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Development and Implementation of AI-empowered energy management based on supply-based feedback control for grid-interactive and energy-efficient buildings

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Research Institute for Smart Energy (RISE)

RISE is established, as a cross-disciplinary research platform in PolyU, for developing innovative energy technologies, sustainable and carbon-neutral solutions.

Research Focus Areas of RISE

Research Institute for Smart Energy (RISE)

智慧能源研究院

District energy systems and smart grid

區域能源系統和智慧電網

Smart buildings and smart energy systems

智慧建築和智慧能源系統

Advanced energy storage technologies

先進儲能技術

Advanced and renewable energy conversion technologies

先進及可再生能源轉換技術

Advanced energy materials

先進能源材料

Smart energy system technologies

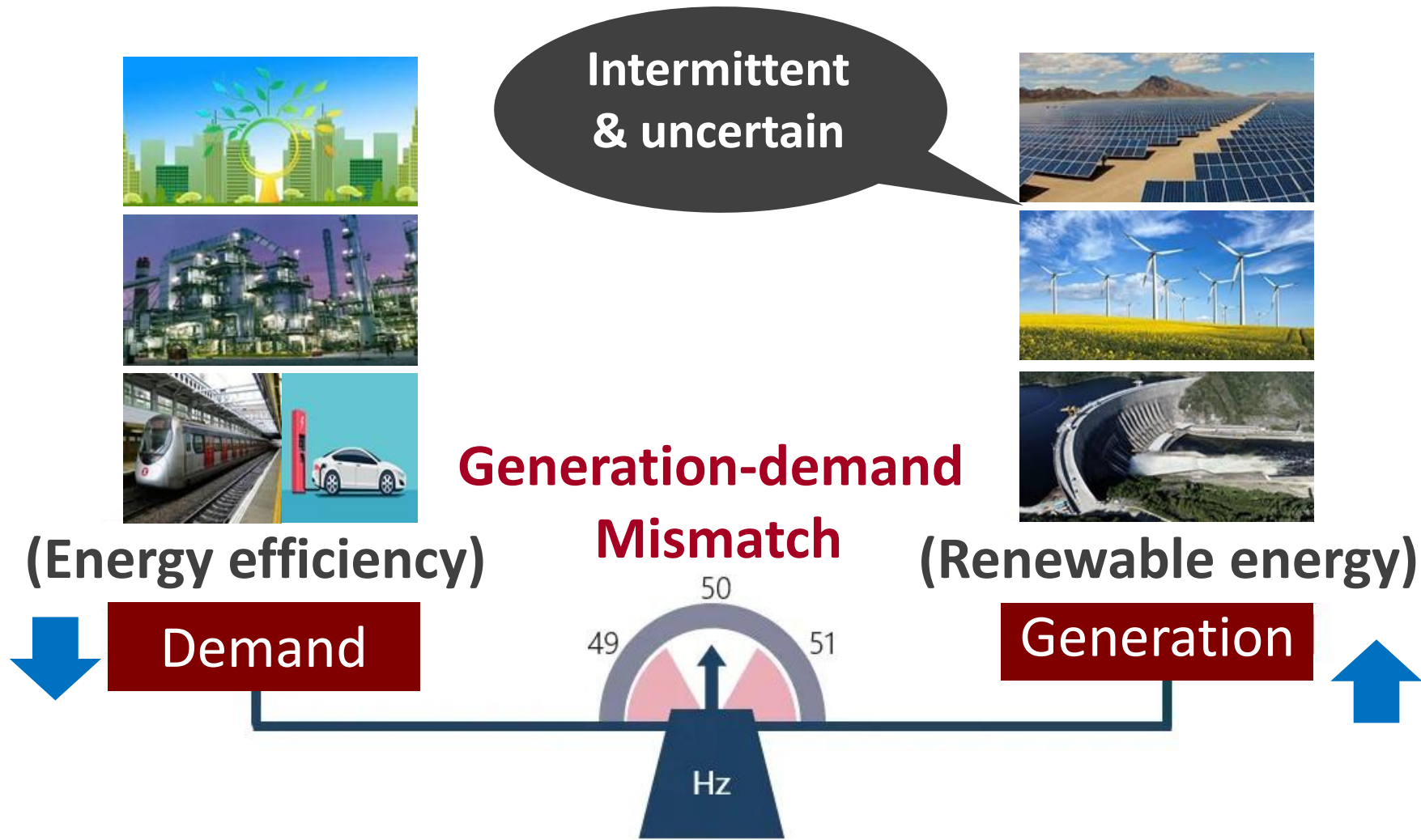
➤ Energy system and service industries

Enabling energy technologies

➤ energy product manufacturing industries

- ✓ RISE is a university-level research institute in PolyU, involving about 70 professors/faculty members from 12 departments in the university

