Chapter 20 Safety Programming in the PLC

Introduction

In engineering, redundancy is the duplication of critical components or functions of a system with the intention of increasing reliability of the system, usually in the form of a backup or fail-safe, or to improve actual system performance.

In many safety-critical systems, some parts of the control system may be triplicated, which is formally termed triple modular redundancy (TMR). An error in one component may then be out-voted by the other two. In a triply redundant system, the system has three sub components, all three of which must fail before the system fails. Since each one rarely fails, and the sub components are expected to fail independently, the probability of all three failing is calculated to be extraordinarily small; often outweighed by other risk factors, such as human error. Redundancy sometimes produces less, instead of greater reliability – it creates a more complex system which is prone to various issues, it may lead to human neglect of duty, and may lead to higher production demands which by overstressing the system may make it less safe

What is the difference between fault-tolerant designs and fail-safe designs? A fault-tolerant system is designed to avoid total service failure caused by faults at any single point. Typically, a fault-tolerant design applies redundancy or multiple safety barriers to enable the system to continue its intended mission, possibly with reduced performance or increased response time in the event of some partial failure, rather than to fail completely. An example of a fault-tolerant design is an aircraft with multiple engines, so that it will keep flying even if one of the engines failed. A fail-safe system is designed to fail in a safe and controlled manner, so that the failure will not endanger lives or properties, or at least be no less safe than when it is operating correctly. For example, the brakes on a train are designed to apply when the brake control system fails, to ensure safety by stopping the train. It must be noted that a fail-safe system can also suffer 'wrong-side failure', as when, for example, a malfunctioning traffic light shows green rather than flashing red or goes dark; but is to have a very low probability of this occurring. In some cases, it may not be acceptable for one or even more failures to cause a system to cease functioning. Unlike a fail-safe system that puts safety ahead of function or mission objective, a 'failoperational' system will continue to operate in spite of control systems failure. An example is the thermostats in home air-conditioners.

PLC Systems use Fail-Safe Technology

Industrial automation is now considerably more flexible and open. Modern machines and systems also stand out due to their significantly increased productivity. This is due in no small part to the fact that relay technology has been replaced by the freely programmable controller and decentralization – at least for demanding applications. In spite of this change in technology, very different products and systems were often used until now for safety-oriented functions and standard tasks. If more complex safety tasks are involved, however, the efficiency of an automation solution can be significantly increased even if the safety technology consistently follows the trend toward intelligent PLCs.

A fail-safe PLC serves to control processes and immediately switches to a safer state or remains in the current state if a fault occurs. It provides an integrated, efficient safety solution in systems with increased safety requirements.

Programming is done in Siemens PLCs using the Step 7 languages LAD and FBD and TUV-certified (German Technical Inspectorate) function blocks. The connection to the standard and safety-oriented modules can be optionally made via PROFINET, the open Ethernet standard or via PROFIBUS.

The European guidelines apply today as those that reflect the highest safety standard and are accepted far beyond the boundaries of Europe. In order to ensure the functional safety of a machine or system, the safety-relevant parts of the protective and control systems behave in such a manner in the event of a fault that the system remains in a safe state or is put into a safe state. To this end, special requirements that are defined in standards are placed on the products. Corresponding product certificates can document the compliance with these standards.

Any possible hazards to people and the environment cannot just be averted at the national level. They must always comply with the regulations and rules of the location where the machine or system is operated. Thus the free exchange of goods within the framework of global markets requires internationally agreed codes of practice.

Safety requires protection against a variety of risks. These can be overcome as follows:

- Design in accordance with risk-reducing design principles and risk assessment of the machine
- Technical protection measures, if necessary by the use of safety-related controllers
- Electrical safety

Functional safety involves the part of the safety of a machine or plant that depends on the correct function of its control or protection equipment.

The analysis of risk follows a set procedure.

BGIA is now IFA

The name BGIA for years was associated with the German insurance industry responsible for setting up rules for plant safety or workplace safety. The new name reflects a change in social accident insurance.

The research institutes of the German Social Accident Insurance (DGUV) received new names and abbreviations. As of 1 January 2010, the former BGIA in Sankt Augustin is now be named the "Institute for Occupational Safety and Health of the German Social Accident Insurance", abbreviated as "IFA". Why look to Germany? They have traditionally led the way in quantifying safety in the workplace.

The Internet address of the institute changed accordingly:

As of 1 January 2010, the Institute for Occupational Safety and Health of the DGUV (IFA) is to be found at www.dguv.de/ifa**.**

Application of the Machinery Directive 2006/42/EC [1] has been mandatory since 29 December 2009. The directive lists products that are described as "logic units to ensure safety functions". These products are stated in Annex IV of the Machinery Directive. This appendix lists products which owing to their function are a source of particularly high hazards in the event of a fault. Accordingly, stricter requirements apply to the conformity assessment method. The affected components and the possible assessment methods are stated below.

1 What products are described as "logic units to ensure safety functions"? Products are affected by this provision when:

a) they are safety components (see below) and are therefore governed by the Machinery Directive; and

b) they are "logic units to ensure safety functions" in accordance with Annex IV, No. 21 (see below).

Concerning a): safety component in accordance with the Machinery Directive Article 1 of the Machinery Directive states its scope. The products considered here fall under c) safety components. In Sub-point c), Article 2 contains the definition of a safety component:

c) “safety component” means a component

- which serves to fulfil a safety function
- which is independently placed on the market,
- the failure and/or malfunction of which endangers the safety of persons, and
- which is not necessary in order for the machinery to function, or for which normal components may be substituted in order for the machinery to function.

If the above definition is applied for example to a safety PLC (Programmable Logic Controller), the following conclusion is reached: a safety PLC

- serves to fulfill a safety function
- is placed independently on the market, i.e. it is not supplied solely fitted to a machine
- endangers the safety of persons in the event of its failure and/or malfunction
- is not necessary for the machinery to function when used solely for the implementation of safety functions, or can be substituted by a conventional PLC for the purpose of the functioning of the machine, if non safety related functions are also performed.

Under the provisions of the Machinery Directive, a safety PLC is therefore classified as a safety component. As this example shows, the definition applies both to products which are employed solely for safety functions and to products which at the same time fulfil both safety functions and machine functions. An additional aid for determining whether a component is a safety component can be found in Annex V of the Machinery Directive. This contains a non-exhaustive list of safety components. Concerning b): logic units to ensure safety functions The background to the inclusion of these components in Annex IV is the growing use of functional safety products in machine controls. The Machinery Directive also lists the "logic units to ensure safety functions” in Annex V, but does not define these components. Clarification is provided by the "Guide to application of the Machinery Directive 2006/42/EG" [2]:

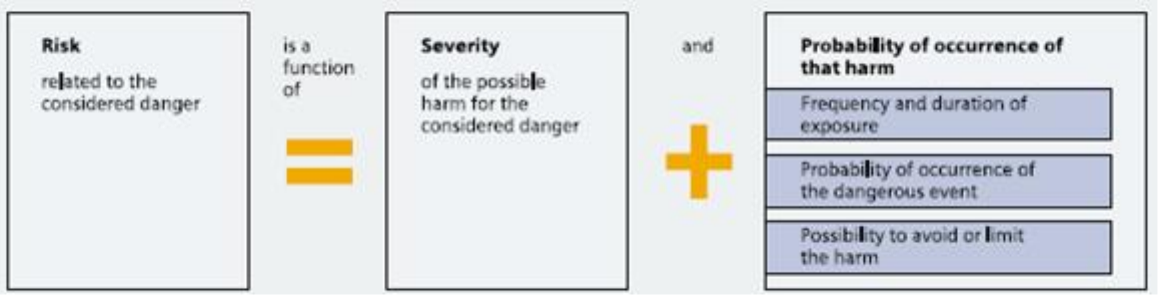
Logic units to ensure safety functions

In accordance with Annex IV of the Machinery Directive

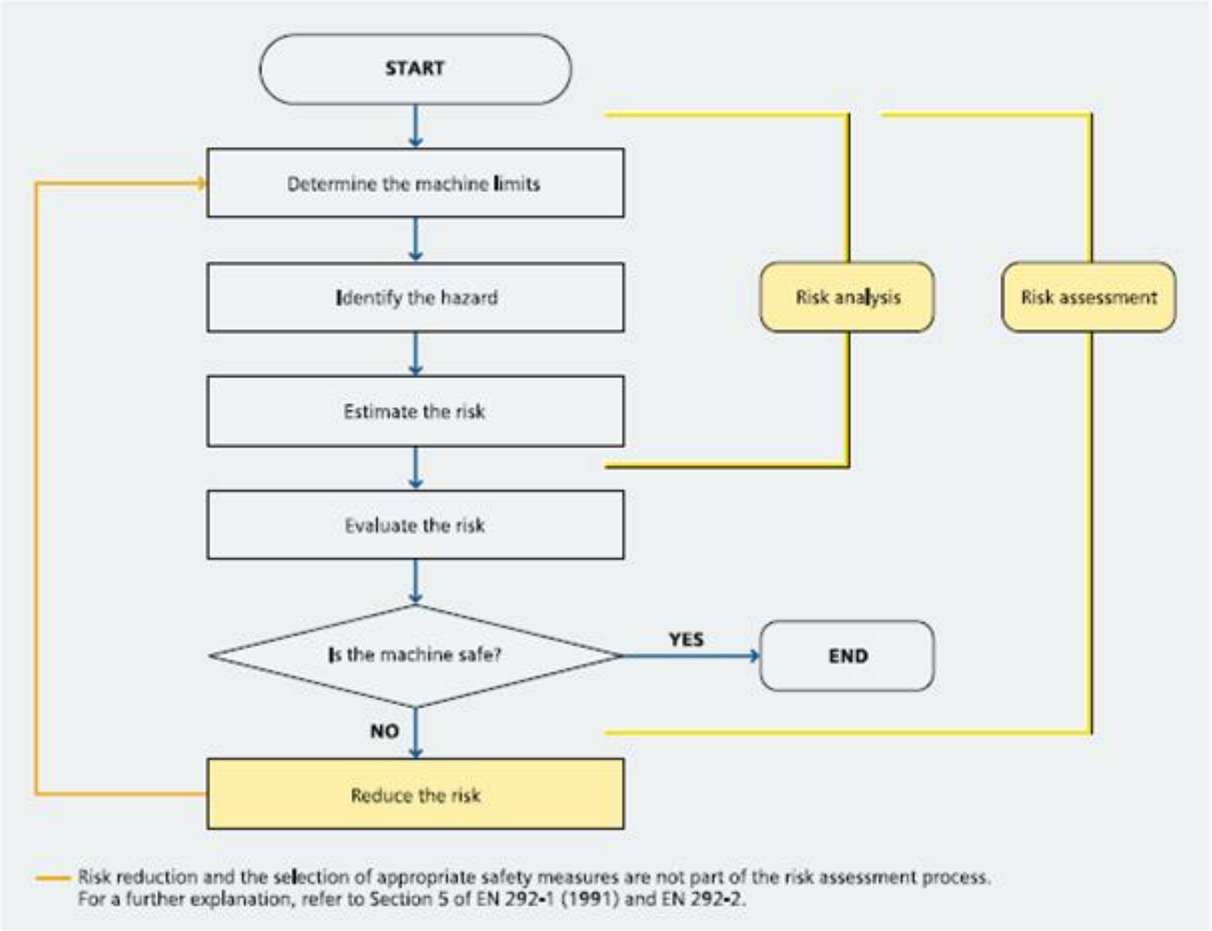
On 29 December 2009, application of the new Machinery Directive, 2006/42/EC, becomes mandatory. One of the associated changes concerns "logic units to ensure safety functions". These are now referred to in Annex IV of the directive. This product group is not precisely defined, however. Owing to the reference to these products in Annex IV of the Machinery Directive, stricter requirements apply to the conformity assessment procedure for application of the CE mark.

For the purpose of defining logic units to ensure safety functions, the IFA has made an article available for download in which it classifies the components frequently employed in machine controls. The products concerned include safety PLCs (programmable logic controllers), power drive systems with integrated safety functions, safety switchgear, and any components for which the manufacturer states a Category, Performance Level or Safety Integrity Level. The classification of a component as a "logic unit to ensure safety functions" constitutes an estimation made by the IFA in liaison with other German test bodies.

A risk is defined below:



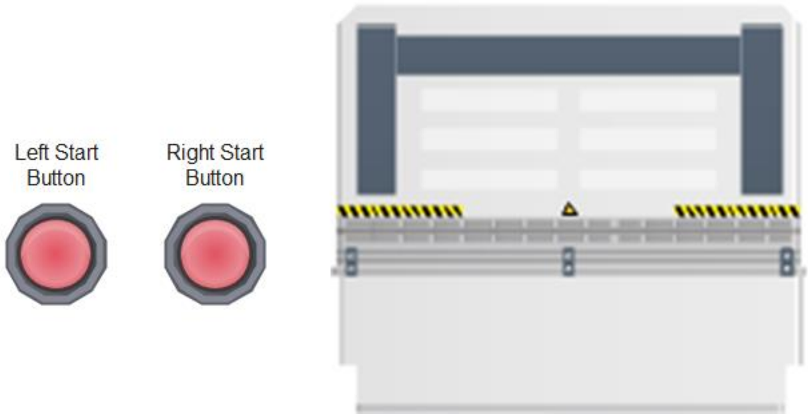
A process to reduce risk is defined as:



Independent safety devices may be used in the design of a safety system. Two such devices are given below. The first is a safety relay. The second is a two-hand safety circuit. Both are stand-alone and are not to be incorporated in the PLC system other than as an add-on to an existing PLC system. They have been supplanted by the safety PLC with the function of these devices incorporated into the PLC itself after 2003 and the changes in standards permitting safety functions to be allowed inside the PLC.

Movement into Safety

Some years ago, I had a part-time job with a local machine builder. This individual provided all electrical control equipment except a program. That job was left to me. Most of the projects involved a press of some kind. They were slow and used pneumatic power to press the material for a car hood liner. All had two buttons to start the press. They were spaced far enough apart that the operator could not operate both with the same hand. Both hands had to be in a position away from the press far enough that they were safely out of the way of the movement of the press down.



In those early days, the buttons were programmed in the PLC. There was about a half second time delay allowed between the two buttons turning to innitiate the press to start. Any delay beyond the half second would have not allow the press to begin.

Later, there was a device that handled this action with an output that allowed the PLC program to execute. The device was similar to the one below.

Since we have heard much from Siemens and Allen-Bradley in this text, we give time to another voice – Schneider – the French automation giant who is the owner of multiple PLCs including the original PLC – Modicon. The following, however, are not PLCs but rather discrete devices that pre-dated PLCs for safety functions:

Schneider Electric XPSBF1132P

SAFETY RELAY FOR TWO HAND CONTROL STATIONS, OUTPUT: 2; AUX: 2 SOLID STATE; 24VDC

Operating principle

Two-hand control stations are designed to provide protection against hand injury. They require machine operators to keep their hands clear of the hazardous movement zone. The use of two-hand control is an individual protective measure, which can safely protect only one operator. Separate two-hand control stations must be provided for each operator in a multiple-worker environment.
Safety modules XPSBA, BC and BF for two-hand control stations comply with the requirements of European standard EN 574/ISO 13851 for two-hand control systems.

The control stations must be designed and installed such that they cannot be activated involuntarily or easily rendered inoperative. Depending on the application, the requirements of type C standards specific to the machinery involved must be met (additional personal protection methods may have to be considered).

To initiate a hazardous movement, both operators (two-hand control pushbuttons) must be activated within an interval y 0.5 s (synchronous activation). If one of the two pushbuttons is released during a hazardous operation, the control sequence is cancelled. Resumption of the hazardous operation is possible only if both pushbuttons are returned to their initial position and reactivated within the required time interval.

The control sequence does not occur if:

• Both two-hand control push buttons are pressed during a time period greater than 0.5 seconds,
• A short-circuit is present in a push button contact,
• The feedback loop is not closed at start-up.

The safety distance between the control units and the hazardous zone must be sufficient to ensure that when only one operator is released, the hazardous zone cannot be reached before the hazardous movement has been completed or stopped.

This device has been replaced in most applications by an instruction in the PLC, specifically a safety PLC with the safety instruction pre-approved for the purpose.

Legal requirements and standards regarding safety at work in North America

An essential difference between the legislation associated with safety at work between North America and Europe is the fact that in the US there is no standard legislation regarding machinery safety that addresses the responsibility of the manufacturer/supplier. There is a general requirement that the employer must provide a safe place of work.

US – general

The Occupational Safety and Health Act (OSHA) from 1970 is responsible in regulating the requirement for employers to ensure safe working conditions. The core requirements of OSHA are listed in Section 5 "Duties":

(a) Each employer
  (1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;
  (2) shall comply with occupational safety and health standards promulgated under this Act.

The requirements from the OSH Act are administered and managed by the Occupational Safety and Health Administration. OSHA deploys regional inspectors who check whether workplaces fulfill the applicable regulations. The regulations, relevant for safety at work of the OSHA, are defined and described in OSHA 29 CFR 1910.xxx.

The following is stated at the beginning of the regulations for the Safety and Health Program:

(b)(1) What are the employer's basic obligations under the rule? Each employer must set up a safety and health program to manage workplace safety and health to reduce injuries, illnesses and fatalities by systematically achieving compliance with OSHA standards and the General Duty Clause.

And later

(e) Hazard prevention and control

(e)(1) What is the employer's basic obligation? The employer's basic obligation is to systematically comply with the hazard prevention and control requirements of the General Duty Clause and OSHA standards.

(h)(6)(xvii)

Controls with internally stored programs (e.g., mechanical, electro-mechanical, or electronic) shall meet the requirements of paragraph (b)(13) of this section, and shall default to a predetermined safe condition in the event of any single failure within the system. Programmable controllers which meet the requirements for controls with internally stored programs stated above shall be permitted only if all logic elements affecting the safety system and point of operation safety are internally stored and protected in such a manner that they cannot be altered or manipulated by the user to an unsafe condition.

The OSHA regulations define minimum requirements to guarantee safe places of employment. However, they should not prevent employers from applying innovative methods and techniques, e.g. "state of the art protective systems" in order to maximize the safety of employees.
In conjunction with specific applications, OSHA specifies that all electrical equipment used to protect

employees, must be certified for the intended application by a nationally recognized testing laboratory (NRTL) authorized by OSHA. OSHA requires that all electrical products used by employees must be treated and approved for their intended use by an OSHA Approved Nationally Recognized Testing Laboratory.

NFPA 79

This Standard applies to the electrical equipment of industrial machines with rated voltages less than 600 V (a group of machines that operate together in a coordinated fashion is considered as a machine).

The comparison of European SIL and US Category (Cat) is shown below. Category 3 and 4 require safety equipment installed to protect employees.

