# TJU Research on Community Integrated Energy System(CIES)


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# Contents



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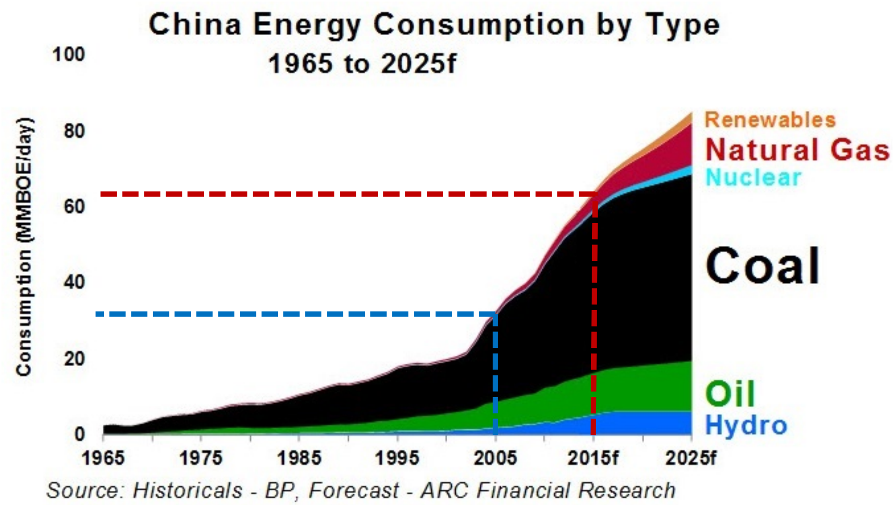
# Background

## Demand & Pressure & Resource

China is under the stage of

- Industrialization
- Urbanization




Environmental Problems:





Chinese Government:

- ✓ 40%~45% of $CO_2$ emission for per unit GDP will be reduced by 2020 compared with 2005.
- ✓ To cap the $CO_2$ emission growth by 2030

Rich Renewable Energy Resources

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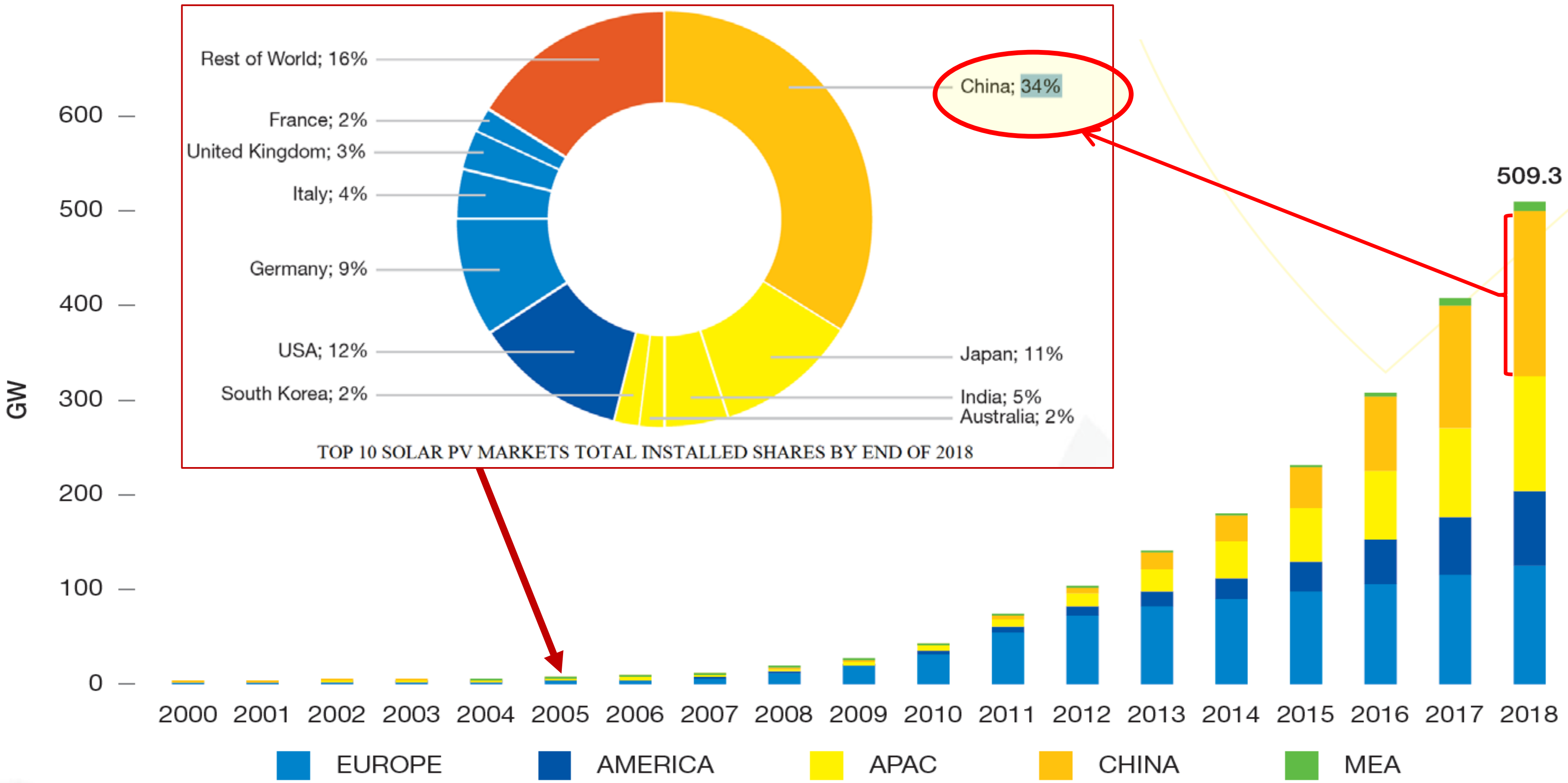
# Background

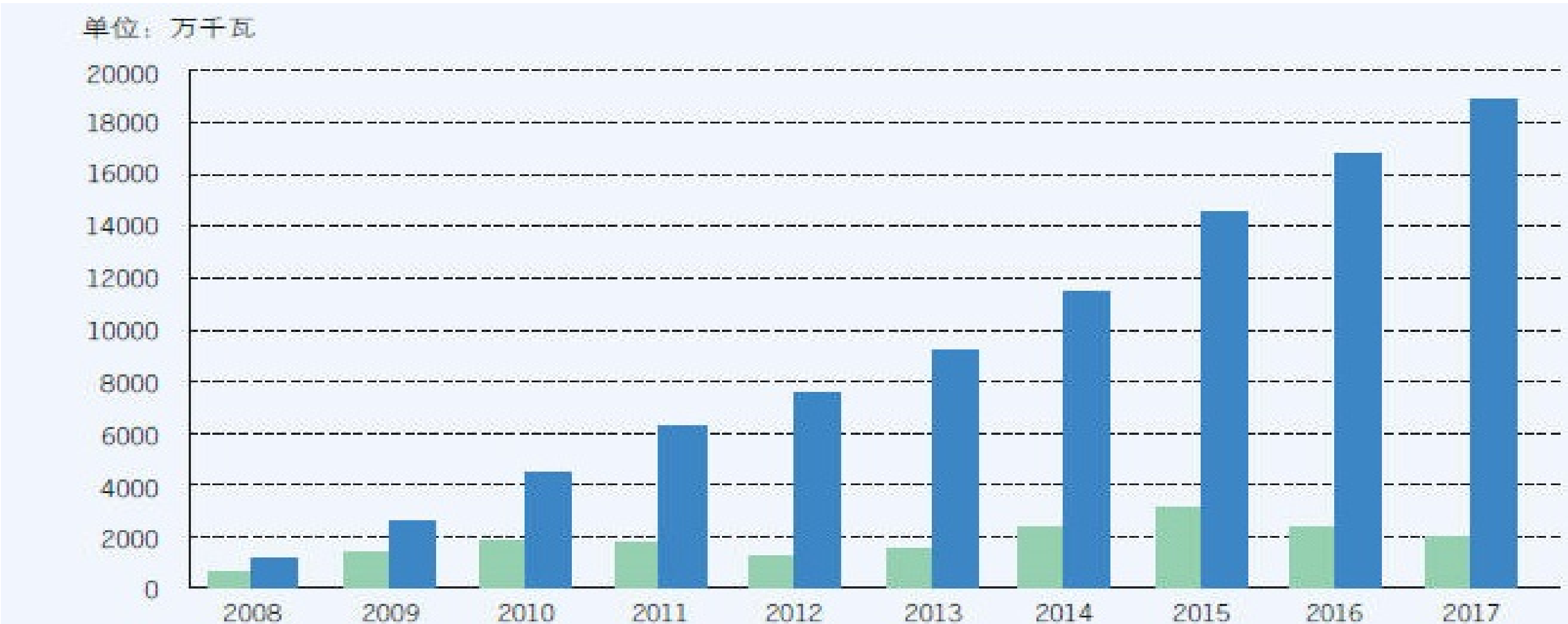
## Total Solar Power Installation




**Data from SolarPower Europe 2019**

**Solar: In 2005, total solar power capacity was 0.5GW. It increased to 175 GW (+44.3 GW) in 2018, 34% of the global market share.**

# Installation of Wind Power

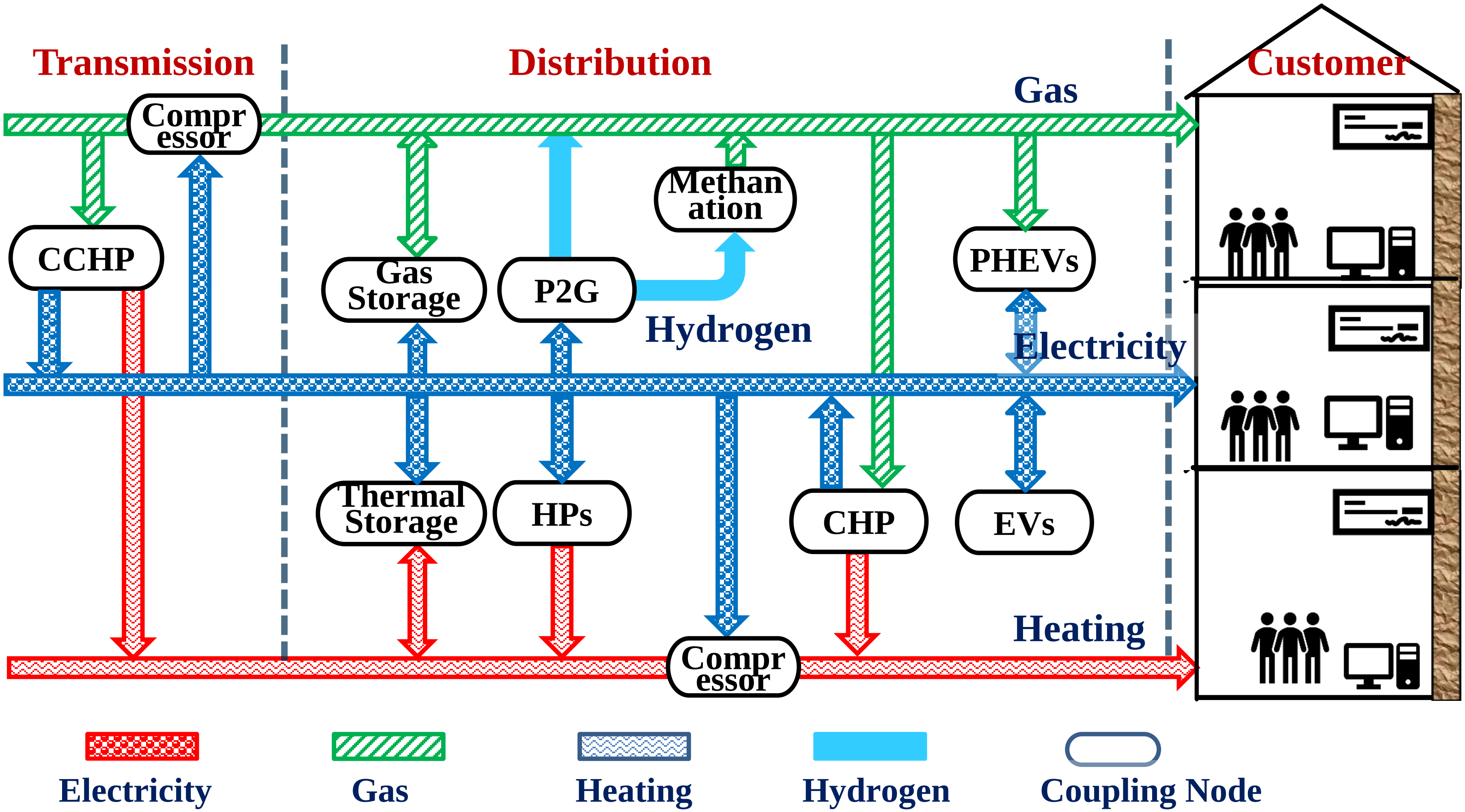



| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| 新增装机 | 615 | 1380 | 1893 | 1763 | 1296 | 1609 | 2320 | 3075 | 2337 | 1996 |
| 累计装机 | 1200 | 2581 | 4473 | 6236 | 7532 | 9141 | 11461 | 14536 | 16873 | 18839 |

数据来源：CWEA

**In 2005, installation of wind power was only 1.25GW in China, and the number turned to 188.39GW in 2017 (about 150 times).**

# Background




CIES is composed of multiple terminals and energy networks including thermal (heating/ cooling), natural gas, hydrogen, electricity and transportation systems in the customer sider. It is regarded as an effective way to increase the energy efficiency and renewable energy penetration. So it has been drawing more and more attention recently. It has obtained strong support from the government.

# Background

中华人民共和国国家统计局
National Bureau of Statistics of the People's Rep

检索 | 高级

走近统计 国家统计局 派驻纪检组 机构职能
统计数据 最新发布 数据查询 数据解读
统计工作 统计动态 通知公告 图片新闻
统计知识 统计百科 统计词典 常见问题解答
统计服务 网上办事 曝光台 失信企业公示
信息公开 公开指南 公开规定 公开目录

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## 2017年全国科技经费投入统计公报

来源：国家统计局　发布时间：2018-10-09 13:57　关闭窗口 打印本页

**2017年全国科技经费投入统计公报**

国家统计局 科学技术部 财政部

2018年10月9日

2017年，我国科技经费投入力度加大，研究与试验发展（R&D）经费投入增速加快，国家财政科技支出平稳增长，研究与试验发展（R&D）经费投入强度稳步提高。

**一、研究与试验发展（R&D）经费情况**

2017年，全国共投入研究与试验发展（R&D）经费17606.1亿元，比上年增加1929.4 亿元，增长12.3%，增速较上年提高1.7个百分点；研究与试验发展（R&D）经费投入强度（与国内生产总值[1]之比）为2.13%，比上年提高0.02个百分点。按研究与试验发展（R&D）人员（全时工作量）计算的人均经费为43.6万元，比上年增加3.2万元。

分活动类型看，全国基础研究经费975.5亿元，比上年增长18.5%；应用研究经费1849.2亿元，增长14.8%；试验发展经费14781.4亿元，增长11.6%。基础研究、应用研究和试验发展经费所占比重分别为5.5%、10.5%和84%。

附表1　2017年分行业规模以上工业企业研究与试验发展（R&D）经费情况

| 行业 | R&D经费（亿元） | R&D经费投入强度（%） | 行业 | R&D经费（亿元） | R&D经费投入强度（%） |
|---|---|---|---|---|---|
| **合　计** | **12013.0** | **1.06** | 化学原料和化学制品制造业 | 912.5 | 1.11 |
| 采矿业 | 281.8 | 0.59 | 医药制造业 | 534.2 | 1.97 |
| 煤炭开采和洗选业 | 148.9 | 0.60 | 化学纤维制造业 | 106.1 | 1.34 |
| 石油和天然气开采业 | 57.3 | 0.76 | 橡胶和塑料制品业 | 307.2 | 1.01 |
| 黑色金属矿采选业 | 7.3 | 0.18 | 非金属矿物制品业 | 362.8 | 0.61 |
| 有色金属矿采选业 | 31.2 | 0.61 | 黑色金属冶炼和压延加工业 | 638.7 | 0.99 |
| 非金属矿采选业 | 11.9 | 0.28 | 有色金属冶炼和压延加工业 | 461.6 | 0.85 |
| 开采辅助活动 | 25.4 | 1.62 | 金属制品业 | 343.2 | 0.95 |
| 制造业 | 11624.7 | 1.14 | 通用设备制造业 | 696.8 | 1.53 |
| 农副食品加工业 | 274.6 | 0.46 | 专用设备制造业 | 636.9 | 1.78 |
| 食品制造业 | 148.1 | 0.67 | 汽车制造业 | 1164.6 | 1.38 |
| 酒、饮料和精制茶制造业 | 99.8 | 0.58 | 铁路、船舶、航空航天和其他运输设备制造业 | 428.8 | 2.53 |
| 烟草制品业 | 19.8 | 0.22 | 电气机械和器材制造业 | 1242.4 | 1.73 |
| 纺织业 | 233.2 | 0.64 | 计算机、通信和其他电子设备制造业 | 2002.8 | 1.88 |
| 纺织服装、服饰业 | 110.5 | 0.53 | 仪器仪表制造业 | 210.2 | 2.11 |
| 皮革、毛皮、羽毛及其制品和制鞋业 | 65.1 | 0.46 | 其他制造业 | 32.6 | 1.31 |
| 木材加工和木、竹、藤、棕、草制品业 | 60.3 | 0.47 | 废弃资源综合利用业 | 16.3 | 0.42 |
| 家具制造业 | 55.4 | 0.63 | 金属制品、机械和设备修理业 | 14.7 | 1.35 |
| 造纸和纸制品业 | 144.6 | 0.97 | 电力、热力、燃气及水生产和供应业 | 106.4 | 0.16 |
| 印刷和记录媒介复制业 | 53.9 | 0.69 | 电力、热力生产和供应业 | 85.8 | 0.15 |
| 文教、工美、体育和娱乐用品制造业 | 100.5 | 0.63 | 燃气生产和供应业 | 11.1 | 0.18 |
| 石油加工、炼焦和核燃料加工业 | 146.6 | 0.36 | 水的生产和供应业 | 9.6 | 0.40 |