Regular means for carbon neutrality in power sector and **the key problems**



A new and more cost-effective approach for carbon neutrality

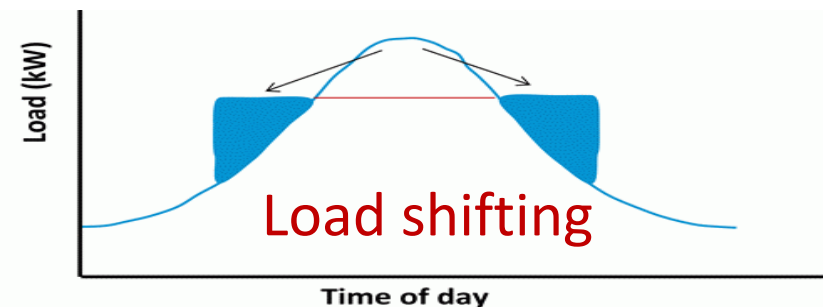
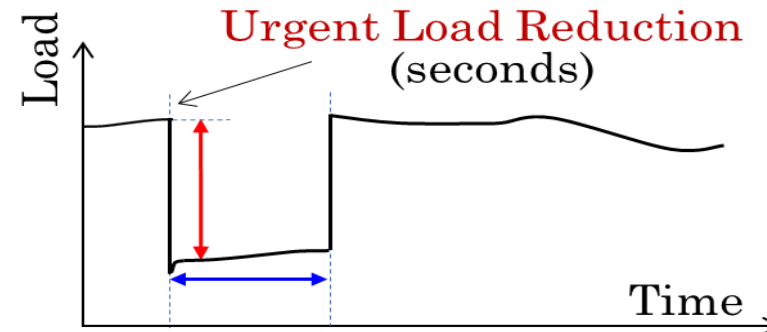
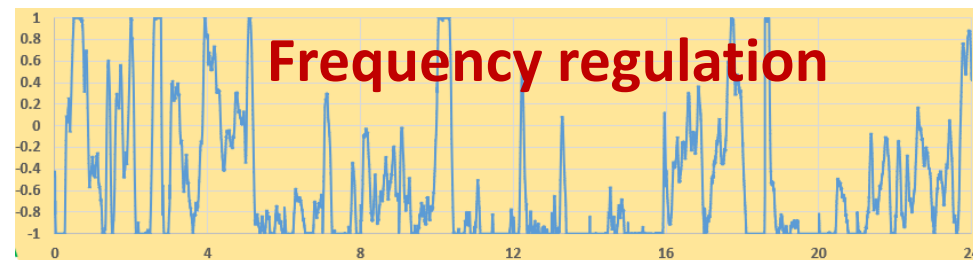
– Load Flexibility and Energy-flexible Building

In the past: Power generation follows power demand (generation side has good controllability)

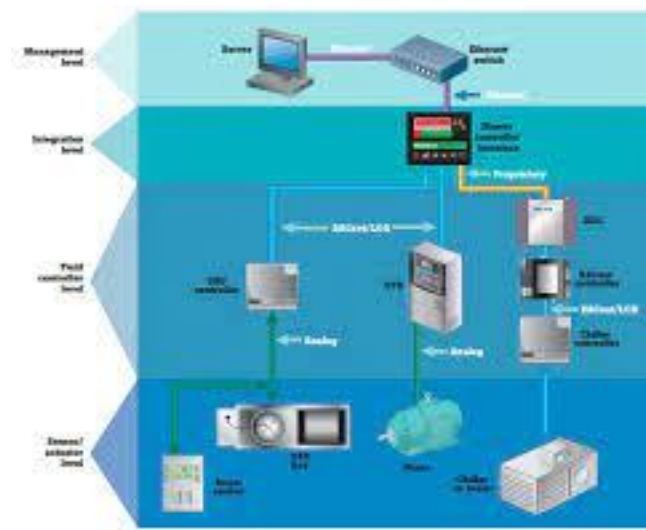
In the future: Demand has to “follow” power generation (generation side has poor controllability under high renewable penetration)

“**Load flexibility**” refers to ability of consumers at demand side, such as buildings, to **reduce and reshape their power use** without unacceptable compromise on services when there is short or surplus of power supply.

