CHAPTER 4
Case Study

4.1 Chapter Overview

In order to test the proposed research framework, Provincial Electricity Authority (PEA), Thailand is selected to be the case study. The research proposes to test the framework with the 22kV switchgear inspection and maintenance job. This study is comprised of 3 case studies. These case studies prove the research hypothesis shown in Chapter 1. The first case study shows that the framework can be efficiently used to identify the personnel ability especially for specific knowledge and visual inspection skill. The second case study proves that the research framework provides the proper method for capturing the knowledge and experience of expert to develop the game scenario. This knowledge can be utilized for creating the game scenario with a systematic structure. The final case study verifies that this game-based knowledge management is the appropriate method for enhancing visual inspection skills. This chapter presents the detail of the case studies such as general description, target group, and testing method.

4.2 Case Study 1: Capability Level of PEA North 3 Area (Lop Buri Province) Substation Maintenance Personnel

4.2.1 General Description

This case study is done to prove the hypothesis that "the proposed framework can be utilized to identify the capability level of the individual personnel better than the traditional method". In order to test this hypothesis, PEA is selected as a case study. The research proposes to study the 22kV switchgear maintenance job. Due to the problem of traditional training programs which was presented in Chapter 1, PEA needs an alternative method to classify the capability of the substation maintenance staff in order for PEA to provide them with the most suitable training materials. This paper proposes

the framework to classify the capability of the staff. The research used the framework to classify the substation maintenance capability of PEA North Area3 (Lop Buri Province) (PEA N3) personnel. The results of capability classification are compared with the current competency model of PEA substation maintenance personnel.

As presented in Chapter 1, PEA is divided into 4 regions. They are North, North East, Central, and South. Each region is divided in 3 area offices. In the northern part of Thailand, the area offices comprise of PEA North Area1 (Chiang Mai Province), PEA North Area2 (Phitsanulok Province), and PEA North Area3 (Lop Buri Province). The research proposes to study the capability of PEA North Area3 (Lop Buri Province) personnel as Lop Buri is not far from Bangkok. Moreover, the capabilities of substation maintenance personnel of PEA N3 are diverse. For substation maintenance work, there are newcomer operators, operators, engineers, senior operators, and experts.

The PEA North 3 Area (Lop Buri Province) is responsible to supply electricity to customers in 6 provinces in the north of Thailand. These provinces include Lop Buri, NakhonSawan, Sing Buri, Phetchabun, Uthaithani, and Chainat as show in Figure 4.1. Statistical data of PEA is shown in Table 4.1.

