MELTAC Platform ISG-04 Conformance Analysis

Non-Proprietary Version

November 2013

Revision History

Revision	Date	Page (Section)	Description
0	November 2013	All	Original issue as MUAP-13018. This document has been issued as JEXU-1012-1009. Refer to Revision History of JEXU-1012-1009 also.
		iii, iv (Abstract, Sec. 0.1)	Description of requirement of conformance analysis is added based on RAI 995-7024(07.01-45).

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

This MHI Technical Report describes the conformance analysis of the safety-related digital platform for the US-APWR against the requirements of DI&C Interim Staff Guidance (ISG)-04 “Highly-Integrated Control Rooms—Communications Issues (HICRc)”. Requirements of the conformance analysis of the safety digital platform are identified first, followed by the results of the conformance analysis of the Mitsubishi Electric Total Advanced Controller (MELTAC) platform, the safety-related digital platform for the US-APWR.

0.1 Requirement of Conformance Analysis

Purpose and Scope

The purpose of this document is to describe the conformance analysis of the safety-related digital platform for the US-APWR to the requirements of DI&C ISG-04 “Highly-Integrated Control Rooms—Communications Issues (HICRc)”.

The results of the conformance analysis of the MELTAC platform, the safety-related digital platform for the US-APWR, to the requirements of DI&C ISG-04 are attached in this document.

The other level of the conformance analysis of safety-related digital instrumentation and control (I&C) systems (i.e., system and application level conformance analysis), not described in this report (e.g., interdivisional communications among the safety-related systems, interdivisional communications from the non-safety systems, including operational visual display unit (VDU) to the safety-related systems), is described in the US-APWR Design Control Document (DCD) Chapter 7 and the other associated technical reports.

Conformance Analysis of Safety-related Digital I&C System

The safety-related digital I&C system conforms to DI&C ISG-04.

As described in DCD Section 7.1, the safety-related I&C for the US-APWR consists of a fully digital platform. The conformance of safety-related digital I&C system to ISG-04 are described in the following documents.

“Safety I&C System Description and Design Process” (MUAP-07004), for system and application level.
“MELTAC Platform ISG-04 Conformance Analysis” (MUAP-13018), this report, specific for platform level.

Requirement of Conformance Analysis

The requirements of ISG-04 from Sections 1.0 to 3.1 are provided as analysis criteria of the safety-related digital platform. Conformance to Section 3.2 "Human Factors Considerations" and Section 3.3 "Diversity and Defense-in-Depth (D3) Considerations" is demonstrated at the system and application level. Therefore, requirements of Sections 3.2 and 3.3 are not provided as analysis criteria in this report, but described in MUAP-07004 Appendix E.

Conformance Analysis

To demonstrate the conformance analysis specific for safety-related digital platforms, the results of a conformance analysis of the MELTAC platform to the requirements of DI&C ISG-04 is attached in this document (from Section 1.0 to Section 4.0 of this document) with following information.

- Conformance analysis result, which demonstrates that the safety-related digital platform design conforms to the requirements of DI&C ISG-04.
- Modification information, which demonstrates the design modification if it is needed to conform to the requirements of DI&C ISG-04.

MELTAC Platform ISG-04 Conformance Analysis

Non-Proprietary Version

November 2013

Prepared:	Yukiko Hirano, Manager Control & Protection Systems Section	Nov. 20, 2013 Date	Yasunobu Koga, Manager Instrumentation And Control Systems Development Section	Nov. 20, 2013 Date
Reviewed:	Manabu Taniguchi, Manager Control & Protection Systems Section	Nov. 20, 2013 Date	Makoto Ito, Manager Instrumentation And Control Systems Development Section	Nov. 20, 2013 Date
Approved:	Hidetoshi Matsushita, Section Manager Control & Protection Systems Section	Nov. 21, 2013 Date	Kentaro Sadayuki, Section Manager Development Quality Control Section	Nov. 21, 2013 Date

Signature History

	Rev.0	Rev.1	Rev.2	Rev.3
Prepared	Tomonori Yamane	Yasunobu Koga	Yasunobu Koga	Yasunobu Koga
Reviewed	Makoto Ito	Makoto Ito	Makoto Ito	Makoto Ito
Approved	Shigeo Ueno	Masahiko Nambu	Kentaro Sadayuki	Kentaro Sadayuki

	Rev.4			
Prepared	Kazufumi Yoshida Yasunobu Koga			
Reviewed	Hitomi Sasaki Makoto Ito			
Approved	Hozumi Kadohara Kentaro Sadayuki			

Revision History

Revision	Date	Page (section)	Description
0	February 2007	All	Original issued
1	October 2009	All	● MELCO reflected the result of NRC audit "Audit of MHI Documents in support of the MELTAC platform safety evaluation" in September 2008. NRC ISG-04 Sections 1, 2, and 3.1 on Digital I&C were added to the criteria for communication analysis. ● Self-Diagnosis Functions were added to the analysis. ● Post-Development Procedures were added to the analysis.
2	March 2010	All	The document title is modified to "MELTAC Platform Basic Software Safety Report".
		1 (Sec.1)	Description of purpose is modified for MELTAC platform.
		(Sec.1.2)	"MELTAC Basic Platform Software Program" is added for reference document. "US-APWR Software Safety Plan" is deleted.
		2 (Sec.2.1)	Description of Potential Hazard is modified.
		3 (Sec.2.2)	Description of Acceptance Criteria is modified.
		9 (Sec.3.2.4)	Description of Evaluation is modified.
		35 (Sec.3.4.1)	Description of Evaluation is modified.
		39 (Sec.3.4.6)	Description of Evaluation is modified.
		(Sec.3.4.7)	Description of Analysis and Evaluation is modified.
		56 (Sec.3.6.2)	Description of EXM is added in Table3.6-2C.