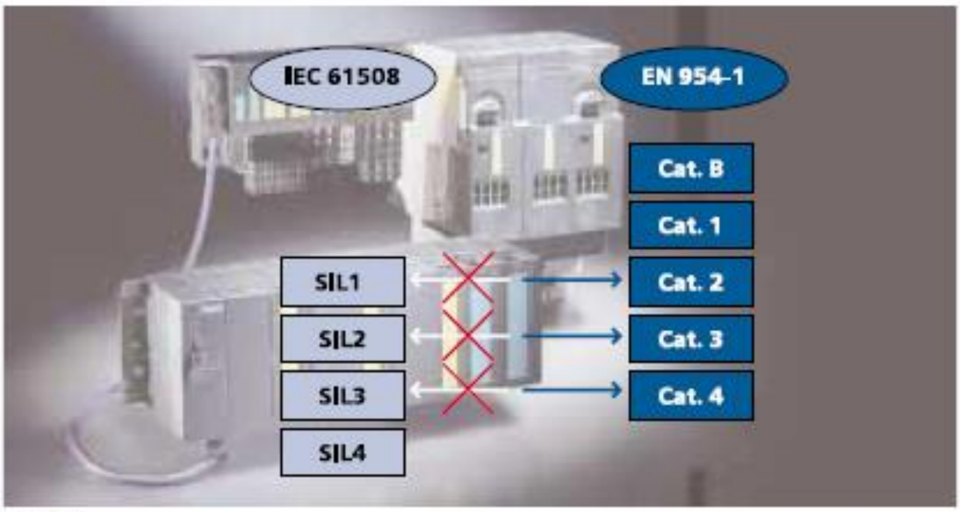
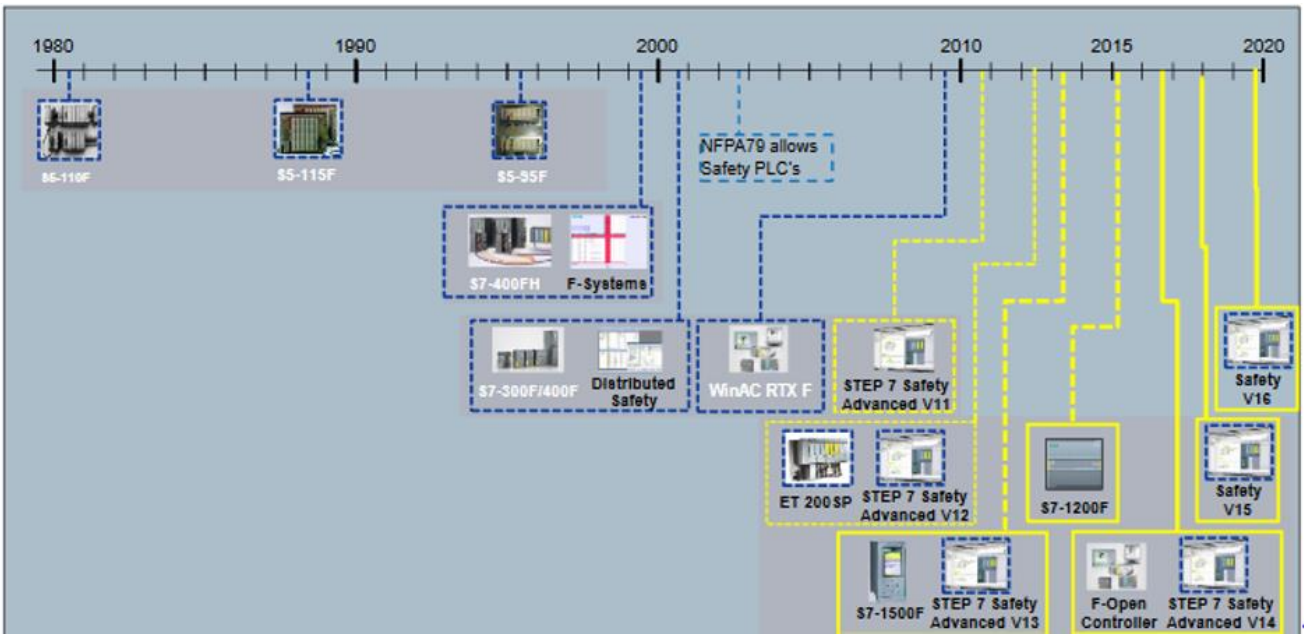


Fig. 2/3
SIL necessary to fulfill specific categories

The following gives a timeline of Siemens' development of safety equipment. The most significant date here is 2003, the year NFPA70 allows safety PLCs in the US marketplace.



Next we have a lab using Safety PLC equipment. Siemens' Reference Book on S7-1200 Safety can be found at:

Industrial Software SIMATIC Safety - Configuring and Programming Manual (642 pgs)

Safety Programming Guideline for SIMATIC S7-1200/1500 (48 pgs)

Industrial Controls SIRIUS Safety Integrated Application Manual Application Manual (200 pgs)

S7-1200 Functional Safety Manual, V4.2, 09/2016, A5E03470344-AB

This last manual has an example program similar to our lab with an outline of how to program and successfully implement the application. We are given a program complete and ready to go. All that is needed is to successfully wire the application. This may sound easy but in fact is not. The task still is difficult. When successful, the run light will turn on and the two relays will click 'on'. This signifies the running of the motor which would be attached to the two relays in an industrial application.

https://new.siemens.com/us/en/products/automation/distributed-control-system/pa-webinars/process-automation-pdh-webinars-registration/process-safety-webinars-form/process-safety-webinars.html

Choose: What is a safety PLC Part 3 of 4 series

In the Video there is a description of the KCPL Explosion. The Vendor referenced was A-B with a description that follows:

"

KCP&L wins $135 million judgment

Kansas City, Mo. ? A jury has determined a Milwaukee parts manufacturer should pay more than $135 million in damages related to a 1999 gas explosion that destroyed a Kansas City Power & Light Co. plant.

A spokesman for Allen-Bradley Corp. said the company was disappointed with Friday's verdict and said it would appeal. Allen-Bradley recently became part of Rockwell Automation Inc. in Milwaukee.

Jurors in Jackson County assessed damages at $452 million, and found KCP&L was liable for 70 percent.

Tom Robinson, a spokesman for KCP&L, said the utility was "gratified the jury recognized we should receive compensation."

The explosion at KCP&L's Hawthorn 5 plant on Feb. 17, 1999, left it out of operation for 838 days. The utility claimed a loss of $552 million for rebuilding the plant, lost business and other expenses.

KCP&L blamed what it called defective computer safety equipment, but Allen-Bradley blamed the utility and wastewater that leaked into the equipment.

"They both had to be at fault," jury foreman Bob Palmer said.

KCP&L said it did not cause the explosion. It blamed an errant Allen-Bradley guidebook for installing switching equipment that malfunctioned and opened the gas line, which caused the explosion.

Allen-Bradley contended a short circuit from sewer water caused the malfunction that opened the gas line. It blamed the sewer problem and poorly trained KCP&L technicians who repaired the damage.

KCP&L asked jurors to place a value of $621 million on damage that included the cost of rebuilding and lost income and to find Allen-Bradley negligent for much of that.

Allen-Bradley contended that number should be only $130.6 million and all blame should be on KCP&L.

The local report from the Kansas City Star follows:

“Fire, Explosion at KCP&L's Hawthorn Power Plant

By MALCOLM GARCIA - The Kansas City Star Date: 05/23/00 01:09

Firefighters from Kansas City and area departments were cautiously trying to put out a fire at KCP&L's Hawthorn plant in the East Bottoms early this morning.

Area fire departments were brought in to try to put the fire out with foam. Firefighters were being careful in how they approached the fire because of concern about explosions.

The cause of the fire was not known early this morning. No injuries had been reported.

The fire caused a brief outage across the city after 11 p.m. Monday. The outage was a result of the load being shifted from the 345,000-volt transformer to other areas of the transformation system to maintain power in the area, said Tom Robinson, a Kansas City Power & Light spokesman.

Johny Teegarden, an iron worker at the plant, was leaving to get something to eat when he heard the explosion.

"We heard a big boom and saw a big flash, and then a bunch of little fires," he said. "By the time we got out of the plant that fire was burning good."

In February 1999, the complex near Front Street and Interstate 435 was rocked by a boiler explosion.

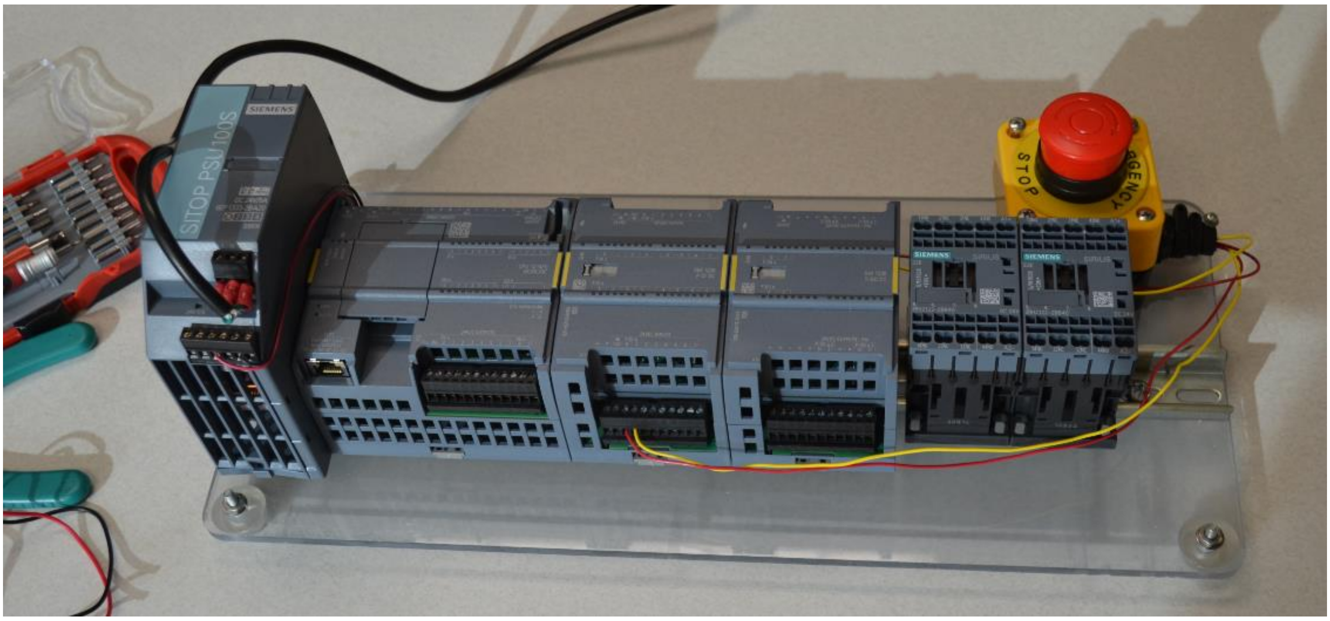
That late-night explosion woke people 20 miles away, knocked nearby workers off their feet and launched flames 200 feet into the night sky. The explosion was caused by a buildup of natural gas used to start the plant's boiler. One minor injury was reported.

That part of the plant, which is still not functioning, was one of KCP&L's main generating plants.

KCP&L decided to rebuild the plant, which accounted for 15 percent of the utility's capacity to generate electricity. The plant is scheduled to resume operation in summer 2001.

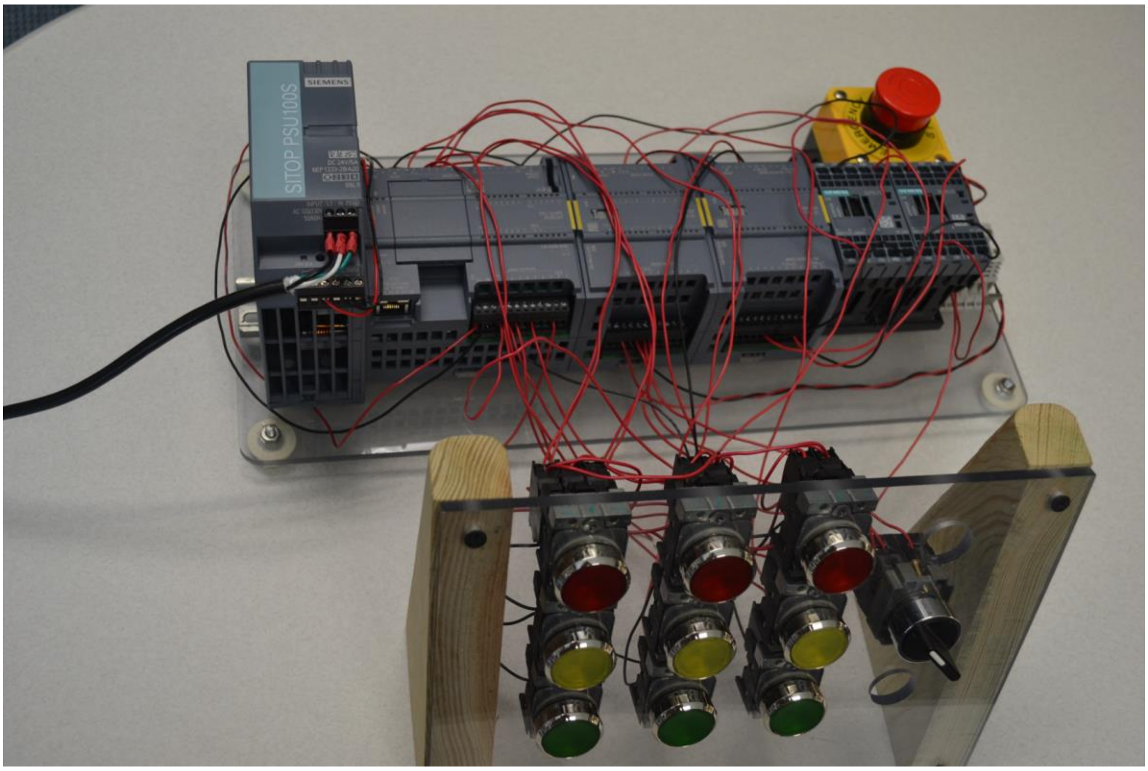
Our Equipment includes:

Siemens CPU 1214FC DC/DC/DC PLC
Siemens SM 1226 F-DI DC Input Module
Siemens SM 1226 F-DQ DC Output Module
Two Siemens Sirius 3RH2122-2BB40 Relays
An Emergency Stop Station

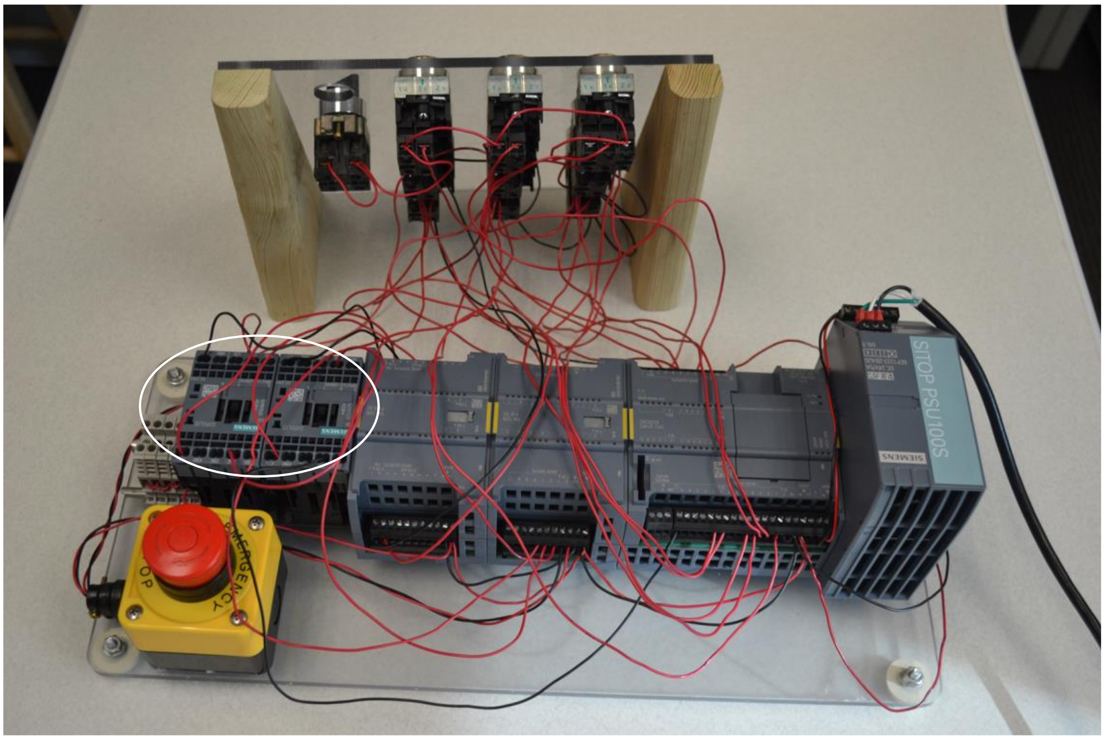


Since several non-safety Inputs and Outputs are used in the lab, we will use the pushbutton station from the lab, shown below:

The two figures below show the completed wiring job with the PLC ready to run the program.



Use the relays pictured at right instead of the ones above for the run relays. These relays have screw terminals instead of push terminals and are more secure with smaller wire. They also may be reused many more times. For a wiring diagram, refer to Chapter 2.



The relays to be removed are circled in the figure above.

