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Implementation of Cooperative Education Projects Utilizing S-BEST for Research and Development Department in Thailand: A Case Study in Building Energy System Industry

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Abstract

Cooperative education is a modern work-integrated leaning designed to mainly: 1) enhance practical student learning in companies; 2) learn methods for solving problems in real applications; 3) increase career opportunities after graduation; and 4) develop research collaboration in terms of research and development (R&D) in a companies. The aforementioned objectives are considerably successful for the students who do choose cooperative education instead of senior projects in developed countries because the collaborated companies have been planning procedures and experienced advisors for training co-op students to be their employees after graduation. Especially, utilizing practical problems from research and development (R&D) department is an excellent strategy for long-term cooperation between an institution and the incorporation. However, it is still one of co-op gaps in developing counties to efficiently conduct the co-op education in terms of R&D. This paper feasibly proposes systematical procedures to design and implement co-op projects in Thailand energy management industry by using smart building energy solution technologies (S-BEST), which is a non-invasive and smart technology based on existing technologies in each building; five main components of S-BEST are briefly introduced and are adjusted appropriately to evaluate how to develop R&D department of an energy management company. To this end, 6 steps of the designed projects and 5 steps of R&D development are used to design co-op projects corresponding to co-op student skills. With the implementation of the procedures, 11 projects are eventually designed. Utilizing qualitative research method based on the focused group interview, the proposed methodology can satisfy the executive members and project engineering teams of three relating companies, and can be further used for research cooperation for challenging the research fund of novel building technologies from Thailand association agencies. For the future co-op study, this paper contributes a guideline for ongoing co-op projects applied in real and commercial applications as long-term research collaborations, which are still infancy in Thailand.

Keywords: Cooperative Education, Energy Management, Intelligent Building Collaboration, Smart Building Energy Solutions Technologies, Research and Development.

1. Introduction

A project-based learning approach has been designed for training senior engineering students before graduation; each student group can choose a topic from the list corresponding to their interests or designed projects. Contributions and advantages to senior students may depend on: 1) their personal skill being able to link between a selected project and real applications in related companies; 2) a topic which is designed based on the practical problem assigned by a company or factory; 3) a funded research topic of the faculty member that can be applied in practice. However, practically, senior project learning leads to significant barriers: 1) the first issue is difficultly happened since most senior engineering students lack of experiences and visions, and then they could not understand exactly how to apply a research topic in the real world; 2) the second issue is familiar to one of cooperative education concepts as commonly known as a co-op, but students mostly do experiment or conduct a topic in a university, rather than work in a cooperating company; this happen may lead to misunderstanding of the project objectives and expected research outcomes; and 3) Lastly, this issue may be applicably succeeded in developed counties. For example, in the U.S., fundamental research and enabling research are distinguished evidently. Know-how or innovative theories will be funded in the fund namely National Science Foundation (NSF) Grant, and then the U.S. fund agencies such as Department of Energy (DOE) and American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) awarded several enabling projects. The conducted reports can be applied by potential and effective companies in research and development (R&D) department. As a consequence, undergraduate or graduate students who joined the funded NSF or ASHRAE are highly recommended and are increased opportunities to obtain jobs in R&D of companies.

To tackle the aforementioned limitations of the senior project-based learning, co-op education has been developed and ensured the quality of the co-op program by the Accreditation Board for Engineering and Technology (ABET) because many universities have adjusted co-op processes in engineering program resulting in different work evaluation [1]. With the applied standard, co-op projects can mainly overcome the first barrier that senior students can learn practical works, thus they can understand the correlation between interesting research topics and real applications. Meanwhile, co-op education can reduce the misunderstanding of the project objectives and expected research outcomes because each student works full-time at a company under the company supervision, so the project outcomes and objectives will be directly conducted under the scope of the company. As a result, the project can be finalized and applied in solving company problems. Additionally, NSF and ASHRAE fund are considerably competitive to be awarded. Therefore, co-op projects can strongly penetrate this barrier between research and commercialization as mentioned in the last issue. To this end, a company can cooperate with a university to jointly develop patents or fundamental researches for generating a product prototype or innovative technology.