Revision	Date	Page (section)	Description
2	March 2010	61 (Sec.3.6.4)	Description of ECC is added in Table 3.6-4B.
		63 (Sec.3.6.4)	PCI bus is changed into FutureBUS+ in Table 3.6-4D.
		65 (Sec.3.6.5)	PCI bus is changed into FutureBUS+ in Table 3.6-5A.
		66 (Sec 3.6.5)	Description of L bus is added in Table 3.5-5B.
		67 (Sec 3.6.6)	Numbering error is corrected. (Table 3.6-4A -> Table 3.6-6A)
		77 (Sec 3.6.12)	Numbering error is corrected. (Table 3.6.12A -> Table 3.6.12B)
		81 (Sec.3.7.2)	Description of Operation Phase is modified.
3	October 2010	[redacted]	[redacted]

Revision	Date	Page (section)	Description
3	October 2010	27 (Sec.3.3.3)	Description of connection between MELTAC and Maintenance Network is added
			[redacted]
			[redacted]
			[redacted]
		36 (Sec.3.4)	Term is modified (“Unit Bus” to “Control Network”)
			[redacted]
			[redacted]
			[redacted]
			[redacted]
			[redacted]
			[redacted]
			[redacted]

Revision	Date	Page (section)	Description
3	October 2010	[redacted]	[redacted]
4	May 2011	-	The title of this document is changed from "MELAC Platform Basic Software Safety Report" to "MELTAC Platform ISG-04 Conformance Analysis" based on RAI 655-5220 (07-14 Branch Technical Position-42).
		1 (Sec.1)	Description of communication message data field analysis described in Section 3.5 is added.
		1 (Sec.1)	Description of analysis of communication errors defined in NUREG/CR6991 is added.
		1 (Sec.1.2)	NUREG/CR6991 is added in reference document.
		[redacted]	[redacted]

Revision	Date	Page (section)	Description
4	May 2011	56 (Sec.3.2.4)	Analysis of Safety VDU (Touch screen to S-VUD processor communication) is revised.
		56 (Sec.3.2.5)	Analysis of Inter-divisional Communication Interface to Power Interface (PIF) Module is added.
		56 (Sec.3.2.6)	Analysis of Inter-divisional Communication Interface for Analog Inputs is added.
		72-130 (Sec.3.5)	This section is added to describe the data field failure analysis for communication messages required as a result of the analysis in Section 3.2.
		[	]
		-	The following sections in revision 3, which are not related to ISG-04 conformance analysis, are deleted: - Section 3.1 "Detectability of Input, Operation, and Output hazards" - Section 3.6 "Analysis of Self-Diagnosis Functions - Section 3.7 "Analysis of Post-Development Procedures".
5	Nov 2013	general	All sections are revised to unify the terminology based on RAI722-5597 (07.01-30).
		0-7 (Revision history)	Correct the wrong RAI number to the right one in the revision history of Rev.4.
		[	]
		[	]
		[	]

Revision	Date	Page (section)	Description
5	Nov 2013		

Revision	Date	Page (section)	Description
5	Nov 2013		

Revision	Date	Page (section)	Description
5	Nov 2013	( )	( )
		( )	( )
		6,18,29,30, 31,32,33,34 45,48,93 (Sec 3.1.3, Sec 3.1.19, Sec 3.2.1, Sec 3.2.2, Sec 3.5.1)	Sentences are modified to make them clearer.
		General	Editorial changes are made.
		7,8 (Sec.3.1.4)	Footer mark in the requirement paragraph and explanation of the footer are added.
		( )	( )
		General	The document number of MUAP-13018 and the company name “Mitsubishi Heavy Industries. LTD” are added to the header and footer of this Technical Report in accordance with the response to RAI995-7024 Q07.01-45.
		( )	( )
		( )	( )

Revision	Date	Page (section)	Description
5	Nov 2013	[redacted]	[redacted]
		58 (Sec.3.2.5, Sec.3.2.6)	Identified the full names of the acronyms when they are used for the first time.
		0-17 (List of Acronyms)	List of Acronyms is added.

Table of Contents

List of Tables

List of Figures

List of Acronyms

ASIC	Application Specific Integrated Circuit
ATWS	Anticipated Transients Without Scram
CCF	Common Cause Failure
CFR	Code of Federal Regulations
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CYC	Constant-Cycle
DAS	Diverse Actuation System
DCD	Design Control Document
DI	Digital Input
DP	Data Packet
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESF	Engineered Safety Features
ESFAS	Engineered Safety Features Actuation System
FET	Field Effect Transistor
FMEA	Failure Modes and Effects Analysis
FPGA	Field Programmable Gate Array
F-ROM	Flash Electrically Erasable Programmable Read Only Memory
F/W	Firmware
I&C	Instrumentation and control
IEEE	Institute of Electrical and Electronics Engineers
I/F	Interface
I/O	Input/Output
IPL	Interposing Logic
ISG	Interim Staff Guidance
LSI	Large Scale Integration
MELTAC	Mitsubishi Electric Total Advanced Controller
NACK	Negative Acknowledgement
NaN	Not a Number
NMR	N-Modular Redundant
NRC	U.S. Nuclear Regulatory Commission
PIF	Power Interface
PLD	Programmable Logic Device
POL	Problem Oriented Language
PP	Protection Packet
QAP	Quality Assurance Program
RAM	Random Access Memory
RFI	Radio Frequency Interface
RG	Regulatory Guide
RPS	Reactor Protection System
RT	Reactor Trip
UDP/IP	User Datagram Protocol Internet Protocol
UV-ROM	Ultra-Violet Erasable Programmable Read Only Memory
VDU	Visual Display Unit
V&V	Verification and Validation

1.0 PURPOSE

This document reports the results of a conformance analysis of the MELTAC platform to the requirements of DI&C ISG-04 “Highly-Integrated Control Rooms – Communications Issues“.

The communication errors defined in NUREG/CR-6991 “Design Practices for Communications and Workstations in Highly Integrated Control Rooms”, Section 2.3 “General Nature of Digital Communication Errors“ covers the items provided in ISG-04 Section 1, Staff position 12 “Communication faults” as well as some additional items. The additional items are included in response to the NRC’s request to evaluate these items together with the conformance assessment to ISG-04 Section 1, Staff position 12.

In addition, Section 3.5, provides the analysis for errors in the specific fields of the communication messages that are unique to the application of the Control Network (W-NET) to inter-divisional communication, such as for the Unit Bus in the US-APWR. For inter-divisional applications, these errors are considered particularly important because they have the potential to adversely affect communication independence and/or functional independence between non-safety and safety divisions. This analysis demonstrates that even for these unique and highly unlikely errors, communication independence and functional independence are maintained.

1.1. Definition

No special definitions.