Typical flexibility services

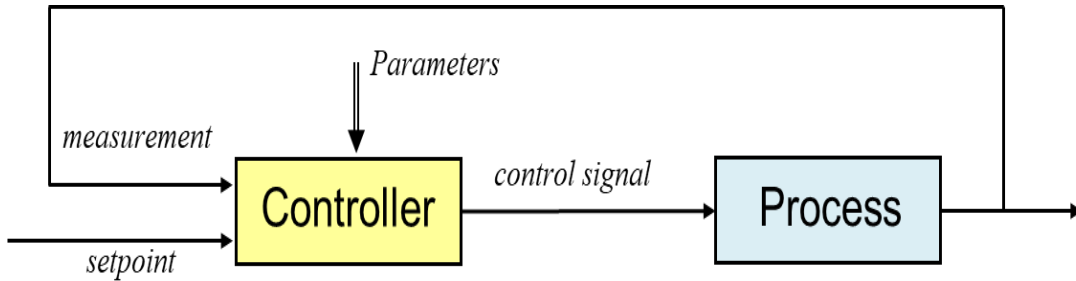


Control of building air-conditioning systems under limited cooling supply



Conventional Building process control needs conceptual upgrade

Demand-based feedback control



=> Normal working condition with sufficient supply

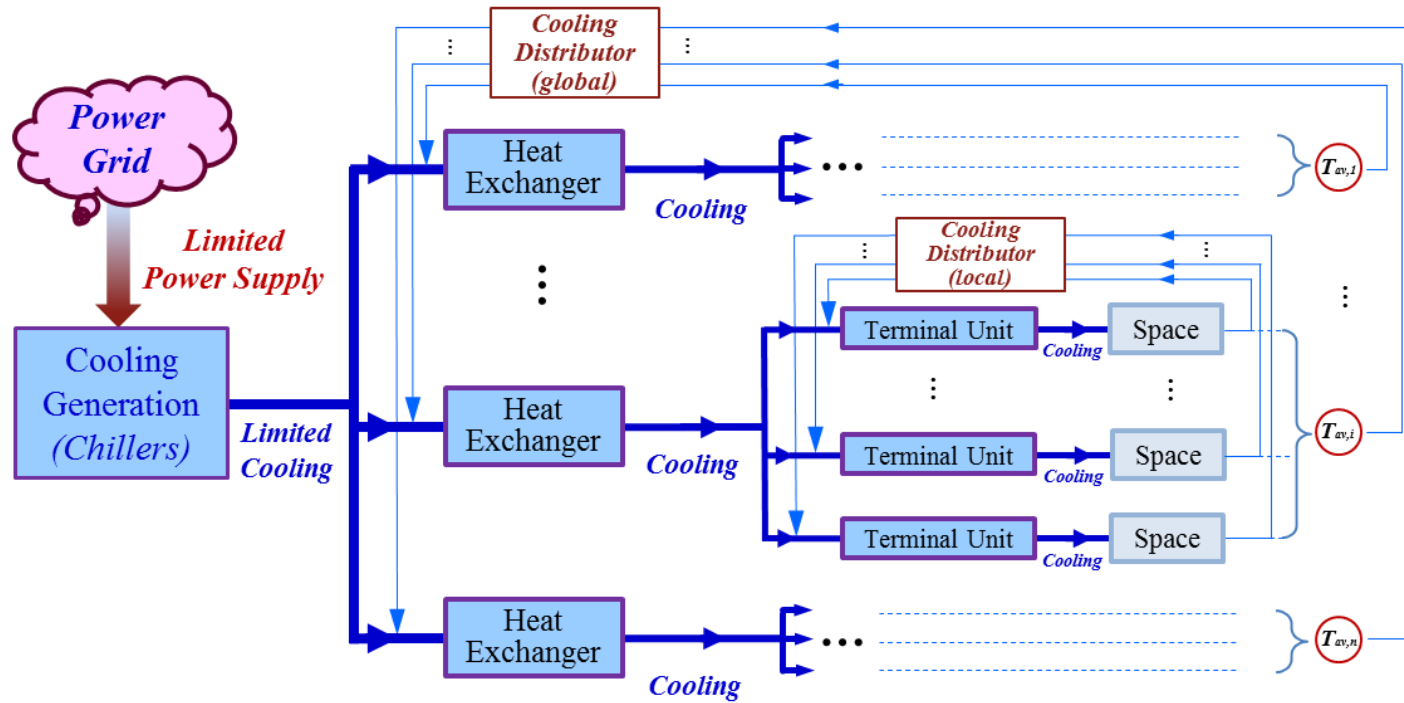
Supply-based feedback control

=> Under limited cooling supply

- *Demand limiting control*
- *Morning start*
- *Soft stop*

Limitation: Regular controlled variables are floating and cannot be control at desired steady-state setpoints. It is therefore can be used