**Data from China's National Bureau of Statistics**

**The R&D investment of China in 2017 is 1760.60 billion RMB (255.22 billion US dollars), which is about 2.13% of China's GDP in that year. The investment in the fields of IES (electric/thermal/gas/water) is about 10.64 billion RMB (1.55 billion US dollars) in the year of 2017.**

# Contents



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# R&D work of TJU: Framework of CIES

CIES Framework

- **Electrical system**
  - Active distribution network
  - Microgrid

- **Heating/Cooling System**
  - Virtual Power Plant
  - Demand response

- **Transportation System**
  - Spatial–Temporal Planning of charging facilities
  - V2G, G2V

- **Natural Gas System**
  - CCHP
  - Gas-fired generation power plant

Traditional Energy | Renewable Energy

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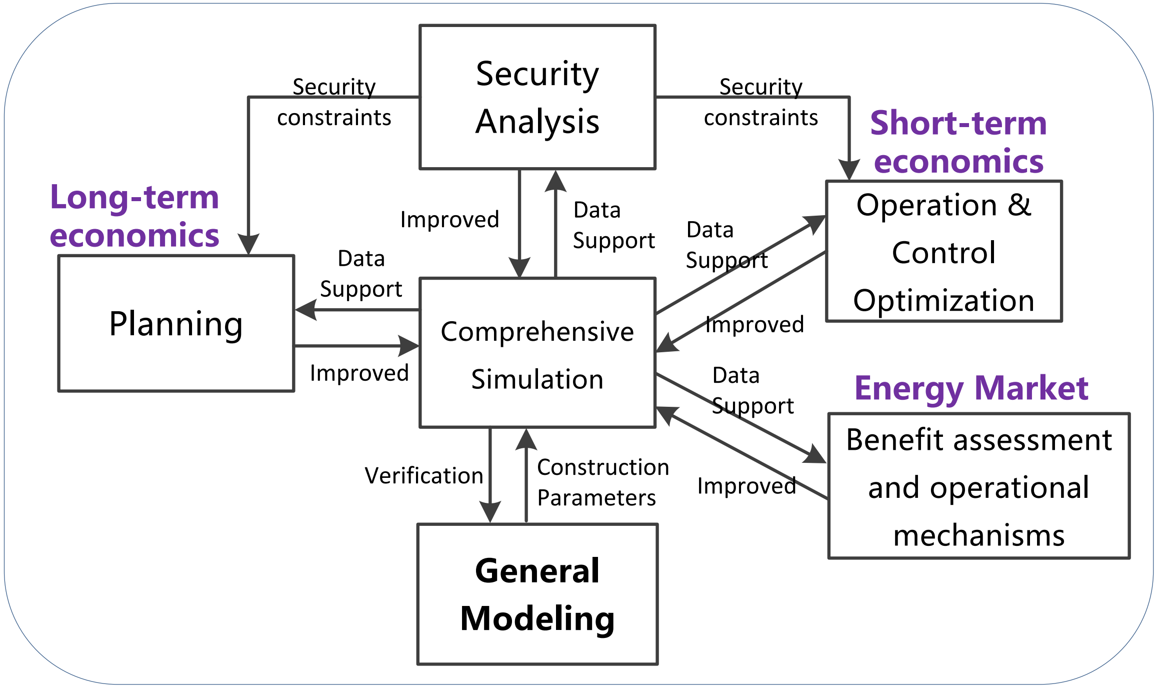
# R&D work of TJU: Key Techniques of CIES

## Research Framework




### ① Modeling and Simulation

- High dimension;
- High nonlinearity;
- Multiple-time scales;
- Reasonable simplification
- Computing speed requirements
- ...

### ② Security and Control(short-term economics)

- Stability analysis in different time-scales;
- Self-healing ability after faults;
- Operation optimization model(static);
- Control optimization model(dynamic);
- …

### ③ Planning and Market (long-term economics)

- High dimension (Optimization Model);
- Constraints complexity for energy supply network
- Constraints complexity for energy consumption unit
- Marketing design
- …

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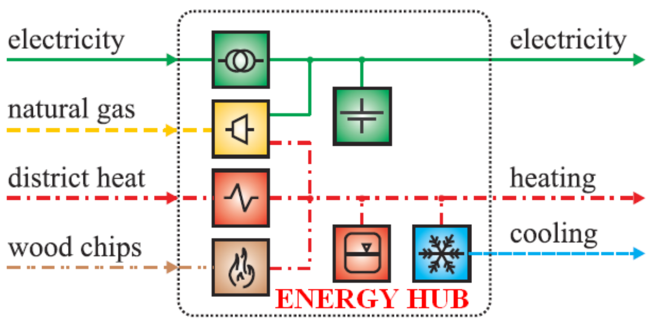
## 1.1 General Modeling of Community Integrated Energy System

### Energy Hub Model

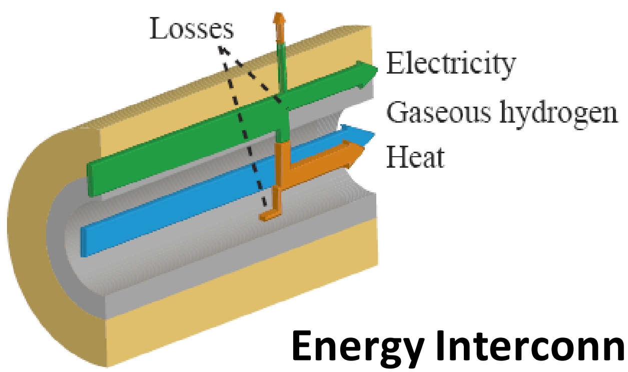
- Energy Hub (Dispatch, Storage and Transform)
- Energy Interconnector (Transfer)

### Typical Demand

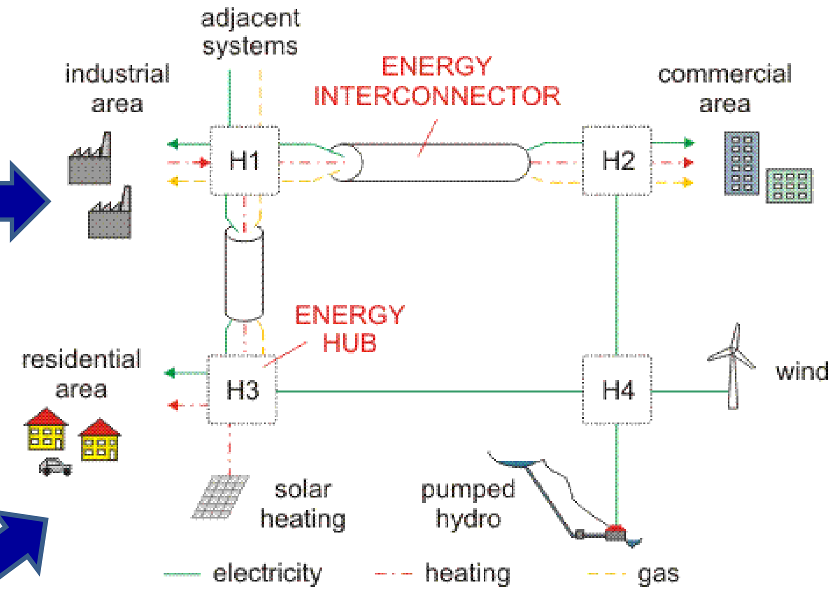
- Heating load
- Cooling load
- Electrical load




**Energy Hub**




**Energy Interconnector**




**Integrated Energy System**

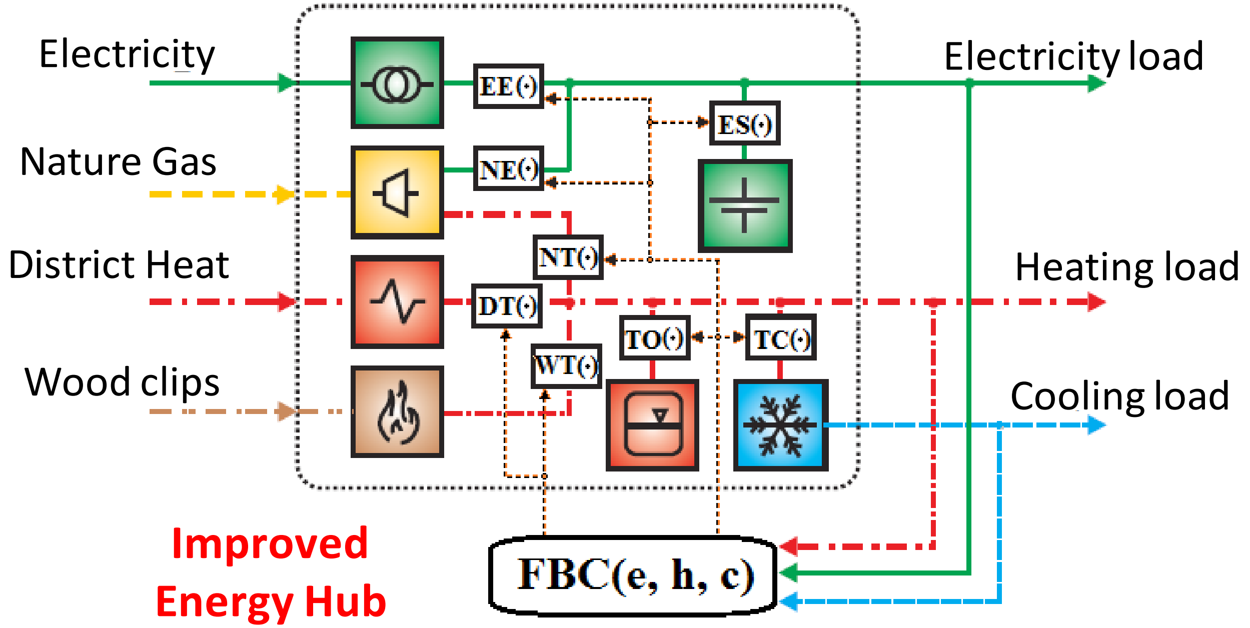
- Proposed by Prof. G. Anderson (ETH)

**Energy Hub**

**Static model !!**

## 1.1 General Modeling of Community Integrated Energy System

- **Improved Energy Hub**
  - **Transform link**: Dynamical Impacts between different energy supplies
    - EE(.), ES(.), NE(.), NT(.), DT(.), WT(.), TO(.), TC(.)
  - **Feedback link**: to reflect the end-user's control behaviors
    - FBC(e, h, c) , such as ***demand response***



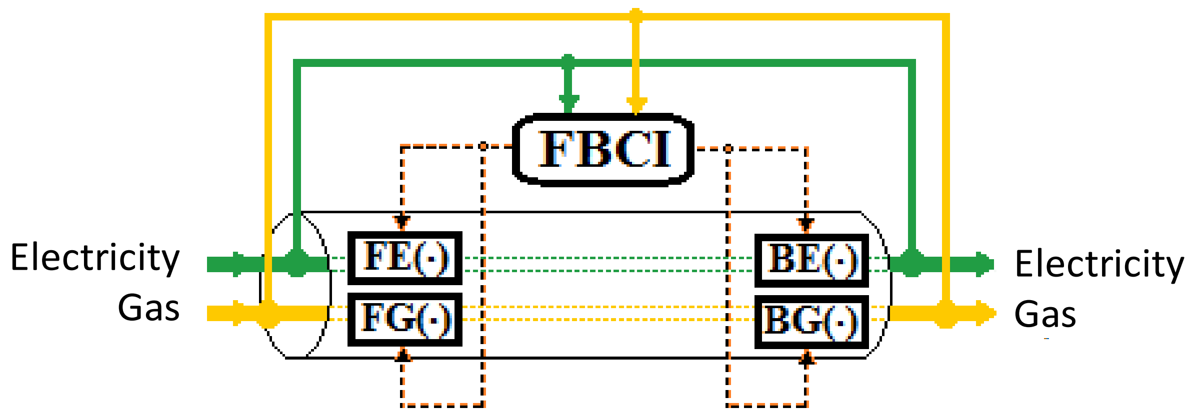

**Improved Energy Hub**

Xu X. Jin X, Jia H, Yu X., Li K., Hierarchical management for integrated community energy systems, Applied Energy, 2015, 160:231-243.
Xu X, Jia H, et al, Dynamic modeling and interaction of hybrid natural gas and electricity supply system in microgrid, IEEE T Power Systems, 2015, 30(3):1212-1221.
Xu X, Modeling, Simulation and energy management research for electricity, gas and heat based micro-energy system, Ph.D Thesis of Tianjin University, 2014.

## 1.1 General Modeling of Community Integrated Energy System

### ➢ Improved Energy Interconnector

- **Transform link**: Dynamic impacts between different energy supplies
  - FG(·), BG(·)
  - Reflect dynamics of fuel transmission process, such as turbine, pressure fluctuations and transfer, turbulence, etc.
- **Feedback link**: Coordinate control between two terminals
  - FBCI(·), such as the coordinate control of converter system in DC-DC, DC-AC, or two terminals of gas pipeline

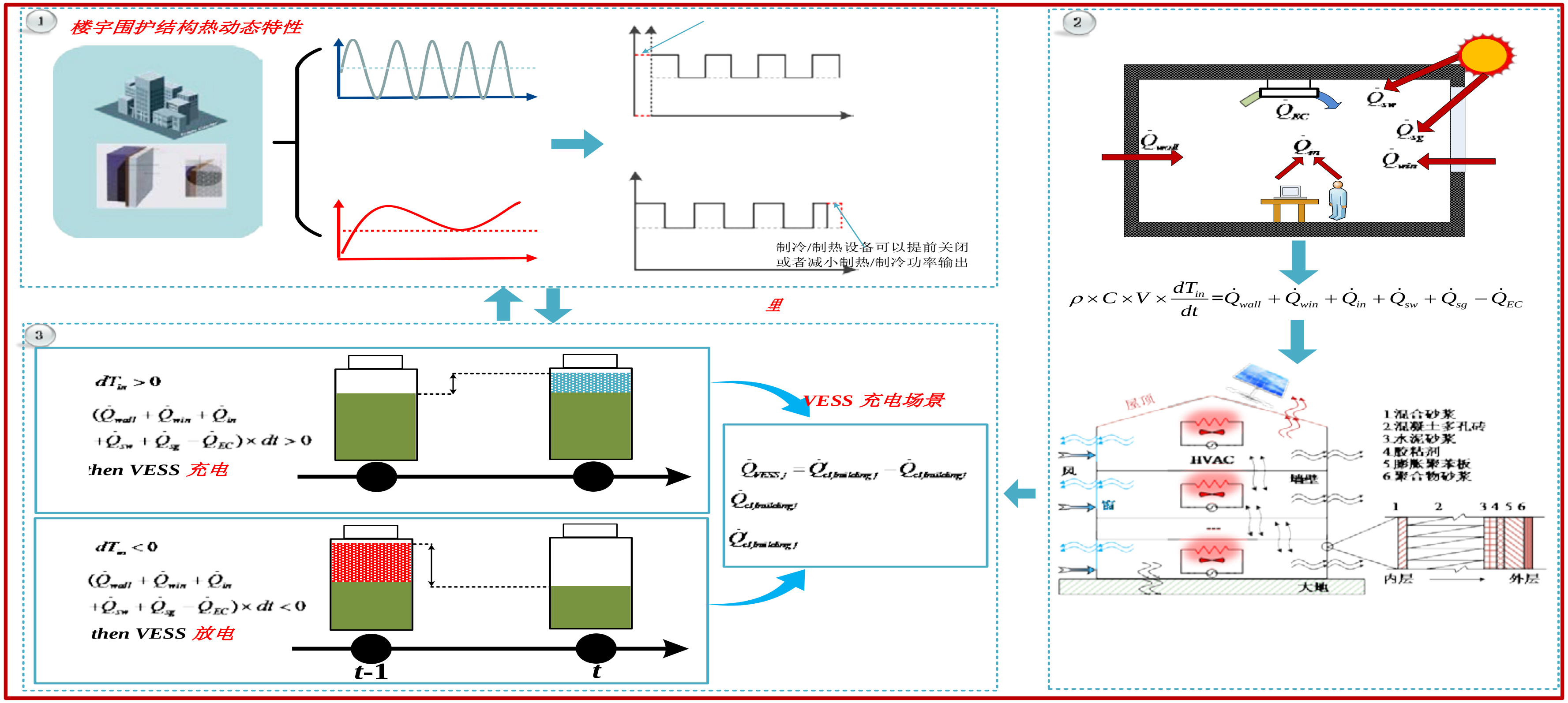



Improved Energy Interconnector

Xu X. Jin X, Jia H, Yu X., Li K., Hierarchical management for integrated community energy systems, Applied Energy, 2015, 160:231-243.
Xu X, Jia H, et al, Dynamic modeling and interaction of hybrid natural gas and electricity supply system in microgrid, IEEE T Power Systems, 2015, 30(3):1212-1221.
Xu X, Modeling, simulation and energy management research for electricity, gas and heat based micro-energy system, Ph.D Thesis of Tianjin University, 2014.

## 1.1 General Modeling of Community Integrated Energy System

### Smart buildings and virtual energy storage




**The improved model was used to construct dynamic model of smart buildings, which further can be aggregated and coordinated into virtual energy storage.**


Jin X.L., Mu Y.F., Jia H.J, et al. Dynamic economic dispatch of a hybrid energy microgrid considering building based virtual energy storage system. Applied Energy, 2017, 194: 386-398.
Jin X.L., Wu J.Z., Mu Y.F., et. al. Hierarchical microgrid energy management in an office building. Applied Energy, 2017, 208: 480-494.

