PRELIMINARY DEVELOPMENT OF RETUNING PROCESS FOR ENERGY SAVINGS IN THAILAND

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Abstract

The retro-commissioning process has been energy-saving, around 20% on average in the United States. However, it has not been intensively used due to the cost-prohibitive issue of improving the building's existing air conditioning system to make it more efficient, which consists of the cost of the measurement system, replacing more efficient equipment, the cost of pre-and post-improvement inspections, resulting in a payback of more than three years. To solve the above problem, the Pacific Northwest National Laboratory (PNNL), a national laboratory under the control of the United States Department of Energy, has carried out designing a new process called re-tuning process; the process emphasizes correcting the original control system of the building, efficient use of building resources while remaining only the labour cost of adjusting the correct control system resulting in savings about 5 – 30% and low investment. The process can be performed every three years when building operations have improper operations. This research analyses and develops the retuning process applied in Thailand using the BAS data framework by analysing three main constraints, which are 1) CPMS (chiller plant manager system) guide, 2) AHU (air-handing unit) guide, and 3) zone guide to finding limitations of re-tuning to Thailand. Due to data and connectivity limitations of the BAS systems, the new process includes five steps of chiller operations. This tool can modify a CPMS system and lead to energy savings when existing systems are corrected by the tool to achieve an average of 5% energy savings for the chiller power consumption.

Keywords: *Building automation system (BAS), Chiller plant manager system (CPMS), Retuning, Retro-commissioning*

1. Introduction

Retro-commissioning (RCx) is a systematic process for investigating, analysing, and optimizing an existing machine building performance by measuring improved operations and maintenance to ensure their continued performance over time. Although RCx can upgrade the efficiency of the existing buildings' air conditioning system, leading to energy savings of 15 – 30% (Yu et al, 2015), the return on investment is practically over three years. As a result, this process is typically applied in only LEED EBOM (the leadership in energy and environmental design for existing buildings: operations & maintenance) approval.

To solve the problem of high cost and shorter payback period, Pacific Northwest National Laboratory (PNNL) is a national laboratory under the control of the United States Department of Energy which created the process of using the BAS system for maximum efficiency in energy saving of air conditioning system to obtain a payback period of less than one year (Brambley and Katipamula, 2009). The new design process, called the retuning process, focuses on correcting the existing control system of the building by operating from the existing BAS system. It also focuses on monitoring the control system, especially the critical sensor set-point, on ensuring the Efficient use of building resources and reducing costly equipment changes.

Started in 2007 - 2010 by the State of Washington, 25 buildings were expanded by 50 buildings with funding from The American Recovery and Reinvestment Act of 2009 (ARRA) between 2010 - 2013 using the process - Meta-analysis, which maps data patterns between air conditioning systems of similar buildings to create big data (big data) and usage patterns for energy-saving air conditioning systems. It can be performed every three years when an abnormality of the sensor system and performance is found, as shown in the figure. Along with creating an online training course to promote the retuning process in campaigning on using the BAS system to save energy on average 5-30% from adjusting existing BAS system, resulting in low investment.

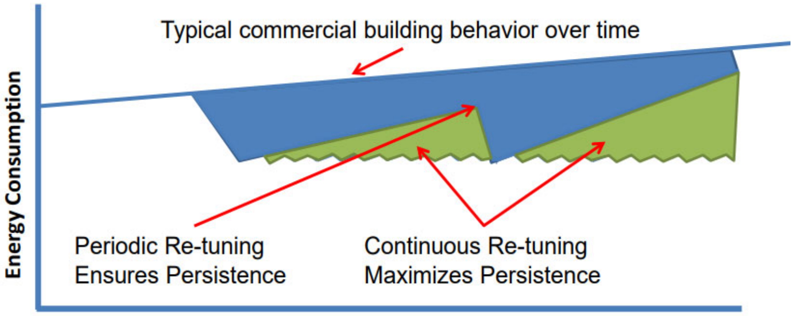


Figure 1 Periodic and continuous re-tuning process (Brambley and Katipamula, 2009)

