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Mana Patamakajonpong Tirapot Chandarasupsang

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Mana Patamakajonpong and Tirapot Chandarasupsang
College of Arts Media and Technology, Chiang Mai University, Chiang Mai, Thailand

Abstract

Purpose – This paper aims to present an alternative practical framework to classify the skill and knowledge of the individual trainees by comparing it with the expert in an organization. This framework gives the benefit to the organization in order to know the ability level of the personnel and to be able to provide the personnel development method both in academic learning and workplace learning.

Design/methodology/approach – This research develops the framework based on relevant methodologies. Competency-Based Development is applied to investigate the knowledge and skill of the specific task. Knowledge Engineering is used to capture the experiences and construct knowledge model from relevance parties. Capability Maturity Model is then adapted to develop the capability and maturity level of the personnel. It can then be used to cluster the knowledge and skill. Finally, the Substation Maintenance Department of Provincial Electricity Authority (PEA), Thailand, is selected as a case study to test the proposed framework.

Findings – The results have shown that the proposed framework can be utilized to identify the capability level of the individual personnel. Furthermore, the appropriate maturity development of the employees in each level can also be identified. This proposed framework provides better results when comparing to the current PEA competency model, as the criteria in this framework are systematically derived from experts rather than relying solely on the proficiency level. Although, this framework was tested with the switchgear maintenance task, the results and its systematic approach have indicated that it can also be used to develop the capability maturity model for other fields of work.

Originality/value – The main originality of this research is the proposed competency analysis table, which integrates human resource development with knowledge management, risks management and management information system. Rather than performing these tasks separately for continuous quality improvement, organization can practically plan and perform the quality improvement-related tasks spontaneously. Moreover, the application of the capability maturity model to classify knowledge and skill of the maintenance tasks into maturity level is another academic value presented in this paper. The proposed framework gives the benefit to organization to classify the capability of the personnel. This is potentially beneficial to the human resource development personnel than traditional methods in the sense that it provides the information on how to develop the specific skill of the employees.

Keywords Continuing professional development, Workplace learning, Lifelong learning, Competency framework, Engineers, Training and development

Paper type Research paper

1. Introduction

As one of the main state enterprises in Thailand, Provincial Electricity Authority (PEA) is responsible for the supply of electricity to customers in its 510,000-km^2 service areas. Its portfolio of physical assets includes 9,697 circuit-km of transmission systems,

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752,882 circuit-km of distribution systems and more than 400 substations. The performance of these physical assets directly affects the reliability of the PEA power system and its revenues. As a result, maintenance activities are regarded as an important task, and consequently, a proportion of the annual budget is allocated for the replacement, repairing and relocation of these assets. However, with the limitation and constrains on the available budget, strategic maintenance is required to balance costs, performances and risks associated. This is also known as the asset management framework. As there is a limitation on information available for maintenance decision, experiences of staff working on the assets on a daily basis become even more essential. According to PAS55 (2008), one key element for the successful asset management activity is the continuing development of the organization's human assets. The organization should provide the personnel with an opportunity to enhance their ability by human resource development (HRD) intervention, and provide them with the lifelong learning programme. The organization has to make the personnel believe that the workplace is the site of learning.

In 2013, PEA set up 145 million baht for the overall training activities. This budget can be divided into 84 million baht for technical training, and 61 million baht for non-technical training. With conventional training methods, this would not be sufficient, and presents PEA with difficulties in practical implementation. This is due to the fact that PEA's employees are scattered throughout the service areas. Under technical training budget, over 10 million baht is allocated specifically for substation maintenance-related tasks. This includes all levels of trainees with an aim to cover as many staff as possible. As a result, most courses are attended by trainees with varied technical backgrounds, and inevitably impossible to match well with the training materials.

Learning a visual inspection skill is a more complex process that utilizes problem-solving and insightful thinking in addition to repetition of the stimulus response chain. Therefore, the maintenance personnel should have chances to do and learn by trial and error with a real situation (Siang and Rao, 2003). Unfortunately, the real fault events are very rare for a training event, and can be very costly. Hence, this presents a challenge for PEA to develop an alternative training method with the right balance between skill and difficulty.

The aim of this paper is to propose an alternative framework to classify staff based on the level of knowledge and skill. The management framework is applied to analyse the organization context and strategic tasks where personnel need to perform efficiently. The capability maturity model is then utilized to divide the maintenance task into levels ranging from a newcomer to an expert of that task. The Knowledge Engineering (KE) methodology is used as a tool to construct the knowledge model and the skill set of each defined level. With this proposed classification framework, an organization can appropriately identify the current capability of the individual maintenance personnel, and specify the proper maturity development in each level. This alternative classification framework of engineering capability is part of the game-based knowledge management for the development of visual inspection skill.

The next section reviews literature relating to competency, provides an explanation on the development of the current PEA competency model and presents an alternative framework proposed in this paper. Section 3 then explains the concept of the KE methodology as well as the justification on the selection of the CommonKADS. Section 4 presents the research framework used in this paper. Section 5 then gives the explanation on the case studies. The real scenarios from PEA substation maintenance tasks are selected. The discussion and conclusion are given in Section 6 and 7, respectively.

2. Current PEA competency model

2.1 Reviews on existing competency literature

Presently, the competency-based development is regarded as one of the most important methods in HRD intervention. It is the mean for developing the employees to achieve higher standards of performance through training activity, reward management and another HRD intervention. Originally, the competency terminology was presented by McClelland (1973). His research stated that the performance of individual personnel cannot be predicted by academic aptitude, academic grade or IQ. Important factors, which influence job performance, are person's competencies and characteristics. Huang (1996) presented that competency is the capability of employees for doing their job. It is a combination of knowledge, skills, behaviours and attitudes, which relate to personal effectiveness. Marrelli *et al.* (2005) defined competency as a measurable personnel capability required for effective performance. It is composed of knowledge, skill and personal characteristic. The knowledge is defined as an understanding of the principle related to a particular subject. Skill is the capability to apply the knowledge to complete the task, and it relates to the action. Ability is a physical capability to successfully perform a task. It is time-consuming and difficult to develop. (McClelland, 1973; Werner and DeSimone, 2006; Marrelli, 1998).