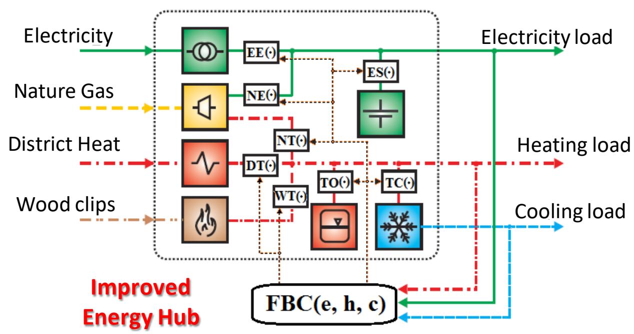
## 1.1 General Modeling of Integrated Energy System

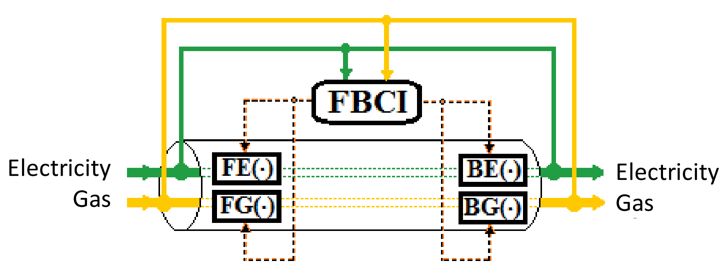
**The mathematical model of IES system will be more complex one, namely PDAE model.**

① Dimension reduction (Balance/Schur/Hankel Martrix, etc)

② Parameter Identification

- Reasonable order number
- Measurements usage




Improved Energy Interconnector

### Improved Energy Hub Model (IEHM)

$$\dot{w} = \xi\left(\frac{\partial w}{\partial v}, \frac{\partial w}{\partial y}, v, y, u\right)$$

$$\dot{v} = f(w, v, y, u)$$

$$0 = g(w, v, y, u)$$

$$z = h(w, v, y, u)$$

**PDAE System**

**Partial differential-difference-algebraic equations**

Xu X. Jin X, Jia H, Yu X., Li K., Hierarchical management for integrated community energy systems, Applied Energy, 2015, 160:231-243.
Xu X, Jia H, et al, Dynamic modeling and interaction of hybrid natural gas and electricity supply system in microgrid, IEEE T Power Systems, 2015, 30(3):1212-1221.
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## 1.2 Simulation Technologies of Community Integrated Energy System

### Some potential solutions:

#### ① From PDAE to DAE

$$
\begin{aligned}
\dot{w} &= \xi\left(\frac{\partial w}{\partial v}, \frac{\partial w}{\partial y}, v, y, u\right) \\
\dot{v} &= f(w, v, y, u) \\
0 &= g(w, v, y, u) \\
z &= h(w, v, y, u)
\end{aligned}
$$

- Boundary conditions
- Nonlinear transformation

System Identification

**Conventional Numerical Methods can be used**

$$
\begin{aligned}
\dot{x} &= f(x, y, u) \\
0 &= g(x, y, u) \\
z &= h(x, y, u)
\end{aligned}
$$

#### ② From digital to hybrid (digital & analog)

Electricity system → Physical equipment

Coupled strongly parts → Physical equipment

Coupled weakly parts → Digital simulation

Physical equipment → Electronics interface

Digital simulation → Electronics interface

**Microgrid Simulation Laboratory in SEEA/ TJU**

**Real Time Digital Simulator in SEEA/ TJU**

Xu X, Jia H, et al, Hierarchical energy management system for multi-source multi-product microgrids, Renewable Energy, 2015, 78: 621-630.
Xu X, Jia H, et al, Study on hybrid heat-gas-power flow algorithm for integrated community energy system, Proceedings of the CSEE, 2016, 35(14):3634-3642.

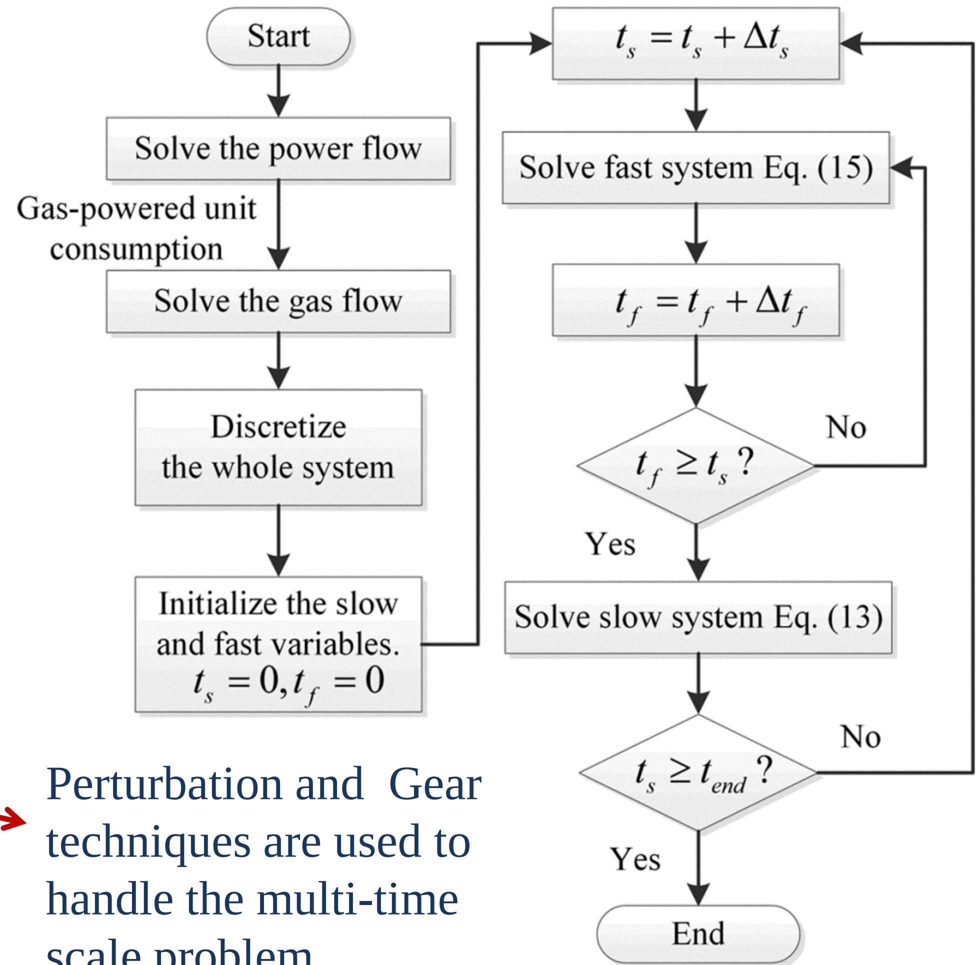
# R&D work of TJU: 1. Theoretical Studies

## 1.2 Simulation Technologies of Community Integrated Energy System

$$\begin{cases} \dot{x}_h = f\left(\dfrac{\partial x_p}{\partial l_p}, x_h, l_p, y_h\right) \\ 0 = g\left(\dfrac{\partial x_p}{\partial l_p}, x_h, l_p, y_h\right) \end{cases}$$

$$x_h = (x_s, x_f)$$

$$\begin{cases} \dot{x}_s = f_s\left(\dfrac{\partial x_p}{\partial l_p}, x_h, l_p, y_h\right) \\ \varepsilon \dot{x}_f = f_f\left(\dfrac{\partial x_p}{\partial l_p}, x_h, l_p, y_h\right) \\ 0 = g\left(\dfrac{\partial x_p}{\partial l_p}, x_h, l_p, y_h\right) \end{cases}$$




Perturbation and Gear techniques are used to handle the multi-time scale problem.

**Hybrid Gas and Power System - Two time-scale algorithm**


Xu X, Jia H, et al, Hierarchical energy management system for multi-source multi-product microgrids, Renewable Energy, 2015, 78: 621-630.
Xu X, Jia H, et al, Study on hybrid heat-gas-power flow algorithm for integrated community energy system, Proceedings of the CSEE, 2016, 35(14):3634-3642.

## 1.3 Optimal Operation and Control of CIES

**Possible Model:**

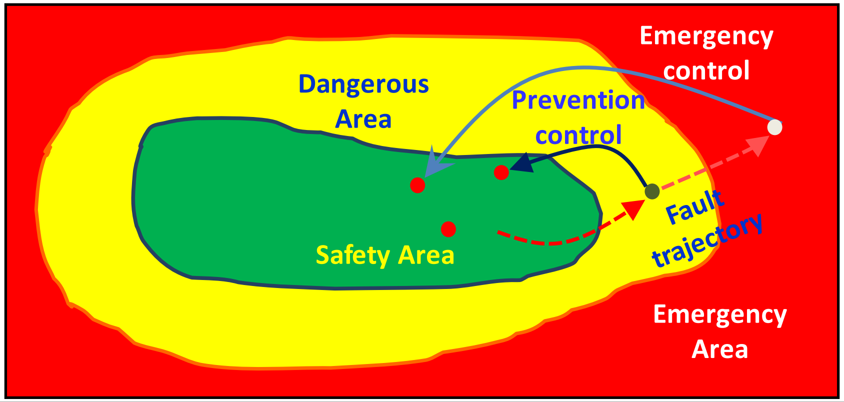
$$\begin{aligned} & \min F_C(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{p}) \\ s.t \quad & \boldsymbol{C}_E(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{p}) = 0 \\ & \boldsymbol{C}_I(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{p}) \leq 0 \\ & \dot{\boldsymbol{x}} = \boldsymbol{C}_D(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{p}) \end{aligned}$$

**It's a typical optimization problem with dynamic constraints.**

| Items | Descriptions |
|---|---|
| $\boldsymbol{x}$<br>$\boldsymbol{y}$<br>$\boldsymbol{p}$ | Dynamic operation variables,<br>Static operation variables,<br>Control variables,<br>All are the functions of $\boldsymbol{T}_c, \boldsymbol{E}_c, \boldsymbol{G}_c$ |
| $F_C(\cdot)$ | System control objective function, such as system loss caused by faults, region size where faults happened, fault remaining time, et al. |
| $\boldsymbol{C}_E(\cdot)$<br>$\boldsymbol{C}_I(\cdot)$<br>$\boldsymbol{C}_D(\cdot)$ | Equality constraints<br>Inequality constraints<br>Dynamics constraints |

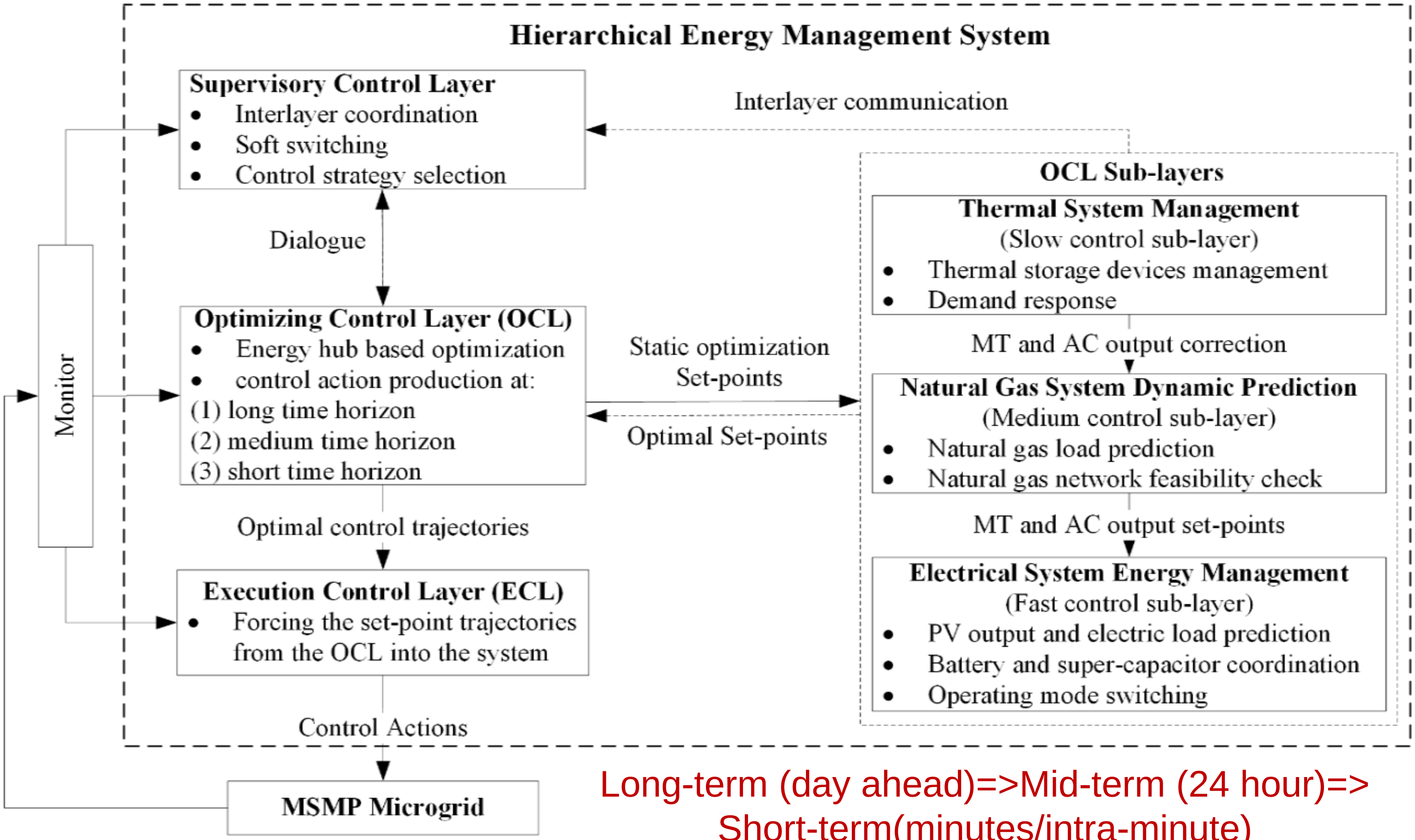
**Possible Solutions:**

It's similar with optimal power flow with transient stability constraints (**TCOPF**) in power system analysis




Jin X, Mu Y, Jia H, et al, Optimal day-ahead scheduling of integrated urban energy systems, Applied Energy, 2016, 180: 1-13.
Jia H, Jin X, Mu Y, et al, A multi-level service restoration strategy of distribution network considering microgrids and electric vehicles, Proc of 2014 IGBSG, Taipei.

## 1.3 Optimal Operation and Control of CIES




Long-term (day ahead)=>Mid-term (24 hour)=> Short-term(minutes/intra-minute)

Jin X, Mu Y, Jia H, et al, Optimal day-ahead scheduling of integrated urban energy systems, Applied Energy, 2016, 180: 1-13.
Jia H, Jin X, Mu Y, et al, A multi-level service restoration strategy of distribution network considering microgrids and electric vehicles, Proc of 2014 IGBSG, Taipei.

## 1.4 Interaction between transportation and power systems

**Intelligent Transportation System**

- EVs charging location
- EVs start charging time
- EVs daily travel distance

• GIS, GPS
• Origin-Destination Analysis

**Power System**

**Planning and Evaluation**

Distribution system planning evaluation tool based on EV characteristics, user daily transportation behavior, *etc*.