With continuous improvements in BAS performance coupled with lower equipment costs, BAS installations have a payback period of less than two years, down from the 5.4 years estimated in the 1980s by research surveys and reports more than 40 years of installation (Cheng and Lee, 2018) from the use of 2 main technologies, consisting of control systems for air conditioning and lighting systems, divided into 5 sub-technologies as follows: 1) Schedule control of central plant system 2) The control system in the air-conditioned area achieves thermal comfort according to building standards 3) The use of variable speed control (VSD) to control water pumps and fans 4) The use of occupant-based control to control the on-off of electricity and 5) Use the energy management system to control the lighting system. From the above technologies, it is the same system used in Thailand. According to the research conducted by the author over the past 5 years on continuous BAS in Thailand (Woradechjumroen, 2022)., it was found that there is no study on the correct use of BAS systems, lack of proper installation guidelines and lack of proper evaluation of functionality compared to price. As a result, the re-tuning process is beneficial to improve these limitations. The re-tuning process should be applied in data training improvement and process utilization, systematically leading to potential data standards and analysis guidelines for BAS and CPMS in the future.

2. Literature Reviews

2.1 Re-tuning process

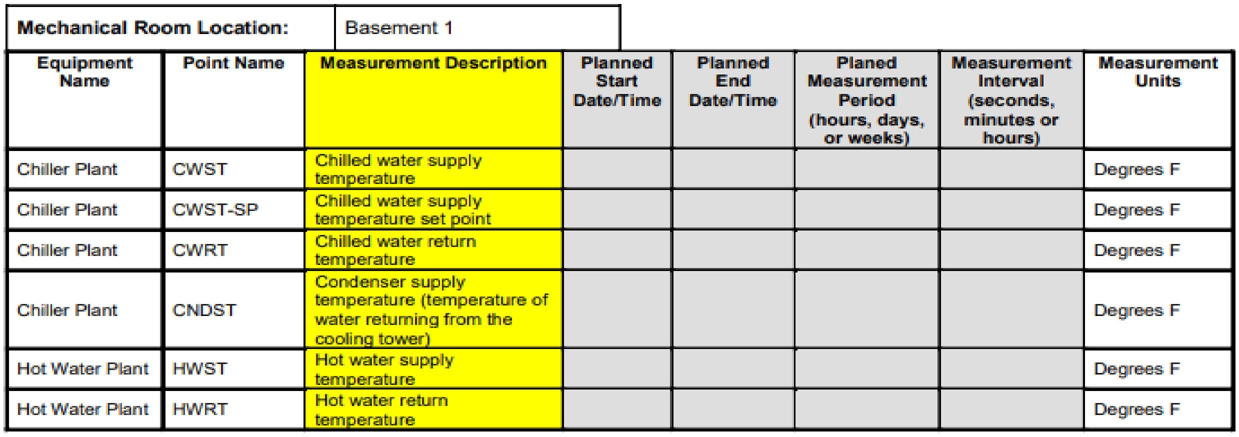
Performing re-tuning from the BAS control system is fundamentally resource intensive. It is based on the system configuration from the problem analysis process in the form of an offline analytic tool created from the data relationship between the input and output variables used to control each part of the air conditioning system, such as the outside air temperature leading to energy saving when wet-bulb temperatures drop or prevent chiller damage if temperatures drop below normal during winter consisting of 7 steps.

2.1.1 Step 1: Collection of BAS data and information

A collection of area information, building occupancy schedules, air conditioning, ventilation system operation data, installer and manufacturer data and BAS system usage data, and other data are collected to analyse the building's air conditioning system.

2.1.2 Step 2: Trend-data collection and analysis

Historical data is collected for fundamental problem analysis during building opening and closing time, both from the CPMS system and the air conditioning in the area. It can be used to identify faults from improper control system functions, enhancing the detection of faults that the building supervisor cannot detect. An example is a survey form for CPMS system data to design and create, as shown in Figure 2.