Nowadays, many HRD scholars explore the possibility to apply the competency concept to enhance the employees' performance. For example, Kudngaongarm and Sujivorakul (2012) developed the competency framework for a civil engineer in Thailand. In the training and development aspect, a competency is a cluster of knowledge, skills and attitudes, which relates to effective job performance. It can be measured and evaluated. It can be improved through training and development (McLagan, 1983; Richey *et al.*, 2001; Berge *et al.*, 2002). Competency can be used as a guide to suggest a relevant development intervention for the employees (Ley *et al.*, 2008). Hackett (2001) stated that the purpose of competency-based training is to ensure that trainees attain practice in specific skills to establish the working standards, which are generally applicable across the different contexts and situations in learning that exist.

Competency model is the important tool for the present HRD activity. It is a list of competencies, which are analysed from exceptional employee performance for a specific task (Draganidis and Mentzas, 2006). There are many scholars proposing the competency model development framework. Consequently, many various competency models have emerged over the year. Harzallah (2002) presented that the function competency model development includes four steps. These are:

(1) analyse work or job;

(2) derive the behaviours and performance of the tasks;

(3) define the required individual characters; and

(4) evaluating.

Draganidis and Mentzas (2006) presented the steps to develop the competency, including the identification of the performance metrics, the development of the tentative competencies list, defining the competencies indicators, the development of the initial competency model, cross-checking the initial model, refining model, validating the model and performing the finalized model. Serpell and Ferrada (2007) developed the competency-based management framework. Its steps include the analysis of business processes, identification of critical labour functions, development of the competency profile, evaluation of competencies, design of the training plan, execution of the training plan and evaluation. Marrelli *et al.* (2005) presented seven steps for competency modelling. These include defining the objectives, obtaining the support of a sponsor, developing and implementing a communication and education plan, planning the methodology, identifying the competencies and creating the competency model, applying the competency model and evaluating and updating the competency model.

As reviewed above, these frameworks can be used as the guideline to develop the competency model. However, it is found that most frameworks need more effort of experts to develop the competency model and competency profile of each job position. The skills of experts in job analysis, job description and narrative are necessary for the knowledge elicitation. Moreover, these competency models are used to evaluate the competency gap by comparing the present ability level of individual personnel and the standard competency level of the job position that the employee should be. This evaluation may not be an effective development method of maintenance operators in the real industry. This is because most maintenance operators have learnt and developed their performance on their work. As some of them can develop their ability faster, their abilities may be higher than the proficiency level of their job position. As a result, they will likely not get the opportunity to develop their ability until promoted to a higher position. Instead, the competency model proposed in this paper is based on the learning pattern of experts rather than relying solely on the proficiency level of a job position.

2.2 Result of current PEA competency model development

PEA defines the competency model as the set of knowledge, skill and attribute, which is used to facilitate human resource activities. These activities include recruitment, training and development, performance appraisal, career path development, talent management and organization culture rebranding. The PEA competencies are divided into core competency and functional competency. Presently, PEA has developed both core competency and functional competency. PEA applied Spencer's framework for developing the current competency model (Spencer and Spencer, 1993). The processes used to develop the competency model are divided into seven steps, which consist of:

(1) organization analysis;

(2) competency model study;

(3) share value study and core competencies;

(4) functional competency specification;

(5) competency dictionary development;

(6) proficiency level development; and

(7) proficiency description.

The first three steps involve the development of the core competencies, which the relevant data were collected through document reviews and executive meeting. This collected data includes mission, vision, policy and core value. The functional competency is divided into managerial competency and technical competency. The managerial competency is only specified to management level. The technical competency is assigned to both management and operation level. PEA has developed the functional competency models for every personnel, who cluster by job families. The data collecting process involves reviewing the job description, the focus group meeting and the benchmarking. For the substation maintenance personnel, PEA set up the competency model comprising five competencies. Each competency is divided into proficiency level of five levels by five patterns. Then, the competency model is validated by line executive peer review. After competency models are set up, they are used to evaluate the competency gap of individual personnel, and the results are used to set up the individual development plan.

2.3 Proposed competency model development of substation maintenance job

As explained in the previous subsection, it is found that the current models do not emphasize on technical skill, especially in the engineering aspects. Besides, the existing competency profile of substation maintenance sections presents the technical competencies including knowledge in protective device in power system, inventory system, electrical equipment installation and maintenance. These competency skills are rather general maintenance knowledge, which is inefficient for enhancing the episodic knowledge, especially the inspection capability. Moreover, the proficiency levels in the current PEA competency model only provide the characteristics of each level, with insufficient details for HRD personnel to set up the suitable method to develop the maturity of the personnel. For the competency model development of the maintenance task, it has to focus on the functional competency because the maintenance personnel should have the specific skill, knowledge and ability to complete their job. Therefore, it is important to understand the learning process of the experts in the maintenance job. Chandarasupsang *et al.* (2008) proposed the organizational learning model on maintenance activities to categorize and develop the maintenance tasks by applying the KE. The development of the learning model is based on experience collectively gained over a period. It is a time-consuming process with many parties involved to develop the common best practices. This learning model proposes that there are five steps in maintenance processes; these are breakdown maintenance, corrective maintenance, preventive maintenance, predictive maintenance and proactive maintenance. The model presents a step-by-step learning development from breakdown to proactive maintenance. Therefore, the competency of the maintenance task and maturity model can be developed based on this learning model.

In this paper, the Capability Maturity Model (CMM) is applied to develop the competency model of the maintenance task. CMM is a method for evaluating the ability of the organization. Although CMM is originally developed for software development, it can be used in various fields as a general model of the maturity of the process. These include, for example, software engineering CMM, and people CMM (Williams, 2008). This methodology describes essential attributes that would be expected to characterize an organization at a particular maturity level. A maturity level is a well-defined evolutionary period towards achieving a mature process. Each maturity level provides a layer in the foundation for continuous process improvement. Each level comprises a set of process goals that, when satisfied, stabilize an important component of the software process. Achieving each level of the maturity framework establishes a different component in the software process, resulting in an increase in the process capability of the organization. The CMM organizes the capability of software process development into five levels and prioritizes improvement action for increasing the software process maturity (Paulk *et al.*, 1993). Kim and Grant (2010) stated that CMM offers guidelines about essential requirement and component of each maturity level. Therefore, this research proposes to apply CMM to specify the proficiency level, and define the competency profile of each maturity level. By applying the CMM in the proposed framework, it gives the benefit for specifying the continuous development process of personnel capability, which cannot be found in the current PEA competency model.