In Thailand, even though the co-op program concept was initially proposed in 1993 by the founder of Suranaree University of Technology (SUT), Prof. Dr. Wichit Srisaarn [2], and the co-op education implementation which were successfully applied to real industries can be further studied in Chakpitak and Tonmukayakul [3] and Sermsuke [4]. The co-op concept can address only the first barrier, but it cannot solve the other barriers because it still lacks of standard evaluation and potentially cooperating companies. To enhance these last two barriers, this paper proposes the methodology applying smart building energy solution technologies (S-BEST) to one of the professional Thailand energy management companies namely Innovation Technology Co., Ltd. This company actively joins the co-op program with School of Engineering at Sripatum University so as to be the first incorporation for producing a new company sector as R&D department. This company envisions scalable, intelligent and sustainable buildings which provide personalizable, comfortable and productive indoor environments with low energy and environmental impacts in terms of novel technologies and patents via applicably and effective co-op projects in Thailand.

2. S-BEST Applied to Thailand Energy Management Companies

To leverage traditional energy management strategies and approaches to decrease service costs and maintenances in terms of efficiently measured data and optimal assigned work load in commercial buildings, this section briefly proposes Smart Building Energy Solutions Technologies (S-BEST) which is applied and adjusted to suitably match with existing technologies in current Thailand building energy technologies [5]; the projects will be initially deployed in one of the best conventional Thailand energy management companies which also agree with the first author to leverage and penetrate existing energy management technologies with S-BEST. In the contents, we will systematically analyze how to apply the novel methodology to efficiently improve out-of-date solutions. The proposed design of co-op project can contribute as a role model of powerful co-op education in terms of developing research and development cooperation through a long-term co-op project strategy.

According to the vision illustration as depicted in Fig. 1, S-BEST is integrated the multi operations with multiple connections of energy systems, building environment, community and manufacturers through data exchange carrier in terms of web-based or on-line monitoring system (e.g. chiller monitoring systems). The procedures of S-BEST for leveraging building energy efficiency are suitably adjusted for Thailand building technologies as follows:

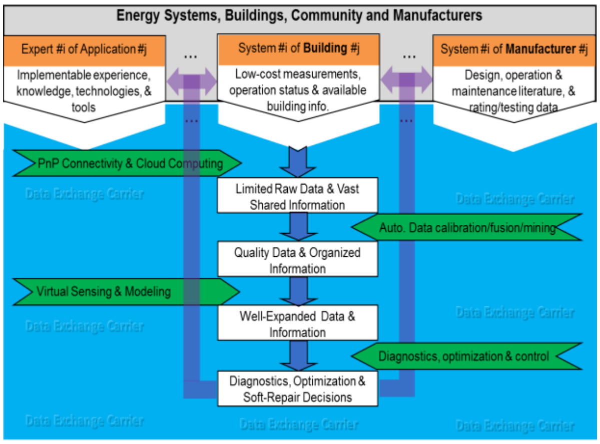

Fig. 1 Vision of S-BEST [6]

2.1 Data exchange carrier

Currently, data exchange carrier consists of: 1) building automation system (BAS) that is mainly utilized as the local centralized data storage in each smart building; and 2) cloud computing which is utilized to extend limited data storage of the local building server, and to share recorded building data via wired sensor or wireless sensor systems. With this system implementation, manufacturers or building system analyzers can evaluate building system performances and resend alarm or diagnosed faults to building operators immediately. However, shared data information via the carrier could be a future technology in Thailand. In the short-term development using co-op projects for R&D, the existing technologies are chiller monitoring system through the on-board controller, and BAS are systematically utilized for enhancing building energy efficiency.

2.2 Automated calibration and data fusion

This is an automated process to permanently reduce or eliminate inherent errors which are always occurred in physical sensors. Typically faulty measurements are caused by bad location, out-of-calibration and sensor failure leading to energy savings significantly at field control levels. To automatically eliminate sensor faults, errors are compensated by errors measurement based on simple regression analysis. This step will be designed as a co-op project in terms of investigating faulty sensors in chiller systems. Also, the recorded data of BAS systems are surveyed and analyzed through several case studies of BAS installations using scoring rubrics for efficiently evaluating the surveyed data. Meanwhile, data fusion will be conducted in the verification of recorded data because sensor calibration and data verification are seldom included in Thailand energy management process.