Mechanical Room Location:	Basement 1

Equipment Name	Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
Chiller Plant	CWST	Chilled water supply temperature					Degrees F
Chiller Plant	CWST-SP	Chilled water supply temperature set point					Degrees F
Chiller Plant	CWRT	Chilled water return temperature					Degrees F
Chiller Plant	CNDST	Condenser supply temperature (temperature of water returning from the cooling tower)					Degrees F
Hot Water Plant	HWST	Hot water supply temperature					Degrees F
Hot Water Plant	HWRT	Hot water return temperature					Degrees F

Figure 2 Data and example monitoring Plan (PNNL, 2012)

2.1.3 Step 3: Building walk-down system

Area survey procedures are to confirm the fault analysis results obtained from the above information for finding solutions with re-tuning or re-commissioning. In this step, two main issues are focused on (1) modification of the building automation control system and (2) correction of the sensor system related to the control system.

2.1.4 Step 4: Identification and implementation of retuning actions

The survey procedure confirms control system problems from trend data by establishing a system relationship between control input data and control output data variables that can be used to verify the set operation during the regular operation period and closed building periods, such as discharge air temperature of cooling air delivery system and pressure set-point value to check control variable, cooling coil valve according to building usage schedule. The outside air temperature may not be used as the driving force affecting the system to be analysed and corrected because feedback control systems are not designed to cover various air conditioning systems. It results in unnecessary energy waste.

2.1.5 Step 5: Report of findings, recommended actions, and recommendations implementation

Corrective action steps are based on fault details to identify the results of solving problems by using data from the BAS system to verify the results of appropriately correcting the air conditioning system's opening and closing from the control system. If an error occurs, the correction may be recalibrated back to steps 2 – 4. Most of the problems encountered in the retuning process include (1) lack of proper automatic timing settings, (2) Lack of detection of the correct position of the sensor in control, (3) Lack of automatic lighting control system, (4) Lack of calibration of the sensor system in the control system (5) Local air delivery damper and VAV damper stuck (6) Lack of reset pressure sensor at building closing time interval (7) Lack of reset chilled water set-point (8) Lack of reset discharge temperature set-point (9) Lack of setting The reset discharge temperature set-point (10) lacks the differential reset pressure chilled water loop and (11) the dead-band set-point is not suitable.

2.1.6 Step 6: Savings analysis

Corrective measurement procedures are compared with reduced electricity costs and creating appropriate set-point utilization charts, as well as various essential instruction manuals on the new BAS system.

2.1.7 Step 7: Continuous use of retuning in operation and maintenance

An additional periodic retuning procedure is performed in the additional operations and maintenance process, emphasizing regularly checking set-point settings and related trended data every 1-2 months.

2.2 Retuning system examples

2.2.1 AHU (air-handling unit) re-tuning:

According to the study data, it was found that the most common problems in the prototype building were (1.1) The pressure sensor setting for the air volume control of the cooling system was not appropriate (1.2) The pre-cool set point is not suitable according to the change in outside air temperature. Other problems that affect AHU energy loss include calibration of the sensors used in the controls and the installation or modification of the system from the lack of standardized testing.

2.2.2 Zone retuning

The most common problem of this system is (2.1) Setting the minimum VAV box is too low, causing insufficient cooling air when the system is working at part-load (2.2) Adjusting the set-point dead-band range is too wide, the VAV box cannot control the temperature correctly. (2.3) The temperature sensor has a problem with distorted readings, causing problems that result in power loss. For example, it measured higher than normal value, affecting the use of cold water more than usual.

2.2.3 Schedule retuning

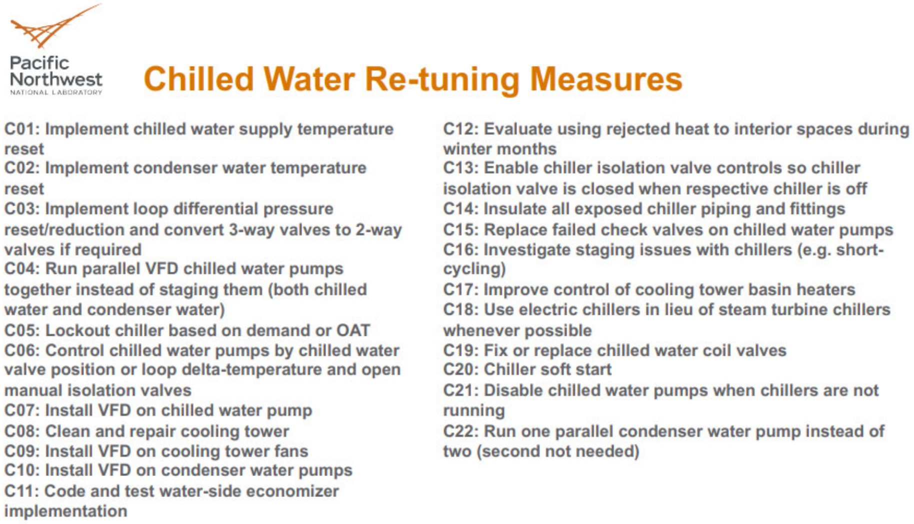
The study's results summarize common problems caused by inappropriate set-point settings of the building's usage schedule, including the usage data of building tenants. This problem results in unnecessary energy wastage and thermal comfort issues.