3. KE: the knowledge and experience gathering method

3.1 Reviews on KE

To develop the competency model, the data, information and knowledge have to be collected from many sources within the organization. Normally, the important techniques for collecting these resources are interview, document reviews and/or observation. The method should be suitably selected and applied. KE is the methodology that can be applied with the interviewing method to collect the knowledge and experience of expert in an organization. Basically, KE focuses on the acquisition of knowledge about the process, and represents it in the knowledge-based systems. KE comprises several activities such as knowledge acquisition, knowledge representation, knowledge validation, knowledge utilization, etc. The important KE frameworks that have be widely used are CommonKADS (Schreiber *et al.*, 1999), MIKE (Model-based and Incremental Knowledge Engineering) (Angele *et al.*, 1996) and PROTÉGÉII (Eriksson *et al.*, 1995). Studer *et al.* (1998) studied and compared three KE frameworks mentioned above. They stated that CommonKADS is prominent for having defined the structure of the expertise model (knowledge model). MIKE puts emphasis on formal and executable specification of the expertise model as the result of the knowledge-acquisition phase, while PROTÉGÉ exploits the notion of ontologies. It provides a modelling tool for ontological analysis of organizational knowledge. Therefore, the CommonKADS and MIKE are similar in that a major contribution of the approach is its proposal for structuring the expertise model. In contrary, the PROTÉGÉ is different from CommonKADS and MIKE in the sense that it focuses on organization knowledge level. In this paper, the KE methodology is applied to elicit and model the knowledge of the organization's expert in order to create the competencies of the switchgear maintenance task. As a consequence, this research emphasizes on the development of the expertise knowledge (expertise model). Therefore, only CommonKADS and MIKE are suitable for this research.

Under CommonKADS, the organization model, the task model, the agent model, the communication model, the knowledge model and the design model are distinguished. The first three models are regarded as the context level, which analyses the organizational environment and the corresponding critical success factors for a knowledge system. The knowledge model (or expertise model) and communication model are categorized in the concept level. This level yields the conceptual description of the problem-solving function and data that are handed and delivered by the knowledge system. The knowledge model is a major contribution of the CommonKADS approach.

The purpose of this model is to explicate the types and structures of the knowledge used to perform the task. Finally, the design model is the artifact. This level combines the above levels together to construct the requirement specification for the knowledge system (Schreiber *et al.*, 1999).

MIKE (Angele *et al.*, 1996) is the KE methodology, which provides a development process covering all step of knowledge-based system development. MIKE proposes the integration of semi-formal specification and formal specification techniques and prototyping to develop the expertise model. The first process of MIKE is the knowledge elicitation to create the knowledge protocols, which express in natural language. Methods like structured interviews are used to elicit the informal description of the knowledge in this elicitation process. Then, the knowledge protocols are represented in a semi-formal form of the expertise model. This representation provides an initial structured description, and can be used as a communication basis between the knowledge engineer and the expert. This second process is interpretation process, which transforms the knowledge protocols to be the structure model. The structure model is the foundation for the formalization process. The result of the formalization process is the formal expertise model or the KARL (Knowledge Acquisition and Representation Language) model. The KARL model contains the description of domain knowledge and knowledge about the problem-solving method. The KARL model also captures all functional requirements for the final knowledge-based system. Then, the KARL model is used in the design process to consider the additional non-functional requirements. Therefore, the design phase in MIKE constitutes the sufficient detail design. The result of the design process is to transform KARL model to the designKARL model. The design model captures all functional and non-functional requirements for implementing the knowledge-based system in the implementation process.

3.2 Application of CommonKADS in capability classification model development

CommonKADS (Schreiber *et al.*, 1999) is the famous framework to support structured KE methodology. It enables the organization to spot the opportunities in how organizations develop, distribute and apply their knowledge resources, and so gives tools for corporate knowledge management. It also provides the methods to perform a detailed analysis of knowledge-intensive tasks and processes. CommonKADS provides a method to model knowledge of organization and represent knowledge with notation. It gives the benefit to develop the knowledge systems that support selected parts of the business process. It is a complete methodological framework for the development of a knowledge management. In summary, it supports most aspects of a knowledge management development project, such as project management, organizational analysis (including problem/opportunity identification), knowledge acquisition method (including initial project scoping), knowledge analysis and modelling, capture of user requirements, analysis of system integration issues and knowledge system design. CommonKADS has been broadly applied in power business; for instance, knowledge management for planning, design, operation, maintenance, asset management and regulatory issues. KADS can be applied to capture the knowledge and experience from the power system protection design expert and store them into the knowledge management website (Strachan *et al.*, 2001). Moreover, CommonKADS provides the common knowledge model templates to elicit knowledge and experience from the expert. These templates can be used as a guideline to set up the questionnaires for the knowledge elicitation process.

For the competency model development of the maintenance task in the paper, the CommonKADS is applied to elicit the knowledge and experience of experts. These knowledge and experiences are resource materials to set up the competency model. The CommonKADS inference templates are used as a guideline to interview the experts. According to the learning model on maintenance tasks, the CommonKADS templates, including the planning inference template, the diagnosis inference template, the scheduling inference template, the monitoring inference template and the assessment inference template (Chandarasupsang *et al.*, 2008), are selected and applied for the knowledge elicitation as shown in Figure 1.

4. Research framework

This section presents the proposed classification framework for the capability enhancement of PEA maintenance personnel. It focuses on how to identify the performance of the maintenance personnel and how to specify the capability maturity development. The CMM methodology is applied in this framework to develop the competency model and competency profile of the capability classification model proposed in Section 2. The CommonKADS is then used to elicit the knowledge and experience of the subject matter experts, as discussed in Section 3. With this proposed framework, the organization can make the right decision to provide the suitable method for enhancing the employee performance. The proposed framework is shown in Figure 2.

This framework can be divided into three stages as described in the following text.