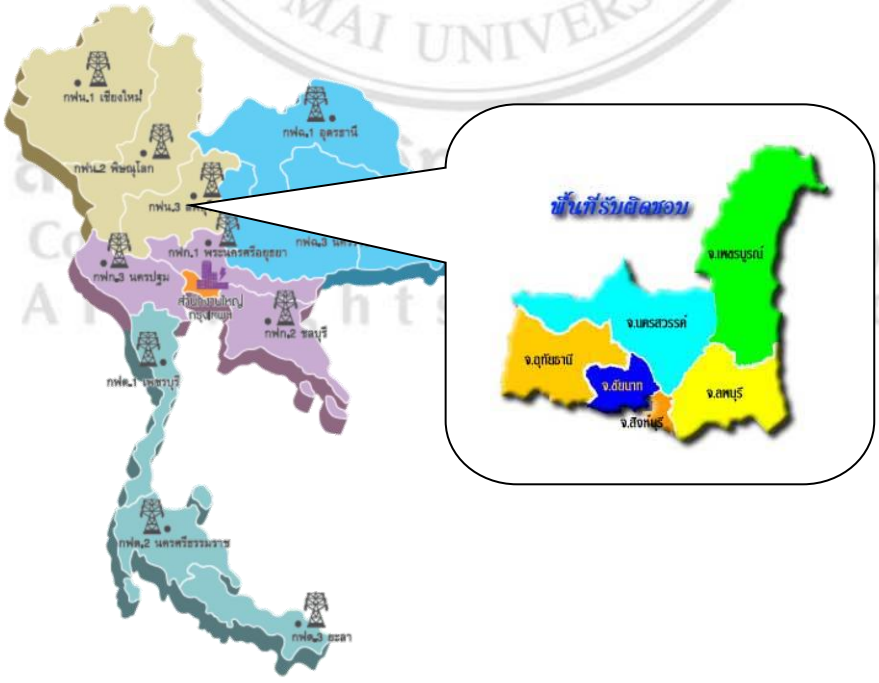

Figure 4.1 PEA N3 Service Area

Table 4.1 Statistic Data of PEA N3

Topic	Data
Customer	1,119,582
Transmission System (km)	545.545
Distribution System (km)	23,197.258
Power Substation	30
Net Revenue (Mil. Baht)	19,035.45
Employees	1,688
Provinces	6

For the 22 kV switchgear maintenance of PEA N.3, the Protection and Relaying Section, Power System Control and Maintenance Division, is responsible for this task. This section has been taking responsibility since 2011. However, this section is not only responsible for substation maintenance task but it is also responsible for the maintenance of the equipment of the distribution line as well. The job description of Protection and Relaying Section are shown as follows:

1. Setting the distribution system protection
2. Control, install, and maintain the equipment in power system substation.
3. Plan, survey, and install recloser and Automatic Voltage Regulator (AVR)
4. Maintain recloser and AVR
5. Record the historical data of recloser
6. Inspect, maintain, and clean substation

Presently, there are 30 substations which are undertaken by PEA N3. These substations are divided into 2 categories. These are 115/22 kV substation and 22 kV substations. According to PEA standard, each substation has to be done the preventive maintenance at least 1 time/year. Normally, the maintenance team consumes 2-3 days to maintain each substation. Presently, there are 6 staff in the PEA N3 maintenance team. These staff include the first line manager, senior engineer, engineer, senior operator, and 2 operators. This team is responsible for 22 kV switchgear part maintenance. The duties of this team include:

1. 22 kV circuit breaker maintenance
2. Insulation testing
3. Main contact resistance testing
4. Close/Open timing testing
5. Clean and lubricate the mechanism of circuit breaker
6. 22 kV circuit breaker operation testing
7. 22 kV protective relaying testing
8. AC system, DC system, Battery, and battery charger testing
9. Grounding system testing

For the substation maintenance staff, PEA sets up the competency model is comprised of 5 competencies. Each competency is divided into proficiency level of 5 levels by 5-pattern. Then the competency model is validated by line executive peer review. After competency models are set up, it is used to evaluate the competency gap of individual staff and use this information to set up the individual development plan (IDP). However, it was found that the current competency model do not emphasize in the technical skill especially in the engineering aspects. Besides, the competency profile of substation maintenance sections presents the technical competencies including knowledge in protective device in the power system, inventory system, electrical equipment installation and maintenance. These competency skills are rather general maintenance knowledge which is not efficient 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 staff to set up the suitable method to develop the maturity of the staff. For the competency model development of the maintenance task, it has to focus on the functional competency because the maintenance staff should have the specific skill, knowledge and ability in order to complete their job. Table 4.2 presents the current competency model of PEA.

Table 4.2 PEA Substation Maintenance Competency Model

Topic	Current Competency Model
Objective	To support various HR activities
Competency Type	- Core Competency - Functional Competency includes managerial and technical competency
Data Gathering Method	- Descriptive Meeting - Focus Group - Benchmarking
Competency Mapping Method	- Supervisory Assessment Survey - Benchmarking
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
Proficiency Level	5 Patterns Level1: Beginner Level2: Apply Level3: Supervise Level4: Master Level5: Strategic

4.2.2 Target Group

This case study was carried out with PEA N3 switchgear maintenance staff. The target group includes supervisor, senior technician, technician, and new technician. The detail of the individuals is as shown Table 4.3.