1.2. Applicable Standards

- Digital I&C Interim Staff Guidance-04 Highly-Integrated Control Rooms – Communications Issues (ISG-04)
- NUREG/CR-6991 Design Practices for Communications and Workstations in Highly Integrated Control Rooms

1.3. Reference Document

Document name	Document number	Revision
Design Control Document for the US-APWR	-	4
Safety I&C System Description and Design Process	MUAP-07004	8
Safety System Digital Platform -MELTAC	MUAP-07005	9
HSI System Description and HFE Process	MUAP-07007	5
US-APWR Function Assignment Analysis for Safety Logic System	MUAP-09020	2
US-APWR Response Time of Safety I&C System	MUAP-09021	3

2.0 SCOPE

2.1. Analysis Target

[

]

2.2. Analysis Criteria

[

]

3.0 ANALYSIS RESULT

Analysis is performed to determine if faults can be detected and mitigated at the architecture level.

If detection and mitigation were done by software, its implementation was confirmed through verification of specification document and source code. The Analysis subsections in Sections 3.1.1 to 3.1.20 describe the method of handling (i.e. detecting and mitigating) the hazard, and the specific section(s) of the document(s) which identify this tolerance method.

Compliance to some requirements is determined through the application system configuration or application software. For these requirements, the analysis identifies example(s) of the compliance method(s), without identifying specific documentation. The documentation reference is application specific.

3.1. Analysis of Inter-divisional Communications

The results of analyzing the MELTAC inter-divisional communications for compliance to ISG-04 Section 1 are provided in this section, with the exception of the communication faults identified in Section 1.12, which are analyzed in Section 3.2. This section is applicable to the Data Link, Control Network and Maintenance Network. Inter-divisional communication for the PIF module is discussed in Sec. 3.3.5.

As noted in section 2.2, Staff Positions from ISG-04 Section 1 are used as criteria, as well as communication fault detectability.

3.1.1. ISG-04 1.1

Requirement
A safety channel should not be dependent upon any information or resource originating or residing outside its own safety division to accomplish its safety function. This is a fundamental consequence of the independence requirements of IEEE603. It is recognized that division voting logic must receive inputs from multiple safety divisions.
Analysis

3.1.2. ISG-04 1.2

Requirement
The safety function of each safety channel should be protected from adverse influence from outside the division of which that channel is a member. Information and signals originating outside the division must not be able to inhibit or delay the safety function. This protection must be implemented within the affected division (rather than in the sources outside the division), and must not itself be affected by any condition or information from outside the affected division. This protection must be sustained despite any operation, malfunction, design error, communication error, or software error or corruption existing or originating outside the division.
Analysis

3.1.3. ISG-04 1.3

Requirement
A safety channel should not receive any communication from outside its own safety division unless that communication supports or enhances the performance of the safety function. Receipt of information that does not support or enhance the safety function would involve the performance of functions that are not directly related to the safety function. Safety systems should be as simple as possible. Functions that are not necessary for safety, even if they enhance reliability, should be executed outside the safety system. A safety system designed to perform functions not directly related to the safety function would be more complex than a system that performs the same safety function, but is not designed to perform other functions. The more complex system would increase the likelihood of failures and software errors. Such a complex design, therefore, should be avoided within the safety system. For example, comparison of readings from sensors in different divisions may provide useful information concerning the behavior of the sensors (for example, On-Line Monitoring). Such a function executed within a safety system, however, could also result in unacceptable influence of one division over another, or could involve functions not directly related to the safety functions, and should not be executed within the safety system. Receipt of information from outside the division, and the performance of functions not directly related to the safety function, if used, should be justified. It should be demonstrated that the added system/software complexity associated with the performance of functions not directly related to the safety function and with the receipt of information in support of those functions does not significantly increase the likelihood of software specification or coding errors, including errors that would affect more than one division. The applicant should justify the definition of “significantly” used in the demonstration.
Analysis

3.1.4. ISG-04 1.4

Requirement
The communication process itself should be carried out by a communications processor[ii] separate from the processor that executes the safety function, so that communications errors and malfunctions will not interfere with the execution of the safety function. The communication and function processors should operate asynchronously, sharing information only by means of dual-ported memory or some other shared memory resource that is dedicated exclusively to this exchange of information. The function processor, the communications processor, and the shared memory, along with all supporting circuits and software, are all considered to be safety-related, and must be designed, qualified, fabricated, etc., in accordance with 10 C.F.R. Part 50, Appendix A and B. Access to the shared memory should be controlled in such a manner that the function processor has priority access to the shared memory to complete the safety function in a deterministic manner. For example, if the communication processor is accessing the shared memory at a time when the function processor needs to access it, the function processor should gain access within a timeframe that does not impact the loop cycle time assumed in the plant safety analyses. If the shared memory cannot support unrestricted simultaneous access by both processors, then the access controls should be configured such that the function processor always has precedence. The safety function circuits and program logic should ensure that the safety function will be performed within the timeframe established in the safety analysis, and will be completed successfully without data from the shared memory in the event that the function processor is unable to gain access to the shared memory.
Analysis

[ii] “Processor” may be a CPU or other processing technology such as simple discrete logic, logic within an FPGA, an Application Specific Integrated Circuit (ASIC), etc.

3.1.5. ISG-04 1.5

Requirement
The cycle time for the safety function processor should be determined in consideration of the longest possible completion time for each access to the shared memory. This longest-possible completion time should include the response time of the memory itself and of the circuits associated with it, and should also include the longest possible delay in access to the memory by the function processor assuming worst-case conditions for the transfer of access from the communications processor to the function processor. Failure of the system to meet the limiting cycle time should be detected and alarmed.
Analysis

3.1.6. ISG-04 1.6

Requirement
The safety function processor should perform no communication handshaking and should not accept interrupts from outside its own safety division.
Analysis

3.1.7. ISG-04 1.7

Requirement
Only predefined data sets should be used by the receiving system. Unrecognized messages and data should be identified and dispositioned by the receiving system in accordance with the pre-specified design requirements. Data from unrecognized messages must not be used within the safety logic executed by the safety function processor. Message format and protocol should be pre-determined. Every message should have the same message field structure and sequence, including message identification, status information, data bits, etc. in the same locations in every message. Every datum should be included in every transmit cycle, whether it has changed since the previous transmission or not, to ensure deterministic system behavior.
Analysis

