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Building Energy Saving through Life-Cycle Optimization, Commissioning and Diagnosis – Experiences in International Commerce Center (ICC) of Hong Kong

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Outline of Presentation

- Basic approaches for building energy saving
- Life-cycle diagnosis/commissioning and optimization
- Technologies and deliverables
- Research areas and expertise
- Application Case 1 – ICC
- Application Case 2 – A Hotel Building
- Recent existing Building Energy Projects

Basic Approaches for Energy Efficient Buildings

- Reduced heating/cooling loads
  – Building envelope design, passive design, etc.
- Use of energy efficient building systems and technologies
- Optimization of system and technology integration, operation and control
  – Life-cycle commissioning, design optimization, control optimization, etc.

Team's Research Objectives and Applicable Deliverables

- **Life-cycle Diagnosis/Commissioning and Optimization**

Objectives of Diagnosis/Commissioning and Optimization

Objective of Diagnosis/Commissioning

- To ensure the operation performance of the systems delivered meet the design intent.

Objective of optimization

- To push the operation performance of the systems delivered to approach the best, often exceed the design intent.

Steps towards Energy Efficient Buildings

Operation Stage and T&C Stage

- Push systems approach the best
- Ensure systems operate as good as intent

Construction Stage

- Construct/install systems correctly

Design Stage

- Optimize designs and selections
- Make designs proper and correct

Contents of Diagnosis/Commissioning and Optimization

Content of Diagnosis/commissioning

Deviations of performances of a deliverable from its design intent come from different sources at different stages, diagnosis and commissioning should cover different stages:

- Design configuration;
- Component selection and sizing;
- Installation;
- (Monitoring and control) instrumentation;
- Test and commissioning;
- Operation and control;
- Maintenance, etc.

Design Intent *vs* Deliverable

Content of Optimization

Optimization of HVAC&R systems

Optimization could be performed at different stages allowing the systems to provide expected quality of services (comfort and health environment) with reduced (minimum) energy consumption by means of:

- Optimizing design configuration;
- Optimizing selection and sizing;
- Optimizing (monitoring/control) instrumentation;
- Optimal operation and control, etc.

Technologies and Deliverables

Examples of Technologies

- Building Performance Quick Evaluation and Diagnostic Tool
- Detailed Evaluation and Diagnostic Tool for A/C and BA systems
- Building System Online Performance Simulation Test Platform
- Existing Building Commissioning and Upgrading Assessment Tool
- BA Control and Diagnosis Strategy Online Test Platform
- Package of Online Optimal and Energy Efficient Control and Fault Diagnosis Strategies
- Intelligent Building Integration and management Platform-IBmanager

Both new building development and Existing Building Energy Saving are the targets.

Building Life-cycle Diagnosis, Commissioning and Optimization

- International Commerce Centre (ICC)

