Introduction

ProSafe-RS is a safety instrumented system conforming to IEC 61508. This technical information (TI) document introduces various features and functions of the ProSafe-RS.

Document Structure

An overview of the ProSafe-RS system is described in this TI. After reading this TI, go over to read other documents such as General Specifications (GS) or Instruction Manuals (IM) for more details.

This TI consists of five chapters. Chapter 1 discuss about the importance of safety instrumented system, while the remaining chapters will explain the features of ProSafe-RS, system configuration, safety control station, engineering, operation and maintenance.

Reference Documents

Refer to the following document for a system integrated with CENTUM VP.

- Integrated Production Control System CENTUM VP System Overview (General Overview) (TI 33J01A10-01EN)

Target Readership

- Managers who are considering introduction of a new safety instrumented system.
- Instrumentation, power and computer engineers who evaluate for purchasing or installation of ProSafe-RS.

Representation of Drawings

- Drawings in this TI may be emphasized, simplified, or omitted some features for convenience of explanations.
- The screen captures may be slightly modified for the convenience of the better understanding without disturbing the functional understanding or operation and monitoring.

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1. Necessity of Safety Instrumented System

In this chapter, a plant owner’s responsibility, the international standards, positioning of a safety instrumented system and safety evaluation scales are explained.

- **Plant owner’s responsibility**

  During 1970s and 1980s, serious incidents that occurred at petroleum and chemical plants initiated several countries to legislate that "owners of industrial plants where dangerous materials are handled must evaluate possible risks that may occur in the plants."

  These legal regulations stipulate that the plant owners are socially responsible in the entire lifecycle, from planning to disposal, to minimize the risks of causing hazards over “human beings, physical assets and environments.” In order to fulfill these social responsibilities, the plant owners are expected to identify risk factors of hazardous elements that cause incidents; to analyze and evaluate them; then to reduce the risks to a socially acceptable level.

  The international standards of IEC 61508 and IEC 61511 defined procedures of how to identify, analyze and evaluate risks, then implement the risk reduction measures based on legal regulations of several countries.

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**Figure** Flow from incidents to standardization

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>1989 DIN (Germany)</td>
<td>1996 ISA S84 (U.S.)</td>
<td>1999 IEC 61508 (Int’l)</td>
<td>2003 IEC 61511 (Int’l)</td>
</tr>
</tbody>
</table>

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July 15, 2016-00
IEC 61508 / IEC 61511 international standards

The IEC 61508 defines the basic safety standard for functional safety for all industries. The IEC 61511 is dedicated for the process industry, in reference to the IEC 61508. These safety standards for functional safety are not established on the premise of “100% accident free,” but with some risks always remain. By converting the risks into numerical value by the globally standardized scale, the necessity and effectiveness of safety measures can be verified.

Positioning of the safety instrumented system in the viewpoint of layer of protection

A “layer of protection” approach is adopted as the basis of securing the plant safety that is to reduce risks by combining independent protection layers with the international standards of the IEC 61511, as shown below. Each protection layer has to be independent from each other, sets quantitative target for reducing risks, and establishes means of achieving these goals. A safety instrumented system is positioned in the prevention layer for reducing the risk of hazardous event occurrence and the mitigation layer for mitigating the influence of a hazardous incident that has occurred.

![Figure: The layer of protection](image-url)
In order to work out countermeasures for risks based on the layer of protection, risk assessments to the plant must be implemented and essential risk levels inherent in the process must be calculated. (1) In order to reduce the risks to a socially permissible risk level, multiple layers of protection have to be assigned. (2) The figure below shows reducing the risks to the tolerable level by combining external mitigation facilities (e.g. shelter panels, breakwaters, etc.); a process control system (e.g. CENTUM); and a safety instrumented system for emergency shutdown (ESD).

### Safety evaluation scales

The IEC 61508 introduces the Safety Integrity Level (SIL) as a method of describing the safety integrity requirements required at each layers of protection. The SIL is classified into four levels according to the value of average Probability of a dangerous Failure on Demand (PFDavg). The PFDavg of manual operation is $1/10$ or so, which means a failure may occur out of 10 operation requests and unable to perform its safety operation.