Note:

"

Sensor evaluation

There are two types of sensor evaluation:

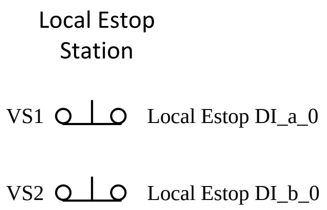
- 1oo1 evaluation – sensor signal is read once
- 1oo2 evaluation - sensor signal is read twice by the same → F-I/O and compared internally

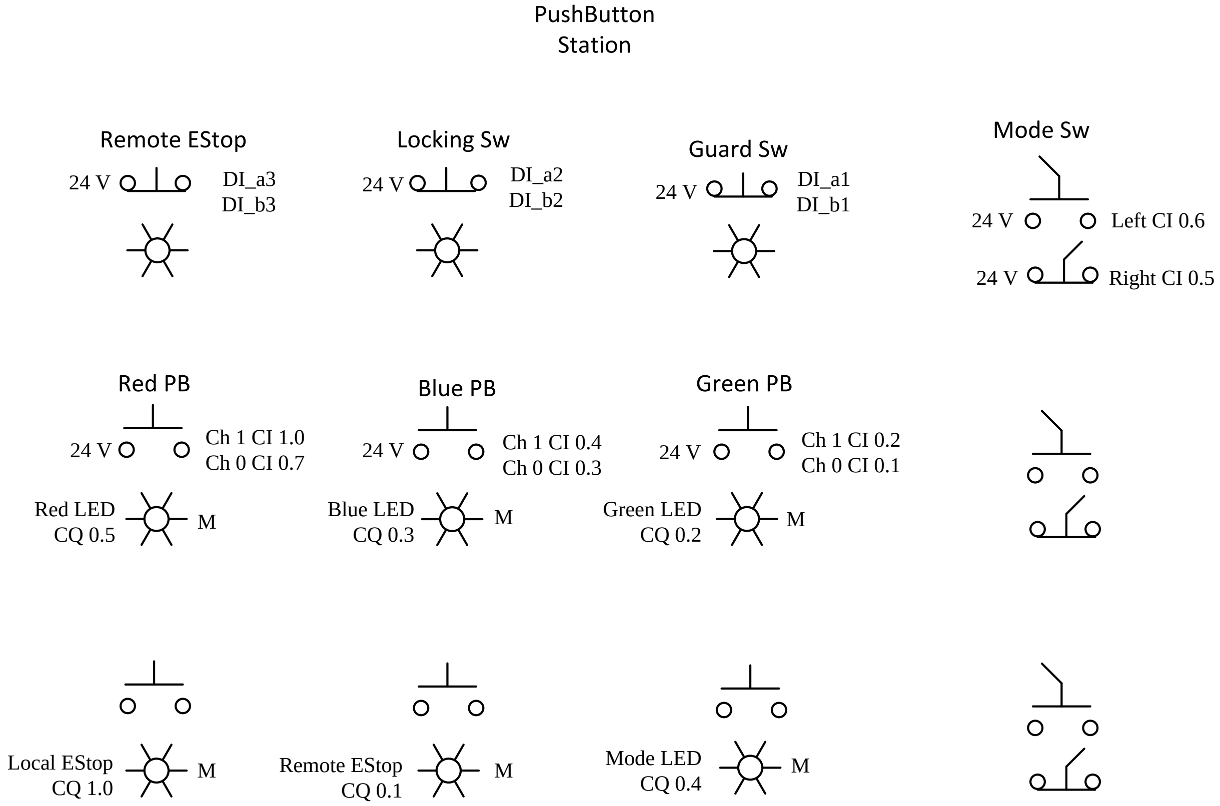
"

Also, note that the two relays are extremely difficult to secure the wires in the terminals. You would be advised to substitute the relays from Ch. 2's lab (24 VDC ones) instead.

It was noted that the use of timers in the fail-safe portion of the program was extremely burdensome on the time overhead of the system. Any use of timers should be limited. The solving of logic twice (once for positive logic and once for negative logic determines that with each tick of the timer, the logic must be evaluated again). That is a large over-head and should be avoided.

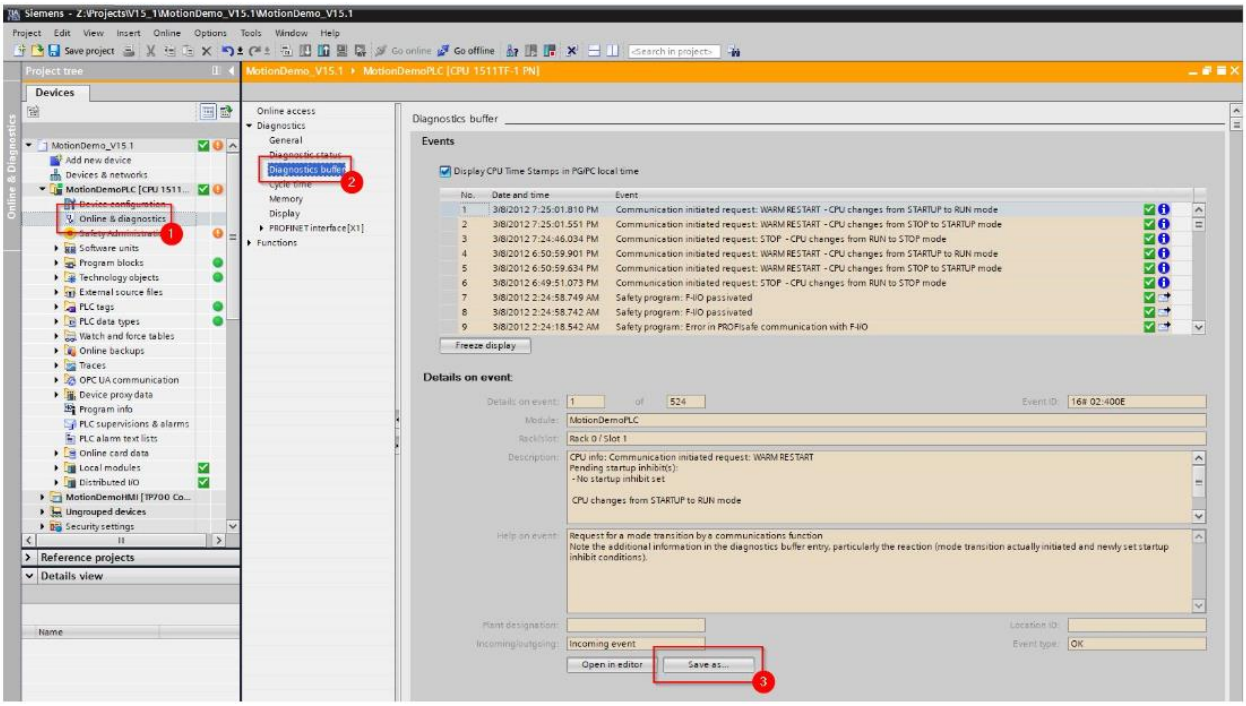
To better step through the process of setting up a Safety System from scratch, the lab in Lab Text Ch. 26 provides a complete wiring diagram of the project at UToledo. The following button layout shows the actual buttons used and their function. In the example from Siemens, there are a number of local switches from external devices. We provided substitutes for these switches with simple pushbuttons labelled appropriately.





Note that the referenced Red PB, Blue PB and Green PB are not actually these colors but are labelled as such in the program. The button colors for all three are yellow.

The following is a troubleshooting page to be used if there is an error in the wiring or configuration of the program:

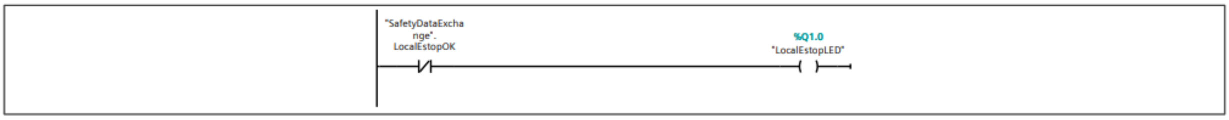


The figures that follow are the program listing for the programs as well as the configuration pages of the various OB's and FB's:

First, OB1:

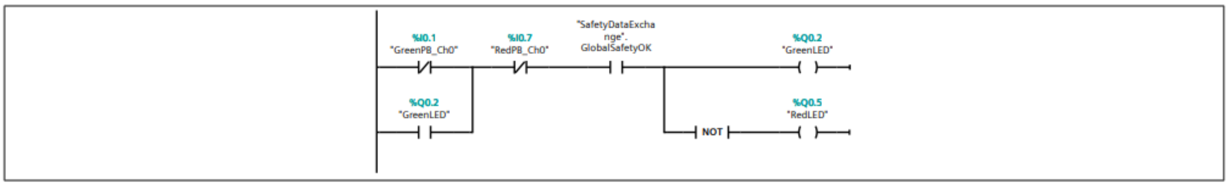
Name	Data type	Default value	Comment
▼ Input			
Initial_Call	Bool		Initial call of this OB
Remanence	Bool		=True, if remanent data are available
Temp			
Constant			

Network 1:



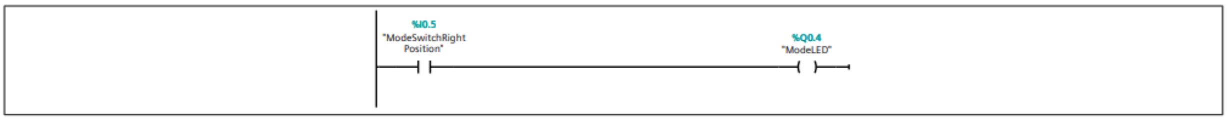
Network 2:

Network 3:

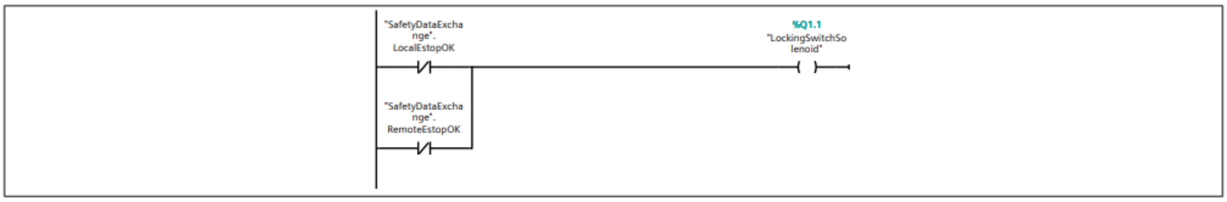


Network 4:

Network 5:

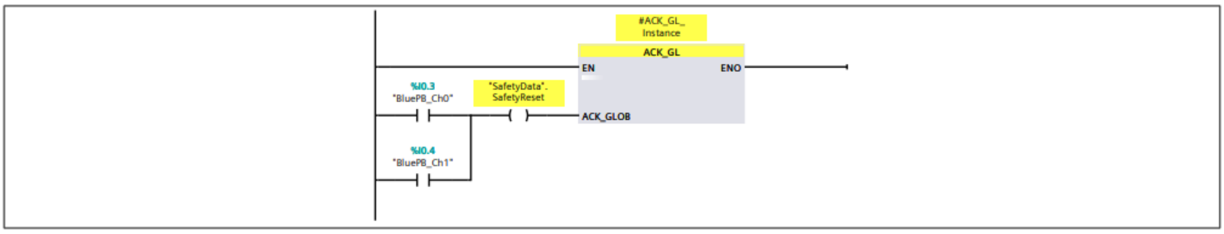


Network 6:

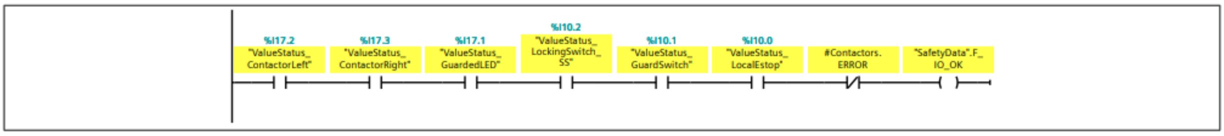


Name	Data type	Default value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/ OPC UA/ Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
▼ LocalEstopStatus	ESTOP1			True	True	True	True		
▼ Input									
E_STOP	Bool	false	Non-retain	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	Non-retain	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	Non-retain	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	Non-retain	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	Non-retain	True	True	True	False		1=Enable
Q_DELAY	Bool	false	Non-retain	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	Non-retain	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	Non-retain	True	True	True	False		Service information
InOut									
Static									
▼ GuardStatus	ESTOP1			True	True	True	True		
▼ Input									
E_STOP	Bool	false	Non-retain	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	Non-retain	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	Non-retain	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	Non-retain	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	Non-retain	True	True	True	False		1=Enable
Q_DELAY	Bool	false	Non-retain	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	Non-retain	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	Non-retain	True	True	True	False		Service information
InOut									
Static									
▼ RemoteEstopStatus	ESTOP1			True	True	True	True		
▼ Input									
E_STOP	Bool	false	Non-retain	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	Non-retain	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	Non-retain	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	Non-retain	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	Non-retain	True	True	True	False		1=Enable
Q_DELAY	Bool	false	Non-retain	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	Non-retain	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	Non-retain	True	True	True	False		Service information
InOut									
Static									
▼ Contactors	FDBACK			True	True	True	True		
▼ Input									
ON	Bool	false	Non-retain	True	True	True	False		1=Enable output
FEEDBACK	Bool	false	Non-retain	True	True	True	False		Feedback input
QBAD_FIO	Bool	false	Non-retain	True	True	True	False		QBAD signal of FI/O/channel of output Q
ACK_NEC	Bool	true	Non-retain	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	Non-retain	True	True	True	False		Acknowledgment
FDB_TIME	Time	T#0ms	Non-retain	True	True	True	False		Feedback time
▼ Output									
Q	Bool	false	Non-retain	True	True	True	False		Output
ERROR	Bool	false	Non-retain	True	True	True	False		Feedback error
ACK_REQ	Bool	false	Non-retain	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	Non-retain	True	True	True	False		Service information
InOut									
Static									
ContactorOutput	Bool	false	Non-retain	True	True	True	False		
▼ LockingSwitch_SS_Status	ESTOP1			True	True	True	False		
▼ Input									
E_STOP	Bool	false	Non-retain	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	Non-retain	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	Non-retain	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	Non-retain	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	Non-retain	True	True	True	False		1=Enable
Q_DELAY	Bool	false	Non-retain	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	Non-retain	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	Non-retain	True	True	True	False		Service information
InOut									
Static									
Temp									
Constant									

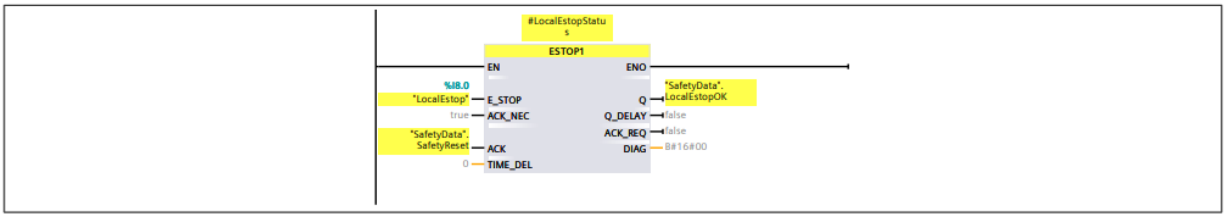
Network 1:



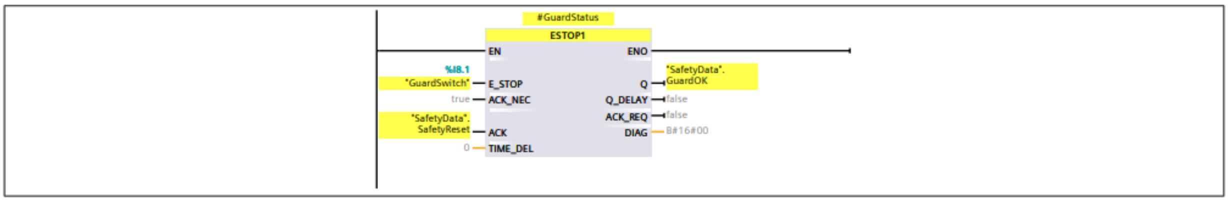
Network 2:



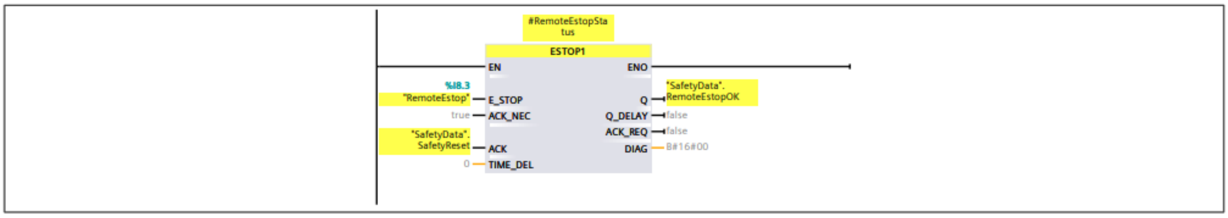
Network 3:



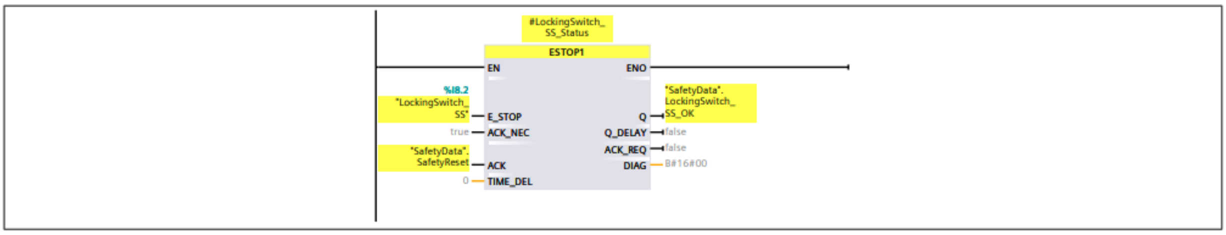
Network 4:



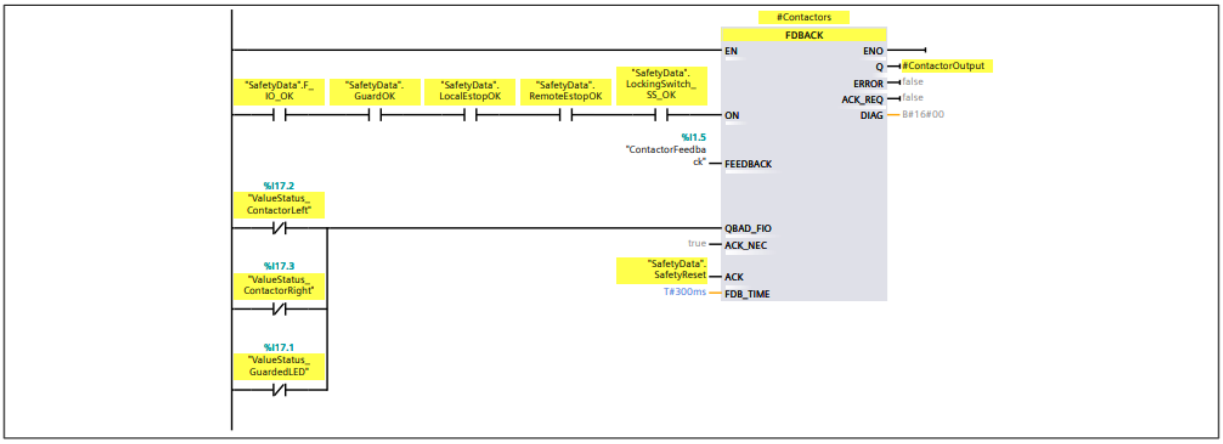
Network 5:



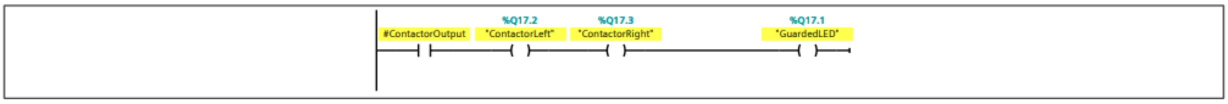
Network 6:



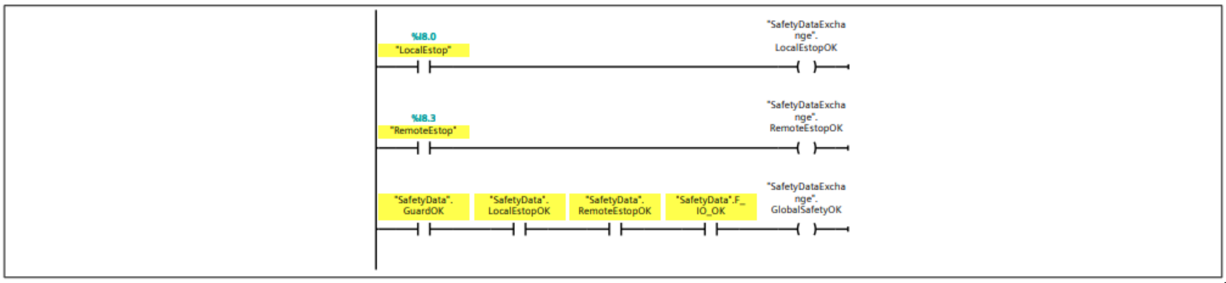
Network 7:



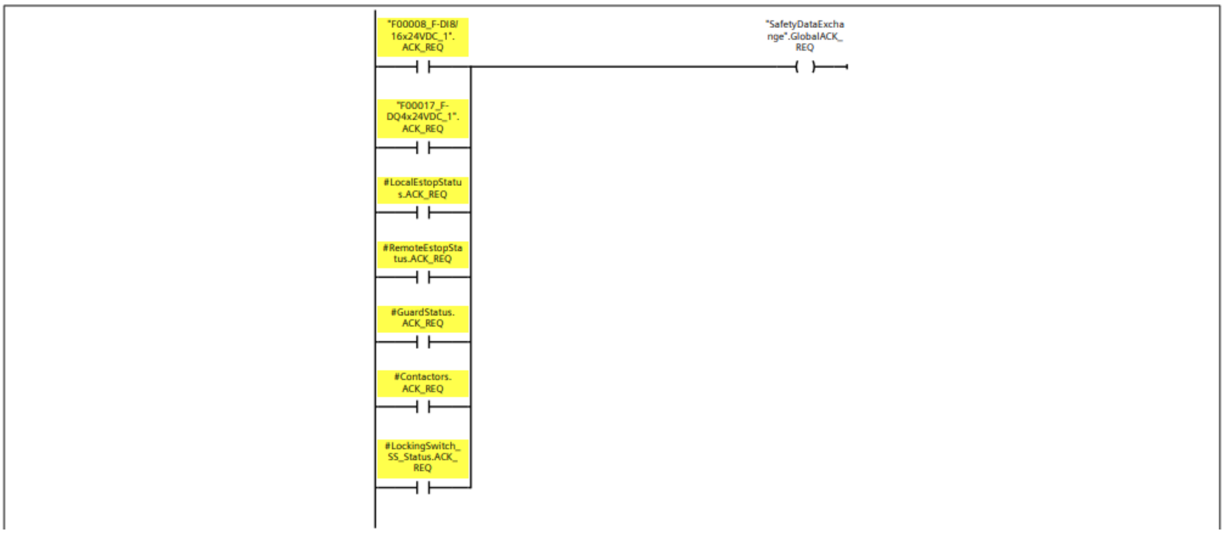
Network 8:



Network 9:



Network 10:



Program blocks

Main_Safety_RTG1_DB [DB1]

Main_Safety_RTG1_DB Properties							
General							
Name	Main_Safety_RTG1_DB	**Number**	1	**Type**	DB	**Language**	DB
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**	FUSI				

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writ-able from HMI/OPC UA/Web API	Visible in HMI engi-neering	Setpoint	Supervi-sion	Comment
Input									
Output									
InOut									
▼ Static									
▼ ACK_GL_Instance	ACK_GL		False	True	True	True	True		
▼ Input									
ACK_GLOB	Bool	false	False	True	True	True	False		1=acknowledgment for reintegration
Output									
InOut									
Static									
▼ LocalEstopStatus	ESTOP1		False	True	True	True	True		
▼ Input									
E_STOP	Bool	false	False	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	False	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	False	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	False	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	False	True	True	True	False		1=Enable
Q_DELAY	Bool	false	False	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	False	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	False	True	True	True	False		Service information
InOut									
Static									
▼ GuardStatus	ESTOP1		False	True	True	True	True		
▼ Input									
E_STOP	Bool	false	False	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	False	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	False	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	False	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	False	True	True	True	False		1=Enable
Q_DELAY	Bool	false	False	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	False	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	False	True	True	True	False		Service information
InOut									
Static									
▼ RemoteEstopStatus	ESTOP1		False	True	True	True	True		
▼ Input									
E_STOP	Bool	false	False	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	False	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	False	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	False	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	False	True	True	True	False		1=Enable
Q_DELAY	Bool	false	False	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	False	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	False	True	True	True	False		Service information
InOut									
Static									
▼ Contactors	FDBACK		False	True	True	True	True		
▼ Input									
ON	Bool	false	False	True	True	True	False		1=Enable output
FEEDBACK	Bool	false	False	True	True	True	False		Feedback input
QBAD_FIO	Bool	false	False	True	True	True	False		QBAD signal of FI/O/channel of output Q
ACK_NEC	Bool	true	False	True	True	True	False		1=Acknowledgment necessary

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
ACK	Bool	false	False	True	True	True	False		Acknowledgment
FDB_TIME	Time	T#0ms	False	True	True	True	False		Feedback time
▼ Output									
Q	Bool	false	False	True	True	True	False		Output
ERROR	Bool	false	False	True	True	True	False		Feedback error
ACK_REQ	Bool	false	False	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	False	True	True	True	False		Service information
InOut									
Static									
ContactorOutput	Bool	false	False	True	True	True	False		
▼ LockingSwitch_SS_Status	ESTOP1		False	True	True	True	False		
▼ Input									
E_STOP	Bool	false	False	True	True	True	False		Emercency STOP
ACK_NEC	Bool	true	False	True	True	True	False		1=Acknowledgment necessary
ACK	Bool	false	False	True	True	True	False		1=Acknowledgment
TIME_DEL	Time	0	False	True	True	True	False		Time delay
▼ Output									
Q	Bool	false	False	True	True	True	False		1=Enable
Q_DELAY	Bool	false	False	True	True	True	False		Enable is OFF delayed
ACK_REQ	Bool	false	False	True	True	True	False		1=acknowledgment request
DIAG	Byte	B#16#00	False	True	True	True	False		Service information
InOut									
Static									

Program blocks

SafetyData [DB2]

SafetyData Properties							
General							
Name	SafetyData	**Number**	2	**Type**	DB	**Language**	DB
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
▼ Static									
SafetyReset	Bool	false	False	True	True	True	False		
LocalEstopOK	Bool	false	False	True	True	True	False		
GuardOK	Bool	false	False	True	True	True	False		
RemoteEstopOK	Bool	false	False	True	True	True	False		
F_IO_OK	Bool	false	False	True	True	True	False		
LockingSwitch_SS_OK	Bool	false	False	True	True	True	False		

Program blocks

SafetyDataExchange [DB3]

SafetyDataExchange Properties							
General							
Name	SafetyDataExchange	**Number**	3	**Type**	DB	**Language**	DB
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
▼ Static									
GlobalACK_REQ	Bool	false	False	True	True	True	False		
GlobalSafetyOK	Bool	false	False	True	True	True	False		
LocalEstopOK	Bool	false	False	True	True	True	False		
RemoteEstopOK	Bool	false	False	True	True	True	False		

Program blocks / System blocks / STEP 7 Safety

F_SystemInfo_DB [DB30001]

F_SystemInfo_DB Properties							
General							
Name	F_SystemInfo_DB	**Number**	30001	**Type**	DB	**Language**	DB
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**	F_GLOBDB				

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
▼ Static									
FCCValue	DWord	16#0	False	True	True	True	False		

Program blocks / System blocks / STEP 7 Safety

RTG1SysInfo [DB30000]

RTG1SysInfo Properties							
General							
Name	RTG1SysInfo	**Number**	30000	**Type**	DB	**Language**	DB
Numbering	Automatic						
Information							
Title		**Author**	SafeSys	**Comment**		**Family**	F_CTRL
Version	2.2	**User-defined ID**	F_CTRL_1				

Name	Data type	Start value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
Input									
▼ Output									
MODE	Bool	false	False	True	True	True	False		1 = deactivated safety mode
▼ F_SYSINFO	F_SYSINFO		False	True	True	True	False		F-Runtime group information
MODE	Bool	false	False	True	True	True	False		1 = deactivated safety mode
TCYC_CURR	DInt	0	False	True	True	True	False		current cycle time of the F-Runtime group in ms
TCYC_LONG	DInt	0	False	True	True	True	False		longest cycle time of the F-Runtime group in ms
TRTG_LONG	DInt	0	False	True	True	True	False		longest runtime of the F-Runtime group in ms
T1RTG_CURR	DInt	0	False	True	True	True	False		current runtime in ms for further use
T1RTG_LONG	DInt	0	False	True	True	True	False		longest runtime in ms for further use
F_PROG_SIG	DWord	DW#16#2B4F015	False	True	True	True	False		Collective F-signature of the safety program
▼ F_PROG_DAT	DTL	DTL#2021-4-1-19:20:26.508300200	False	True	True	True	False		Compilation date of the safety program
YEAR	UInt	2021	False	True	True	True	False		
MONTH	USInt	4	False	True	True	True	False		
DAY	USInt	1	False	True	True	True	False		
WEEKDAY	USInt	5	False	True	True	True	False		
HOUR	USInt	19	False	True	True	True	False		
MINUTE	USInt	20	False	True	True	True	False		
SECOND	USInt	26	False	True	True	True	False		
NANOSECOND	UDInt	508300200	False	True	True	True	False		
F_RTG_SIG	DWord	DW#16#1901059E	False	True	True	True	False		Collective F-signature of the F-Runtime group
▼ F_RTG_DAT	DTL	DTL#2021-4-1-19:20:26.508300200	False	True	True	True	False		Compilation date of the F-Runtime group
YEAR	UInt	2021	False	True	True	True	False		
MONTH	USInt	4	False	True	True	True	False		
DAY	USInt	1	False	True	True	True	False		
WEEKDAY	USInt	5	False	True	True	True	False		
HOUR	USInt	19	False	True	True	True	False		
MINUTE	USInt	20	False	True	True	True	False		
SECOND	USInt	26	False	True	True	True	False		
NANOSECOND	UDInt	508300200	False	True	True	True	False		
VERS_S7SAF	DWord	DW#16#16000000	False	True	True	True	False		Version label of STEP 7 Safety
InOut									
Static									

Program blocks / System blocks / STEP 7 Safety

F_ACK_GL [FB219]

F_ACK_GL Properties							
General							
Name	F_ACK_GL	Number	219	Type	FB	Language	FBD
Numbering	Automatic						
Information							
Title	F_: Global acknowledgement of all F-I/Os in an F-Runtime group	Author	Safety	Comment		Family	F_FUNC
Version	1.0	User-defined ID	F_ACK_GL				

Name	Data type	Default value	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Setpoint	Supervision	Comment
▼ Input									
ACK_GLOB	Bool	false	Non-retain	True	True	True	False		1=acknowledgment for reintegration
Output									
InOut									
Static									

To better understand the above configuration and program, turn to the following Siemens Manual:

SIEMENS

SIMATIC

S7
S7-1200 Functional Safety Manual

Equipment Manual

V4.6, 11/2022
A5E03470344-AC

This manual steps through a number of videos showing the complete configuration of a system similar to the one outlined in the lab and above.

In this manual are found a number of informational websites. The first gives information for overall maintenance of the safety system in a plant:

"

Note

Important note for maintaining operational safety of your plant

Plants with safety-related features are subject to special operational safety requirements on the part of the operator. Even suppliers are required to observe special measures during product monitoring. For this reason, we inform you in the form of personal notifications about product developments and features that are (or could be) relevant to operation of systems from a safety perspective.

By subscribing to the appropriate notifications, you will ensure that you are always up-to-date and able to make changes to your system, when necessary.

Log onto Industry Online Support. Go to the following links and, on the side, right click on "email on update":

- SIMATIC S7-300/S7-300F (https://support.industry.siemens.com/cs/ww/en/ps/13751)
- SIMATIC S7-400/S7-400H/S7-400F/FH (https://support.industry.siemens.com/cs/ww/en/ps/13828)
- SIMATIC WinAC RTX (F) (https://support.industry.siemens.com/cs/products?mfn=ps&pnid=13917&lc=en-WW)
- SIMATIC S7-1500/SIMATIC S7-1500F (https://support.industry.siemens.com/cs/ww/en/ps/13716)
- SIMATIC S7-1200/SIMATIC S7-1200F (https://support.industry.siemens.com/cs/ww/en/ps/13716)
- Distributed I/O (https://support.industry.siemens.com/cs/ww/en/ps/14029)
- STEP 7 (TIA Portal) (https://support.industry.siemens.com/cs/ww/en/ps/14667)

"

The next shares information concerning various manuals involved in PLC programming of the Safety System:

"

Documentation and information

S7-1200 and STEP 7 provide a variety of documentation and other resources for finding the technical information that you require.

- The *S7-1200 Functional Safety Manual* presents an overview of the Siemens Safety software and fail-safe CPUs and signal modules (SMs) and a Getting Started configuration and programming example. However, the focus of the manual is the S7-1200 fail-safe SMs. SM installation, configuration, diagnostics, applications, and technical specifications are emphasized.

  The English version of the *S7-1200 Functional Safety Manual* is the authoritative (original) language for Functional Safety-related information. All translated manuals refer back to the English manual as the authoritative and/or original source. Siemens identifies the English manual as the authoritative and/or original source in the case of discrepancies between the translated manuals.
- The *SIMATIC Safety - Configuring and Programming, Programming and Operating Manual* provides information that enables you to configure and program SIMATIC Safety fail-safe systems. In addition, you will obtain information on acceptance testing of a SIMATIC Safety fail-safe system. Before configuring and programming an actual live fail-safe operation, it is essential that you refer to this manual.

- The *S7-1200 Programmable Controller System Manual* provides specific information about the operation, programming, and the specifications for the complete S7-1200 product family. In addition to the system manual, the *S7-1200 Easy Book* provides a more general overview to the capabilities of the S7-1200 family.
- The *S7-1200 Functional Safety Manual; SIMATIC Safety - Configuring and Programming, Programming and Operating Manual; S7-1200 Programmable Controller System Manual*; and the *S7-1200 Easy Book* are available as electronic (PDF) manuals. You can download or view the electronic manuals from the Siemens Industry Online Support Web site (http://support.industry.siemens.com). These manuals are also available on the Documents Disk that ships with every S7-1200 CPU.
- The STEP 7 (TIA portal) online help information system provides immediate access to the conceptual information, specific instructions, and error code event IDs that describe the operation and functionality of the programming package and basic operation of SIMATIC CPUs.
- The Siemens Industry Online Support Web site (http://support.industry.siemens.com) provides access to the electronic (PDF) versions of the SIMATIC documentation set. Existing documents are available from the Product Support link. With this online documentation access, you can also drag and drop topics from various documents to create your own custom manual.

  You can access online documentation by clicking "mySupport" from the left side of the page and selecting "Documentation" from the navigation choices. To use the mySupport Documentation features, you must sign up as a registered user.
- Siemens also provides online comprehensive support for your use of safety technology. A Safety Evaluation Tool assists you in determining required safety levels, Functional Examples guide you in your safety applications, and Siemens training (SITRAIN) classes offer training in safety standards and products. Visit the following web sites to access these support activities:
  - Safety Evaluation Tool (http://www.siemens.com/safety-evaluation-tool)
  - Functional examples (http://www.siemens.com/safety-functional-examples)
  - SITRAIN (http://www.siemens.com/sitrain-safetyintegrated) "

Also shared in the beginning pages of this manual are the instructional videos prepared for stepping through the configuration process along with full explanations in the manual itself:

"

2.1.1 Instructional videos

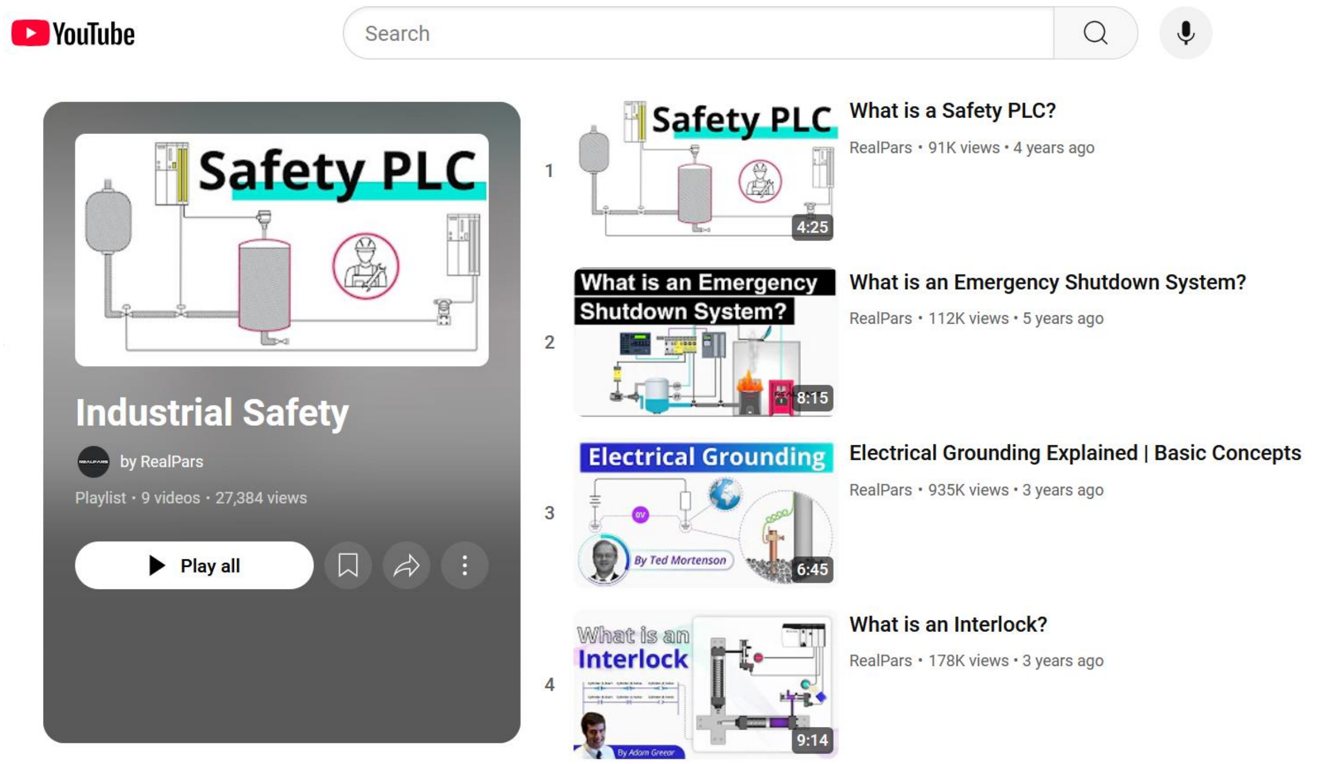
The "Getting Started" chapter contains eleven instructional videos. Nine instructional videos take you step-by-step through many of the configuring and programming tasks. These instructional videos show the completed task at the beginning of the video, with a fadeout to a step-by-step tutorial that demonstrates all of the required sub-tasks:

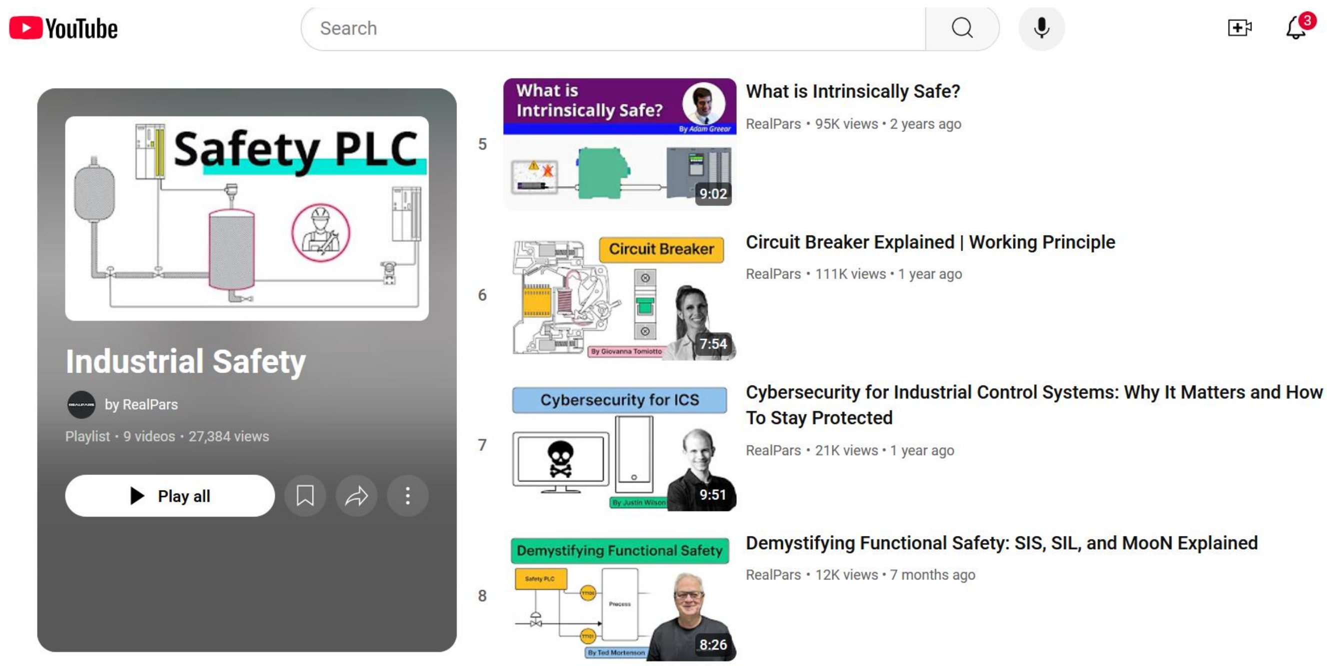
- "Procedure" (Page 29) (shows a wiring overview of the S7-1200 Fail-Safe application example)
- "Step 1: Configuring the S7-1200 CPU 1212FC, CPU 1214FC, or CPU 1215FC" (Page 32) (step-by-step tutorial)
- "Step 6: Creating an F-FB" (Page 51) (step-by-step tutorial)
- "Step 7: Programming the safety door function" (Page 52) (step-by-step tutorial)
- "Step 8: Programming the emergency stop function" (Page 54) (step-by-step tutorial)
- "Step 9: Programming the feedback monitoring" (Page 56) (step-by-step tutorial)
- "Step 10: Programming the user acknowledgment for reintegration of the fail-safe SM" (Page 58) (step-by-step tutorial)
- "Step 11: Programming of the main safety block" (Page 59) (step-by-step tutorial)
- "Step 12: Compiling the safety program" (Page 60) (step-by-step tutorial)
- "Step 13: Downloading the complete safety program to the fail-safe CPU and activating safety mode" (Page 61) (step-by-step tutorial)
- "Step 13: Downloading the complete safety program to the fail-safe CPU and activating safety mode" (Page 61) (second video; shows the end result of the LAD programming steps)

"

This documentation gives a very good start to mastering the safety systems from Siemens. The goal is to understand a system well enough to start one up. That first system can be the one in the lab.

The RealPars Video Series on Safety PLCs is interesting and its playlist is given below:





Summary

The chapter is a first try to define the type of safety needed in the factory. There is no need to provide the same equipment as is provided for a rocket to the moon – especially one carrying human cargo. However, equipment is to be safe and the need for safe PLCs has grown through the years.

The German BGIA approach is introduced. If one were to design a system especially for the European market, these documents would be essential. Moving the machine from Europe to the US will show many of the techniques employed to meet the standards of the EU.

There is included a major lab demonstrating the implementation of the safe PLC by Siemens. The S7-1200 is used. GO FOR IT!

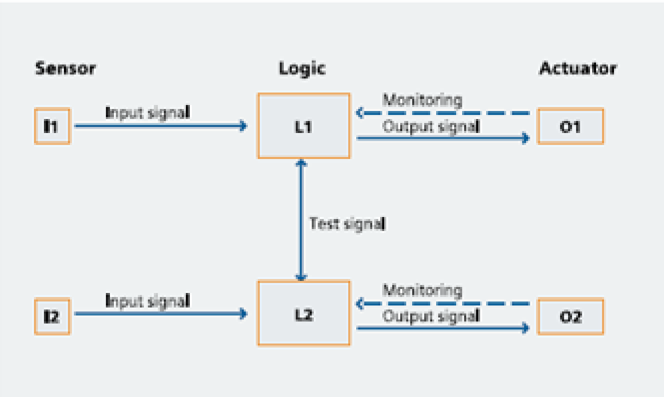
Questions

1. The following is a two-hand control station by Schneider Electric. Describe how this function has been moved into the PLC. Be specific.

Schneider Electric XPSBF1132P

SAFETY RELAY FOR TWO HAND CONTROL STATIONS, OUTPUT: 2; AUX: 2 SOLID STATE; 24VDC

2. The following describes how an input, logic and output interacts in a safety circuit for Siemens. Describe how logic can be guaranteed to be safe in this configuration. In your answer describe both logic written by the user and logic approved and provided by the manufacturer.



3. There was a chart comparing Categories (Cat) with SIL values. Show the comparisons between the two and show where fail-safe is required.

   At what level is the power-supply incorporated into the safety hardware?

4. If you were to walk up to a Siemens PLC or an Allen-Bradley PLC, what would give you an indication where the safety I/O is housed? Give an example of each:

5. What is Stuxnet?

   From Wikipedia, the following:

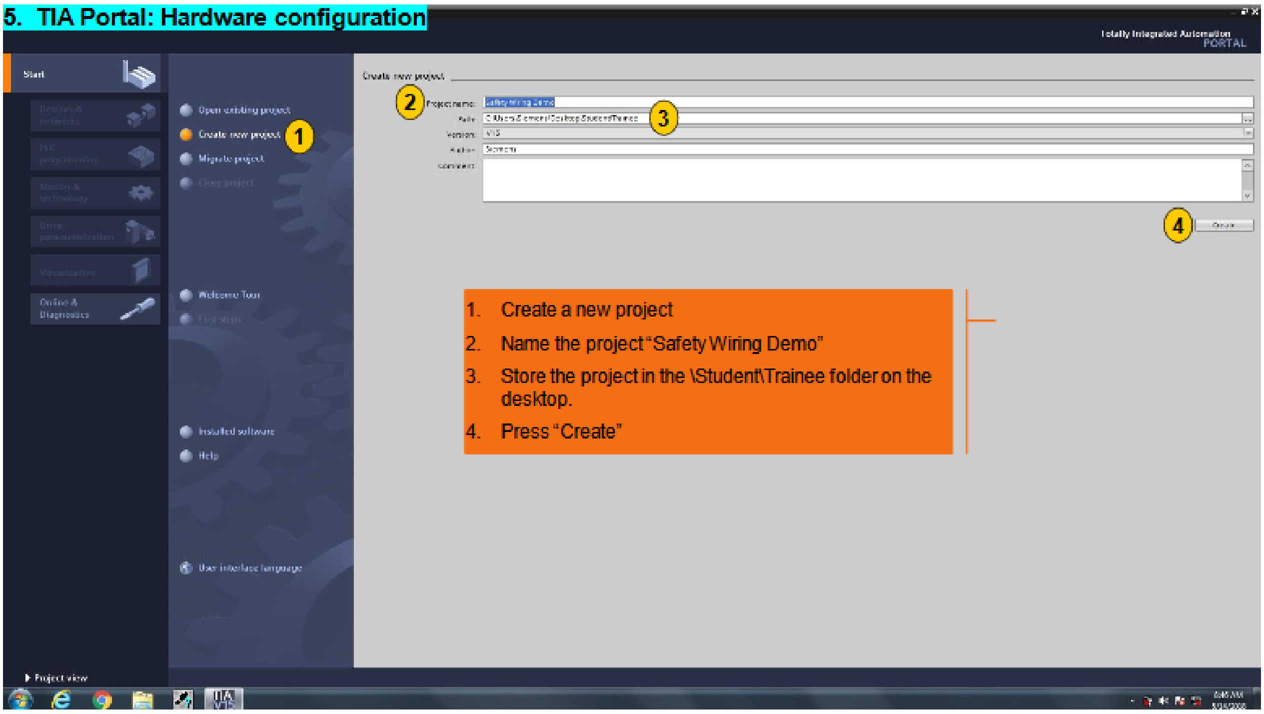
   "**Stuxnet** is a malicious computer worm, first uncovered in 2010 by Kaspersky Lab. Thought to have been in development since at least 2005, Stuxnet targets SCADA systems and was responsible for causing substantial damage to Iran's nuclear program. Although neither country has openly admitted responsibility, the worm is believed to be a jointly built American/Israeli cyberweapon.[1][2]

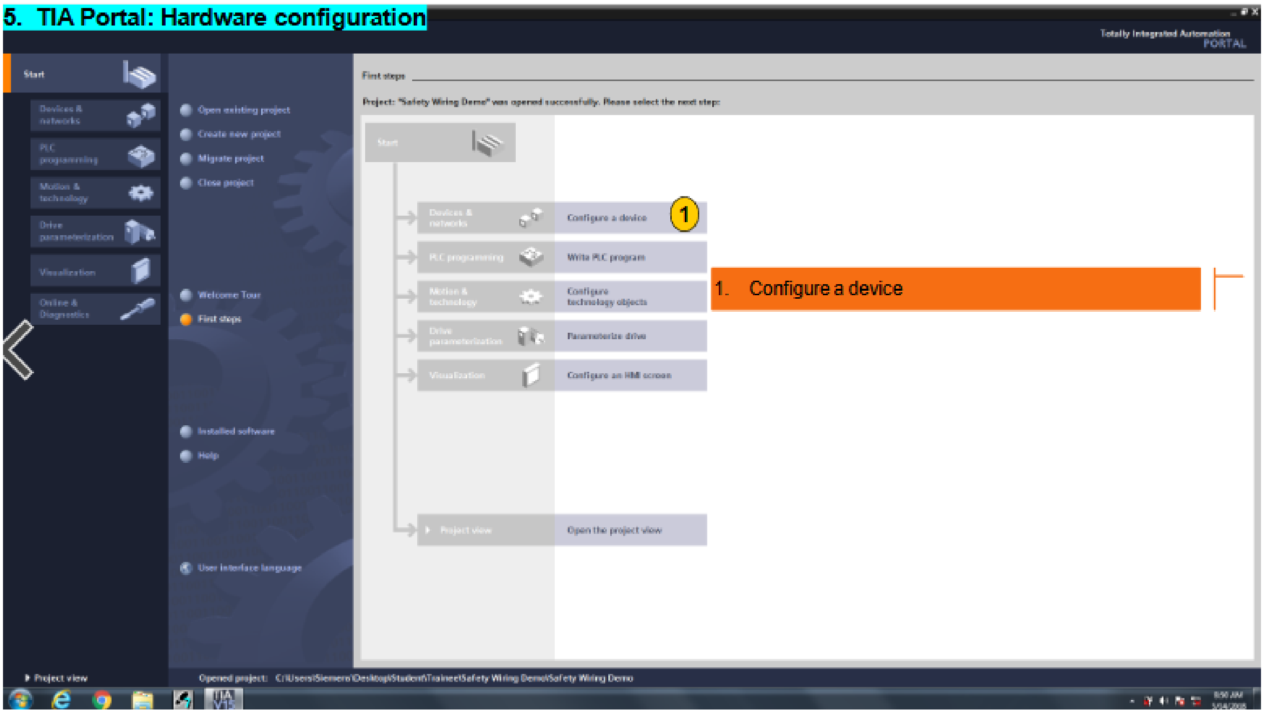
   Stuxnet specifically targets programmable logic controllers (PLCs), which allow the automation of electromechanical processes such as those used to control machinery on factory assembly lines, amusement rides, or centrifuges for separating nuclear material. Exploiting four zero-day flaws,[3] Stuxnet functions by targeting machines using the Microsoft Windows operating system and networks, then seeking out Siemens Step7 software. Stuxnet reportedly compromised Iranian PLCs, collecting information on industrial systems and causing the fast-spinning centrifuges to tear themselves apart.[4] Stuxnet's design and architecture are not domain-specific and it could be tailored as a platform for attacking modern supervisory control and data acquisition (SCADA) and PLC systems (e.g., in factory assembly lines or power plants), the majority of which reside in Europe, Japan and the US.[5]Stuxnet reportedly ruined almost one fifth of Iran's nuclear centrifuges.[6] Targeting industrial control systems, the worm infected over 200,000 computers and caused 1,000 machines to physically degrade.[7]"

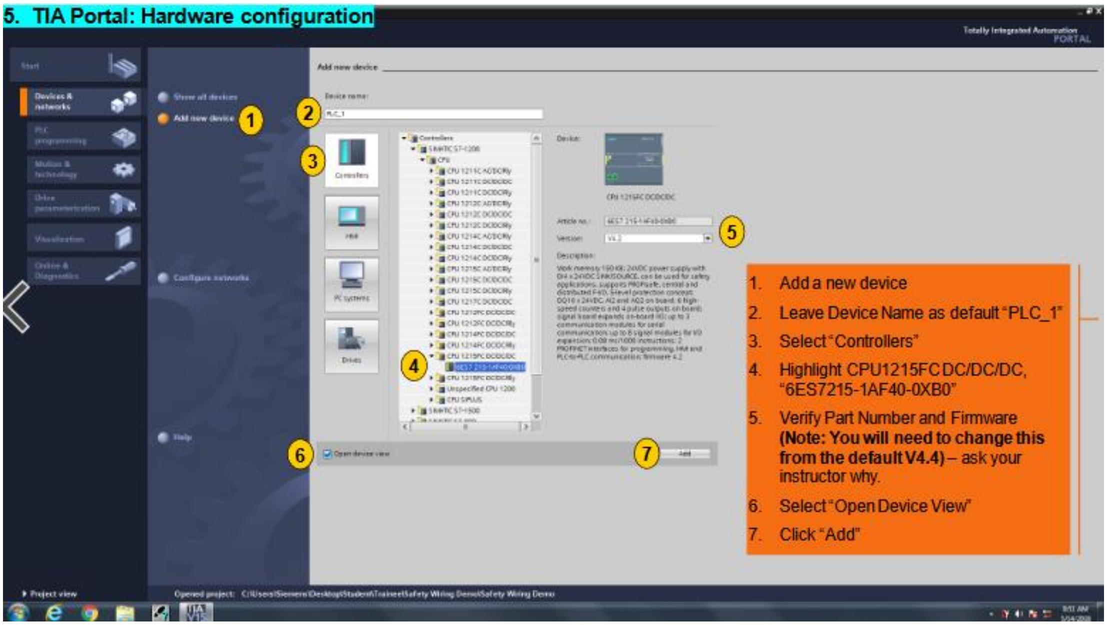
Appendix A

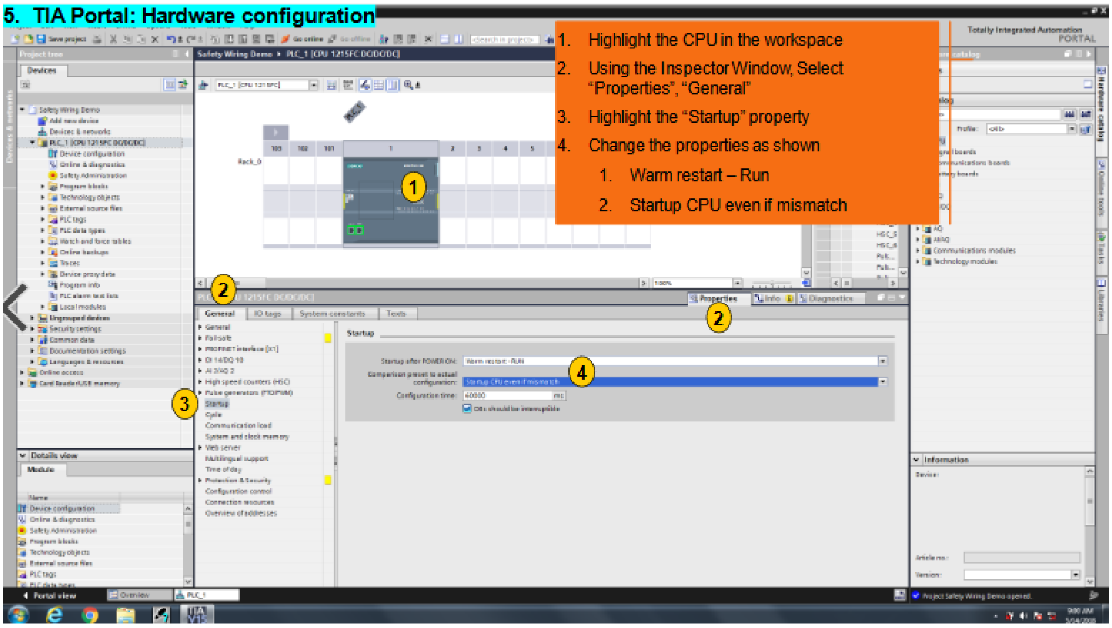
Safety Lab taken from Vendor Presentation – Slides Only

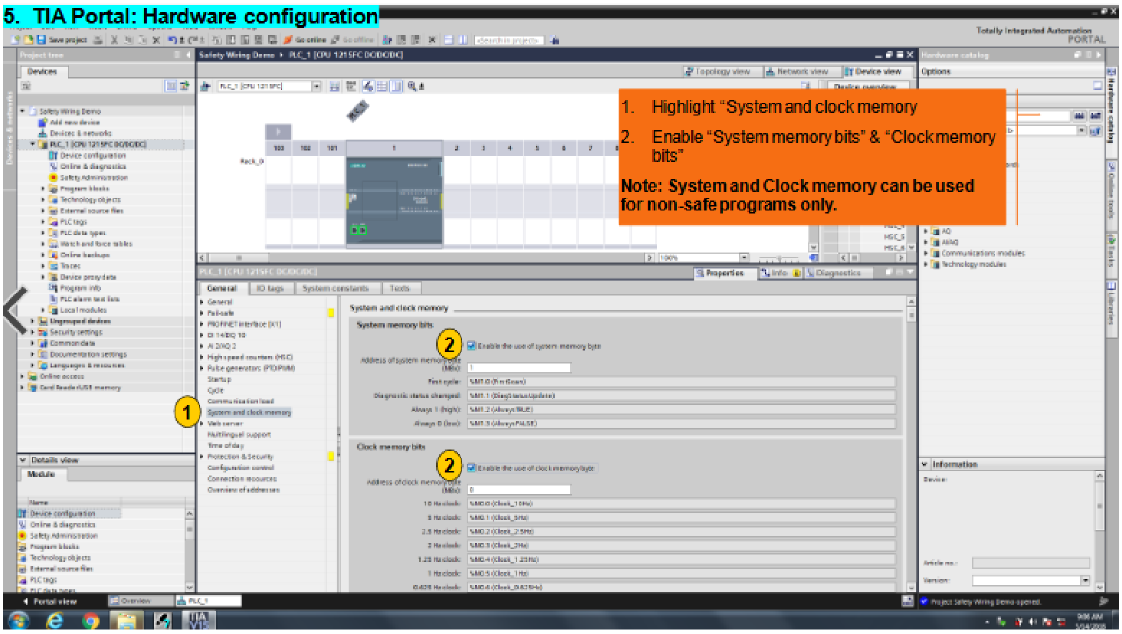
How to Integrate a Safety PLC – S7-1215F (must change to 1214F for UToledo Lab Exercise)






5. TIA Portal: Hardware configuration
1. Add a new device
2. Leave Device Name as default "PLC_1"
3. Select "Controllers"
4. Highlight CPU1215FC DC/DC/DC, "6ES7215-1AF40-0XB0"
5. Verify Part Number and Firmware (Note: You will need to change this from the default V4.4) – ask your instructor why.
6. Select "Open Device View"
7. Click "Add"


5. TIA Portal: Hardware configuration
1. Highlight the CPU in the workspace
2. Using the Inspector Window, Select "Properties", "General"
3. Highlight the "Startup" property
4. Change the properties as shown
1. Warm restart – Run
2. Startup CPU even if mismatch


5. TIA Portal: Hardware configuration
1. Highlight "System and clock memory
2. Enable "System memory bits" & "Clock memory bits"
Note: System and Clock memory can be used for non-safe programs only.