3.1.8. ISG-04 1.8

Requirement
Data exchanged between redundant safety divisions or between safety and non-safety divisions should be processed in a manner that does not adversely affect the safety function of the sending divisions, the receiving divisions, or any other independent divisions.
Analysis

3.1.9. ISG-04 1.9

Requirement
Incoming message data should be stored in fixed predetermined locations in the shared memory and in the memory associated with the function processor. These memory locations should not be used for any other purpose. The memory locations should be allocated such that input data and output data are segregated from each other in separate memory devices or in separate pre-specified physical areas within a memory device.
Analysis

3.1.10. ISG-04 1.10

Requirement
Safety division software should be protected from alteration while the safety division is in operation. On-line changes to safety system software should be prevented by hardwired interlocks or by physical disconnection of maintenance and monitoring equipment. A workstation (e.g. engineer or programmer station) may alter addressable constants, setpoints, parameters, and other settings associated with a safety function only by way of the dual-processor / shared-memory scheme described in this guidance, or when the associated channel is inoperable. Such a workstation should be physically restricted from making changes in more than one division at a time. The restriction should be by means of physical cable disconnect, or by means of keylock switch that either physically opens the data transmission circuit or interrupts the connection by means of hardwired logic. “Hardwired logic” as used here refers to circuitry that physically interrupts the flow of information, such as an electronic AND gate circuit (that does not use software or firmware) with one input controlled by the hardware switch and the other connected to the information source: the information appears at the output of the gate only when the switch is in a position that applies a “TRUE” or “1” at the input to which it is connected. Provisions that rely on software to effect the disconnection are not acceptable. It is noted that software may be used in the safety system or in the workstation to accommodate the effects of the open circuit or for status logging or other purposes.
Analysis

3.1.11. ISG-04 1.11

Requirement
Provisions for inter-divisional communication should explicitly preclude the ability to send software instructions to a safety function processor unless all safety functions associated with that processor are either bypassed or otherwise not in service. The progress of a safety function processor through its instruction sequence should not be affected by any message from outside its division. For example, a received message should not be able to direct the processor to execute a subroutine or branch to a new instruction sequence.
Analysis

3.1.12. ISG-04 1.12

Refer to Section 3.2.

3.1.13. ISG-04 1.13

Requirement
Vital[iii] communications, such as the sharing of channel trip decisions for the purpose of voting, should include provisions for ensuring that received messages are correct and are correctly understood. Such communications should employ error-detecting or error-correcting coding along with means for dealing with corrupt, invalid, untimely or otherwise questionable data. The effectiveness of error detection/correction should be demonstrated in the design and proof testing of the associated codes, but once demonstrated is not subject to periodic testing. Error-correcting methods, if used, should be shown to always reconstruct the original message exactly or to designate the message as unrecoverable. None of this activity should affect the operation of the safety-function processor.
Analysis

3.1.14. ISG-04 1.14

Requirement
Vital[iii] communications should be point-to-point by means of a dedicated medium (copper or optical cable). In this context, “point-to-point” means that the message is passed directly from the sending node to the receiving node without the involvement of equipment outside the division of the sending or receiving node. Implementation of other communication strategies should provide the same reliability and should be justified.
Analysis

[iii] “Vital” communications as used herein are communications that are needed to support a safety function. Failure of vital communications could inhibit the performance of the safety function. The most common implementation of vital communications is the distribution of channel trip information to other divisions for the purpose of voting.

3.1.15. ISG-04 1.15

Requirement
Communication for safety functions should communicate a fixed set of data (called the "state") at regular intervals, whether data in the set has changed or not.
Analysis

3.1.16. ISG-04 1.16

Requirement
Network connectivity, liveness, and real-time properties essential to the safety application should be verified in the protocol. Liveness, in particular, is taken to mean that no connection to any network outside the division can cause an RPS/ESFAS communication protocol to stall, either deadlock or livelock. (Note: This is also required by the independence criteria of: (1) 10 C.F.R. Part 50, Appendix A, General Design Criteria (“GDC”) 24, which states, “interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired.”; and (2) IEEE 603-1991 IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.) (Source: NUREG/CR-6082, 3.4.3)
Analysis

3.1.17. ISG-04 1.17

Requirement
Pursuant to 10 C.F.R. § 50.49, the medium used in a Vital[iii] communications channel should be qualified for the anticipated normal and post-accident environments. For example, some optical fibers and components may be subject to gradual degradation as a result of prolonged exposure to radiation or to heat. In addition, new digital systems may need susceptibility testing for EMI/RFI and power surges, if the environments are significant to the equipment being qualified.
Analysis

[iii] "Vital" communications as used herein are communications that are needed to support a safety function. Failure of vital communications could inhibit the performance of the safety function. The most common implementation of vital communications is the distribution of channel trip information to other divisions for the purpose of voting.

3.1.18. ISG-04 1.18

Requirement
Provisions for communications should be analyzed for hazards and performance deficits posed by unneeded functionality and complication.
Analysis

3.1.19. ISG-04 1.19

Requirement
If data rates exceed the capacity of a communications link or the ability of nodes to handle traffic, the system will suffer congestion. All links and nodes should have sufficient capacity to support all functions. The applicant should identify the true data rate, including overhead, to ensure that communication bandwidth is sufficient to ensure proper performance of all safety functions. Communications throughput thresholds and safety system sensitivity to communications throughput issues should be confirmed by testing.
Analysis

3.1.20. ISG-04 1.20

Requirement
The safety system response time calculations should assume a data error rate that is greater than or equal to the design basis error rate and is supported by the error rate observed in design and qualification testing.
Analysis

3.2. Detectability of Communication Faults

This section describes the results of analyzing the communication faults identified in ISG-04 Section 1, Staff position 12. The subsections below analyze each communication type.

