Design of Competency based Knowledge and Skill Training System on Assembly, Test, and Installation for Main Switch Board

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***Abstract*-This paper, design of competency based knowledge and skill training system on assembly, test, and installation for main switch board was proposed. Necessary competencies were analyzed to define learning outcome and all learning outcomes were considered to define needed knowledge and skill. These were applied to define pedagogy in proposed training system. Lecture and skill practice were chosen to accomplish all competencies. All contents were following IEC standard. In knowledge content learning, pre-test and post-test exams were applied to evaluate learners. In skill practice learning, Romiszowski's skill cycle was applied and it was evaluated by non-conformity record and timer. The procedure correction and timing were considered in this learning. The sample was 116 staffs in Asefa public company. The proposed system was applied to the sample. For the results, all people can pass with good score both knowledge and skill training.**

I. INTRODUCTION

Main Switch Board (SWB) is one of the most important equipment in electrical system due to the electrical energy consumption in Thailand is rapidly increased by many areas such as in commercial, residential and industrial. It will be large cost if select without standardized SWB for maintaining and controlling electrical system due to it might have system troubles that in some worst case, the power might be not able to supply electrical power to the system. In general, the SWB is consist of switching devices, control devices, signaling equipment, protective equipment, regulating equipment, bus bars, cables, and bus bar support, cabinet, and other accessories. In present, assembled SWBs that cover controlling both low voltage and high voltage are developed in Thailand and has been used in several applications such as industries, condominiums, buildings, department stores, hospitals, and etc. In addition, these applications tend to be increased rapidly and widely and due to have many request from overseas, then they tend to be exported to the other countries. In Thailand, the assembled SWB maker or panel builder were registered around 127 companies (information from Thailand Board of Investment in 2013). Some model can be passed IEC standard testing but some is not passed. Because Thailand is possible to be leader of SWB assembly, standard test, and installation including a standard approved SWB maker and exporter for ASEAN region, then, the businesses for assembled SWB maker must have electrical technologist or engineer who have ability on both theory knowledge and skill practice enough for assembling, testing, and installing all equipment in SWB.

To set up all registered assembled SWB makers for having all product meet to IEC standards, the methodology for educating knowledge and skill by training is necessary. To evaluate the ability of learner that meet to professional requirements for work in assembled SWB, the way of competency based training program is a good one. Since the outcome performance and ability of learner can be defined at beginning of training before program running, theory contents and skill practice topics can be defined following desired competencies. Finally, all of knowledge and skill can be evaluated by many methods such as paper exam for theory test and practice skill can be tested by real practice.

In this paper, design of competency based knowledge and skill training system on SWB assembly, test, and installation is introduced. The analysis of competency following requirements in IEC standard for SWB assembly, test, and installation is detailed. Knowledge and skill following defined competencies are mentioned. Active learning based class management in each knowledge and skill will be shown. To approve the proposed design competency based training system, it was tried out to perform to electrical technologists for 60 peoples in Asefa Public Company, Thailand. This result also will be shown the learning achievement of

learners is following to research hypothesis or not.

II. COMPETENCY ANALYSIS

To design topic of knowledge and skill training on assembly, test, and installation on assembled SWB, necessary competencies of electrical technologist must be analyzed as detailed in Table 1.

TABLE 1. Competency Analysis

No.	Necessary Competency	Learning Outcome
1	Reading Diagrams	Technologist must be able to read front panel drawing, frame work and construction drawing, electrical symbols, single line diagram, metering diagram and wiring diagram
2	Selection and Installation of Main Devices	Technologist must be able to select and install main devices in SWB such as Switching devices (circuit breaker, magnetic contactors), Protective equipment (fuse, current protection relay, and voltage protection relay), Monitoring devices (volt, amp, and watt meters, pilot lamps), Control equipment (variable speed drive, PLC, HMI etc.), Regulating equipment (CT, PT)
3	Selection and Installation of Busbars	Technologist must be able to read drawing busbar section, cut, bend, punch, select busbar for installing in SWB
4	Cable Selection and Wiring for Control and Power Circuits	Technologist must be able to select cable following main equipment functions such as metering part, protection part, control devices, and measuring part, to design pattern of wiring for devices, to define mark number for each cable, to select connector for each terminal and to select crimping tools for cable and lugs size
5	Accessory and hardware Selection	Technologist must be able to select accessory and hardware matching to designed main equipment, to select torque wrenches and torque screw drivers fitting for required torque of nut and bolt class on SWB

III. KNOWLEDGE AND SKILL ANALYSIS

After competencies and learning outcomes were defined, knowledge and skill for each competency must be analyzed and are shown in Table 2. In some competency such as competency 3 that shows what knowledge and skill were required for electrical technologist who must have ability on busbar selection and installation for SWB work. Technologist must learn knowledge of how to select busbar drawing before starting installation job and must learn skill for busbar selection for matching required installation. Moreover, to have skill of busbar installation, skills of cutting, bending, and punching for busbar also must be learned. All details of knowledge and skill that required for achieving all learning outcome were analyzed. In this table, K is representation of knowledge and S is representation of skill.