2.2.4 Chilled water retuning: Chilled water retuning

Summarizing the error data shown in Figure 3, the most common problems are (1) improper adjustment of the chilled water set-point according to the external climate and (2) inlet cold water adjustment is improper causing the opening and closing of the cooling towers which are not related to the chiller operations (3) If adjustment of the differential pressure sensor loop set-point is improper, the chilled water retuning problem affects higher power consumption.

2.2.5 Control system retuning

The most common problem is the BAS system upgrade; the system works abnormally from the original works. The problems that affect the loss of BAS system power include installing different equipment brands and being unable to work correctly with the original system.



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)

Figure 3 Chiller water re-tuning measures (PNNL, 2012)

3. Methodology

From section 2.1 and 2.2, the parameters and monitoring in the retuning process can be summarized as shown in Table 1. For this research project, the BAS system control was not considered due to the installation limitations in Thailand: 1) The CPMS system is typically linked to t the data and control of the BAS system, and 2) The BAS system does not record data in the system. For the re-tuning development of CPMS tools, Sections 3.1 and 3.2 are analysed for the PNNL guide limitations according to the available datal; the analysis is used to design the re-tuning process in section 3.3. This developed process has applied the principles of data interaction (Woradechjumroen (2019) and Widsonkun et al (2019)) previously researched by the author to improve the retuning process for Thailand. Initially considering the exact scope of application as the PNNL guide and adding essential procedures in Thailand from the AFDD (automated fault detection and diagnostics) audit data with the EMIS (energy management information system) tool, Table 1 summarize limited data and conditions in Thailand, and Table 2 concludes the data used to create a retuning system guideline. CPMS and zone retuning are only analysed in this article because AHU data are typically unavailable in BAS.

3.1 CPMS retuning analysis

3.1.1 Resetting the chilled water set-point

This function cannot be performed like PNNL because the CPMS is not connected to the BAS systems in Thailand because they are different brands. System integration requires additional costs, so the cooling control valve signal (CC_signal) cannot be applied in the new guideline. Zone monitoring can compensate for the cooling control valve percentage.

3.1.2 Adjustment of Tevo set-point values according to OAT temperature

Temperature adjustment without causing low-delta T syndrome cannot be examined similarly because the PNNL system operates on OAT for two seasons and has a broader range of OAT variations than Thailand. In addition, some buildings in Thailand are not equipped with OAT sensors. In CPMS systems, investigations can be made using data interaction principles to verify Tevo set-point adjustments and low delta syndrome by using two functions: 1. Use the Tevo value for the chiller load, and 2. Use the cold-water temperature difference (CQ1) for the chiller load to verify that the cold water is adequate for the system without causing the low-delta syndrome.

3.1.3 The pressure set-point adjustment

The pressure set-point adjustment cannot be performed because the CC_signal value is not connected to the CPMS, but it can be substituted by using the pressure set-point value to the building load and local moisture value instead of the original analysis of PNNL.

3.2 Zone control retuning analysis

3.2.1 Set-point setback during night operation

The control functions use OCC_mode and HC_signal to check suitability; however, both values are not used in Thailand. In addition, the building is not operated 24 hours a day, and there is a typical air-side short circuit problem in Thailand, leading to different feature investigations. Zone temperature and humidity can be used with the control signal of the VAV box instead of the PNNL guideline.