in special and transient conditions and needs to work together with demand-based feedback control

Supply-based feedback control for air-conditioning systems under limited cooling-supply – The Concept

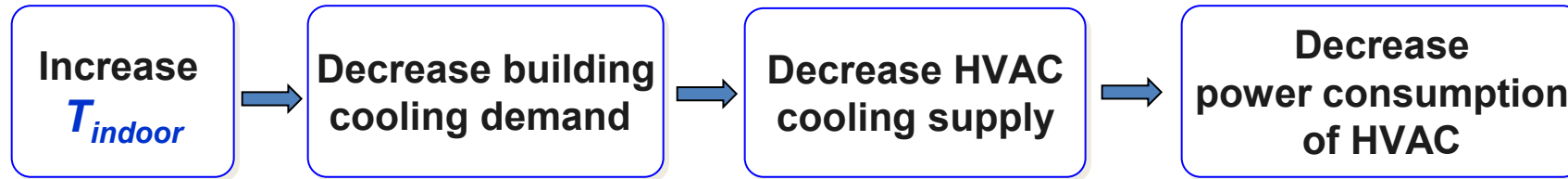


SW Wang, R Tang, "Supply-based feedback control strategy of air-conditioning systems for direct load control of buildings responding to urgent requests of smart grids", Applied Energy 201, 2017

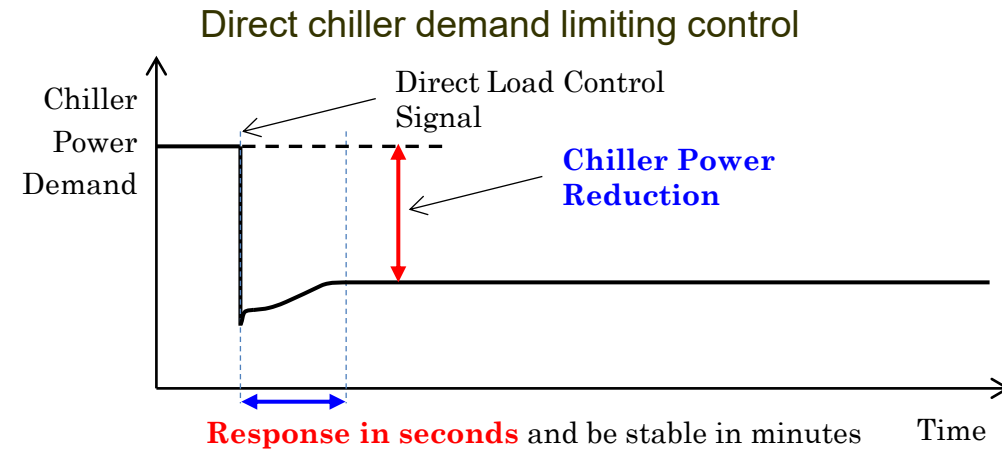
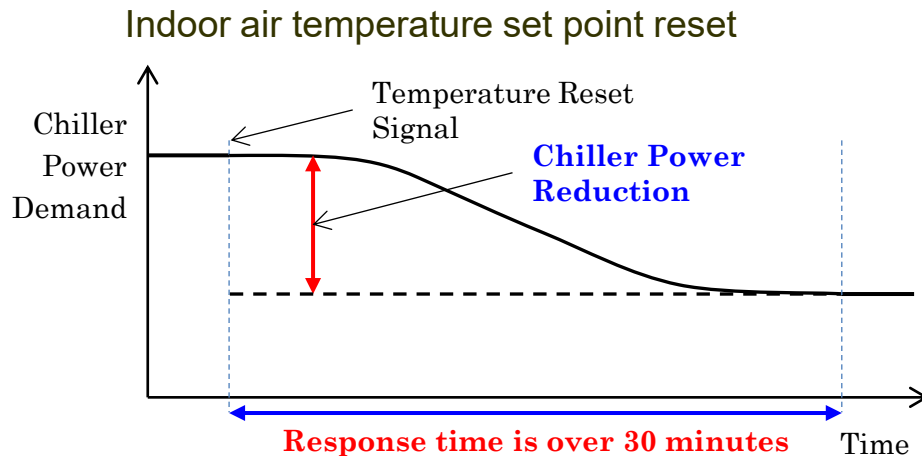
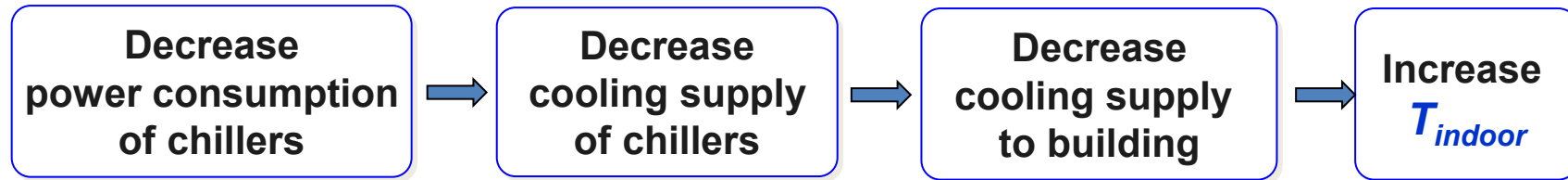
Needs for proactive demand response