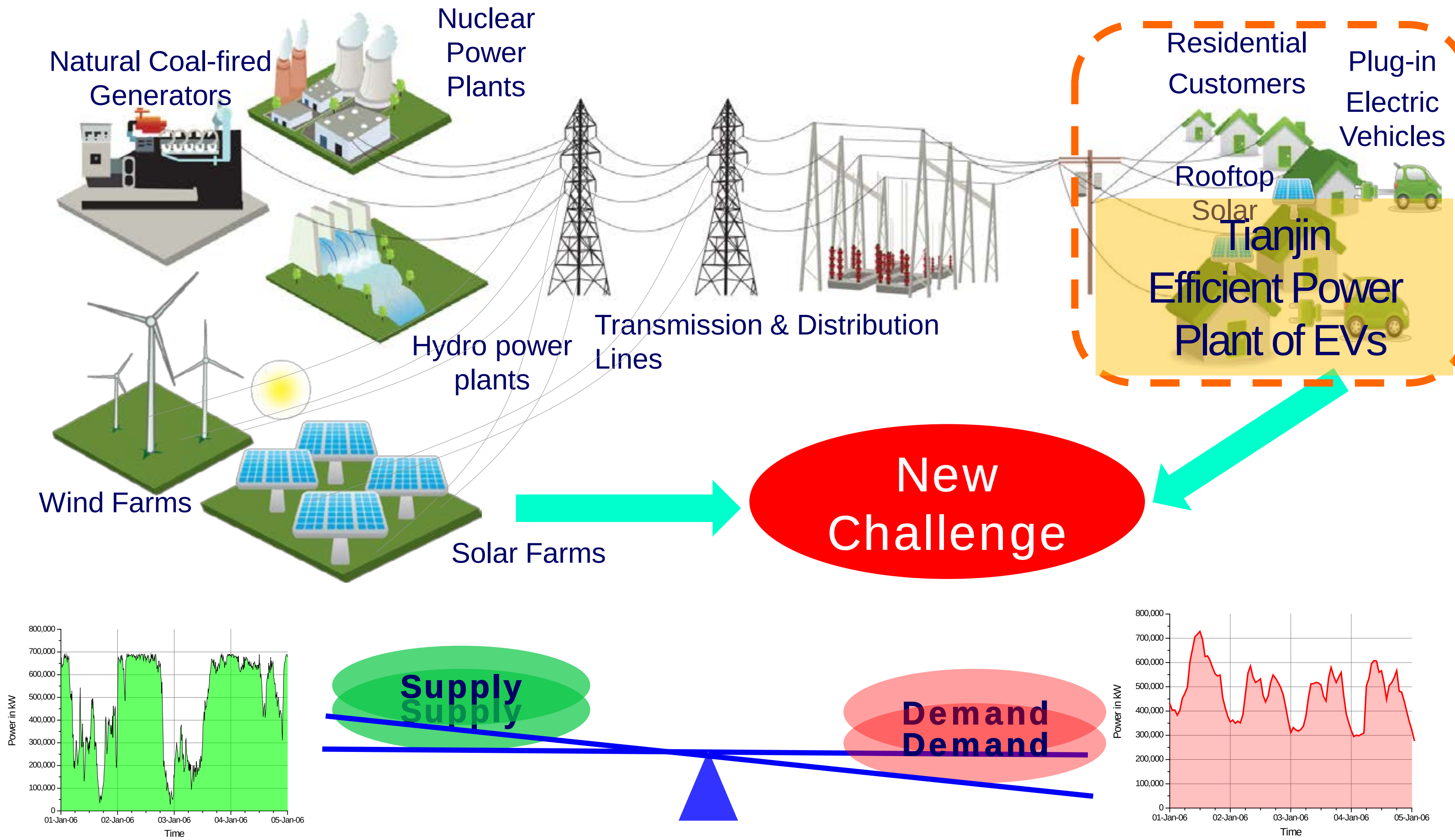
**Operation**

Voltage stability analysis and preventive control

Coordination between EVs and large scale wind farms

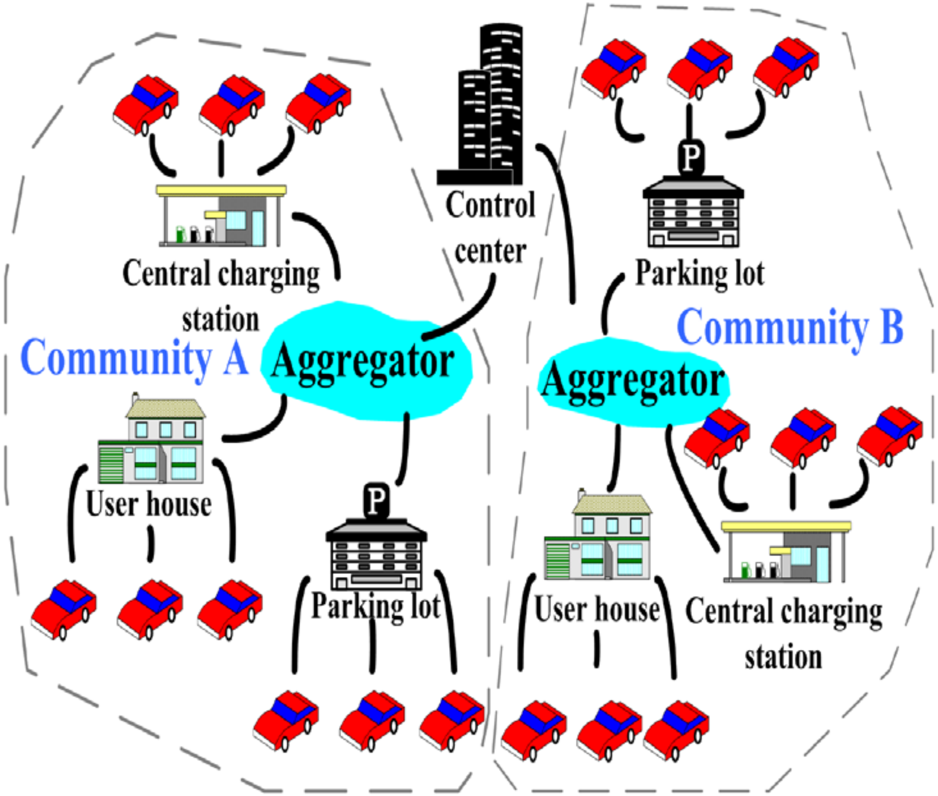
**Bridge**

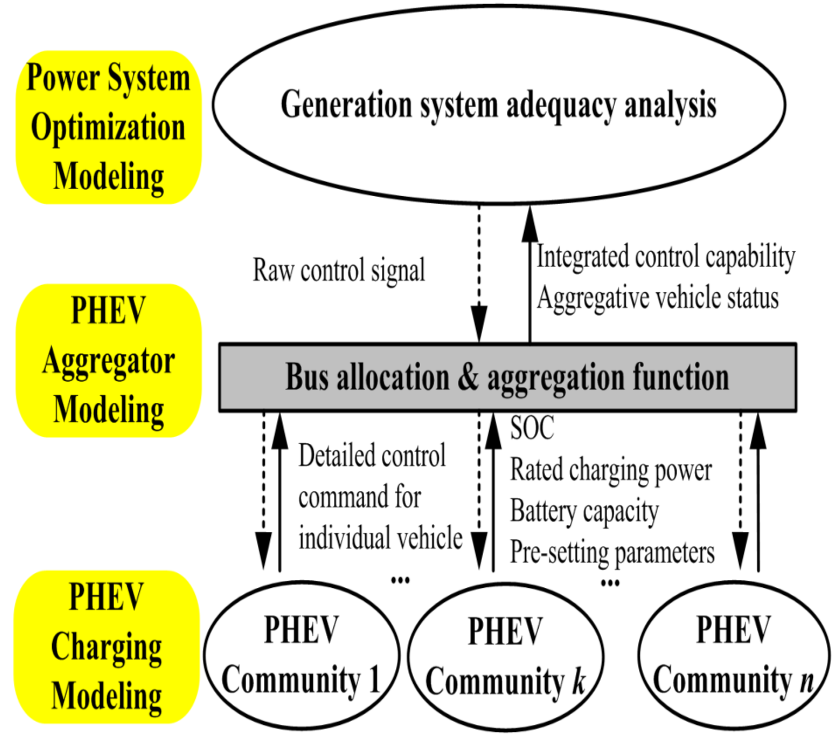
## 1.4 Interaction between transportation and power systems




Liu Z, Wang D, Jia H, et al, Power system operation risk analysis considering charging load self-management of plug-in hybrid electric vehicles, Applied Energy,2014,136: 662-670.
Liu Z, Wang D, Jia H, et al, Aggregation and bidirectional charging power control of plug-in hybrid electric vehicles: generation system adequacy analysis, IEEE Trans. on Sustainable Energy, 2015, 6(2): 325-335.
Wang M, Mu Y, Jia H, et al, A preventive control strategy for static voltage stability based on an efficient power plant model of electric vehicles, Journal of Modern Power System and Clean Energy, 2015, 3(1): 103-113.

## 1.4 Interaction between transportation and power systems




# Two-level Aggregation VPP Model

Liu Z, Wang D, Jia H, et al, Power system operation risk analysis considering charging load self-management of plug-in hybrid electric vehicles, Applied Energy,2014,136: 662-670.
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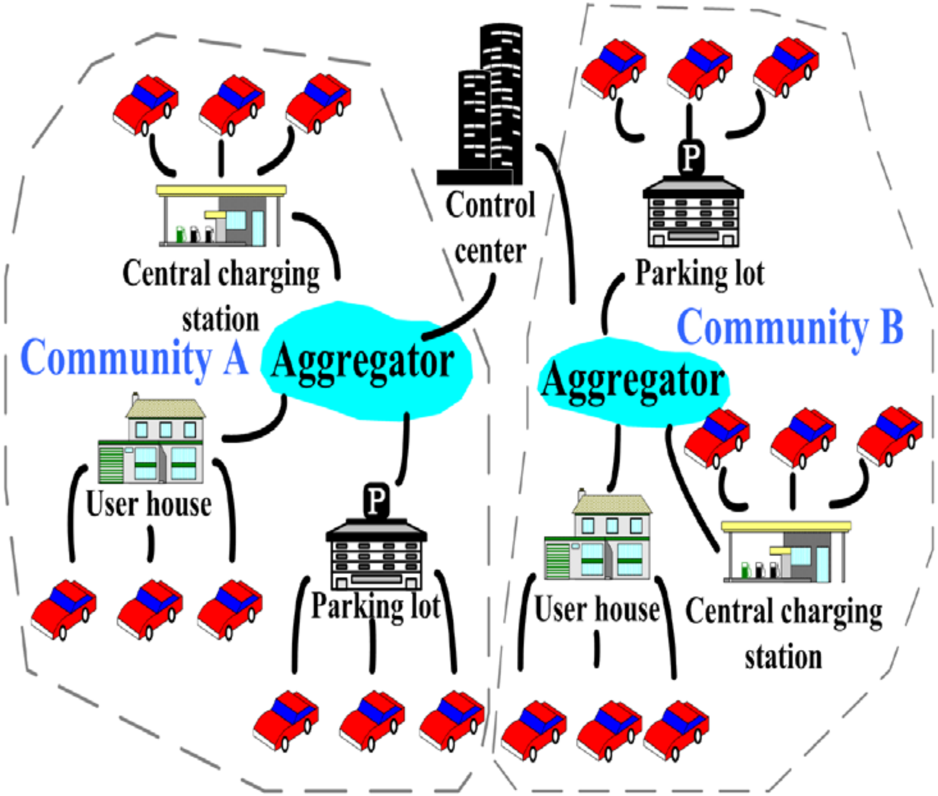
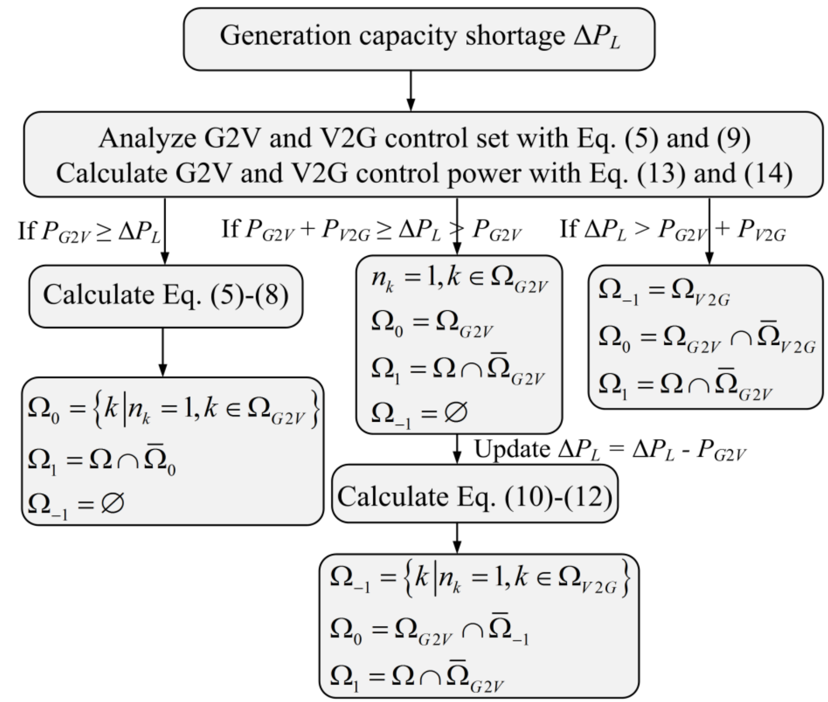
## 1.4 Interaction between transportation and power systems




**Two-level Aggregation VPP Model**

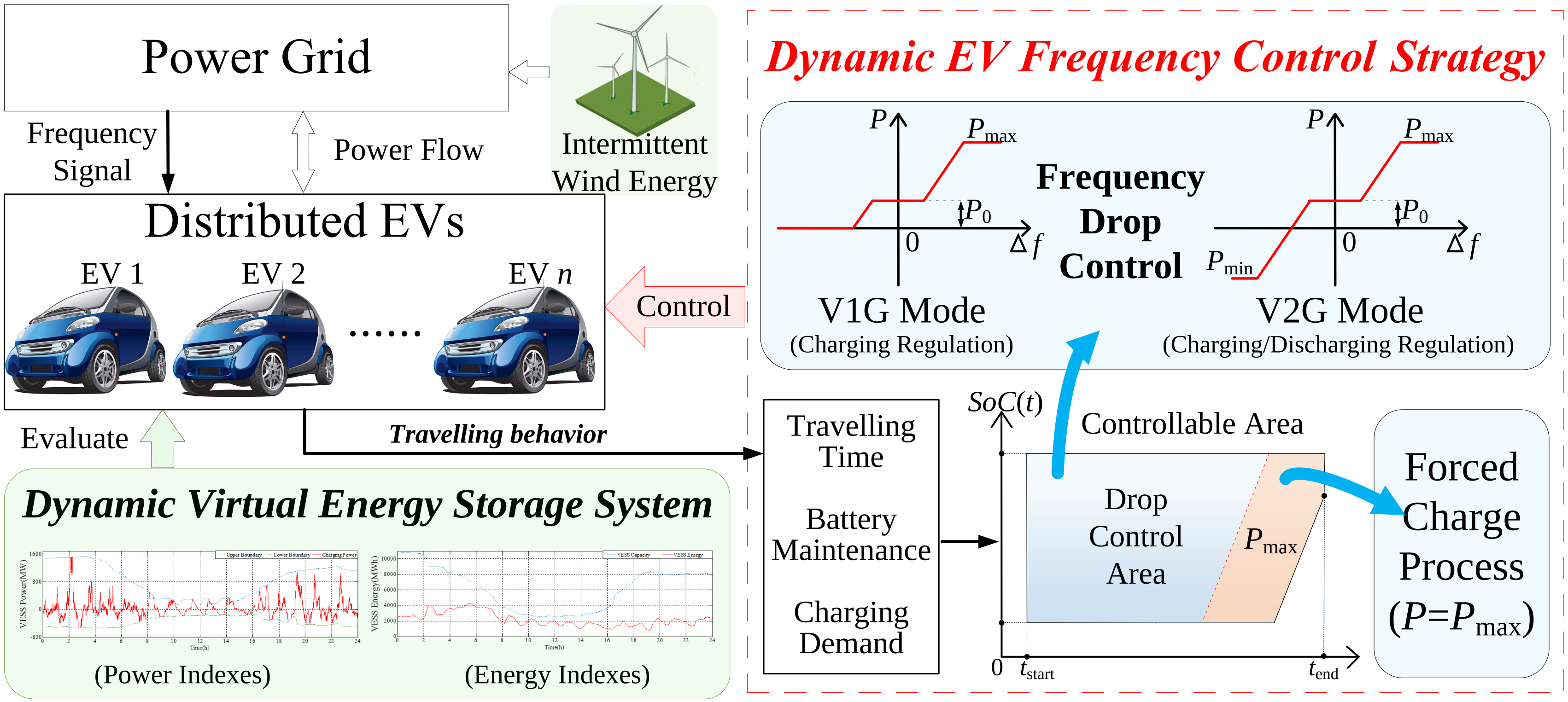



**To achieve a better control result, EVs are grouped according to their types, capacities and states.**

Liu Z, Wang D, Jia H, et al, Power system operation risk analysis considering charging load self-management of plug-in hybrid electric vehicles, Applied Energy,2014,136: 662-670.
Liu Z, Wang D, Jia H, et al, Aggregation and bidirectional charging power control of plug-in hybrid electric vehicles: generation system adequacy analysis, IEEE Trans. on Sustainable Energy, 2015, 6(2): 325-335.
Wang M, Mu Y, Jia H, et al, A preventive control strategy for static voltage stability based on an efficient power plant model of electric vehicles, Journal of Modern Power System and Clean Energy, 2015, 3(1): 103-113.

## 1.4 Interaction between transportation and power systems

➢ Load Demand Response and Frequency Control

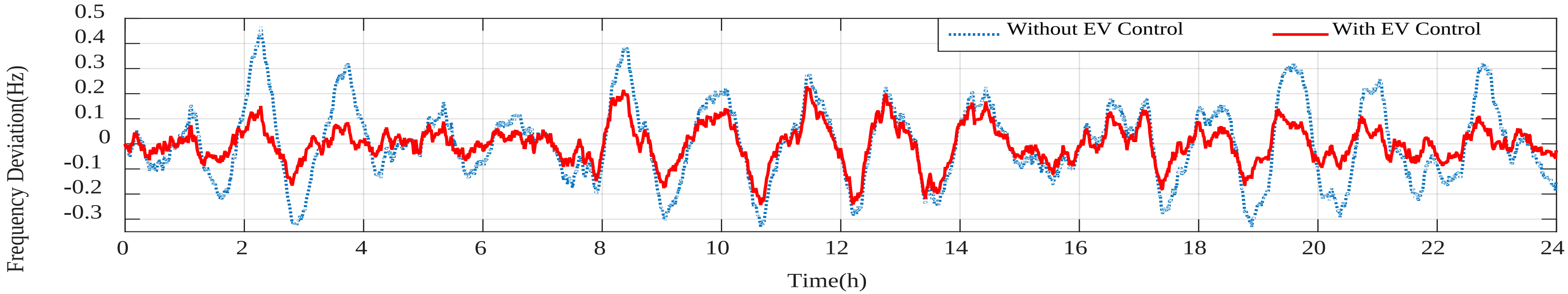


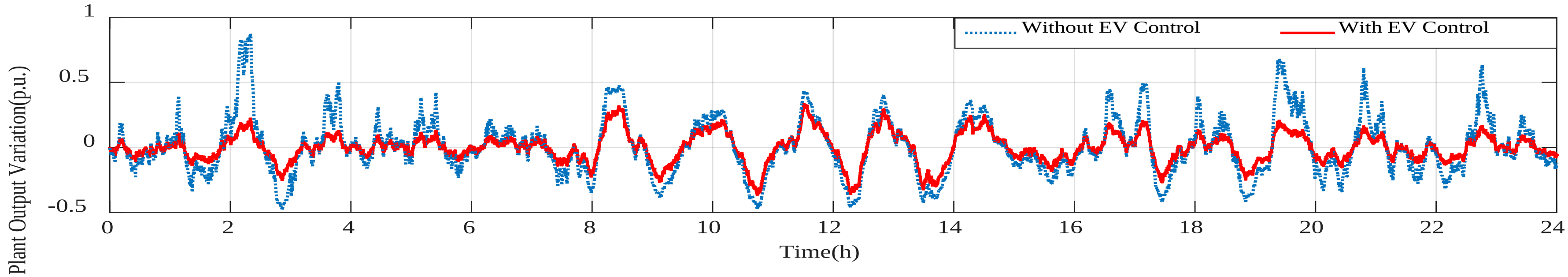

**Control strategy is designed based on drop control technique.**

Jia H, Qi Y, Mu Y, Frequency response of autonomous microgrid based on family-friendly controllable loads, Science China E-Technological Sciences, 2013, 56(3): 693-702.
Meng J, Mu Y, Jia H, et al, Dynamic frequency response from electric vehicles considering travelling behavior in the great Britain power system, Applied Energy, 2016:162:966-979.