3.2.2 Simultaneous verification of cooling and heating systems

This problem is not necessary to consider as there is no reheat coil system in Thailand, but there will be abnormally high humidity in the area due to too much minimum VAV box setting and air short-circuit problem causing the system not to work.

Table 1 Retuning process and limitations

PNNL guide	Investigation	Parameters	Data limitations
CPMS	1. Setback chilled water set-point	Tevo (chilled water temperature), CC_signal (cooling coil valve signal), OAT (outdoor air temperature)	CC_signal and OAT are not recorded and linted to CPMS
	2.Adjusting Tevo set-point	Setpoint, Tevi (return chilled water temperature), Tevo	OAT sensor is unavailable in some buildings
	3.Adjusting pressure set-point	Setpoint, Ploop (loop pressure),CC_signal	-
Zone	1.Setback set-point for any periods	OCC_mode (occupancy mode), ZAT (zone air temperature), HC_signal (heating coil signal)	OCC_mode and HC_signal are unavailable
	2. Simultaneous cooling and heating check	OAT, ZAT, HC_signal	Not incurred in Thailand

Table 2 Parameters per a chiller

No.	Parameters	Description	Use
1	Tcdi	Inlet condenser temperature	Cooling tower control
2	Tcdo	Outlet condenser temperature	CQ1 = Tcdo -Tcdi
3	Tevi	Inlet evaporator temperature	CQ2 = Tevi - Tevo
4	Tevo	Outlet evaporator temperature	Chiller control
5	kW or kWh	Power or energy consumption	Energy savings
6	Load	Evaporator cooling load	Baseline
8	Tcond or Pcond	Condenser pressure or temperature	CQ6
9	App_cond	Condenser approach temperature	CQ6 = Tcond - Tcdo

3.3 Retuning design process

From the analysis of sections 3.1 to 3.2, the process and limitations are used to design the modified retuning procedures in Thailand using Table 2. Five-step procedures are designed as shown in Figure 4.

Figure 4 5 steps of CPMS retuning process in Thailand

4. Retuning process implementation

4.1 Step 1 - Tevo graph versus chiller load

It examines the behavior of the Tevo set-point setting by showing the graph against the chiller load and then considering the characteristics of the chiller over time, such as the building opening period, insufficient cooling or normal range. According to Figure 5 when the system operates at normal condition, Tevo values must be controlled within the set-point range. Outliers occur at 7:00 a.m. at a 30% chiller load and at 8:30 a.m. at 97.2% of the chiller load. When the building is open, and the system is still unable to cool down regularly and can cool properly after 10:00 a.m.

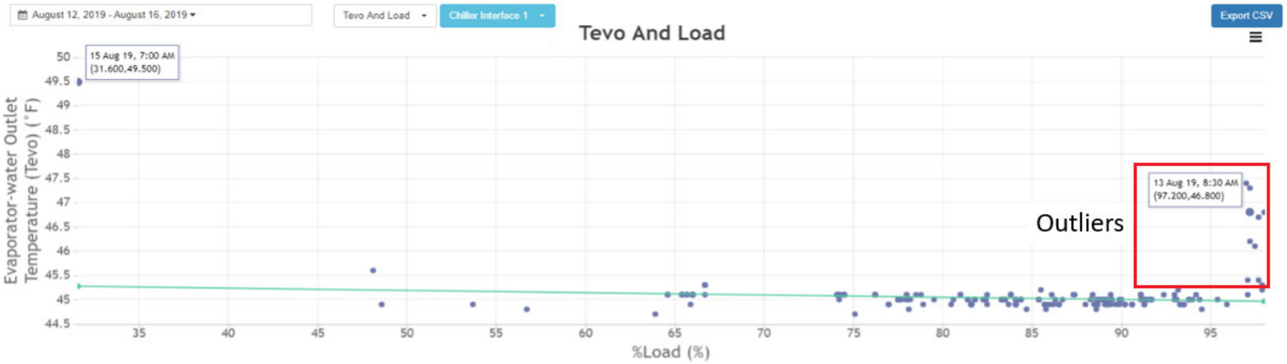


Figure 5 Step 1 Check Tevo values against chiller load, constant chiller type system, and constant flow rate system.