TABLE 2. Knowledge and skill Analysis

No.	Necessary Competency	Knowledge & Skills
1	Reading Diagrams	- Front panel drawing (K&S) - Frame work & construction drawing (K&S) - Electrical symbols (K) -Single line diagram (K&S) -Metering diagram (K&S) -Wiring &schematic diagram (K&S)
2	Selection and Installation of Main Devices	-Switching devices (circuit breaker, magnetic contactors) (K&S) -Protective equipment (fuse, current protection relay, and voltage protection relay) (K&S) -Monitoring devices (volt, amp, and watt meters, pilot lamps) (K&S) -Control equipment (variable speed drive, PLC, HMI etc.), -Regulating equipment (CT, PT) (K&S)
3	Selection and Installation of Busbars	-Drawing busbar section (K&S) -Busbar cutting (S) -Busbar bending (S) -Busbar punching (S) -Busbar selection (S) -Busbar Installation (S)
4	Cable Selection and Wiring for Control and Power Circuits	-Cable selection for metering part (K&S) -Cable selection for protection part (K&S) -Cable selection for control devices (K&S) -Cable selection for measuring part (K&S) -Bending and Wiring for power and control cables (K&S) -Mark number for each cable (K&S) -Connector and lug selections for each terminal (K&S) -Crimping, cable and lugs selection (K&S)
5	Accessory and hardware Selection	-Accessory and hardware selection (K) -Torque wrenches and torque screw drivers selection (K&S) -Torque range setting (K&S)

IV. PEDAGOGY FOR TRAINNING

To transfer knowledge and skill that required for accomplishing each learning outcome or competency, various training pedagogies were designed. Both lecture and practice based learning were considered. Knowledge contents will be transferred by lecture based learning and skill contents will be obtained by real job

based practice. In some competency, both knowledge and skill were required as shown in Table 3.

TABLE 3. Pedagogy for Knowledge and skill

No.	Knowledge & Skills	Pedagogy
1	- Front panel drawing (K&S) - Frame work & construction drawing (K&S) - Electrical symbols (K&S) -Single line diagram (K) -Metering diagram (K) -Wiring &schematic diagram (K)	-Lecture overview of front panel and practice by selecting real part from drawing and bill of material assignments -Lecture overview of frame work type & construction type drawings and practice by selecting real part from drawing and bill of material assignments -Lecture IEC standard symbol comparing with other standards and practice by selecting real part from drawing and bill of material assignments -Lecture IEC standard based cable wiring -Lecture IEC standard based single line diagram -Lecture IEC standard based metering diagram -Lecture IEC standard based wiring and schematic diagrams
2	-Switching devices (circuit breaker, magnetic contactors) (K&S) -Protective equipment (fuse, current protection relay, and voltage protection relay) (K&S) -Monitoring devices (volt, amp, and watt meters, pilot lamps) (K&S) -Control equipment (variable speed drive, PLC, HMI etc.), -Regulating equipment (CT, PT) (K&S) - Device installations (S)	-VDO clip based lecture following IEC standard and practice by selecting real part from drawing and bill of material assignments -VDO clip based lecture following IEC standard and practice by selecting real part from drawing and bill of material assignments -VDO clip based lecture following IEC standard and practice by selecting real part from drawing and bill of material assignments -VDO clip based lecture following IEC standard and practice by selecting real part from drawing and bill of material assignments -Practice on real workplace
3	-Drawing busbar section (K&S) -Busbar cutting (S) -Busbar bending (S) -Busbar punching (S) -Busbar selection (S) -Busbar Installation (S)	-Lecture IEC standard based busbar drawing and selection and practice by selecting real part from drawing and bill of material assignments -VDO clip instruction and practice on real work place -VDO clip instruction and practice on real work place -VDO clip instruction and practice on real work place -VDO clip instruction and practice on real work place -VDO clip instruction and practice on real work place
4	-Cable selection for metering part (K&S) -Cable selection for protection part (K&S) -Cable selection for control devices (K&S) -Cable selection for measuring part (K&S) -Bending and Wiring for power and control cables (K&S) -Mark number for each cable (K&S) -Connector and lug selections for each terminal (K&S) -Crimping, cable and lugs selection (K&S)	-Lecture IEC standard based cable selection for metering part and practice by selecting real part from drawing and bill of material assignments -Lecture IEC standard based cable selection for protection part and practice by wiring real part from drawing -Lecture IEC standard based cable selection for control part and practice by wiring real part from drawing -Lecture IEC standard based cable selection for measuring part and practice by wiring real part from drawing -VDO based lecture bending and wiring for power and control cables following IEC standard and practice by bending and wiring real part from drawing -Lecture IEC and DIN standards based mark number for each cable and practice by wiring real part from drawing -Lecture IEC and DIN standards based connector and lug selections for each terminal and practice by selecting real part from drawing -Lecture IEC and DIN standards based crimping, cable and lugs selection and practice by crimping, cable and lugs real part from drawing
5	-Accessory and hardware selection (K) -Torque wrenches and torque screw drivers selection (K&S) -Torque range setting (K&S)	-Lecture IEC and other standards based accessory and hardware selection -Lecture IEC and other standards based torque wrenches and torque screw drivers selection and practice by torque selection from drawing -Lecture IEC and other standards based torque range setting and practice by torque setting