Table 3.2-1 Communication Faults Described in NRC Digital I&C ISG-04 Section 1, Staff Position 12 and NUREG/CR-6991 Section 2.3

	Fault	Description
1	Message corruption	Messages may be corrupted due to errors in communications processors, errors introduced in buffer interfaces, errors introduced in the transmission media, or from interference or electrical noise.
2	Repeated messages	Messages may be repeated at an incorrect point in time.
3	Incorrect sequences of messages	Messages may be sent in the incorrect sequence.
4	Message reception failure	Messages may be lost, which includes both failures to receive an uncorrupted message or to acknowledge receipt of a message.
5	Delayed message	Messages may be delayed beyond their permitted arrival time window for several reasons, including errors in the transmission medium, congested transmission lines, interference, or by delay in sending buffered messages.
6	Message from unexpected source	Messages may be inserted into the communication medium from unexpected or unknown sources.
7	Wrong destination message	Messages may be sent to the wrong destination, which could treat the message as a valid message.
8	Over-length message	Messages may be longer than the receiving buffer, resulting in buffer overflow and memory corruption.
9	Out-of-range message	Messages may contain data that is outside the expected range.
10	Incorrect location of data	Messages may appear valid, but data may be placed in incorrect locations within the message.
11	High rate messages	Messages may occur at a high rate that degrades or causes the system to fail (i.e., broadcast storm).
12	Message header / address corruption	Message headers or addresses may be corrupted.

In addition to the analysis for the communication faults identified above, this section also analyzes the communication faults described in Section 2.3 of NUREG/CR-6991, as shown below.

Table 3.2-1 Communication Faults Described in NRC Digital I&C ISG-04 Section 1, Staff Position 12 and NUREG/CR-6991 Section 2.3 (Continued)

	Fault	Description
13	Invalid data “masquerade” as valid ones	Correctly formatted messages are received from an incorrect source that disguises itself as a correct source.
14	Commission fault (Babbling idiot)	Messages sent from other nodes are corrupted due to frequent message transmission at incorrect timing by a failed node.
15	Inconsistency	Single failure propagates via the cooperative mechanisms that the N-Modular Redundant (NMR) system uses and causes the failure of the entire NMR system.
16	Excessive jitter	Messages arrive at non-constant timing due to network jitter.
17	Data collision	Messages sent from other nodes are corrupted due to collision of data transmission right acquisition protocols.
18	Out of sync	Messages are missed by the receiving side because data is updated by the sending side too soon.
19	Incorrect encoding/decoding	Communication becomes impossible due to inconsistency between the sending side (encoding) and the receiving side (decoding).
20	Interruption	Messages may be interrupted completely or in the middle of data transmission.

3.2.1. Control Network

[

]

3.2.2. Data Link

3.2.3. Engineering (Maintenance) Network

The table below analyzes message errors only from the perspective of the safety controller, not the MELTAC engineering tool.

The table is applicable when the controller(s) is connected to the Maintenance Network. The MELTAC Controller is only temporarily connected to the Maintenance Network. This temporary connection is under administrative controls to ensure that before a controller(s) is connected to the Maintenance Network it is formally taken out of service with appropriate management of affected plant technical specifications.

3.2.4. Safety VDU (Touch screen to safety VDU processor communication)

The data link used between the safety VDU touch screen and the safety VDU processor is used only within the same safety division. Therefore, it is not evaluated within the scope of DI&C ISG-04, which applies only to inter-divisional data communication.

3.2.5. Inter-divisional Communication Interface to Power Interface (PIF) Module

For some applications the Power Interface Module may receive control inputs from outside its safety division. For example, for the US-APWR the PIF receives signals from the Diverse Actuation System (DAS). However, since these are conventional hardwired binary inter-divisional signals, they are not subject to the digital communication errors defined in DI&C ISG-04. Other aspects of DI&C ISG-04 compliance for these signals is analyzed in Section 3.3.5.

3.2.6. Inter-divisional Communication Interface for Analog Inputs

For some applications analog inputs to the safety division may be shared with a non-safety division. For example, for the US-APWR the analog inputs to the RPS are shared with the DAS. These analog signals are distributed prior to the analog to digital converters within the MELTAC analog input modules. Since these are conventional hardwired analog inter-divisional signals, they are not subject to the digital communication errors defined in DI&C ISG-04. Since the safety division only transmits these signals (i.e. there are no inter-divisional analog signals received by the safety system) other DI&C ISG-04 requirements are not applicable.

3.3. Analysis of Command Prioritization

The results of analyzing the command prioritization are as follows. It is noted that in MELTAC there are two priority logic functions. One is in the function processor which prioritizes safety commands over non-safety commands received via the Control Network. The second is within the PIF module which employs state based priority logic to ensure that either the primary system or the backup system can put the component in its preferred safety state.

As noted in Section 2.2, Staff Positions from ISG-04 Section 2 are used as criteria.

3.3.1. ISG-04 2.1

Requirement
A priority module is a safety-related device or software function. A priority module must meet all of the 10 C.F.R. Part 50, Appendix A and B requirements (design, qualification, quality, etc.) applicable to safety-related devices or software.
Analysis

3.3.2. ISG-04 2.2

Requirement
Priority modules used for diverse actuation signals should be independent of the remainder of the digital system, and should function properly regardless of the state or condition of the digital system. If these recommendations are not satisfied, the applicant should show how the diverse actuation requirements are met.
Analysis

3.3.3. ISG-04 2.3

Requirement
Safety-related commands that direct a component to a safe state must always have the highest priority and must override all other commands. Commands that originate in a safety-related channel but which only cancel or enable cancellation of the effect of the safe-state command (that is, a consequence of a Common-Cause Failure in the primary system that erroneously forces the plant equipment to a state that is different from the designated “safe state.”), and which do not directly support any safety function, have lower priority and may be overridden by other commands. In some cases, such as a containment isolation valve in an auxiliary feedwater line, there is no universal “safe state:” the valve must be open under some circumstances and closed under others. The relative priority to be applied to commands from a diverse actuation system, for example, is not obvious in such a case. This is a system operation issue, and priorities should be assigned on the basis of considerations relating to plant system design or other criteria unrelated to the use of digital systems. This issue is outside the scope of this ISG. The reasoning behind the proposed priority ranking should be explained in detail. The reviewer should refer the proposed priority ranking and the explanation to appropriate systems experts for review. The priority module itself should be shown to apply the commands correctly in order of their priority rankings, and should meet all other applicable guidance. It should be shown that the unavailability or spurious operation of the actuated device is accounted for in, or bounded by, the plant safety analysis.
Analysis

3.3.4. ISG-04 2.4

Requirement
A priority module may control one or more components. If a priority module controls more than one component, then all of these provisions apply to each of the actuated components.
Analysis

3.3.5. ISG-04 2.5

Requirement
Communication isolation for each priority module should be as described in the guidance for inter-divisional communications.
Analysis

