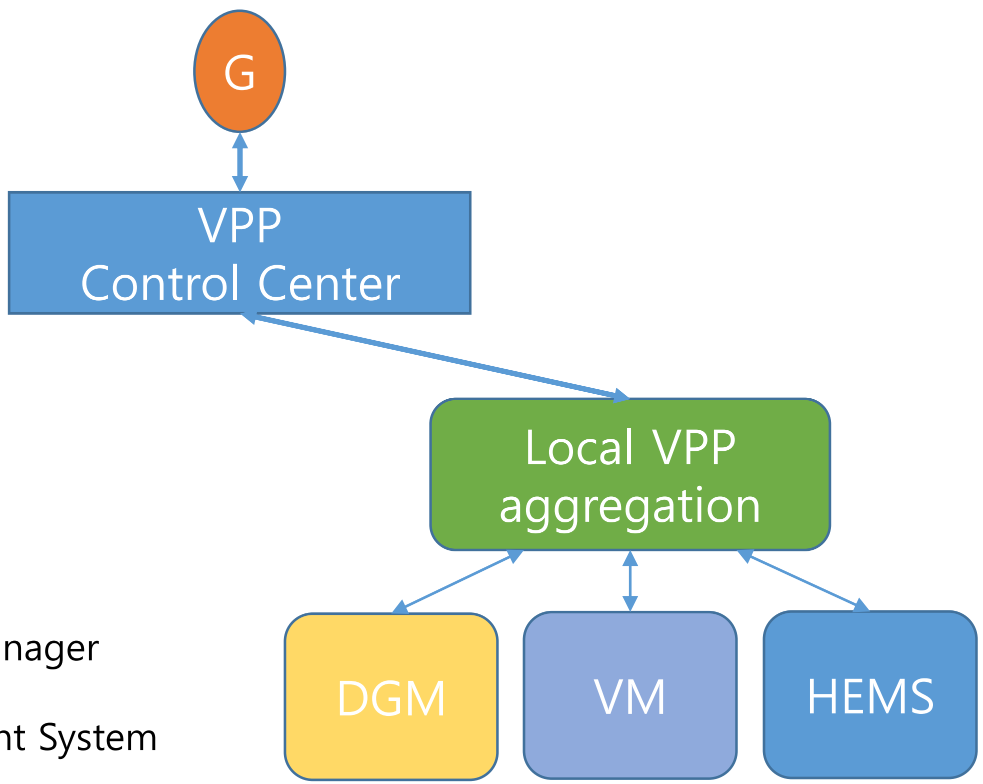
Virtual Power Plant Using EV

- Registered EV in Korea is doubled each year from 2014
- 10M EV by 2030(?)
- Use of EV batteries as ESS is required to cope with uncertainties of renewable energies

Virtual Power Plant Using EV

- Aggregator integrates EVs and DERs and enable their market(grid) interface



DGM : Distributed Gnenerator Manager
VM : Vehicle Manager
HEMS : Home Energy Management System

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Control Issues

- Different control objectives can be defined for VPP Control Center, Local Aggregator, VM, DGM, HEMS etc.
- Different time scale of optimization
- Case studies for 2 approaches presented in IFAC Symposium CPES 2018

