TIE SMART SOLUTIONS

AI Energy Platform

Better Life Quality with Energy Saving by our Big Data and AI Diagnostics

Smart Chiller and Chiller Plant Manager System – 25/04/2566

by

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Agenda

- What are smart HVAC machines in the U.S.?
- Chiller Fault and Fault-free Data
- BMS Market in the world
- Analytic Tool (Fault Alarm) Market in Thailand
- Analysis Problem Examples
- USA Retuning process
- Smart chiller and CPMS Examples

Backgrounds

- อาคารอัจฉริยะ โดยเฉพาะด้าน ระบบปรับอากาศ และระบายอากาศ มากกว่า 10 ปี
- พัฒนาระบบวินิจฉัยระบบปรับอากาศแบบอัตโนมัติด้วย AI platform
- พัฒนาระบบ IoT and Monitoring based Commissioning (MBCx) for all type HVAC systems

Projects

- การพัฒนากระบวนการและแนวทางการสร้างมาตรฐานการใช้งานระบบอาคารอัตโนมัติสำหรับการประหยัดพลังงานระบบปรับอากาศและระบายอากาศ ด้วย EMIS tool – ระยะที่ 1 ทุน กฟผ – สกว ปี 2562 – 2563
- ASHRAE RP 1615 – Fault Diagnostics for supermarket systems (USA)
- ASHRAE RP 1486 – Fault diagnostics for a chiller system (USA vs. THA)
- ไอโอทีแพลตฟอร์มอัจฉริยะสำหรับระบบควบคุมของระบบปรับอากาศหลายเครื่องสำหรับอาคารพาณิชย์ขนาดเล็กถึงกลาง (Control)
- ระบบควบคุมเพื่อการฟื้นฟูประสิทธิภาพระบบปรับอากาศขนาดใหญ่แบบอัตโนมัติ (Control)
- ต้นแบบอาคารอัจฉริยะเพื่อการวินิจฉัยความผิดปกติของระบบชิลเลอร์อัตโนมัติ (Diagnostics)
- การพัฒนามาตรฐานการคอมมิชชันนิ่งด้วยระบบตรวจวัด (Monitoring for Commissioning (Cx))
- การออกแบบมาตรฐานระบบวินิจฉัยความผิดพลาดระบบปรับอากาศและระบายอากาศ (Diagnostics standard)

วุฒิการศึกษา :

ปริญญาเอก : Ph.D. in Architectural Engineering: University of Nebraska - Lincoln, USA in 2015

ปริญญาโท : M. Eng in Mechanical Engineering: Chulalongkorn University, Thailand in 2009

ปริญญาตรี : B. Eng in Mechanical Engineering: Chulalongkorn University, Thailand in 2005

ความเชี่ยวชาญ

มีความเชี่ยวชาญทางด้าน Fault detection and diagnosis, Advanced control in HVAC&R, Building data analytics, Virtual sensing and modeling, building simulation platform สำหรับระบบอาคารอัจฉริยะ มากกว่า 10 ปี

ผู้พัฒนาระบบวินิจฉัยระบบปรับอากาศแบบอัตโนมัติ (AFDD), ผู้พัฒนาระบบ IoT เพื่อส่งเสริมกระบวนการ Monitoring based Commissioning (MBCx)

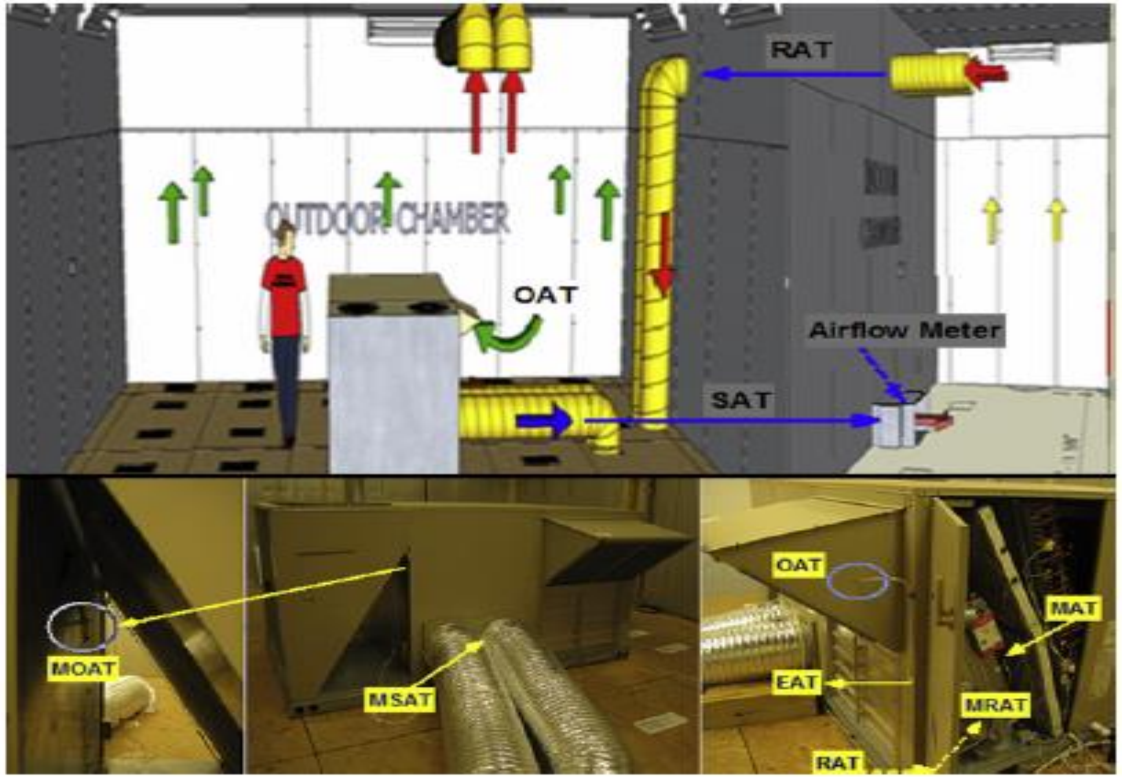
หัวหน้าโครงการวิจัย

การพัฒนากระบวนการและแนวทางการสร้างมาตรฐานการใช้งานระบบอาคารอัตโนมัติสำหรับการประหยัดพลังงานระบบปรับอากาศและระบายอากาศ ด้วย EMIS tool – ระยะที่ 1 ทุน กฟผ – สกว ปี 2562 – 2563

SECTION 1

What are smart HVAC machines in the U.S.?

Lab Demonstration – UNL Nebraska



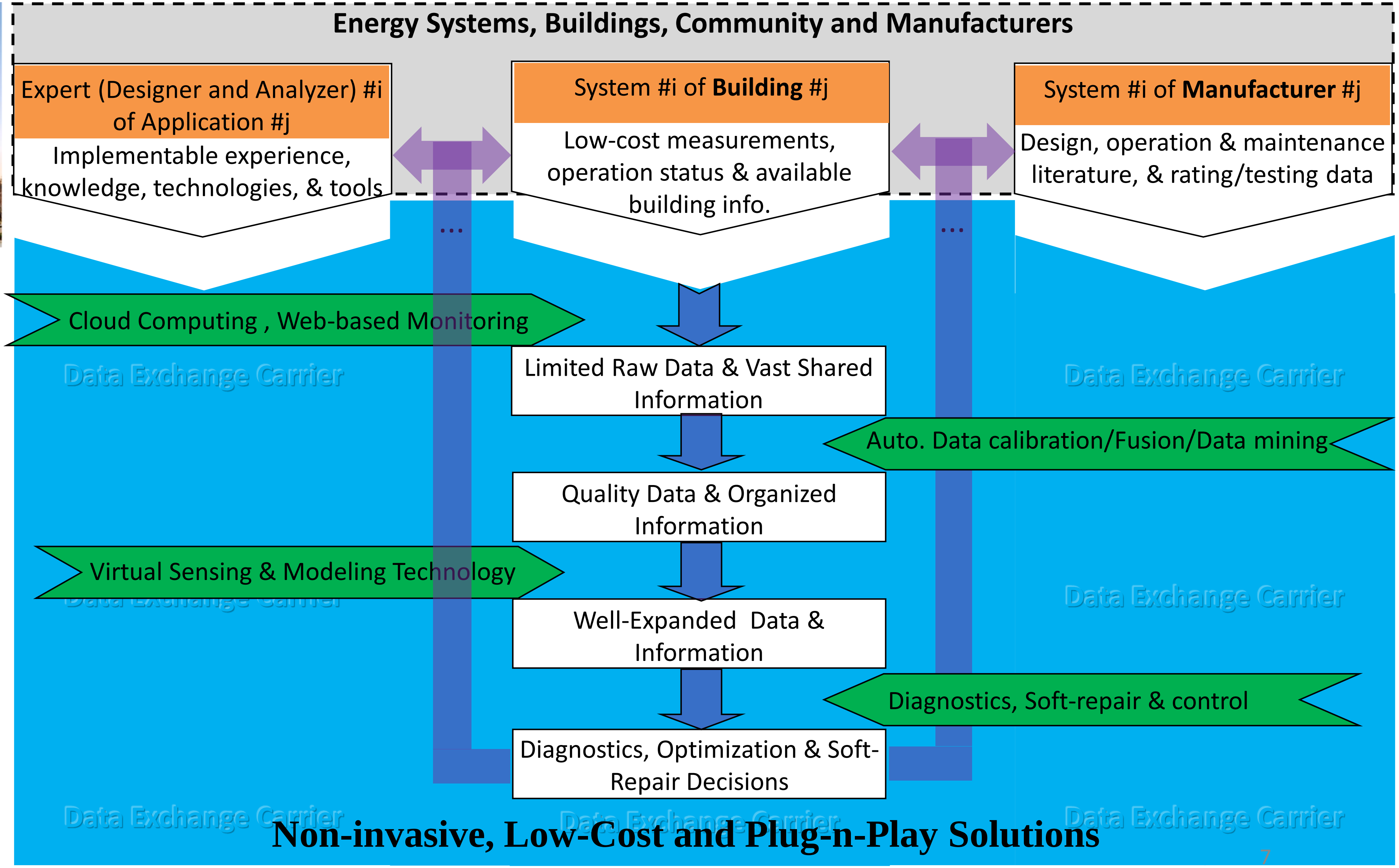
Over **2000 field testing** of data platform **in USA,** they were established to deploy AFDD research and to analyze RTUs oversizing

This data platform includes the data of HVAC systems and climates information from big-box retail stores, building supermarkets, office buildings and other relating fields.

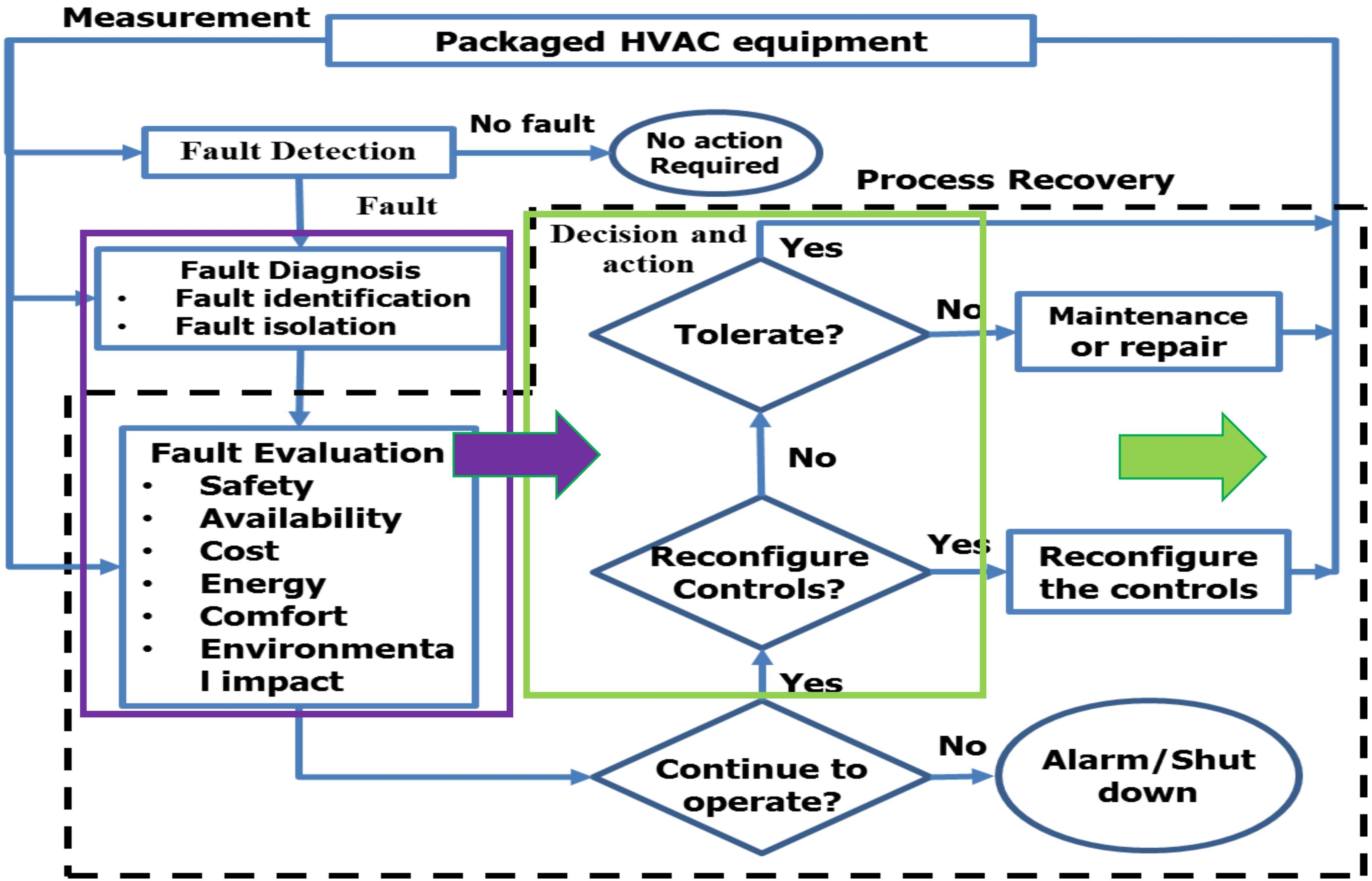
Rooftop Unit Data Points

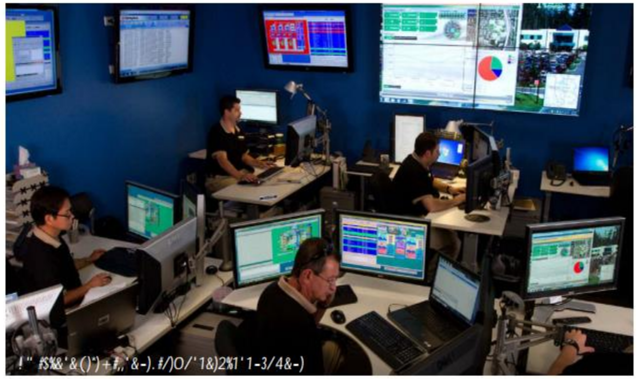
Job Name:	Input/Output Point List Summary																																							
System Apparatus or Area Point	Analog In										Discrete In						Outputs							System Features																
	Measured						Calc										D/O			A/O				Alarms					Programs											
	Duct Temperature	Pipe Temperature	Temperature	Relative Humidity	Pressure	Other	KWH	Enthalpy	Run Time	Efficiency	Status	Filter	Smoke/Fire	Freeze	Hi - Lo	Other	On - Off	Open/Close	Enable/Disable	Speed Control	Damper Position	Valve Position	Other	Hi Analog	Low Analog	Hi Discrete	Low Discrete	Status	Time Scheduling	Demand Limiting	Duty Cycle	Staging Control	Enthalpy Optimization	Reset	PID Algorithm	Nighttime Free Cooling	Damper Optimization	Power/Fail Restart	Night Setback	Sensor Averaging
AH1																																								
Location:																																								
Space Air Temp(2)			X																																					X
Supply Air Temp	X																																							
Mixed Air Temp	X																																							
Filter Status												X																												
Static Pressure					X																																			
Outside Air Temperature			X																																					
Return Air Temp	X																																							
Fan Status											X																		X		X									
Mixing Dampers																		X																						
Cooling Coil Valve																						X													X					
Speed Control																				X															X					
Start/Stop																	X																							

Smart Retail and Supermarkets (algorithm)



Automated fault detection and diagnostics (AFDD)





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Smart Retail and Supermarkets (algorithm)

A cloud based data exchange carrier was used to store data for all of the building systems. To compensate for missing sensors and the inability to take on site measurements, five virtual sensors were created. Then, the appropriate algorithms were deployed and an independent contractor tested the results to ensure accuracy in the full rollout to 252 locations. The data exchange carrier collects a total of 555,200 data points continuously from 16,480 machines encompassing multiple systems and external data sources. The fault diagnostics identified 27,754 issues for an annual calculated savings of $3,790,096.

The California Energy Public Interest Energy Research sponsored Plug-n-Play Diagnostics and Optimization for Smart Buildings project goals have been to develop and demonstrate that low-cost and quickly deployable multi-system diagnostic technology can more effectively scale the benefits of commissioning, and fault detection and diagnostics. This project will facilitate faster adoption of the technology, facilitating financial and carbon reduction savings from large opportunity commercial buildings.

The goals of this project were to develop, demonstrate, deploy, and evaluate near-zero-cost, non-invasive, plug-n-play diagnostics and optimization technologies that could be adopted by both existing and new buildings immediately. The objectives were to:

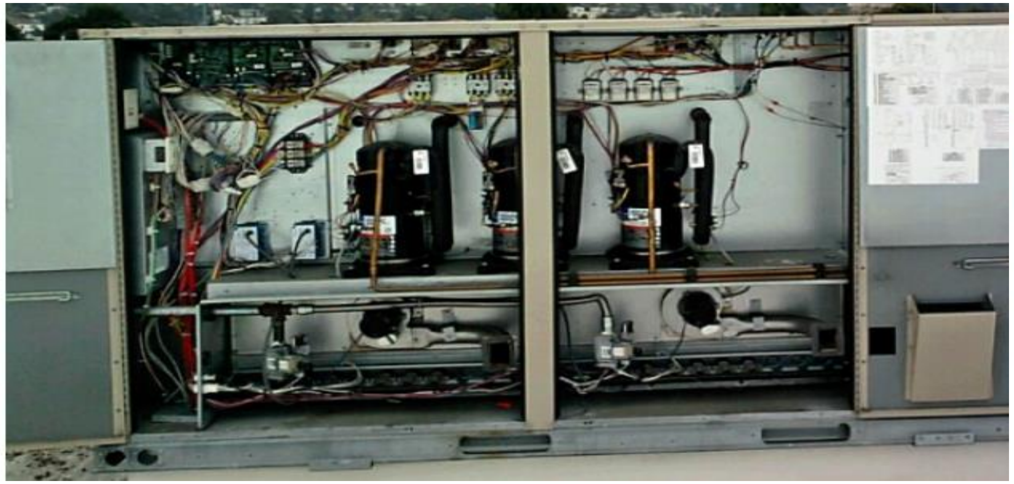
1. Big data Platform of machines

2 Low cost virtual sensors or monitoring

3. Automated machine diagnostic

4. Deploy and solving

5. Evaluate cost savings (investment 150,000 USD, get savings 3.8 MUSD, (5% - 15% savings by average))



Deployment examples – faulty sensors and operations

The specific issues inspected for both HVAC and refrigeration are as follows:

HVAC

- Outdoor air damper modulation
- Economizer enable/disable settings
- Energy recovery wheel effectiveness
- Supply fan operation
- Cooling coil heat transfer and charge
- Cooling coil valve operation
- Store humidity
- Sensor operation
- Occupied cooling setpoints
- Unoccupied cooling setpoints
- Occupied times
- Unoccupied times

Refrigeration

- Defrost cycle count
- Defrost cycle duration
- Case temperature
- Anti-sweat heaters
- Condenser pressure
- Evaporator pressure
- Sensor operation

1. HVAC systems (Rooftop units and dehumidification unit)

2. Data of refrigeration from the remote system

Fault	System	Results	Impact ($)	Validation Attempted	Validation Method	# Validated	% Accuracy (# Validated / Validation Attempted)
Store Hours	HVAC	9	n/a	9	BMS Analysis	9	100%
HVAC Schedules	HVAC	462	$10,430	462	BMS Analysis	462	100%
Cooling/ Heating Setpoint	HVAC	680	$6,970	680	BMS Analysis	680	100%
Economizer Damper Excessive Rate of Change/ Hunting/Cycling	HVAC	336	n/a	336	BMS Analysis	336	100%
No Communication	HVAC	24	n/a	10	On-site Validation	10	100%
Improper Cooling Staging: Multiple Stages Starting Simultaneously and Short Delay Between Stages	HVAC	377	n/a	376	BMS Analysis	376	100%
Setpoint Not Met - ZAT - Over Cooling - Occupied/Unoccupied	HVAC	35	$33,006	35	BMS Analysis	35	100%
ZAT Drift: Cooling Not Activated - Occupied/Unoccupied	HVAC	17	n/a	16	BMS Analysis	16	100%
ZAT Drift: Heating Not Activated -	HVAC	17	n/a	17	BMS Analysis	17	100%

Deployment examples – fault diagnostic categories

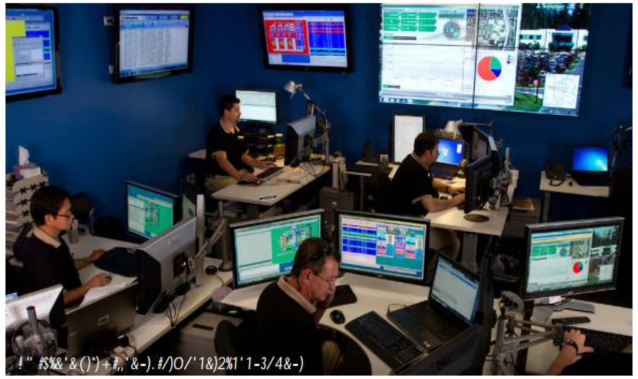
Table 20: Fault Detection Categories by Machine Type

Machine Category	Machine Type	Fault Detection Categories
HVAC	Air Handling Unit	Air flow
		Controller
		Cooling
		Dehumidification
		Economizing
		Fan
		Heating
		Outside Air Damper
		Scheduling
		Sensor
		Setpoint
	Constant Volume Air Terminal Unit	Controller
		Cooling
		Damper or Air flow
		Heating
		Scheduling
		Sensor
		Setpoint
	Fan Coil Unit	Controller
		Cooling
		Fan
		Heating
		Scheduling
		Sensor
		Setpoint
	Fan Powered Air	Controller

Machine Category	Machine Type	Fault Detection Categories
	Terminal Unit	Cooling
		Damper or Air flow
		Fan
		Heating
		Scheduling
		Sensor
		Setpoint
	Rooftop Unit	Air flow
		Controller
		Cooling
		Dehumidification
		Economizing
		Fan
		Heating
		Outside Air Damper
		Scheduling
		Sensor
		Setpoint
	Variable Volume Air Terminal Unit	Controller
		Cooling
		Damper or Air flow
		Heating
		Scheduling
		Sensor
		Setpoint
HVAC/Refrigeration	Global Machine	Controller
		Dehumidification
		Economizing
		Scheduling
		Sensor
Lighting	Lighting Machines	Contactor/Relay
		Controller
		Manual Switch Overrides
		Scheduling
		Sensor

Machine Category	Machine Type	Fault Detection Categories
Power Meter	Power Meter	Controller
		Energy
		Loading
		Sensor
Refrigeration	Refrigeration	Controller
		Cooling
		Defrost
		Dehumidification
		Fan
		Heating
		Sensor
		Setpoint
Weather	Weather Station	Controller
		Sensor

Source: Ezenics



SECTION 2

Chiller Fault and Fault-free Data – Lab Development (Purdue University Indiana & UNL Nebraska)