2.3 Virtual sensing and modeling technology

Virtual sensing and modeling technology are mainly developed for expanding limited sensing with low-cost measurements and available data obtained from manufacturers. The modeling method can be developed by utilizing system dynamics, system identification techniques and regression analysis. In designing a co-op project, chiller system modeling is never developed for energy optimization in Thailand. A student will use data fusion to verify the recorded data obtained from BAS to construct a simplified chiller system model based on regression analysis.

2.4 Automated diagnostics

Automated diagnostics can be fully referred to automated fault detection and diagnosis (FDD) which currently plays increasingly important role in the operation and maintenance of HVAC equipment. Enabling AFDD can eliminate waste energy caused by faults and non-optimal operations in HVAC systems up to 30% in average [7] and enhance productivity and reduce maintenance costs by 70% of yearly preventative maintenance [5] because sudden or degradation faults occurred during routine operations, service maintenance and commissioning are practically caused by unsuitable and/or faulty design and system operations; they can be diagnosed before the systems become failure. In Thailand, preliminary FDD results are not investigated yet.

Thus, two simple FDD projects are designed to consider Thermodynamic properties of chiller and real-time chiller power monitoring system. The self-correction of diagnosed FDD can be coded in terms of soft-repair technique based on the controller functions of a chiller. However, in Thailand, this technique cannot be conducted because soft-repair performing as a supervisory or coordination control that combines all feedback measurements from each sub-system to the coordination control for making decisions. This main controller requires the complete functions of BAS which are mostly unavailable features in Thailand high-rise buildings. Specifically, building prototypes supervised by Innovation Technology Co., Ltd., in which S-BEST will be enabled, have incomplete BAS functions. As a result, the co-op project will be designed by proposing easy-to-use optimization technique to reduce excessive power consumptions in chiller operations.

3. Methodology

The design procedures of co-op projects are systematically discussed in this section; the process is designed based on utilizing optimally adjusted S-BEST to apply in developing smart energy management technologies for the building prototypes under the supervision of Innovation Technology Co., Ltd. The procedures are briefly described as follows:

3.1 Steps Design

The projects are designed by the following steps: 1) the advisor introduces S-BEST and adjustment to Thailand existing technologies to both the executive board and all project engineers; 2) scopes and contributions of each co-op project are discussed and shared between the company and the co-op advisor; 3) the advisor analyzes how to apply and adjust S-BEST in motivating the company technologies; 4) the advisor matches the designed projects to co-op students based on their performances, backgrounds and satisfactions; 5) the scopes, solutions and contributions of each project and the relations between each project are proposed to the company; and 6) If the concept is both acceptable and agreed by the company, the projects are approved and assigned to the co-op students; otherwise, the process is redone from step 3 to step 6;

3.2 Designed Projects

With the aforementioned 6 procedures, 11 co-op projects are designed in Table. 1. The table identifies the applied steps of S-BEST and the projects status.

Table 1 The co-op projects for Innovation Technology Co., Ltd

No	Project Titles	S-BEST steps	Projects status
1	Automated data sorting for chiller monitoring systems	2.1	Done
2	Study of BAS design and utilization for high-rise building energy efficiency	2.1, 2.2	Done
3	Utilizing BAS and power Monitoring chiller operation optimization	2.1,2.3,2.4	Done
4	Power modeling of building energy consumption and chiller operation systems	2.2, 2.3	Done
5	Feasible development of virtual water flow meter for chiller operations	2.2, 2.3	Not finished
6	Feasibility of FDD based on refrigerant-side properties in chiller systems	2.2, 2.4	Done
7	Feasibility of FDD based on water–side properties in chiller systems	2.2, 2.4	Done
8	Development of preventative maintenance for chiller systems	2.4	Done

9	Elevator power modeling and operation optimization	2.3, 2.4	Done
10	Study of risk factors to decrease chiller operation efficiency	2.4	Not finished
11	Scoring rubrics for evaluating the standard of chiller operations	2.4	Not finished