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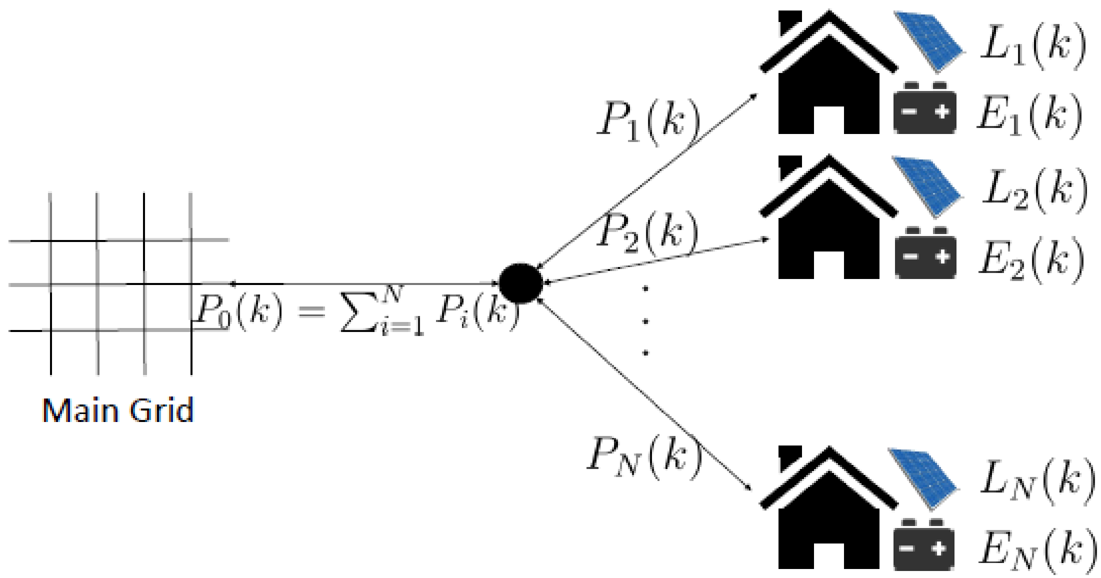
CASE Study

1. Mixed-Integer vs. Real-Valued Formulations of Battery Scheduling Problems, (Alexander Murray, Timm Faulwasser, Veit Hagenmeyer, Germany)



Schematic diagram of the battery scheduling problem for some time step k

The objective function for the central node (VPP Control Center)

$$C_0 := \sum_{k\in \mathrm{K}} (a^+(k)P_0^+(k) + a^-(k)P_0^-(k))\tau, \quad \mathrm{K} = \{0,1,\cdots,K\}$$

$$a^+, a^- : \textbf{\textit{prices for buying and selling electricity}}$$

The objective function for every other node (VM)

$$C_i := \gamma(\bar{E}_i - E_i(K))^2 + \zeta \sum_{k\in \mathrm{K}} ((P_i^+(k) + P_i^-(k) - P_i^{AVG})\tau)^2$$

$$S_i(k) = (1-l)P_i^+(k) + (1+l)P_i^-(k) - L_i(k)$$

$$E_i(k) = E_i(k-1) + (S_i(k) - l\,|\,S_i(k)\,|)\tau$$

$$P_i^+(k)P_i^-(k) = 0$$

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Mixed Integer Formulation

$$\min_{P,z} \sum_{i \in I_0} C_i^{\text{int}}$$

$$C_0^{\text{int}} := \sum_{k \in K} \left(\frac{1 - z_0(k)}{2} a^{+}(k) + \frac{1 + z_0(k)}{2} a^{-}(k) \right) P_0(k) \tau$$

$$C_i^{\text{int}} := (\bar{E}_i - E_i(K))^2 + \xi \sum_{k \in K} ((P_i(k) - P_i^{AVG}) \tau)^2$$