On the other hand, a safety instrumented system reduces the probability of failures as low as possible by enhancing its self-diagnosis function and failure analysis. This means a safety instrumented system with the SIL3 guarantees to perform the operation compared with manual operations.

<table>
<thead>
<tr>
<th>SIL</th>
<th>PFDavg</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>$10^{-4}$ to $10^{-1}$</td>
<td>Frequency of risk occurrence is reduced to the ranges in between 1/10000 and 1/100000 under the current conditions.</td>
</tr>
<tr>
<td>3</td>
<td>$10^{-3}$ to $10^{-1}$</td>
<td>Frequency of risk occurrence is reduced to the ranges in between 1/1000 and 1/10000 under the current conditions.</td>
</tr>
<tr>
<td>2</td>
<td>$10^{-2}$ to $10^{-1}$</td>
<td>Frequency of risk occurrence is reduced to the ranges in between 1/100 and 1/1000 under the current conditions.</td>
</tr>
<tr>
<td>1</td>
<td>$10^{-1}$ to $10^{-1}$</td>
<td>Frequency of risk occurrence is reduced to the ranges in between 1/10 and 1/100 under the current conditions.</td>
</tr>
</tbody>
</table>
This chapter describes about the features of the ProSafe-RS safety instrumented system which conforms to the Safety Integrity Level 3 (SIL3) defined by the IEC 61508.

- **Achieving SIL3 in single configuration**

ProSafe-RS is a safety instrumented system which achieves the SIL3 in a single configuration and its performance is certified by TÜV Rheinland, an external certification organization.

Each of the processor and input/output modules of the ProSafe-RS contain built-in computation matching function and self-diagnostic function, which keeps the modules failure rates to extremely low. The ProSafe-RS flexibly complies with customers’ requirements with its single configuration and the SIL3 certification.
2. Features of the ProSafe-RS

- **Redundancy achieves higher reliability**
  ProSafe-RS allows selecting dual-redundant module configurations in order to achieve higher reliability. Since the system already achieves SIL3 with a single configuration, the SIL3 is maintained even when one of the modules fails.

- **System integration with CENTUM VP**
  By integrating with the CENTUM VP system, the operation status of the ProSafe-RS are monitored on the CENTUM VP’s operation and monitoring screen. ProSafe-RS and CENTUM VP synchronize time, share data, and notify event & alarm in a single step.

- **Segregating functions of CENTUM VP from ProSafe-RS**
  International safety standards require that control and safety functions are independent of each other. Even when the ProSafe-RS and the CENTUM VP systems are integrated, the control and the safety functions are securely segregated. The operation of the CENTUM VP has no influence over safety functions of the ProSafe-RS.

- **Connecting with other systems**
  The operating status and data of the ProSafe-RS can be referred to by a supervisory computer or Modbus master via an OPC interface (*1), or a Modbus slave communication. Furthermore, the subsystem data such as sequencers can be set or referred by the ProSafe-RS via a Modbus communication.

*1:  The OPC is a way of communication among standard applications of Windows OS applied to process control. The OPC enables to send/receive process data among multiple Windows applications.
Security measures

The ProSafe-RS is accredited with the ISASecure Embedded Device Security Assurance (EDSA) of the ISASecurity Compliance Institute (ISCI), an international accreditation organization. The exida, an American accreditation organization certified by the ISASecure EDSA performed the Communication Robustness Test (CRT), the Fabricated Security Assessment (FSA) and the Software Development Security Assessment (SDSA). Then the ISCI evaluated and verified the conformity to the standard. The ISASecure EDSA certification certifies that the ProSafe-RS’s controllers have adequate security measures against threats of cyberattacks.