3.3.6. ISG-04 2.6

Requirement
Software used in the design, testing, maintenance, etc. of a priority module is subject to all of the applicable guidance in Regulatory Guide 1.152, which endorses IEEE Standard 7-4.3.2-2003 (with comments). This includes software applicable to any programmable device used in support of the safety function of a prioritization module, such as programmable logic devices (PLDs), programmable gate arrays, or other such devices. Section 5.3.2 of IEEE 7-4.3.2-2003 is particularly applicable to this subject. Validation of design tools used for programming a priority module or a component of a priority module is not necessary if the device directly affected by those tools is 100% tested before being released for service. 100% testing means that every possible combination of inputs and every possible sequence of device states is tested, and all outputs are verified for every case. The testing should not involve the use of the design tool itself. Software-based prioritization must meet all requirements (quality requirements, V&V, documentation, etc.) applicable to safety-related software.
Analysis

3.3.7. ISG-04 2.7

Requirement
Any software program that is used in support of the safety function within a priority module is safety-related software. All requirements that apply to safety-related software also apply to prioritization module software. Nonvolatile memory (such as burned-in or reprogrammable gate arrays or random-access memory) should be changeable only through removal and replacement of the memory device. Design provisions should ensure that static memory and programmable logic cannot be altered while installed in the module. The contents and configuration of field programmable memory should be considered to be software, and should be developed, maintained, and controlled accordingly.
Analysis

3.3.8. ISG-04 2.8

Requirement
To minimize the probability of failures due to common software, the priority module design should be fully tested (This refers to proof-of-design testing, not to individual testing of each module and not to surveillance testing.). If the tests are generated by any automatic test generation program then all the test sequences and test results should be manually verified. Testing should include the application of every possible combination of inputs and the evaluation of all of the outputs that result from each combination of inputs. If a module includes state-based logic (that is, if the response to a particular set of inputs depends upon past conditions), then all possible sequences of input sets should also be tested. If testing of all possible sequences of input sets is not considered practical by an applicant, then the applicant should identify the testing that is excluded and justify that exclusion. The applicant should show that the testing planned or performed provides adequate assurance of proper operation under all conditions and sequences of conditions. Note that it is possible that logic devices within the priority module include unused inputs: assuming those inputs are forced by the module circuitry to a particular known state, those inputs can be excluded from the "all possible combinations" criterion. For example, a priority module may include logic executed in a gate array that has more inputs than are necessary. The unused inputs should be forced to either "TRUE" or "FALSE" and then can be ignored in the "all possible combinations" testing.
Analysis

3.3.9. ISG-04 2.9

Requirement
Automatic testing within a priority module, whether initiated from within the module or triggered from outside and including failure of automatic testing features, should not inhibit the safety function of the module in any way. Failure of automatic testing software could constitute common-cause failure if it were to result in the disabling of the module safety function.
Analysis

3.3.10. ISG-04 2.10

Requirement
The priority module must ensure that the completion of a protective action as required by IEEE Standard 603 is not interrupted by commands, conditions, or failures outside the module's own safety division.
Analysis

3.4. Analysis of Multi-divisional Control and Display Stations

The results of analyzing the command prioritization are as follows.
As noted in Section 2.2, Staff Positions from ISG-04 Staff position 3.1 are used as criteria.

3.4.1. ISG-04 3.1.1

Requirement
Non-safety stations receiving information from one or more safety divisions: All communications with safety-related equipment should conform to the guidelines for inter-divisional communications.
Analysis

3.4.2. ISG-04 3.1.2

Requirement
Safety-related stations receiving information from other divisions (safety or non-safety): All communications with equipment outside the station's own safety division, whether that equipment is safety-related or not, should conform to the guidelines for inter-divisional communications. Note that the guidelines for inter-divisional communications refer to provisions relating to the nature and limitations concerning such communications, as well as guidelines relating to the communications process itself.
Analysis

3.4.3. ISG-04 3.1.3

Requirement
Non-safety stations controlling the operation of safety-related equipment: Non-safety stations may control the operation of safety-related equipment, provided the following restrictions are enforced.
Analysis

No.	Requirement
1	The non-safety station should access safety-related plant equipment only by way of a priority module associated with that equipment. Priority modules should be designed and applied as described in the guidance on priority modules.
2	A non-safety station should not affect the operation of safety-related equipment when the safety-related equipment is performing its safety function. This provision should be implemented within the safety-related system, and must be unaffected by any operation, malfunction, design error, software error, or communication error in the non-safety equipment.
3	The non-safety station should be able to bypass a safety function only when the affected division has itself determined that such action would be acceptable.

No.	Requirement
4	The non-safety station should not be able to suppress any safety function. (If the safety system itself determines that termination of a safety command is warranted as a result of the safety function having been achieved, and if the applicant demonstrates that the safety system has all information and logic needed to make such a determination, then the safety command may be reset from a source outside the safety division. If operator judgment is needed to establish the acceptability of resetting the safety command, then reset from outside the safety division is not acceptable because there would be no protection from inappropriate or accidental reset.)
5	The non-safety station should not be able to bring a safety function out of bypass condition unless the affected division has itself determined that such action would be acceptable.

3.4.4. ISG-04 3.1.4

Requirement
Safety-related stations controlling the operation of equipment in other safety-related divisions: Safety-related stations controlling the operation of equipment in other divisions are subject to constraints similar to those described above for non-safety stations that control the operation of safety-related equipment. - A control station should access safety-related plant equipment outside its own division only by way of a priority module associated with that equipment. Priority modules should be designed and applied as described in the guidance on priority modules. - A station must not influence the operation of safety-related equipment outside its own division when that equipment is performing its safety function. This provision should be implemented within the affected (target) safety-related system, and should be unaffected by any operation, malfunction, design error, software error, or communication error outside the division of which those controls are a member. In addition: - The extra-divisional (that is, “outside the division”) control station should be able to bypass a safety function only when the affected division itself determined that such action would be acceptable. - The extra-divisional station should not be able to suppress any safety function. (If the safety system itself determines that termination of a safety command is warranted as a result of the safety function having been achieved, and if the applicant demonstrates that the safety system has all information and logic needed to make such a determination, then the safety command may be reset from a source outside the safety division. If operator judgment is needed to establish the acceptability of resetting the safety command, then reset from outside the safety division is not acceptable because there would be no protection from inappropriate or accidental reset.) - The extra-divisional station should not be able to bring a safety function out of bypass condition unless the affected division has itself determined that such action would be acceptable.
Analysis