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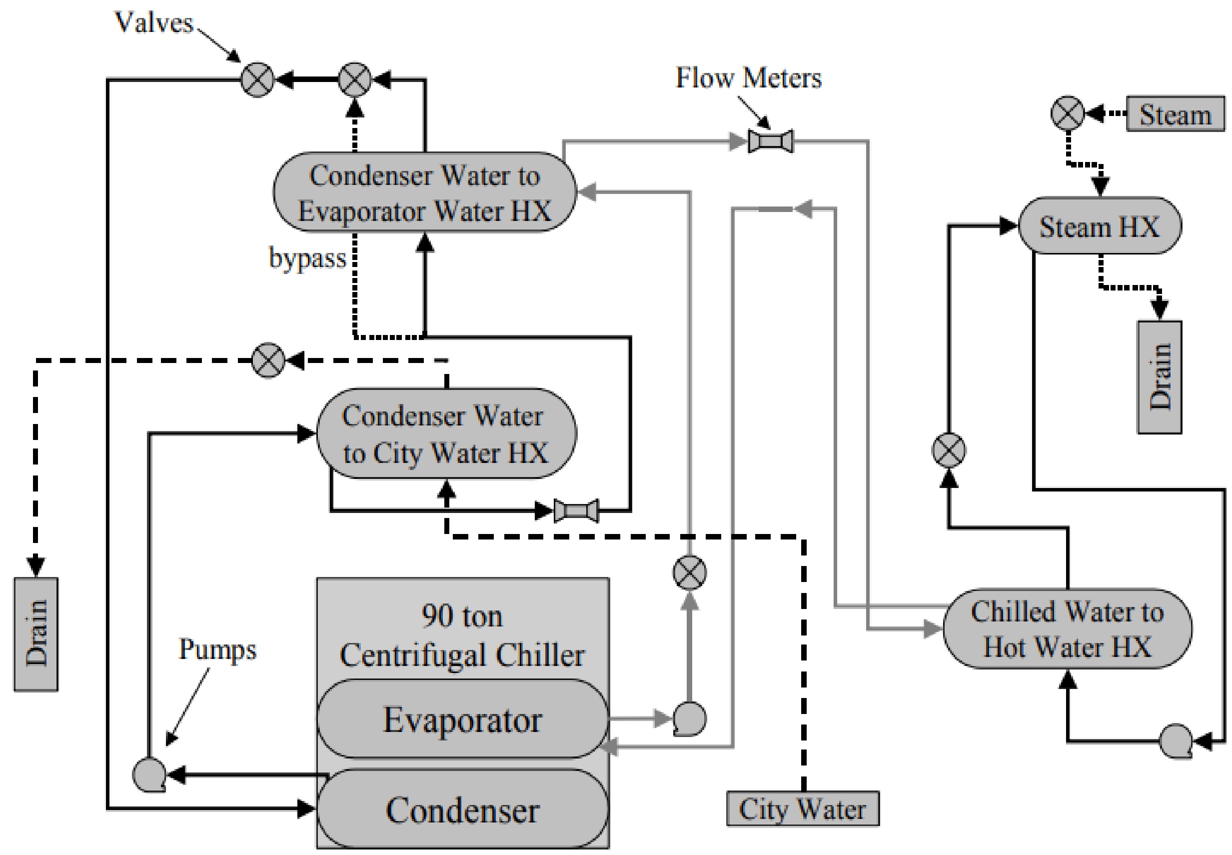
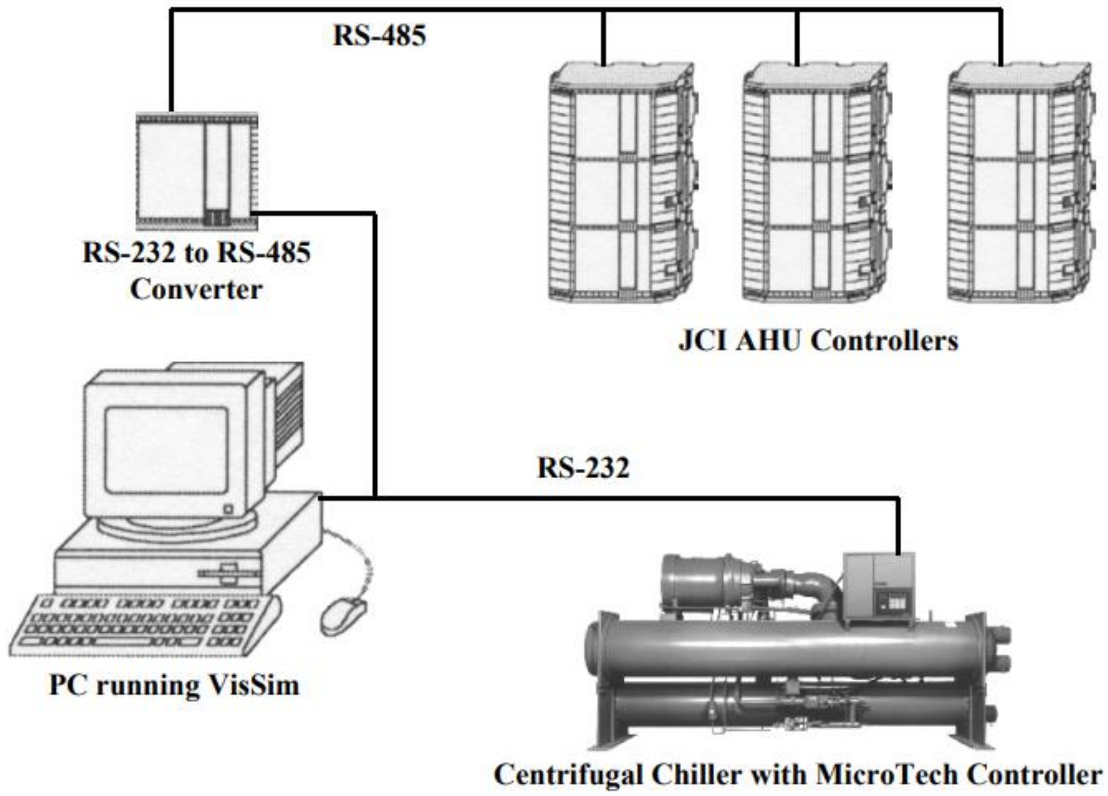
ASHRAE standard 147

Chilled Water (or other secondary coolant)	Flow	Condenser Water	Flow
	Inlet Pressure		Inlet Pressure
	Inlet Temperature		Inlet Temperature
	Outlet Pressure		Outlet Pressure
	Outlet Temperature		Outlet Temperature
Evaporator	Refrigerant Pressure	Condenser	Refrigerant Pressure
	Refrigerant Temp.		Refrigerant Temp.
Oil	Level	Refrigerant	Level
	Pressure		Compressor Discharge Temp.
	Temperature		Compressor Suction Temp.
	Addition of		Addition of (in Refrigerant Log)
Vibration Levels			PPM Refrigerant Monitor Level
Purge	Exhaust Time	Logs	Date and Time Data
	Discharge Count		Signature of Reviewer
Ambient Temperatures	Dry Bulb	Motor	Amperes Per Phase
	Wet Bulb		Volts Per Phase

Chiller Fault and Fault-free Data – Lab





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Manufacturers' Data

Table 1. Chiller manufacturers' rating output example.

Percent load	T_{cdi} (°C (°F))	T_{evo} (°C (°F))	FWC (L/S (cfm))	FEW (L/S (cfm))	W_{ac} (kW)	P_{cond} (Kpa (psi))	P_{evap} (Kpa (psi))	T_{sc} (°C (°F))	T_{sh} (°C (°F))
100	30.0 (86.0)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	311.0	821.0 (119.0)	268.0 (38.9)	4.6 (8.3)	0.6 (1.1)
90	27.7 (81.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	253.3	748.1 (108.5)	269.0 (39.0)	4.2 (7.6)	0.6 (1.1)
80	25.3 (77.5)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	211.9	678.3 (98.4)	269.9 (39.1)	3.8 (6.8)	0.6 (1.1)
70	23.0 (73.4)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	181.3	615.4 (89.2)	270.9 (39.3)	3.4 (6.1)	0.6 (1.1)
60	20.7 (69.3)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	156.8	556.7 (80.7)	271.8 (39.4)	3.0 (5.4)	0.6 (1.1)
50	18.3 (64.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	135.8	500.1	272.8 (39.6)	2.6 (4.7)	0.6 (1.1)
40	18.3(64.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	121.9	489.4 (71.0)	273.8 (39.7)	2.2 (4.0)	0.6 (1.1)
30	18.3 (64.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	106.2	478.7 (69.4)	274.7 (39.8)	1.7 (3.1)	0.6 (1.1)
20	18.3 (64.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454.0)	86.4	467.9 (67.8)	275.7 (40.0)	1.2 (2.2)	0.6 (1.1)
10	18.3 (64.9)	7.0 (44.6)	104.3 (1655.6)	91.6 (1454)	57.7	456.8 (66.2)	276.7 (40.1)	0.6 (1.1)	0.6 (1.1)

FWC: Condenser water flow rate; FWE: evaporator water flow rate.

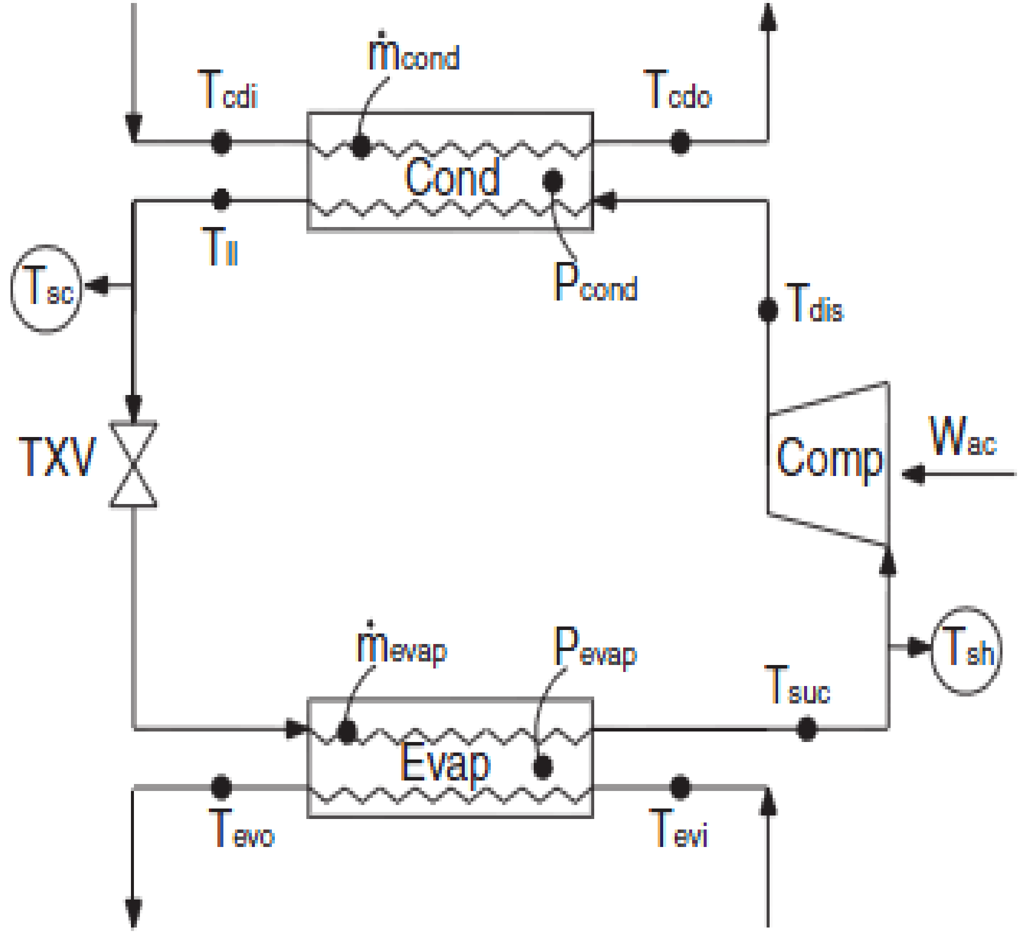
USA Database

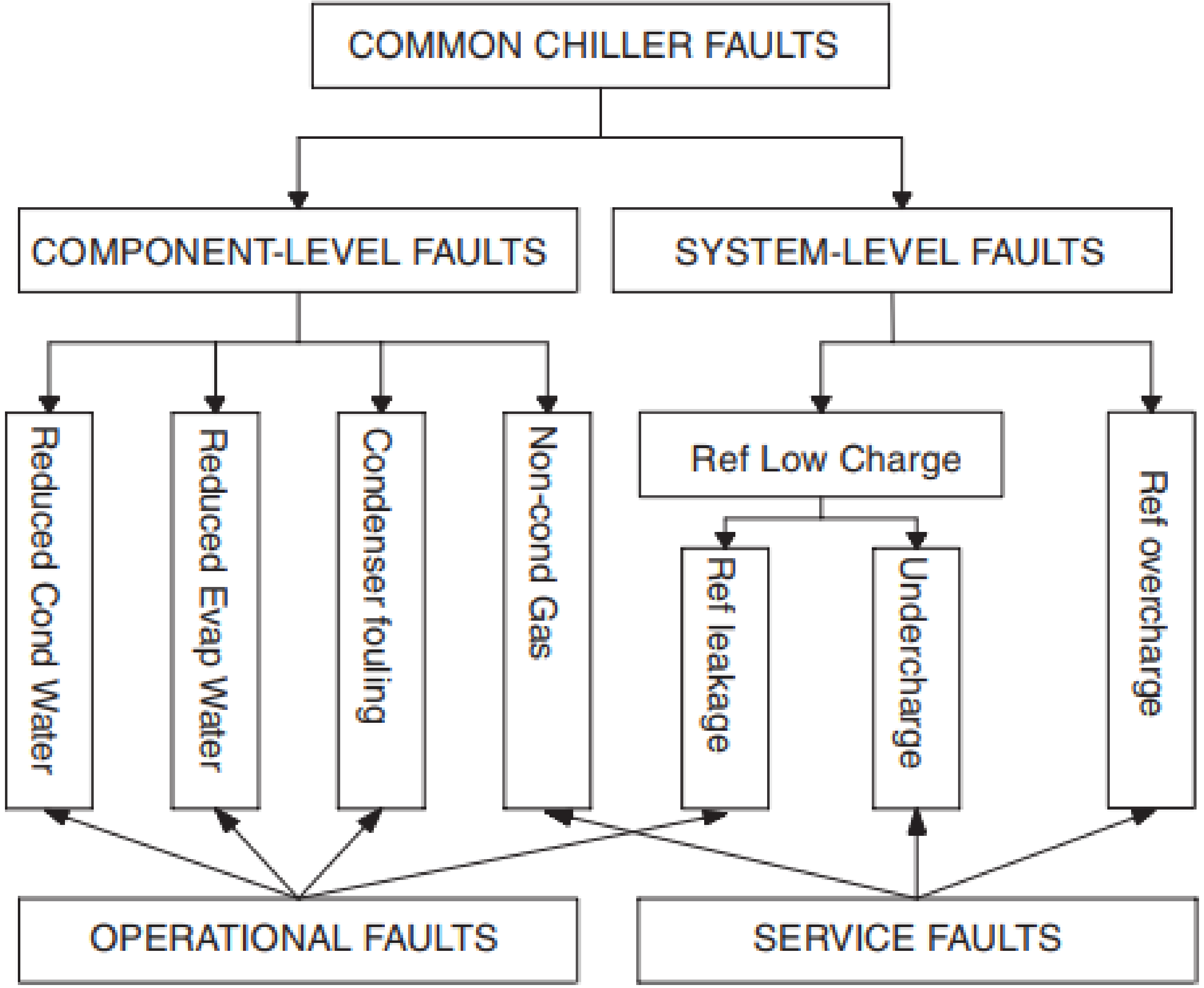
PART LOAD PERFORMANCE:

Pct Load	CAP (TR)	Pct Power	Inp Pwr (KW)	EEFT (°F)	ELFT (°F)	CEFT (°F)	CLFT (°F)	Sys Perf (KW/TR)
100.0	350.0	100.0	216	54.99	45.00	88.00	97.27	0.617
90.0	315.0	87.0	188	53.99	45.00	87.00	95.30	0.597
80.0	280.0	75.5	163	52.99	45.00	86.00	93.34	0.582
70.0	245.0	66.2	143	51.99	45.00	85.00	91.42	0.584
60.0	210.0	57.4	124	50.99	45.00	84.00	89.51	0.590
50.0	175.0	50.5	109	49.99	45.00	84.00	88.62	0.623
40.0	140.0	44.0	95	48.99	45.00	84.00	87.73	0.679
30.0	105.0	38.0	82	48.00	45.00	84.00	86.85	0.781
20.0	70.0	31.9	69	47.00	45.00	84.00	85.97	0.986
15.1	53.0	29.2	63	46.51	45.00	84.00	85.54	1.189

Thai Database

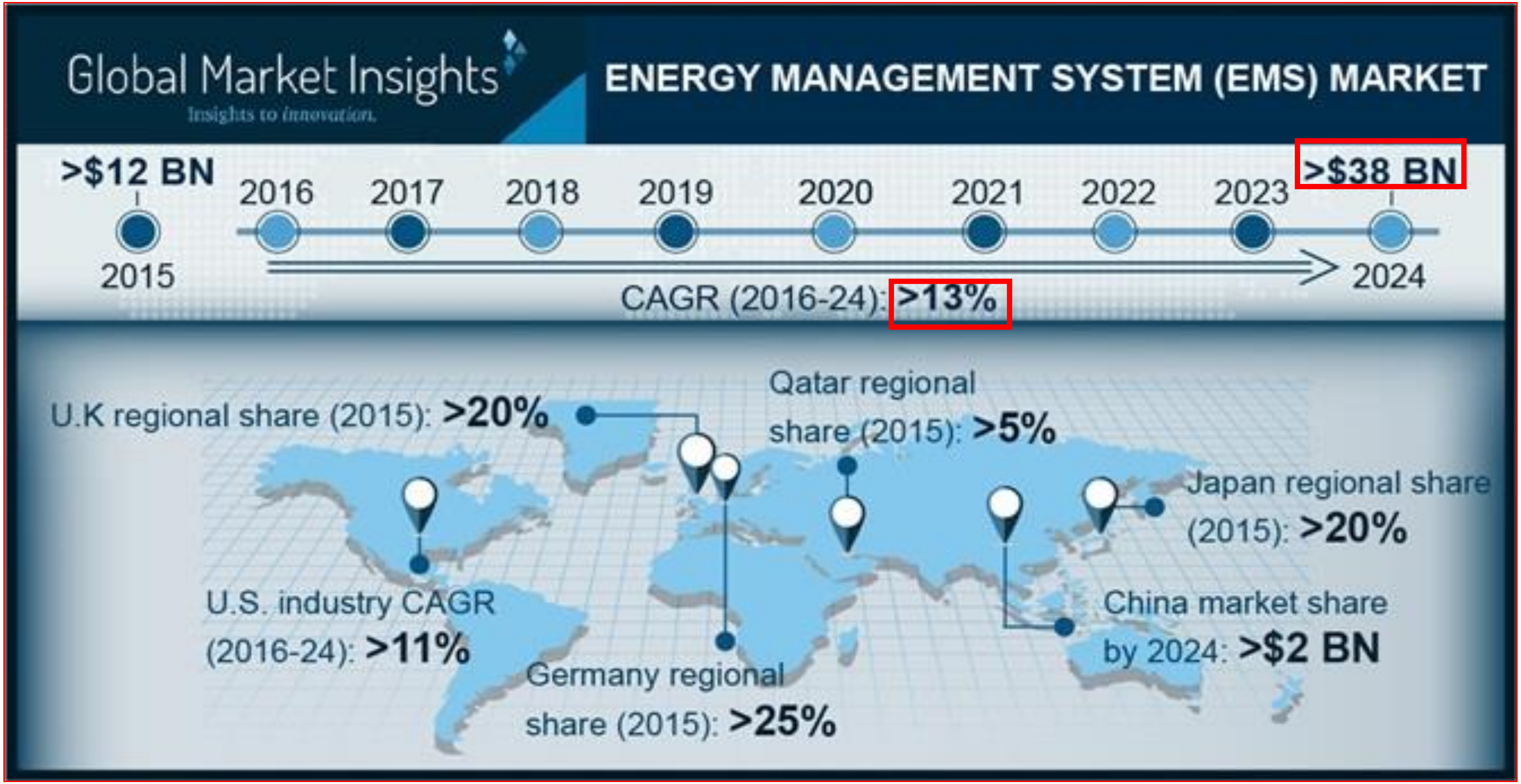
Typical fault development





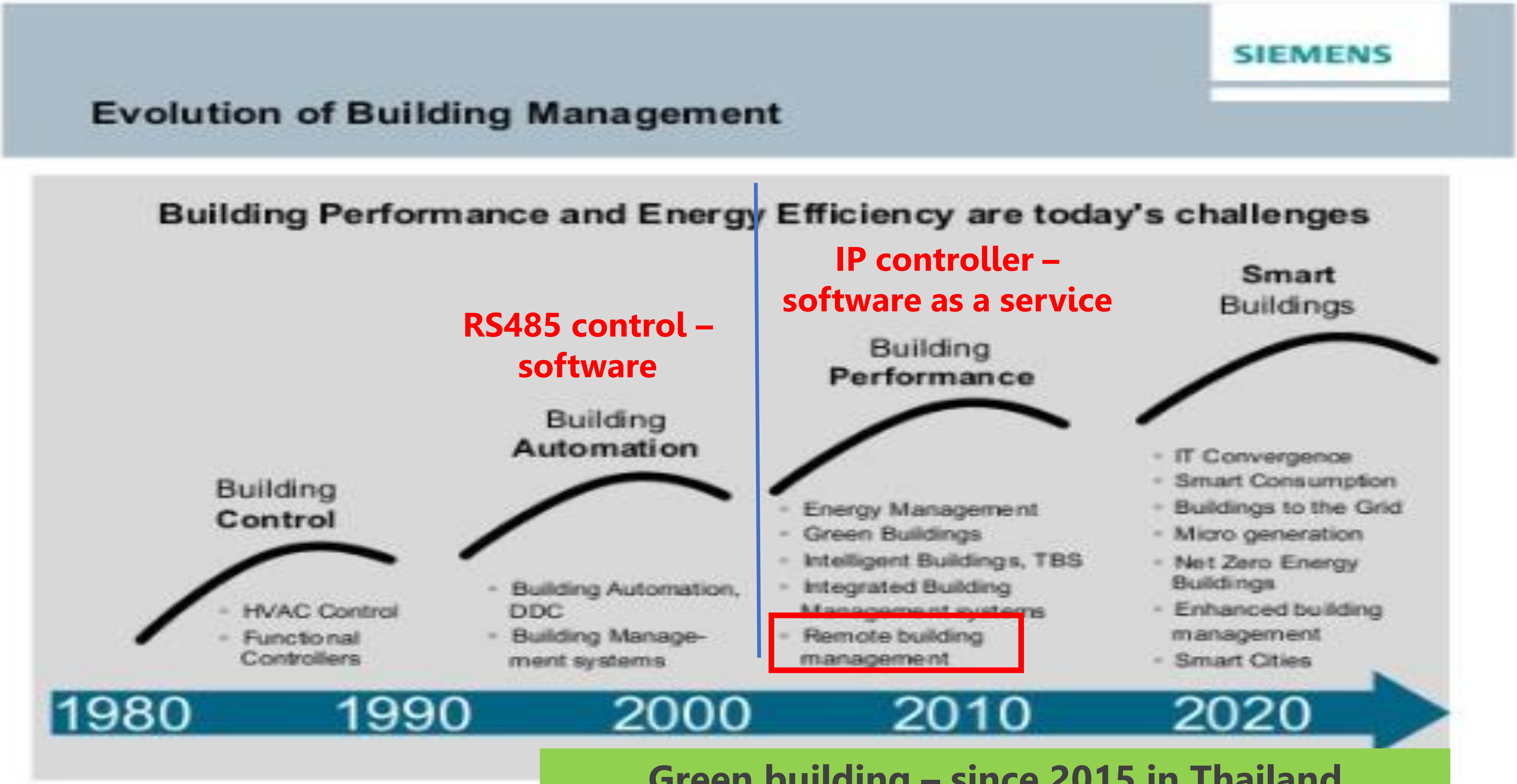
SECTION 3

BMS Market in the world



[1] Global Market Insights, Inc.

BMS evolution



RS485 control – software

IP controller – software as a service

Green building – since 2015 in Thailand

Global Market Insights, Inc.

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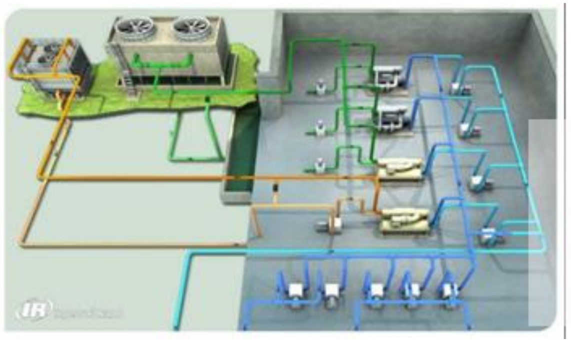
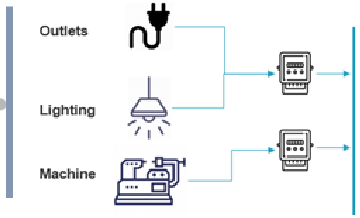
CPMS, BAS, EMS and BEMS (Thailand)

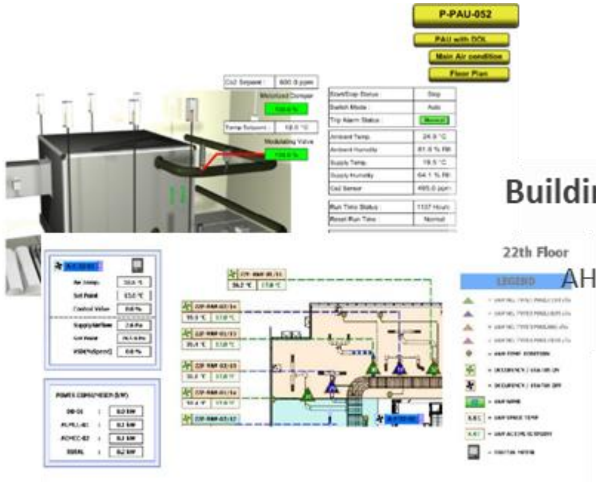


Chiller plant manager (CPM)
Chiller | Pumps | Cooling tower

Data on Cloud



Energy Management System (EMS) or Energy information system (EIS)
Managing energy data, display, benchmarking and predicting



Building Automation System (BAS)
AHU | VAV | Air-side systems etc.