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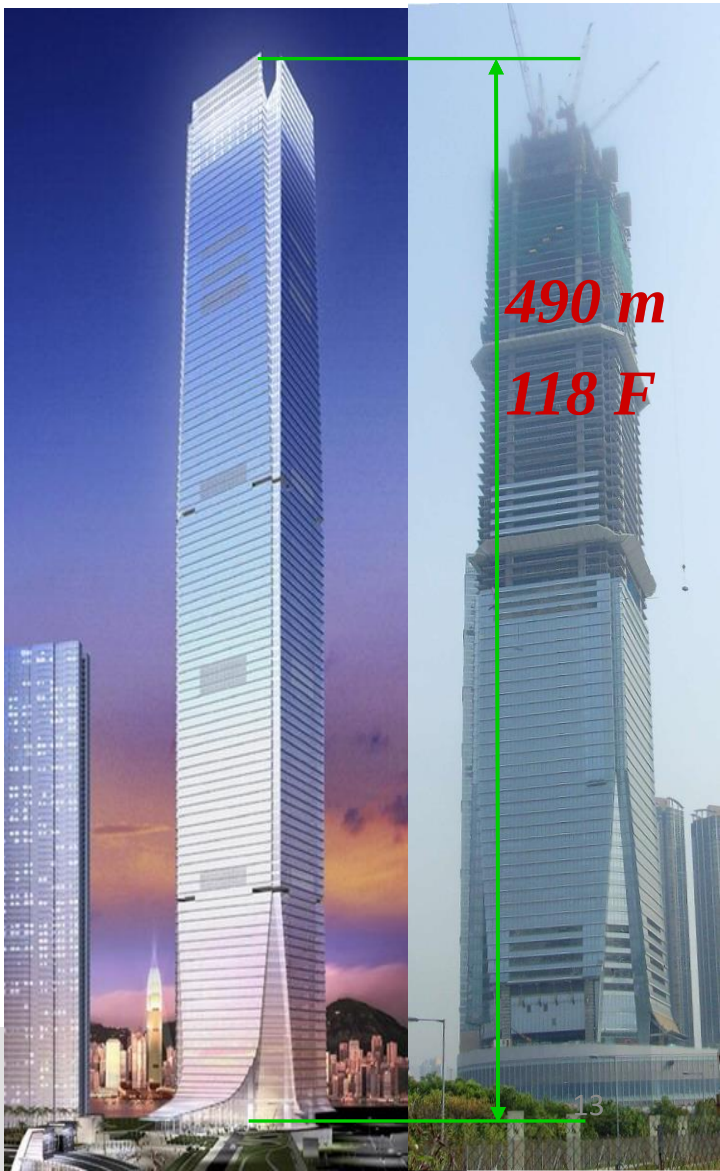
Our Roles in ICC Project

- Independent Energy Consultant (Independent Commissioning Agent)
- To Develop the HVAC Energy Optimal Control System



Virtual Building System Simulated ⇔ BA & Strategies

(updated throughout the entire process)

Commissioning at Design Stage

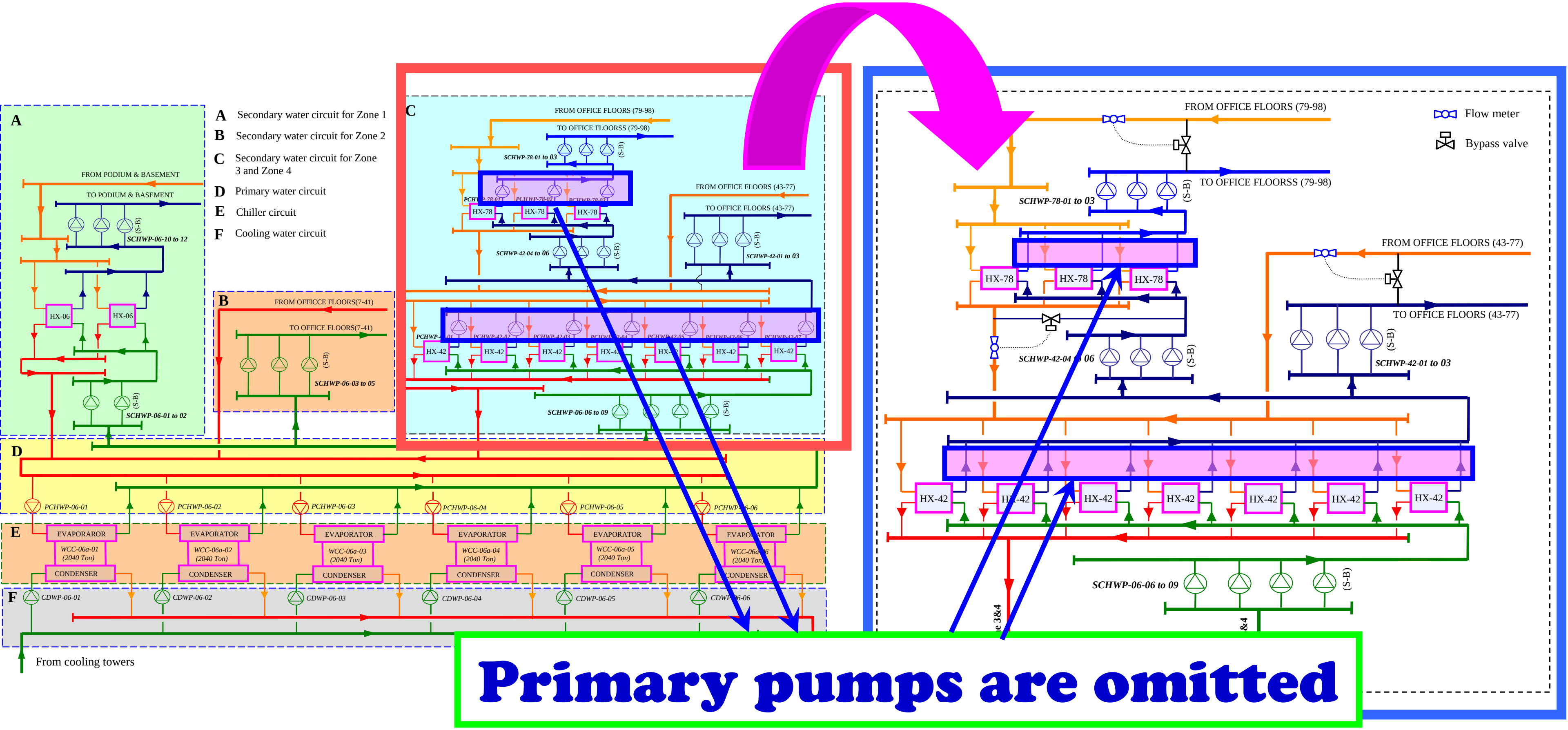
Design commissioning mainly concerns the future operation and control performance of HVAC systems, including:

- *Verifying/improving the system configuration and component selection including the chiller system, water system (primary/secondary system), heat rejection system (cooling towers), fresh air system etc.*
- *Verifying and improving the metering system for proper local control, and the original proposed control logics at the design stage.*
- *Proposal of additional metering system for implementing supervisory control and diagnosis strategies and related facilities for implementing these strategies*

An Example of Diagnosis and Optimization at Design Stage

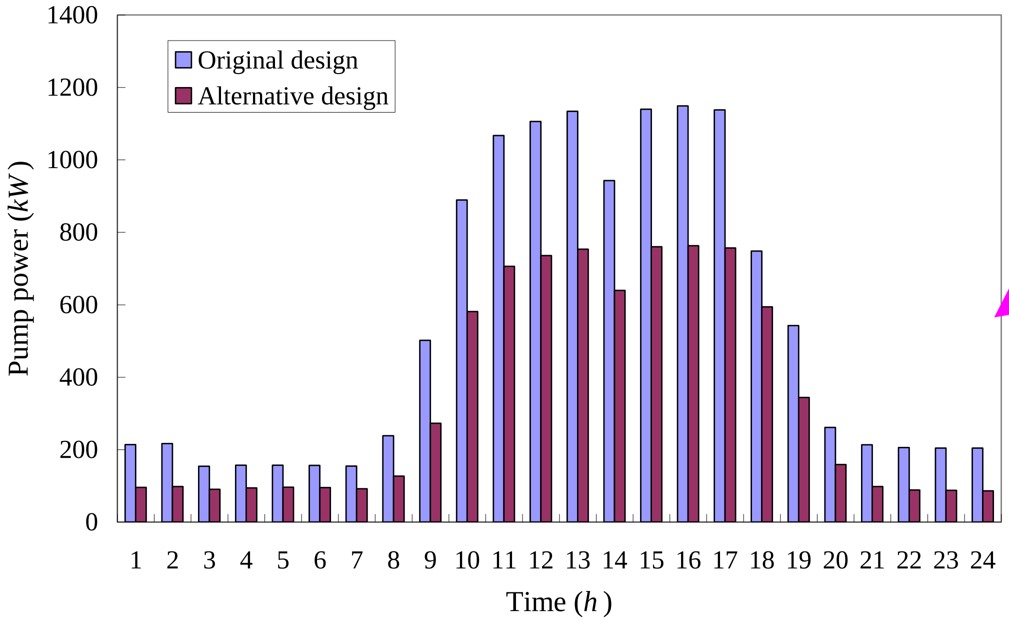
System Design Verification and Optimization