3.4.5. ISG-04 3.1.5

Requirement
Malfunctions and Spurious Actuations: The result of malfunctions of control system resources (e.g., workstations, application servers, protection / control processors) shared between systems must be consistent with the assumptions made in the safety analysis of the plant. Design and review criteria for complying with these requirements, as set forth in 10 C.F.R. § 50.34 and 50.59, include but are not limited to the following:
Analysis

No.	Requirement
1	Control processors that are assumed to malfunction independently in the safety analysis should not be affected by failure of a multidivisional control and display station.
2	Control functions that are assumed to malfunction independently in the safety analysis should not be affected by failure of a single control processor.
3	Safety and control processors should be configured and functionally distributed so that a single processor malfunction or software error will not result in spurious actuations that are not enveloped in the plant design bases, accident analyses, ATWS provisions, or other provisions for abnormal conditions. This includes spurious actuation of more than one plant device or system as a result of processor malfunction or software error. The possibility and consequences of malfunction of multiple processors as a result of common software error must be addressed.

No.	Requirement
4	No single control action (for example, mouse click or screen touch) should generate commands to plant equipment. Two positive operator actions should be required to generate a command. For example: When the operator requests any safety function or other important function, the system should respond “do you want to proceed?” The operator should then be required to respond “Yes” or “No” to cause the system to execute the function. Other question-and-confirm strategies may be used in place of the one described in the example. The second operation as described here is to provide protection from spurious actuations, not protection from operator error. Protection from operator error may involve similar but more restrictive provisions, as addressed in guidance related to Human Factors.
5	Each control processor or its associated communication processor should detect and block commands that do not pass the communication error checks.

No.	Requirement
6	Multidivisional control and display stations should be qualified to withstand the effects of adverse environments, seismic conditions, EMI/RFI, power surges, and all other design basis conditions applicable to safety-related equipment at the same plant location. This qualification need not demonstrate complete functionality during or after the application of the design basis condition unless the station is safety-related. Stations which are not safety-related should be shown to produce no spurious actuations and to have no adverse effect upon any safety-related equipment or device as a result of a design basis condition, both during the condition and afterwards. If spurious or abnormal actuations or stoppages are possible as a result of a design basis condition, then the plant safety analyses must envelope those spurious and abnormal actuations and stoppages. Qualification should be supported by testing rather than by analysis alone. D3 considerations may warrant the inclusion of additional qualification criteria or measures in addition to those described herein.
7	Loss of power, power surges, power interruption, and any other credible event to any operator workstation or controller should not result in spurious actuation or stoppage of any plant device or system unless that spurious actuation or stoppage is enveloped in the plant safety analyses.
8	The design should have provision for an “operator workstation disable” switch to be activated upon abandonment of the main control room, to preclude spurious actuations that might otherwise occur as a result of the condition causing the abandonment (such as control room fire or flooding). The means of disabling control room operator stations should be immune to short-circuits, environmental conditions in the control room, etc. that might restore functionality to the control room operator stations and result in spurious actuations.

No.	Requirement
9	Failure or malfunction of any operator workstation must not result in a plant condition (including simultaneous conditions) that is not enveloped in the plant design bases, accident analyses, and anticipated transients without scram (ATWS) provisions, or in other unanticipated abnormal plant conditions.

3.5. Analysis of Message Field Failure in the Inter-divisional Communication

This section describes the analysis for ISG-04 Section 1, Staff position 12 "incorrect location" in Control Network and Data Link.

The target of the analysis is as described below.