## 1.4 Interaction between transportation and power systems

### ➢ Load Demand Response and Frequency Control



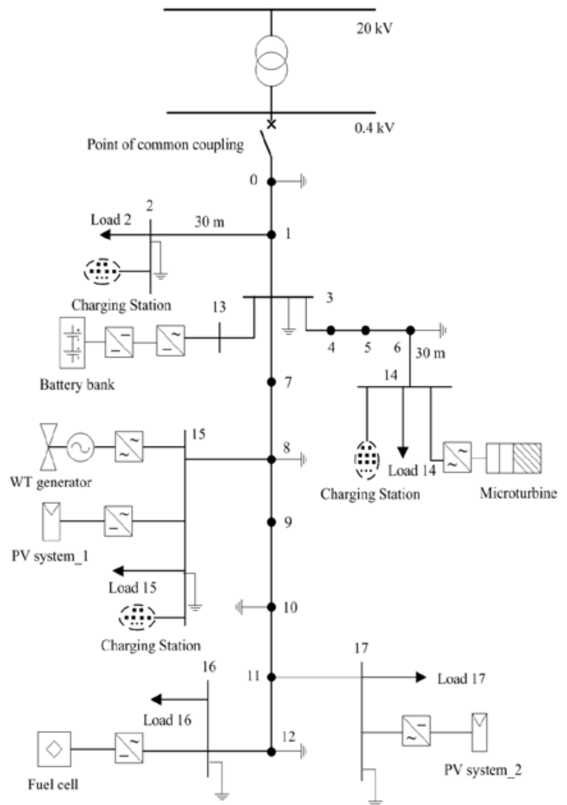



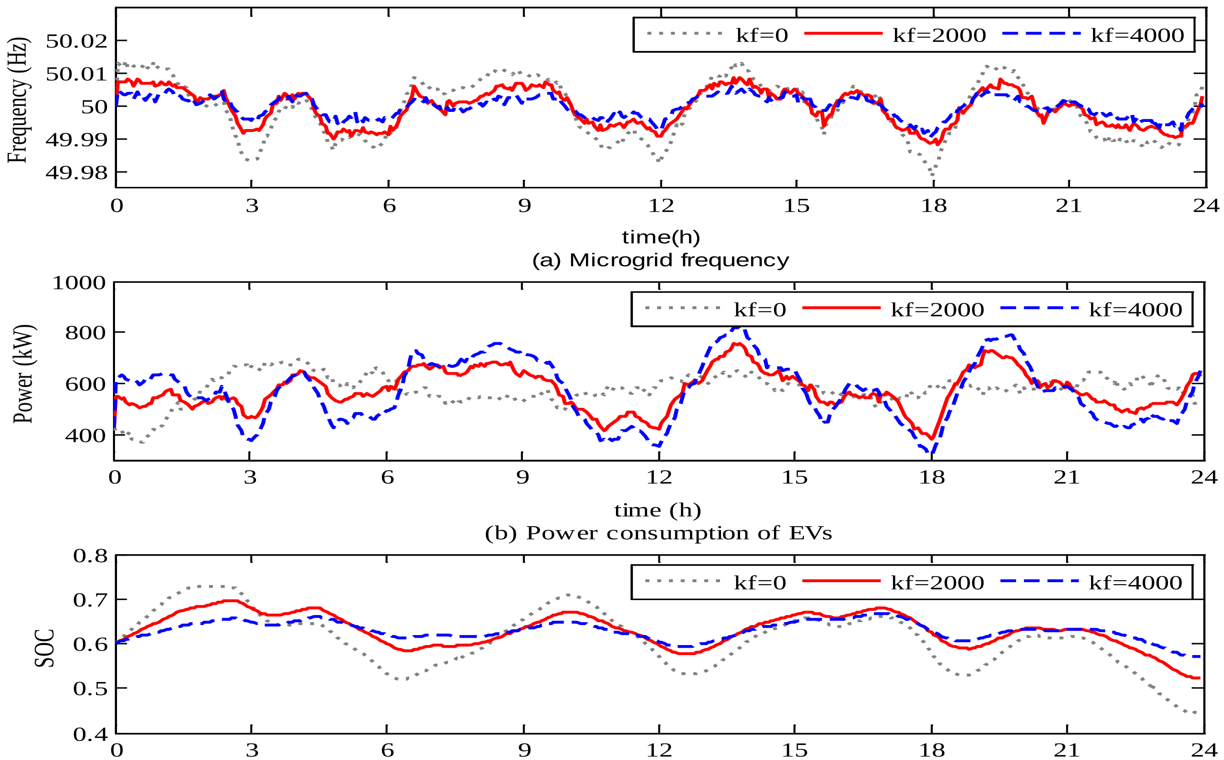

**System frequency is smoothed when the EV controller is adapted.**

Jia H, Qi Y, Mu Y, Frequency response of autonomous microgrid based on family-friendly controllable loads, Science China E-Technological Sciences, 2013, 56(3): 693-702.
Meng J, Mu Y, Jia H, et al, Dynamic frequency response from electric vehicles considering travelling behavior in the great Britain power system, Applied Energy, 2016:162:966-979.

## 1.4 Interaction between transportation and power systems

➢ Virtual Energy Storage in Micro-Grid



(a) Microgrid frequency
(b) Power consumption of EVs
(c)Battery SOC

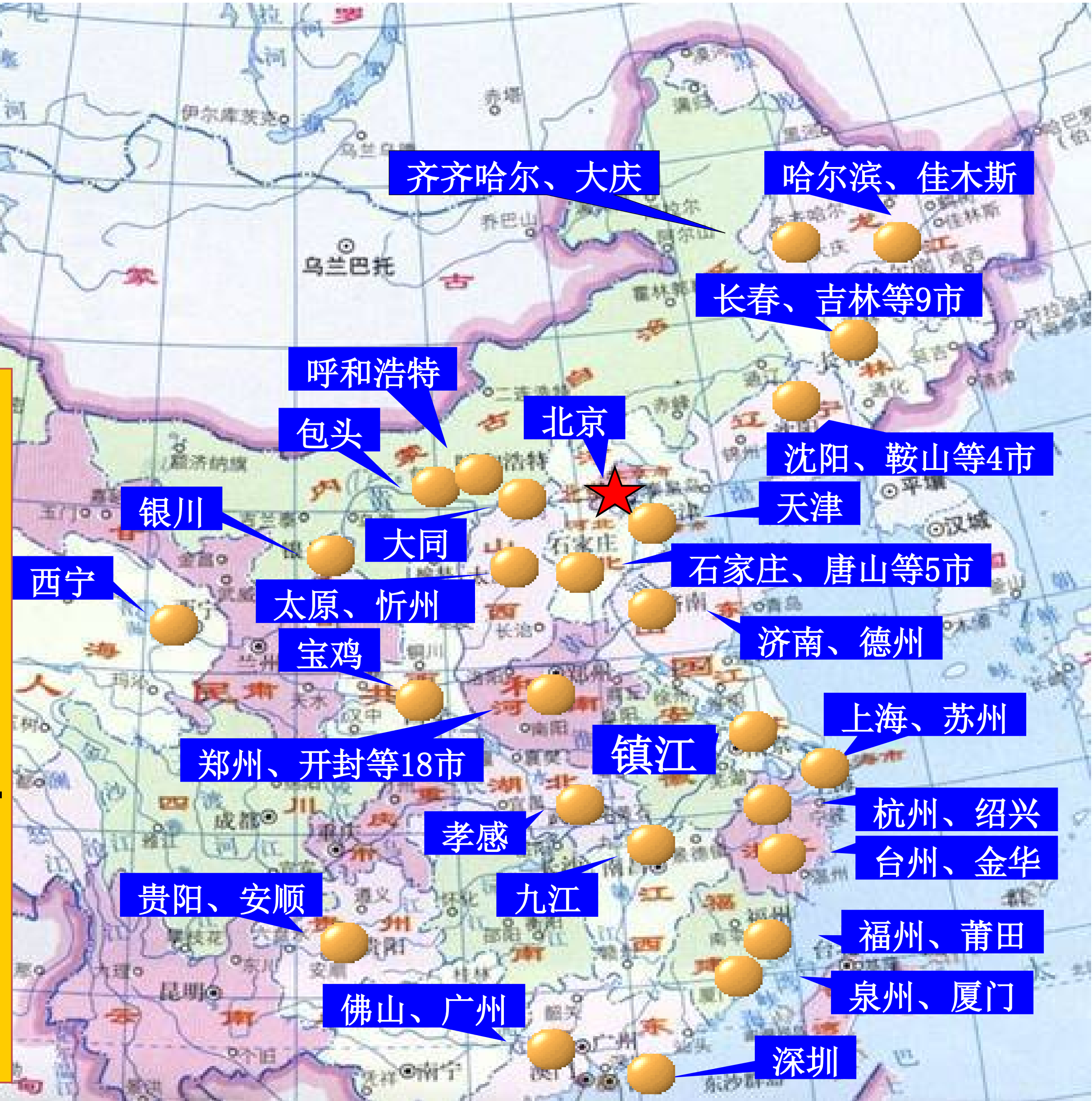
**Usage of the real energy storage in the micro-grid will be reduced.**

Wang Dan, Ge Shaoyue, Jia Hongjie, Wang Chengshan, Zhou Yue, Lu Ning, Kong Xiangyu, A demand response and battery storage coordination algorithm for providing microgrid tie-line smoothing services, IEEE Transactions on Sustainable Energy, 2014, 5(2): 476-486.
Wang Dan, Jia Hongjie, Wang Chengshan, et al, Performance evaluation of controlling thermostatically controlled appliances as virtual generators using comfort-constrained state-queueing models, IET Generation Transmission & Distribution, 2014, 8(4): 591-599.

# R&D work of TJU: 2. Software Developments

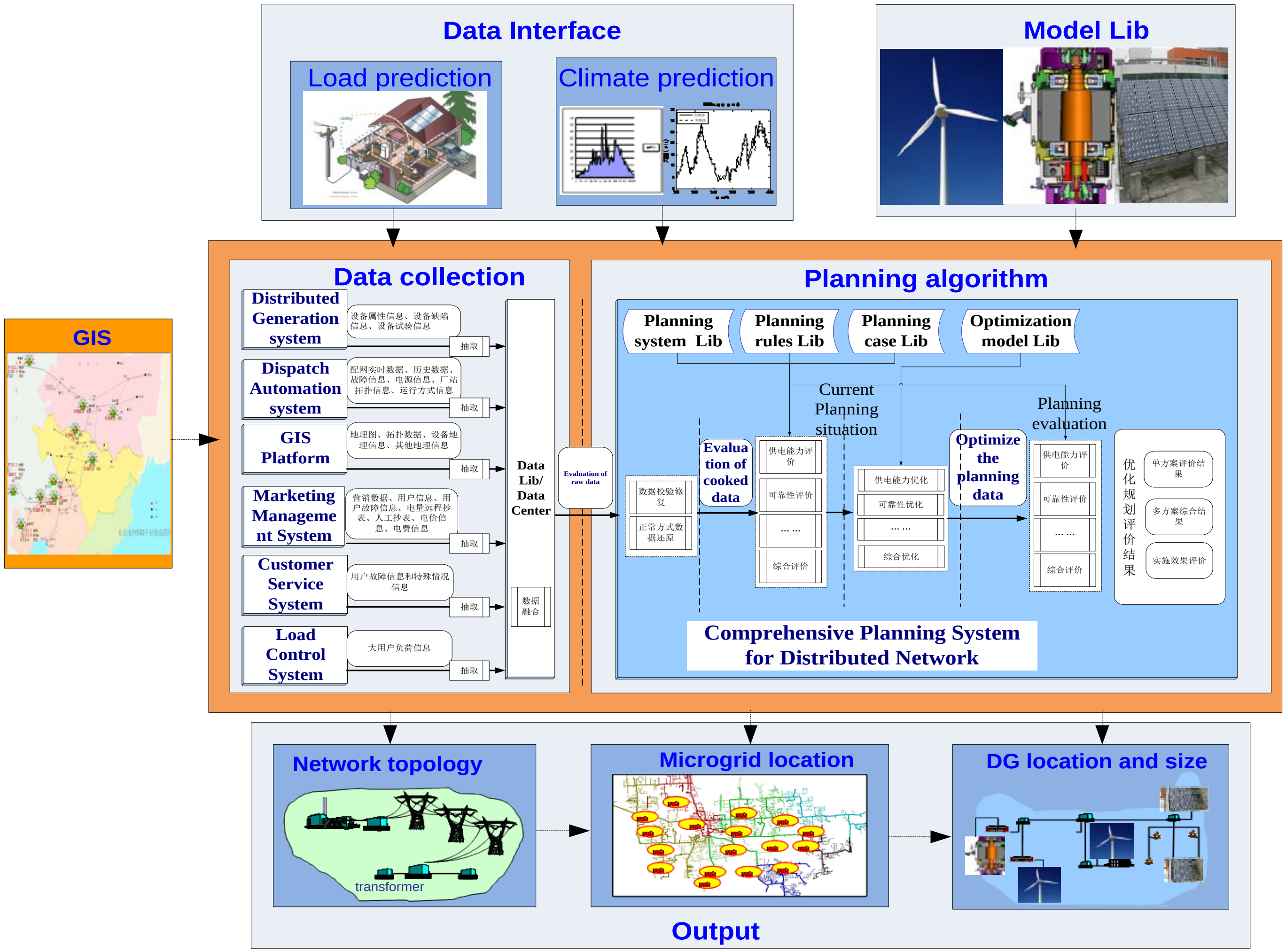
## 2.1 Planning of CIES System

- Up to now, the theory, method, software of electric distribution system planning developed by us have been used in more than **4000 projects and 300 cities in China** successfully.
- In the future, we want to develop new planning software for community integrated energy system.



# R&D work of TJU: 2. Software Development

## 2.1 Planning of CIES System

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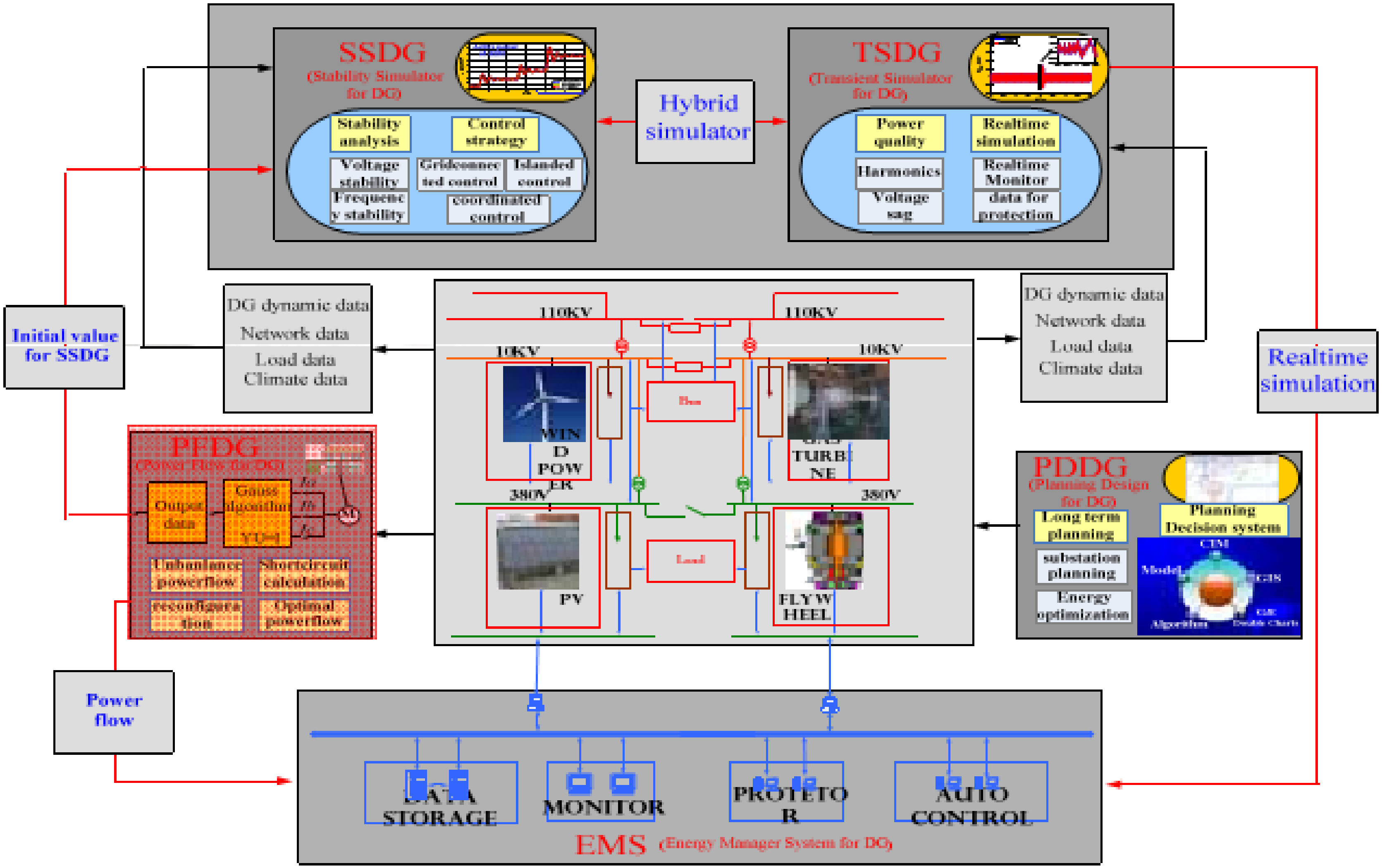
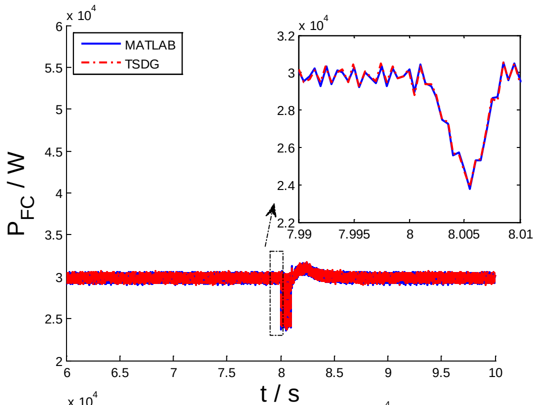
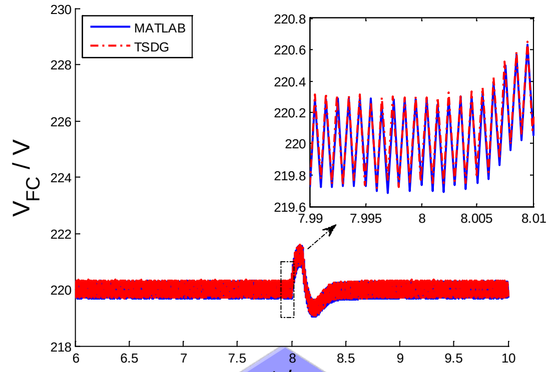
## 2.2 Simulation, Analysis, Energy Management Tools for CIES System