5. TIA Portal: Hardware configuration – Technical Info

- From S7-1500 System Manual, 12/2017(A5E03461182-AE), Chapter 8.2:

Note

Communication

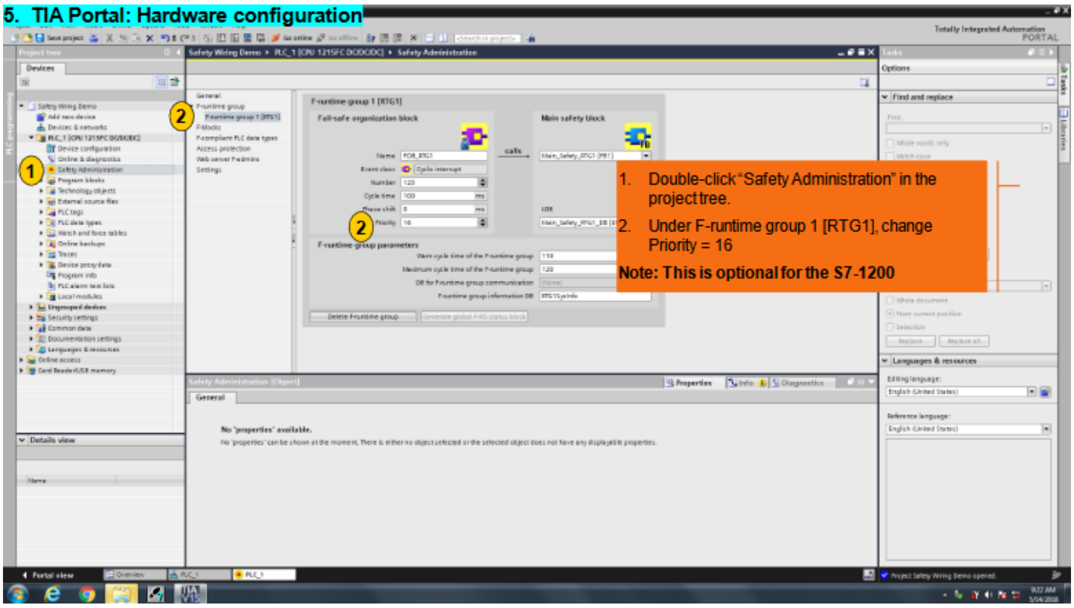
The communication (e.g. test functions with the PG) always works with priority 15. To prevent extending the program runtime unnecessarily in time-critical applications, these OBs should not be interrupted by communication. Assign a priority > 15 for these OBs.

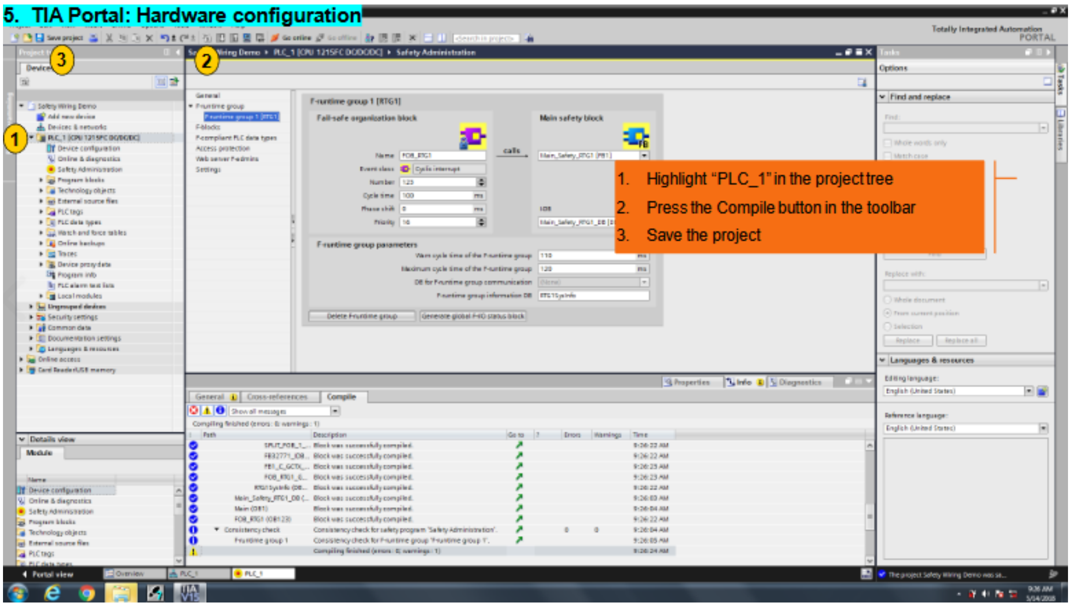
- Per Siemens Hotline, for S7-1200F, communication has the same priority class as OB1.
- From SIMATIC Safety - Configuring and Programming Manual, 03/2017 (A5E02714440-AF), Chapter 5.2.1:
- (S7-1200, S7-1500). The F-OB should be created with the highest priority of all OBs.

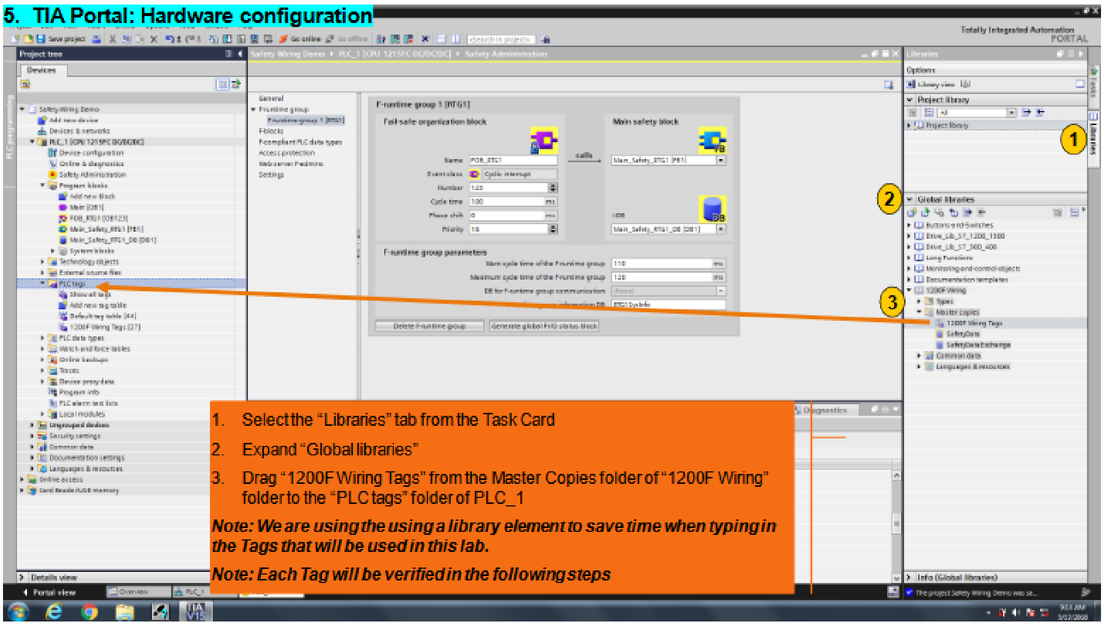
Conclusion:

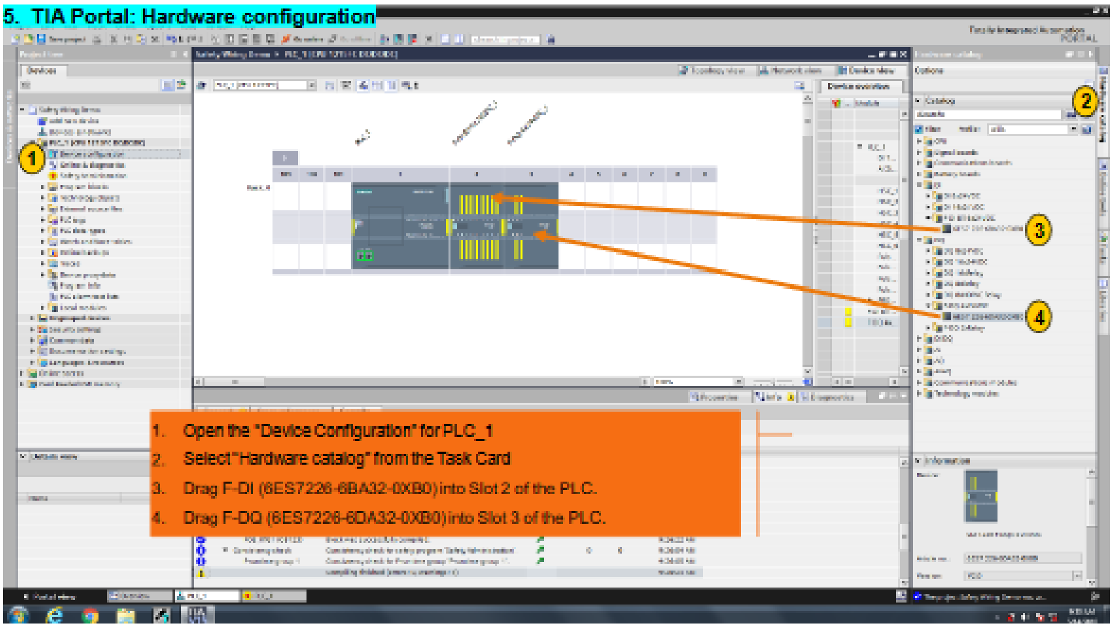
For S7-1200F, F-OB priority should be set to >=9.

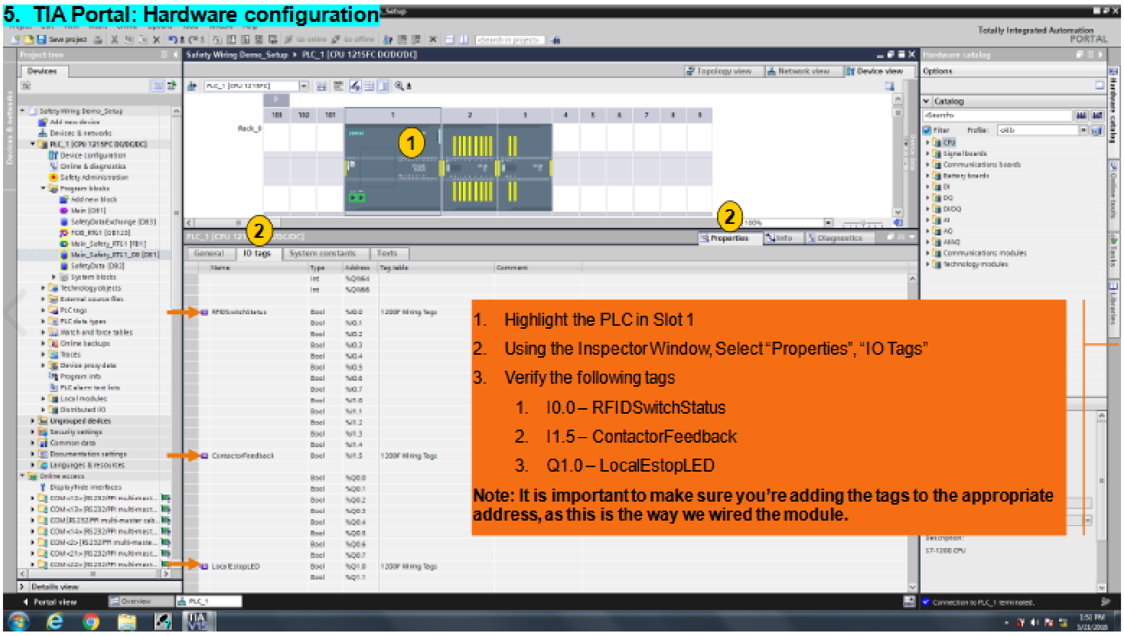
For S7-1500F, F-OB priority should be set to >=16.



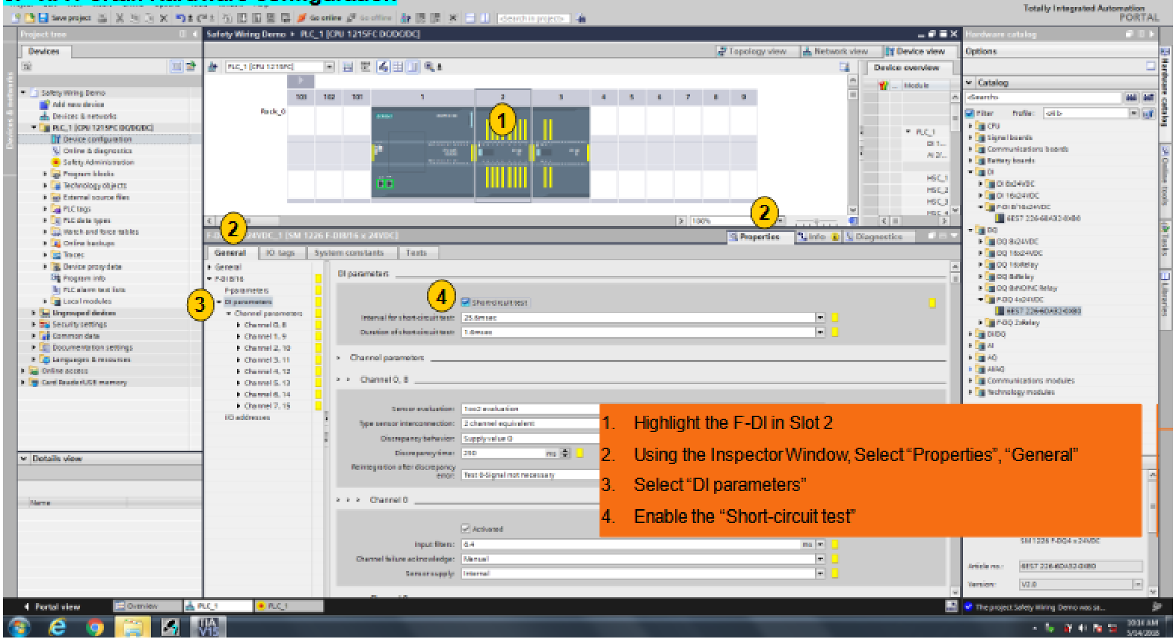



5. TIA Portal: Hardware configuration
1. Select the "Libraries" tab from the Task Card
2. Expand "Global libraries"
3. Drag "1200F Wiring Tags" from the Master Copies folder of "1200F Wiring" folder to the "PLC tags" folder of PLC_1
Note: We are using the using a library element to save time when typing in the Tags that will be used in this lab.
Note: Each Tag will be verified in the following steps

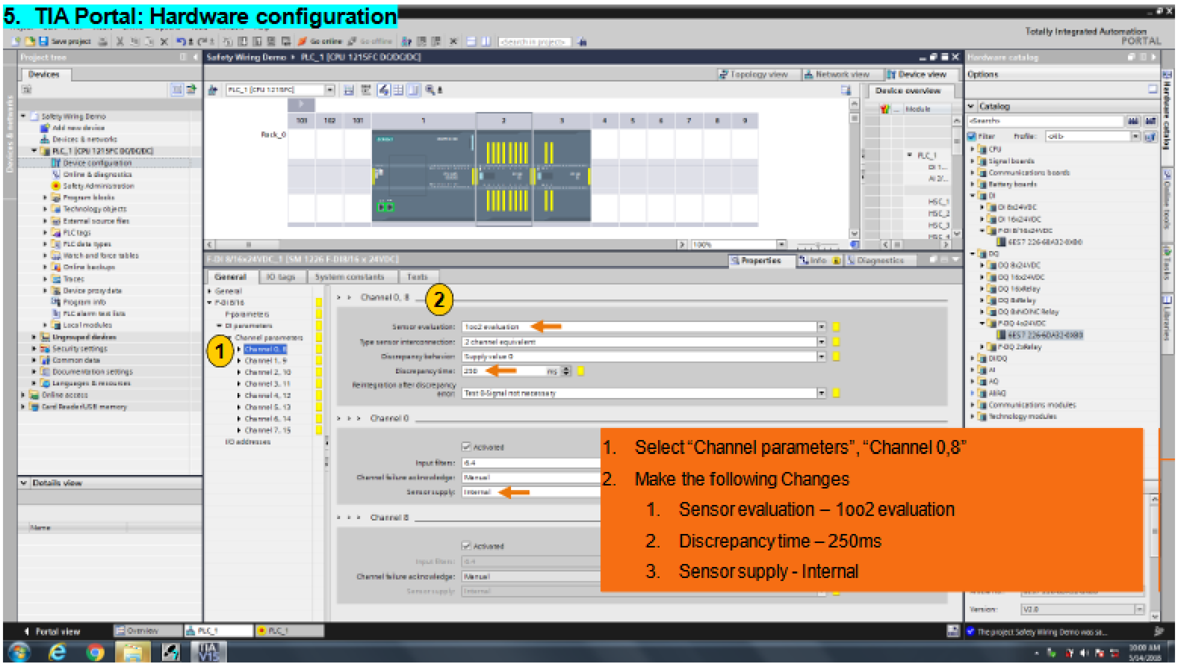

5. TIA Portal: Hardware configuration
1. Open the "Device Configuration" for PLC_1
2. Select "Hardware catalog" from the Task Card
3. Drag F-DI (6ES7226-6BA32-0XB0) into Slot 2 of the PLC.
4. Drag F-DQ (6ES7226-6DA32-0XB0) into Slot 3 of the PLC.