Secondary water loop systems of 3rd/4th zones



Original System ***Revised System***

Comparison between Two systems



Typical sunny-summer day

Annual Pump Energy Saving is 1M kWh

Pump Power	Original Design (kWh)	Alternative Design (kWh)	Savings (kWh)	Savings (%)
Annual	2,760,758.4	1,726,163.5	1,034,594.9	37.48
Spring day	8,587.7	5,392.7	3,195.0	37.20
Mild-Summer Day	10,505.8	6,490.4	4,015.4	38.22
Sunny-Summer Day	12,894.5	8,212.8	4,681.7	36.31

Optimal control strategies for central air-conditioning systems

- **Chiller sequence, optimal start**

  Optimal chiller sequence - based on a more accurate cooling load prediction using data fusion method, and considering demand limiting

  Adaptive online strategy for optimal start - based on simplified sub-system dynamic models

- **Ventilation strategy for multi-zone air-conditioning system**

  Optimal ventilation control strategy - based on ventilation needs of individual zones and the energy benefits of fresh air intake

- **Peak demand limiting and overall electricity cost management**

Optimal control strategies for central air-conditioning systems

- **Chilled water system optimization**

  Optimal pressure differential set point reset strategy

  Optimal pump sequence logic

  Optimal heat exchanger sequence logic

  Optimal control strategy for pumps in the cold water side of heat exchangers

  Optimal chilled water supply temperature set-point reset strategy

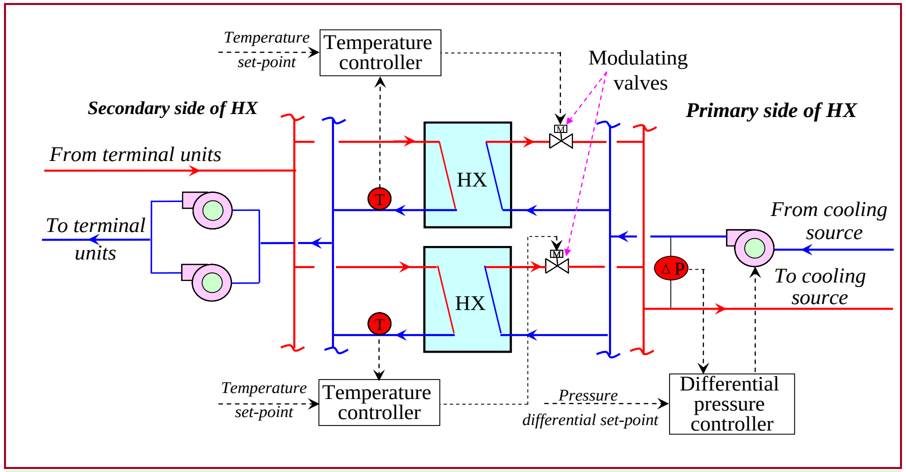
- **Cooling water system optimization**

  Optimal condenser inlet water temperature set point reset strategy

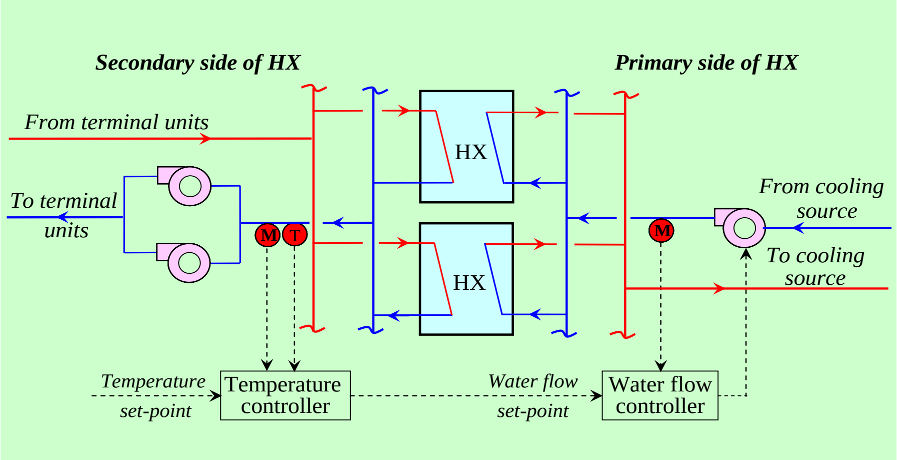
  Optimal cooling tower sequence

Optimal Control of Variable Speed Pumps

- *Speed control of pumps distributing water to heat exchangers*



- *Original implemented strategy – differential pressure control and by resorting to the modulating valve*



- *Revised strategy – cascade controller without using any modulating valve*

Performance test and evaluation

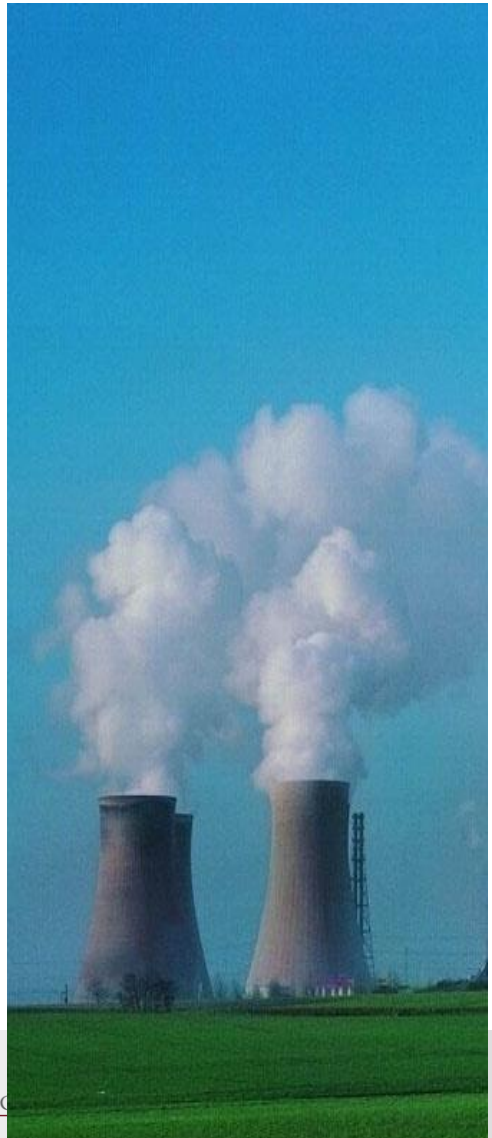
- ***Site practically tests show that the proposed strategy can provide stable and reliable control.*** *Compared to original implemented strategy, about 22.0% savings for pumps before heat exchangers in Zone 1 was achieved.*
- ***Due to the low load of Zone 1 in ICC at current stage, a simulation test of annual energy savings by using PolyU strategy is performed***

Energy saving of primary pumps before heat exchanges due to the use of PolyU strategy is about 250,000 kWh.