Network IoT sensors
Thermal & Zone parameters

การใช้งาน BAS ในต่างประเทศ

Received: 7 April 2018 | Revised: 11 June 2018 | Accepted: 17 June 2018
DOI: 10.1002/er.4159

REVIEW PAPER

WILEY ENERGY RESEARCH

Return on investment of building energy management system: A review

Chin-Chi Cheng | Dasheng Lee

For **commercial buildings**, technology progress yields payback periods of BEMS **decreased from 5.4 yrs to 0.7 yr.** (P = 0.002 < 0.05)

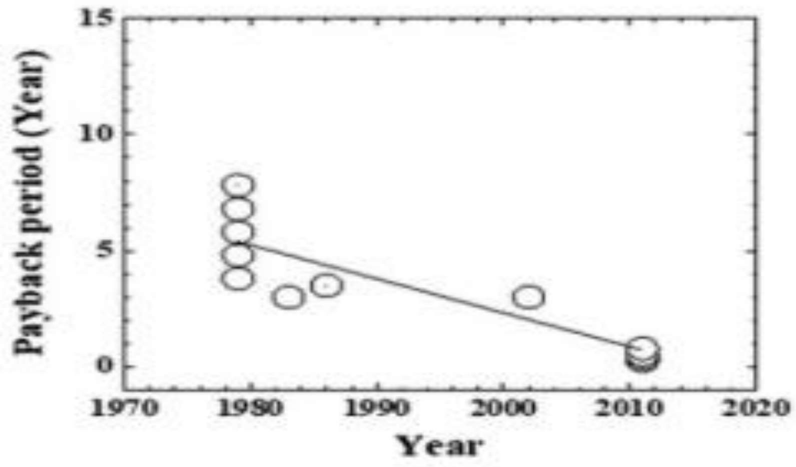


FIGURE 2 Payback periods of building energy management system (BEMS) for commercial buildings

For **compound buildings**, technology progress yields payback periods of BEMS **decreased from 3.74 yrs to 1.8 yrs.** (P = 0.041 < 0.05)

Technologies

- **Schedule control of central plant system**
- **Optimal control for thermal comfort ตามมาตรฐานอาคาร (temperature, pressure and flow rate)**
- **Variable speed control (VSD)**
- **Occupant-based control ควบคุมการเปิดปิดไฟฟ้า**
- **การใช้ระบบการจัดพลังงานควบคุมระบบแสงสว่าง**

[2] CC Cheng, D. Lee. Return on investment of building energy management system: A review. International Journal of Energy Research 42 (2018); 4034–4053.

CPMS, BAS, EMS and BEMS (Thailand)

BMS ประกอบด้วย 4 levels จาก World market (function-based)

1. Monitoring 2. Schedule control (operator selects set-points) 3. Automated Diagnostic (predictive maintenance) 4. Optimization control (automated set-point)

BMS – Thai market (machine-based)

1. Chiller plant manager system (CPMS) – e.g. Trane แยก package – chiller schedule control (plant kW/ton (efficiency) guarantee using magnetic bearing chiller)

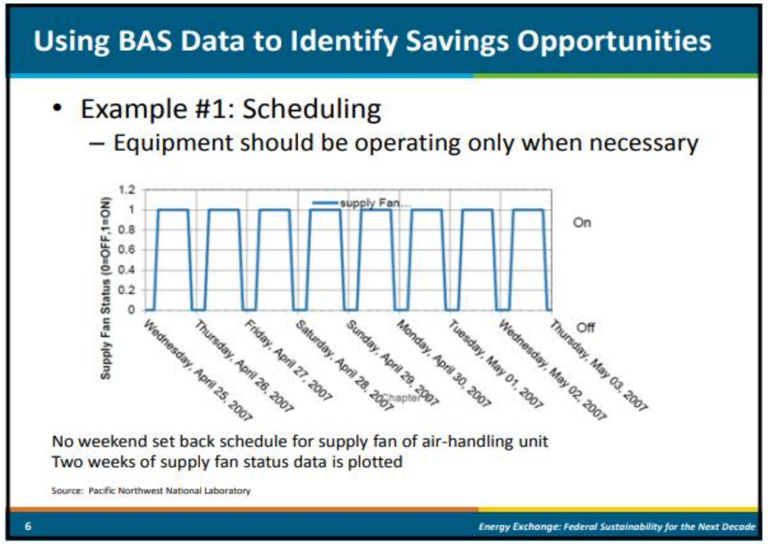
2. Building automation system (BAS) – AHU schedule control or air-conditioning control

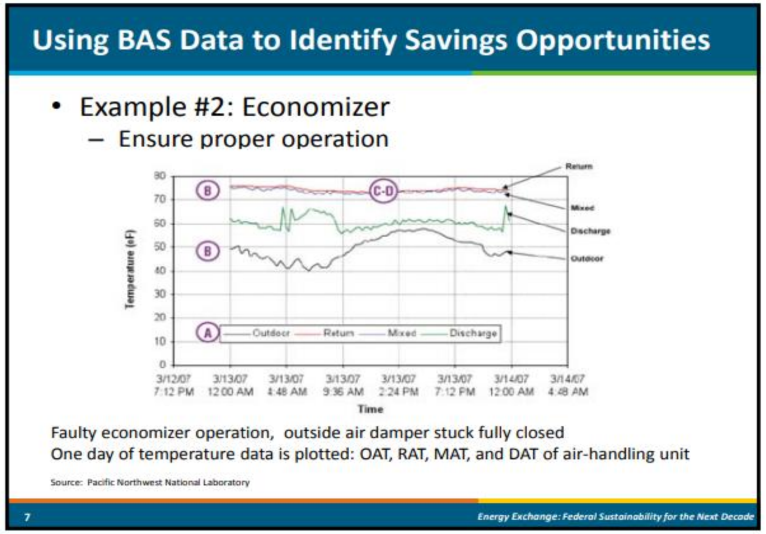
3. Building management control system (BMS) – AHU including: lighting control, Security control
4. Energy management system (EMS) – online power meter software (energy monitoring)

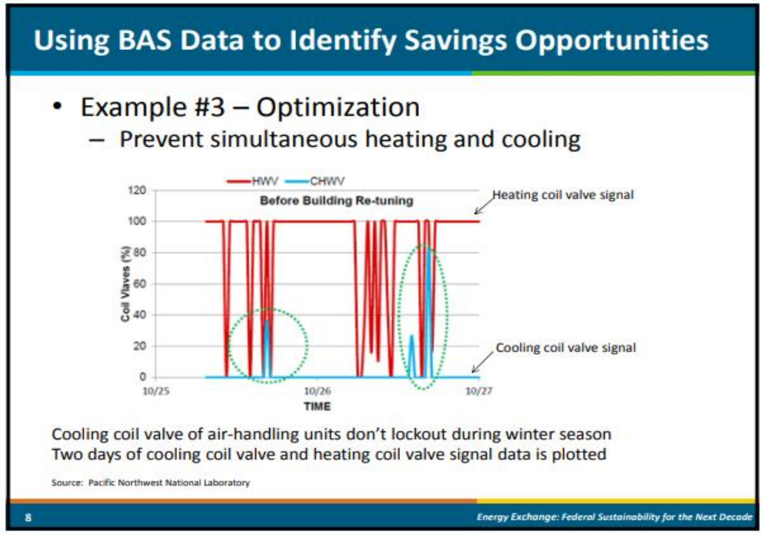
5. Building energy management system (BEMS) – AHU schedule control and energy monitoring

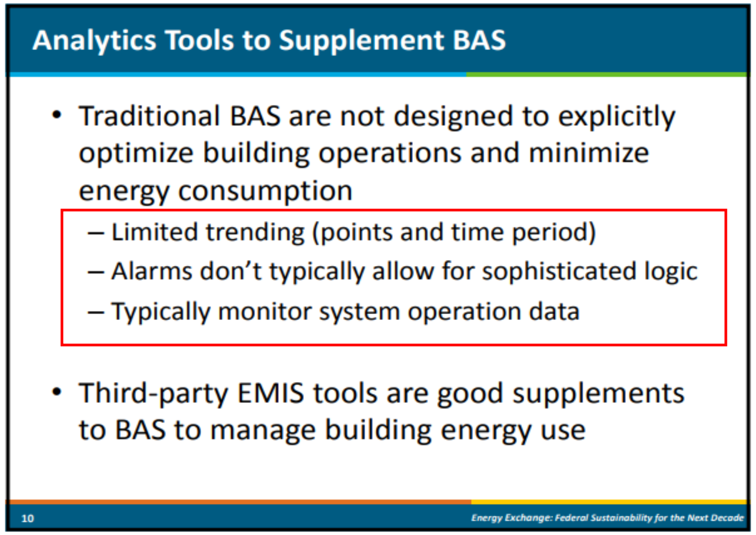
BAS function for HVAC control

*"Traditional BAS are **not designed** to explicitly optimize building operations and minimize energy consumption"*
Source: Pacific Northwest National Laboratory



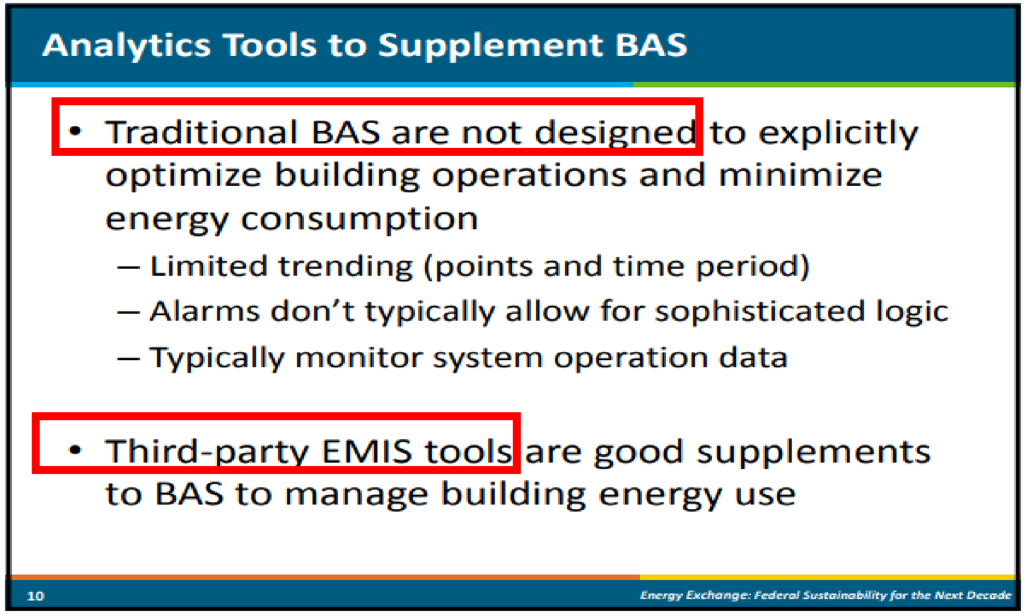


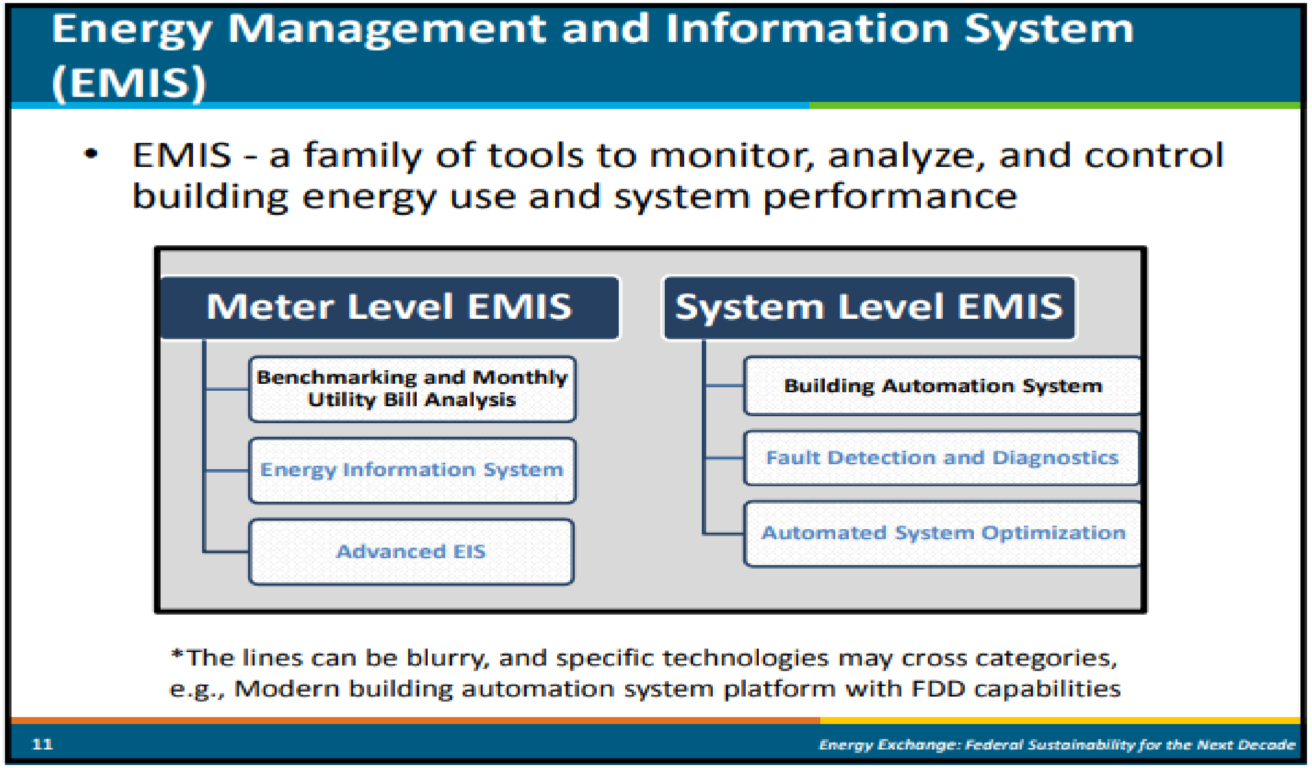


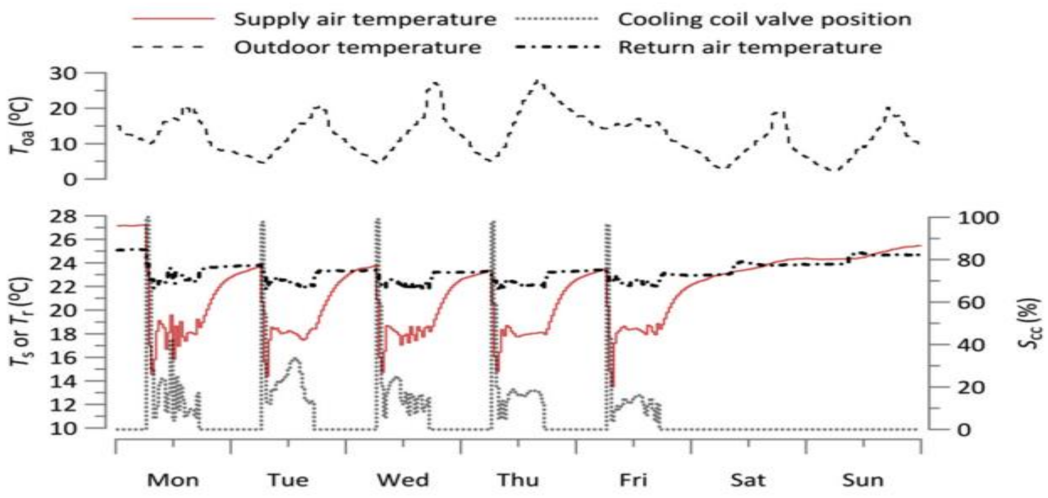


Source: Pacific Northwest National Laboratory

EMIS (Energy management information system) vs. BAS







EMIS tool performance and functions

- ❑ **Automated fault detection and diagnostics**
- ❑ **Automated system optimization control (automated set-point selection)**

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EMIS (Energy management information system) vs. BMS

MBCx Findings

HVAC Systems Faults

- Over-enabling/unoccupied run-time
- Deficient pressure/fan speed reset
- Sub-optimal SAT reset
- Over or under-ventilation
- Simultaneous heating and cooling
- Faulty, disconnected zone sensors
- Spaces under-heated or cooled

HVAC Plant Faults

- Equipment rapid cycling
- Sub-optimal equipment sequencing
- Lack of or deficient SWT reset
- Lack of pressure/pump speed reset
- Pump over-enabling

Lighting Faults

- Excessive unoccupied use
- Unresponsive occupancy sensor switching
- Faulty photocells

➢ Complex systems give rise to more points of failure

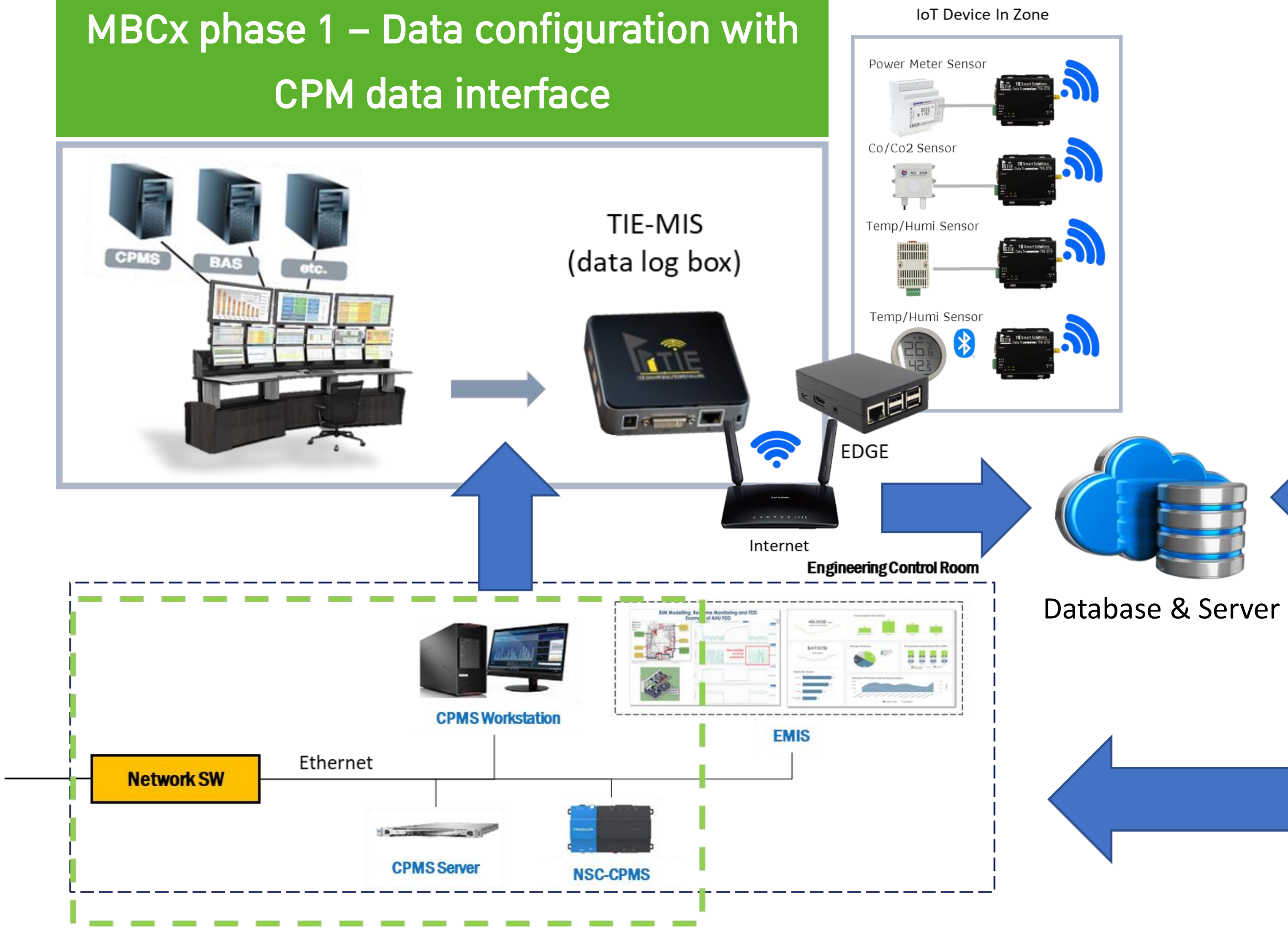
➢ Occupant comfort may be maintained while faults persist, wasting $$$

EMIS – Monitoring based commissioning (MBCx)

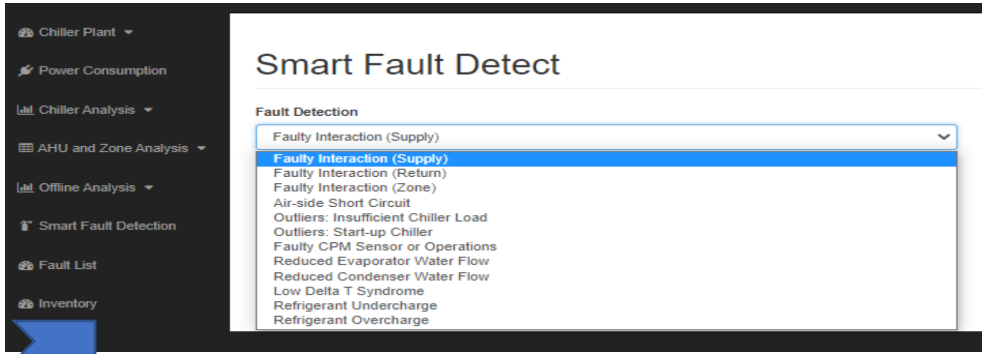
Chiller faults
F1 :Reduced evaporator water flow
F2: Reduced condenser water flow
F3: Low T syndrome
F4: Condenser fouling (CF)
F5: Non-condensable gas (NC)
F6: Refrigerant undercharge based CQ7
F7: Refrigerant overcharge based CQ7
F8: Compressor valve leakage
F9: Surging
F10: improper pump control
F11: Outliers from start-up chiller
F12: Faulty CPM sensor
F13: Insufficient load
F14: Air-side short circuit

EMIS – System Monitoring, Diagnostic and Control

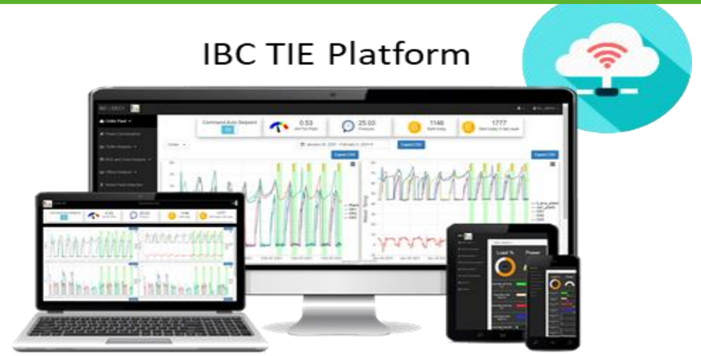
MBCx phase 1 – Data configuration with CPM data interface



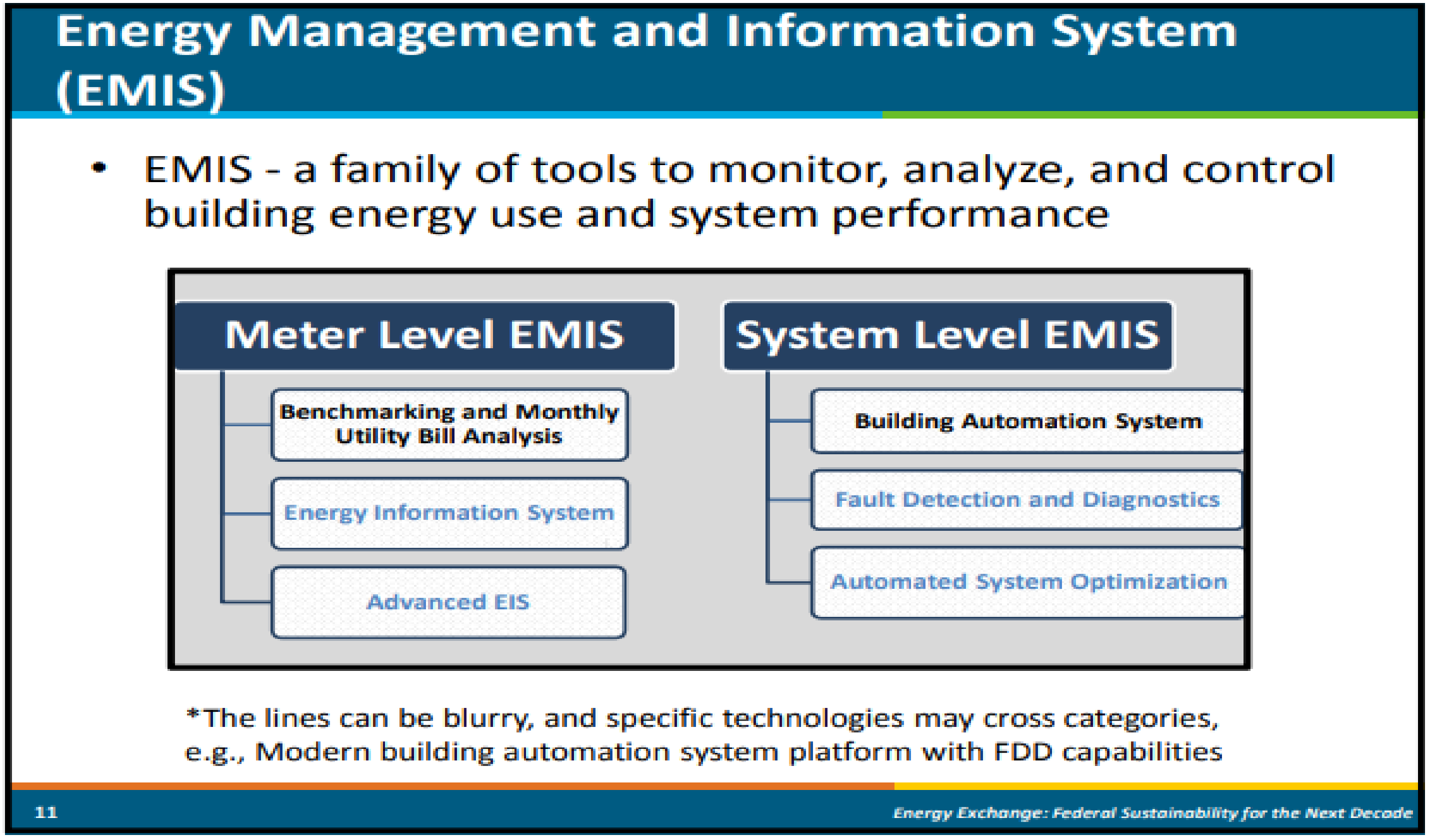
MBCx phase 2 – AFDD design and Implementation