Table 4.3 Target Group Detail of Case Study 1

Target	Topic	Detail
Supervisor	Job Position	7th Engineer Level
	Education Background:	Bachelor Degree in Electrical Engineering
	Maintenance experience:	7 years
	Substation training course:	6 courses
Senior Technician	Job Position	Technician Level
	Education Background:	Bachelor Degree in Electrical Engineering
	Maintenance experience:	7 years
	Substation training course:	3 courses
Technician	Job Position	4th Technician Level
	Education Background:	High Vocational Certificate
	Maintenance experience:	4 years
	Substation training course:	1 course
New Technician	Job Position	3rd Technician Level
	Education Background:	Bachelor Degree in Electrical Engineering
	Maintenance experience:	1 year
	Substation training course:	Never

4.2.3 Testing Method

The framework of this research proposes an alternative classification framework for an enhancement of the engineering capability of the technical staff. Therefore, the knowledge and skill relating to management are not emphasized in this framework. In the case study, the capability classification model of switchgear maintenance staff which development in Chapter 3 is used to test the capability of PEA N3 22 kV switchgear maintenance personnel. The testing is done by interviewing method. The interview questions are divided into 6 groups according to the competency model. These include planning, coordination, maintenance operation, measuring, equipment

correction, and assessment analysis. The Figure 4.2 presents the proficiency level of the maintenance competency model. This case study evaluates the capability of the staff and plot the result in the diagram to define the gap of the ability level compared to the competency profile.

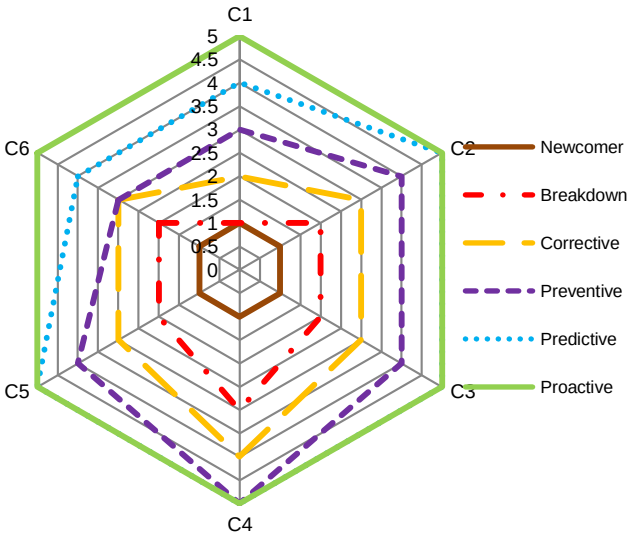

Figure 4.2 Radar Diagram of Maintenance Classification Maturity Model

These questions are developed based on the proficiency level of each competency. These questions were used to evaluate the staff's knowledge. This evaluation was done by the self and supervisory assessment method. In this first evaluation process, the staff were tested by oral interviewing with the placement question. The question increased the difficulty level if staff can answer and express their knowledge and finished when staff cannot answer. The first line manager of staff was asked to join the interviews. The results of testing were plotted into a radar diagram of classification model to identify the skill and knowledge gap. Then the classification models of every staff were validated by the first manager. In this validation, the first line manager was asked to expose the evidence from the past performance of his subordinates.

After that, the second evaluation process is done by using the prototype of placement scenario which is developed. It is done to check the validity of the placement scenario. The results are compared with the first evaluation and evident which observed from past performance. The purpose of testing is to prove that the placement scenario can be used to define the ability level of the game player.

4.3 Case Study 2:22 kV Switchgear Maintenance Personnel Development Program

4.3.1 General Description

This research proposes the framework to develop the knowledge game as the alternative method for enhancing the substation personnel performance. This case study aims to prove the research hypotheses which are concerned with the scenario development. These hypotheses are stated as follows:

H2: The proposed knowledge game framework can be used to develop the game scenario.

H3: The proposed game development framework and knowledge engineering methodology are the proper methods for capturing the knowledge and experience of experts to develop the game scenario.

As presented in chapter 1, in the past, the 22 kV parts of substation maintenance jobs have been done by Substation Maintenance Division staff. The area office staff cannot do this job by themselves. Due to the fact that PEA continually expands power system to improve its quality and reliability, the number of power system substations increases. Many problems will occur if the area office's personnel cannot maintain equipments just in time by themselves. Currently, PEA has to disperse the 22 KV parts of substation maintenance jobs from head office to the area offices. Therefore, PEA has to prepare the maintenance staff by enhancing their maintenance knowledge and skill of concerned personnel.