$$E_i(k+1) = E(k) + ((1 - z_i(t) l) P_i(k) - L_i(k)) \tau$$

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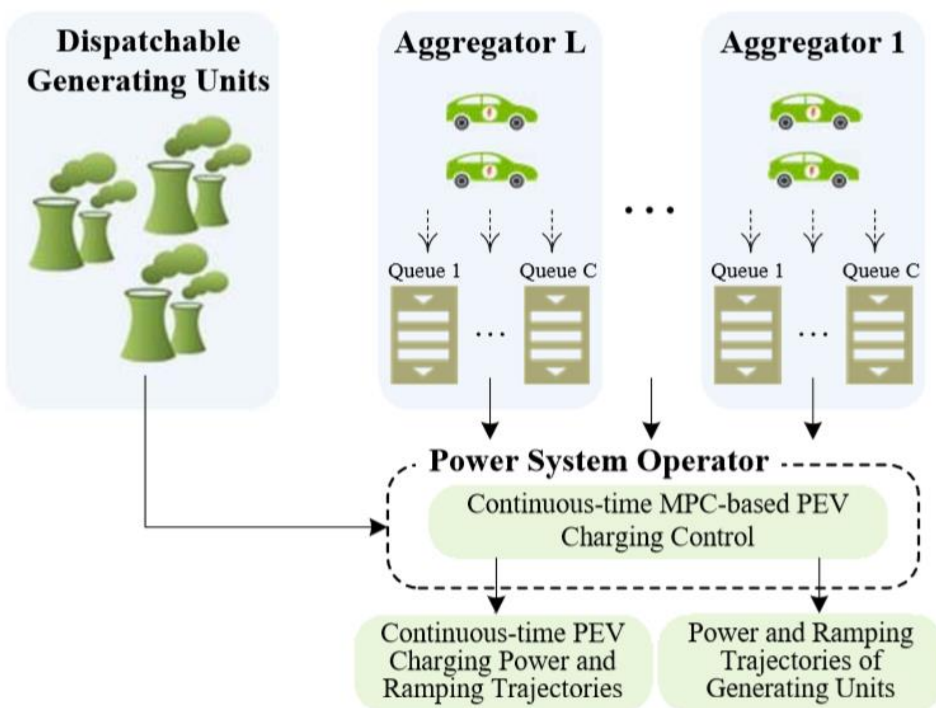
2. Continuous-time Model Predictive Control for Real-time Flexibility Scheduling of Plugin Electric Vehicles(Roohallah Khatami, Masood Parvania, Avishan Bagherinezhad, USA)

- Uses multiple queuing systems to cluster the PEV charge requests
  - ✓ amount of energy required,
  - ✓ service quality requirements (i.e., delay or deadline constraints)
  - ✓ location of chargers (e.g., residential, workplace, public)
  - ✓ type of chargers (level 1-3),
  - ✓ service quality requirements



$$\min_{\dot{\mathbf{G}}(t),\dot{\mathbf{D}}(t)} \int_{\mathcal{T}_\tau} \mathcal{C}\big(\mathbf{G}(t)\big)dt$$

$$\begin{aligned}
\dot{\mathbf{Q}}(t) &= \mathbf{J}(t) - \mathbf{D}(t), \quad t \in \mathcal{T}_\tau, \\
\mathbf{1}_K^T \mathbf{G}(t) &= \mathbf{1}_{LC}^T \mathbf{D}(t) + D^I(t), \quad t \in \mathcal{T}_\tau, \\
\underline{\mathbf{G}}(t) \leq \mathbf{G}(t) &\leq \overline{\mathbf{G}}(t), \quad t \in \mathcal{T}_\tau, \\
\underline{\mathbf{D}}(t) \leq \mathbf{D}(t) &\leq \overline{\mathbf{D}}(t), \quad t \in \mathcal{T}_\tau, \\
\underline{\dot{\mathbf{G}}}(t) \leq \dot{\mathbf{G}}(t) &\leq \overline{\dot{\mathbf{G}}}(t), \quad t \in \mathcal{T}_\tau, \\
\underline{\dot{\mathbf{D}}}(t) \leq \dot{\mathbf{D}}(t) &\leq \overline{\dot{\mathbf{D}}}(t) \quad t \in \mathcal{T}_\tau, \\
\underline{\mathbf{Q}}(t) \leq \mathbf{Q}(t) &\leq \overline{\mathbf{Q}}(t), \quad t \in \mathcal{T}_\tau, \\
\mathbf{G}(\tau) = \mathbf{G}^\tau, \; \mathbf{D}(\tau) &= \mathbf{D}^\tau, \; \mathbf{Q}(\tau) = \mathbf{Q}^\tau.
\end{aligned}$$

Consider Charging Requirement but Do not cover V2G Case

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Conclusions

- Increase of renewable energies decrease the system inertia → Increase Power Grid Frequency Instability
- Operational methods of renewable energies compensating the rack of inertia has been developed
- Use of more ESS is required and EVs can be used as ESS through V2G
- Use of EVs as ESS poses many complicated control problems
- Development of smart operation method(or Business Model) considering benefits of EV owners and Power Grid Stability should be developed

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2019 IFAC Workshop (TC6.3)

Control of Smart Grid and Renewable Energy Systems (CSGRES 2019)

10-12 June, 2019, Jeju, Korea

http://CSGRES2019.com

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Executive Summary

◆ Workshop Date : 10(Mon)-12(Wed) June, 2019

◆ Title : **Control of Smart Grid and Renewable Energy Systems**

◆ Venue : Hyatt Regency Jeju, Republic of Korea

◆ Jeju, Korea

- Ocean-front resort-style venue.
- Jeju is a test bed for smart grid and EV charging infra structure.
- Jeju is a Free Trade Zone and allows visa-free entry for ~180 countries.
- Jeju is a beautiful island with 3 UNESCO designations.