- Facing sudden pricing changes/urgent incentives, demand reduction should be achieved within a very short time, i.e. minutes.

Conventional Method – Cooling Demand-based Control Method

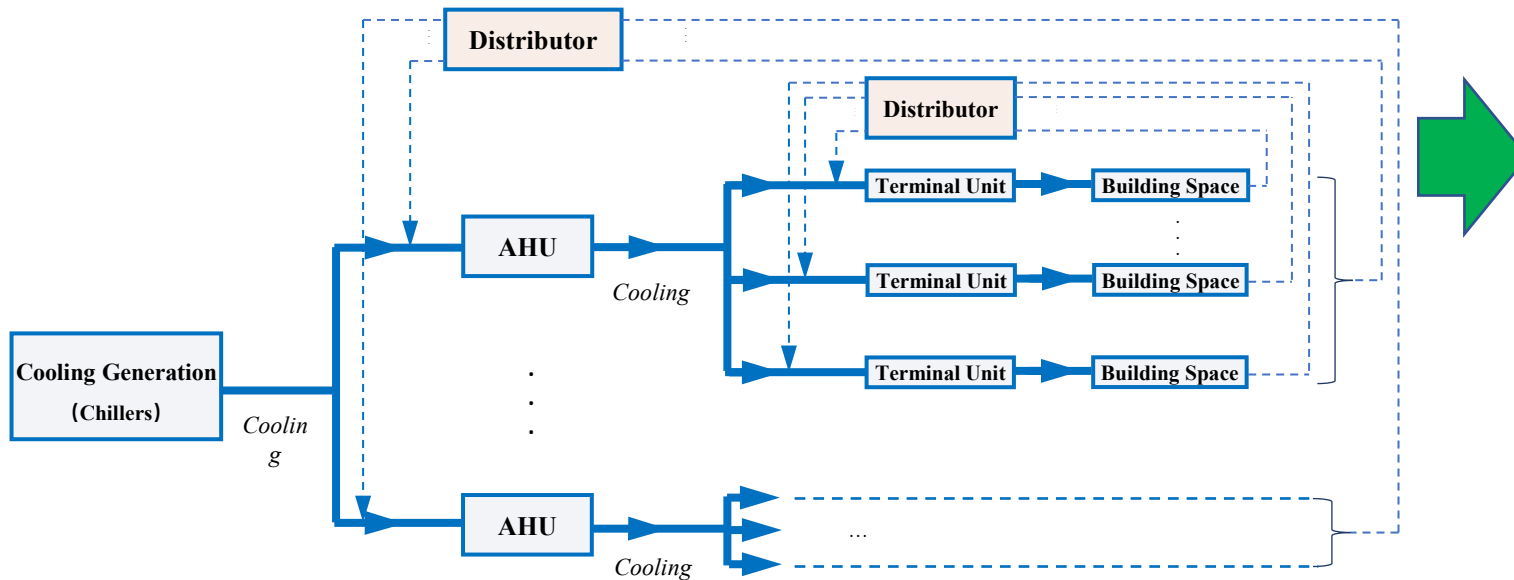


Proactive Method – Cooling Supply-based Control Method



Existing supply-based control and limitations

First-generation of **supply-based** feedback control adopting utility function



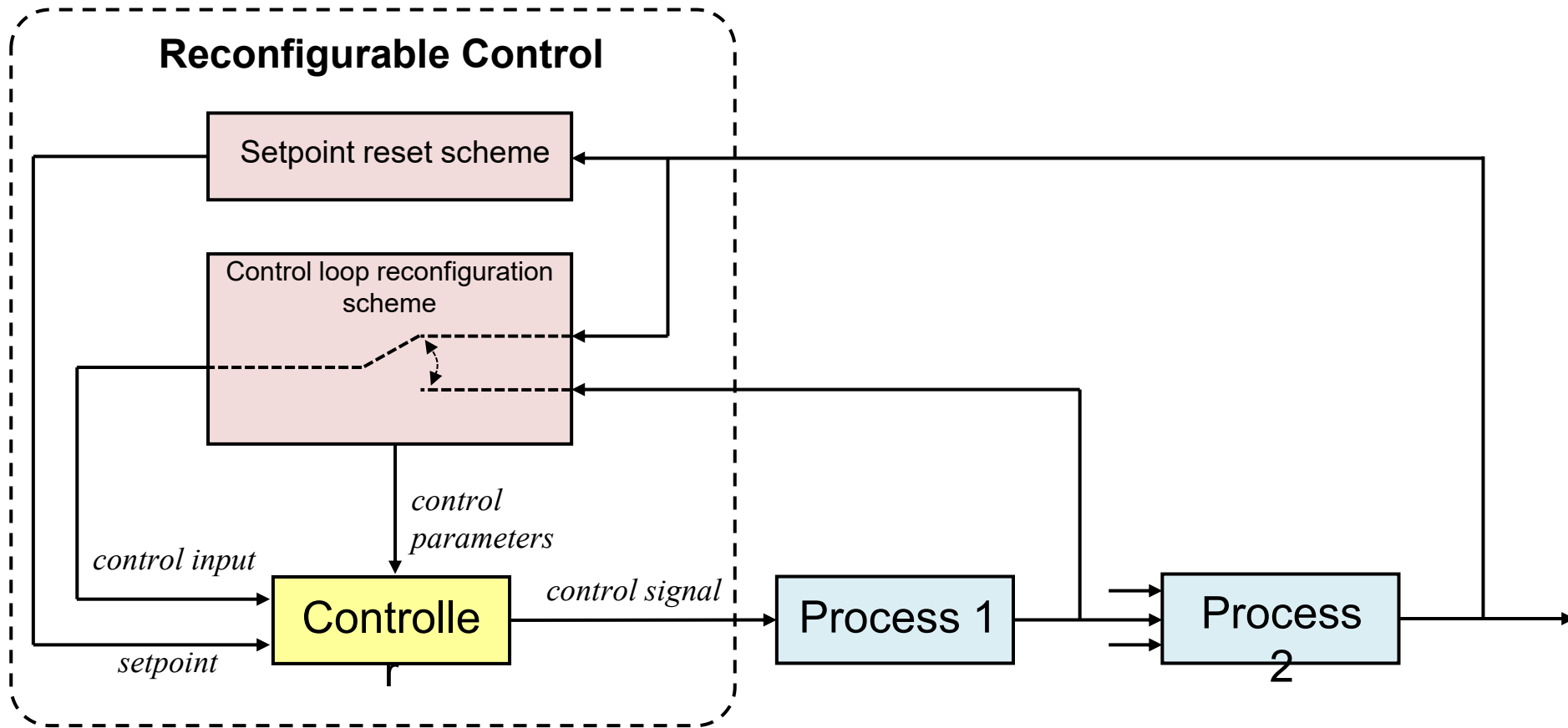
Limitation and Research gaps

- **Implementation** of supply-based feedback control in conventional building automation systems (BASs)
- A strategy **deployable** in commonly-used digital controllers, such as DDCs, is urgently needed.
- **Integration** with regular demand-based feedback control

SW Wang, R Tang, "Supply-based feedback control strategy of air-conditioning systems for direct load control of buildings responding to urgent requests of smart grids", Applied Energy 201, 2017

Reconfigurable supply-based feedback control strategy

- The proposed **reconfigurable control strategy** can adjust **feedback control loop** online to **match different needs or objectives of controls** under **demand limiting** with limited resource/supply and under **normal situation** with sufficient supply.