At the present, many HRD intervention methods have been deployed by PEA to increase knowledge and skill relating to maintenance task. These include in-class training, coaching and on-the-job training. In order to set up the training program, the experts of related division have to discuss with training staff to create the training objective, training schedule, contents, instructors, and target group. After that the experts have to devote their time to create the training materials such as presentation, training document. The contents of training course are depended on knowledge and

experience of the instructor. Normally it cannot increase any contents during the training program.

As presented in Chapter 1, PEA is divided into 12 areas offices. This matter impacts the substation maintenance process. Each area has its own process. Although the concept of maintenance is similar, the steps are different. Moreover, each area also uses different types of instruments. These reasons cause problem when developing the training program and content of the staff and instructors. Normally, the training instructors set up the training contents and training material depending on their knowledge and experience. Therefore, the training material and content might be developed based on the equipment and process on experts' knowledge. The current training programs of switchgear maintenance are shown in Table 4.4 and 4.5.

Table 4.4 Substation Equipment Maintenance Course

Topic	Detail
Background	Presently PEA has the plan to increase the Power Substation. The maintenance processes are quite different based on the various producers of equipments. Therefore, basic maintenance knowledge is more important in order to extend the lifecycle of power substation.
Objective	1. To enhance maintenance staff's knowledge in order to do the correct substation equipment process 2. To develop maintenance staff on the diagnosis of failure equipment
Target Group	Technician and Engineer
Content	- Safety of Maintenance Operation - Equipment in Substation - Life cycle of Substation Equipment - Substation Equipment Maintenance and Operation - Practice in Substation Maintenance
Method	Lecture, Demonstrate and Practice

Table 4.4 Substation Equipment Maintenance Course

Topic	Detail
Duration	3 Days
Competency	- Electrical equipment Installation and Maintenance - Analytical skill

Table 4.5 22 kV Switchgear Maintenance Course

Topic	Detail
Background	Due to PEA plan to assign the area offices to do the switchgear maintenance process, therefore PEA has to prepare the area office staffs knowledge in order to analyze and maintain the 22 kV part equipment in substation by themselves.
Objective	1. To prepare the substation maintenance operator in order to do the switchgear maintenance 2. To make the operator understand in the switchgear maintenance standard
Target Group	Maintenance Operator
Content	- Switchgear Maintenance Task - Coordination of Maintenance - Maintenance Pattern - Failure and Waiting Time - Maintenance Planning Process and Data Collection - Visual Inspection - Measuring instrument for Condition Monitoring - Testing Results Analysis - Supporting Document and Standard for Maintenance Task - Testing Form and Report - Measuring Instrument Calibration - Practice

Table 4.5 22 kV Switchgear Maintenance Course (Continued)

Topic	Detail
Method	Lecture, and Practice
Duration	3 Days
Competency	- Electrical equipment Installation and Maintenance - Analytical skill - Coordination Skill

4.3.2 Testing Method

There are 2 assumptions proved by this case study. Both assumptions support research hypotheses H2 and H3. The first assumption is that the proposed structure of game is appropriate for knowledge game development. The second assumption is that the knowledge engineering methodology is the proper method to elicit the knowledge from experts. In this research, the structure of the game narrative is divided into 6 subparts. These include planning, coordination, operation, measuring, corrective, and monitoring. Each part is independent.

In order to establish the accuracy of these assumptions, the first prototype of game was developed based on knowledge of PEA N3 experts and were tested by the maintenance personnel of PEA C1. After finish testing, the PEA C1 expert was interviewed to investigate the validity and usefulness of the contents with their work. The aim of this test is to find out the scenarios that are different from PEA C1 maintenance process. The PEA C1 expert was then interviewed in order to capture knowledge about the maintenance process. Through this interview, the new knowledge was used to create the new scenario of the game. According to the plug-in design structure, the former scenario can be replaced by the new scenario. This replacement is done only for specific parts which are different from the PEA C1 maintenance process. After the new scenario was created and replaced in the game narrative, the new scenario was then tested by asking the PEA C1 technician to play the game. While the technician plays the game, the pre-test and post-test scores were recorded for analyzing the usefulness of game story.

