Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Component Functional Allocations of the ESF Multi-loop Controller for the KNICS ESF-CCS Design

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1. Introduction

The safety related components in nuclear power plants are traditionally controlled by single-loop controllers. Traditional single-loop controller systems utilize dedicated processors for each component but that components independence is compromised through a sharing of power supplies, auxiliary logic modules and auxiliary I/O cards. In the new design of the ESF-CCS, the multi-loop controllers with data networks are widely used. Since components are assigned to ESF-CCS functional groups in a manner consistent with their process relationship, the effects of the failures are predictable and manageable. Therefore, the key issues for the design of multi-loop controller is to allocate the components to the each multi-loop controller through plant and function analysis and grouping [1,2].

This paper deals with an ESF component functional allocation which is performed through allocation criteria and a fault analysis.

2. Summary of KNICS ESF-CCS

The KNICS ESF-CCS consists of the 2-out-of-4 architecture to prevent a single failure (See Fig 1). A single channel of the ESF-CCS consists of three (3) Group Controllers (GC), twelve (12) Loop Controller (LC), an ESF Test & Interface Processor (ETIP), a Cabinet Operator Module (COM), a Control Channel Gateway (CCG), two (2) Control Panel Multiplexer (CPM), and Soft Controllers. [3]

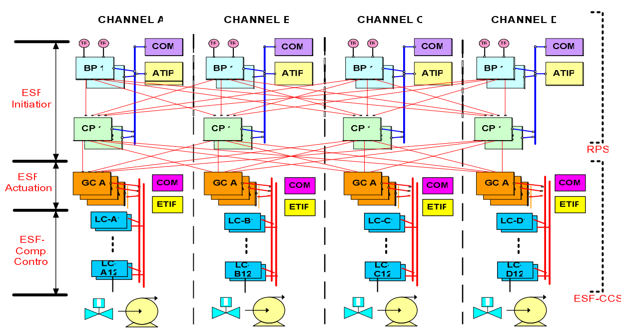

Fig 1. ESF Control Architecture

The GC acquires the logic level ESF actuation signals transferred from the four Coincidence Processors in the RPS. When two or more logic-level actuation signals from the RPS are activated, the GC will activate the ESF function-level initiation signals. The LC generates a control signal to control the grouped ESF components which belong to each LC through performing the two-out-of-three logic by using the ESF function-level initiation information from the three GCs within a channel.

3. Component Functional Allocations

3.1 Allocation Criteria and Procedure

General criteria for an assignment of the ESF components to LCs are classified into safety criteria and performance criteria. Table 1 shows the details of the general allocation criteria. Figure 2 represents a general procedure for an assignment of the ESF components to LCs.

Table 1. General criteria of component functional allocation

Category	Allocation Criteria	Remarks
Safety	Functional diversity	e.g. SIS, CSS
	Single failure criteria	e.g. ESF Trains
	Fluid independency	
	Component redundancy	e.g. Dual atm. dumps
	Electric power Independency	e.g. Electric divisions
	Diverse means	e.g passive/active SIS
Perfor-mance	No. of controls in a LC	less than 20
	Minimization of interfaces	
	Response time	
	Processing load of a LC	
	LC Location	Local installation
	Minimization of unexpected operation	Plant availability
	Testability	Test groups