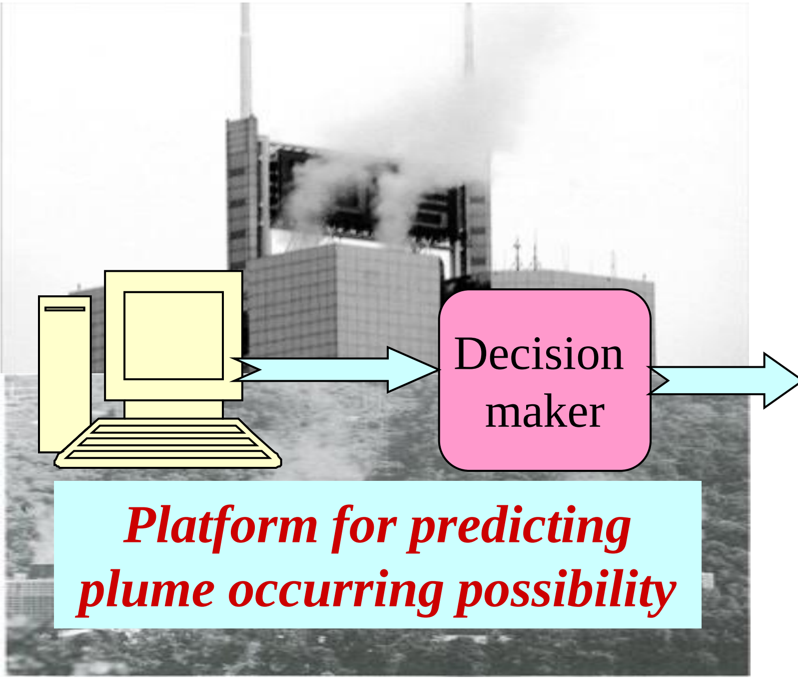
...on (kWh)	Saving (kWh)
...lternative Strategy (kWh)	
...456,132	71,876
795,830	125,405
346,420	54,588
	251,869

Visible Plume Abatement

Visible Plume



Visible Plume Abatement



Normal operation when there is no predicted plume occurs

At first-level warning, increase airflow rate by 20% when plume potential is marginal

At second-level warning, increase airflow by 40% when plume potential is high

Start heating using heat pumps when visual plume is observed

	Operating Condition			Power Consumption			Difference	
							W	%
								--
							4.0	1.5
S							0.6	5.5
ng heat pumps	22.7	3CT+1HP	26.51	856.2	59.1	1215.2	300	32.8

Additional energy consumption for plume control could be reduced from 32.8% to 5.5% or 1.5% at low Load

Chiller Plant Sequencing Control of Enhanced Robustness using Data Fusion Technique

Cooling Load Measurement based on Data-Fusion

Cooling load measurement

- **Direct measurement of building cooling load**

$$Q_{dm} = c_{pw}\rho_w M_w (T_{w,rtn} - T_{w,sup})$$

c_{pw} is the water specific thermal capacity; ρ_w is the water density; M_w is water flow rate; $T_{w,rtn}$, $T_{w,sup}$ are chilled water return/supply temp.

