User Interface and Interaction for Procedure Execution to Reduce Human Error

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APR1400 has introduced CPS (Computerized Procedure System). Unlike monitoring and control system, CPS has no standardized user interface because of variety of their tasks. APR1400 however introduced so called Flowlogic diagram by combining flowchart and logic tree. Flowlogic diagram is evaluated to be useful to reduce human error, and applied to SKN3,4 and the successive *APR1400 nuclear power plants. Computerized procedure is decomposed from procedure to instruction. Flowlogic diagram is used to present element step. Interaction of Flowlogic diagram is defined to highlight instructions to be executed.*

I. INTRODUCTION

Most tasks are performed in three different ways; skill based operation, rule based operation, and knowledge based operation. Tasks in nuclear power plants are recommended to be performed according to the rule based operation. Therefore more than 1000 procedures are prepared in nuclear power plants. The procedures cover normal operation, abnormal operations, and emergency operation in Fig.1. Whenever an event occurs, operators resort to a procedure even though they have enough skill or experience. Fig.1 shows procedures classified with event severity. ARP or SOP is alarm response procedure, and system operation procedure. When abnormal event occurs AOP(abnormal operating procedure) shall be performed. More severe events require EOP(Emergency Operating Procedure), FRP(Functional Recovery Procedure) and SAMG(Severe Accident Mitigation Guideline).

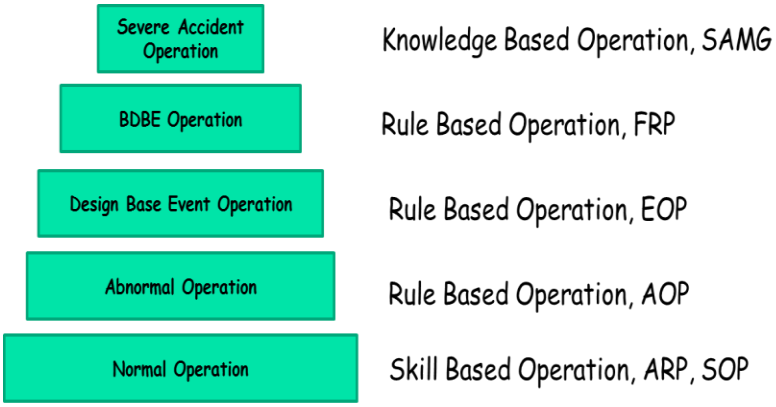

Fig. 1 Procedure Classification

Traditionally procedures have been prepared on paper. Either commercial text editors or graphic tools are used to prepare the procedures. Tasks in procedures are so various that text documents written in natural language have been preferred. Most nuclear power plants provide several templates suitable for procedure types. One of the templates is dual column format. The left column of the template is dedicated to normal actions, whereas the right column is dedicated to contingency actions which should be executed in case that normal action cannot be performed for any reason. Dual column format is effective method to deal with contingency actions. Practically exception handling mechanism is difficult even in computer program where Try-Catch mechanism has been used widely for Java or C++. However Try-Catch mechanism is not suitable for

human to interpret. Dual column format rather than Try-Catch is easy for operator to follow. Especially emergency EOPs(operating procedure) are usually written in dual column format.

There have been trials to introduce computer based procedures replacing paper procedure since 1990 [1]. But these trials are not successful as much as expected comparing with monitoring and control systems which have been already computerized. Monitoring and control system consists of monitoring display, soft control, and alarm system. These displays are well characterized as being similar to P&ID.

Procedure descriptions include lots of logic words such as AND, OR, ALL, IF_THEN, and ELSE_THEN. Furthermore procedure descriptions include statements having action verbs such as verify, confirm, and close. The logic operators and action verbs constitute procedure statements. In the paper procedure, there is no limitation while writing the procedure statement in natural language. On the other hand, computerized procedure is usually not written in natural language. Computerized procedure is more dynamic rather than static in order to reduce human error and enhance comprehension. Some computerized procedure, occasionally has PDF like format with static text. Therefore lots of design works have been focused on creating user friendly interfaces for CPS. For example flowchart format [2] or logic diagram is mostly tried format for CPS. However flowchart is not suitable for CPS because it is format for programing language such as C++. Similarly logic diagram is not suitable for CPS because it is for control logic diagram. After lots of trials, most CPSs make use of text presentation again rather than graphical diagram.