Figure ISASecure EDSA certification
3. System Configuration of the ProSafe-RS

In this chapter the system configuration of the ProSafe-RS is explained. The ProSafe-RS consists of Safety Control Station (SCS), Safety Engineering Station (SENG), Automation Design Server (AD Server) and others. AD Server is a Database Server which preserve the project data in a system. A minimum configuration system consists of an SCS and a SENG (including an AD Server).

3.1 Typical configuration

The figure below shows an example of the ProSafe-RS system configuration.

![Diagram of ProSafe-RS system configuration](F030001E.ai)
Safety control station (SCS)

An SCS is a controller to perform safety control of the ProSafe-RS.

Main features

- Executes safety control function
- Receives input data from field devices (e.g., temperature, pressure, flow, ON/OFF status of a switch)
- Transmits output instructions to field devices (e.g., open/close of valves, instruction of equipments’ ON/OFF)
- Performs inter-station communications (e.g., inter-SCS safety communication, SCS link transmission safety communication)
- Communicates with field devices (HART communication)
- Communicates with other systems (e.g., Modbus communication)

Safety engineering station (SENG)

The SENG is a computer for performing SCS’s engineering and maintenance tasks.

Main features

- Creates and verifies safety control functions (application programs)
- Downloads the created application programs to SCSs
- Monitors SCSs status
- Receives and displays alarm messages from SCSs
3.2 Integration with the CENTUM VP

The ProSafe-RS and the CENTUM VP systems can be integrated. The figure below shows an example of a system configuration that the ProSafe-RS and the CENTUM VP are integrated.

![System configuration example of ProSafe-RS integration with CENTUM VP](F030201E.ai)

**HIS**
An operation and monitoring station of CENTUM VP for operating a plant.

**ENG**
An engineering station to perform system configuration and maintenance management of the CENTUM VP.

**FCS**
A controller that controls a process.

- An HIS operates and monitors both FCSs and SCSs.
- The SCS’s data can be referred from HISs or FCSs.
- The SENG performs engineering of SCSs and the ENG performs engineering of FCSs and HISs. The engineering of the CENTUM VP integration systems are performed by both the SENG and the ENG. The SENG, ENG and HIS functions can be resided on a single computer or independently installed on different computers.
- The SCS’s data setting can be performed from HISs or FCSs; however, the data setting for the SCS is managed with the special security scheme.
### System scale

In a ProSafe-RS and CENTUM VP integrated system, the maximum number of station that can be configured is as follows:

- Number of connectable domains: 16
- Number of connectable stations (*1) per domain: 64
- Number of connectable stations: 256

Note: For a Vnet/IP system configuration, refer to General Specifications of “ProSafe-RS Safety Instrumented System Overview (for Vnet/IP)” (GS 32P01B10-01EN).

*1: A station is a generic name for SENG, SCS, ENG, HIS and FCS.
3.3 Communications among stations

“Inter-SCS safety communication,” “SCS link transmission safety communication,” and “SCS global switch communication” are used for communications among control stations.

- **Inter-SCS safety communication**

  The Inter-SCS Safety Communication can be established between an SCS and another SCS (in the same or in the different domain). (*1) Transmission of essential data at the SIL3 level can be performed while maintaining the communication quality.

  *1: In order to perform the Inter-SCS safety communication while inter-domain, the integration with CENTUM VP system is needed.

  ![Inter-SCS safety communication](F030301E.ai)

- **SCS link transmission safety communication**

  The SCS Link Transmission Safety Communication is a safety communication to concurrently broadcast Boolean data from an SCS to multiple SCSs (in the same domain). By this communication, broadcasting of essential data at the SIL3 level can be performed.

  ![SCS link transmission safety communication](F030302E.ai)
**SCS global switch communication**

The SCS Global Switch Communication concurrently broadcasts data from an SCS to multiple FCSs, which is an interference-free communication that has no influence over safety control.

![SCS global switch communication](image)
4. Safety Control Station (SCS)

This chapter explains the hardware configuration of a safety control station (SCS) that provides SIL3 in single configuration.