4.1 Stage 1: Data gathering

First stage is the process to collect the data, information, knowledge and experience of the expert in a specific job. The KE is applied in this stage to elicit the knowledge and experience of the relevant personnel. The focus group is selected for interviewing. The

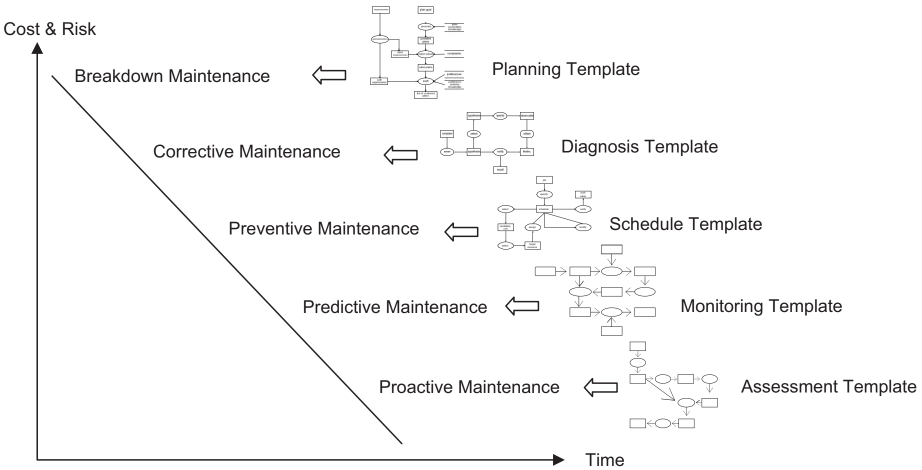

Figure 1. Organizational learning model on maintenance activities

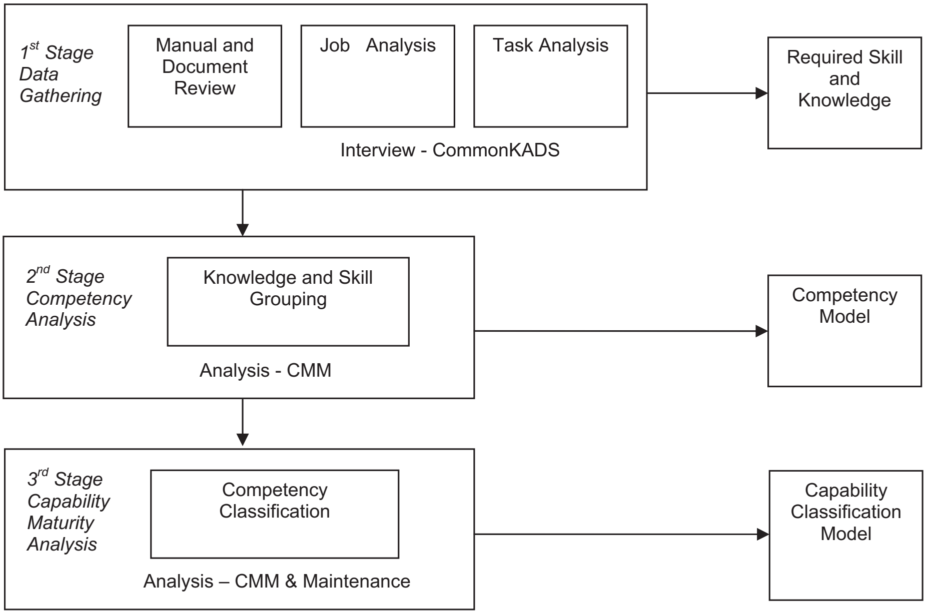

Figure 2.
Personal capability classification development framework

selected group comprises executives from the relevant departments, the subject matter experts, operators and HRD personnel. This stage is divided into three steps for collecting the resources.

Step 1: Manual and document review. The process starts by reviewing the concerned documents and manuals. These cover relevant working manuals, worksheets and training documents. By reviewing the materials mentioned, the interviewing questions for job analysis and task analysis steps can then be prepared constructively. This step provides the interviewer a better understanding of the basic concepts and ontology of the specific task.

Step 2: Job analysis. This step starts by reviewing the existing job description. Then, the line manger is interviewed to define the needs of HRD effort in organization and job description, and to identify tasks or sub-task of the job. Required knowledge and skill of the job as well as the subject matter experts are also identified during this step. After that, the questionnaires can then be developed by applying the CommonKADS templates.

Step 3: Task analysis. A task analysis is a step to collect the data about a specific job. The aim of this process is to determine what an employee should acquire to achieve optimal performance (Werner and DeSimone, 2006). The data collection of this process is conducted by applying the methods such as interviewing, and observing a job. This research proposes the semi-structured interview as a means to elicit experiences from the selected group of experts. As mentioned previously, the CommonKADS concept can be applied to prepare the questionnaires. After that, the experts of the task are selected to interview. The results include the appropriate standards of performance; details of how tasks should be performed to meet these standards; and the knowledge, skills, abilities and other characteristics that employees need to possess to meet the standards.

4.2 Stage 2: Competency analysis

To perform the task successfully, it is required that personnel possess the knowledge and skill to perform the task. This stage is conducted to analyse the data, information, knowledge and experience to ultimately model the competency framework of a specific job. The framework presented in this paper proposes the competency analysis table (as shown in Table I) for the classification of the knowledge and skill relating to the maintenance tasks. The proposed analysis table is developed according to the State Enterprise Performance Appraisal (SEPA) in Thailand, which represents a lesser version of the Malcolm Baldrige National Quality Award (MBNQA). Essentially, SEPA provides the framework to improve performance and competitiveness of an organization by considering six separate parts. Normally, the HRD, the knowledge management, risks management and the management of information system of SEPA are considered separately from each other. This results in more burdens to the organization to fulfil these parts separately. Furthermore, it results in duplication of similar and overlapping works. However, for organization development to be fully efficient, HRD needs to be integrated with other parts of organization development holistically. In this paper, an alternative analysis method to construct the competency model is proposed. This competency analysis table defines organization into strategic tasks representing communities of practice. It then further defines the knowledge and skill set of personnel required to perform that task. Finally, risks associated with that task can be identified.

Step 4: Knowledge and skill grouping. This step identifies the necessary knowledge and skill of the task by using the competency analysis table as show in Table I.

The list of the task is clarified and filled in Table I. The list of knowledge and skill is stated as what the personnel must be equipped with to perform each task. Clear knowledge and skill statements are written. After knowledge and skill are clarified in the competency analysis table, they are evaluated to select the importance knowledge/ skill and grouped into the competency cluster.

4.3 Stage 3: Capability maturity analysis

After the knowledge and skill are grouped, CMM is applied to classify the level of the knowledge and skill. Normally, many organizations, including PEA, identify the proficiency level by a simple rating system such as four patterns or five patterns. Currently, PEA divides the proficiency level into five levels; these are beginner, apply, supervise, master and strategic levels, respectively. Although this classification method is convenient for the development of the competency model, this rating system is insufficient for enhancing the personnel's performance in some special skill, especially the inspection skill. Therefore, to overcome this issue, this framework proposes to apply CMM when ranking the competency level for each skill and knowledge.