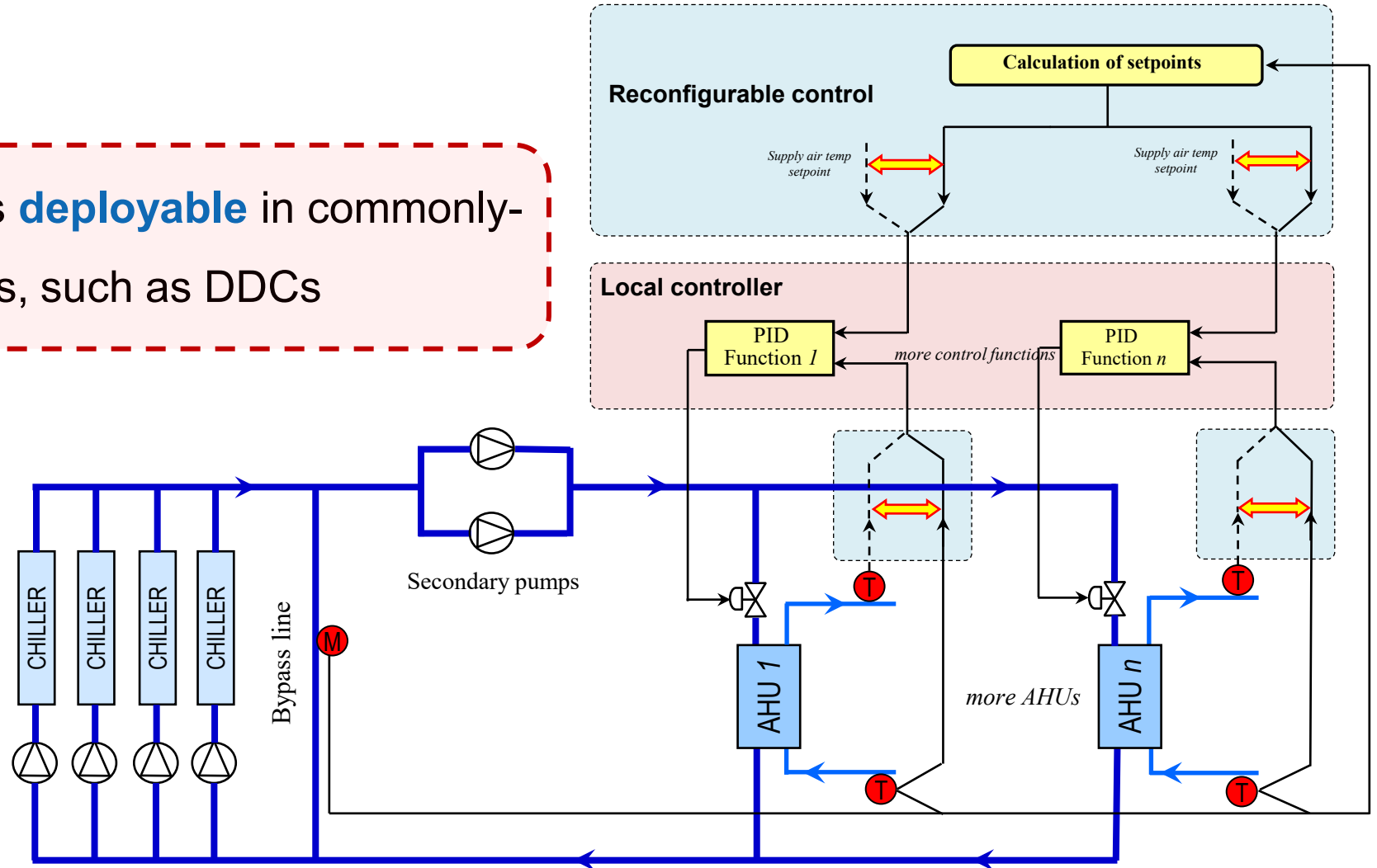


Block diagram of the feedback loop reconfiguration

Mingkun Dai, Hangxin Li, Xiuming Li, Shengwei Wang. (2024). Reconfigurable supply-based feedback control for enhanced energy flexibility of air-conditioning systems facilitating grid-interactive buildings. *Advances in Applied Energy*, 14, 100176.

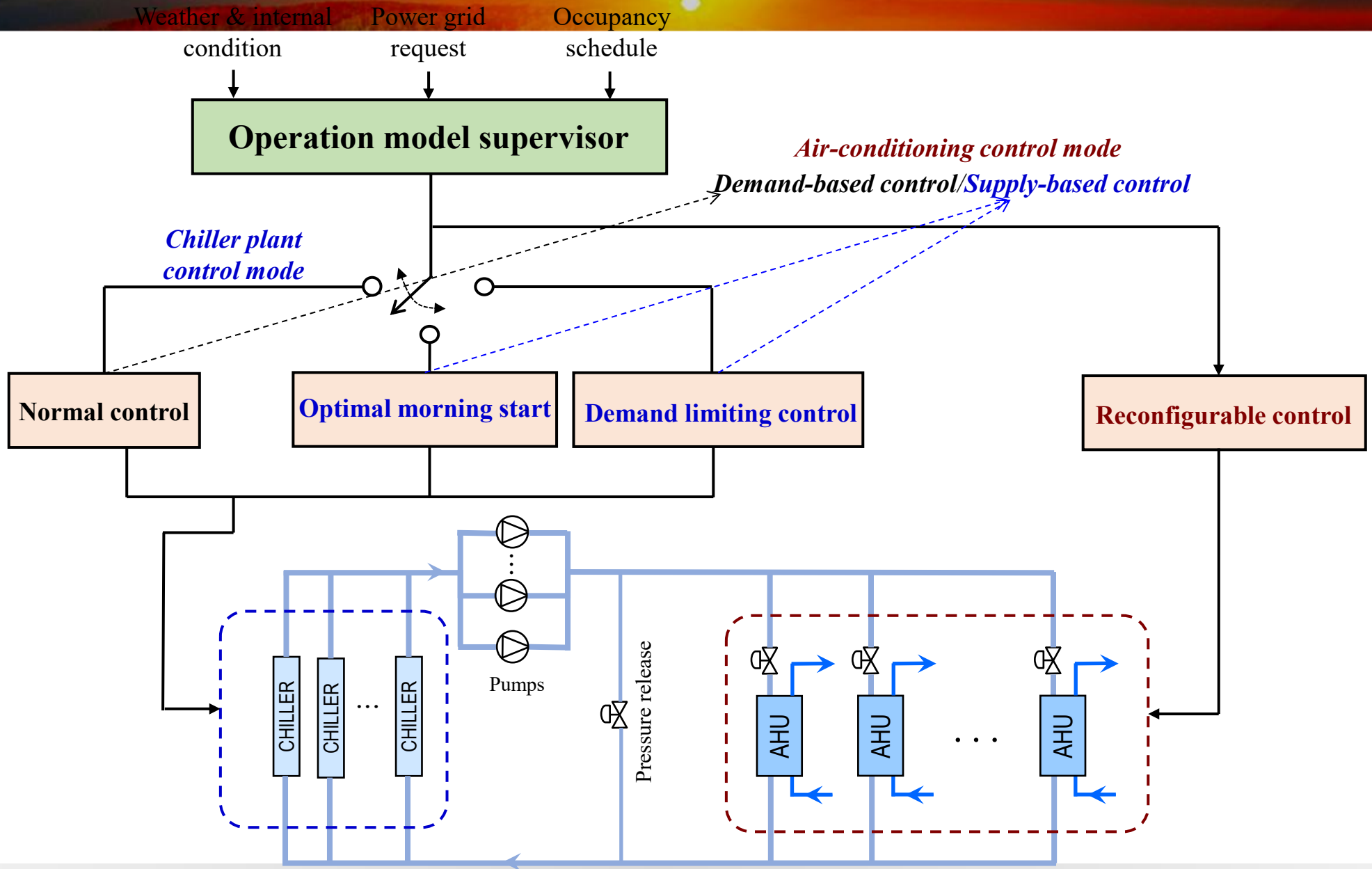
Control deployment

The proposed control strategy is **deployable** in commonly-used digital controllers, such as DDCs

