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Study on Signal Validity Checking Logic Used in ESF-CCS

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1. Introduction

The purpose of this paper is to define and illustrate the Signal Validity Checking Logic (SVCL) performed by Engineered Safety Features-Component Control System (ESF-CCS) in SMART. This paper gives a brief description about ESF-CCS followed by an overview of SVCL and its objective, reasons of possible failure, methods used to perform SVCL and lastly an evidence to illustrate its features and benefits by analyzing all possible combination of signals in some locations where SVCL is used.

2. Overview of ESF-CCS

ESF-CCS actuates and controls the operation of the ESF systems and plant components by receiving the ESF actuation initiation signal in DBEs (Design Bases Events). ESF-CCS also provides instrumentation and controls for other safety-related pumps, fans, heaters, dampers, motor operated valves and solenoid operated valves. ESF-CCS receives a manual actuation signal generated by the operator to perform the required component control functions and provides the status monitoring function of the related component.

ESF-CCS consists of four independent channels, each consisting of Group Controller (GC) performing an actuation logic, Loop Controller (LC) performing an individual component control function, Component Interface Module (CIM), Interface and Test Processor (ITP), Maintenance and Test Panel (MTP), Control Channel Gateway (CCG), Control Panel Multiplexer (CPM). The block diagram of ESF-CCS is shown in Figure 1.

ESF-CCS receives the ESF actuation initiation signal from RPS (Reactor Protection System) and generates the following ESF actuation signals for Nuclear Steam Supply System (NSSS) ESF systems [1]:

- Containment Isolation Actuation Signal (CIAS)
- Core Makeup Tank Actuation Signal (CMTAS)
- Safety Injection Tank Actuation Signal (SITAS)
- Passive Residual Heat Removal Actuation Signal (PRHRAS)
- Automatic Depressurization Actuation Signal (ADAS)
- Chemical and Volume Control System Isolation Actuation Signal (CVCSIAS)
- Three Main Steam and Feedwater Lines Isolation Actuation (TMSFLIAS)
- LetDown Line Isolation Actuation Signal (LDLIAS)
- Boron Dilution Actuation Signal (BDSAS)

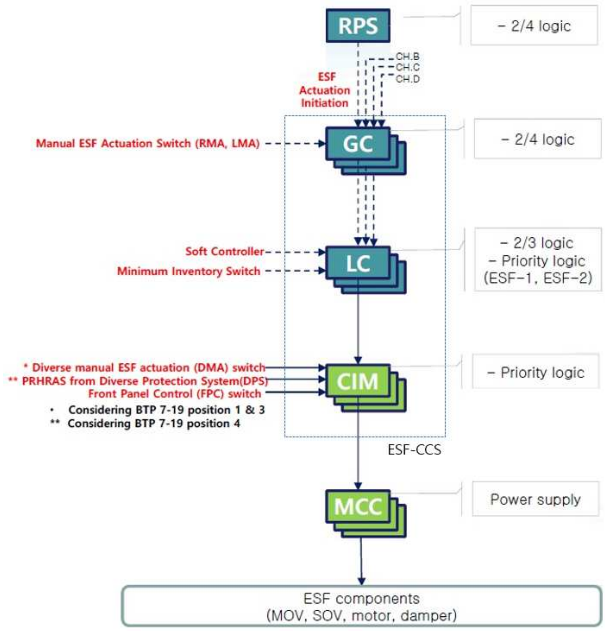

Fig. 1. The Simplified block diagram of ESF-CCS (Ch.A)

Actuation logic performed in the Group Controller (GC) generates NSSS ESF actuation signals according to 2-out-of-4 actuation logic using automatic NSSS ESF actuation initiation signals from the RPS.

ESF-CCS receives the ESF actuation initiation signal from Balance of Plant (BOP) Radiation Monitoring System (RMS) and generates the following ESF actuation signal for BOP ESF systems [1]:

- Control Room Emergency Ventilation Actuation (CREVAS)
- Fuel Handling Area Emergency Ventilation Actuation Signal (FHAEVAS)
- Containment Purge Isolation Actuation Signal (CPIAS)

Actuation logic generates BOP ESF actuation signals according to 1-out-of-2 actuation logic using automatic BOP ESF actuation signal from the BOP Radiation Monitoring System (RMS).

3. Overview of SVCL

Most of ESF-CCS signals have an associated signal validity attribute specified as "Good" or "Bad". When downstream signal processing module detects errors due to processor failures and communication failures as described in below sentence from the signals of upstream signal processing module, downstream signal processing module attaches "Bad" signal validity attribute to the signals of upstream signal processing module.

The SVCL functions by defining a signal's validity as either "Good" or "Bad", and then the actuation logic changes if Bad signal is detected.

The objective of using SVCL is to avoid frequent actuation of field components by using the characteristic of digital system (Diagnostic function). This gives ESF-CCS better operability and reliability.

The frequent actuation to field components by ESF-CCS can be due to one of the following reasons:

- Failure or physical damage of CP. (Coincidence Processor)
- Loss of communication between CP and GC.
- Error of communication between CP and GC.
- Failure or physical damage of GC.
- Loss of communication between GC and LC.
- Error of communication between GC and LC.

One of these reasons can make the GC or LC send a false actuation signal which can be ignored if SVCL is used.

There are many methods used to do SVCL, for example:

- Sequence number check.
- CRC (Cyclic Redundancy Check)
- Cable connection check
- Heart beat signal from other platform.

All of this happens in the self-diagnostic time allocation, as it can be seen in Figure 2.

