Computerized Procedure Interface for Nuclear Power Plant

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Abstract: Computerized procedure system for nuclear power plant has been designed and applied to power plants. User interface is based on both flowchart and logic tree. Both interfaces are integrated in Flowlogic Diagram.

Keyword:APR1400, CPS, Flowlogic Diagram, Procedure

1 Introduction

User Interface for CPS(Computerized Procedure System) has been developed for decades world widely. User Interface for monitoring and control systems are based on P&ID, and turns out useful. But lots of UI for CPS has been tried. There are not well defined UI for CPS comparing with monitoring and control system.

EPRI stated advantages or disadvantage of CPS [1]. According to automation level of CPS, EPRI distinguishes CPS in several levels. If presentation of CPS is similar to paper based procedure, it is called EP (Electronic Procedure). EPRI also demanded lots of requirements for transition from CPS to backup procedures. When UI for CPS is not suitable, EP is alternative. When CPS is unstable, there must be lots of requirements for transition from CPS to backup. Therefore EPRI report means that there is not suitable UX for CPS.

EP is a non-interactive procedure on FPD, whereas CPS is an interactive procedure. NRC IGS-05[2] states level of automation in CPS. The automation in IGS-05 means navigation among procedures, step, and instruction. After executing current step, it is difficult to find the next step suitable for current plant.

CPS standard of IEC[3] describes that CPS should display all necessary elements of to enable the operators to understand and be in control of the plant in any situation.

The paper describes UI for CPS not requiring EP any more, and reliability of CPS eliminating lots of transition requirements. Presentation of CPS is described in well-defined graphic diagram called Flowlogic diagram. Flowlogic diagram consists of flowchart with arrows, and logic diagram with AND, OR, Sequence. Flowlogic diagram supports transition from normal instructions to contingency instructions. After one instruction is carried out, next instruction is automatically selected and navigated. The navigation is simple and transparent for all crewmembers. Operator cannot be confused with Flowlogic diagram.

Because navigation rules for Flowlogic is clear, its software is also reliable and available throughout all years without failure. Especially because CPS is used during EOP execution, its safety grade should be higher than monitoring and control system. CPS has functions not only presenting procedures, but also keeping execution status. Integrity of CPS SW can be improved by analyzing their functionality in systematic manners.

This paper explains functions of initial CPS for APR1400 which is applied to ShinKori3,4 and functions of current CPS. Flowlogic diagram have been refined in interface and interactions. Logic operators to evaluate instructions have been re-formalized, and device symbols for CPS are simplified. Human factor evaluation is described too.

2 History of APR1400 CPS

User interface for car navigator is based on road map. Whoever develops car navigators, the navigators are looks similar. User interfaces for monitoring and control system is based on P&ID. Whoever develops monitoring and control systems are looks similar. They are almost standardized. These two system have well defined functions which are supported either road map or P&ID.

Main purpose of car navigator is showing the continuous road to follow. Therefore road map can be major element of car navigator. Main purpose of monitoring and control system is making fluid flow along pipe. The pipe is drawn in P&ID and become major element of monitoring and control system.

What is major element of CPS user interface? Main purpose of CPS is showing suitable instruction for the present plant state. Why don't you follow instructions sequentially? In paper procedure, procedures are written in sequentially and procedure user has to read the instruction one by one and applies the instruction if necessary. EP in EPRI[1] means this kind of interface which

is developed in pdf. There is no supporting function in EP. Operators could skip some instruction because they don't read process value correctly.

Procedure is written deeply and broadly in order to cover all kind of situations such as novice operators, and malfunctions of components. The experienced operator can skip irrelevant instructions which are suitable for malfunction devices. The problem is that it is difficult to skip the instruction without reading the instruction. Reading instructions generate much workload. Therefore user interface for CPS is reducing irrelevant instructions for the present plant state.

When procedure is analyzed in logic, there are typical logic operators such as All, And, Or, Any, If-Then, If-Then-Else, Contingency, and Goto. These logic operators are widely used in computer programming languages except Goto, that is not good vocabulary for structured programming language. Contingency handling mechanism in program language is a little difficult to explain in the paper. But contingency are handled by try-catch algorithm.

Programmers have capability to understand these logic operators very well and program runs well without bug. Why don't you write procedure in the same way as program. The answer is that operator rather than programmer cannot understand the procedures. Human factor engineers have tried to develop suitable interfaces covering all these logic. Unfortunately all trials have failed. Operator who urged to CPS has refused to use trial interfaces.

CPS interface returned to plain text. Computer can follow complicated instruction if well organized. But human operators can not follow the organized instruction if the instruction complicated. Human operator behaves differently from computer. Typical example is that operators cannot evaluate complex arithmetic equation, that is simple evaluation for computer. This is reason that CPS interface adopting the plain text.

APR1400 CPS has repeated the same way. Initial CPS adopted revised COPMA-II developed by HRP. COPMA-II has well organized instruction structure. It decompose instruction into action or check. But both action and check are too fragmented resulting in lots of mouse interactions. Finally APR 1400 CPS introduced Flowlogic diagram to integrate all instructions.