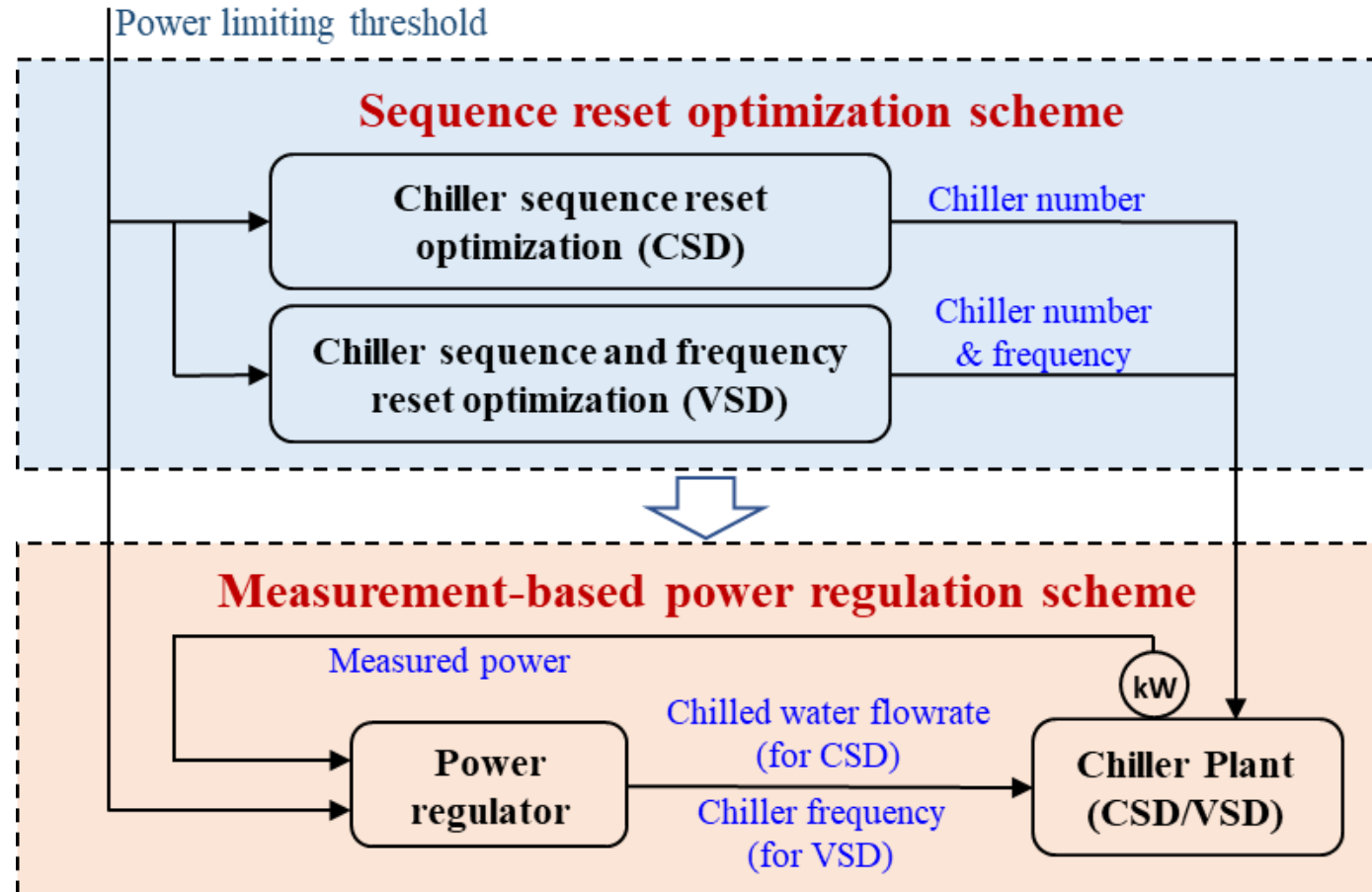




Integration of supply-based feedback control with AI-empowered grid-interaction and energy management strategies for buildings