4.2 Step 2 - CQ1 versus chiller load graph

It examines the difference in cold water temperature that can be achieved from the chiller (CQ1) compared to the chiller load. Specify the same operating time as in step 1, as shown in Figure 6. Both insufficient cooling periods are outside the red parallel lines generated from the chiller manufacturer's data.

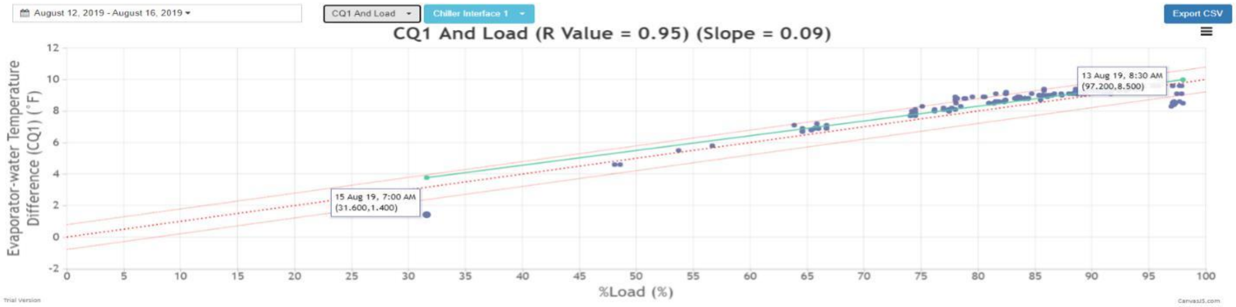


Figure 6 Step 2 Check CQ1 value concerning chiller load, constant chiller type system, and constant flow rate system

4.3 Step 3 - Tcdi and Tcdo versus chiller load graph:

This step checks the cooling tower cooling by checking whether the Tcdi and Tcdo values meet the design, e.g., Tcdi at 100% is at 90 °F while Tcdo of 100% is about 100 °F. If the cooling tower is degraded or out of service, both values will increase, resulting in reduced cooling efficiency affecting the condenser performance. Check the operating range is affected by steps 1 and 2. Figure 7 shows that Tcdi increases by about 1.5 – 2°F at 100% chiller load, and Figure 8 shows Tcdo increases by about 1.5 – 2°F at 100% chiller load, the same results in higher cooling and electricity bills. Moreover, faulty operations in the condenser and cooling tower due to over flow-rate lead to severe outliers and reduce the R-value level.

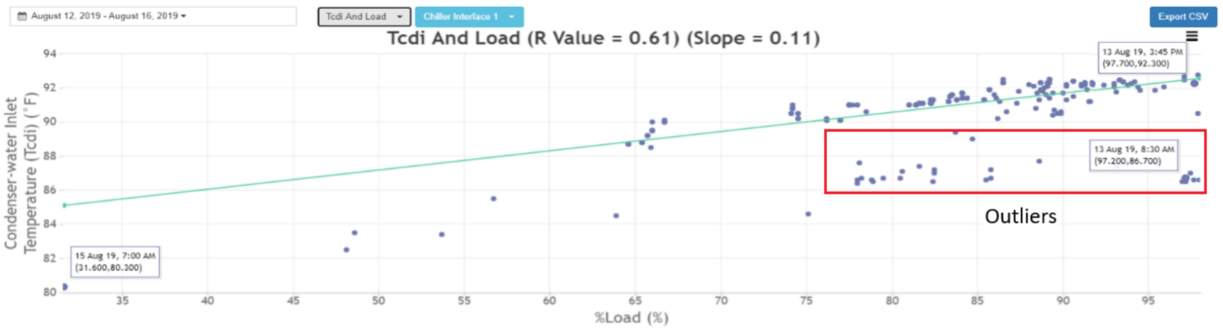


Figure 7 Step 3 check Tcdi value with chiller load, constant chiller type system, and constant flow rate system.