There have been efforts to standardize criteria for CPS [3]. The criteria describe how to automate procedure system and how to write procedures. Some criteria can be applied to CPS design; other criteria can be applied to edit procedure itself.

APR1400 has tried lots of user interfaces for CPS. APR1400 firstly modified COMPA-II which was developed by HRP (Halden Reactor Project). COPMA-II was CPS with well formalized language. HRP introduced several atomic instructions such as manual check, actions, and message. But their language and their interfaces seem too fragrant for human execution. That means operator has to click lots of instructions to move to next instructions. APR1400 finally introduced Flowlogic diagram for CPS and apply the system to SKN3,4.

II. USER INTERFACE for APR1400 CPS

Even though user interface is graphic element, user interface shall be formally specified in text to be saved in file. Before designing user interface for CPS, APR1400 specifies procedures in formal language. Naturally the language decomposes procedure hierarchically from procedure to instruction.

Root element procedure consists of grosssteps which are similar to chapter of book. Grosssteps are used to present purpose of procedure, entry or termination conditions, and real procedure steps. Operator can easily select grossstep to carry out or to view. Grosstep also consists of steps which are similar to page of book. Step looks like a sliding window for procedure execution or turning page for paper based procedure. When a step is completed, operator clicks next button to go to next step. Step consists of instructions which are sentences in book. The instructions are atomic unit to execute. Operators do as instructions are saying. For example they close valves or pumps. Or they reports plant situation to other departments. Or they evaluate whether pressure of a tank is below average value. All these tasks are described in instructions.

After instruction is performed by clicking , CPS highlights another instruction for execution according to rules specified by procedure writer. The instructions are leaf elements of procedure hierarchy. The hierarchy is shown in Fig.2

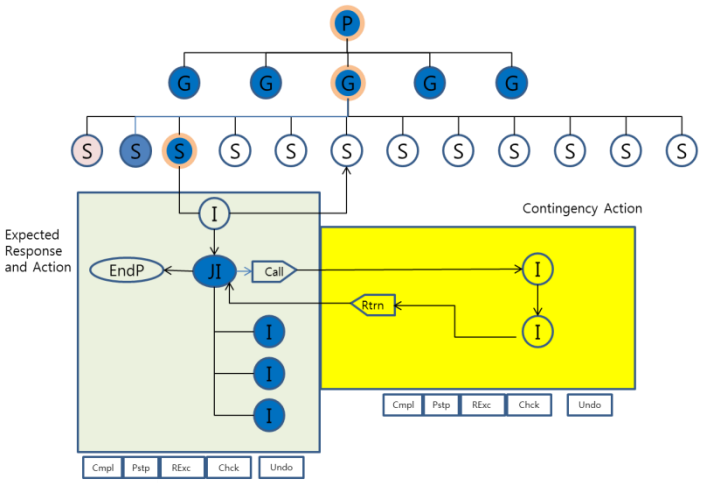

Fig. 2 Procedure Hierarchy

Connections among instructions are denoted by arrows or lines in the hierarchy. Generally step is categorized as either normal expected step or contingency steps. Background of contingency steps in Fig.2 is colored in yellow. While executing normal expected step, the contingency step is hidden. If instruction of normal expected step is not satisfied, however, button 'call' is enabled to go to contingency step. After executing contingency step, operator clicks button 'rtrn' to go to the normal expected step. Furthermore, instructions can be linked to another step beyond focused step. Whenever next step is determined while executing step, button 'complete' is enabled.

Instructions of step are more comprehensively depicted in the following picture. This graph is called Flowlogic diagram that APR1400 introduced. Flowlogic diagram is combination of flowchart and logic diagram. Instruction A and Instruction G are connected by arrows which is similar to flowchart. Instruction G is AND-gated combination of child instruction B, E, and F, which is similar to logic diagram. Transversal begins with instruction A, and terminates at instruction G. Transversal occurs successively from A to G.