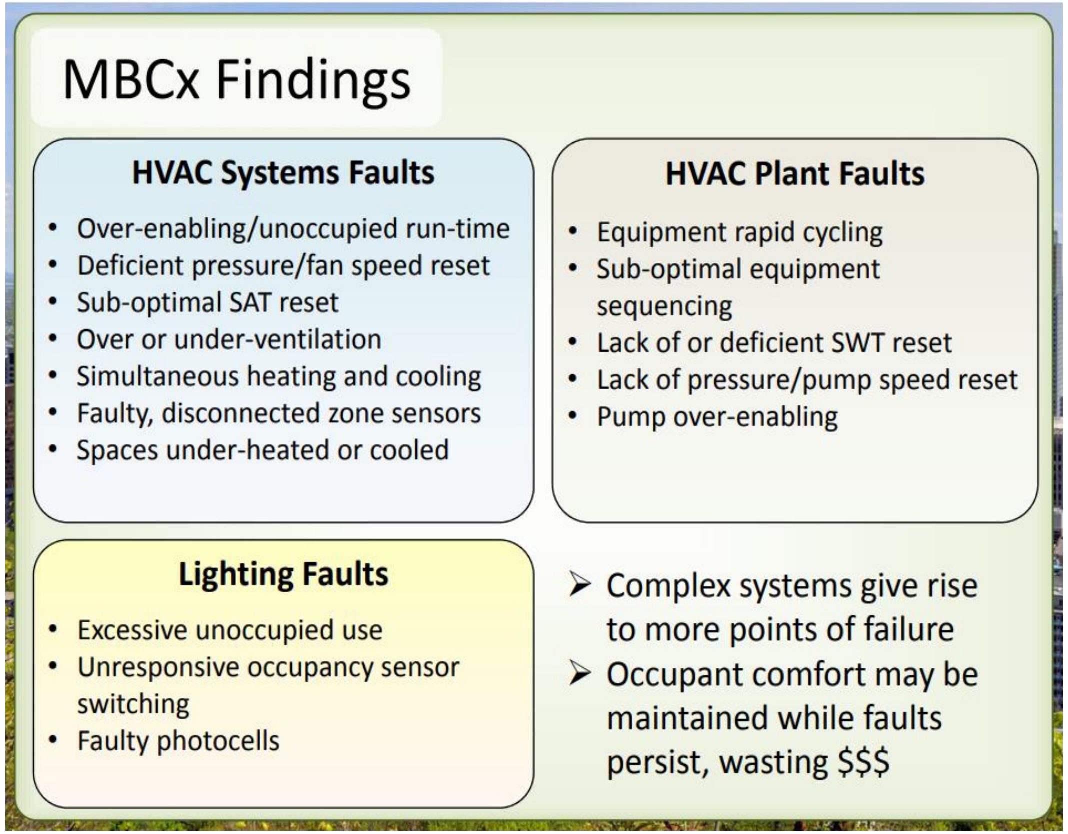


MBCx phase 3 – Automated Repair by smart controller



EMIS Tool – Monitoring based Commissioning





Commercialization

EMIS includes: Advanced EIS (EE fault alarm)

Rule-based fault detection and diagnostics

Excluded: Optimization Control

SECTION 4

Analytic Tool (Fault Alarm) Market in Thailand

Smart Chiller - Carrier

With Advanced Analytics,
you can be assured of:

- Improved visibility of operations
- Reduced incidents of failure
- Increased uptime
- Proactive management
- Better equipment performance and efficiency
- Reduced operating and maintenance costs

Carrier SMART

Real-time transmision of equipment operating data by Carrier SMART, leveraging wireless technology and Carrier's cloud-based IoT platform to monitor equipment's health and address potential issues before the arise

Operating Inspections

Thorough inspection and adjustment of equipment by Carrier technicians to ensure that it is performing effectively and efficiently

Annual Preventative Maintenance

Overall maintenance in machine shutdown mode, undertaken once a year, to ensure longevity and higher reliability

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Smart Chiller - Carrier

Alarm Notification
Customizable notifications via web portal or application for facility management teams

Live Data Access
Real-time, remote supervision of data - 24/7, 365 days a year

Corrective Action
Remote or on-site intervention for advanced diagnostics

Reporting
Automatically generated, customizable monthly reports

Trend Diagnostics
Operational data analysis for enhanced equipment reliability

Performance Analysis
Continuous energy performance improvement

Predictive Maintenance
Advanced analytics tools to identify hidden problems before they become emergency issues

Email Alerts
Real-time data retrieved from website, including parameters log, event/temperature curve, and more

Smart Chiller Plant – JEM Solution

Three Options

Access to Metasys ADX SQL (Only for Metasys Sites

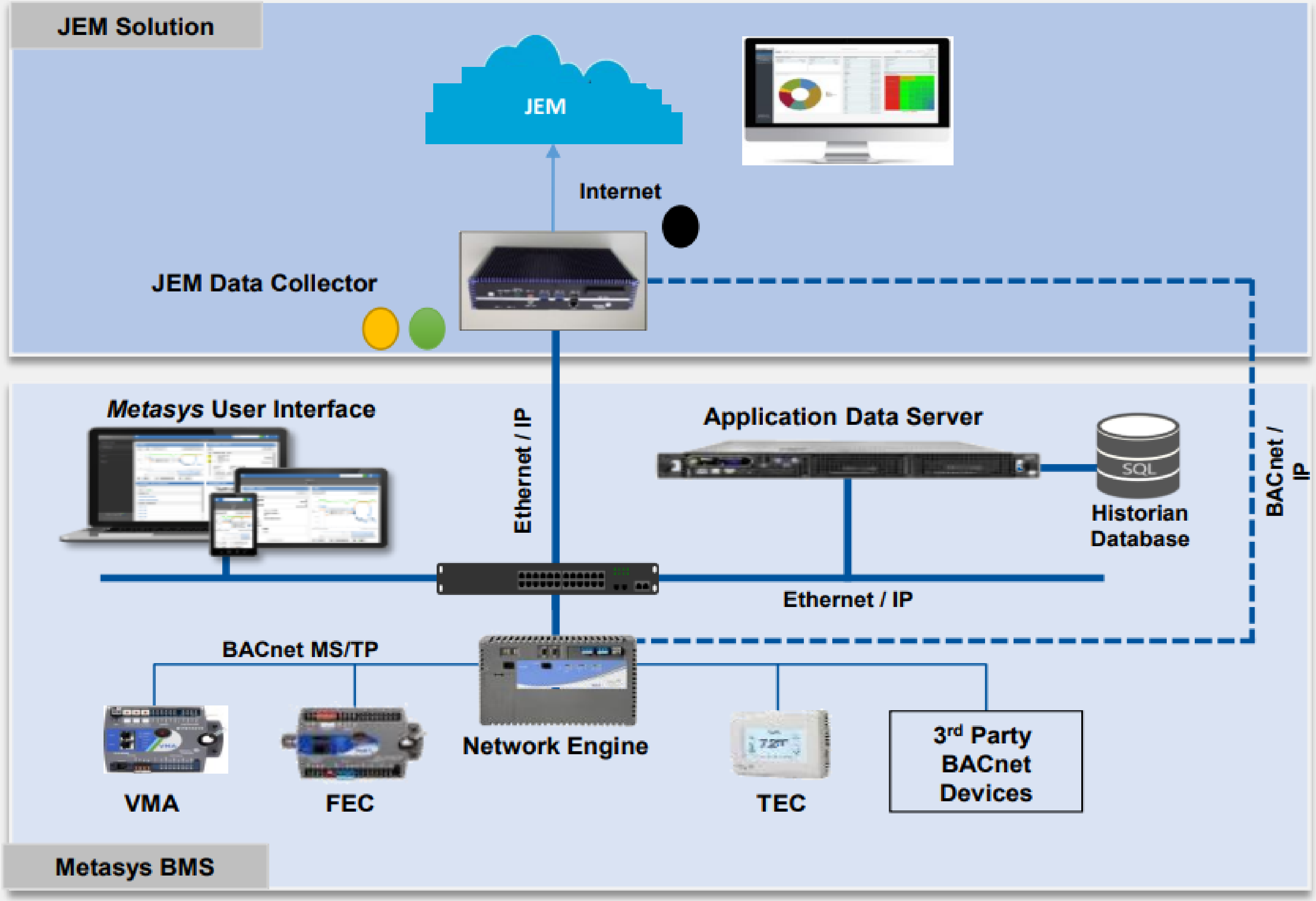
TCP Port 1433 access for the Data Collector to communicate to the Metasys ADX server internally

Access to BACnet/IP

UDP Port 47808 access for the Data Collector to communicate to the BACnet/IP server/devices internally

Access to Internet

Port 443 (HTTPS) open outgoing from the Johnson Controls Enterprise Management Data Collector box to the Johnson Controls cloud vendor



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Smart Chiller Plant – JEM Solution

Equipment Fault Detection and Diagnostics uncover critical faults and root cause.

Monitor, analyze, troubleshoot and maintain configured equipment located in a customer's portfolio.

Rule driven fault detection, notification and diagnostics are displayed in a time series format with total duration of existence allowing operations staff to easily pinpoint and fix equipment problems.

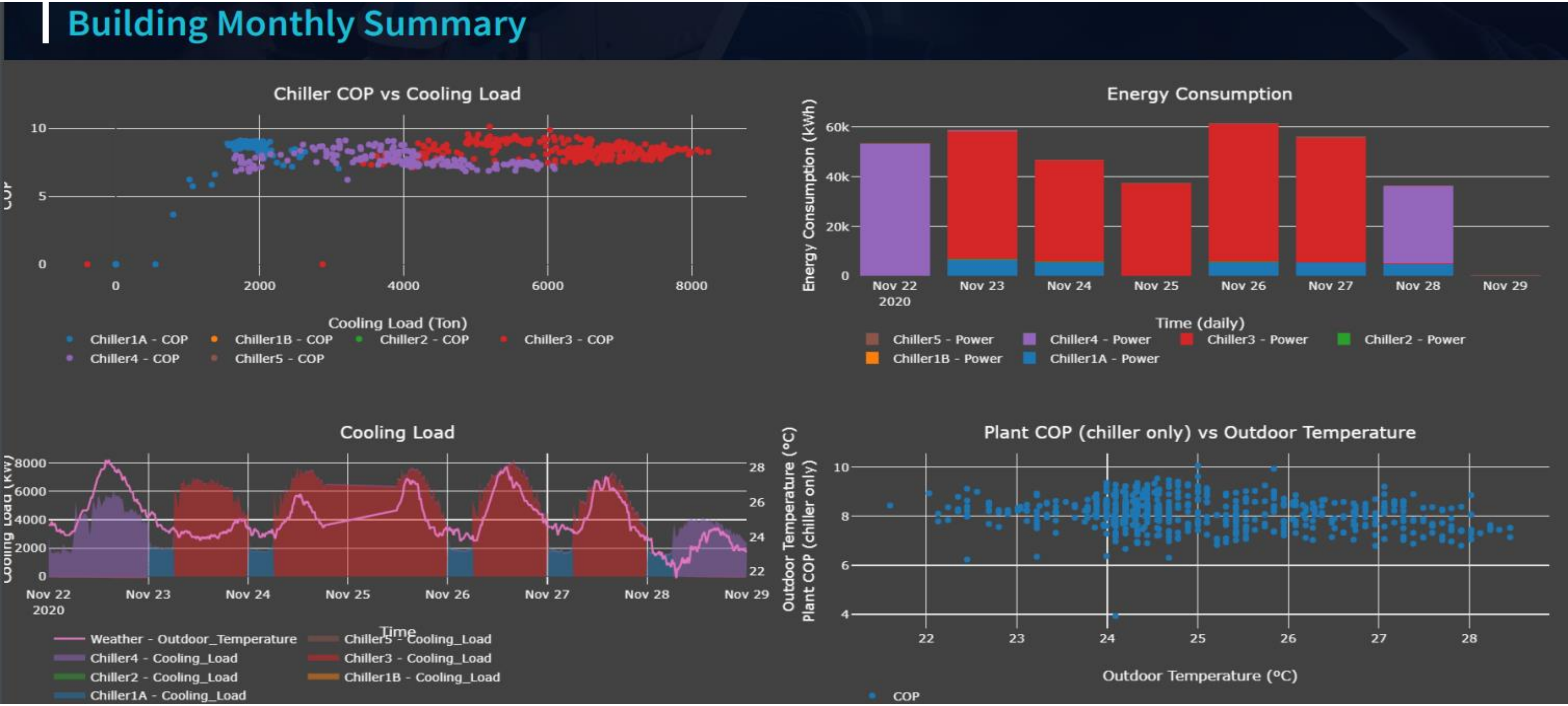
Plant room equipment dashboards provide more visibility into central plant performance

System level Fault Detection and Diagnostics allows the user to write custom faults to identify faults for an entire system as opposed to an isolated equipment

Case Based Learning enables the user to add site specific details and the JEM algorithm remembers equipment faults and the root cause

Smart Chiller Plant – JEDI

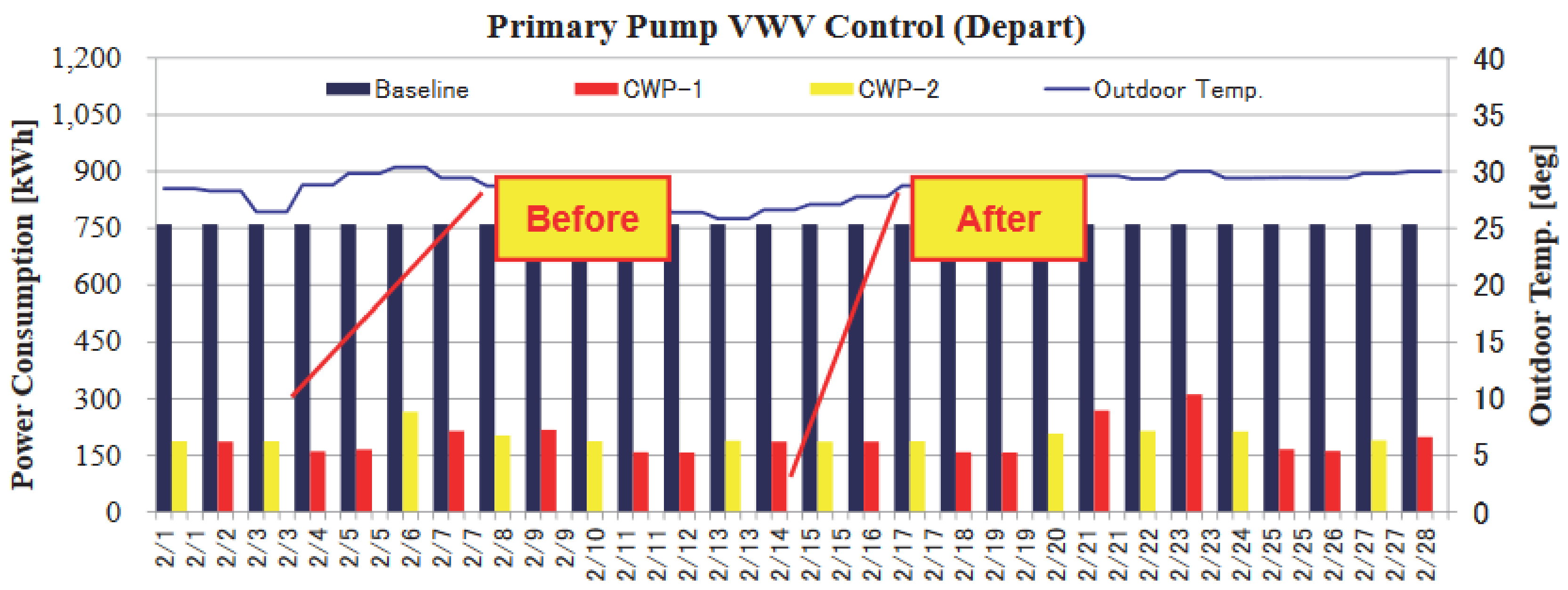
Smart Chiller Plant – JEDI



Smart Chiller Plant – Azbil

Primary Pump VWV Control

Saving
▲74% saved



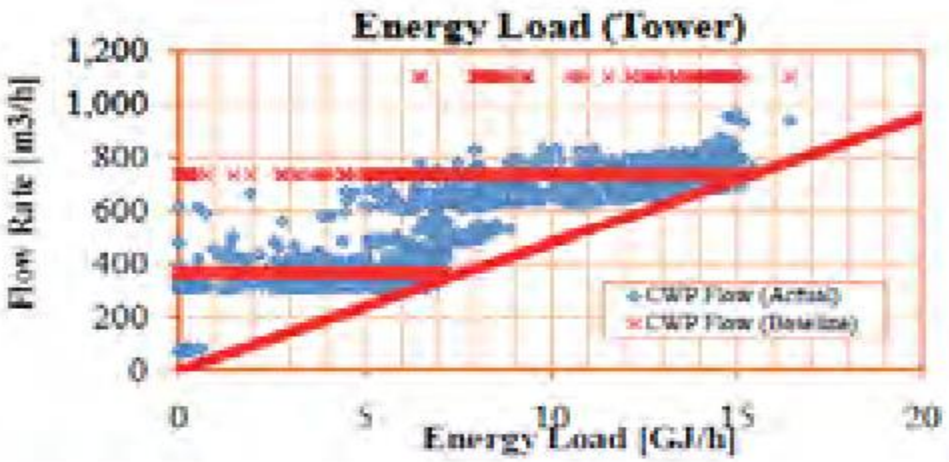
Actual Data Month	Before (kWh)	After (kWh)	Saving (kWh)
Feb-2017	21,286	5,460	15,826

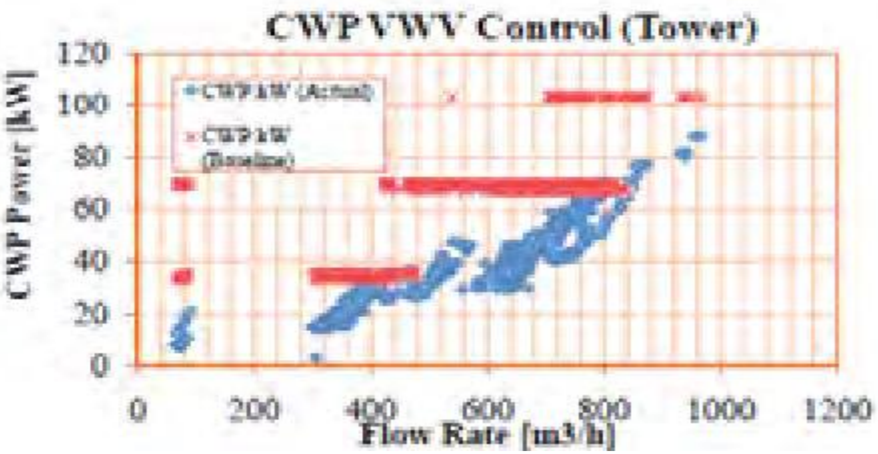
Smart Chiller Plant – Azbil

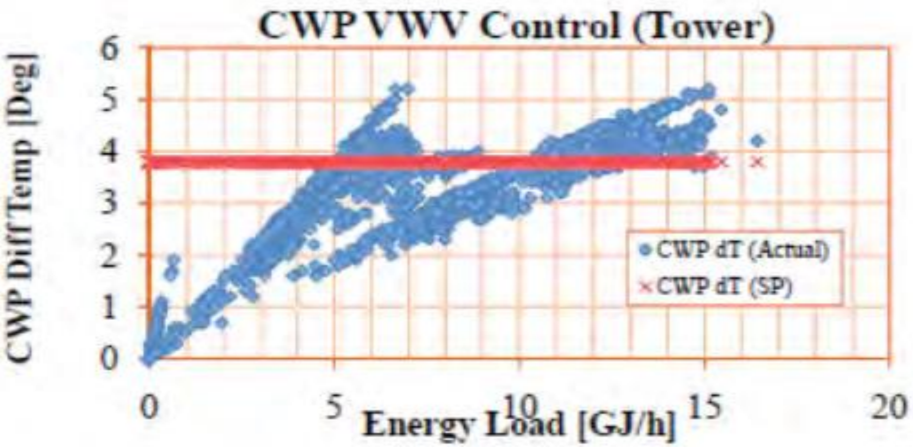
Detail Analysis by Plant

azbil

Primary Pump VWV Control for Tower Plant (as of September 2014)

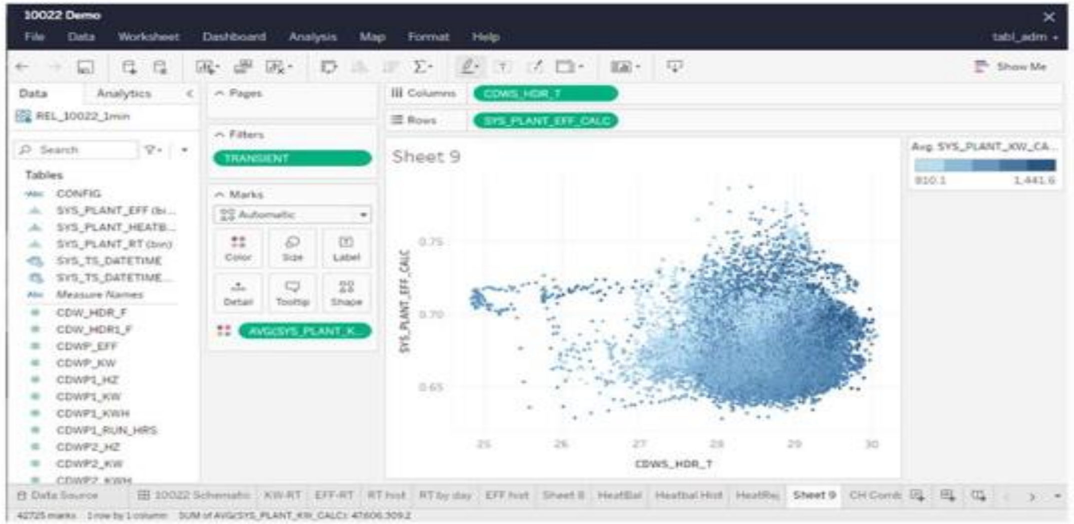


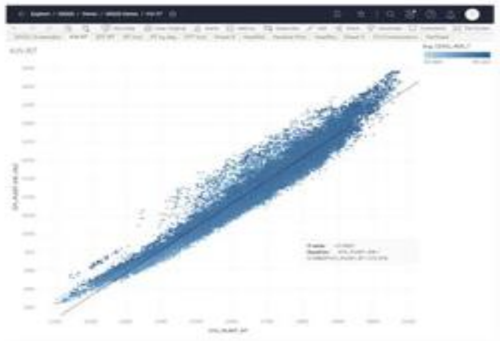




Smart Chiller Plant – Azbil

การเก็บข้อมูลแบบ Big Data





การทำงานของระบบ

1) เก็บข้อมูลทุก 1 นาที
2) มีข้อมูลที่ละเอียดทุกช่วงเวลาในการทำงานของระบบ
3) ใช้ข้อมูลในการแก้ปัญหา ตามสภาวะการทำงาน
4) เก็บข้อมูลได้ไม่จำกัด

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Smart Chiller Plant – BBP Sg

ภาพรวมที่ให้รายละเอียดของแต่ละโครงการ

การแสดงผลของระบบ

1) แสดงผลการประหยัดพลังงานเป็นค่าเงิน , ค่าพลังงาน (kWh) , ค่าคาร์บอนไดออกไซด์ (Co2) แบบต่อเนื่องตลอดเวลา (Real-time)

2) แสดงค่าประสิทธิภาพจริงและเป้าหมาย , ค่าปริมาณการทำความเย็น , พลังงานที่ใช้ ,ค่าการแลกเปลี่ยนความร้อน