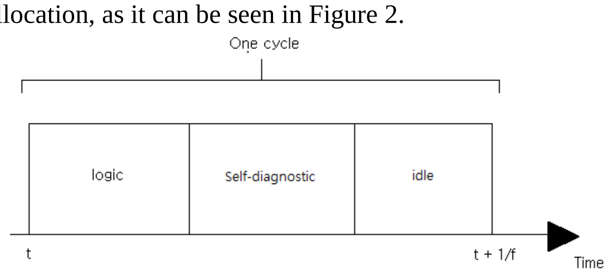

Fig. 2. Time cycle of GC and LC

4. Analysis and result

4.1 Between GC and LC

Each LC receives an input from 3 GCs. Table 1 illustrates all possible cases that might be received from GCs, the logic used and the actuation result for both cases using SVCL and not using SVCL.

From Table 1, these results can be obtained:

- All possible cases are 27cases.
- All the cases which make actuation signal if SVCL is used, also make actuation signal if SVCL is not used.
- The cases which make actuation signal if SVCL is used are 17 cases.
- The cases which make actuation signal if SVCL is not used are 20 cases.
- The difference between them is 3 cases which represents 11.11% of all possible cases (This is the reduction in actuation frequency if SVCL is used).
- There are 7 cases which do not make actuation signal either SVCL is used or not.

Figure 3 is a visual representation for Table 1.

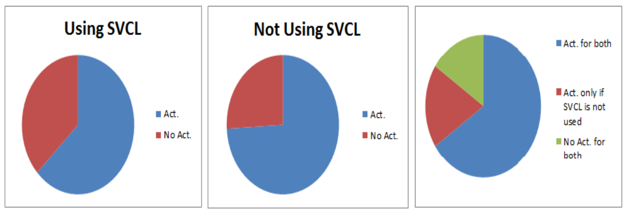

Fig. 3. Visual representation of Table 1 of all possible logics coming from GCs

4.2 Between CP and GC

Each GC receives an input from 4 CPs (one for each channel) from RPS via independent HR-SDL and performs 2/4 logic including the signal quality logic for ESFAS actuation. The GC checks the line diagnostic status and input signal quality status to process the SVCL and if GC detects bad signal, it converts full 2/4 actuation logic to 2/3 or 1/2 actuation logic.

This case has a similar table to Table 1 but it contains more cases (81 cases,), these results can be obtained from that table:

- All possible cases are 81 cases.
- All the cases which make actuation signal if SVCL is used, also make actuation signal if SVCL is not used.
- The cases which make actuation signal if SVCL is used are 50 cases.
- The cases which make actuation signal if SVCL is not used are 72 cases.
- The difference between them is 22 cases which represents 27.16% of all possible cases (This is the reduction in actuation frequency if SVCL is used).
- There are 9 cases which do not make actuation signal either SVCL is used or not.

Figure 4 is a visual representation for the truth table for this case.

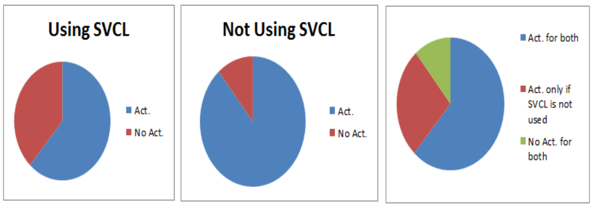

Fig. 4. Visual representation for the truth table of all possible logics coming from CPs

5. Conclusions

This study has been conducted to analyze all possible combination of signals in some locations where SVCL is used, to illustrate the features and benefits of using SVCL.

Using SVCL gives ESF-CCS better operability and reliability and enhances the accuracy of actuation signals by different percentages which depends on the case.

Finally, these study cases do represent all combination of signals but they do not reflect the percentage time of actual time of operation, which means the ESF under normal situations should not actuate any signal and this is the case for most of the time of the design life.

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REFERENCES

[1] K.I.Jeong, C.H.Kim, A Comparison of ESF Actuation Signals in Passive System, Transactions of the Korean Nuclear Society Spring Meeting, 2018.

Table 1: Truth table of all possible logics coming from GCs

#	Logic received from GCs			Using SVCL		Not Using SVCL	
	GC1	GC2	GC3	Logic used	Act.	Logic used	Act.
1	0	0	0	2/3	No	2/3	No
2	0	0	1	2/3	No	2/3	No
3	0	0	x	1/2	No	2/3	No
4	0	1	0	2/3	No	2/3	No
5	0	1	1	2/3	Yes	2/3	Yes
6	0	1	x	1/2	Yes	2/3	Yes
7	0	x	0	1/2	No	2/3	No
8	0	x	1	1/2	Yes	2/3	Yes
9	0	x	x	1/1	No	2/3	Yes
10	1	0	0	2/3	No	2/3	No
11	1	0	1	2/3	Yes	2/3	Yes
12	1	0	x	1/2	Yes	2/3	Yes
13	1	1	0	2/3	Yes	2/3	Yes
14	1	1	1	2/3	Yes	2/3	Yes
15	1	1	x	1/2	Yes	2/3	Yes
16	1	x	0	1/2	Yes	2/3	Yes
17	1	x	1	1/2	Yes	2/3	Yes
18	1	x	x	1/1	Yes	2/3	Yes
19	x	0	0	1/2	No	2/3	No
20	x	0	1	1/2	Yes	2/3	Yes
21	x	0	x	1/1	No	2/3	Yes
22	x	1	0	1/2	Yes	2/3	Yes
23	x	1	1	1/2	Yes	2/3	Yes
24	x	1	x	1/1	Yes	2/3	Yes
25	x	x	0	1/1	No	2/3	Yes
26	x	x	1	1/1	Yes	2/3	Yes
27	x	x	x	0/0	Yes	2/3	Yes

1: Actuation
0: No Actuation
x: Bad signal