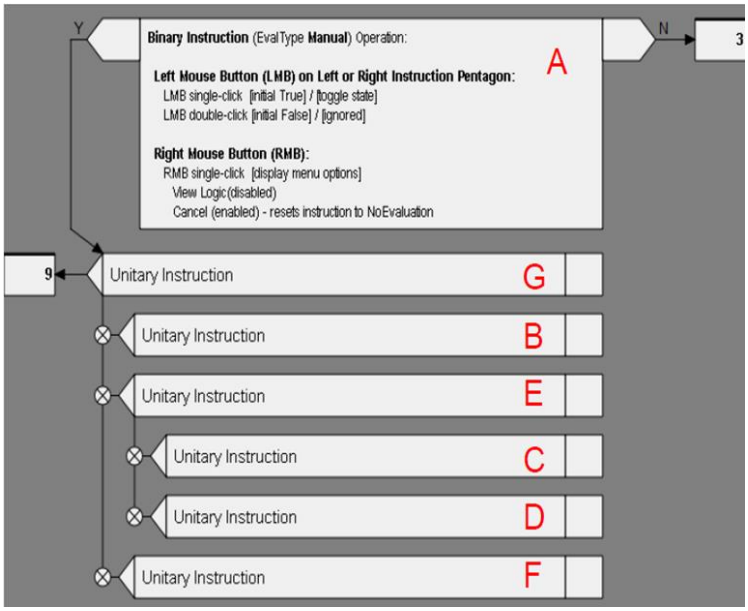

Fig. 3 Flowlogic Diagram

There are 5 types of instructions which participate in Flowlogic diagram. Instructions can have TRUE/FALSE/NA/NULL according to evaluation result. Most evaluation is performed by operator, occasionally can be evaluated by CPS if instruction is defined by AUTO. After instruction of Flowlogic diagram is determined as TRUE/FALSE, outgoing arrow is thickened and operator can go to the next instructions. Join instruction is used to combine child instructions by AND, OR, Sequentially. Characteristics of the instructions are summarized in Table.1

Instruction Type	Input/ Output	Arrow (Line)	Contingency	Join as parent	Logic	Auto/Manual/ ManualAuto	NA (Not Applicable)
Unitary	1/1	Exist	O	O	O	O	O
Binary	1/2	Exist	X	O	O	O	O
Caution	None	No	X	O	O	X	X
Note	None	No	X	O	X	X	X
Case	1/N	Exist	X	X	X	X	X

Table 1 Instruction Type for Flowlogic Diagram

Overview of APR1400 CPS is shown in Fig .4. Opened procedure is shown on window title. Gross steps of the procedure are displayed as tabs in the left top area. The focused grosstep is distinctive as yellow background. All steps of focused grosstep are arrayed sequentially in the middle area. Step with yellow outline is a focused step which shows all instructions in the right

area. The focused step shows its instructions in Flowlogic diagram. Even though there are lots of elements in procedure, operator can access to any instruction by focusing grosstep and step sequentially.