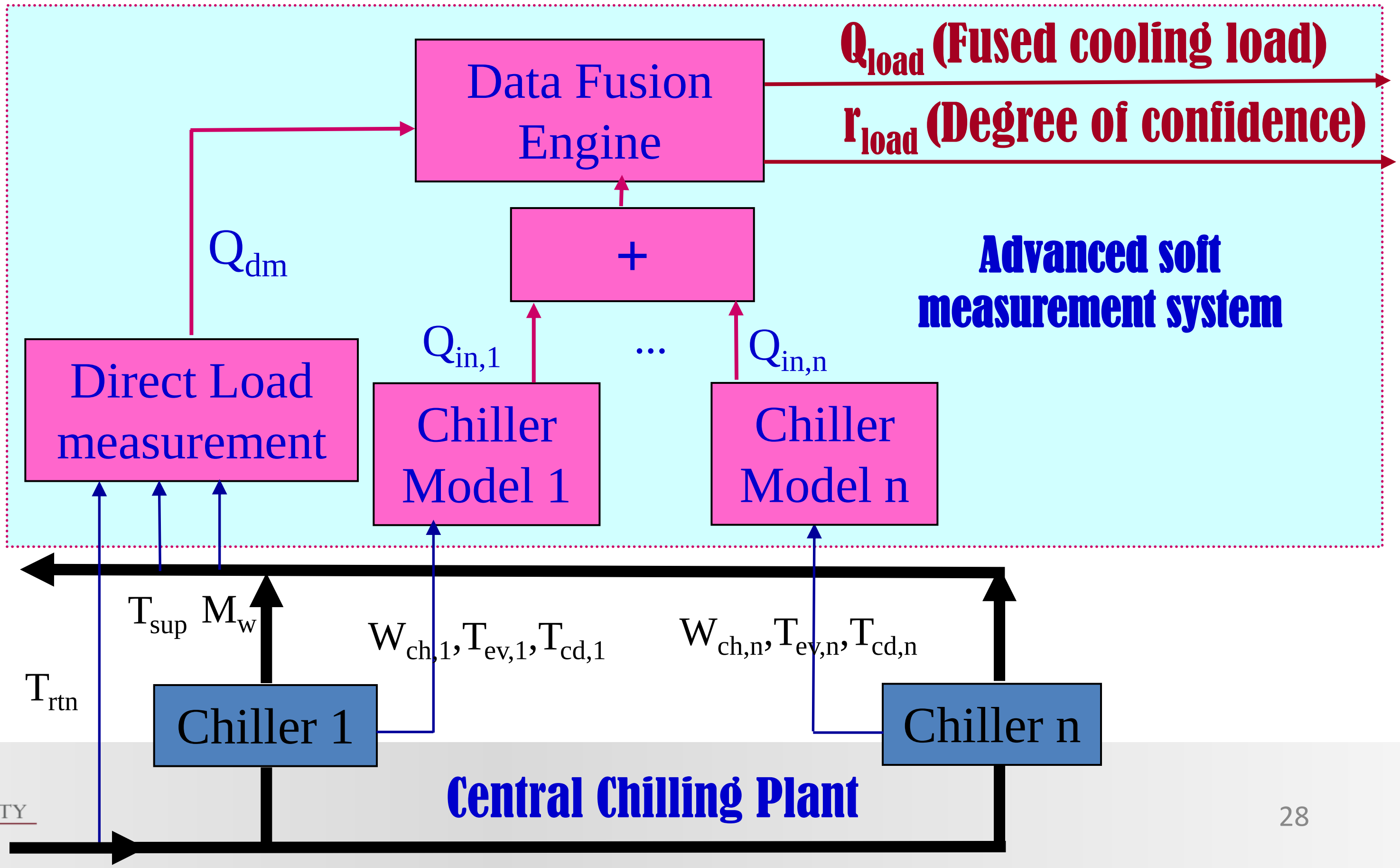
- **Indirect measurement of building cooling load**

$$Q_{im} = f(P_{com}, T_{cd}, T_{ev})$$

P_{com} is chiller power consumption; T_{cd}, T_{ev} are chiller condensing/evaporating temperatures

Robust building cooling load measurement technique Based on Data Fusion

- Data fusion to merge "Direct measurement" and "Indirect measurement" improving the accuracy and reliability of building cooling load measurement



Robust Chiller Sequencing Control Based on Enhanced Cooling Load Measurement Technique

High degree of confidence => Accurate and relatively aggressive control

Medium degree of confidence => Less aggressive and safer control

Low degree of confidence => Safe control and warning for maintenance check

Summary of Energy Benefits

Saving by Commissioning (Improving the system
co

ori

The annual total energy saving is about 7.0M kWh !

Saving by Control Optimization *– compared with the case when the HVAC system operates correctly as the original design intent.* ***3.5M per year***

Contributions in supporting ICC building in getting HK-BEAM Platinum Certificate

The overall assessment grade is based on the percentage of applicable credits (about 145) gained in 5 categories: site aspects， material aspects， energy use， water use , and IAQ (vision 4/04).

Grade	Overall	Performance
Platinum	*75%*	*Excellent*
Gold	*65%*	*Very Good*
Silver	*55%*	*Good*
Bronze	*40%*	*Above average*

HVAC

Annual Energy Use Reduction
By 14.6% to get extra 2 credits

Peak Demand Reduction
By 26.9% to get extra 2 credits

Optimal Control Strategies
“Innovation” for extra 1 credits

Platinum
76.2%]

5 credits
(3.5%)

Gold
72.7%）

A New Hotel Development in Sheung Wan (Holiday Inn Express)

- Independent Energy Consultant (Independent Commissioning Agent)
- To Develop the HVAC Energy Optimal Control System

Summary of Energy Benefits

Saving by Commissioning (Improving the system configuration and selection) and Control Optimization *– compared with the case when the HVAC system operates correctly as the original design intent.* ***20% saved annually***

Thanks!