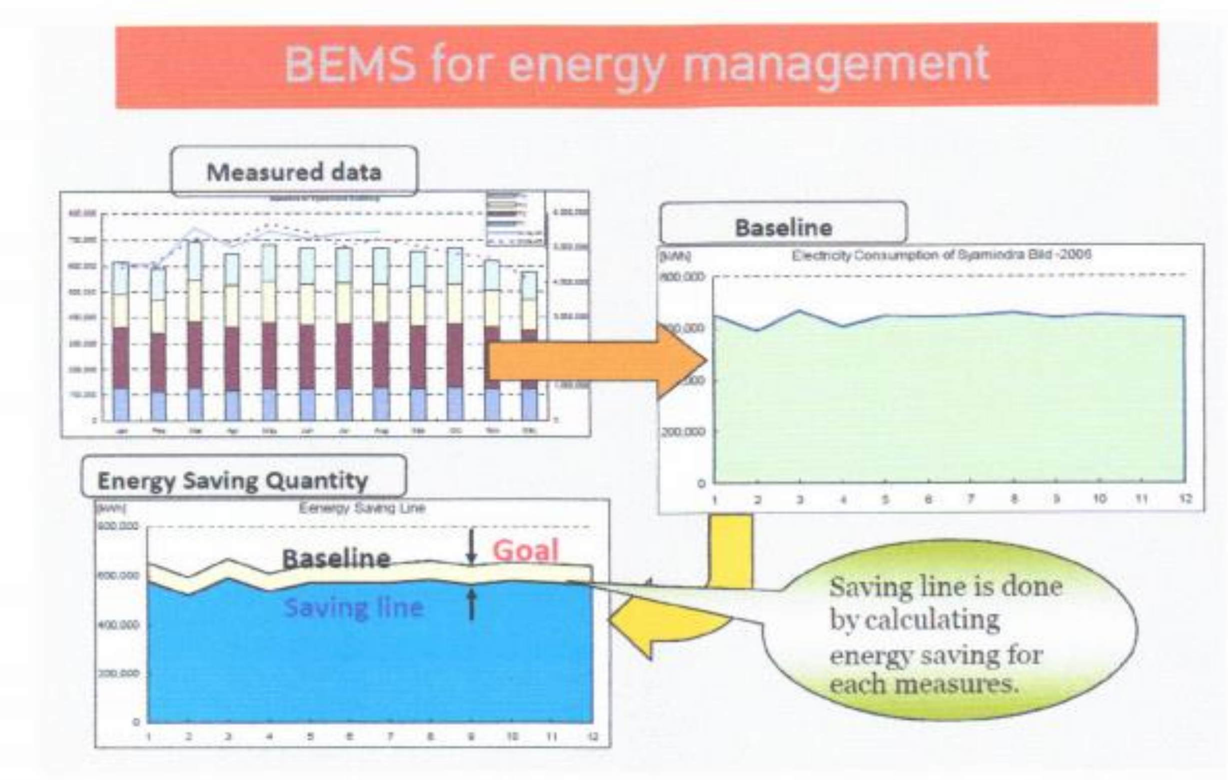
3) ประสิทธิภาพของทุกอุปกรณ์

4) แสดงผลการทำงานต่อเนื่องของระบบ และสามารถกำหนดการแจ้งเตือนเหตุผิดปรกติ

SECTION 5

Analysis Problem Examples

Power Analysis

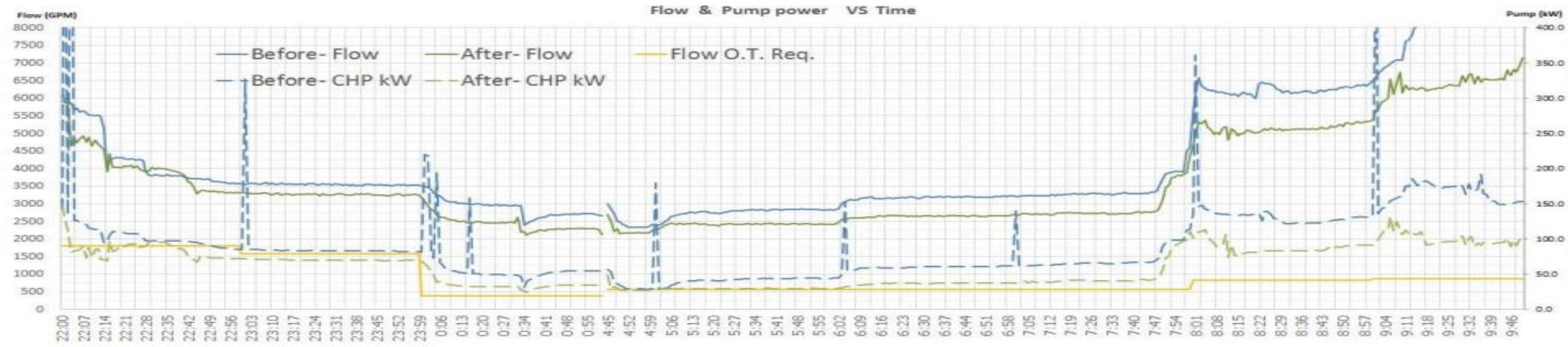


ภาพที่ ๖ แนวทางการกำหนดเป้าหมายและการลดใช้พลังงาน

Parameters ไม่ครอบคลุมการวิเคราะห์การสิ้นเปลืองพลังงาน

Baseline energy เป็นค่าเฉลี่ยที่รวม faults ในระบบ

System Improvement - Standalone

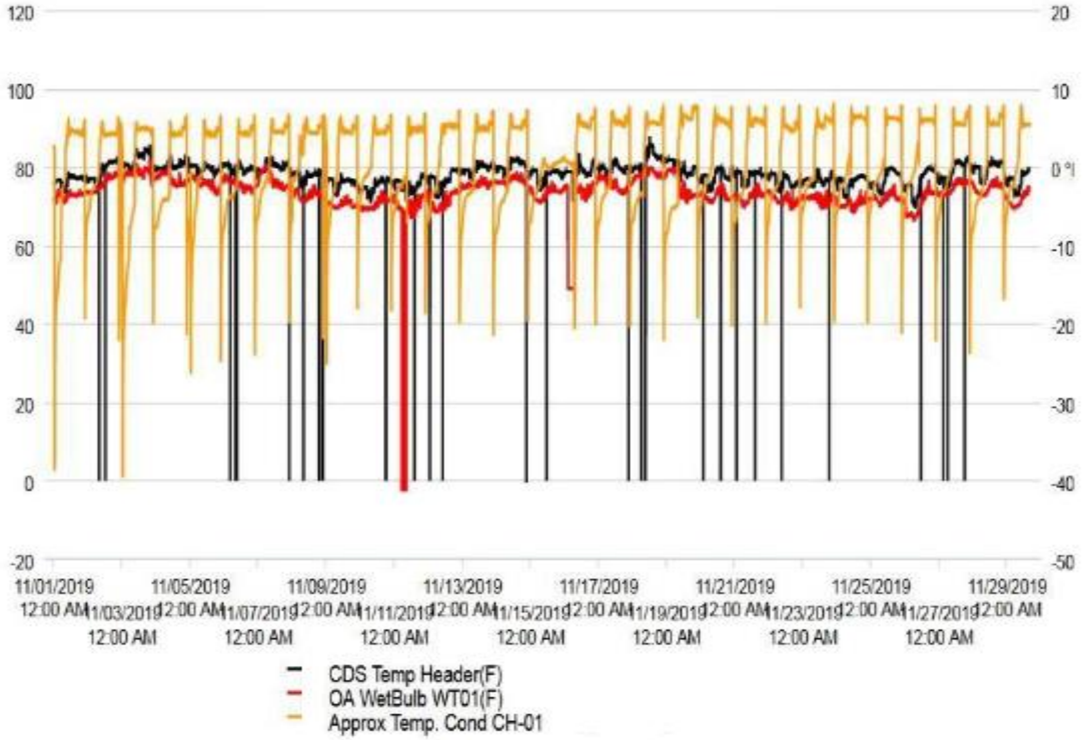


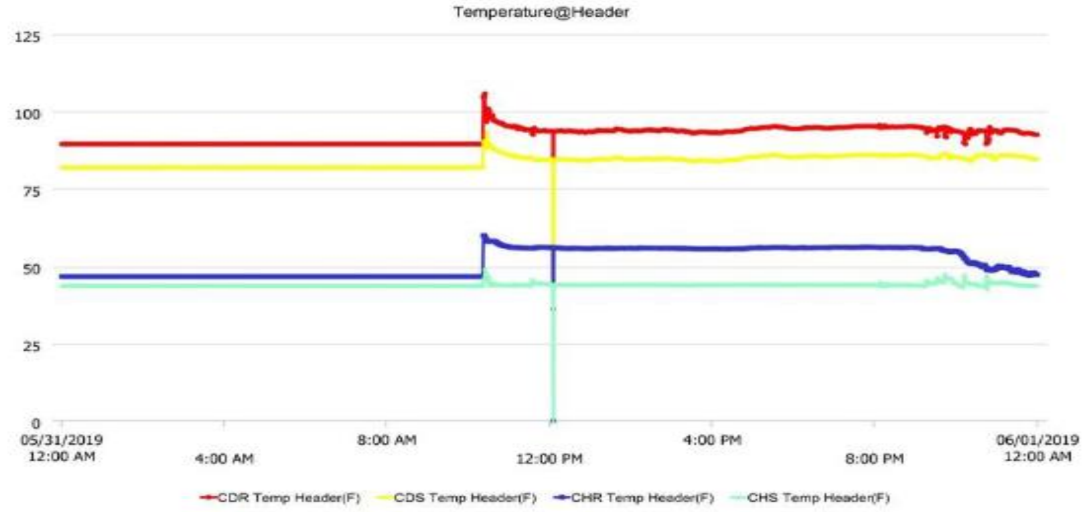
ปรับปรุงระบบ cooling tower pump โดยไม่คำนึงความเสียหายที่เกิดขึ้นในระบบ เช่น indoor relative humidity

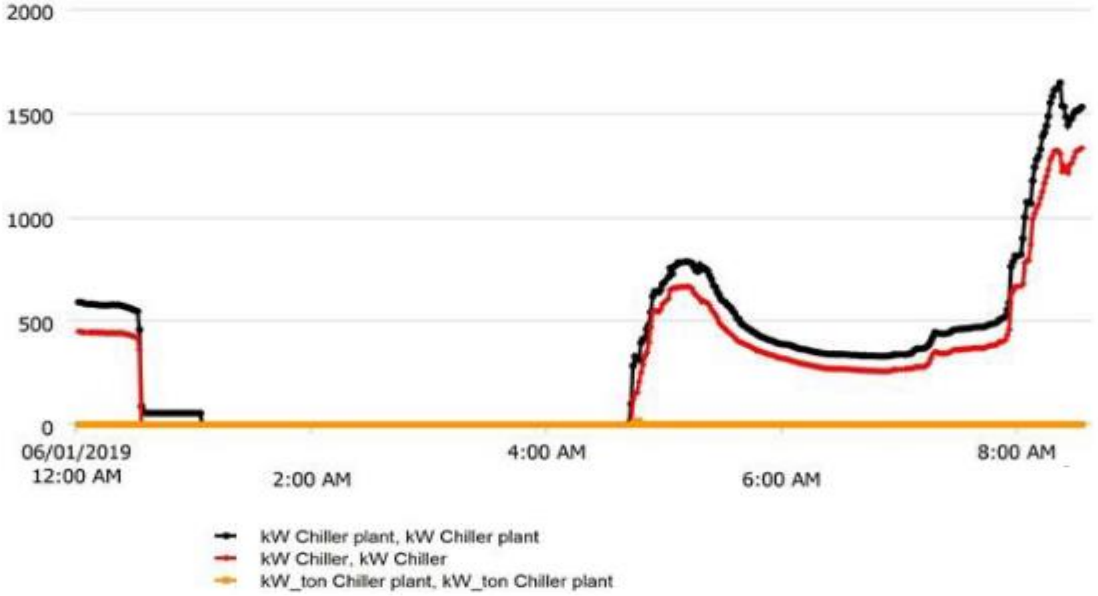
Demonstration Tool

การใช้งาน ไม่ได้จับคู่ตัวชี้วัดเทียบกับการตรวจวัดค่าตัวแปรที่เหมาะสม เช่น การเกิด peak และ kW/ton ไม่สอดคล้องกัน

Demonstration Tool







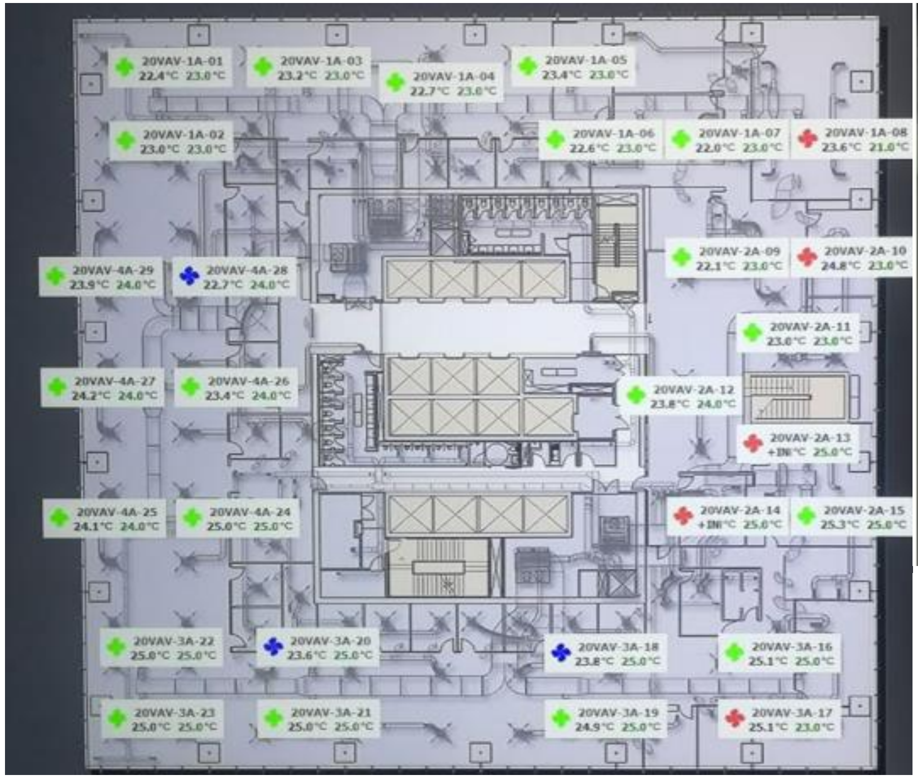
GUI (Graphical user interface) ไม่ได้แสดงถึงปัญหาที่เกิดขึ้น จำเป็นต้องมีผู้เชี่ยวชาญนำข้อมูลมาทำการวิเคราะห์อีกที

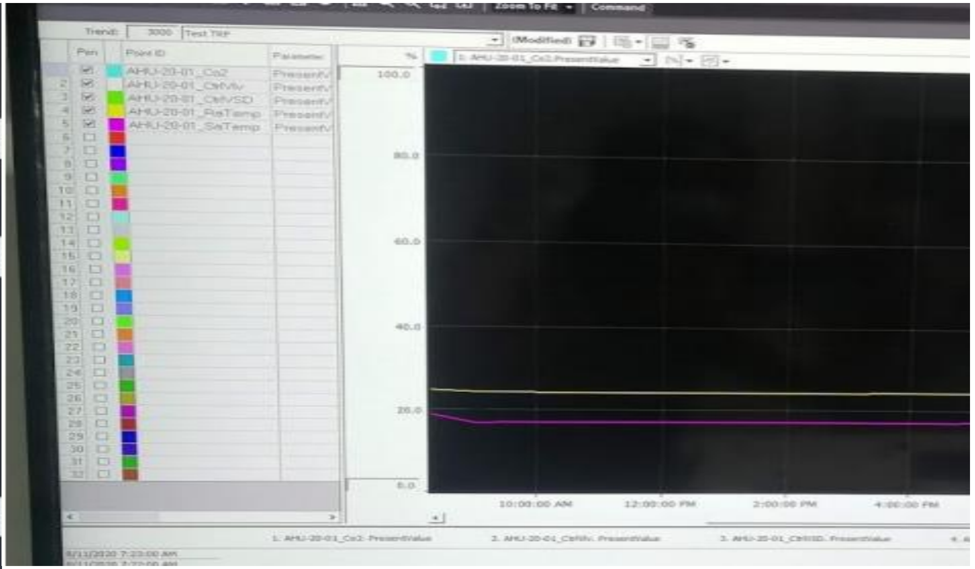
Main data problems

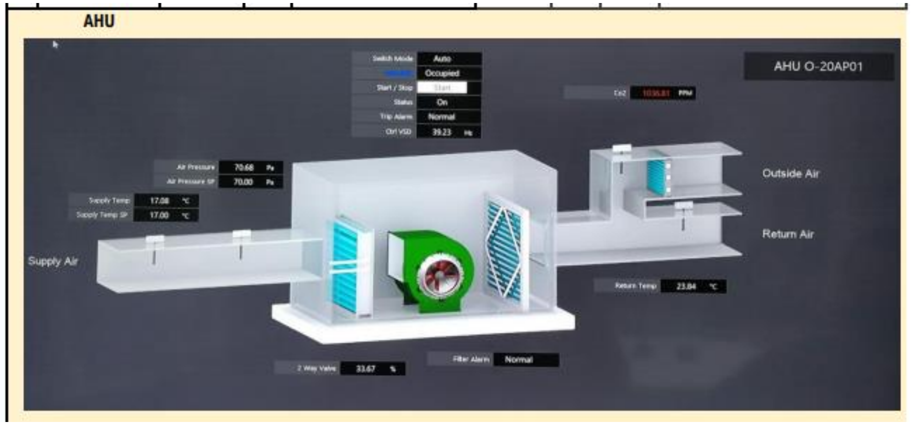
ตัวแปรที่ต้องการ	ตัวแปรที่ มี	ตัวแปรที่ มี
ตัวแปร chiller plant		
- Chiller Plant Setpoint Temp	ขอให้ Log เพิ่มเติม	1. ตั้งค่า (Historical Assignment) เพื่อ Log ด้วยความถี่ไม่เกิน 15 นาที และเริ่มต้นที่ 0, 15, 30, 45 เท่านั้น (Log ต่ำกว่า 15 นาที ได้แต่ขอให้สามารถ Trend หรือ Export ค่าได้ที่ความถี่ไม่มากกว่า 15 นาที) 2. การจัดเก็บต้องสามาร Export ค่าในรูปแบบ txt หรือ CSV"
- Chiller Plant Chilled Water Leaving Temp	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Chilled Water Entering Temp	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Chilled Water Flow (Main Header)	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Condenser Water Leaving Temp	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Condenser Water Entering Temp	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Diff Pressure	ขอให้ Log เพิ่มเติม	
- Chiller Plant Ton Plant	ขอให้ Log เพิ่มเติม	
- Chiller Plant Kw Plant	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant kW/Ton Plant	ขอให้ Log เพิ่มเติม	
- Chiller Plant Ambient Temperature	CPM มีเก็บค่าไว้แล้ว	
- Chiller Plant Ambient Humidity	ขอให้ Log เพิ่มเติม	
- Chiller Plant Wet-Bulb	ขอให้ Log เพิ่มเติม	

ตัวแปรการทำงานของ chiller แต่ละเครื่อง		
- Chilled Water Setpoint	ขอให้ Log เพิ่มเติม	1. ตั้งค่า (Historical Assignment) เพื่อ Log ด้วยความถี่ไม่เกิน 15 นาที และเริ่มต้นที่ 0, 15, 30, 45 เท่านั้น (Log ต่ำกว่า 15 นาที ได้แต่ขอให้สามารถ Trend หรือ Export ค่าได้ที่ความถี่ไม่มากกว่า 15 นาที) 2. การจัดเก็บต้องสามาร Export ค่าในรูปแบบ txt หรือ CSV"
- Chilled Water Temp: Leaving	ขอให้ Log เพิ่มเติม	
- Chilled Water Temp: Entering	ขอให้ Log เพิ่มเติม	
- Chilled Water: Flowrate	ขอให้ Log เพิ่มเติม	
- Evaporator Approach Temp	ขอให้ Log เพิ่มเติม	
- Condenser Water Temp: Leaving	ขอให้ Log เพิ่มเติม	
- Condenser Water Temp: Entering	ขอให้ Log เพิ่มเติม	
- Condenser Water: Flowrate	ขอให้ Log เพิ่มเติม	
- Condenser Approach Temp	ขอให้ Log เพิ่มเติม	
- Operating Capacity (Percent load)	ขอให้ Log เพิ่มเติม	
- Ton	ขอให้ Log เพิ่มเติม	
- Kw/ Ton	ขอให้ Log เพิ่มเติม	
- Unit Power Consumption (kW)	ขอให้ Log เพิ่มเติม	
- Compressor Discharge Temp	ขอให้ Log เพิ่มเติม	
- Condenser Refrigerant Pressure	ขอให้ Log เพิ่มเติม	
- Condenser Refrigerant Temp	ขอให้ Log เพิ่มเติม	
- Evaporator Refrigerant Pressure	ขอให้ Log เพิ่มเติม	
- Evaporator Refrigerant Temp	ขอให้ Log เพิ่มเติม	

Main data problems







1	AHU Ts	Ts	C	Supply air temperature	Yes	No	No
2	AHU Ts set	Ts set	C	Supply air temperature set-point	Yes	No	No
3	AHU Tr	Tr	C	Return air temperature	Yes	No	No
4	AHU Tr set	Tr set	C	Return air temperature set-point	No	-	-
5	AHU Ps	Ps	Pa	Static pressure	Yes	No	No
6	AHU Ps set	Ps set	Pa	Static pressure setpoint	Yes	No	No
7	AHU vsd	vsd	%	Variable Fan %	Yes	No	No
8	AHU valve	valve	%	Cooling coil valve %	Yes	No	No
9	AHU Tfa	Tfa	C	Fresh air temperature	No	-	-
10	AHU CO2	CO2	ppm	Carbondioxide level	Yes	No	No
11	AHU CO2 set	CO2 set	ppm	Carbondioxide level	Yes	No	No

SECTION 6

USA Retuning process

Retuning process (the development from field test data)

Re-tuning Meta-Study

- 2007 – 2010
- Funded by State of Washington
- Developed re-tuning training in 2007
- Service providers
- ~25 buildings

- 2010 – 2013; small programmatic effort in FY14 and FY15
- ARRA funded
- Developed online interactive re-tuning training and training for buildings without BAS
- Large portfolio managers
- ~50 buildings

GENERAL SERVICES ADMINISTRATION

- 2011 –
- Funded by General Services Administration
- Identify and help GSA staff implement re-tuning measures
- ~30 buildings

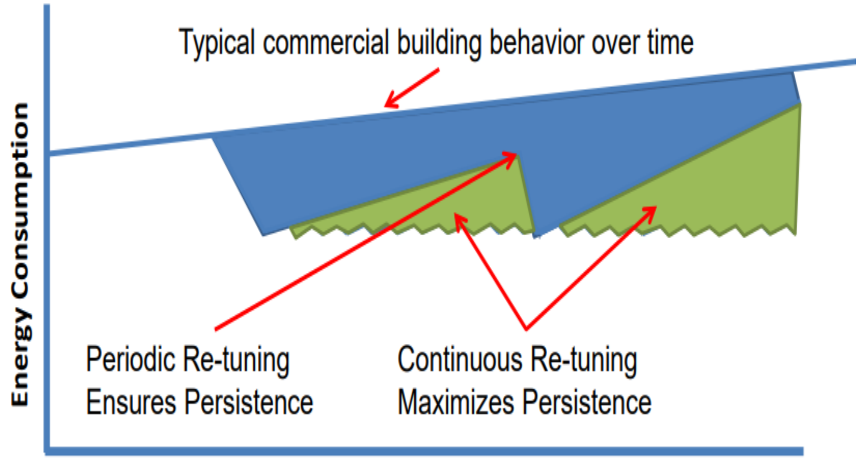
Retuning process and steps (using data from BAS)

The Retuning Process

Retuning consists of seven primary steps:

1. Collection of basic building information;
2. Trend-data collection and analysis;
3. Building walk down;
4. Identification and implementation of retuning actions;
5. Report of findings, recommended actions and recommendations implemented;
6. Savings analysis; and
7. Continued use of retuning in operation and maintenance.