Regarding the approved co-op projects, the company fully obtains the advantages, contributions and applications of each project as follows: 1) project 1 can be used as one of data carrier solution to obtain cleaned and organized data from a chiller controller without BAS installation; 2) project 2 and 3 are studied to potentiality learn how to use BAS optimally in terms of building energy efficiency; 3) project 4 and 5 utilize the modeling technology to be further applied in FDD analysis; 4) project 6 and 7 are feasibly investigated for diagnosing sudden and degradation faults in a chiller system resulting in energy savings because the chiller system performance is recovered to near-design condition when diagnosed faults are repaired in time; 5) project 8 is developed based on both traditional preventive maintenance (PM) and results obtained from project 6 and 7 leading to smart and effective PM; 6) the method of project 9 is integrated project 3 with project 4 and then is applied in optimizing an elevator system. As a result, it can be further used to shift energy savings to the chiller system for developing soft-repair technology to maintain acceptable operations while sudden faults happening in the system; and 9) eventually, project 10 and 11 are further designed to study the evaluation of Thai technicians to reduce faulty operations and installations since the faulty operations of a chiller system are occurred by faulty services, maintenances and commissioning of unstandardized and inexperienced technicians. Some of finalized projects contribute significant energy savings. For example, project 6 and 7 can detect and diagnose refrigerant leakage in the chiller refrigeration cycle and too low evaporator temperature differences causing 30 – 50% excessive energy consumption. With the significant outcomes, S-BEST procedures can be used to develop R&D department or challenge research funds for ongoing projects.

4. Research and Development (R&D) Guideline

After assigning the 11 co-op projects based on six simple six steps with the company approval, this section evaluates the feasible results and implementations of the projects for further developing R&D unit called "Intelligent Building Collaboration (IBC)" and research cooperation proposals including two research universities and three potential companies in building energy system industry.

Five procedures are: 1) the feasible or preliminary results of each project are discussed with a proposed R&D team to possibly plan short- and long-term R&D direction matching to IBC partners budget and affordable Thailand research fund; 2) summary and selection of the most significant project are further proposed to receive agreement and approval of IBC team; 3) the proposal is being developed using the feasible and preliminary results of the related co-op projects; 4) if the summary in step 3 is denied ,the process is repeated from step 1 to step 3; and 5) if the current co-op projects are not significant and sufficient to propose a proposal, the process is restarted by next generation of co-op projects while continuing the existing results and extending the scope of the 11 projects for learning more limitations and leverage significances.

4.1 Project Collaboration Establishment

Utilizing the aforementioned procedures in initially developing R&D department, IBC team focuses on online data carrier (section 2.1) which is based on the project No. 1- 4 in Table 1. Without this online data carrier, S-BEST cannot be further applied to building analytics and diagnostics. In addition, BAS has been gradually increased to install in Thai modern buildings; however, building operators have not been trained well and building owners have tried to reduce BAS functions for mainly decreasing cost installations because they have no idea how to use complete functions efficiently.

In the project No. 2, plug-n-play (PnP) solution of a BAS is used to analyze minimum requirement of chiller system parameters for high building efficiency performance. At this engineering point of view, this optimal BAS design and utilization integrated with chiller monitoring system will be analyzed as the first priority. This integrated multi-function will be publicly assessed by building operators and data analyzers via developing web-based browser protocol. At this initial development, Innovation Technology Co., Ltd envisions full functions and capability of S-BEST in Thailand building energy efficiency industry. For long-term vision, IBC is proposing several proposals of ongoing projects to governmental fund of King Mongkut's University of Technology Thonburi (KMUTT) called "Talent Mobility (TM)" based on the improved BAS performance. The expected building demonstration will be used as novel building energy standard in Thai green buildings and smart cities in near future.

4.2 Two Ongoing Projects Demonstration

The preliminary results of the selected project are presented to an industrial university and three building energy system companies. In terms of academic collaboration, Smart Energy Solutions and Analytics Research Unit, School of Engineering at Sripatum University has joined with Institute of Field Robotics (FIBO), KMUTT for the long-term collaboration to create, develop and implement IBC energy signature and solutions.

Meanwhile, the building industry end-users joining this industrial collaboration are EEC

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Engineering Network Co., Ltd, Goldmarktech Co., Ltd and Innovation Technology Co., Ltd who significantly serve the industry as building system designer and consultant, building automation system contractor and operation and maintenance contractor, respectively.

The first ongoing project - TM 1 is development of low-cost and non-invasive of wireless BAS as illustrated in Fig. 2 and 3.

Fig. 2 Chiller room of TM 1

Fig. 3 Conditioned space of TM 1

Fig. 4 Wireless sensor network (WSN) platform development

In Fig. 2, the chiller system is located in the machine room of the building prototype. It is used to generate chilled water for thermal comfort in the conditioned space in Fig. 3. However, this building prototype is a medium-scale hospital and was built more than 15 years. As a result, it is cost-effective and impossible to install wired BAS for a high performance solution. Wireless sensor network or internet of things (iOT) is more suitable solution for obtaining the building data as shown in Fig. 4.