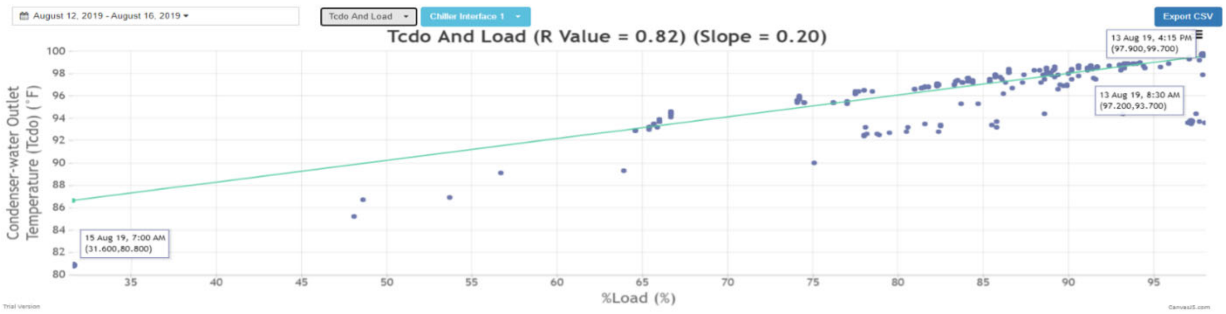


Figure 8 Step 3 check Tcdo value with chiller load, constant chiller type system, and constant flow rate system.

4.4 Step 4 - Tcdi and Tcdo versus chiller load graph

It checks the cooling at the condenser from the CQ2 value by specifying problems from steps 1 to 3, as shown in Figure 9. CQ2 is approximately 2- 2.5 °F lower than the original design. At 100% chiller load, a CQ2 of 9.4 °F is reduced to 7 °F at 97.2% chiller load due to over cell operations of the cooling tower in lower-than-normal CQ2 values.

4.5 Step 5 - Step 5 CQ6 and kW versus chiller load curve

This step checks the cleanliness of the condensing tube with CQ6 value, which is typically about 5 F at 80% chiller load, and used to compared to power consumption (kW) in Figure 10. It shows that the outliers are within the acceptable range. The normal value at 80% chiller load has a CQ6 value of 4.1 °F. It is considered that the condensing tube is clean from the installation of a ball-cleaning system (3% on average). Then the power consumption can be evaluated at the outliers. The power consumption was about 7.3% higher than the manufacturer's data, as shown in Table 3 and Figure 11, due to higher Tcdi and Tcdo values that reduce cooling efficiency. All five steps of the data examples can be used to examine the chiller operations of the CPMS in the design range (CQ1 and CQ2), leading to energy-saving potential when outliers of each step are corrected.

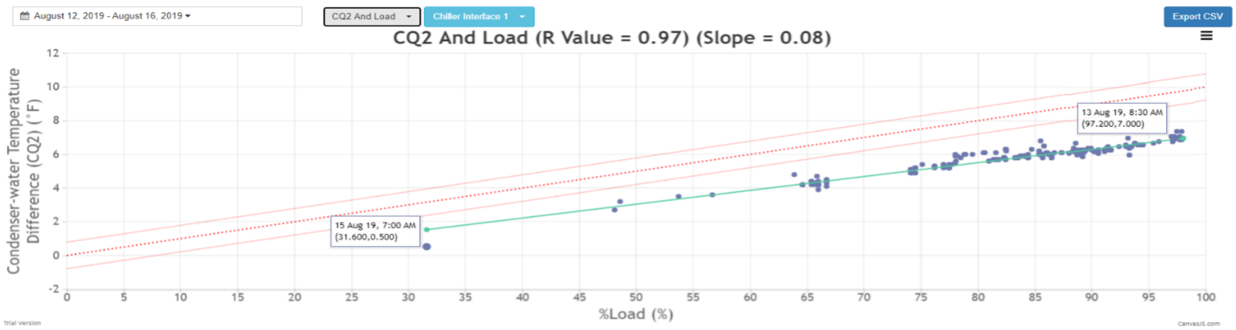


Figure 9 Step 4 Check CQ2 value compared to chiller load, constant chiller type system, and constant flow rate system.