4.1 Hardware configuration of the SCS

The SCS is a safety controller of the ProSafe-RS. The SCS is composed of Safety Control Units (SCU), Safety Node Units (SNU) and N-IO Nodes.

The figure below shows an example of a system configuration.

![System configuration example of SCS](F040101E.ai)
4.2 Safety control unit (SCU)

Overview

The SCU implements safety control function by executing the application programs downloaded from the SENG. By using the Vnet/IP communication function, inter-station communications can be performed. Input/output modules mounted on SCU perform for input/output of field devices’ data.

The input/output modules can be increased by adding safety node units and N-IO nodes.

The following types of the SCU are available.

- S2SC70S/D: For large-scale systems or small to medium-scale systems, applicable to N-IO node
- SSC60S/D: For large-scale systems or small to medium-scale systems
- SSC57S/D: For wide-area systems such as oil and gas production facilities (wellheads) or small to medium-scale systems
- SSC50S/D: For small to medium-scale systems

The following figure shows an example of the SCU configuration.

![Figure: Configuration of safety control unit (S2SC70D)]
4.3 N-IO node and safety node unit (SNU)

- **N-IO node**

An N-IO node consists of an N-IO node interface units and N-IO Input/Output units. The N-IO node interface unit transmits field device signals received by the N-IO I/O unit to the SCU and the SCU data to field devices via an N-IO I/O unit. Input/output modules can be mounted on the N-IO I/O unit.

The figure below shows an example of N-IO node unit configuration.

![N-IO node unit configuration](image)

- **Input/Output modules**

AI, AO, DI, or DO signal can be assigned to the input/output modules by the channel by software.

<table>
<thead>
<tr>
<th>Model</th>
<th>Function</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2MMM843</td>
<td>(AI) Analog Input</td>
<td>4-20 mA, HART Communication function, Module isolation</td>
</tr>
<tr>
<td></td>
<td>(AO) Analog Output</td>
<td>4-20 mA, HART Communication function, Module isolation</td>
</tr>
<tr>
<td></td>
<td>(DI) Digital Input</td>
<td>no-voltage contact, Module isolation</td>
</tr>
<tr>
<td></td>
<td>(DO) Digital Output</td>
<td>24 V DC/0.66 A (*1), Module isolation</td>
</tr>
</tbody>
</table>

*1: The maximum load current up to 2 A device can be connected to DO by multiple channels parallel use.

- **Field wiring**

The terminal(s) provided with the N-IO input/output unit is used for wiring directly to field devices.
Safety node unit (SNU)

The input/output modules can be mounted on the SNU, and the SNU transmits analog input signals and contact signals of field devices to the SCU.

Input/Output modules

The following table shows the input/output modules available for the ProSafe-RS. The input/output modules can take a dual-redundant configuration in order to improve the availability.

<table>
<thead>
<tr>
<th>Model</th>
<th>Name</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAI143</td>
<td>Analog input module</td>
<td>4-20mA, Module isolation, HART Communication function</td>
</tr>
<tr>
<td>SAV144</td>
<td>Analog input module</td>
<td>1 to 5 V/1 to 10 V, Module isolation</td>
</tr>
<tr>
<td>SAT145</td>
<td>TC/mV Input module</td>
<td>Isolated Channels</td>
</tr>
<tr>
<td>SAR145</td>
<td>RTD Input Module</td>
<td>Isolated Channels</td>
</tr>
<tr>
<td>SAI533</td>
<td>Analog output module</td>
<td>4-20mA, Module isolation, HART Communication function</td>
</tr>
<tr>
<td>SDV144</td>
<td>Digital input module</td>
<td>no-voltage contact, Module isolation</td>
</tr>
<tr>
<td>SDV521</td>
<td>Digital output module</td>
<td>24 V DC/2 A, Module isolation</td>
</tr>
<tr>
<td>SDV526</td>
<td>Digital output module</td>
<td>100-120 V AC, Module isolation</td>
</tr>
<tr>
<td>SDV531/SDV541</td>
<td>Digital output module</td>
<td>24 V DC, Module isolation</td>
</tr>
<tr>
<td>SDV53A</td>
<td>Digital output module</td>
<td>48 V DC, Module isolation</td>
</tr>
<tr>
<td>ALR111/ALR121</td>
<td>Serial communication module</td>
<td>RS-232C, RS-422/RS-485</td>
</tr>
<tr>
<td>ALE111</td>
<td>Ethernet communication module</td>
<td></td>
</tr>
</tbody>
</table>