In contrast to TM1, EEC academy building is the engineering educational center of EEC Engineering Network Co., Ltd as depicted in Fig. 5. This building is the project demonstration called “TM 2” which is proposed for automated fault detection and diagnosis on a chiller system for high-end BAS.

Fig. 5 EEC Academy Building

Fig. 6 Web-based monitoring of chiller system

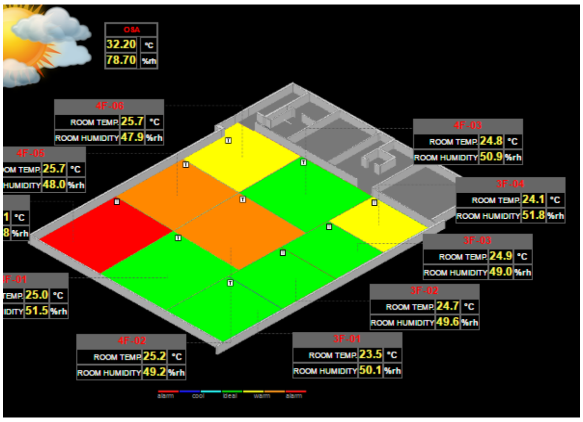

Fig. 7 Web-based monitoring system of the conditioned spaces

In this building, wired BAS is installed by Goldmarktech Co., Ltd utilizing BACnet communication protocol for data transferring from building sensors and chiller signals to local computer workstation. With the efficient protocol, Automatic Logic is the software for remotely controlling the system integration between the chiller system and the conditioned spaces served by multiple fan coil units as shown in Fig. 6 and 7, respectively.

These two demonstration projects will be supervised by IBC team and will be finished in 2017. Utilizing the S-BEST concept, the expected outcomes are to applicably achieve 20 – 40% energy savings goal, and will be an intelligent building prototype in Thailand.

5. Qualitative Research based Focused group

With the collaboration as aforementioned section, two focused groups are interviewed how significant S-BEST is. In the companies, executive members and project engineer team are interviewed separately. The executive teams state that S-BEST are the company solutions, and can be used as an efficient modern tool for Thailand building energy system. Meanwhile, FIBO – KMUTT would like to join IBC team because the S-BEST procedures are one of significant and modern technologies for Building Automation of Thailand Industry 4.0. It is a novel co-op project procedure for R&D and long-term collaboration, which is suitable to Thailand 4.0 policy. The short interview of collaborators is concluded in Table 2.

Table 2 Focused Group Interview and comments

Company	**Executive members**	**Project Engineer Team**
EEC Engineering Network	S-BEST envisions sustainable and innovative applications	It can solve existing problems
Goldmarktech	It enhances the existing company solution	It can enhance and increase existing BAS performance
Innovation Technology	It is the company solution and company future	Its procedure is a modern and non-invasive technology
Academy	**Executive members**	**Faculty**
FIBO-KMUTT	It is essential for Thailand industry 4.0	It is sustainable building automation solution

6. Conclusion and Contribution

Due to inefficient existing energy management approaches in Thailand, smart technologies are required for leveraging existing energy management standard and performance. S-BEST being one of the excellent solutions can be adjusted for enhancing the limited technologies and improving Thailand building environment effectively while minimizing original system intervention. To construct R&D department, field testing are suitable for the developing countries because setting a smart building laboratory is cost-prohibitive and unaffordable. Thus, co-op education based on R&D department of a powerful company is good opportunity to implement S-BEST in practice. To this end, this research article systematically proposes: 1) 6 steps for designing 11 co-op projects utilizing the concept of S-BEST applied in real Thailand buildings; and 2) 5 procedures in order to initially develop short- and long-term plan for co-op projects and research cooperation in terms of proposing research proposal to challenge Thailand research agencies. In the designed 11 project, they are briefly explained the advantages and contributions in developing R&D collaboration called "IBC". The success of this collaboration through the modern work-integrated learning innovatively penetrates the barriers between applied researches and real applications for energy management industry in Thailand. Also, the simple procedures could be applied in others co-op projects in other fields. It is so challenging the co-op policy operators to directly link co-op education to the industrial Thailand 4.0 in near future.

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