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Scope of the workshop

◆ **Two Key Topics**

1. Modelling and Control of Prosumer Resources.

   - Increasing prosumer resources brings many unknowns and risks that need to be identified and controlled.
   - International research has been launched in 2016 and its results could be discussed in the workshop.

2. Battery Charging/Discharging Control for Electric Vehicle

   - Tesla S requires 11kW and 100kW for slow charge and fast charge, respectively.
   - Recently, power-train control draws attention as a key issue of EV.
   - Jeju is an ideal place for EV and IEVE will support the workshop.

Scope of the workshop

Integrating renewable energies and prosumer resources in a smart way leads to the development of Smart Grid.

◆ Topics of the workshop includes:

- Modelling and Identifying Prosumer Resources
- Transaction-based P2P Energy Management System
- Prediction and Control of Prosumer Resources
- Power System Stability and Reliability
- Optimal Design, Control and Operation of Renewables
- Intelligent Integration of Renewable and Energy Storage Systems including District Heating Systems

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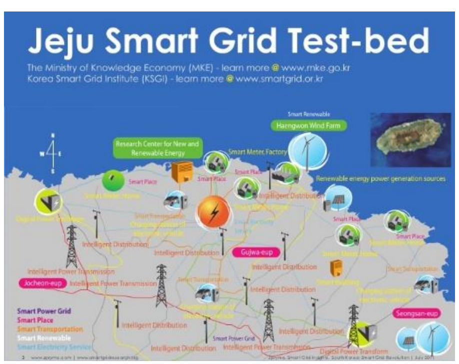
Scope of the workshop

- Control and Communication for Vehicle to Grid and Vehicle to Building
- Coupled Traffic and Energy Transportation Networks
- Control of Power Inverters, FACTS, UPFC, DPFC and HVDC
- Power Systems, Transmission & Distribution Systems Operation and Control
- Control of Smart Devices and Users (Smart Meters, Smart Buildings, Artificial Intelligence, Demand Response)



Due Dates

Submission of invited session proposals	Aug. 25, 2018 --> **Nov. 1, 2018**
Submission of full draft papers	Sep. 25, 2018 --> **Nov. 25, 2018**
Notification of acceptance	Dec 15, 2018 --> **Feb. 15, 2019**
Submission of full papers	Feb. 15, 2019 --> **April 15, 2019**
Early registration	April. 1, 2019

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Sponsors, Co-sponsors

◆ **Technical Committee 6.3 – Power and Energy Systems**

◆ 11 Supporting TCs

TC1.2 TC1.3 TC1.4 TC1.5 TC2.3 TC2.5 TC6.1 TC6.2 TC7.4 TC9.3 TC9.5

- **1.2 Adaptative and Learning Systems, 1.3 Discrete Event and Hybrid Systems, 1.4 Stochastic Systems, 1.5 Networked Systems**
- **2.3 Non-Linear Control Systems, 2.5 Robust Control**
- **6.1 Chemical Process Control, 6.2 Mining, Mineral and Metal Processing**
- **7.4 Transportation Systems**
- **9.3 Control for Smart Cities, 9.5 Technology, Culture and International Stability (TECIS)**

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Sponsors

- ICROS(NMO of IFAC)
- KIEE
- Korea Electric Power Company (KEPCO)
- CIRED Korea branch
- Secretariat of IEVE
- Korea Smart Grid Institute