5. TIA Portal: Hardware configuration
1. Highlight the PLC in Slot 1
2. Using the Inspector Window, Select "Properties", "IO Tags"
3. Verify the following tags
1. I0.0 – RFIDSwitchStatus
2. I1.5 – ContactorFeedback
3. Q1.0 – LocalEstopLED
Note: It is important to make sure you're adding the tags to the appropriate address, as this is the way we wired the module.

5. TIA Portal: Hardware configuration



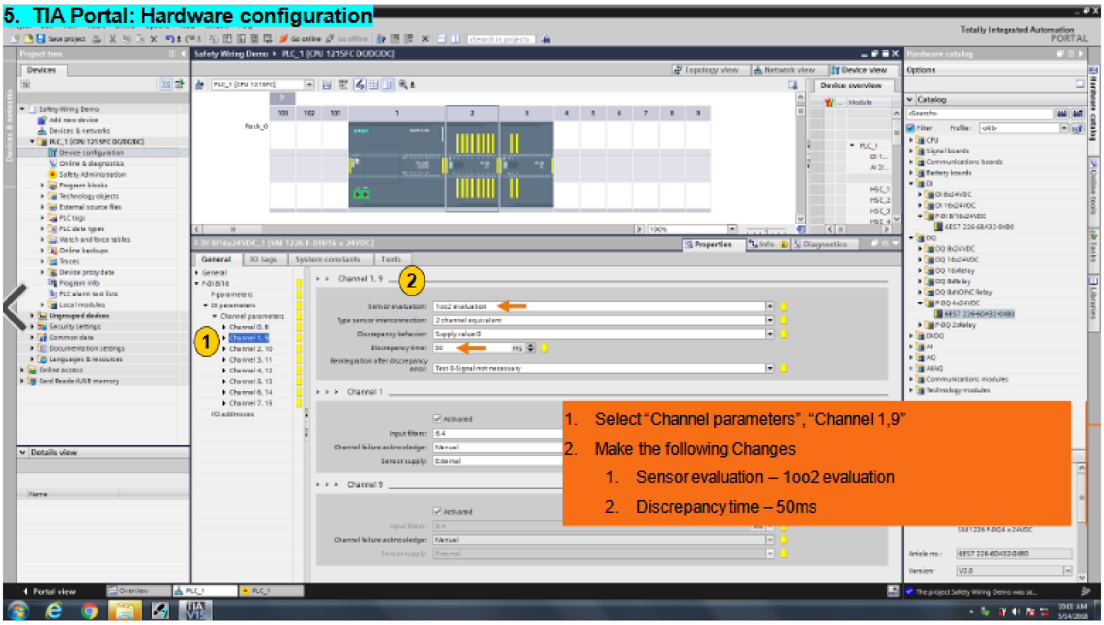
5. TIA Portal: Hardware configuration

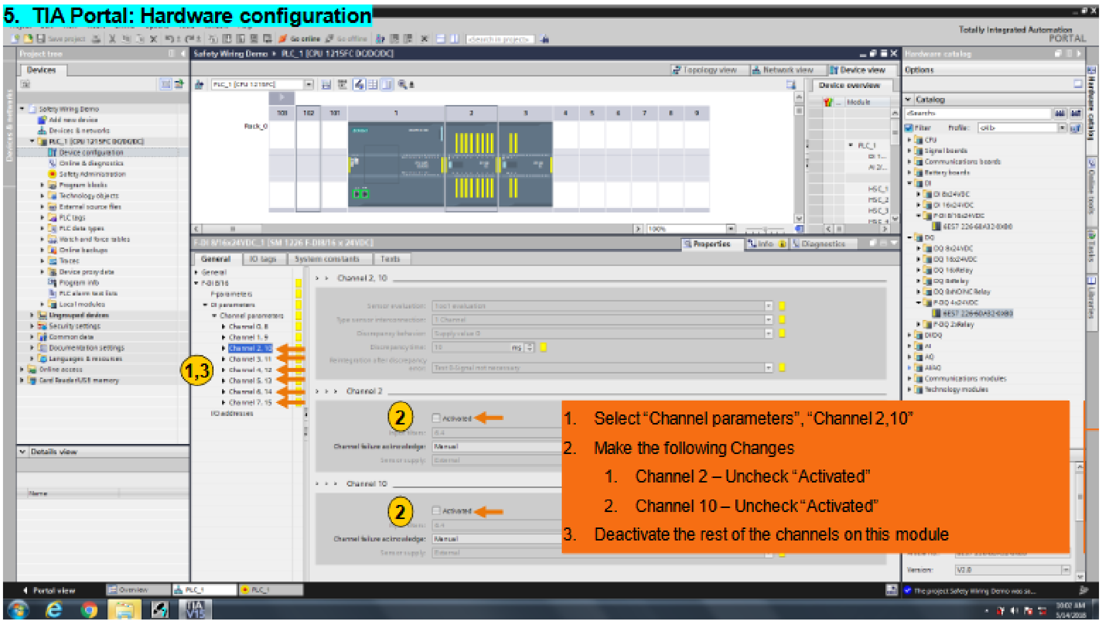


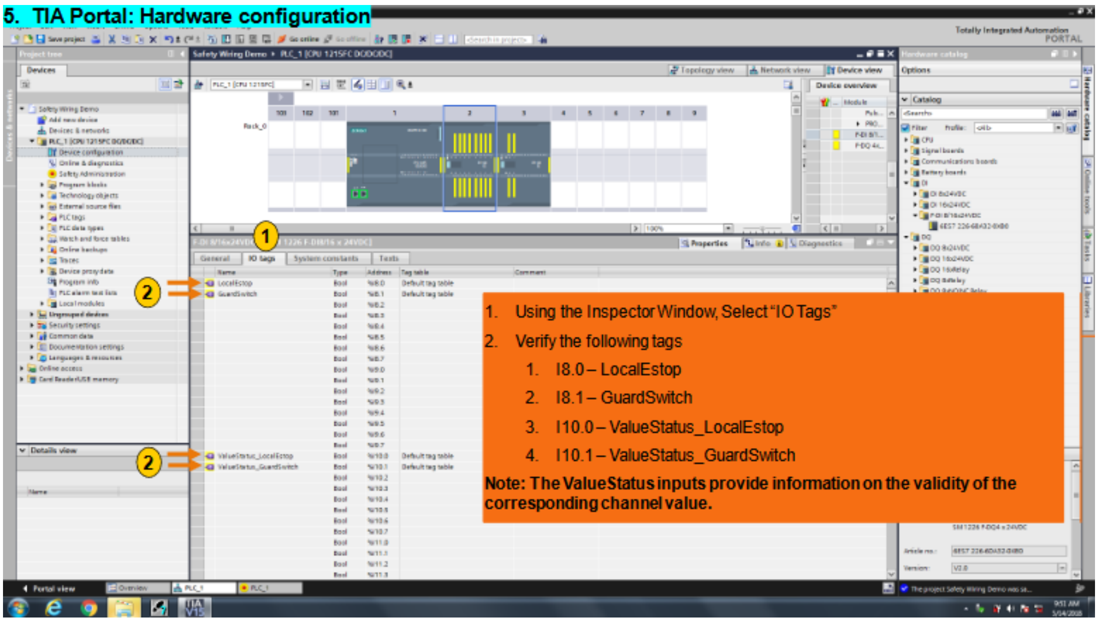
Sensor evaluation

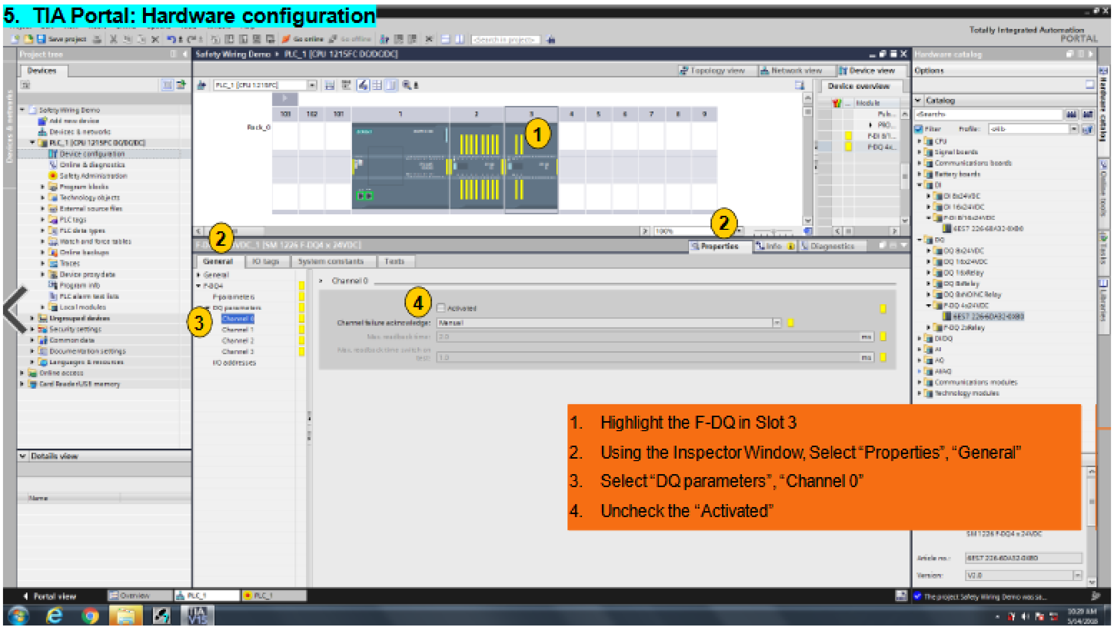
There are two types of sensor evaluation:

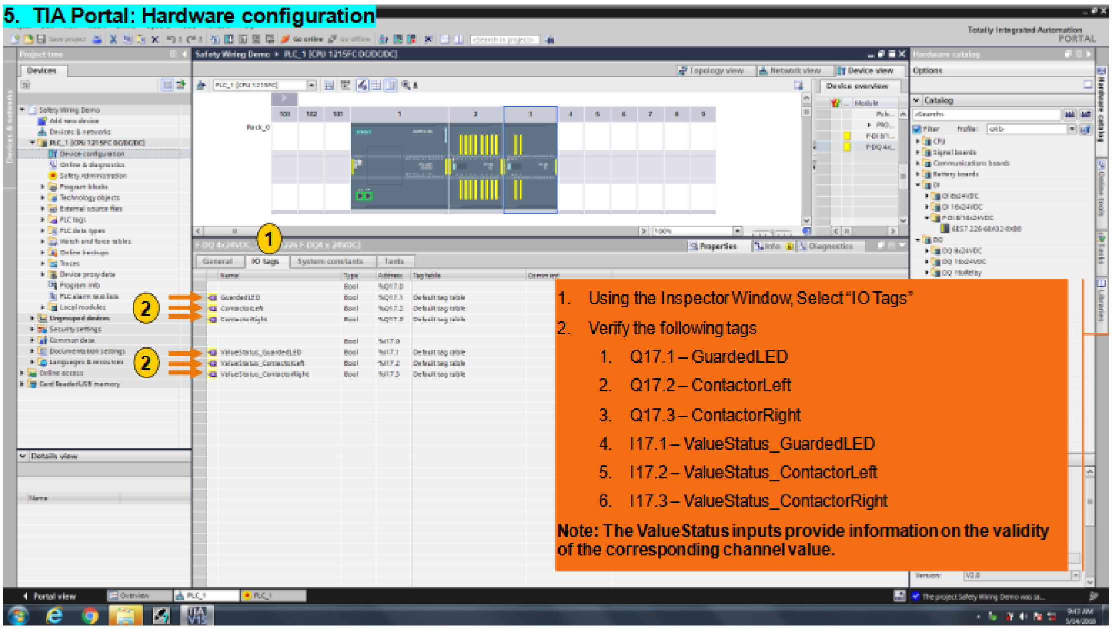
- 1oo1 evaluation – sensor signal is read once
- 1oo2 evaluation - sensor signal is read twice by the same → F-I/O and compared internally

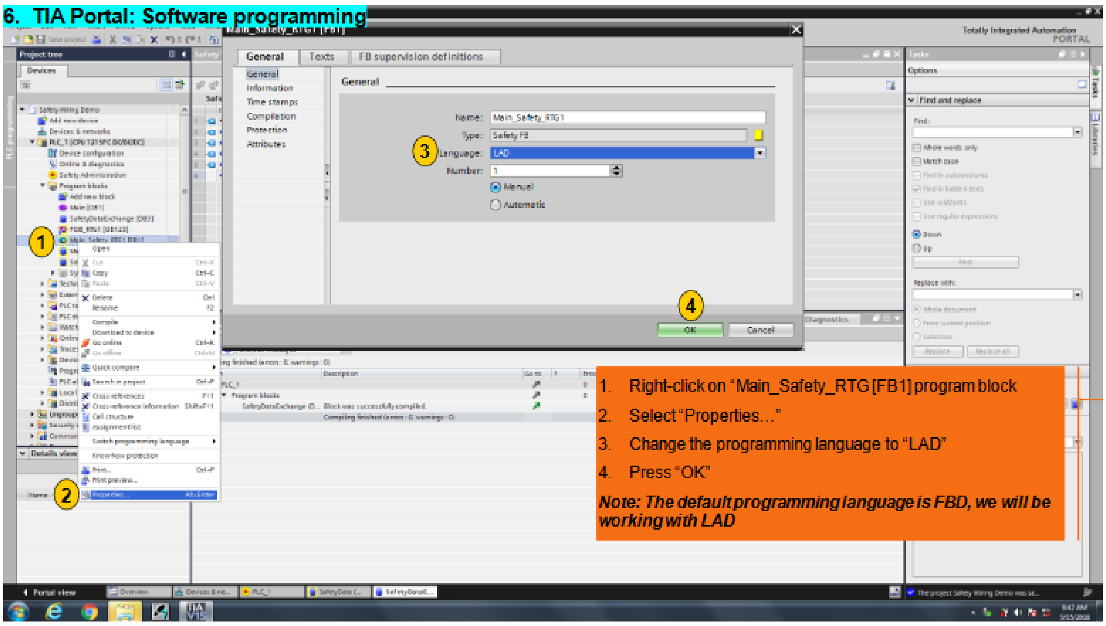

5. TIA Portal: Hardware configuration
1. Select "Channel parameters", "Channel 1,9"
2. Make the following Changes
1. Sensor evaluation – 1oo2 evaluation
2. Discrepancy time – 50ms

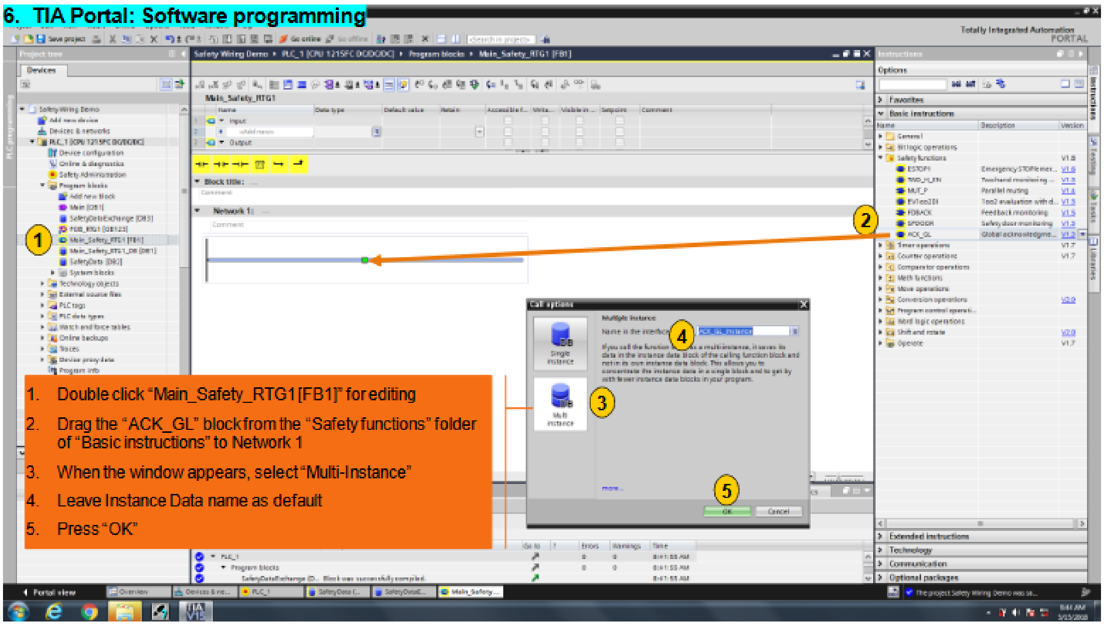

5. TIA Portal: Hardware configuration
1. Select "Channel parameters", "Channel 2,10"
2. Make the following Changes
1. Channel 2 – Uncheck "Activated"
2. Channel 10 – Uncheck "Activated"
3. Deactivate the rest of the channels on this module

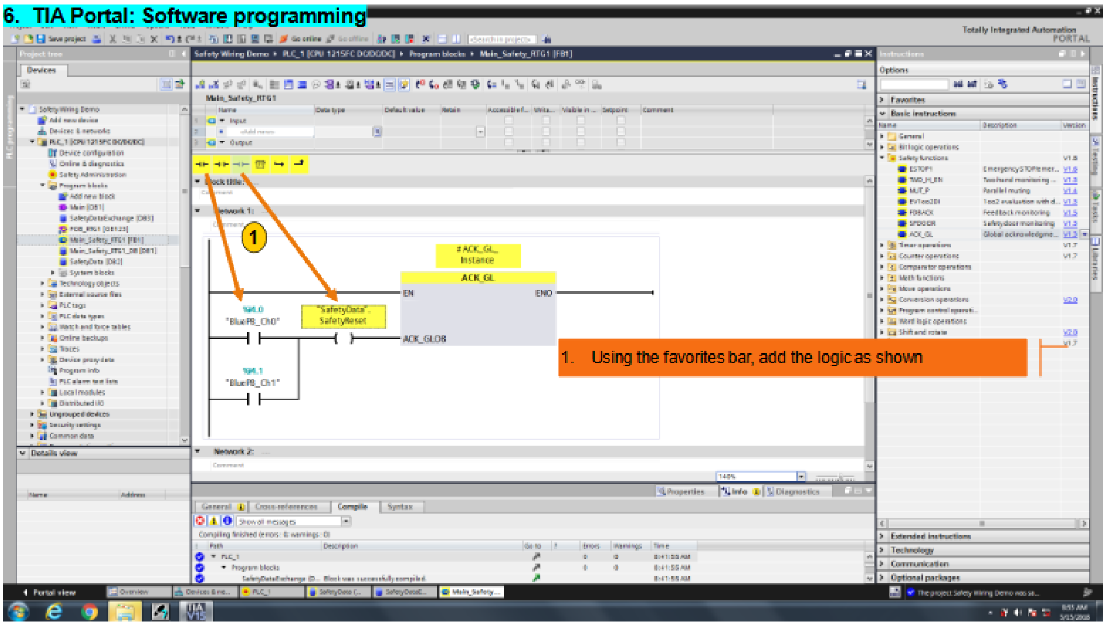

5. TIA Portal: Hardware configuration
1. Using the Inspector Window, Select "IO Tags"
2. Verify the following tags
1. I8.0 – LocalEstop
2. I8.1 – GuardSwitch
3. I10.0 – ValueStatus_LocalEstop
4. I10.1 – ValueStatus_GuardSwitch
Note: The ValueStatus inputs provide information on the validity of the corresponding channel value.