Step 5: Competency classification. This step utilizes the results of the competency table in the fourth step. By applying the maturity level, the competency model can then

Function	System	Process	Task	Knowledge	Skill	Risk

Table I.
Competency analysis table

be revised. The competencies have been grouped according to the CMM classification. The proposed proficiency level in this framework can be divided into five levels. These include initial, repeat, define, manage and optimize. The criteria are developed for classifying the level as follows:

Level 1 – Initial: Basic knowledge or skill of the task.

Level 2 – Repeat: Know the process and able to repeat the process.

Level 3 – Define: Understand the standard of the task.

Level 4 – Manage: able to use the knowledge and skill to analyse the task.

Level 5 – Optimize: Able to use the knowledge to develop task or solve the problem.

By using the above criteria, each competency can be rated, and the staff capability level can be classified. As a result, each capability/maturity level contains a set of knowledge and skill required as shown in the competency analysis table (Table I). Consequently, the proper training programme can be set up and provided to the individual personnel.

5. Case study: PEA maintenance inspection skill development

To test the proposed research framework, PEA is selected as a case study. More specifically, the 22-kV switchgear maintenance task is selected in this paper due to the large amount of equipment installed around PEA service areas. As discussed in the previous sections, an alternative method for the classification of substation maintenance capability is required in order for PEA to provide its personnel with the most suitable training materials. The capability classification framework has been proposed in the previous section and tested with the case study explained in this section.

According to the proposed framework, the data, information and knowledge were gathered by the interviewing method. The focus group interviewers of this study comprise six substation maintenance experts, three maintenance operators, two HRD personnel and three executives of the maintenance task. The process is completed by individual interviewing, and follows the proposed framework steps.

Step 1: Manual and document review. The research is conducted by firstly reviewing the manual and concerned document, such as job description documents, working manuals and training documents. This provides a better understanding of the basic concepts and the ontology of PEA switchgear maintenance.

Step 2: Job analysis. Then, the maintenance executives were interviewed to analyse the context of the substation maintenance task, and to identify the experts of each task. After that, the HRD personnel were also interviewed to enquire the existing personal development method and the competency of the substation maintenance job.

Step 3: Task analysis. The results of the reviewing and executives interviewing provide better understanding of the current maintenance job. This assists in dividing the substation maintenance job of PEA into four tasks, including breakdown maintenance, corrective maintenance, preventive maintenance and predictive maintenance. Moreover, it covers the objective and expectation of each maintenance task. Therefore, the questionnaire and meeting agenda for expert interviewing can be developed. The planning inference template was selected and used for the elicitation of breakdown maintenance. The diagnosis inference template was selected and used for the elicitation of corrective maintenance. The scheduling inference template was selected and used for the elicitation of preventive maintenance. Finally, the monitoring inference template was selected and used for the elicitation of the predictive maintenance. These are shown in Figure 3.

Figure 3 shows the CommonKADS inference templates selected and used for the knowledge elicitation in this paper. In the breakdown maintenance scheme, equipments are de-assembled and assembled to get the basic knowledge. Corrective maintenance scheme represents knowledge on "how-to" repair equipment when failures occur. In preventive maintenance scheme, most activities involve resource scheduling to avoid unplanned outages. Predictive maintenance scheme indicates the abilities of the knowledge workers to foresee the future faults and events based on present condition of the equipments.

From the interviewing, it is found that although PEA did not explicitly complete the organizational learning model on maintenance activities shown in Figure 1, PEA experts have implicitly accumulated the knowledge in the proactive maintenance task. Therefore, PEA can apply the knowledge management methodology to develop the best practice and create the proactive maintenance knowledge. Referring to learning model on maintenance activities shown in Figure 1, the assessment inference template can be

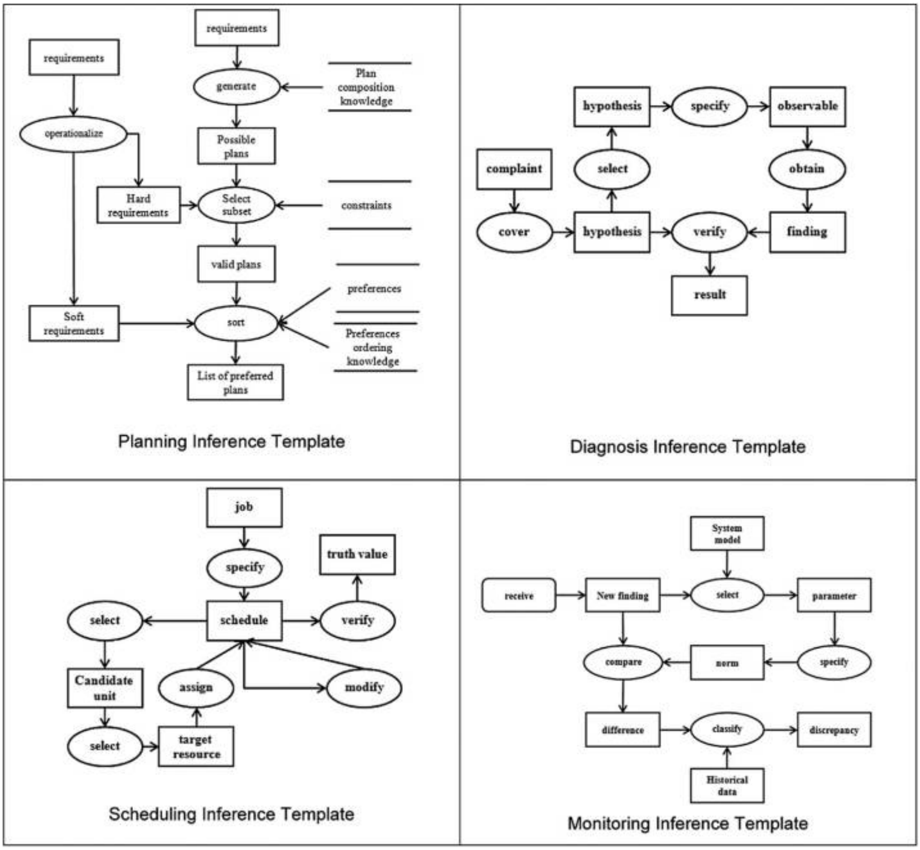

Figure 3.
CommonKADS inference template

used to capture the knowledge in the proactive maintenance task. This assessment template is shown in Figure 4.