October 2009 ASHRAE Journal



- Occupancy scheduling
- Discharge-air temperature control
- Discharge-air static pressure control
- Air-handling unit (AHU) heating & cooling
- AHU outside/fresh air makeup
- AHU economizer operation
- Zone conditioning
- Meter profiles
- Central plant

Source: PNNL

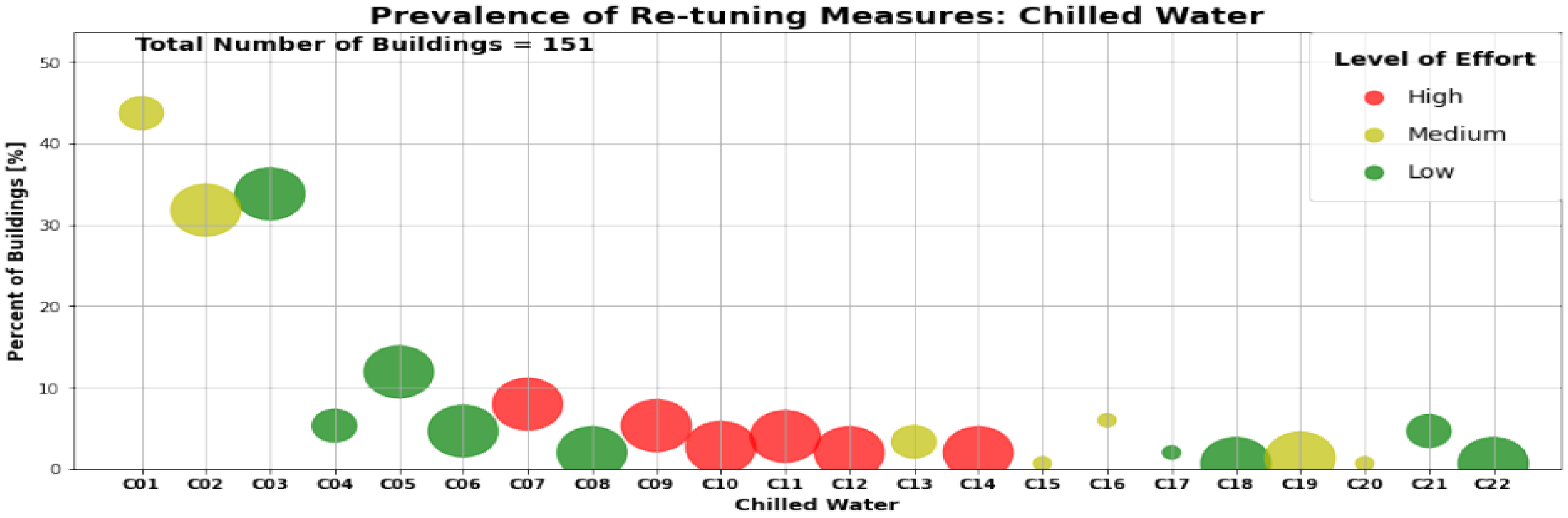
- Re-tuning is implemented by leveraging information from BAS
- Cost of implementation is significantly lower than retro-commissioning
- Because re-tuning costs a fraction of retro-commissioning, it can be periodically done to ensure persistence

Retuning process and steps (using data from BAS)

Pacific Northwest NATIONAL LABORATORY

Chilled Water Re-tuning Measures

C01: Implement chilled water supply temperature reset
C02: Implement condenser water temperature reset
C03: Implement loop differential pressure reset/reduction and convert 3-way valves to 2-way valves if required
C04: Run parallel VFD chilled water pumps together instead of staging them (both chilled water and condenser water)
C05: Lockout chiller based on demand or OAT
C06: Control chilled water pumps by chilled water valve position or loop delta-temperature and open manual isolation valves
C07: Install VFD on chilled water pump
C08: Clean and repair cooling tower
C09: Install VFD on cooling tower fans
C10: Install VFD on condenser water pumps
C11: Code and test water-side economizer implementation
C12: Evaluate using rejected heat to interior spaces during winter months
C13: Enable chiller isolation valve controls so chiller isolation valve is closed when respective chiller is off
C14: Insulate all exposed chiller piping and fittings
C15: Replace failed check valves on chilled water pumps
C16: Investigate staging issues with chillers (e.g. short-cycling)
C17: Improve control of cooling tower basin heaters
C18: Use electric chillers in lieu of steam turbine chillers whenever possible
C19: Fix or replace chilled water coil valves
C20: Chiller soft start
C21: Disable chilled water pumps when chillers are not running
C22: Run one parallel condenser water pump instead of two (second not needed)



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Retuning process and steps (examples)

1. การศึกษาและวิเคราะห์ CPMS PNNL guide
- การ reset chilled water set-point
- การปรับค่า Tevo set-point
- การปรับตั้งค่า pressure set-point

2. การศึกษาและวิเคราะห์ AHU PNNL guide
- การศึกษา AHU Minimum Outdoor Air Operation
- การศึกษา AHU Discharge-Air Temperature Control
- การศึกษา AHU Static Pressure Control

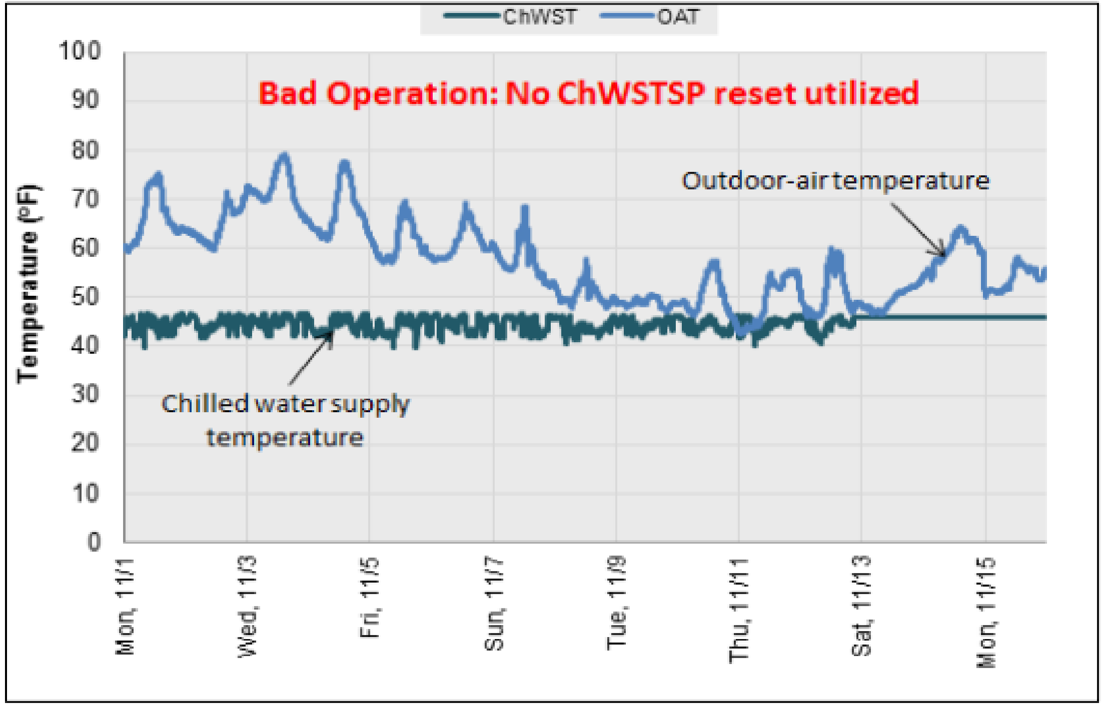
3. การศึกษาและวิเคราะห์ Zone PNNL guide
- Setback set-point ช่วงการทำงานกลางคืน หรืออาคารปิด
- การตรวจสอบ simultaneous cooling และ heating

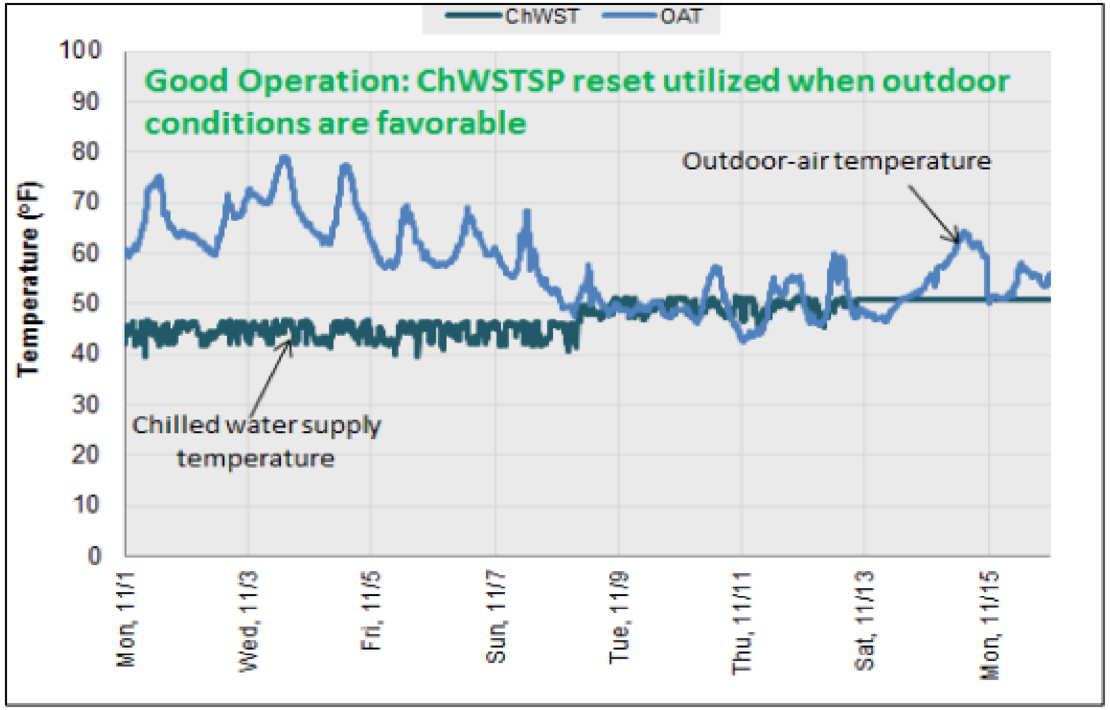
PNNL guide	การตรวจสอบ	ตัวแปร	ข้อจำกัดการประยุกต์
CPMS	1.การ reset chilled water set-point	Tevo, CC_signal, OAT	CC_signal, OAT ไม่เชื่อมต่อกับ CPMS
	2.การปรับค่า Tevo set-point	Tevo_st, Tevi, Tevo	ไม่มี OAT ในบางอาคาร
	3.การปรับตั้งค่า pressure set-point	Ploop_st, Ploop,CC_signal	CC_signal ไม่เชื่อมต่อกับ CPMS
AHU	1.ปริมาณ fresh air น้อยหรือมากเกินไป	OAD, OAF, OCC, OAT	ไม่มีค่า OCC, OAT, OAF
	2.Damper ปิดในช่วงอาคารปิดหรือไม่	OAD, OAF, OCC,	ไม่มีค่า OCC, OAF
	3.การ reset DAT set-point	DAT, DAT,st, OAT, HC_signal	ไม่มีค่า OAT, HC_signal
	4.การควบคุมค่า DAT ตาม set-point	DAT, DAT,st	on-off หรือ P-control
	5.ค่า DAT set-point สูงหรือต่ำไป	DAT,st, OAT, HC_signal	ไม่มีระบบ HC_signal
	6.ค่า DAT ยังสามารถควบคุมได้	DAT,st, DAT	on-off หรือ P-control
	7.Static pressure set-point reset	Pst, Pst,st, VAV_signal	ไม่บันทึกค่า
	8.Static pressure set-point สูงหรือต่ำไป	Pst, Pst,st, VAV_signal	ไม่บันทึกค่า
Zone	1.Setback set-point ช่วงการทำงานกลางคืนหรืออาคารปิด	OCC_mode, ZAT, HC_signal	ไม่มีค่า OCC_mode, HC_signal
	2.การตรวจสอบ simultaneous cooling และ heating	OAT, ZAT, HC_signal	ใช้ cooling เท่านั้น

Retuning process and steps (examples)

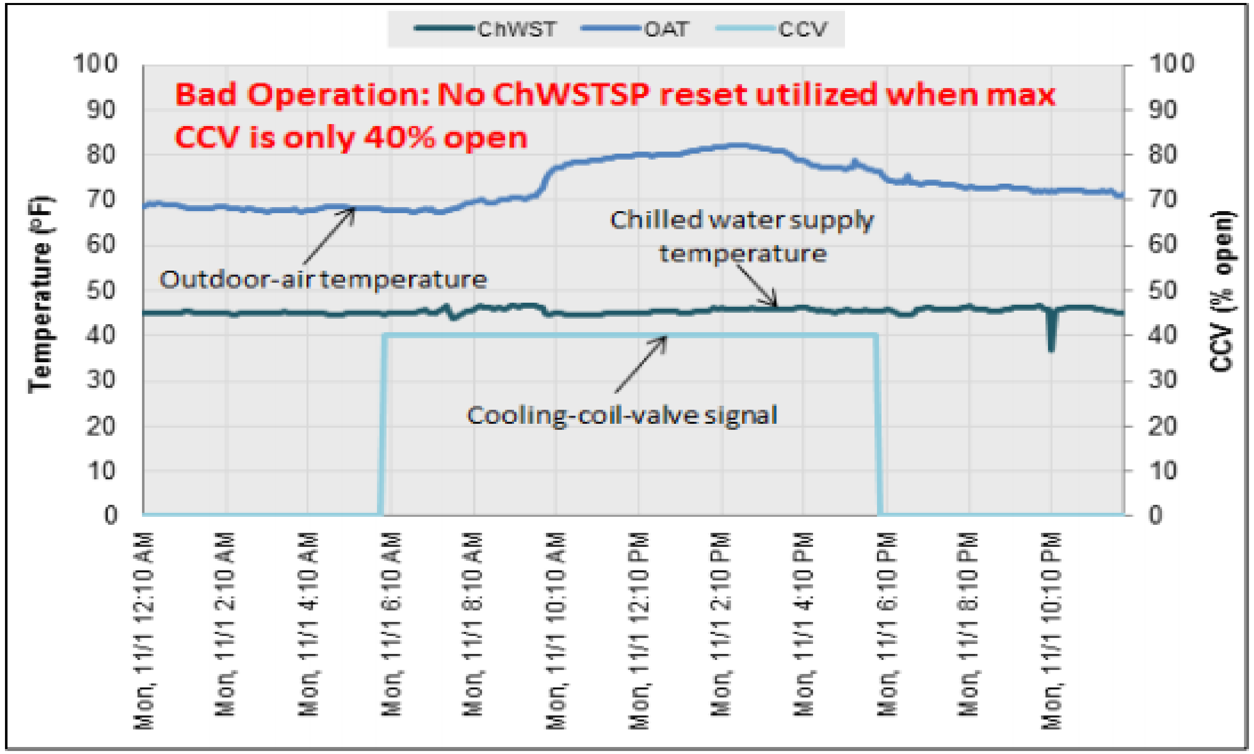
การศึกษาและวิเคราะห์ CPMS PNNL guide

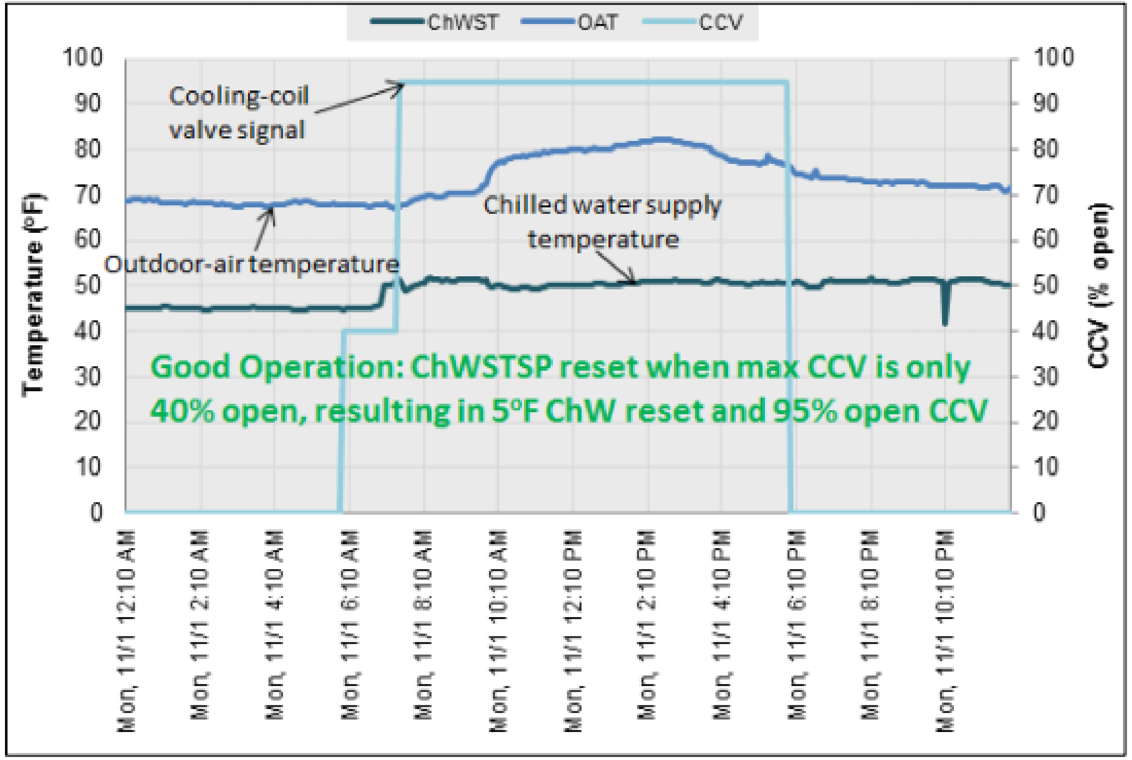
- การ reset chilled water set-point
- การปรับค่า Tevo set-point
- การปรับตั้งค่า pressure set-point





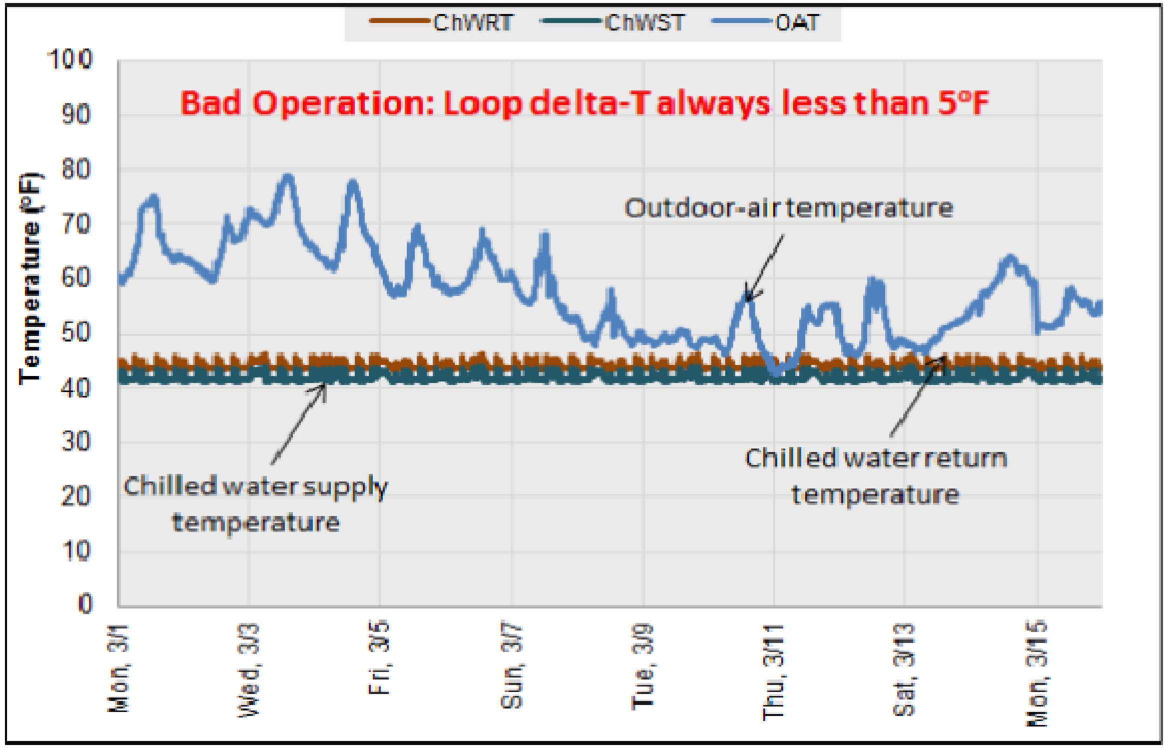
Retuning process and steps (examples)

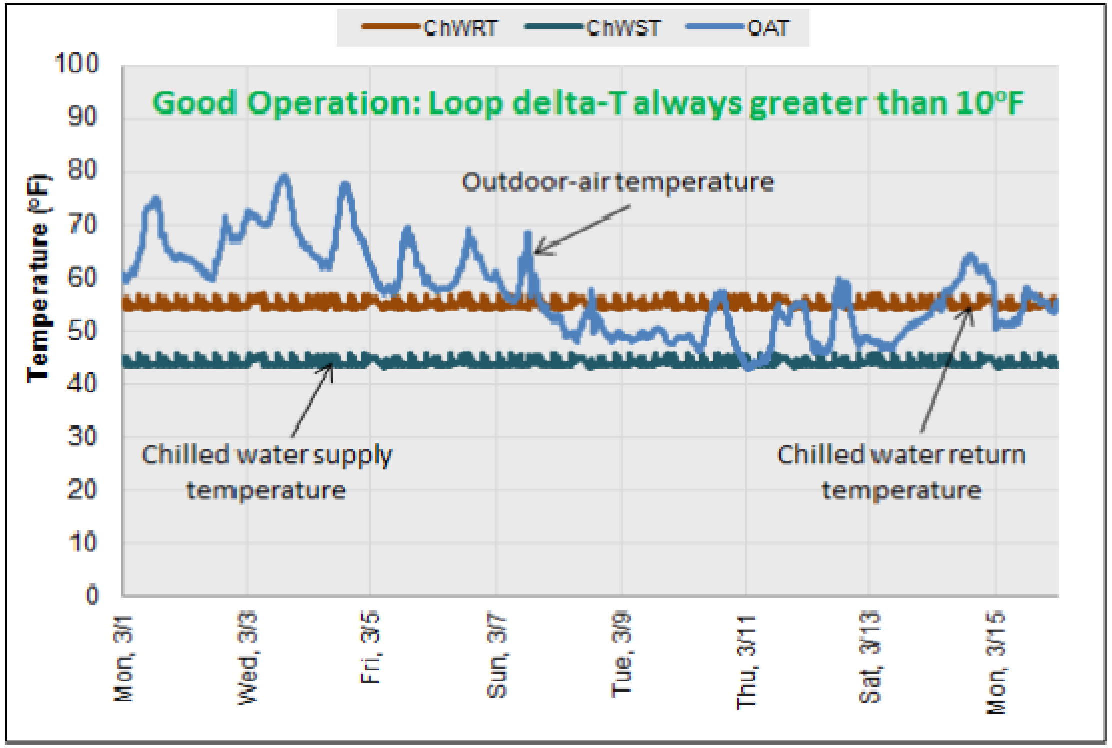




Cooling coil valve – 75 – 90%

Retuning process and steps (examples)