3 Flowlogic Interface for Procedures

Before designing UX for CPS, it is necessary to decompose procedure logically. Grammar of natural language is similar process in view of decomposition and integration. APR1400 CP(Computerized Procedure) is decomposed in Fig.1. Procedure is decomposed into Grosssteps in serial, and Grosssstep is decomposed into Step in serial, and Step is decomposed into Instruction in graph.

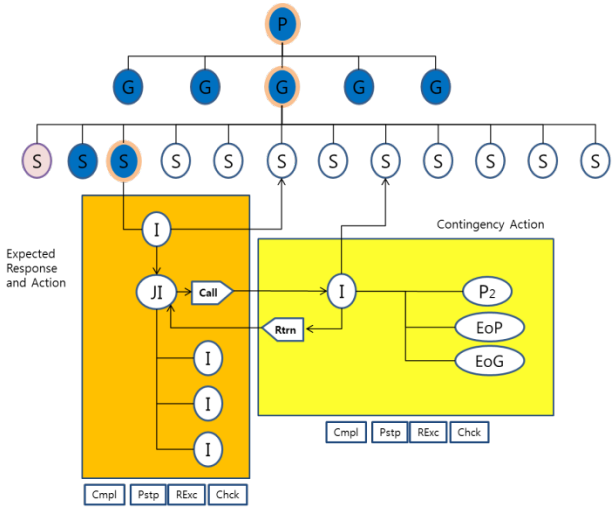

Figure 1 Decomposition of procedure

Instructions are atomic element to carry out. They are placed kept and evaluated by clicking. There is no element below instructions. Actually instruction is a simple sentence or complex sentence consisting of 2~3 sentences. In paper based procedure, place-keeping unit of procedure execution is sentence. Therefore it is reasonable that instruction is atomic unit for execution.

There are 5 types of instructions in APR1400 CPS. They are classified according to number of input or number of output. Unitary instruction has one input and one output, whereas Binary instruction has one

input and two output. Their characteristics are summarized in Table.1.

Table 1 5 Instructions and their Characteristics

Instruction Type	Input/ Output	Arrow (Line)	Contingency	Join as parent	Join as child
Unitary	1/1	Exist	O	O	O
Binary	1/2	Exist	X	O	X
Caution	None	No	X	O	O
Note	None	No	X	O	O
Case	1/N	Exist	X	X	X

Caution and Note instructions don't have arrows. They are shown prior to unitary or binary instruction to be executed. They are read without clicking instructions. Unitary instruction can have contingency actions. If unitary instruction is not satisfied, contingency actions should be performed. Contingency page is called by call button.

Both Unitary and Binary instructions can be parent instruction called join instruction. Join instruction is used to hold child instruction by Join operators such as AND, OR, or Sequence. Evaluation state of parent instruction is determined by these logic operators.

Flowlogic interface has been introduced to integrated all instructions within a step. Flowlogic operator is combination of Flowchart and Logic operator in Fig.2.

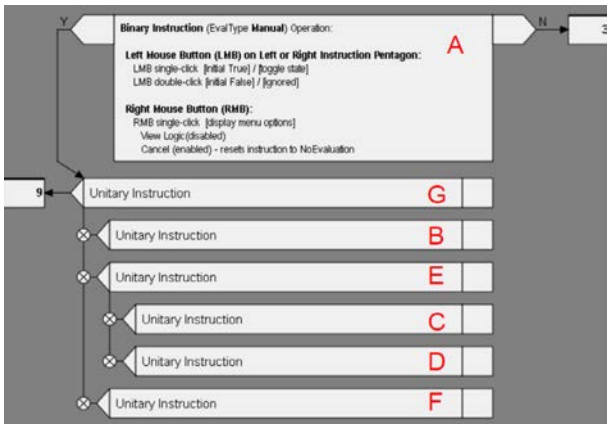

Figure 2 Flowlogic Diagram

Instructions are arranged vertically from top to bottoms. Peer instructions are connected by arrows. After one instruction is performed, next instructions are determined by arrows. Because unitary instruction has one output, unitary instruction should be performed to be true before navigating to the next instruction. But binary instruction has two output, the binary instruction should be evaluated true or false.

Join instruction has child instruction with lines connected by logic operator. The logic operator is similar to AND or OR gate in Boolean algebra. When child instructions are evaluated successfully, its parent instructions can be evaluated automatically.

Therefore Flowlogic interfaces can be navigated from one instruction to another instruction. When instructions are determined true or false, the next arrow is activated and the next instruction becomes interactive. Crew operators don't have to navigate the next instruction. CPS makes next instructions become focal point.

4 Conclusions

There has been no standard user interfaces for CPS. Because performing procedure has lots of different characteristics; actually it is difficult to have universal user interfaces. APR1400 CPS, however, introduced Flowlogic diagram for CPS. Flowlogic diagram does not require frequent mouse clicking. Furthermore Flowlogic shows focal instruction correctly.

Human factor evaluation has been performed for both domestic and abroad nuclear power plants. Even though there is some complaint that place-keeping mechanism is little different those of paper based procedure, operators are generally satisfied with Flowlogic interfaces.

References

[1] EPRI, "Computerized Procedures" EPRI 1015313, 2009.
[2] NRC, Digital Instrumentation and Controls, ISG-05, 2008
[3] IEC 62646, International Standard, Nuclear power plants – Control rooms – Computer-based procedures