Figure 4 illustrates the assessment template for the knowledge elicitation of proactive maintenance. The proactive maintenance indicates abilities of the knowledge workers to assess the asset lifetime as well as its parts, which consequently assists the utilities in the decision-making on the replacement or the refurbishment. This assessment inference template is used as a guideline to identify the existing knowledge of PEA experts to assess the lifetime of the equipment. Then, PEA can combine this existing knowledge with the proactive maintenance theory (related engineering theories) to develop the best practice in the proactive maintenance task. After that, the knowledge can be transferred and specified into the knowledge and skill for PEA personnel in the maintenance capability maturity model.

Then, the experts and operators of the Substation Maintenance Department were interviewed to gather the knowledge and experience. Moreover, after the interview, the experts were requested to do the protocol analysis with real maintenance operation at the Chai Badan 2 Substation in Lopburi Province, Thailand. This protocol analysis was recorded by a video recorder.

Step 4: Knowledge and skill grouping. The data collected from relevant parties in the previous steps were analysed and listed in the proposed competency analysis table. The result of this analysis is the list of knowledge and skill of the switchgear maintenance task as shown in Table II.

After that, the knowledge and skill were categorized into important competencies for the PEA inspection task. In this paper, six groupings of competencies are proposed, as shown in Table III.

Table III describes the definition of individual competency of the PEA maintenance task proposed in this paper. Each competency is also divided into five proficiency levels based on the CMM concept. Then, the competency model and competency catalogue of the inspection maintenance job are systematically developed.

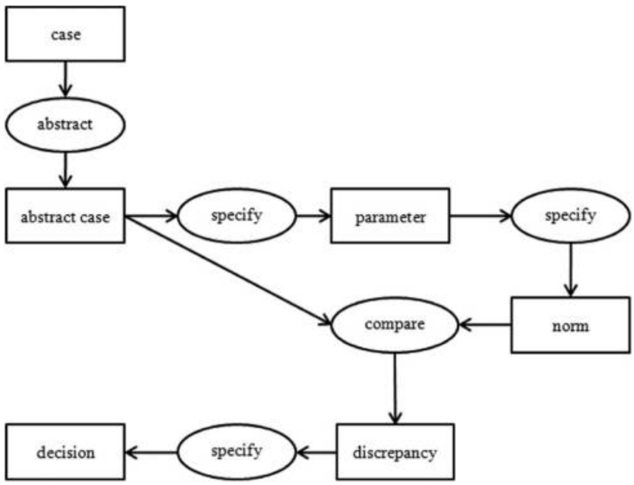

Figure 4.
Assessment inference template

Table II. Switchgear maintenance competency analysis table

Function	System	Process	Task	Knowledge	Skill	Risk
Switchgear Maintenance	Planning Process	Plan setup	Data collection	Concerning data	Data finding	Inefficient plan
				Substation location	Route decision	
			Analyse and plan	Dispatching system configurations		
				Planning step		
				Maintenance process		
			Evaluate plan meeting	Goals and constrains	Decision making	
					Presentation	
		Preparation	Inventory management	Equipment, spare part	Available equipment checking	High cost
				Inventory system	SAP: material management system usage	
				Equipment acquire and procurement		
			Coordination	Related parties	Coordination with other party	Time lost
			Maintenance form preparation	Maintenance process	Microsoft Word	
	Maintenance Operation	Safety	System check	Switchgear system	Safety checking	Poor safety
				Safety in switchgear operation		
				Annunciation and indicator	Annunciator and dispatching status checking	
		Operation	Disassembly	Switchgear mechanism compartment	Switchgear disassembly process	Incorrect operation and damage to the switchgear
			Truck out/in service	Switchgear compartment	Tool and instrument usage	Damage to the switchgear
					Operation with switchgear step	

(*continued*)

Table II.

Function	System	Process	Task	Knowledge	Skill	Risk
				Understanding in mechanism		
		Maintenance	Inspection	Normal and damage equipment	Visual check	Incorrect decisions
		Operation	Cleansing and lubrication	Switchgear component	Mechanism lubrication and cleansing process	Incorrect operation and damage to the switchgear
		Measuring	Measuring instrument setup	Measuring instrument knowledge	Measuring instrument arrangement	Damage to the instrument
						No safety
					Availability check	Miss value record
			Measuring process	Switchgear parameter		
				Measuring method and step	Measuring instrument usage	Miss value record
					Value reading and record	
				Safety clearance		Not safety
		Corrective	Diagnostic	Cause of damage	Cause assumption	Incorrect decisions
		Maintenance		Damage finding	Visual check	
				Damage assumption	Inspection	
			Correction	Know how to correct the equipment	Decision making	Incorrect decisions
	Monitoring	Data analysis	Analysis	Switchgear parameters		Cannot assess the conditions
		Condition	Assessment	Norm value	Value observation	Incorrect assessment
		Assessment		Historical data	Compare the present value with historical case	
			Maintenance decision	Case study		Long time to find the solution
				Organization regulation		Incorrect decisions
				Dispatching condition	Risk assessment	
				Maintenance method	Decision	High risk

No.	Competency name	Description
C1	Planning	Ability to do the maintenance plan by considering the concerned information such as substation location, relevance resource, notification of equipment problem, etc
C2	Coordination	Ability to coordinate the concerning party to complete the job
C3	Maintenance operation	Ability to operate the maintenance process
C4	Measuring	Ability to use the instrument and measure the important parameter of the switchgear
C5	Equipment correction	Ability to find the cause of problem and able to fix that damage
C6	Assessment analysis	Ability to analyse the information which is collected between maintenance process and be able to assess the condition of the switchgear

Table III. Competencies of PEA maintenance job

Step 5: Competency classification. The maintenance learning model is then applied to establish the maintenance maturity model. It divides the maturity development step of maintenance personnel into six levels. These include newcomer level, breakdown level, corrective level, preventive level, predictive level and proactive level, as shown in Table IV.

Table IV specifies and explains the details of each maturity level. It also defines the knowledge and skill, which should be developed in each level. After that, each maturity level is identified and classified by a different competency set based on CMM and maintenance learning model. The analysed competency profiles of each maturity level can be illustrated in Table V.