4.4 Case Study 3:Personnel Development in 22 kV Switchgear Maintenance

4.4.1 General Description

The 3rd case study was done to prove the research hypotheses which stated that:

H4: The game based knowledge management is a more suitable method for enhancing visual inspection maintenance skill and knowledge than traditional HRD methods.

H5: The proposed knowledge game framework can be efficiently used to select the appropriate game level for individual player.

The development of personnel performance in visual inspection is very important for enhancing power system maintenance process. This is because the first step of the process is the decision of staff. They have to know which component needs to be repaired. It means that the visual inspection is the first and important process of maintenance staff. At the present, many training methods have been deployed by PEA to increase knowledge and skill relating to maintenance. These include, for example, in-class training, e-learning and/or on-the-job training. Although these methods are effective to some extent, they failed to provide appropriate environments essential to learn maintenance knowledge and skill. Learning visual inspection skill is a more complex process that utilizes problem-solving and insightful thinking in addition to the repetition of stimulus response chain. Therefore, the maintenance staff should have the chance to do and learn by trial and error with real situation (Siang and Rao, 2003). Unfortunately, the real fault events are very rare for a training event. Therefore, the PEA needs the new method or tool for developing the skill of the staff which should provide the staff an opportunity to make a decision in the visual inspection job by themselves.

In 2013, PEA sets up 145 million Baht for the training and development budget. This budget is allocated into 2 parts. The first part is 84 million Baht, used for technical training. The second part is 61 million Baht, used for non-technical training. However, PEA has more than 28,000 workers scattered though out Thailand. Therefore, this

allocated budget is not adequate for training every employee. Therefore, PEA has to develop the new method which is more efficient than traditional training. For substation maintenance training, PEA set up more than 10 million Baht for training in technical skill of substation maintenance staff. The maintenance training courses were conducted for trainees with varying level of knowledge. Many trainees' levels have to train in the same course. Therefore, some courses did not motivate the entire trainee in the class due to the mismatch between the knowledge and skill level of trainees and the content of the training course. This problem occurred because PEA does not have the practical method to identify the engineering capability of its staffs. Engeser and Rheinberg (2008) applied the flow theory of Csikszentmihalyi (1991) to define 6 components to motivate trainees to learn in training program, where one of them is a balance between personal skills and difficulty of the activity. In the training perspective, if the skill is higher than difficulty, the trainee feels more comfortable and sometimes it makes the trainees uninterested in the training program. On the other hand, if the skill is lower than difficulty, the trainees feel anxiety and sometimes they give up that training program. Therefore, it is very important to design the training course by emphasizing the difficulty of the training contents to match the trainees' skills, knowledge and abilities.

4.4.2 Target Group

In order to test the game prototype, the target group is selected. This target group is the group of substation maintenance staff with varying level of capabilities. These staff are selected from 3 substation maintenance units; Head Office, PEA North Area 3 (Lop Buri Province), and PEA Central Area 1 (AyutthayaProvince). This group includes new technician, new engineer, technician, and senior engineer. The details of individual can be presented in Table 4.6.

Table 4.6 Target Group Detail of Case Study 2

Target	Topic	Detail
Trainee No.1	Position	Technician, HQ
	Education Background	High Vocational Certificate
	Maintenance experience	2 months
	Development Method	On the job training
Trainee No.2	Position	Engineer 5th Level, HQ
	Education Background	Master Degree in Electrical Engineering
	Maintenance experience	None
	Development Method	In class training and Site Visit
Trainee No.3	Position	Technician4th, PEA N3
	Education Background	High Vocational Certificate
	Maintenance experience	5 Years
	Development Method	On the job training and In class training
Trainee No.4	Position	Technician 3rd Level, PEA N3
	Education Background	Bachelor Degree in Electrical Engineering
	Maintenance experience	1 year
	Development Method	On the job training
Trainee No.5	Position	Technician 4th, PEA C1
	Education Background	High Vocational Certificate
	Maintenance experience	6 Years
	Development Method	On the job training
Trainee No.6	Position	Engineer 5th Level, PEA C1
	Education Background	Bachelor Degree in Electrical Engineering
	Maintenance experience	6 Years
	Development Method	In class training, On the job training, Site visit