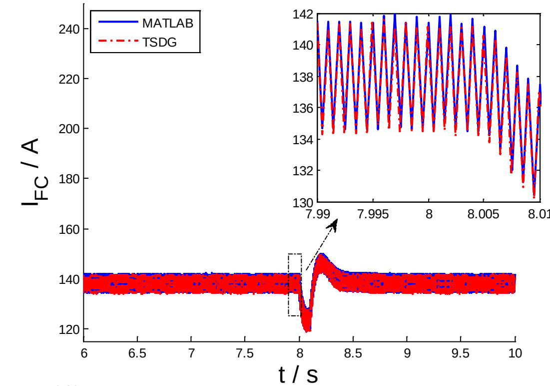


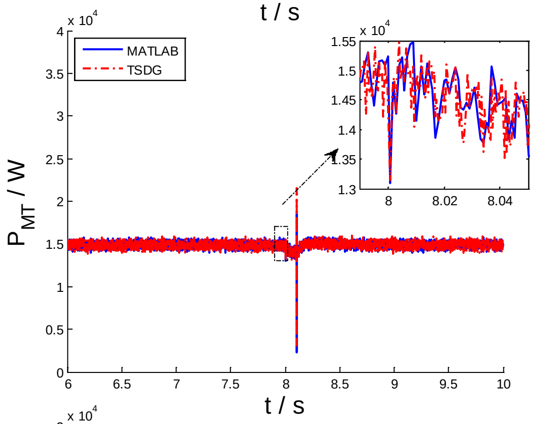
# R&D work of TJU: 2. Software Development

## 2.2 Simulation, Analysis, Energy Management Tools for CIES System

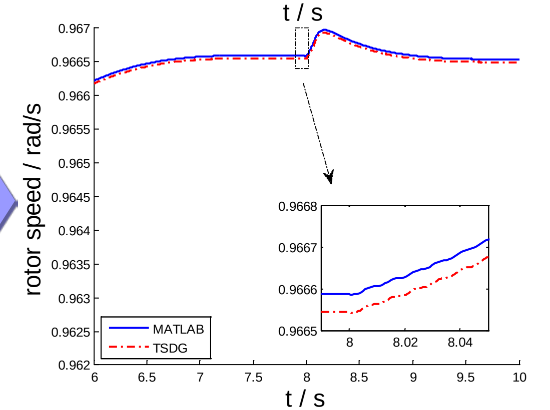


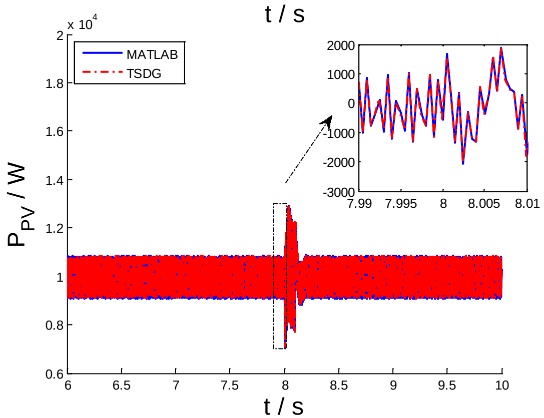



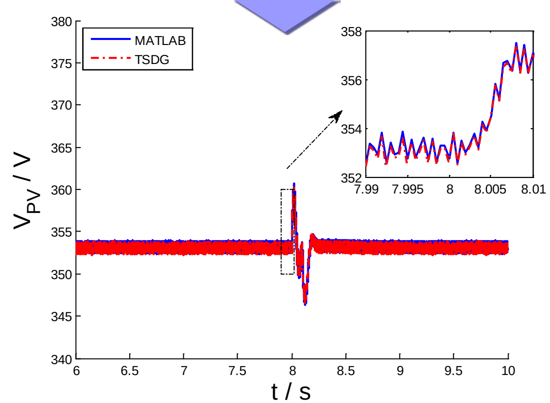



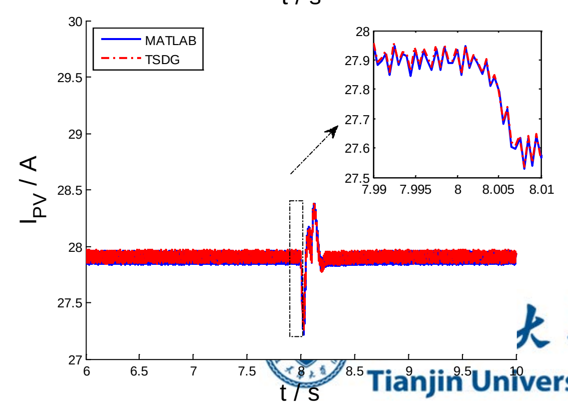




Simulation results of TSDG



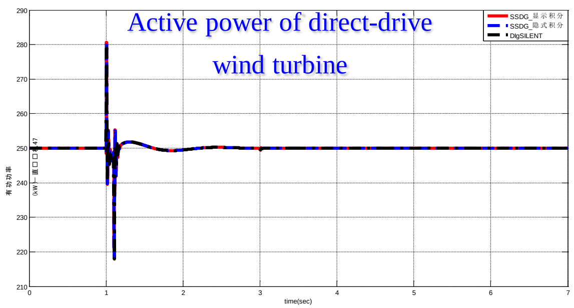



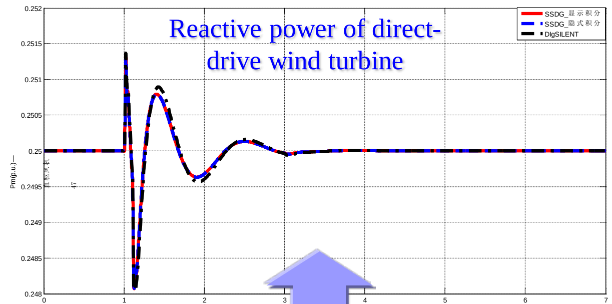



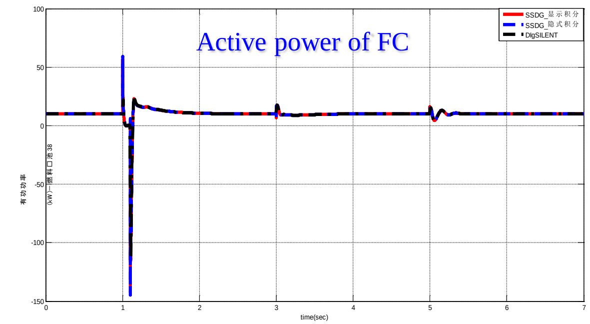



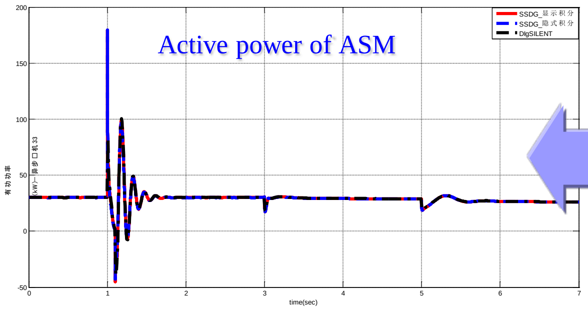
# R&D work of TJU: 2. Software Development

## 2.2 Simulation, Analysis, Energy Management Tools for CIES System

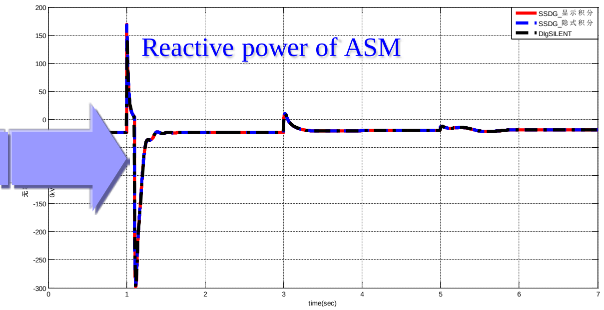


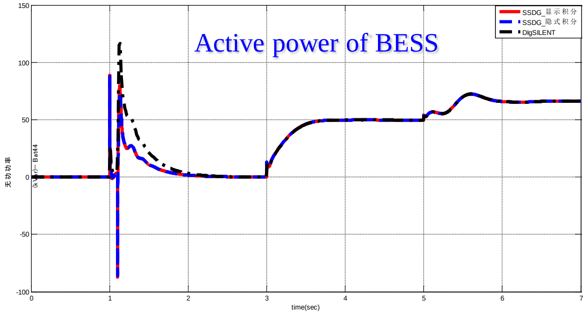



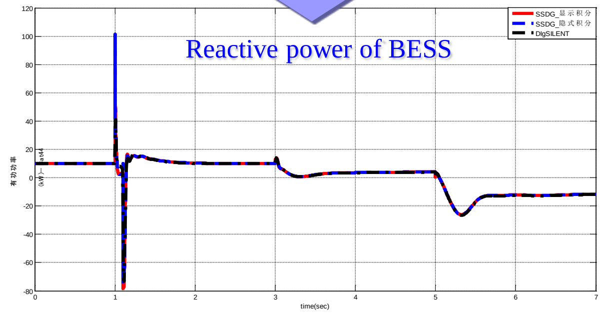



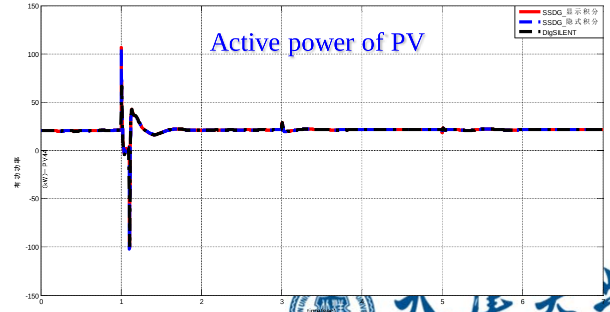




**Simulation results of SSDG with implicit and explicit algorithm**

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# R&D work of TJU: 3. Platform & Demonstrations

## Demos

- CCHP in Foshan, Guangdong
- MG project in Tianjin Eco-city's office building
- MG project of Jinfeng Inc.
- MG project of Dongman Park, Tianjin Eco-city
- MG in Dongfu Island, Zhejiang
- MG project in Nanjing, Jiangsu
- MG in Tianjin Eco-city (government office)

## Research PRJs

- Demo project in Yunnan
- Coordination of EES and renewable DGs in Guangdong
- Wind integration project in Weifang, Shandong
- Stability analysis to power grid with large w-power integration (SGCC)
- Wind integration analysis in Yi county, Guangdong
- MG in Wanshan Island, Guangdong

## Test Beds

- MG Lab of EPRI in Zhejiang
- MG Lab in Yunnan Province
- MG Lab in EPRI of Inner Mongolia
- MG Lab and demonstration project in Shenzhen Electric Power Company
- Tianjin University MG Laboratory

**List of demonstration projects**

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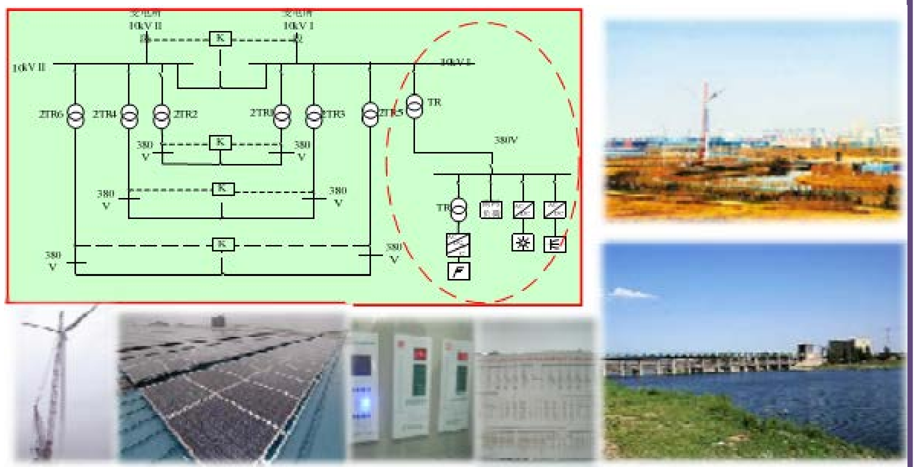
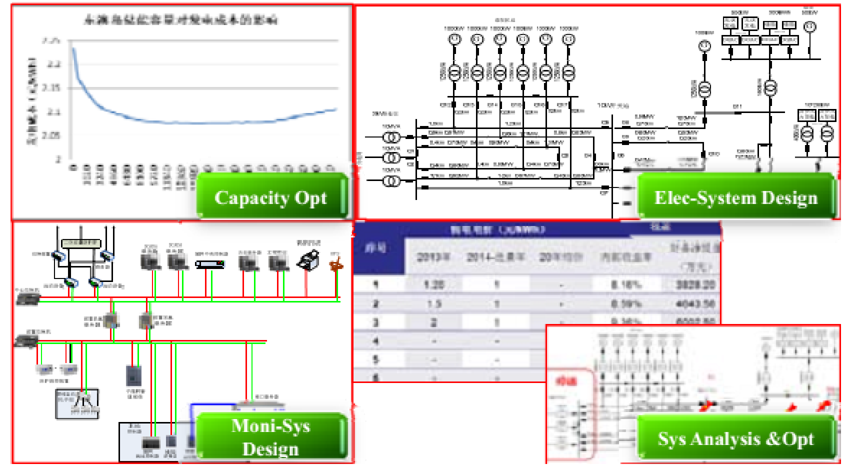
# R&D work of TJU: 3. Platform & Demonstrations

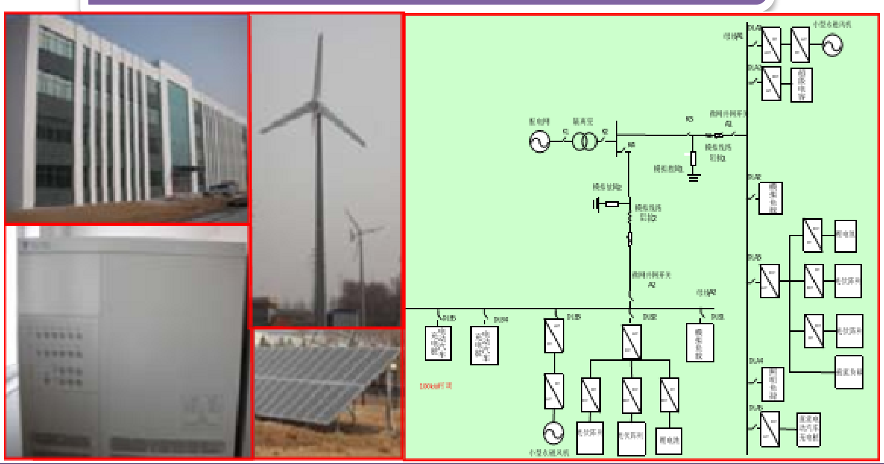
## Jinfeng Research Center



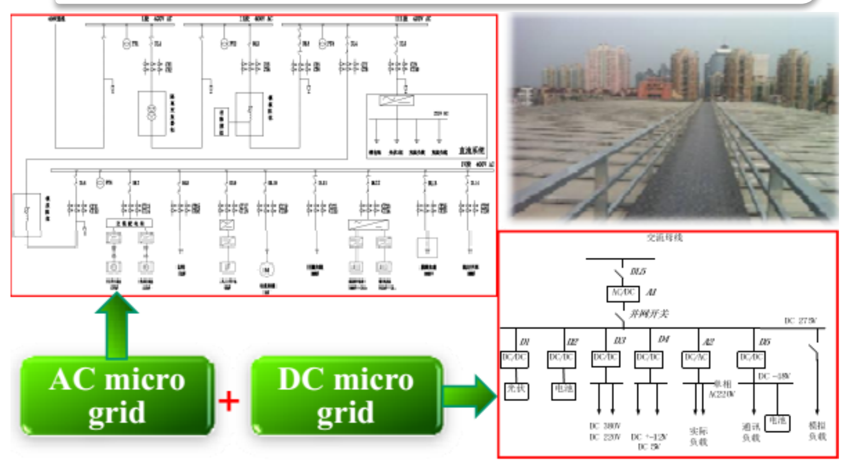
## Wanshan Platform




## Hohhot



## Shenzhen

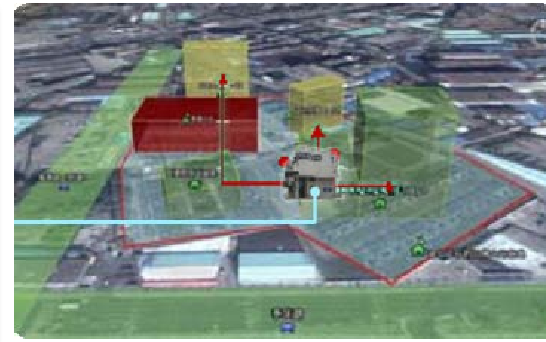


# R&D work of TJU: 3. Platform & Demonstrations

## Demonstration Projects in China

Smart IES system in ZhuHai (WanShan)

Islanding microgrid system in Zhejiang (Dongfushan)



CCHP Project in Guangdong (Fo-shan)

Exhibition Center at China-Singapore Eco-city

Energy Station at China-Singapore Eco-city

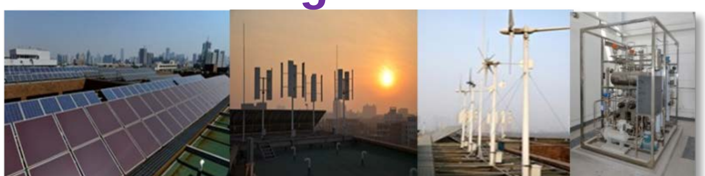
Microgrid in Yunnan (Kunming)

Parrel microgrid in Jiangsu (Nanjing)

# R&D work of TJU: 3. Platform & Demonstrations

## Key Laboratory of Smart Grid of Ministry of Education

## DG & Storages

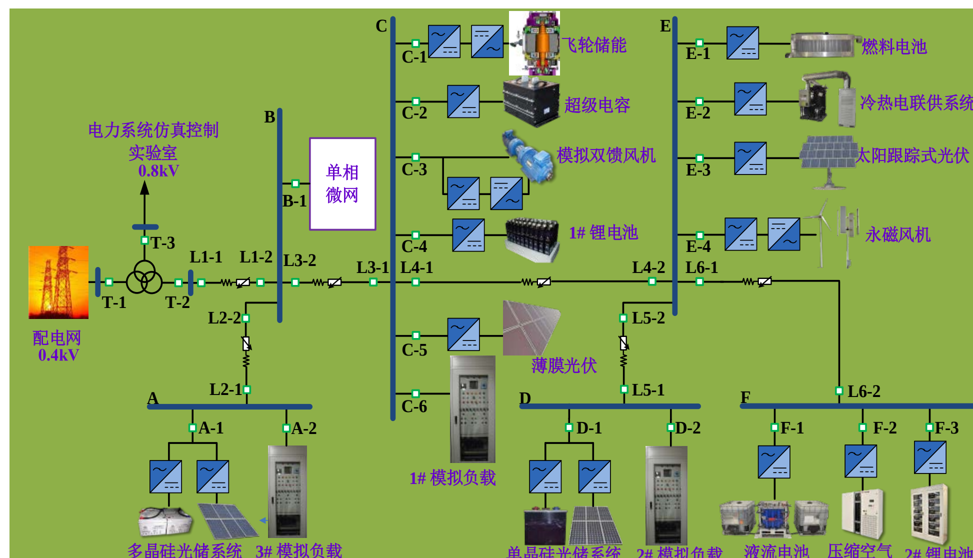


PV Panels Vertical Wind Turbines Horizontal Wind Turbine Fuel Cell

Tracking PV Panels Flow Batteries Lithium Batteries

CCHP Flywheel Compressed Air Storage

## CIES Benchmark

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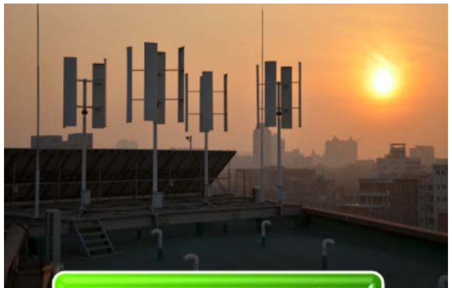
# Devices in the Key Laboratory of Smart Grid of MOE