Figure: Configuration of safety node unit
Field wiring

For connecting a field device and an input/output module can be done by directly wiring using a pressure clamp terminal block or wiring via a terminal board using a cable-interface. Or, connecting a user-provided MIL cable with an MIL connector terminal block is available.

Figure  Example of field wiring
5. Engineering and Operation & Maintenance

The engineering and operation & maintenance of the SCS are described in this chapter.

5.1 Engineering

Application logics need to be generated to activate ESD or fire and gas (FAG) protection systems.

- **Engineering procedure**

  The procedures of how to create applications to activate ESD or FAG systems as well as how to perform operational tests are as shown in the following figure.

![Diagram](F050101E.ai)

**Figure**  Procedures for creating a ProSafe-RS standard application
(A) New project creation
Create a new project to manage application logics. Creation of the application logic is enabled only after a creation of a new project.

(B) Creation of application logics
Create an application logic to materialize the designed SCS operation, by using function block diagram (FBD) or ladder diagram (LD) which conform to the IEC 61131-3 international standard.

Use the multi-language editor to create FBD. By connecting boxes of functional units called function blocks (FB) with lines, application logics from input to output can easily be created.

Figure: Example of creation of application logics by using multi-language editor

Figure: Define of I/O
(C) Verification of application logics

The application logic made in step (B) can be verified by using the virtual test function. The virtual test function performs the verification of the application logics on a computer without having an actual SCS. With the virtual test function, the computation results of the application logics are displayed intuitively as TRUE (blue) and FALSE (red) on a screen. The logic simulation test and the SCS simulation test are available for the virtual test.

Figure  Example of a test window

During the logic simulation test, the SENG executes the application logic using the logic simulator. The SCS security level is disregarded when verifying the application logic of each SCS.

When the SCS simulator on the ENG or the SENG executes application logic during the SCS simulation test, it can also be conducted in accordance with the SCS’s security level, integrated operation environment with CENTUM VP is required. Alarm confirmation on the HIS window enabled by temporarily overwriting application logic variables using override function of the HIS simulator. And if two or more of the SCS simulators are used, the inter-SCS safety communication test can be performed as well.

Figure  SCS simulation test
(D) Off-line download or on-line change download

Download the application program verified in Step (C) from SENG to SCSs. An engineer is to compare the application program on the SENG and the data base in the SCS and confirm if the downloading has been correctly executed.

(E) Target test function

The application logic can be verified on the actual SCS using the target test function. The test can also be performed without mounting input/output modules by using the forcing function (see chapter 5.2 Maintenance Functions) and manually simulate input/output signal status. The target test function can be performed in reference to the security level of the SCS.

(F) Project check-in

Save the projects including the application logics created to the version management database for change management.
### Change management function

The change management function is an engineering support tool to manage change requirements generated during engineering work. By recording the changes in planning, execution, and testing, overlooking of the changes in the application programs can be prevented.

![Change management function window](image)

**Figure  Change management function window**
5.2 Operation and maintenance of SCS

Status of SCS and its operations in response to the plant's operating conditions and maintenance of the safety system are described in this section.

SCS status and operation

A safety system is expected to run properly and safely to prevent operators without authorities from making erroneous operations. The ProSafe-RS manages the SCS's operation and operational authorities by the operating mode and the SCS security level. The override and alarm window functions permits operation and monitoring of the SCS from CENTUM VP’s HIS.

Operating modes

The operating modes indicate the operating statuses of the SCS. Depending on the kinds of operating mode determines how the SCS system program performs.