4.4.3 Testing Method

In order to test the research framework, the paper and pencil testing method is applied to develop the knowledge game prototype. This prototype is developed as paper prototype. The benefit of this kind of prototype is the game developer can get user feedback early on in the development process, before too much investment has been put into actually building the game (Whitton, 2010). The data and information collecting process of this testing is the combination of the interviewing, questionnaire, and observation methods. The testing process starts with interviewing the training background of the trainees. The objective of this interview is to gather the training and education background, and maintenance experience of the trainee. Then the trainee was asked to play the game prototype. This prototype is divided into 3 parts: pre-test and placement test, content scenario, and post-test. The testing concept applied the one-group pre-test-post-test design (Werner and DeSimone, 2006). The trainees were assessed on the variables being observed before training and again after training.

Pre-test and Placement Test → Training or Game Scenario → Post-test

The testing process was done to investigate the knowledge, behavior, and opinion of the trainees. The process includes 3 sub-processes: knowledge testing, behavior change testing and game efficiency survey. The process is shown in Figure 4.3. In this matter the prototypes of game, which were developed, were used in this test. The prototypes of game were created by PowerPoint program by applying the pen-and-pencil method. These prototypes are shown in the appendix.

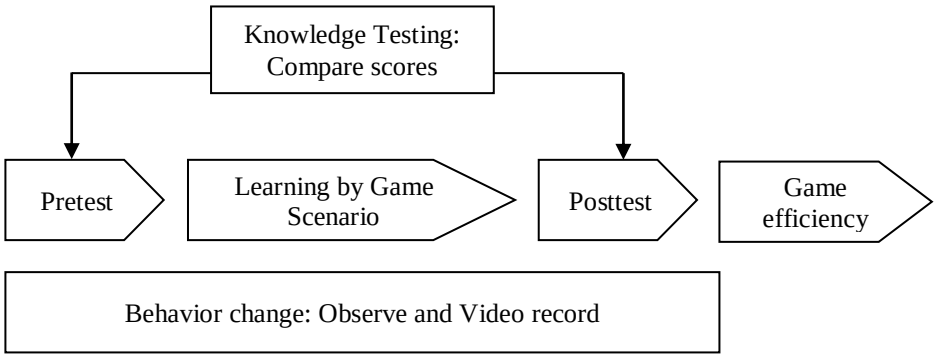

Figure 4.3 The Testing Process of Case Study 3

- The knowledge testing process measured the increased knowledge of the trainee after playing the game. The variables of this testing are the time taken to complete the activities and the corrective decision of trainees compared to that of the expert. This test process starts by asking trainees to do the pre-test and placement scenario. During the pre-test, the scoring was recorded. After that the trainees learned the maintenance knowledge by playing the game scenario. Finally, the trainees did the post-test and recorded the score. Both scores of pre-test and post-test were compared to investigate the increasing of knowledge of the individual. This score is based on the time taken to finish the test and the number of correct decisions made by the player.

- The behavior change testing was done during the trainees play the game. The trainees' behavior was observed and recorded by the video recorder. These recorded videos were used to analyze and investigate the behavior change before and after learning in game.

- The game efficiency survey was done after trainees finished the game playing. The player asks to make the game efficiency survey to analyze the game effectiveness regarding to Prensky's theory and flow theory. The research proposes to apply the EGameFlow which developed by Fu, Su, and Yu (2008). The questionnaire form is shown in the appendix. The EGameFlow is the survey questionnaire to measure the game enjoyment and knowledge improvement. The result of measurement is based on trainees' point of view.

4.5 Chapter Summary

This chapter presents the detail of three case studies in order to prove the research hypothesis. These case studies include Case study 1: Capability Level of PEA North 3 Area (Lop Buri Province) Substation Maintenance Personnel, Case Study 2: 22 kV Switchgear Maintenance Training Course, and Case Study 3: Personnel Development in 22 kV Switchgear Maintenance. The first case study was carried out to test the scenario selection machine framework. The second case study was to approve the framework to develop the knowledge base and scenario. Finally, the last case study tests that the proposed knowledge game is better than traditional HRD interventions.