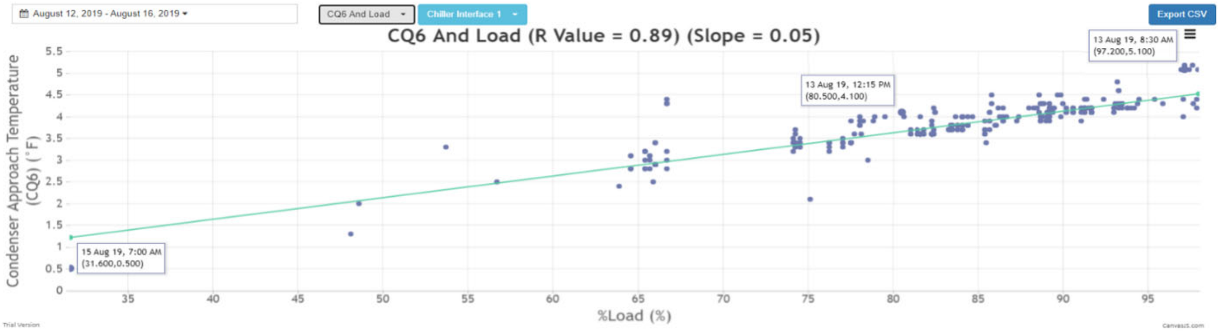


Figure 10 Step 5 Check CQ6 value compared to chiller load, constant chiller type system, and constant flow rate system.

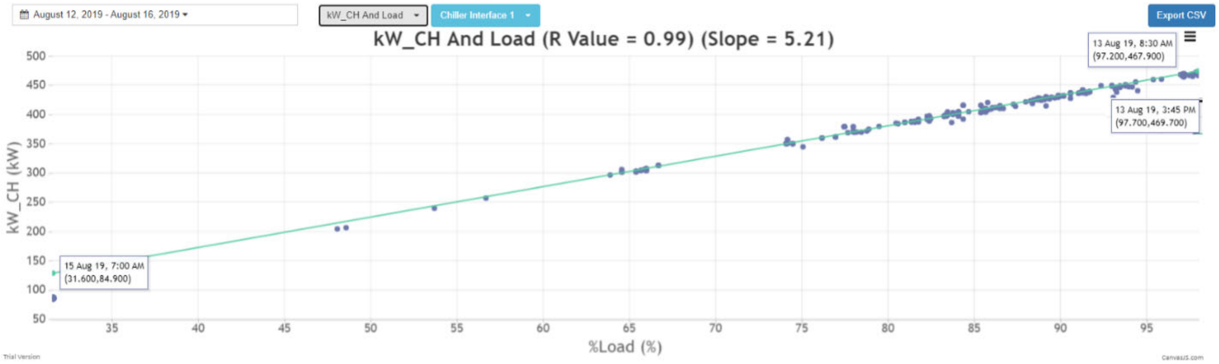


Figure 11 Step 5 Check kW value compared to chiller load, constant chiller type system, and constant flow rate system.

Table 3 Power consumption loss investigated by interaction steps 1 - 5

Load	kW	Actual kW	%	Tcdi	Tcdo
97.2%	436.1	467.9	+7.3%	90	99.4

5. Conclusion

Without the standards and guidelines for CPMS and BAS analytic tools in Thailand, the retuning process of the PNNL lab is studied and analysed to configure data and process limitations applied in Thailand. This project presents the audit and assessment process of data analytic procedures. CPMS retuning of the PNNL guideline are investigated to develop a new interaction tool quantifying relations between the chiller and characteristic quantity (CQ) parameters. The IBC platform designed by a Thai startup company is used to test the new concept of the retuning process. Five steps of the CPMS retuning are designed and tested in two large-scale governmental buildings. As a result, the tool is suitable for downloading the CPMS data to detect outliers incurring energy loss. The results show that energy loss in the existing system leads to energy-saving potential at least 3% on average whenever the proposed returning processes are applied to retrofit the system performance. This tool can be further applied to implement in other buildings to find feasible energy savings and expand all AHUs and zone returning in the future.

6. Acknowledgments

The author is deeply grateful to The Electricity Generating Authority of Thailand (EGAT) and Thailand Science Research and Innovation (TSRI) – RDG62D0006 for financial support to develop standard data in the project titled “Process and metrics development of BAS utilization efficiency for energy savings of a chiller system via EMIS tool – phase 1”.

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