(1) Operational signal
(2) Process signal

3.5.1. Message Format

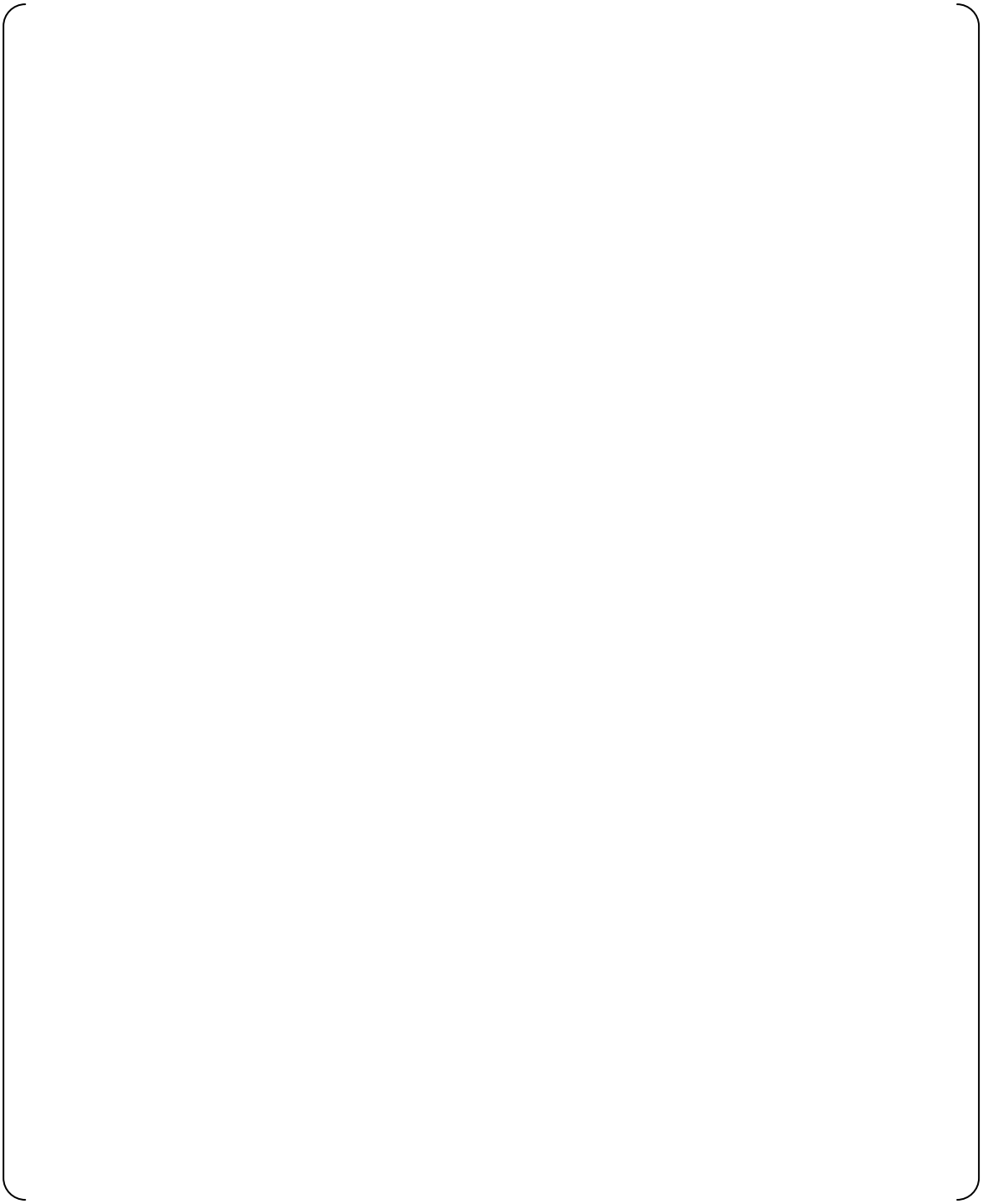

Figure 3.5-1 Message Format of Operational Signal (Control Network)

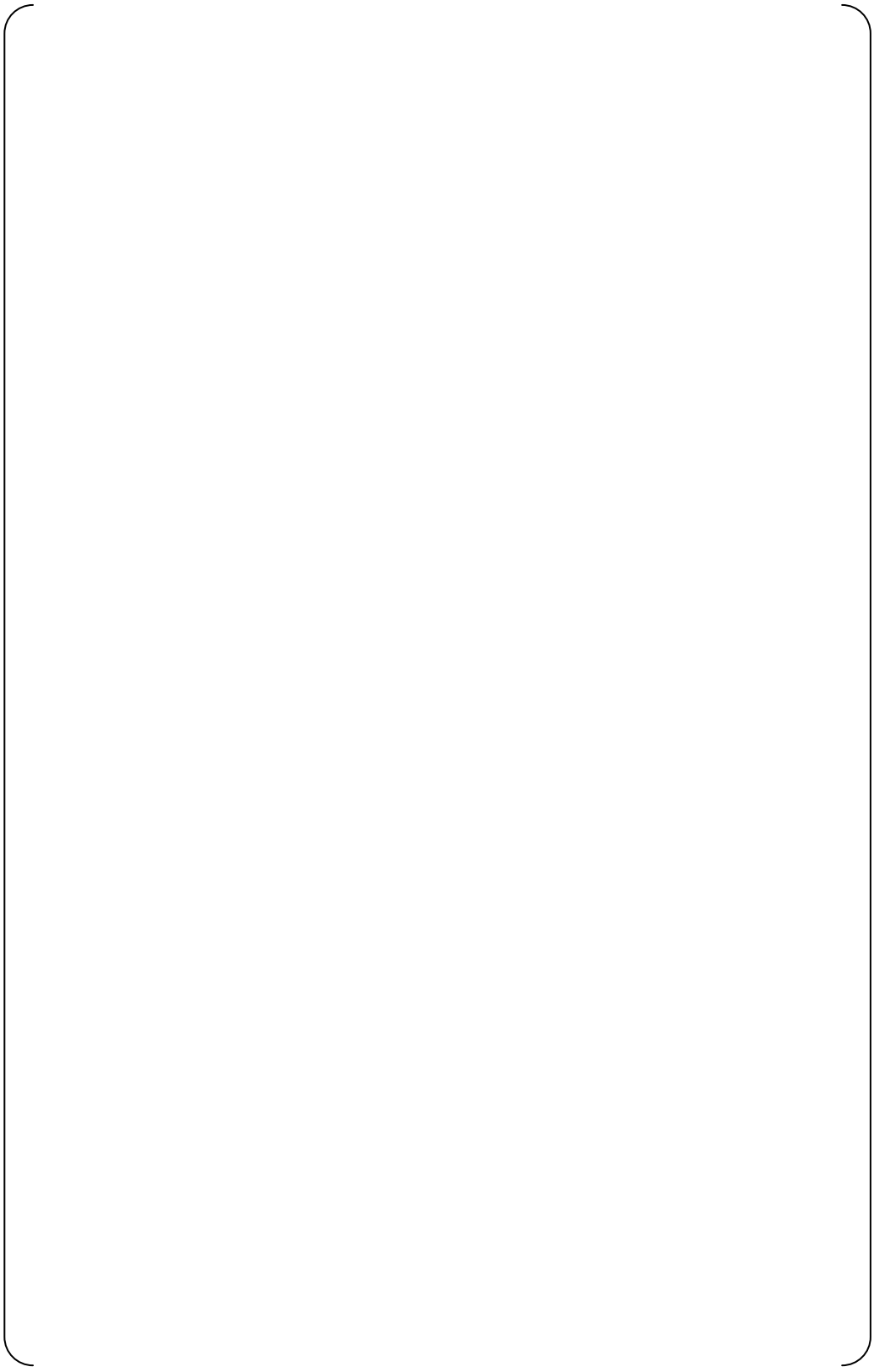

Figure 3.5-2 Message Format of Process Signal (Control Network)

Figure 3.5-3 Message Format of Process Signal (Data Link)

Figure 3.5-4 Message Format of Protection Packet (Network Management Information for Control Network)

Table 3.5-1 Message Field Explanation of Operational Signal through the Control Network

Table 3.5-2 Message Field Explanation of Process Signal through the Control Network

Table 3.5-3 Message Field Explanation of Process Signal through the Data Link

3.5.2. Analysis Result

For each field of messages described in Section 3.5.1, an analysis was conducted to determine if possible invalid data patterns can be detected, and if not, how the controller would be affected.

In the case any measures are considered to be required as a result of the analysis, the content of such measures are also described.

The analysis of this section covers the case where the content of each field in outgoing messages is corrupted before the CRC is added. (Any corruption of fields after the CRC is added is not covered because it will be discarded by the receiving node as a CRC error and will not affect the receiver.)

Table 3.5-4 Message Field Analysis Result of Operational Signal through the Control Network

Table 3.5-5 Message Field Analysis Result of Process Signal through the Control Network

Table 3.5-6 Message Field Analysis Result of Process Signal through the Data Link

4.0 ANALYSIS SUMMARY

[

]