<table>
<thead>
<tr>
<th>Name</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Mode</td>
<td>The initial state of the SCS</td>
</tr>
<tr>
<td>Loading Mode</td>
<td>Downloading a program or database information from the SENG to the SCS.</td>
</tr>
<tr>
<td>Initial Mode</td>
<td>Executing diagnosis, database initialization, I/O module booting and others that are needed for starting initialization of the SCS.</td>
</tr>
<tr>
<td>Waiting Mode</td>
<td>Waiting for all the output modules to activate.</td>
</tr>
<tr>
<td>Running Mode</td>
<td>The SCS is operating normally.</td>
</tr>
</tbody>
</table>

SCS security levels

The SCS security level limits changes made by the operations to the SCS from outside. Enable or disable of the user operation is controlled by the application logics depending on the defined security level.

Two categories of the security levels are available; one is the On-line level to be used during normal operation of SCS and the other is the Off-line level to be used when offline download is required. The security levels are password protected and only the authorized user with specific privileges can change.

On-line level:

- Level 2
  - The highest security level with which the normal operation of the SCS is executed.
- Level 1
  - The security level is temporarily used by an engineer or a specially authorized user for maintenance of the system and changing applications online.

Off-line level:

- Level 0
  - The security level to be used when off-line download is required.
Operation and monitoring of SCS by HIS (Override and alarm windows)

ProSafe-RS allows CENTUM VP’s HIS to control and monitor the SCSs so that the safety instrumented systems perform its functions by knowing the overall plant operation status.

Override

I/O values can be set to a specified value that is different from the actual I/O value by operation from HIS while the system is controlled normally by the SCS. This operation is called override. This override can be created in the application logic using safety function blocks.

Alarm window

The Alarm window is to notify operators essential alarms to sustain the plant safety. By displaying only the SCS alarms extracted from all alarms, operators are able to recognize the important alarms easily.

Figure  Integrated alarm window
5. Engineering and operation & maintenance

- **Maintenance functions**
  A safety instrumented system is required to have regular maintenance because it has to function without fail when an abnormality occurs. For the maintenance of the ProSafe-RS, maintenance support tools and forcing are provided.

- **SCS maintenance support tools**
  The SCS maintenance support tools have been developed for the purpose of simplifying the maintenance of the SCS. Equipped with a user interface to easily spot on a failure section, the function chronologically displays maintenance data necessary for analysis in the form of diagnostic information messages.
  The SCS maintenance support tools are as described below:
  - **SCS status display:** Displays the operating status of the SCS
  - **Diagnostic information display:** Displays diagnostic information in the SCS
  - **Online monitoring:** Displays the operating status of the application logic on the SCS
  - **Message cache tool:** Acknowledges the diagnostic information message and accumulation of SOE events
  - **SOE Viewer:** Displays event information stored on the SCS
  - **Setup Tool:** Customizes how to display and use the SCS maintenance support tools.

- **Forcing**
  The forcing is a function to fix or forcibly change values of input/output modules and application logic for the purpose of maintenance of the SCS or verification of application logics. Different from the override function, a dedicated user interface is used and creation of an application logic is not required.
5.3 Sequence of events recorder (SOER)

The sequence of events recorder (SOER) is a function to record the events (*1) that the SCS detects. Especially when the safety instrumented system is triggered, the SOER can be utilized for analyzing the causes of the plant’s emergency shutdown. The SOER function consists of the event collection, the event storage and the time synchronization functions.

*1: The term an “event” refers to a change to the predefined application logic.

- **Event collection**
  
  Not only digital inputs (DI) but also changes in digital outputs (DO) and analog inputs (AI) are collected as event information. By using the SOER function blocks with the application logic, changes in application logics can be acquired as event information, which enables to record changes in communication data with other SCSs.

- **Event storage**
  
  A certain volume of event information is stored in the SCS, and a computer for the data storage is not required to be activated all the time. On the other hand, the essential event information before and after the ESD are stored separately.
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