V. TRAINNING SYSTEM

Proposed training system was done by dividing as 2 process. The first one was knowledge training process and second one was skill training process. For the first one, before learn each knowledge content, learners must be tested required knowledge by pre-test exam sheet. Next, knowledge content will be trained by applying necessary learning media such as VDO clip from real workplace job in some knowledge. Almost contents were related to IEC standard as mentioned in Table 3. After step of knowledge content learning was done, learner will be tested learned knowledge by post-test exam. Finally, both score from pre-test and post-test for each learner will be applied to final evaluation for each knowledge content.

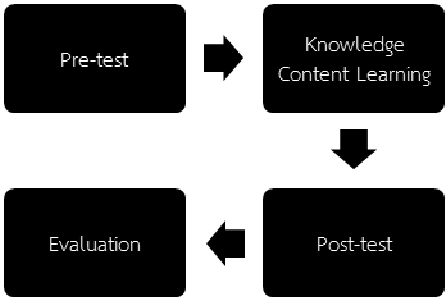

FIGURE 1. Knowledge training process

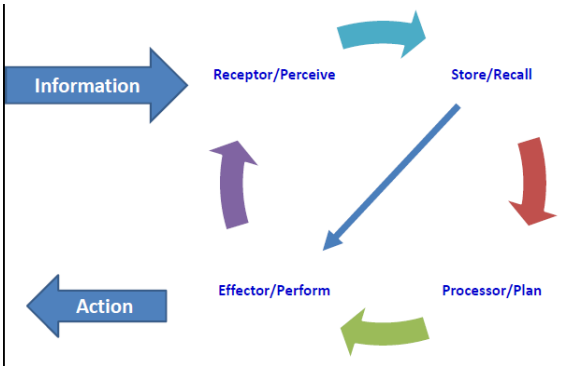

FIGURE 2. Skill training process

For the second one, IEC standard based skills requirement for electrical technologist on SWB assembly, test, and installation jobs were trained by using of Romiszowski's skill cycle shown in Fig.2. **Perceive step** was necessary information guidance such as operating procedures, steps of assembly, test, and installation. Here, learner will be guided all of information to prepare before real work operating.
Recall step was recalling of needed knowledge to make understanding for all guided operating procedures of learners.
Plan step was planning to operate based on understood procedures of learners.
Perform step was performance following planed procedures of learners.
All four steps in this skill cycle were applied to learners for all skill practice on SWB assembly, test, and installation jobs in this training system.

To evaluate learners while skill practice, correction and timing of operation were considered. Trainer will has operating checklist called as non-conformity record and timer in hand. Here, learners have to do work correctly and speedy with defined conditions.

VI. EVALUATION

To evaluate the proposed training system, 116 peoples of operating staffs of Asefa public company, Thailand were selected as sample. All peoples were trained under the proposed system as shown in Fig.3-5.

FIGURE 3. Learners were trained in beginning of SWB assembly

FIGURE 4. Learners was trained in while assembling SWB structure

FIGURE 5. SWB was finished by learners by the proposed system

For the results, all learner can pass all processes of training in the proposed system with good scores.

VII. CONCLUSION

Design of competency based knowledge and skill training system on assembly, test, and installation for main switch board was introduced in this paper. Necessary competencies were analyzed to define learning outcome and all learning outcomes were considered to define needed knowledge and skill. These were applied to define pedagogy in proposed training system. Lecture and skill practice were chosen to accomplish all competencies. All contents were following IEC standard. In knowledge content learning, pre-test and post-test exams were applied to evaluate learners. In skill practice learning, Romiszowski's skill cycle was applied and it was evaluated by non-conformity record and timer. The procedure correction and timing were considered in this learning. The sample was 116 staffs in Asefa public company. The proposed system was applied to the sample. For the results, all people can pass with good score both knowledge and skill training.

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