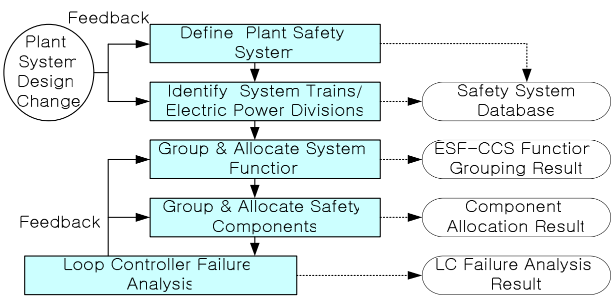

Fig 2. General procedure of component functional allocation

3.2 Application Examples

There are approximately 300 components which are related to the safety injection actuation signal (SIAS), and several process systems such as the safety injection system (SIS), shutdown cooling system (SCS), several HVAC systems, component cooling water system (CCWS), etc., are controlled by the SIAS. All the safety injection components are in the four safety-related divisions AE, BE, CE, and DE. There are approximately 110 components equally divided between the four divisions. The CCWS, essential service water system (ESWS) components are also in the four safety-related divisions. While, the SCS, load sequencers, and HVAC systems are in the two safety related divisions AE and BE. Safety depressurized system (SDS) which is performed to depressurize the primary pressure during an event of a total loss of feedwaters, is not related to the ESF actuation signals, we allocated these system components to the ESF-CCS multi-loop controller. The ESF component functional allocation results related to the SIAS are shown in Fig 3 and 4. Fig 3 represents the functional allocation results to each ESF-CCS division. Fig 4 represents the component allocation results to each loop controller.

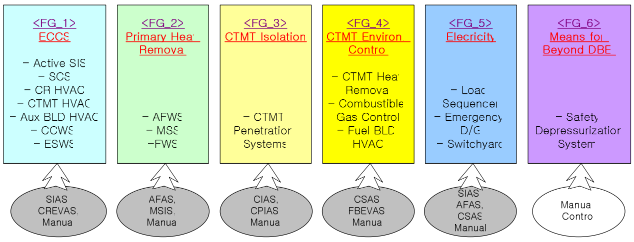

Fig. 3. Functional grouping results

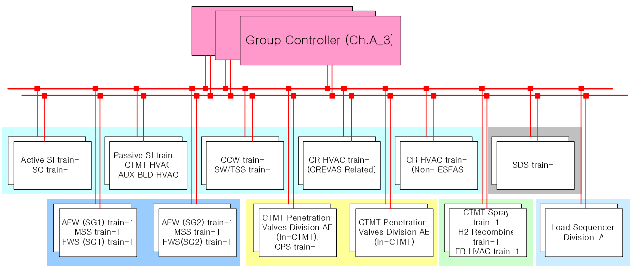

Fig. 4. Summarized component allocation to the LC

3.3 LC Failure Analysis

The component assignment is made with the final aim of being able to tolerate a multi-loop controller failure without the loss of a redundancy provided by the plant components and fluid paths. Majority of the components are valves, which are diaphragm-air-operated, motor-operated and solenoid-operated. Solenoid-operated valves can be fail-open or fail-close but the motor operated valves are fail-as-is. The valve fail status is selected to provide a fail safe valve position from plant safety considerations and sometimes operational considerations. For critical applications, two fail-close valves may be used in a path series if the safety considerations demand valve closure. Table 2 shows the samples of the fault analysis due to a multi-loop controller.

In the case of a LC-A-2 controller fails one active SI-train is faced with the loss of a function, but the remaining of 4-redundancy active SI-trains have the capability to perform their functions. In the case of LC-A-2 failure, when the plant is under normal operations, there is no impact, but under the SIAS actuation condition, the injection flow from the affected passive SI train would be reduced. But there is no impact to perform the required function of the passive SI due to the 4-redundant passive SI-trains.

Table 2. An example of the LC failure analysis (LC-A-2)

Affected components	Normal /Affected status	Compensating Provision
Nitrogen supply valve	Closed/ Closed	Provide Inherent isolation due to fail-close and series valve (BE division)
Atmospheric vent valve	Closed/ Closed	Provide inherent depressurization of SIT due to redundant valve (BE division)
SIT discharge iso. valve	Closed/ Closed	No change in the valve line-up Not allow non-safety function of fill & drain of SIT
SIT fill and drain iso. valve	Closed/ Open Closed /Closed	Not perform safety function. Not allow non-safety function of fill & drain of SIT 3 SITs perform the injection

4. Conclusion

The ESF component functional allocation was performed to design a multi-loop controller such as the loop controller of the ESF-CCS. The criteria and procedure for the component functional allocation were suggested. By using the allocation criteria and procedure, the component functional allocation was performed. The function groups in the ESF-CCS consist of 6(six) groups, and each component in the safety system was allocated into the ESF-CCS loop controllers. As for the results of the loop controller failure analysis, In addition, we suggested the LC failure analysis example. LC Failure analysis using the component functional allocation result will be deeply done.

Acknowledgements

This study has been carried out under the Nuclear R&D Program supported by the Ministry of Commerce, Industry and Energy, Republic of Korea.

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