垂直轴永磁风机


光伏电池阵列


太阳跟踪式光伏


水平轴永磁风机


模拟线路


压缩空气


燃料电池小屋


超级电容


智能家居小屋


单晶硅光储系统


锂电池储能系统

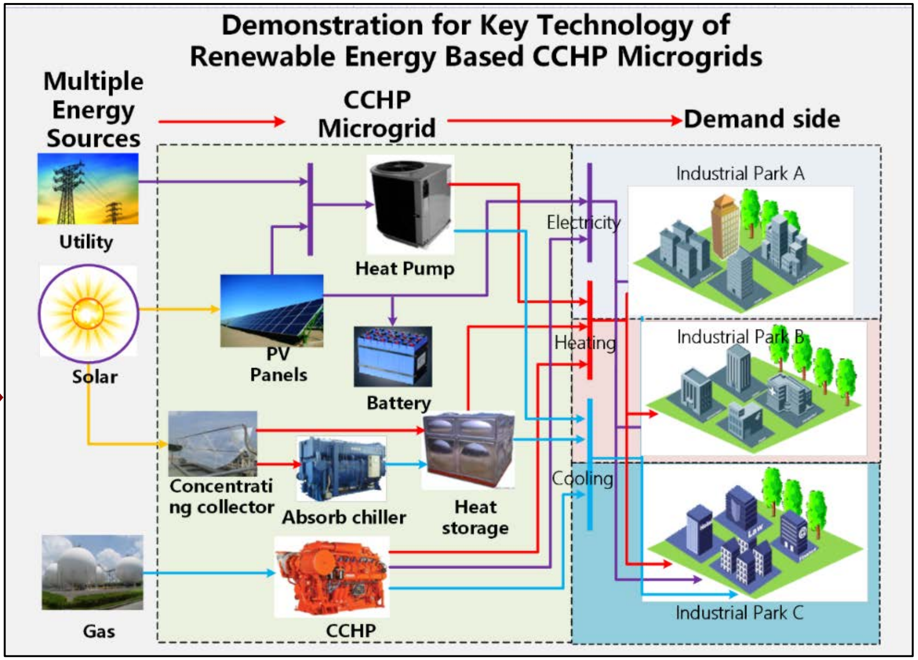
液流电池储能系统

# R&D work of TJU: 3. Platform & Demonstrations

## Community IES Demonstration Project
## --- TJU Binhai Industrial Research Institute


- Area: 308,900m$^2$
- Stable Load (Electricity/Cooling/Heating)
- Sponsored by MoST, TJU, and Tianjin government

- PV panels: 610MW
- CCHP: 120kW
- Heat pump: 150kW
- Battery: 400kW
- Heat/Cool storage: 10t

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# Community IES Demonstration Project
# --- TJU Binhai Industrial Research Institute

**电/热两部分可再生能源渗透率均大于60%，则总的可再生能源渗透率必大于60%。**

**(The total renewable energy penetration is more than 60%)**

## 指标计算公式（电部分）

$$E_p^e = \frac{W_{pv} - W_{pv,h} - W_{other}}{W_e} \times 100\% = 61.9\%$$

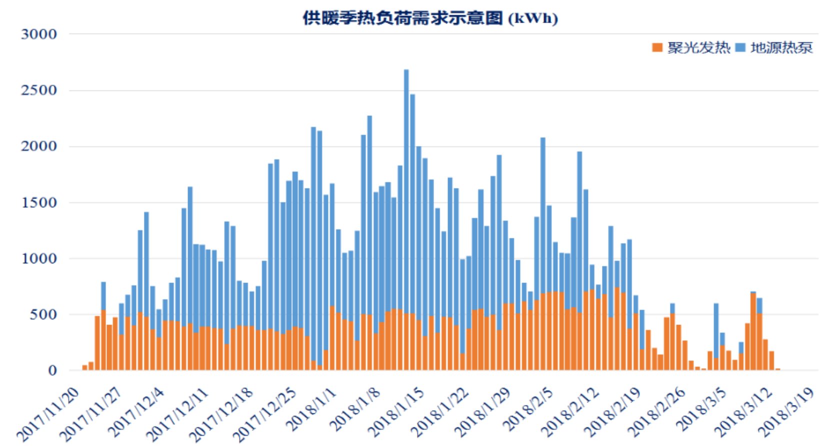
| 序号 | 名称 | 数据 (kWh) |
|---|---|---|
| 1 | 光伏总发电量 | 114354.60 |
| 2 | 地源热泵制热所耗电量 | 16381.25 |
| 3 | 聚光发热及地源热泵环节驱动及循环水泵等附属设备耗电量 | 7731.90 |
| 4 | 总电力负荷需求电量 | 138470.00 |

注：测试期内蓄电池储能采用硬充电模式，SOC变动区间在[0.5，0.9]之间，每日充放电损耗约为20.8%，储能损耗最大约为37.44kWh。

## 指标计算公式（热部分）

$$E_p^{c,h} = \frac{W_{pump,h} + W_j^h}{W_h} \times 100\% = 100\%$$

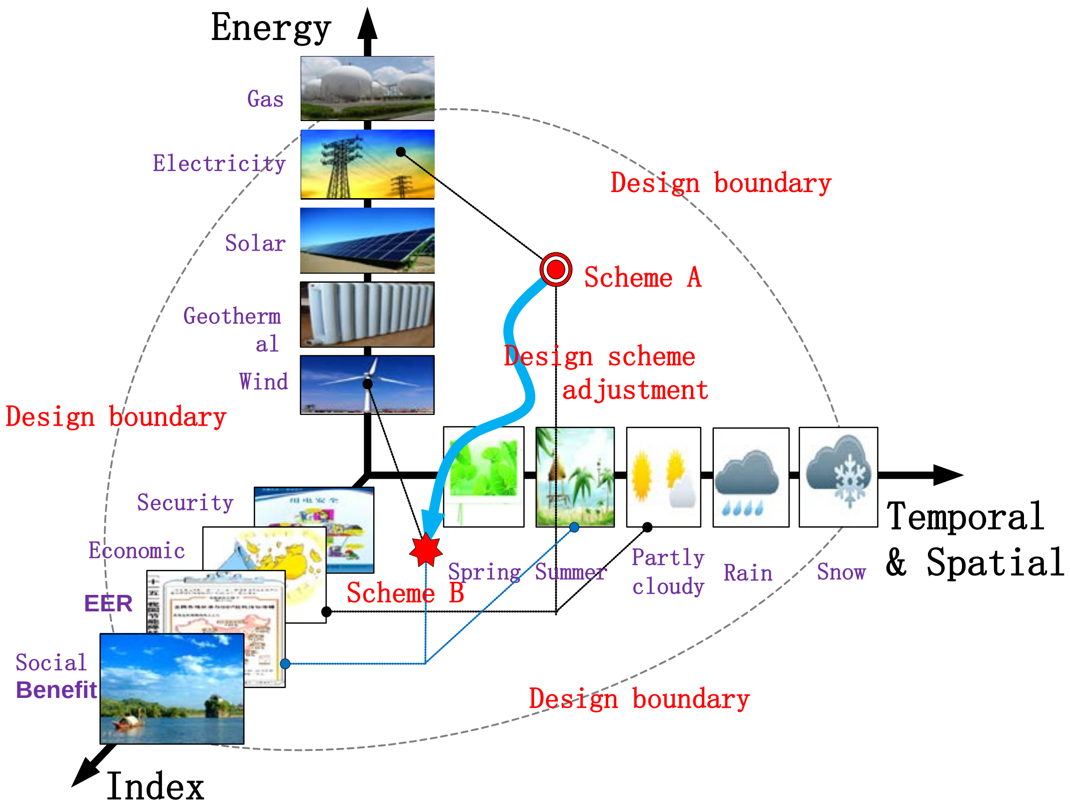
### 供暖季可再生能源支撑热负荷能量需求示意图



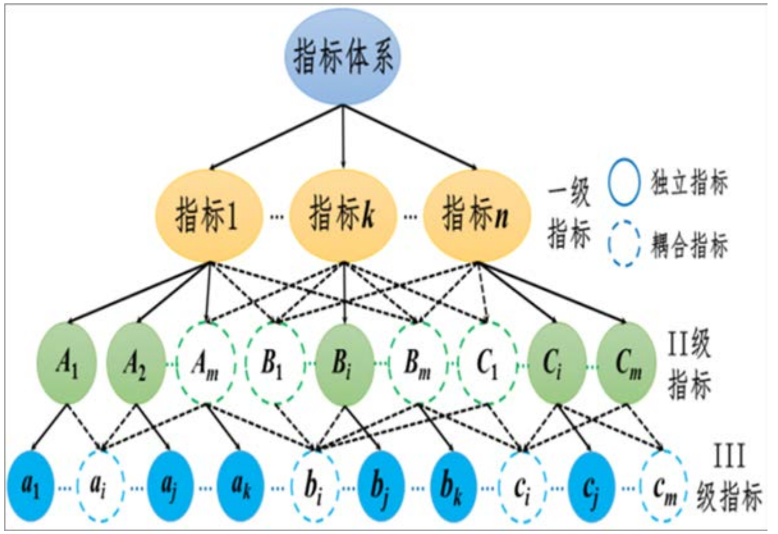
# Contents

# Ongoing Research and Future Work at Tianjin University

## Designing Theory and Software Development for the CIES




### Tree-coupled Index System




**Objective: to achieve a multi-optimal CIES designing scheme in three dimensions: energy, temporal & spatial, various index.**

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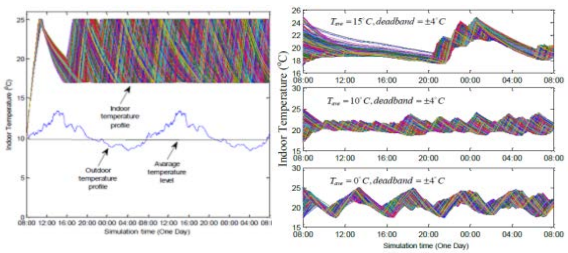
# Ongoing Research and Future Work at Tianjin University

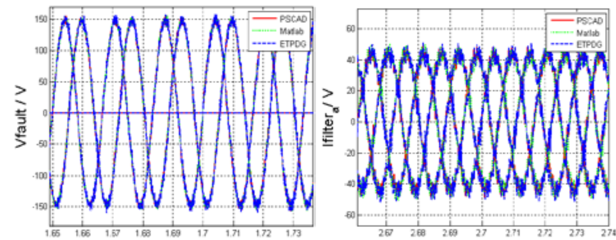
## Hybrid Simulation Platform for the CIES

### Numerical Simulation System

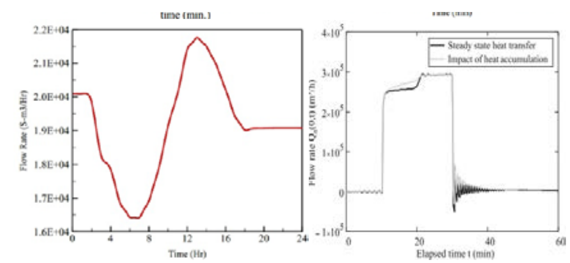
**Thermal System**




**Electrical System**




**Gas System**

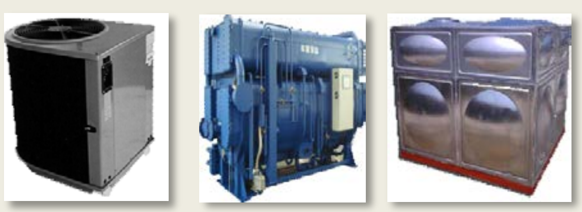



**Digital-Physical Interface Technique**

**Information Bus Technique**

**Configuration Implementation Method**

**Multi-scenario Simulation Technique**



**Thermal System**

**Electrical System**

**Gas System**

### Physical Experimental System

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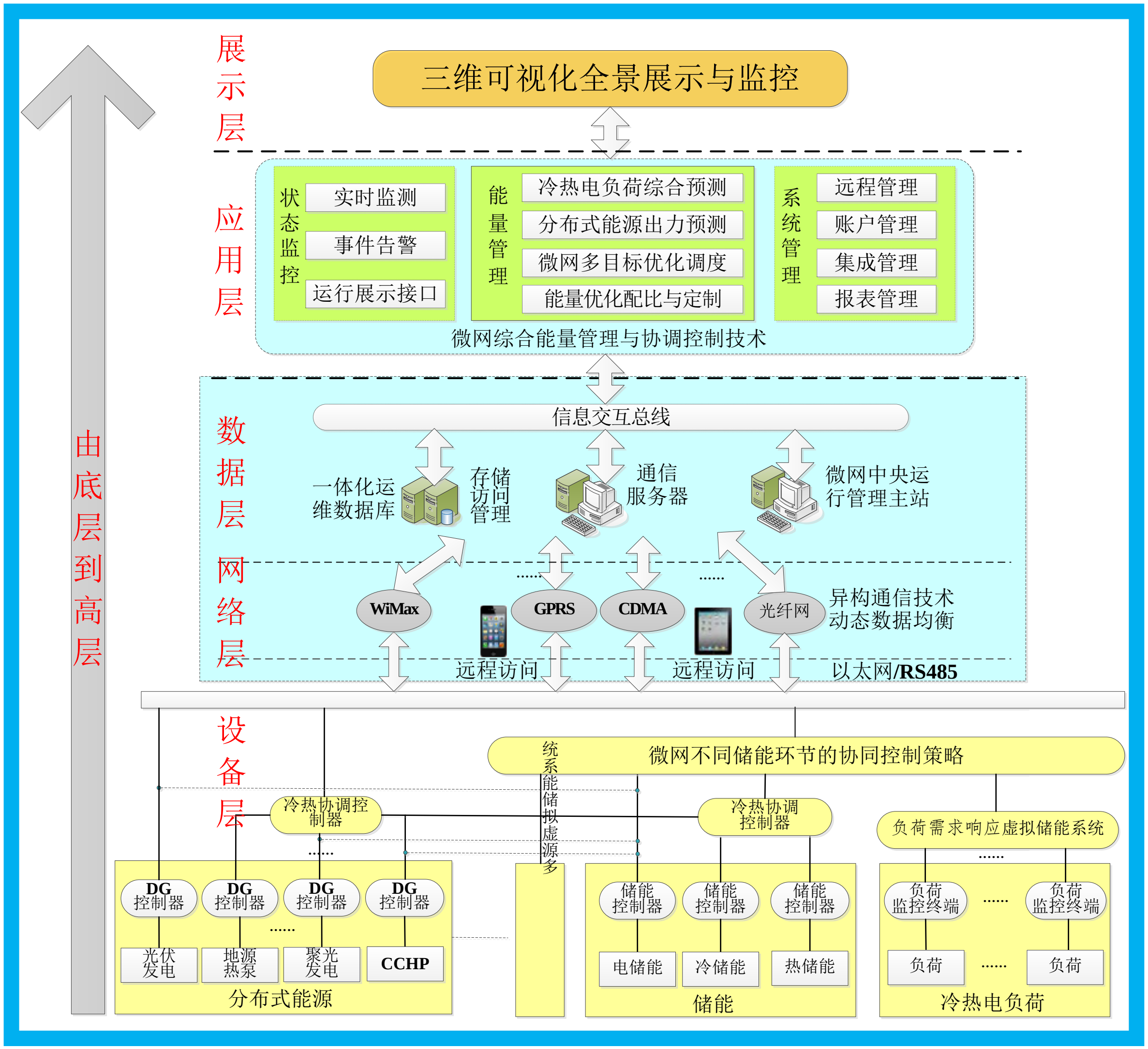
# Ongoing Research and Future Work at Tianjin University

## Optimal Control and Energy Management System




### Hierarchical Framework:

- Exhibition layer
- Application layer
- Data layer
- Communication layer
- Device layer

### Relevant Technologies:

① Powershadow Master

② Plug-in Technology

③ Heterogeneous-based Communication Technology

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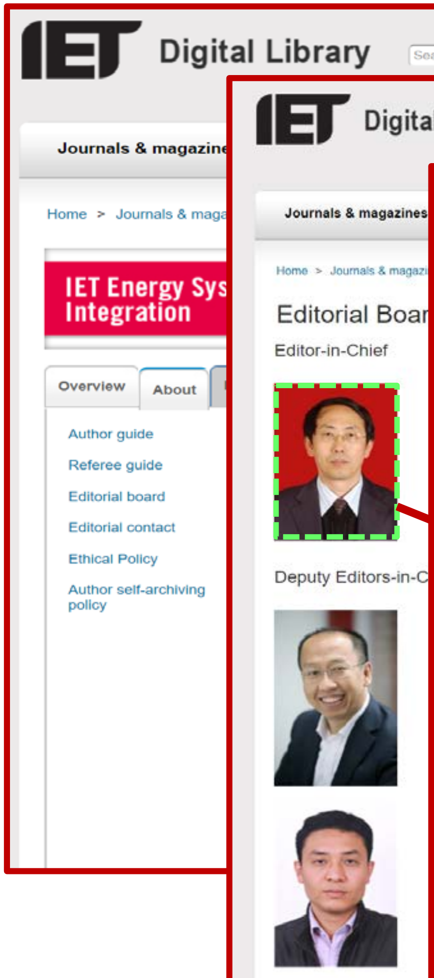
# Ongoing Research and Future Work at Tianjin University