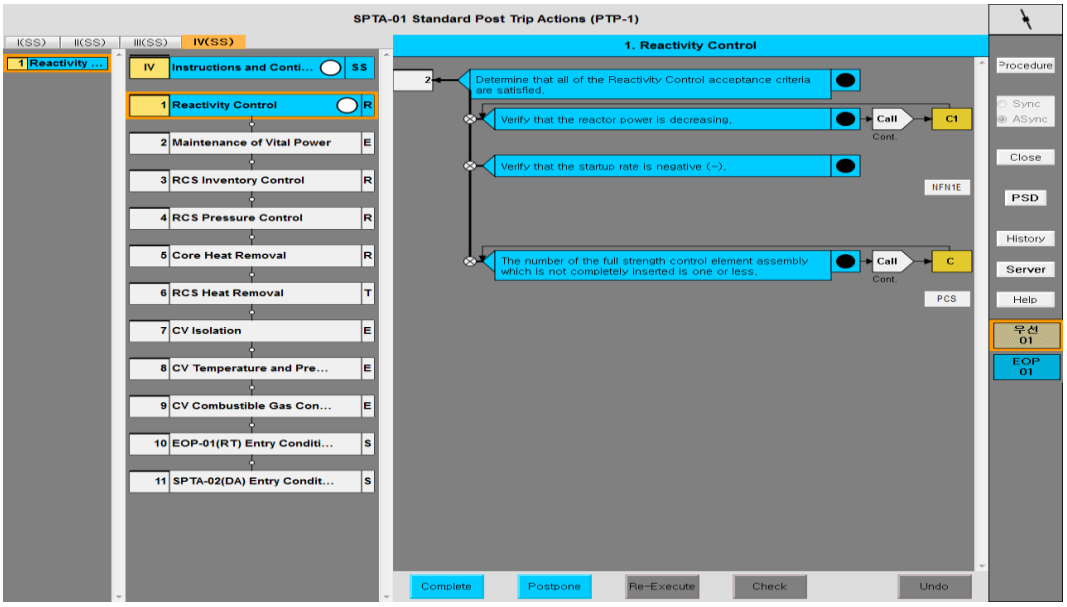

Fig.4 APR1400 CPS

In most cases focused step is a step being executed. Sometimes operator wants to see other step beforehand, then operator clicks the step which appears as focused step. The executing steps are distinguished by their blue background color. Note that several steps can be executed as parallel. Whenever button postpone is clicked, current step is registered as another executing step.

Fig.5 shows transition diagram of steps. When step is opened at first, its execution state is NotExecuted. The step becomes executing when it get token. After then the step become executed sequentially. Execution transitions occur when operator presses step control buttons such as complete, postpone, and check. Because transitions always occur between two steps, its transition diagram looks complicate.

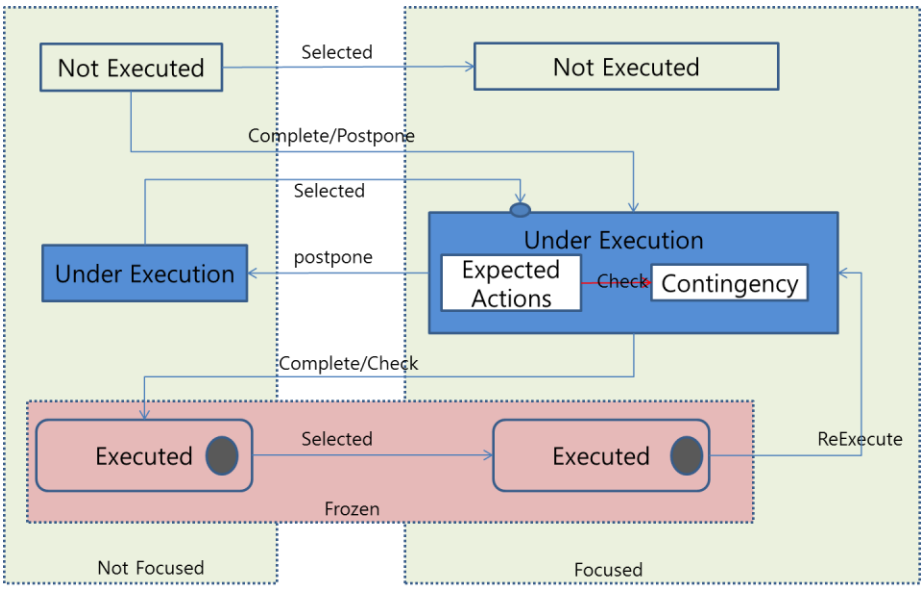

Fig. 5 Step Transition Diagram

II. CONCLUSION

When a new system is introduced, suitable user interfaces for the system should be sought. APR1400 CPS has been tried to find effective user interfaces like other systems. APR1400 CPS devised Flowlogic diagram, which is evaluated to be useful. Flowlogic does not require lots of mouse click, but suitable instruction for the current plant state is well indicated. APR1400 CPS is applied to SKN3,4 and the successive APR1400 nuclear power plants.

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