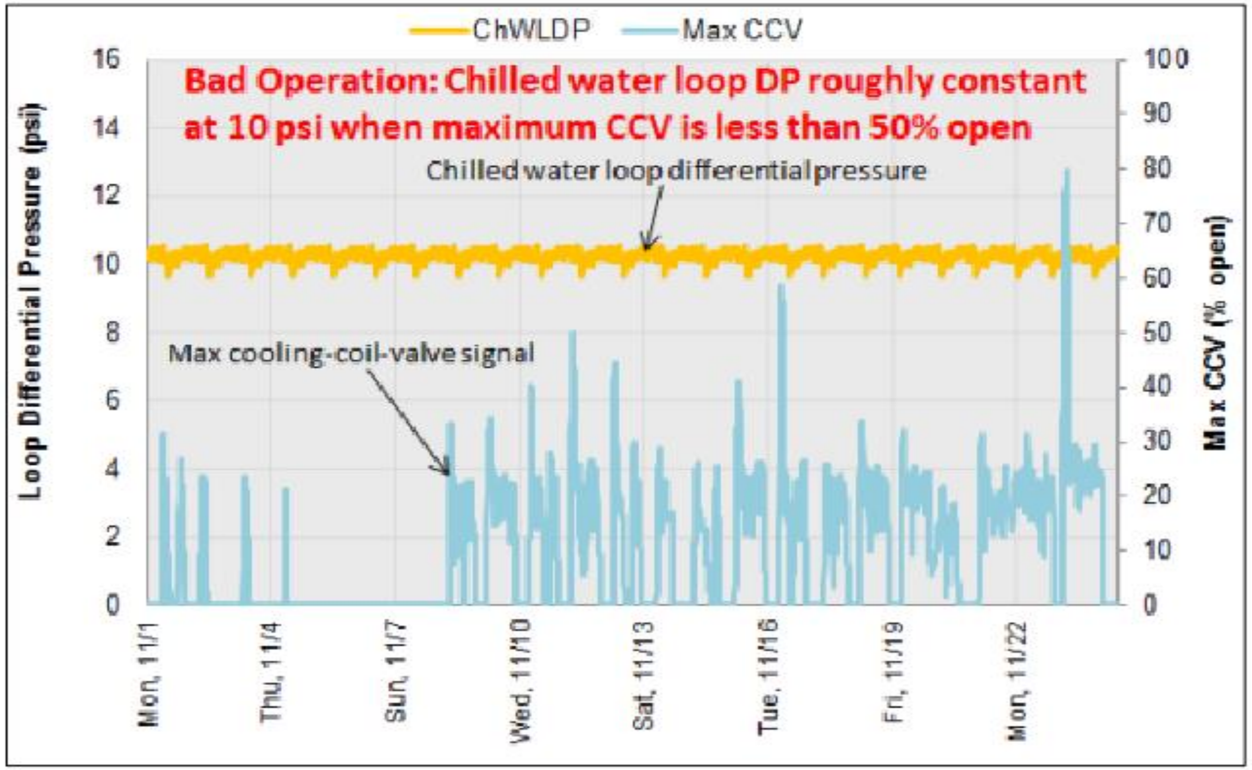


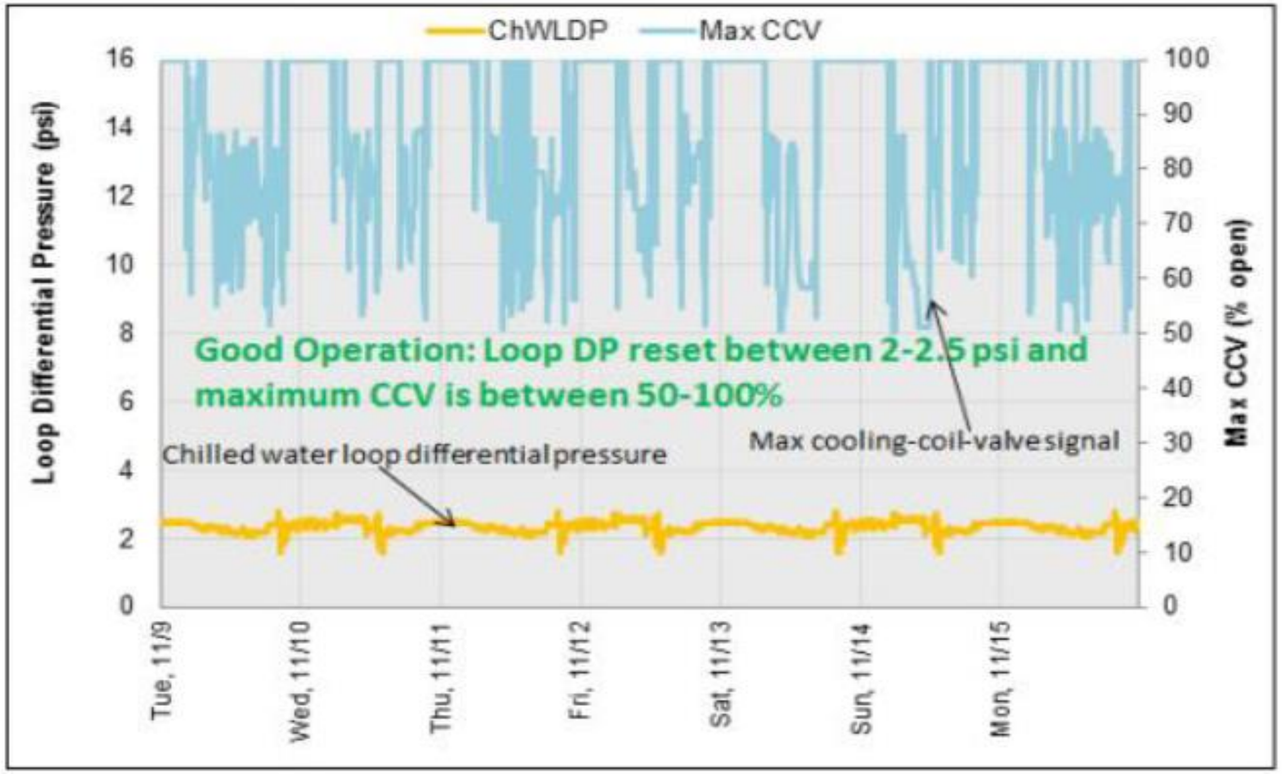


Chilled water temperature difference ไม่ควรต่ำกว่าค่า 8 F หากการตั้งค่า Tevo ต่ำเกินไปในกรณีที่อุณหภูมิอากาศภายนอกต่ำกว่าปกติ

ควร reset ค่า44 F ลต่างอุณหภูมิน้ำเย็นที่เหมาะสมเพิ่มค่าอุณหภูมิ Tevo เพื่อไม่ทำให้ค่าผลต่างน้ำเย็นต่ำกว่าปกติจนเกิด low delta T syndrome

Retuning process and steps (examples)





-Bad operation พบว่าค่าการตั้งความดันของระบบ CPMS (Ploop_st) คงที่ในขณะที่ CC_signal น้อยกว่า 50%

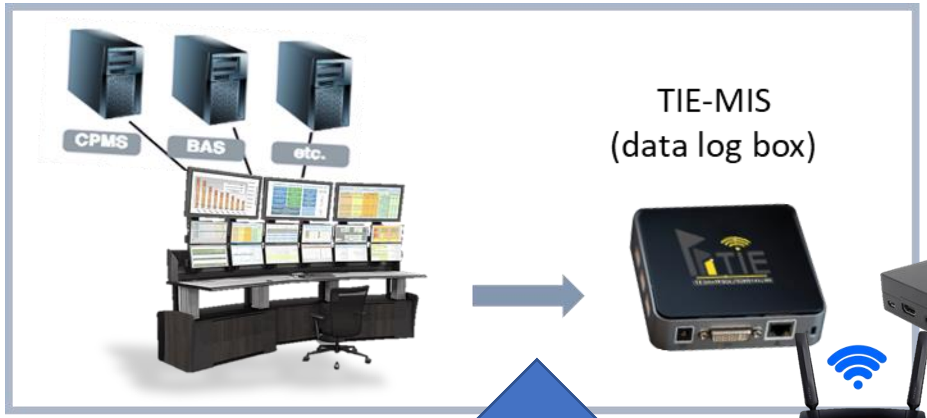
-ทำการ reset pressure loop set-point ให้ต่ำลงเพื่อเพิ่มค่า CC_signal มากกว่า 90% - 100% โดยการ reset set-point ลดจาก 10 psi เหลือ 2.5 psi ทำให้ลดค่าไฟฟ้าระบบปั๊ม และทำให้ค่า CC_signal เพิ่มขึ้นมาตามเกณฑ์การแนะนำ

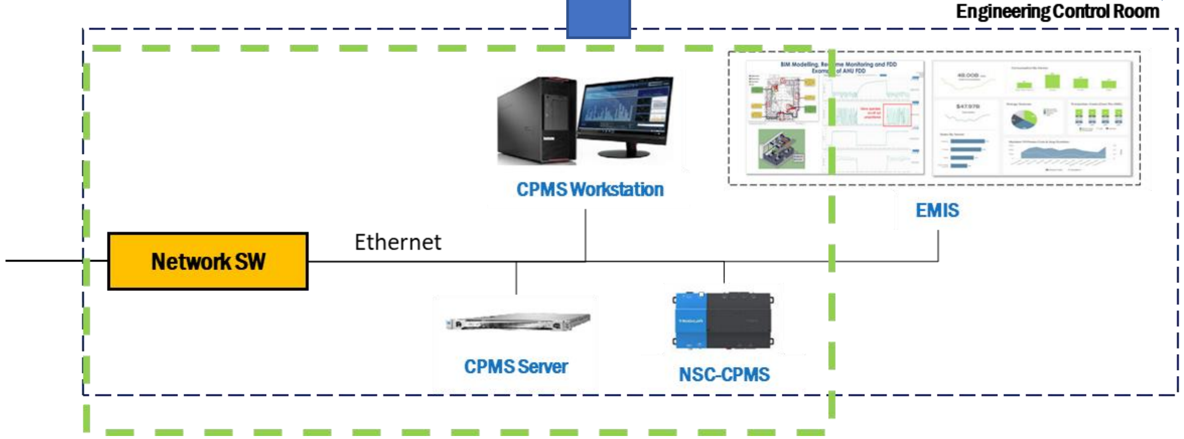
SECTION 7

Smart chiller and CPMS Examples

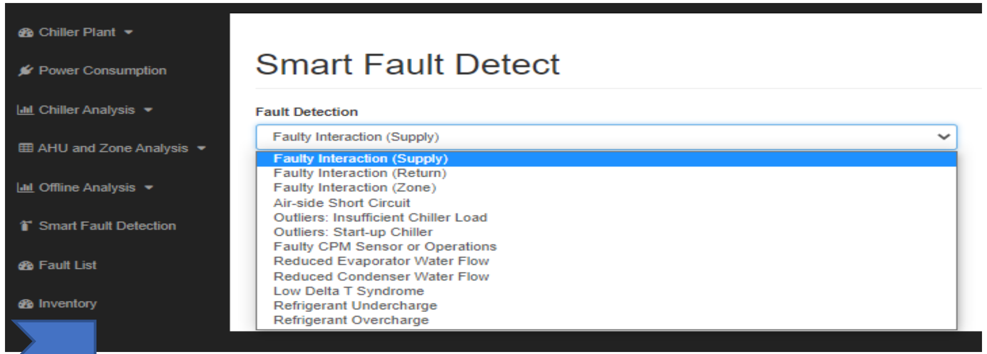
EMIS – System Monitoring, Diagnostic and Control

MBCx phase 1 – Data configuration with CPM data interface

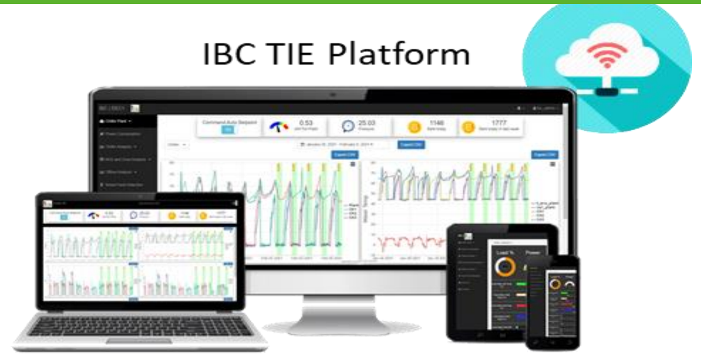




MBCx phase 2 – AFDD design and Implementation



MBCx phase 3 – Automated Repair by smart controller



Data Storage Examples

ตัวแปรที่ต้องการ	Score	Weight	BAS condition						Score	Weight	BAS condition					
ตัวแปร chiller plant				BAS available	is point condition ok?	In trend	Stored?	Sampling rate required				BAS available	is point condition ok?	In trend	Stored?	Sampling rate required
- Chiller Plant Setpoint Temp (set)	3	3	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Chilled Water Entering Temp	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Chilled Water Leaving Temp	0.8	2	0.4	Yes	Yes	No	No	15 mins	1.2	3	0.4	Yes	Yes	No	No	15 mins
- Chiller Plant Chilled Water Flow (Main Header)	0.4	2	0.2	Yes	No	No	No	15 mins	1.2	3	0.4	Yes	Yes	No	No	15 mins
- Chiller Plant Condenser Water Leaving Temp	0.8	2	0.4	Yes	Yes	No	No	15 mins	0.8	2	0.4	Yes	Yes	No	No	15 mins
- Chiller Plant Condenser Water Entering Temp (set)	0	3	0	No	No	No	No	15 mins	0.8	2	0.4	Yes	Yes	No	No	
- Chiller Plant Condenser Water Entering Temp	2	2	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Diff Pressure (set)	1.2	3	0.4	Yes	Yes	No	No	15 mins	1.2	3	0.4	Yes	Yes	No	No	
- Chiller Plant Diff Pressure	2	2	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Ton Plant	1.6	2	0.8	Yes	No	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Kw Plant	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant kW/Ton Plant	0.8	1	0.8	Yes	No	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Chiller Plant Ambient Temperature	0.4	1	0.4	Yes	Yes	No	No	15 mins	0.4	1	0.4	Yes	Yes	No	No	15 mins
- Chiller Plant Ambient Humidity	0.4	1	0.4	Yes	Yes	No	No	15 mins	0.4	1	0.4	Yes	Yes	No	No	15 mins
- Chiller Plant Wet-Bulb	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
ตัวแปรการทำงานของ chiller แต่ละเครื่อง	19.4	30		BAS available	is point condition ok?	In trend	Stored?	Sampling rate required	25	34	10.8	BAS available	is point condition ok?	In trend	Stored?	Sampling rate required
- Chilled Water Setpoint (set)	**3**	**3**	**1**	**Yes**	**Yes**	**Yes**	**Yes**	**15 mins**	**3**	**3**	**1**	**Yes**	**Yes**	**Yes**	**Yes**	**15 mins**
- Chilled Water Temp: Entering	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Chilled Water Temp: Leaving	2	2	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Chilled Water: Flowrate	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Evaporator Approach Temp	3	3	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Water Temp: Leaving	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Water Temp: Entering	3	3	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Water: Flowrate	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Approach Temp	3	3	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Operating Capacity (Percent load)	3	3	1	Yes	Yes	Yes	Yes	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Ton	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Kw/ Ton	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Unit Power Consumption (kW)	2	2	1	Yes	Yes	Yes	Yes	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Compressor Discharge Temp	1.2	3	0.4	Yes	Yes	No	No	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Refrigerant Pressure	0.8	2	0.4	Yes	Yes	No	No	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Condenser Refrigerant Temp	1.2	3	0.4	Yes	Yes	No	No	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
- Evaporator Refrigerant Pressure	0.8	2	0.4	Yes	Yes	No	No	15 mins	2	2	1	Yes	Yes	Yes	Yes	15 mins
- Evaporator Refrigerant Temp	1.2	3	0.4	Yes	Yes	No	No	15 mins	3	3	1	Yes	Yes	Yes	Yes	15 mins
	36.2	44							45	45	18					
	55.6	**74**							**70**	**79**						
	75.14%								**88.61%**							

Automated fault diagnostics and recommendation

EMIS function (AFDD) to avoid:

F1: reduce evaporator water temperature flow-rate

F2: reduce condenser water temperature flow-rate

F3: low delta T syndrome

F4: condensing fouling

F5: refrigerant overcharge

F6: refrigerant undercharge

F7: non-condensable gas

F8: surge

F9: outlier chiller startup

F10: insufficient chiller load

F11: improper CHP control

F12: faulty CPM sensor

F13: Chiller load loss

F14: too low chilled water return temperature

F15: air-side short circuit

F16: non-thermal comfort

F17: wrong CAV control valve

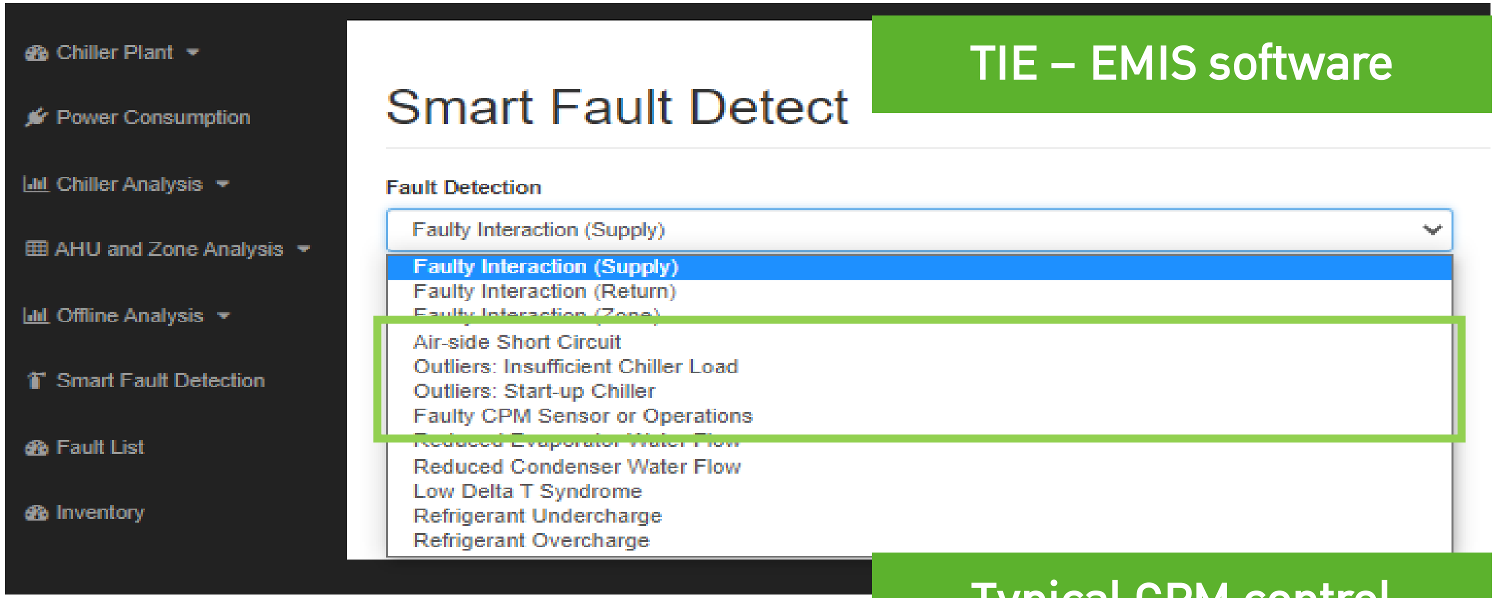
F18: too high supply air temperature of a AHU

F19: too low supply air temperature of a AHU

F20: air zone condensation

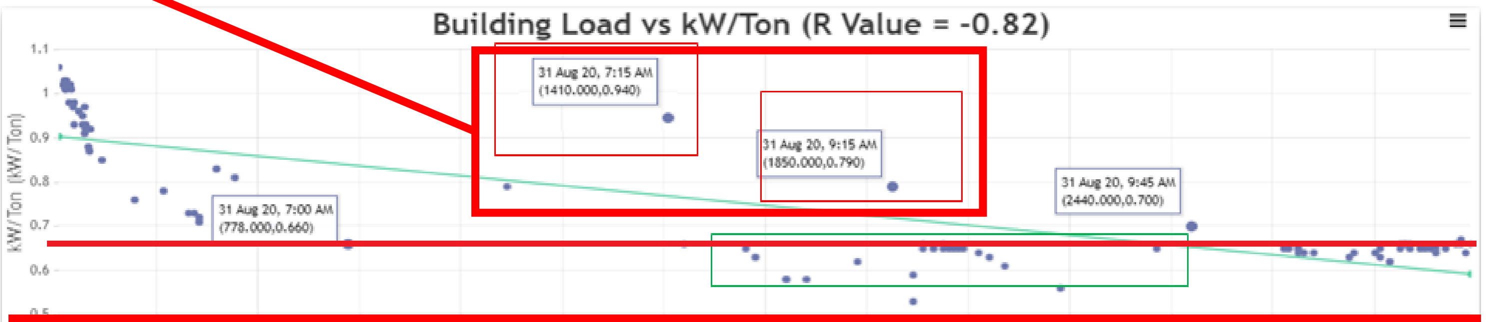
Retuning CHP VSD

TIE – EMIS software



Typical CPM control

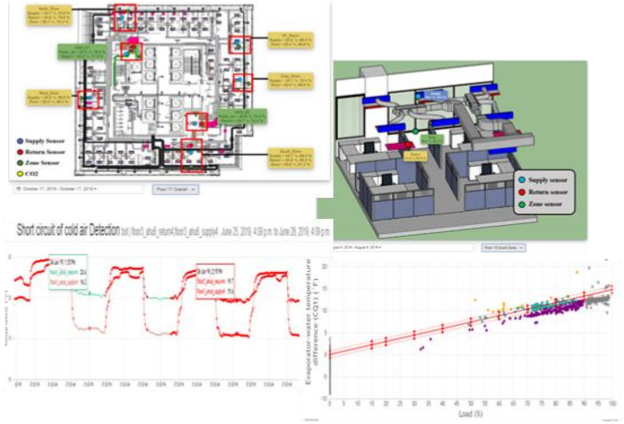
Check Tevo at SP = 44 F; when load is more than 750 tons, Tevo is lifted due to insufficient load



Automated Diagnostic identifies potential root causes

Smart Chiller Diagnostics – Haier

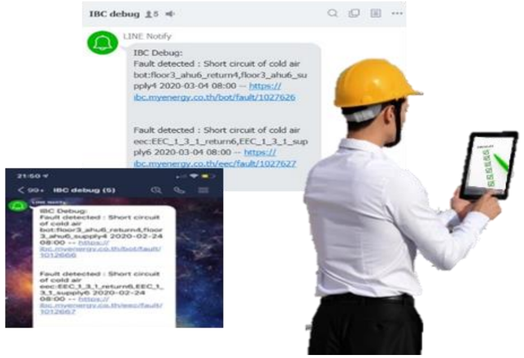
Online analytics and dashboard portal



Report, solve issues and verify performance

FM – Optimize workload, improve efficiency and decision making
Owners – Monitoring energy revenue and FM eff.
Customer dashboard – Environment Facts

Smart advisory report and notification



Bar code from factory :AA8R07E1M0059H630001

Device type: Water cooled oil free centrifugal

Device model: CC2110PWNI

IMU serial No: 110206012

Creation date: 2019-07-24 09:39:56

Operation:

Stop:

Chiller error:

Offline Diagnostic Platform

Fault diagnostics using BACNet data	Behavior and problems
Too low temperature from the set-point	Over-cooling resulting in automated reducing chilled water pump flow-rate and increase heat balance
Too high temp from the set-point	Insufficient load leading to higher full load amp (FLA) and energy use
Too low evaporator water temperature differences (CQ1)	Low delta T syndrome and too high chilled water pump (CHP) flow-rate
Too low condenser water temperature differences (CQ2)	Low delta T syndrome and too high condensing water pump (CDP) flow-rate
Too high evaporator water temperature differences	Too low chilled water pump flow-rate
Too high condenser water temperature differences	Too low condensing water pump flow-rate
Refrigerant undercharge	Liquid valve increases and increase power
Refrigerant overcharge	Liquid valve decreases and cooling ton loss
Condensing fouling	Higher saturated evaporator pressure
Unbalanced condenser and evaporator	Increase subsystem energy use (CQ1 > CQ2)

Offline Diagnostic Platform (B.1)

Excessive Energy - 35.5% from insufficient load

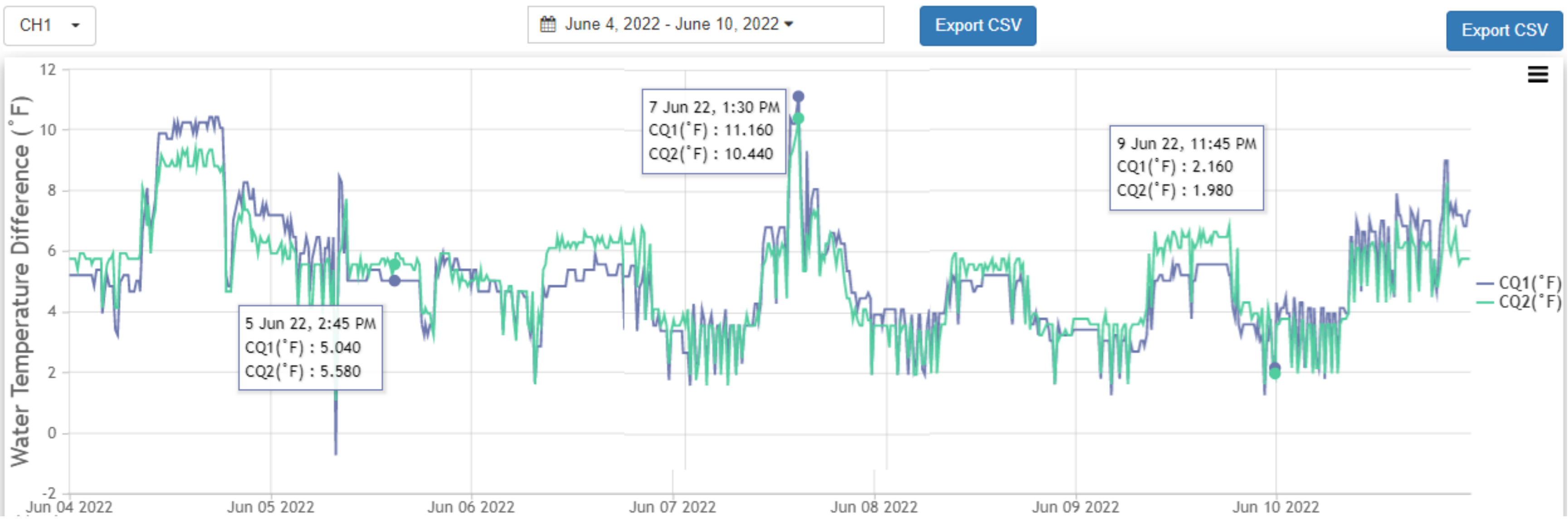
Solve by increasing CHP pump or increase set-point to 47 F instead of 45.5 F