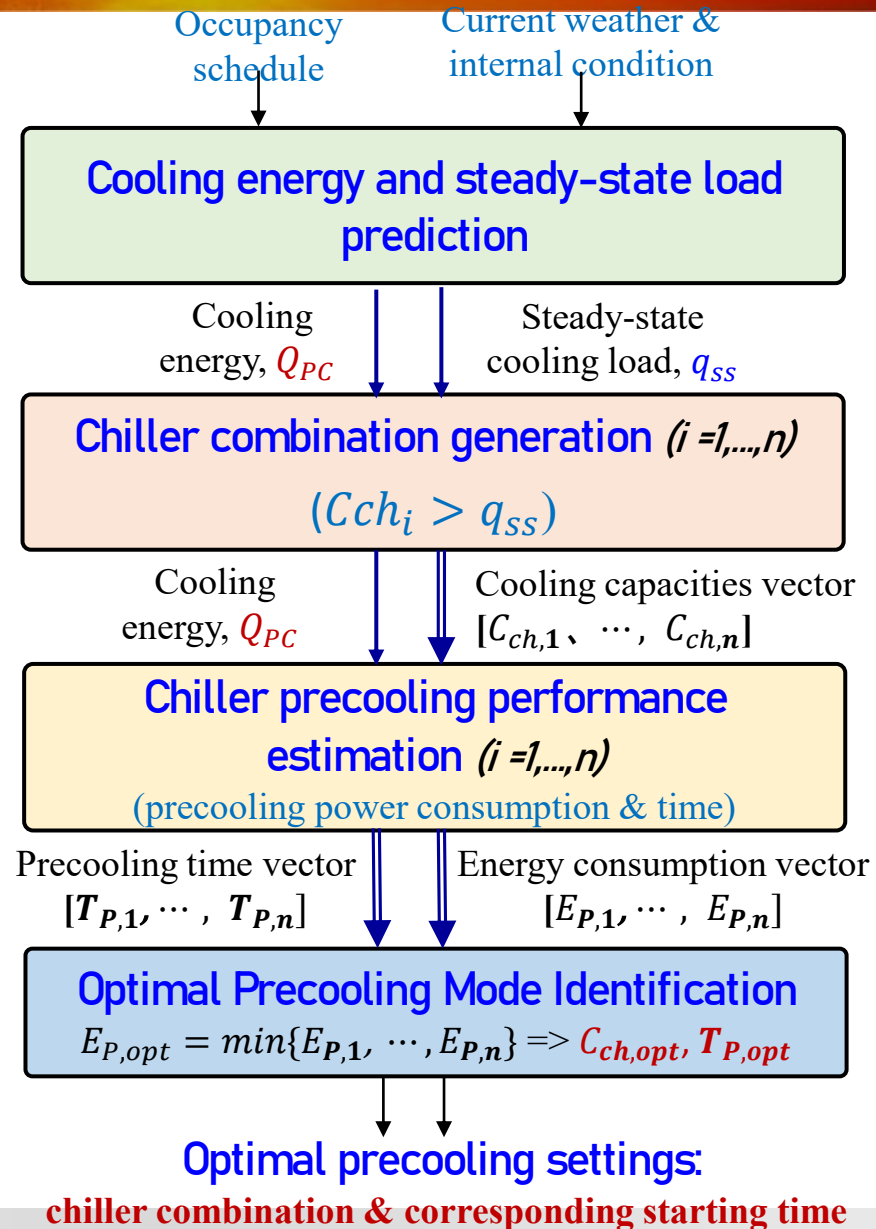


Basic approach of the hierarchical optimization strategy for building demand limiting control

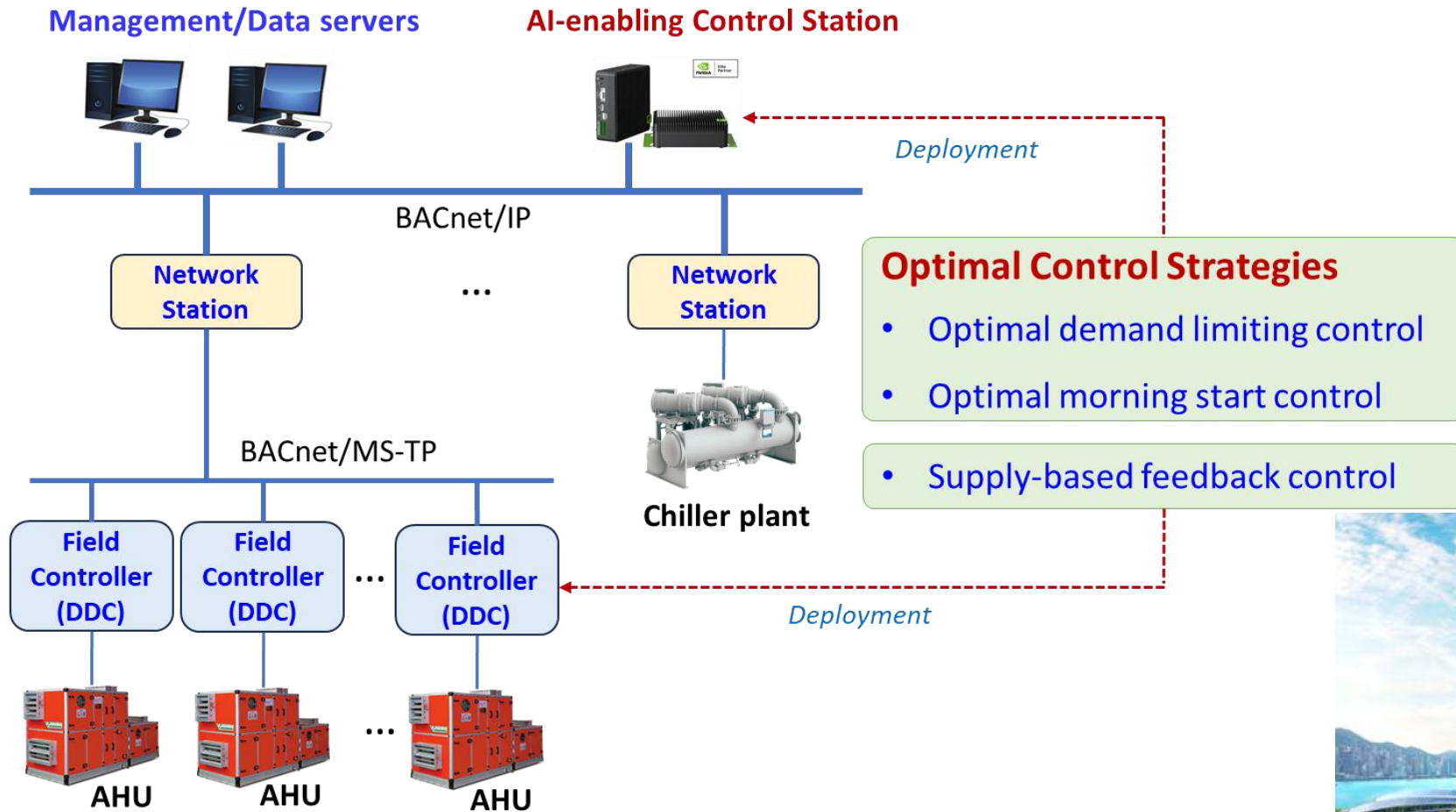


AI-empowered morning start optimization of chiller plants

- chiller combination and starting time



Deployment and Full-scale Implementation in Buildings





Thanks!

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