Level	CMM	Maintenance	Criteria	Knowledge	Skill
0	Newcomer	Basic	Understand an overview of switchgear and relevance equipment	Equipment and instrument	Understand the detail of equipment
1	Initial	Breakdown	How-to operate and how-to maintain assets	Breakdown maintenance	Able to operation the equipment
2	Repeat	Corrective	How to repair the faults	Corrective maintenance	Understand the malfunction of equipment
3	Define	Preventive	Resource scheduling to avoid unplanned outages	Preventive maintenance	Define difference between normal and malfunction
4	Manage	Predictive	Foresee the future faults and events based on present condition of the equipments	Condition-based maintenance	Compare condition of equipment with past situation
5	Optimizing	Proactive	Assess the equipment lifetime and its part's life cycle, and do the decision-making process to refurbish or replace some equipments	Proactive maintenance	Risk assessment

Table IV. Detail and criteria of competency classification

The competency profile data in Table V can also be drawn in the form of the radar diagram shown in Figure 5.

Figure 5 illustrates the radar diagram, which is the result of the competency evaluation. The framework proposed in this paper assists the organization in the evaluation of the personnel' capability, and then plots the result in the diagram to define gap of the ability level comparing with the competency profile. With this classification, the essential knowledge and skill can be indentified for individual personnel. Therefore, the development programme can be effectively set up that focuses on the personnel's capability development from current to higher maturity level.

Finally, to validate the capability classification model, the focus group survey was conducted. The focus group comprises 12 experts and executives of substation maintenance units. In the validation process, the focus group was asked to individually rate each competency according to the importance of each competency. Then, the competencies with average ratings less than four were eliminated from the competency model. The interviewing process began with the competency detail explanation. Then, each member of the focus group was asked to rate importance of each competency. The results of the rating process in average score of each competency are shown in Table VI.

The rating result in Table VI shows that all the average scores of each competency are above four. It means that all of competencies are important for the task. After that, the experts and executives were asked to review and prove the proficiency level and competency profile. Then, the final versions of the competency model and the maintenance classification model were developed.

After the robustness test of the capability classification model discussed earlier, this model was tested with the predefined case study. To test the application, the capability

Table V. Competency profile of maintenance capability classification model

Level	Level name	C1	C2	C3	C4	C5	C6
0	Newcomer	1	1	1	1	1	1
1	Breakdown	1	2	2	3	2	2
2	Corrective	2	3	3	4	3	3
3	Preventive	3	4	4	5	4	3
4	Predictive	4	5	5	5	5	4
5	Proactive	5	5	5	5	5	5

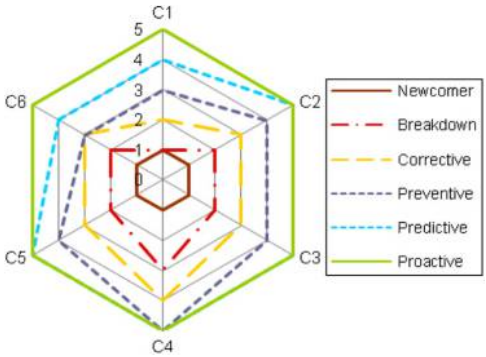

Figure 5. Radar diagram of maintenance classification maturity model

classification-level placement questions were developed and their validity was tested by PEA substation maintenance experts. These questions were developed based on the proficiency level of each competency. These questions were used to evaluate the personnel's knowledge. This evaluation was performed by the self and supervisory assessment method. In this evaluation process, the placement of maintenance personnel was conducted by interviewing with the already developed questions. The difficulty of the placement questions will be increased if personnel can answer and express their knowledge satisfactorily. The supervisor of the personnel was asked to join in the interviewing. The results of testing were plotted into the radar diagram of the classification model to identify the skill and knowledge gap. Figure 6 shows the result of the competency evaluation of the technician who has worked for two years in the substation maintenance job. Figure 7 shows the competencies of a senior technician who has worked for six years in this task.

After finishing the evaluation, the chief supervisor of the interviewees was asked to analyse and verify the results of the competency evaluation. In this process, the chief supervisor was interviewed about the human errors of both personnel, which occurred in the individual maintenance operation. Based on the interview, the chief has indicated that the senior technician made a mistake in the decision when evaluating the condition of the circuit breaker. This can be elaborated as followed:

> The duty after finishing the maintenance job of Mr X (senior technician) is to evaluate the condition of the circuit breaker. The evaluation is performed by monitoring the insulation resistance value. Normally, the PEA standard defines that the condition of normal vacuum circuit breaker must be over one Giga Ohm. This mistake in decision occurred because the insulation resistance value of the circuit breaker A is greater than one Giga Ohm. Therefore, he decided not to replace the circuit breaker A. However, when his chief supervisor observed the data, he found that the measuring value was quite close to one Gaga Ohm, while the measuring values of another circuit breakers under the same condition at the same substation, were greater than three hundred Giga Ohm. Therefore, the data showed that there were some problems occurring with circuit breaker A. Then, the supervisor had to make the decision to replace the circuit breaker A with the new one.

The evidence of this mistake in decision is shown in the substation maintenance report. This mistake in decision by the senior technician illustrates that he lacks the skill to observe the data and compare them with another circuit breaker or historical data rather than just simply following the standard. The lack of this knowledge can also be confirmed in the knowledge and skill assessment diagram shown in Figure 7. It shows that the senior technician lacks the assessment competency.

After the capability level of each employee is verified, Table II was then analysed to select the proper knowledge and skill according to the individual capability level and

Competency	Average importance rating
Planning	4.33
Coordination	4.50
Preventive	4.50
Measuring	4.58
Corrective	4.67
Monitoring	4.00

Table VI. Results of competency model rating

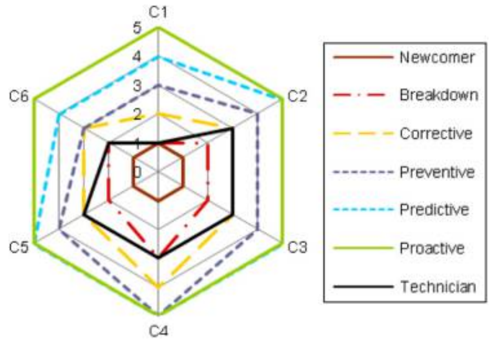

Figure 6.
Competency profile of technician

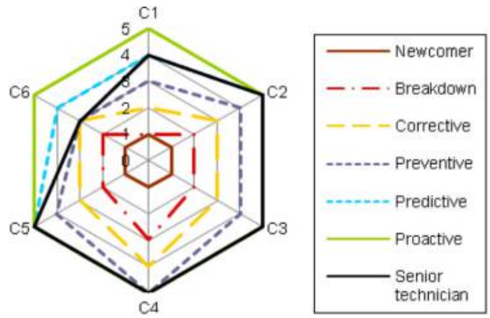

Figure 7.
Competency profile of senior technician

maturity development aspect. In this case, Figure 6 indicates that the technician lacks competency in planning, measuring and assessment analysis. He has to develop the knowledge and skill listed in Table VII. Figure 7 shows that the senior engineer's competency is almost close to the predictive level. However, he lacks the monitoring competency in the management level. Therefore, the list of knowledge and skill in Table VIII is selected to enhance his capability.