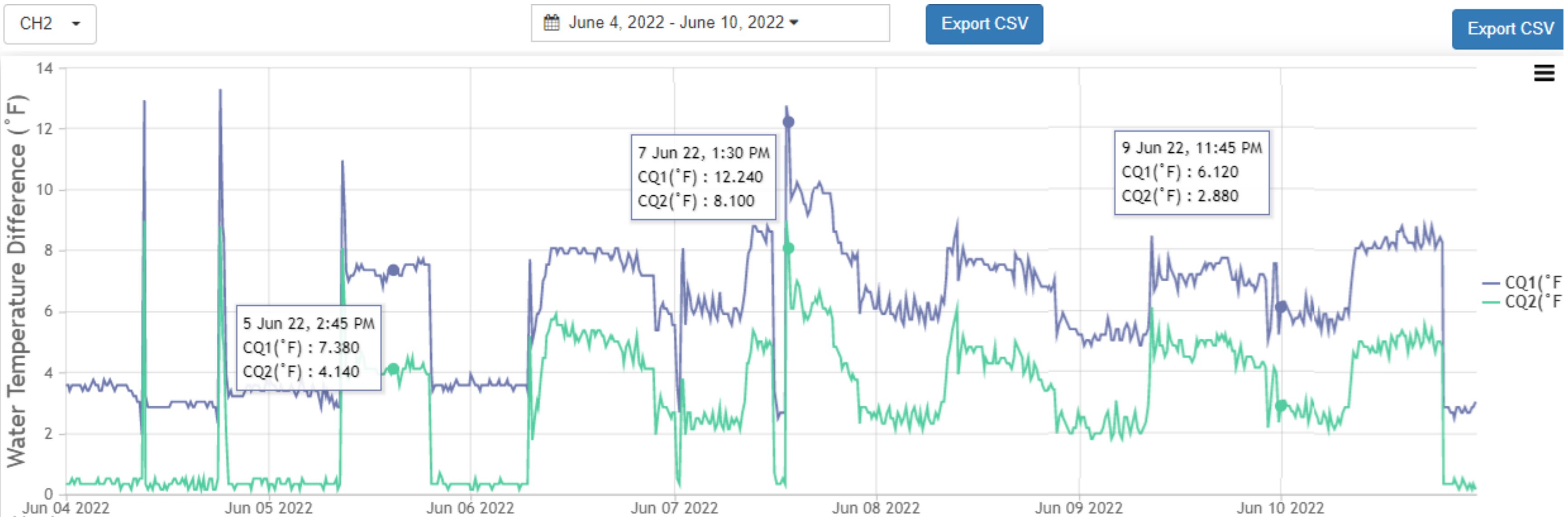
Offline Diagnostic Platform (B.1)

Unbalance CQ1 and CQ2 to increase cooling load

Solve by increasing CHP pump and reducing CDP pump

Offline Diagnostic Platform (B.2)



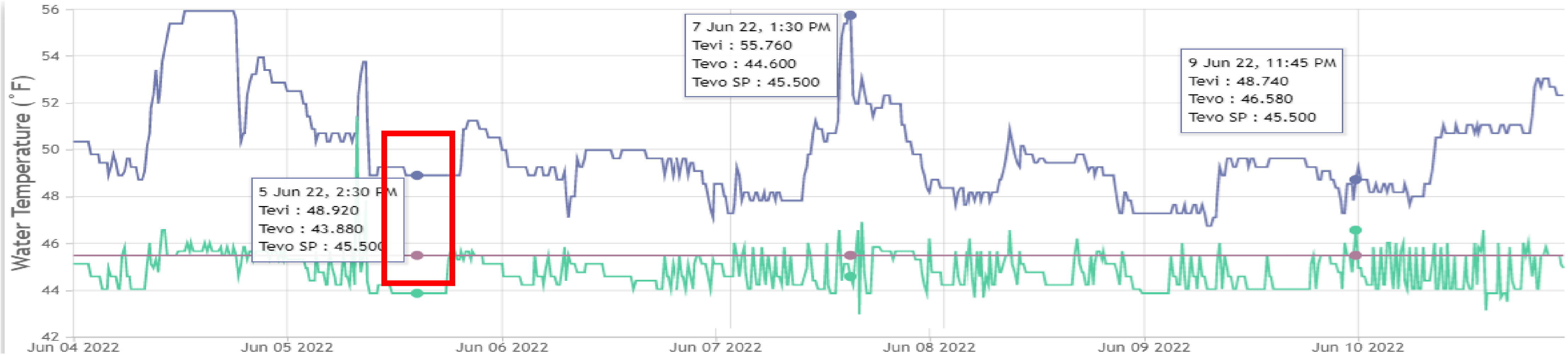


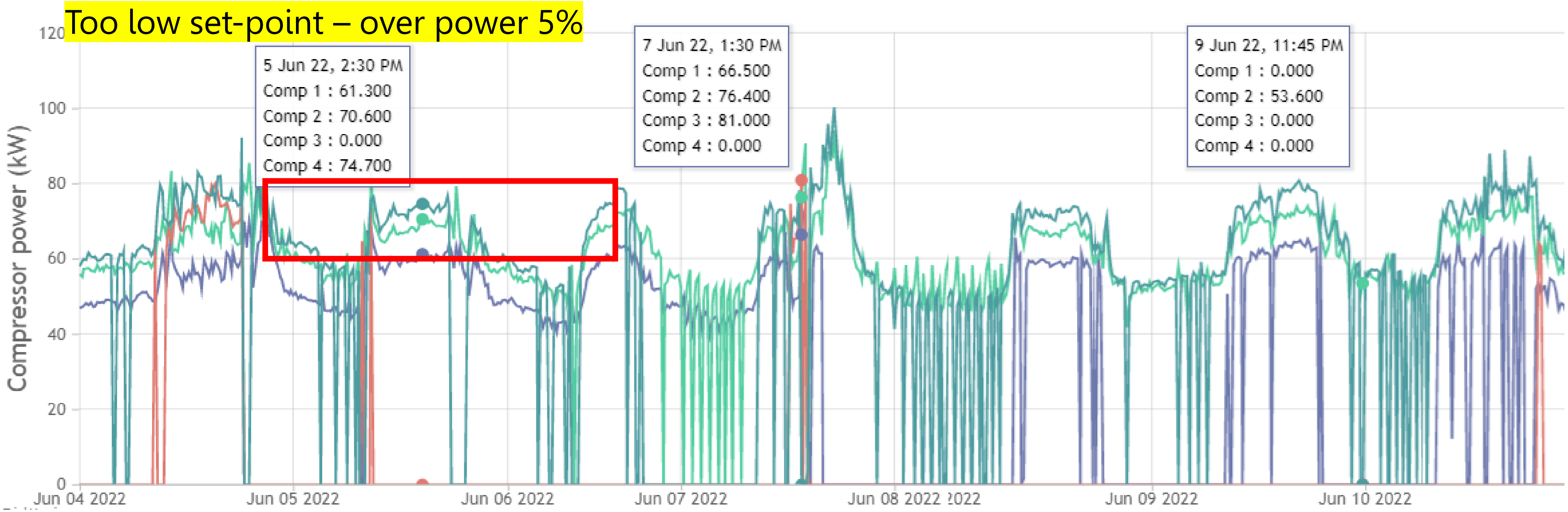
Unbalance Chiller 1 and 2;

increase cooling load

Solved by increasing CHP pump and reducing CDP pump

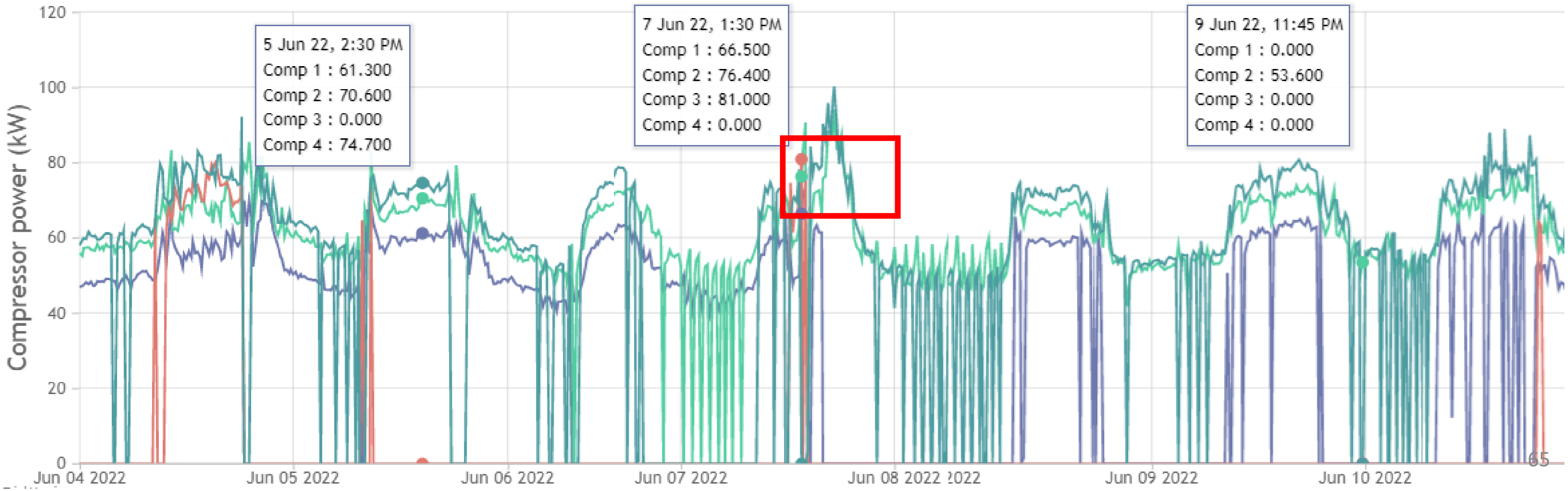
Offline Diagnostic Platform (B.2)



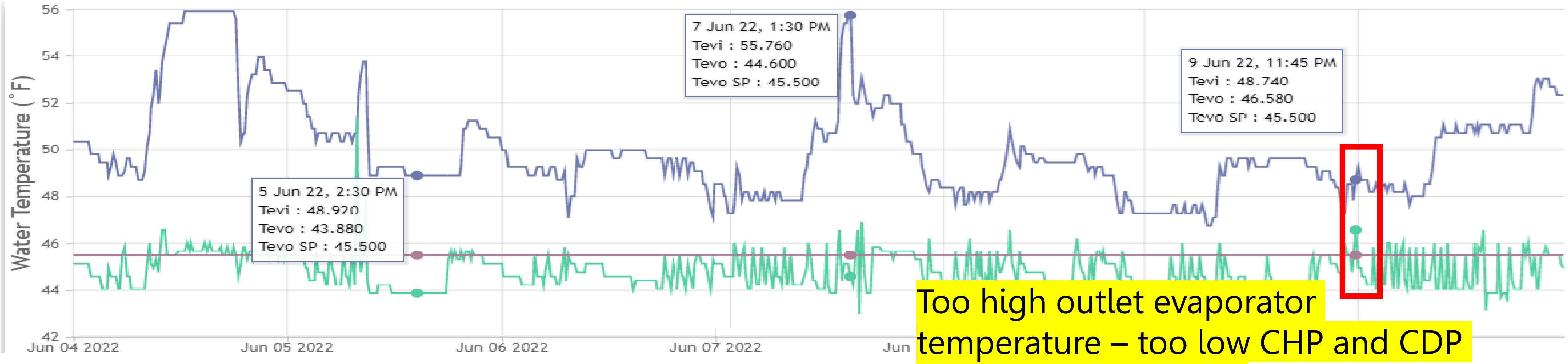


Offline Diagnostic Platform (B.2)

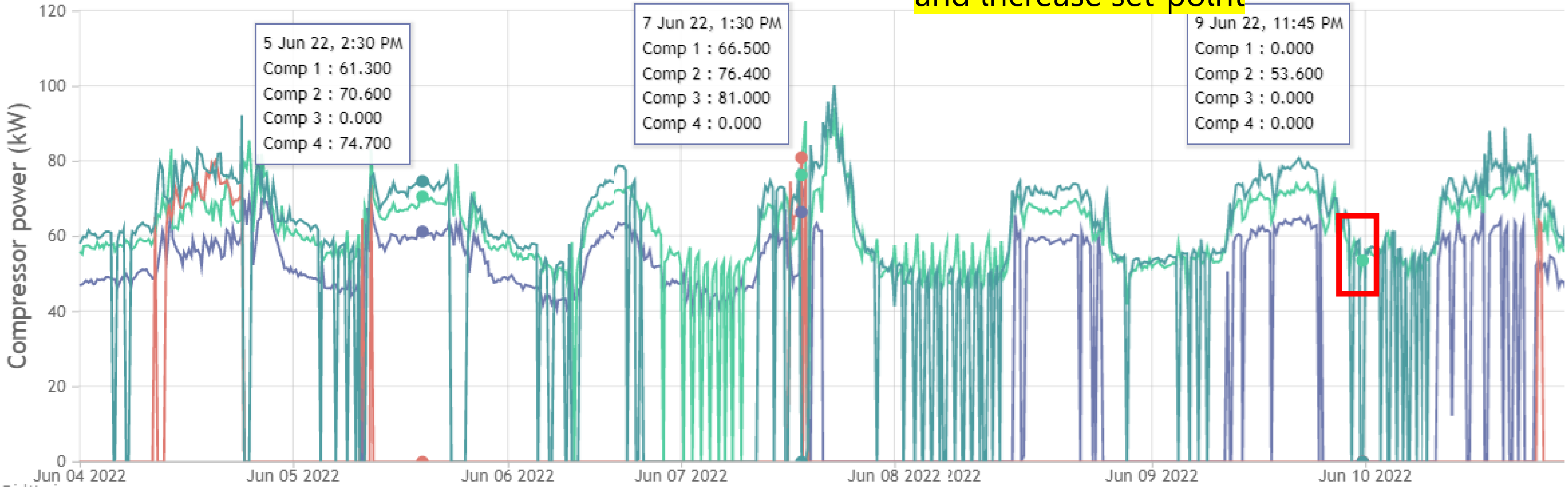
Too high return evaporator temperature – too low CHP and CDP



Offline Diagnostic Platform (B.2)



Too high outlet evaporator temperature – too low CHP and CDP and increase set-point

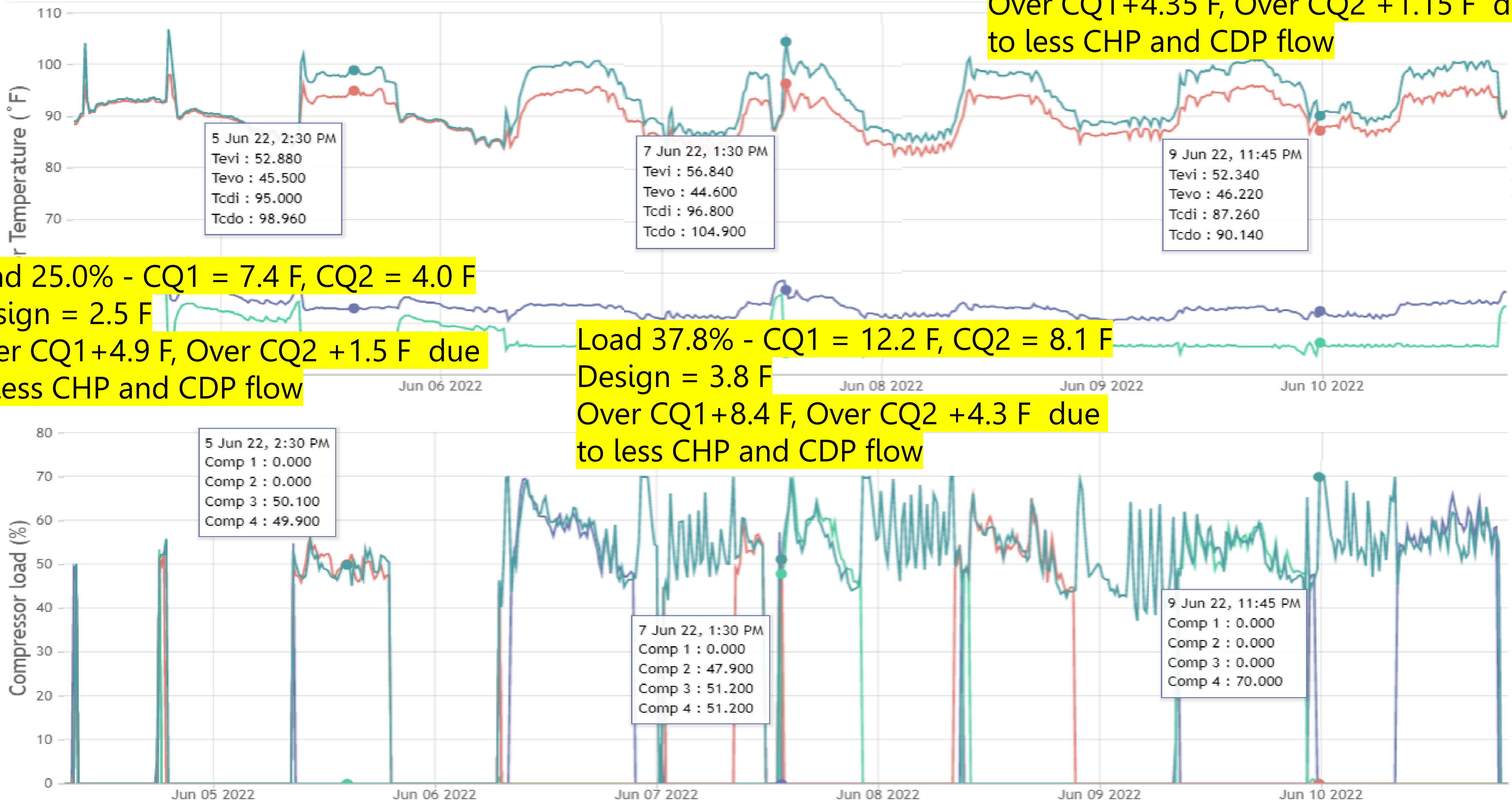


Load Balance Diagnostics

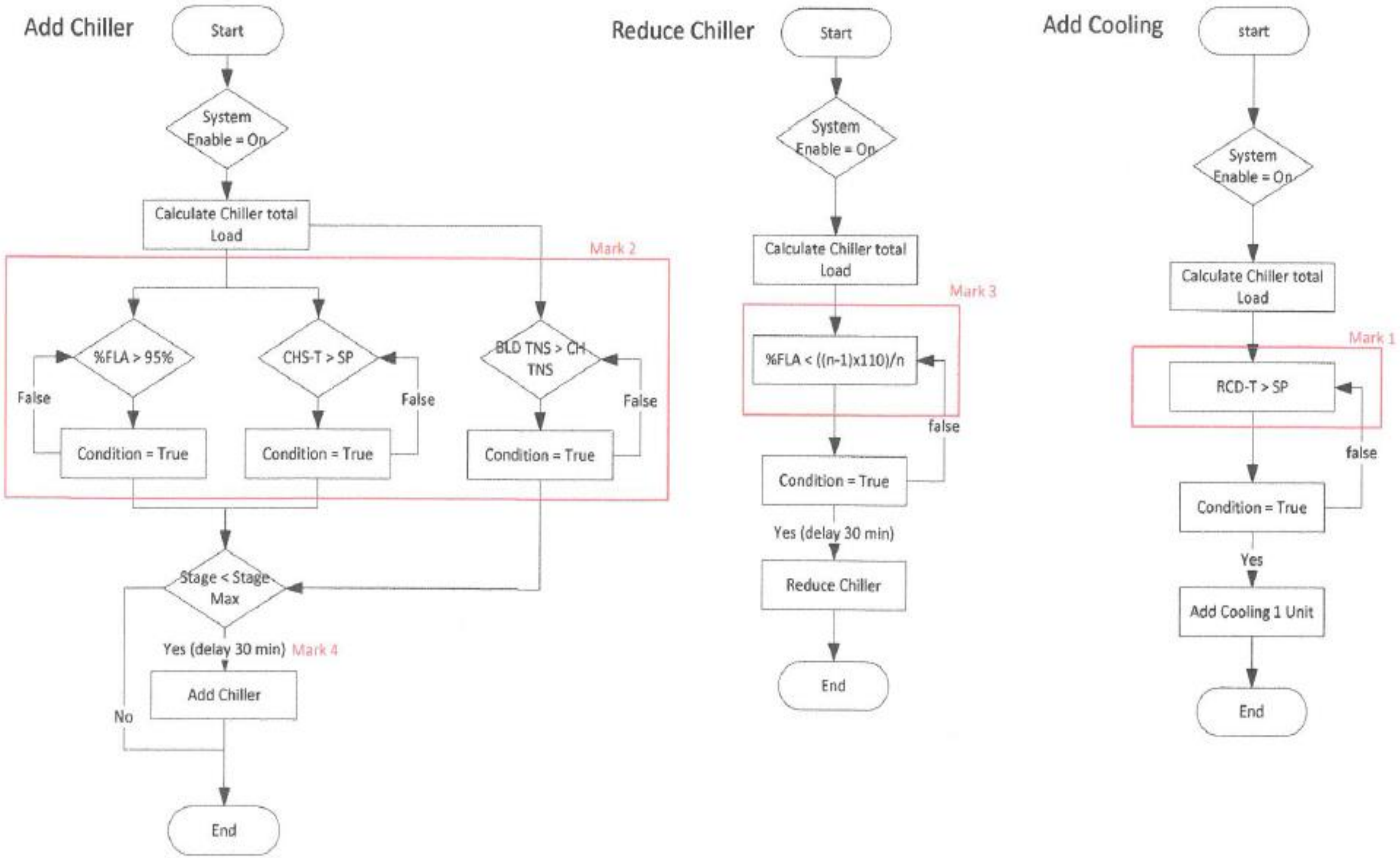
Load 17.5% - CQ1 = 6.1F, CQ2 = 2.9 F
Design = 1.75 F
Over CQ1+4.35 F, Over CQ2 +1.15 F due to less CHP and CDP flow

Load 25.0% - CQ1 = 7.4 F, CQ2 = 4.0 F
Design = 2.5 F
Over CQ1+4.9 F, Over CQ2 +1.5 F due to less CHP and CDP flow

Load 37.8% - CQ1 = 12.2 F, CQ2 = 8.1 F
Design = 3.8 F
Over CQ1+8.4 F, Over CQ2 +4.3 F due to less CHP and CDP flow

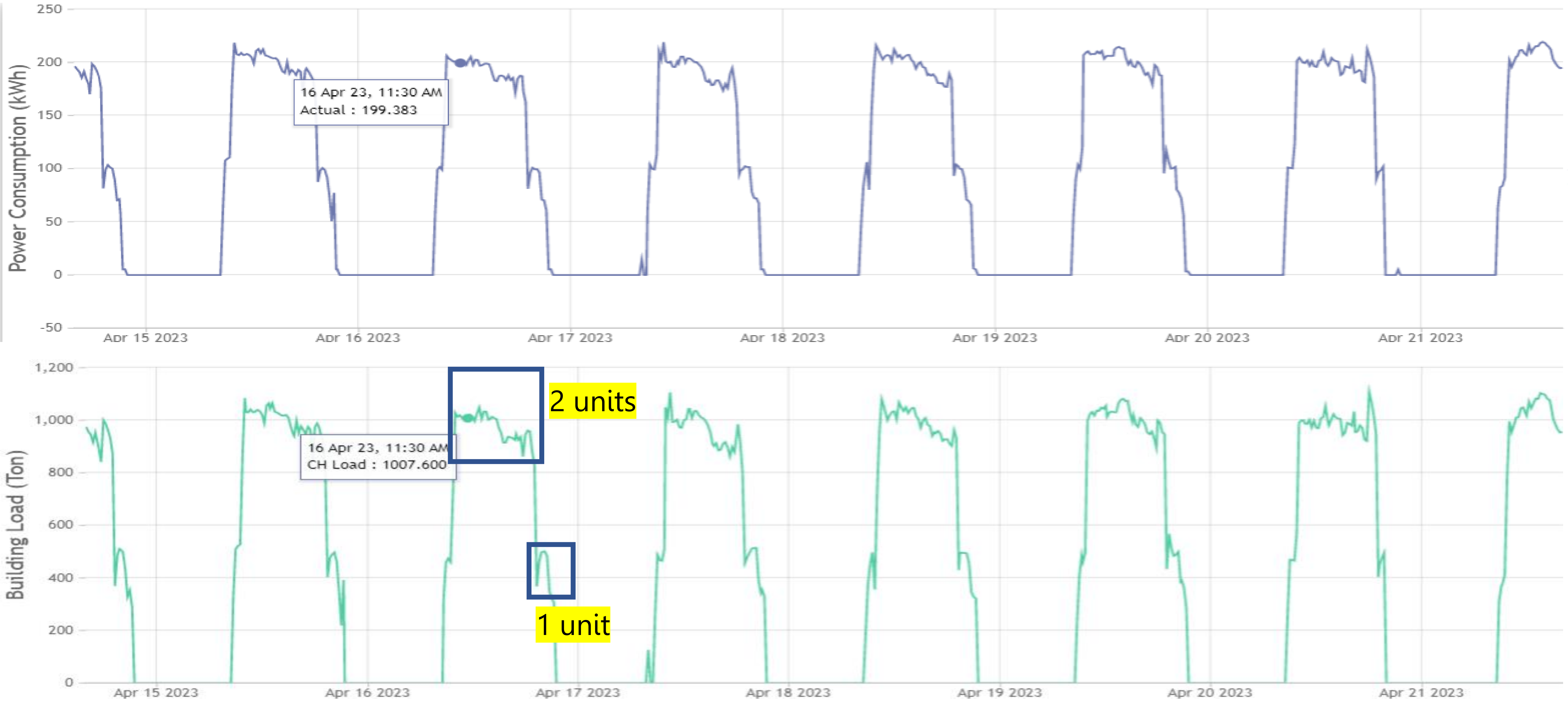


Typical Sequences – Chiller Plant



การตรวจสอบแบบ machine learning

Load Profile (kWh vs. Tons)



Load Profile (Tons vs. kW/ton)

THANK YOU !!

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WEBPAGE

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