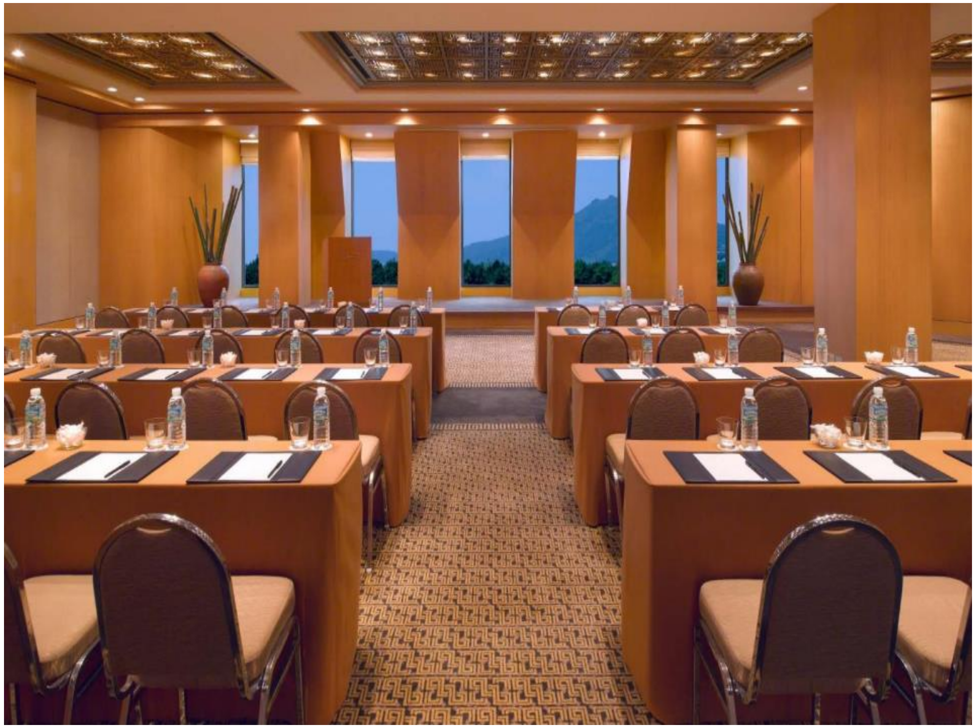
Venue

◆ **HYATT REGENCY JEJU**

- A luxury 4-star hotel in a spectacular resort setting on Jungmun Beach
- Breathtaking ocean views
- A total of 222 rooms, Two Ballrooms
- Five restaurants and bars
- Recreational facilities

Venue – Function Rooms

Two large ballrooms are located on the same level



Both can be divided into smaller sections

Venue – Other facilities

Cliff Garden

Outdoor Korean Restaurant

Outdoor Pool

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Technical Tour

- **Korea Power Exchange – Jeju Branch**
  - Jeju is a testbed of Microgrid for EV
  - Receive 40% of its total use from mainland through HVDC
  - 43.5MWh ESS is under operation in Wind farm
  - Commercial operation of 272MW Wind Power, 70MW Solar Power
  - 12,000 EVs are working

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Technical Tour

◆ Carbon Free Island GAPA Island (GAPADO)

- Only 284 people living in the island and two diesel driven boats taking people there.

- There are plans to put a smart grid and all power used will be from renewable sources. The solar farm is already up and two huge wind generators already in place.

- By 2019, GAPADO will be the World's first carbon-free island.

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Registration Fee

◆ Early registration fee	380 Euro
◆ Standard registration fee	480 Euro
◆ Student early and standard fee	200 Euro
◆ Accompanying person fee	200 Euro

(2 Paper submission per registration will be allowed)

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Accommodations

- The venue is located in the Jungmun Resort Complex
- There are 4-Special first-class hotels within the Jungmoon Resort Complex (5-4Stars)
    - Hyatt Regency Jeju, Lotte Hotel Jeju, The Shilla Jeju, The Suits Hotel Jeju
- Corea Condo Jeju (2.5Star), Aria Hotel (3.5Stars), Jeju Hana Hotel (3Stars)