***Editor-in-Chief***

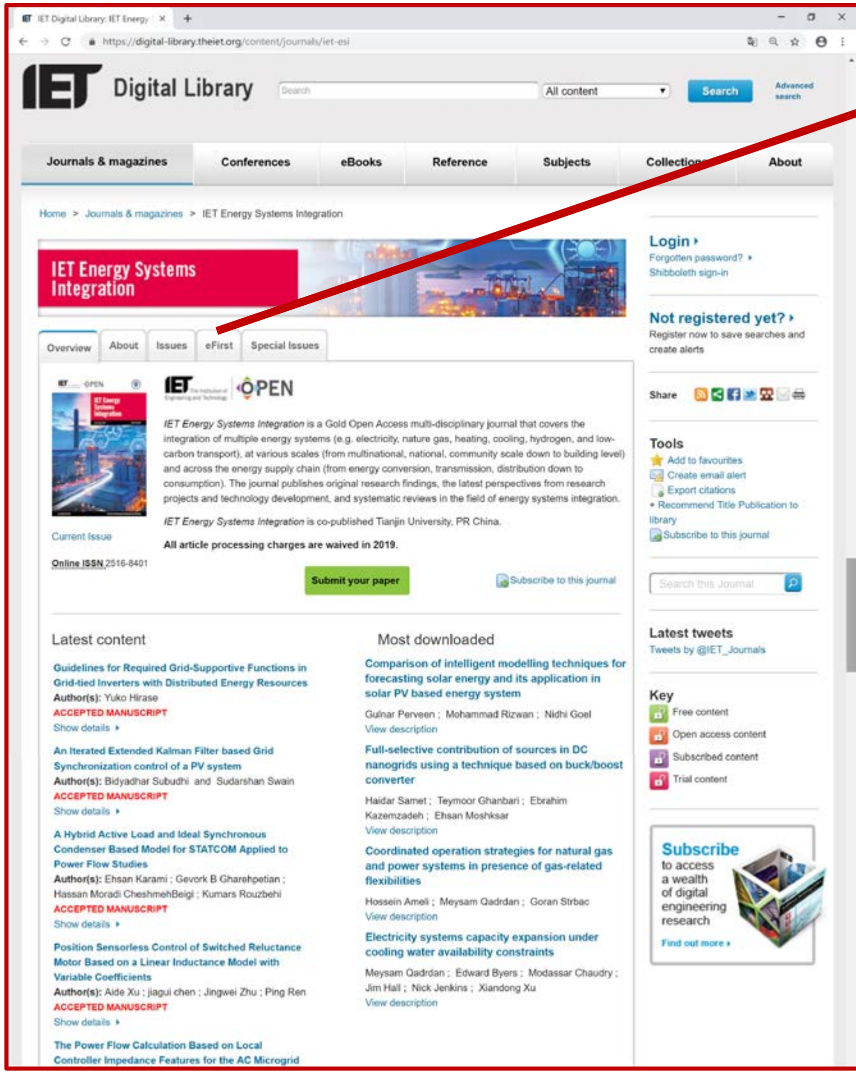
Prof. Chengshan Wang

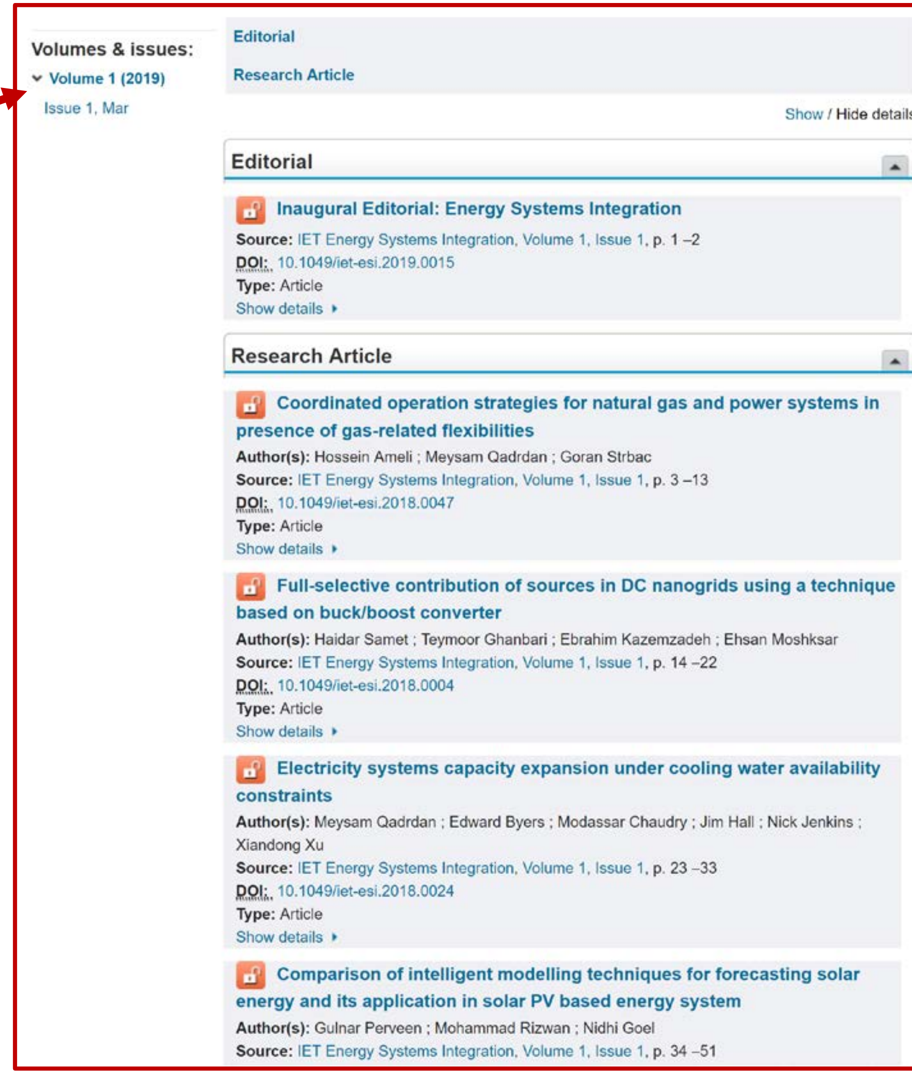
Tianjin University, China

Prof. Chengshan Wang is a professor of the School of Electrical and Information Engineering, Tianjin University, China. He is fellow of IET and senior member of IEEE, senior member of CSEE, member of the national committee of CIRED and member of national committee of CIGRE in China. He was a visiting scientist at Cornell University from 1994 to 1996 and a visiting professor with Carneigie Mellon University from 2001 to 2002. He received four Chinese National Awards of Science and Technology in 2004, 2010, 2012 and 2016 respectively. He was the Principal Investigators of several national and international collaboration research projects, including Chinese National Basic Research Program (973) “Research on the Key Issues of Distributed Generation Systems” from 2009 to 2013 and NSFC-EPSRC “Integrated Operation and Planning for Smart Electric Distribution Networks” from 2012 to 2015. His research interest is in the areas associate with distributed generation and microgrids, power distribution system analysis and planning. And he has published five books and more than 150 papers in world leading journals.

**A new journal organized by IET&TJU, namely Energy Systems Integration, has been approved by IET and the submission system is open. The first issue has published in March this year. Any submission to it is warmly welcome.**

# Ongoing Research and Future Work at Tianjin University

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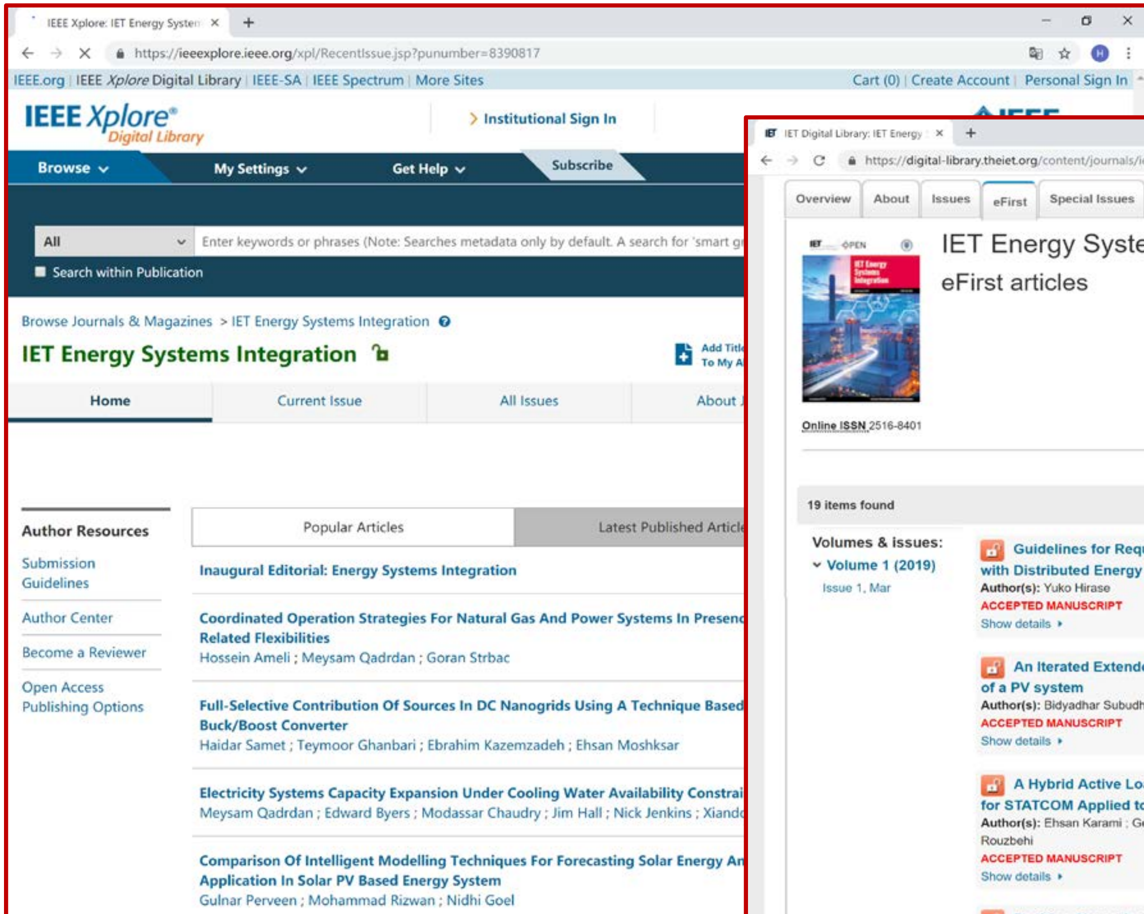


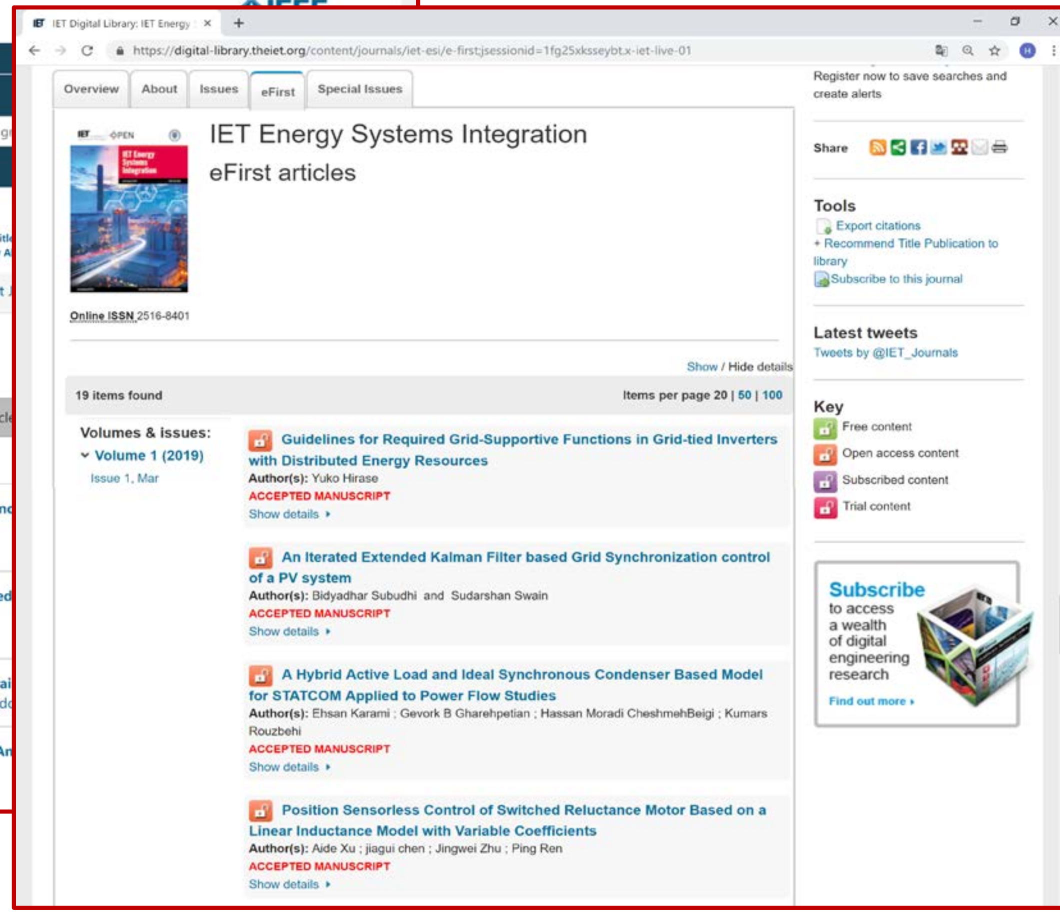


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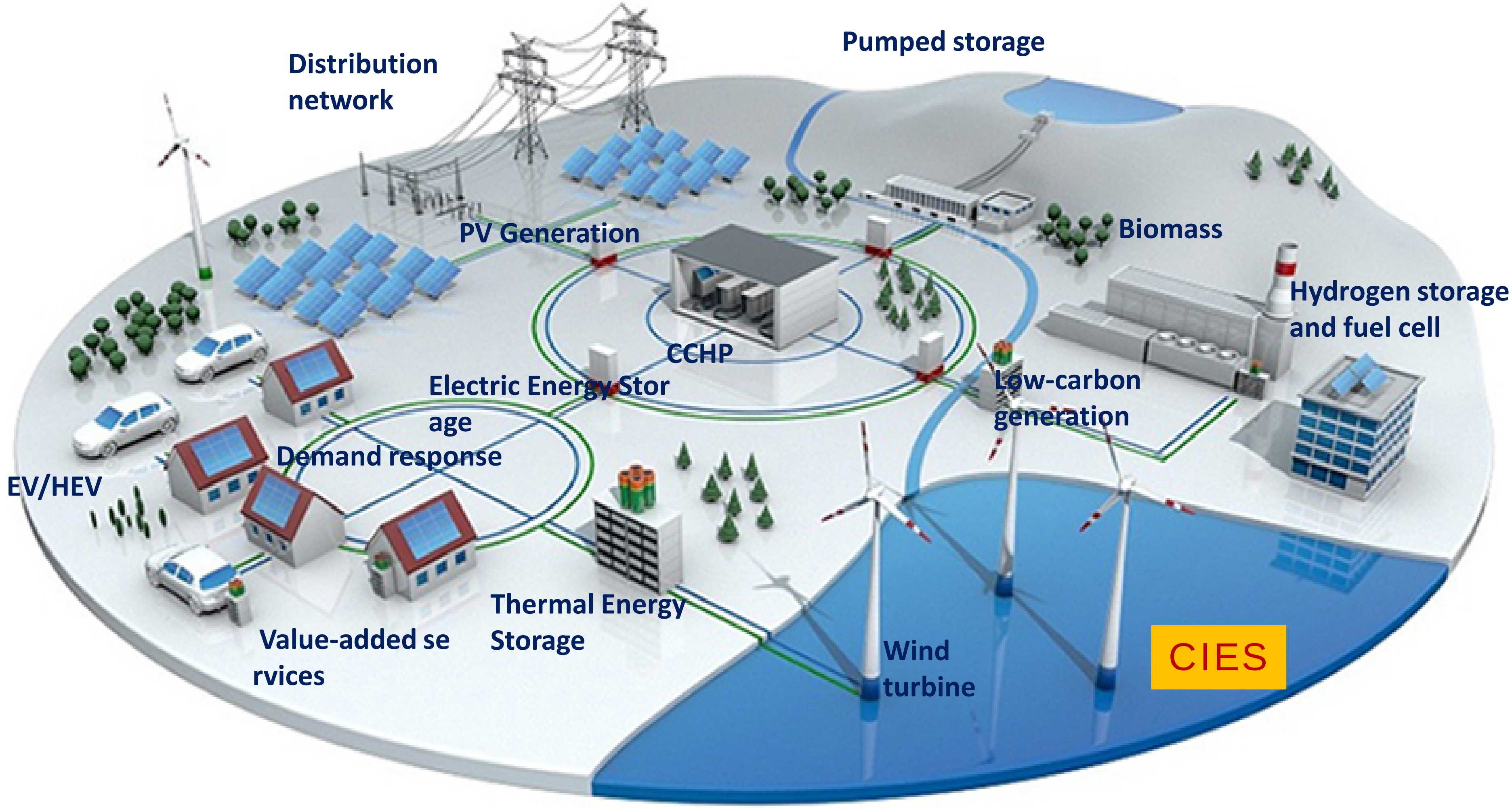
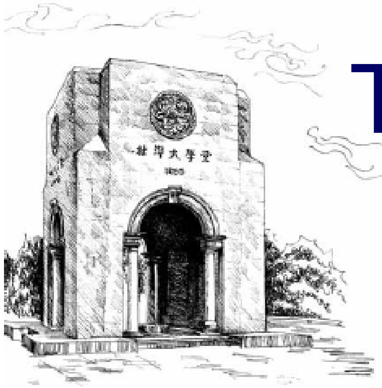
**IET=>https://digital-library.theiet.org/content/journals/iet-esi**

# Conclusions




CIES is a promising researching area in the world. **Tianjin University (TJU) is one of the most important R&D center in this area in China**, especially in the field of micro-grid techniques, IES planning, software development. We earnestly hope to build links with you and to do more collaboration in this field in the future.

Tianjin University



# Thank you for your attention!

天津大学 Tianjin University