With the knowledge and skill developments analysed and listed in Tables VII and VIII, the line manger and HRD department can set up the training and development method to fill the competency gap of each substation maintenance personnel efficiently.

Table VII.
Knowledge and skill development for technician

Competency	Knowledge and Skill
Planning	(1) Planning process; (2) maintenance process
Coordination	–
Maintenance operation	–
Measuring	(1) Availability check of measuring instrument
Equipment correction	–
Assessment analysis	(1) Norm value of equipment

6. Discussion

The research proposes an alternative classification framework for an enhancement of the engineering capability of the technical personnel. Therefore, the knowledge and skill relating to management are not emphasized in this framework. The maintenance task of the PEA switchgear is selected as the case study in this paper. The results have shown that the classification model can effectively be used to identify the capability level of the personnel. Moreover, unlike the conventional competency methodology, this framework also indentifies the set of knowledge and skill for further development according to the maturity level. HRD department can also utilize this information to develop training and development programmes suitable for each maintenance personnel. The utilization and benefits of the proposed framework are quite different from the current PEA competency model. The comparison between the current competency model and the capability classification model proposed in this paper can be seen in Table IX.

Table IX shows that the proposed framework "capability classification model" emphasizes more in training and development aspects. It focuses on how to develop the specific skill of a specific job. Therefore, the capability classification model contains the competencies that are related to the maintenance engineering perspective. This is in contrary to the current competency framework which focuses on the development of the competency model to support various HR functions. It contains both managerial competency and technical competency. The technical competencies as part of the proposed framework are set up based on knowledge and experience of subject matter experts with the utilization of the KE method. It means that the personnel performance is evaluated by comparing to the maintenance expert, or in other words how close it is to the performance of the experts. Moreover, the results of the case study have shown that the proposed framework is the proper practical method to classify the knowledge and skill level of the individual personnel. With this maintenance maturity model, the specific knowledge and skill can be defined to train the personnel in each level. Then, organization can use the list of knowledge and skill for the proper future development programme to enhance the individual personnel performance. Furthermore, the proposed framework needs the effort of subject matter experts only in data gathering phase and validation step. This implies that the proposed framework consumes less of the experts' time than the current PEA competency model method.

7. Conclusion

This paper presents the practical, alternative classification framework of the maintenance personnel's capability. It gives the benefits to the organization to identify the capability level of personnel. Comparing to the current PEA competency model, the

Competency	Knowledge and Skill
Planning	–
Coordination	–
Maintenance operation	–
Measuring	–
Equipment correction	–
Assessment analysis	(1) Value observation; (2) knowledge to compare the present value with historical case

Table VIII. Knowledge and skill development for senior technician

Table IX. Comparison between current competency model development and proposed classification model

Topic	Current competency model	Capability classification model
Objective	To support various HR activities	Focus on training and development
Competency type	Core competency Functional competency includes managerial and technical competency	Technical competency
Data gathering method	Descriptive meeting Focus group Benchmarking	Subject matter expert structural interview with CommonKADS
Competency mapping method	Supervisory assessment survey Benchmarking	Competency analysis table CMM Supervisory assessment
Competency model of substation maintenance section	Protective device in distribution system Inventory system Electrical equipment installation and maintenance Analytical skill Coordination skill Attention to details	Planning Coordination Maintenance operation Measuring Equipment correction Assessment analysis
Proficiency level	Five patterns Level 1: Beginner Level 2: Apply Level 3: Supervise Level 4: Master Level 5: Strategic	Capability maturity model Level 1: Initial Level 2: Repeat Level 3: Define Level 4: Manage Level 5: Optimize

framework proposed in this paper is more appropriate for training and development purpose. This is because the proposed framework not only identifies the capability level of a specific competency, but it also provides maturity development for enhancing the employee performance. This is particularly for the inspection skills of maintenance engineers. The framework also proposes the structured method to apply the KE methodology to capture and analyse the detailed competency of the specific task. Hence, competency can then be developed according to both practical knowledge/experiences required in the field and repository. Moreover, this framework is developed such that it is compliant with the MBNQA. It proposes the holistic model of competency development framework by consolidating all aspects of MBNQA. Even though this research was developed and tested by using PEA's switchgear maintenance task as the case study, it is also possible to apply it for the development of classification capability maturity of any other field. The proposed framework can be used as a scenario selection engine of the game-based knowledge management for the development of a visual inspection skills project. The framework can effectively be used as the mechanism to identify the players' ability level at the beginning of the game. Therefore, the future extension of this research is to develop the pre-test scenarios for placing the ability level of the employees in the classification capability maturity model. By this placement, the game is able to provide the suitable scenario for an individual player, which is a very important factor to motivate the personnel to learn in the game.

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About the authors

Mana Patamakajonpong has a bachelor's degree in electrical engineering from Kasetsart University and a master's degree in the same field from King Mongkut's Institute of Technology Ladkrabang. He is currently serving as the Chief of the Knowledge Management Section, Provincial Electricity Authority, and is a PhD candidate in knowledge management at the Chiang Mai University. Mana Patamakajonpong is the corresponding author and can be contacted at: mana_pat13@yahoo.com

Tirapot Chandarasupsang received his PhD in electronics and electrical engineering from the University of Strathclyde, UK, in 2006. He is currently a Senior Lecturer at the College of Arts, Media and Technology, Chiang Mai University, Thailand. His research interests are Power system economics, electricity market designs, asset management and knowledge engineering. He also provides academic and consultant services to both private and government agencies in the Electricity Supply Industry of Thailand.