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List of Nearby Hotels

Class	Hotel Name	Rooms	Rates	Distance to Venue
SDLX	Hyatt Regency Jeju[Venu]	223	$162	0
SDLX	Lotte Hotel	500	$207	5 min by car
SDLX	Kensington Hotel	221	$200	7 min by car
SDLX	Booyoung Hotel	262	$126	10 min by car
SDLX	Booyoung Resort	187	$142 (69 m^2)	10 min by car
SDLX	The Suites Hotel	90	$105	5 min by car
2nd	Hana Hotel	133	$70	5 min by car
Condominium	Corea Condo	216	$68 (82 m^2)	5 min by car
Condominium	Kensington Resort	246	$103 (85 m^2)	20 min by car
Condominium	POL-A Resort	131	$95 (56 m^2) / $133 (89 m^2)	25 min by car
DLX	Aria Hotel	72	$80	10 min by car
2nd	IlleInn Hotel	42	$80	10 min by car
2nd	Benikea Jungmun Hotel	45	$80	10 min by car
2nd	Hidden Hotel	27	$70	25min by car

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Post Conference Tour

Temperature in Mid-June : 15/25 °C

◆ Seongsan Sunrise Peak

The site is extremely popular with visitors from around the world. It was listed as a UNESCO World Natural Heritage in 2007.

Post Conference Tour

Temperature in Mid-June : 15/25 °C

◆ Geotrails

There are many beautiful paths to explore in jeju, but the island's geotrails have a geological history that is recognized as a unique and precious resource

Accessibility of Jeju Island

- **Visa-free entry for ~180 countries.**
- **Option 1: Direct flights from 48 cities in Asia**
  - 27 airlines flew 14,674 times to Jeju in 2015

26 million visitors in 2015

- **Option 2: Transfer via Seoul**
  - Incheon airport: top-3 hub airport for 5 consecutive years
  - Incheon to Gimpo airport – easy shuttle
  - 7 airlines flew 144,017 times from Gimpo to Jeju in 2015
- **Option 3: Transfer via other hub airports (Beijing, Shanghai, Hong Kong, Tokyo, Osaka, …)**

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Transportation from Airport

- The Venue is 38 km from Jeju International Airport
- Limousine buses to the venue and nearby hotels run every 20 minutes (~10 USD)
- Metered taxis are readily available (~50 USD)

Program Committee Chairs

- IPC Chair : Prof. Kwang Y. Lee, Baylor University, USA
- IPC Co-Chair : Prof. Yrjö Majanne, Tampere University of Technology, Finland
- IPC Vice-Chair : Prof. Furong Li, University of Bath, UK
- IPC Vice-Chair from Industry : Dr. Woo-Hyun Hwang, KEPCO, Korea

- NOC Chair: Prof. Young Il Lee, SeouTech, Korea
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- NOC Local Arrangements Chair: Prof. Ho Chan Kim, Korea
- NOC local Arrangements Co-Chair: Dr. Heesang Ko, Korea
- NOC Financial Affairs Chair: Prof. Jungsu Kim, SeoulTech, Korea

- 93 IPC Members from 11 supporting TCs (TC1.2 TC1.3 TC1.4 TC1.5 TC2.3 TC2.5 TC6.1 TC6.2 TC7.4 TC9.3 TC9.5) and other

Plenary Speakers

- Dr. WooHyun Hwang
  President of Human Resource Developing Center, KEPCO(Korea Electric Power Company)
  Title : Status of Electric Vehicle Operation and onstruction of Intelligent Power Network in Jeju Island

- Professor Henrik Madsen
  Dept. of Applied Mathmatics and Computer Science, Head of Centre for IT-Intelligent Energy Systems in cities (CITIES)
  Title : How to use AI and Big Data Analytics to Control the Future Smart Grids

- Professor Furong Li
  Department of Electronic & Electrical Engineering, Center for Sustainable Power Distribution

- Professor Sukumar Mishira
  Department of Electrical Engineering, Indian Institute of Tech. Delhi

Invited Sessions under Preparation

- Modeling and Control of Prosumer in Power-Grid
- Control of EV Charging System
- Effect of Renewable Energies on Power Grid
- DC-microgrid
- Control of Wind Turbine Generation
- Operation and Control of Hybrid AC/DC Power Network

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Thank you very much!