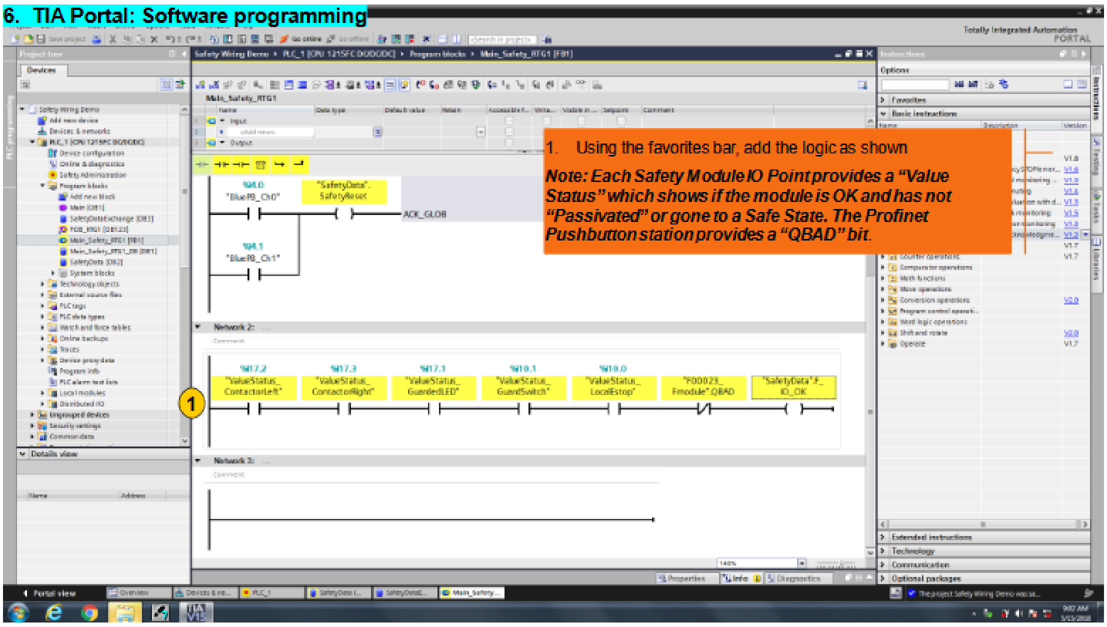

5. TIA Portal: Hardware configuration
1. Highlight the F-DQ in Slot 3
2. Using the Inspector Window, Select "Properties", "General"
3. Select "DQ parameters", "Channel 0"
4. Uncheck the "Activated"

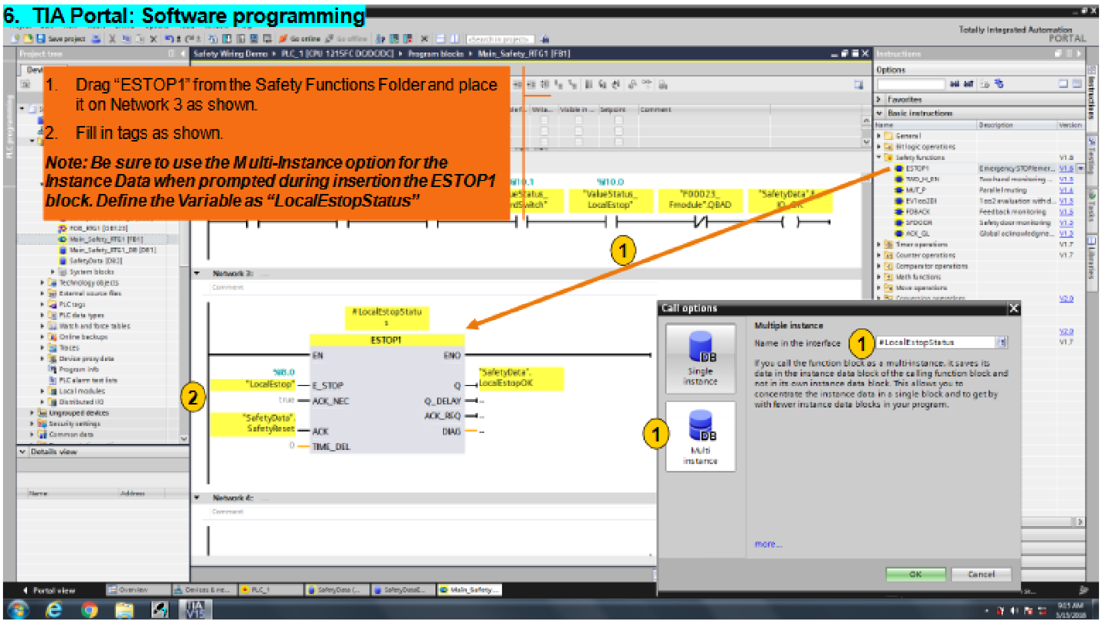

5. TIA Portal: Hardware configuration
1. Using the Inspector Window, Select "IO Tags"
2. Verify the following tags
1. Q17.1 – GuardedLED
2. Q17.2 – ContactorLeft
3. Q17.3 – ContactorRight
4. I17.1 – ValueStatus_GuardedLED
5. I17.2 – ValueStatus_ContactorLeft
6. I17.3 – ValueStatus_ContactorRight
Note: The ValueStatus inputs provide information on the validity of the corresponding channel value.

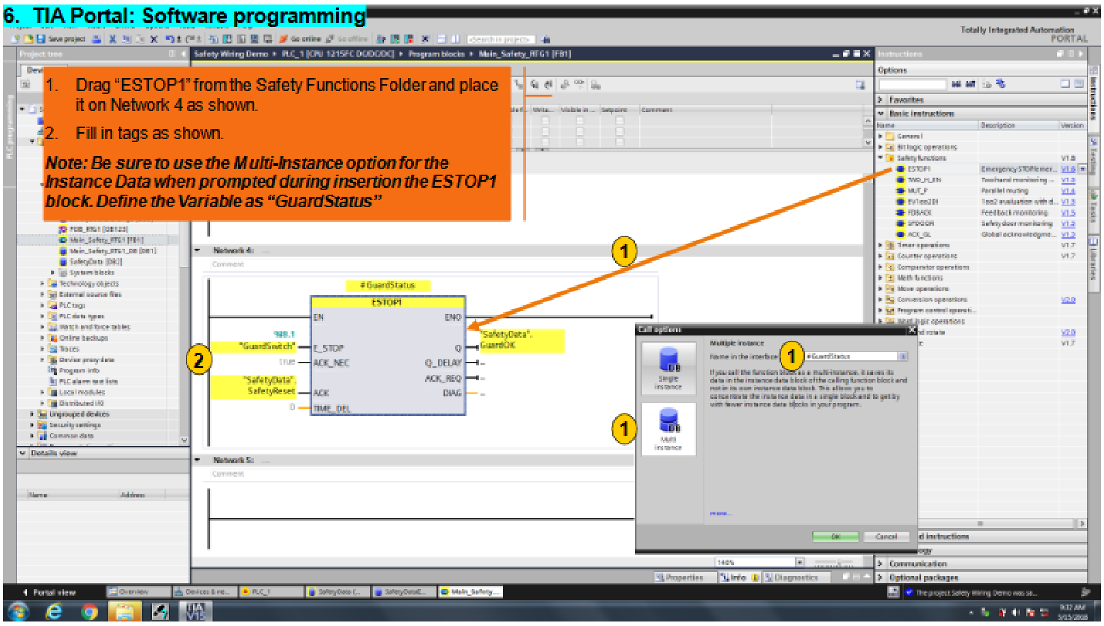

6. TIA Portal: Software programming
1. Right-click on "Main_Safety_RTG [FB1] program block
2. Select "Properties…"
3. Change the programming language to "LAD"
4. Press "OK"
Note: The default programming language is FBD, we will be working with LAD

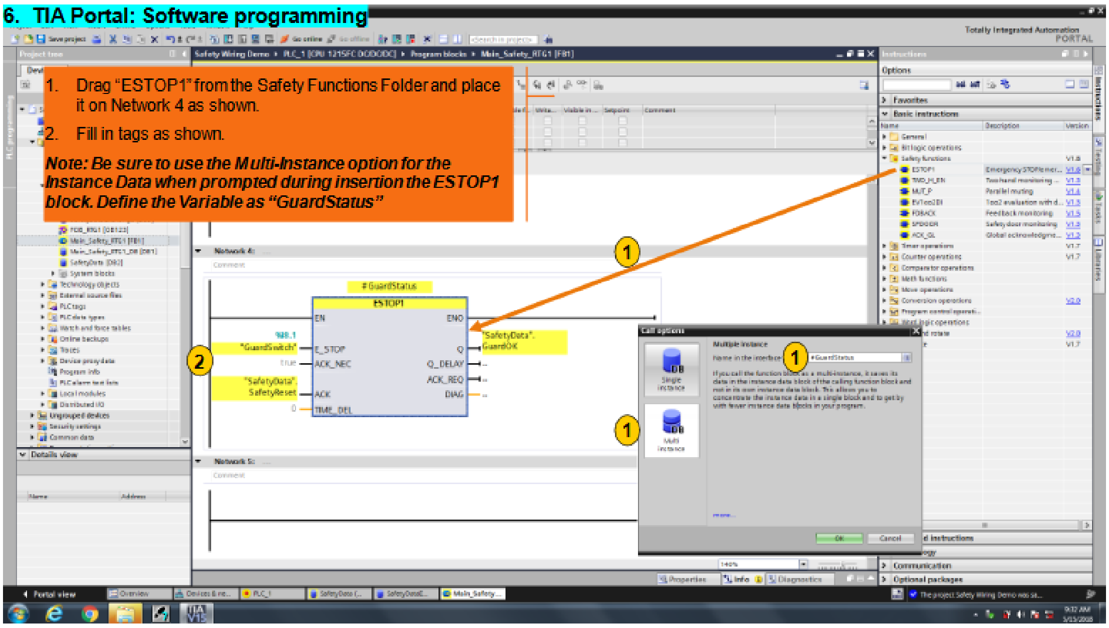

6. TIA Portal: Software programming
1. Double click "Main_Safety_RTG1 [FB1]" for editing
2. Drag the "ACK_GL" block from the "Safety functions" folder of "Basic instructions" to Network 1
3. When the window appears, select "Multi-Instance"
4. Leave Instance Data name as default
5. Press "OK"

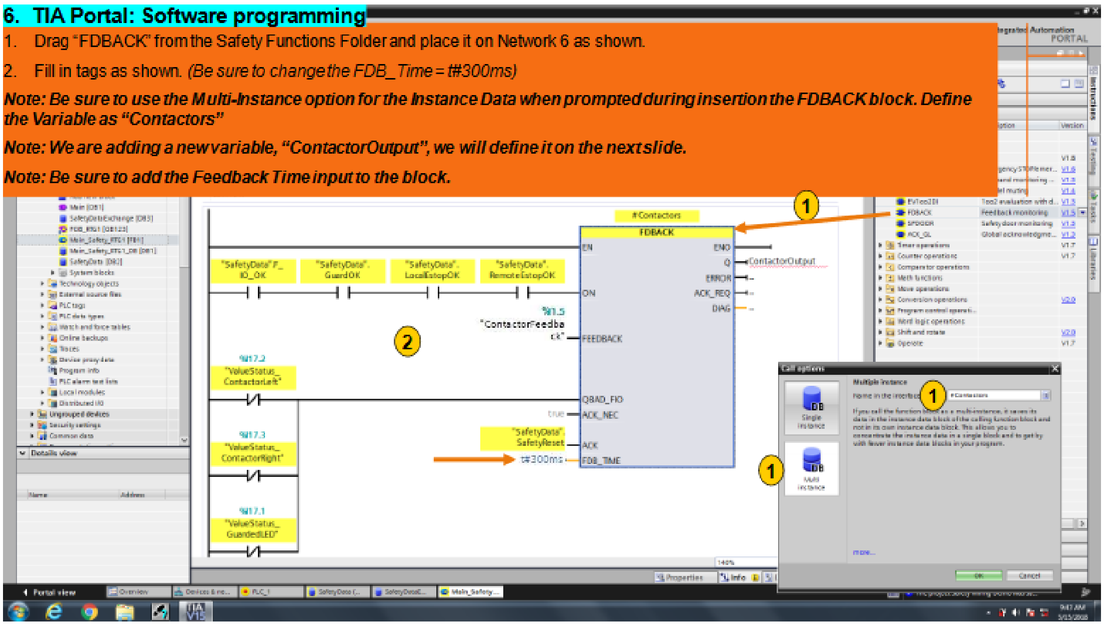

6. TIA Portal: Software programming
1. Using the favorites bar, add the logic as shown

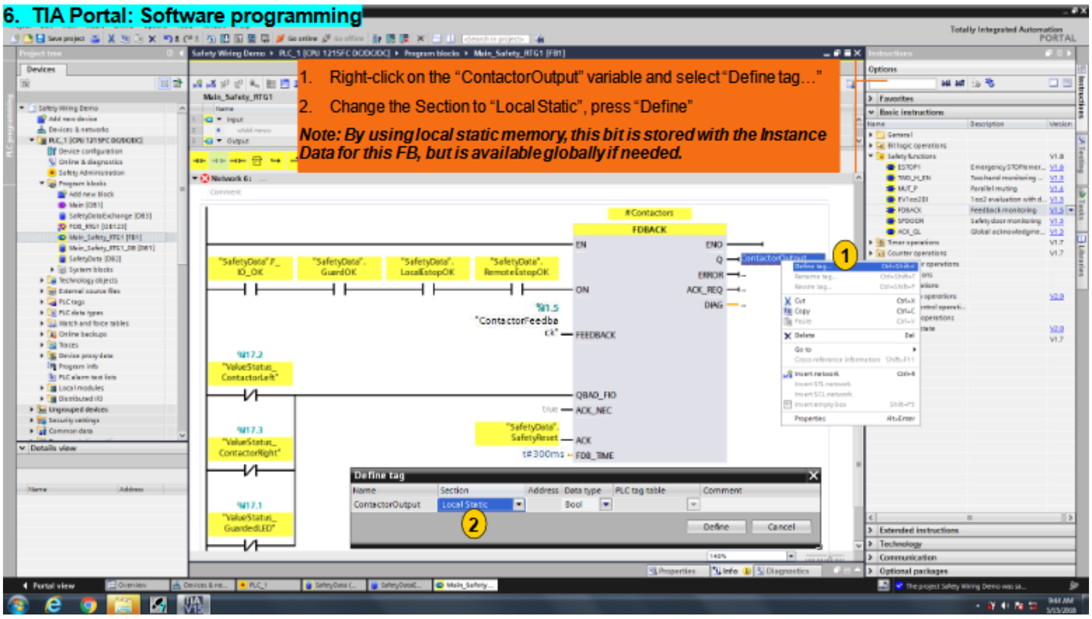

6. TIA Portal: Software programming
1. Using the favorites bar, add the logic as shown
Note: Each Safety Module IO Point provides a "Value Status" which shows if the module is OK and has not "Passivated" or gone to a Safe State. The Profinet Pushbutton station provides a "QBAD" bit.

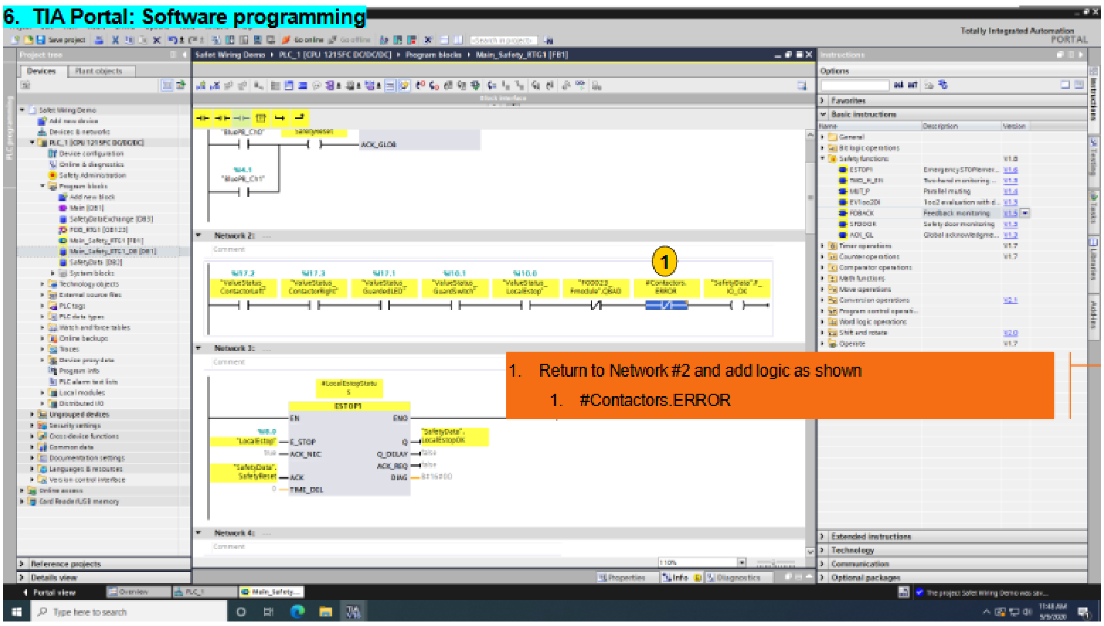

6. TIA Portal: Software programming
1. Drag "ESTOP1" from the Safety Functions Folder and place it on Network 3 as shown.
2. Fill in tags as shown.
Note: Be sure to use the Multi-Instance option for the Instance Data when prompted during insertion the ESTOP1 block. Define the Variable as "LocalEstopStatus"

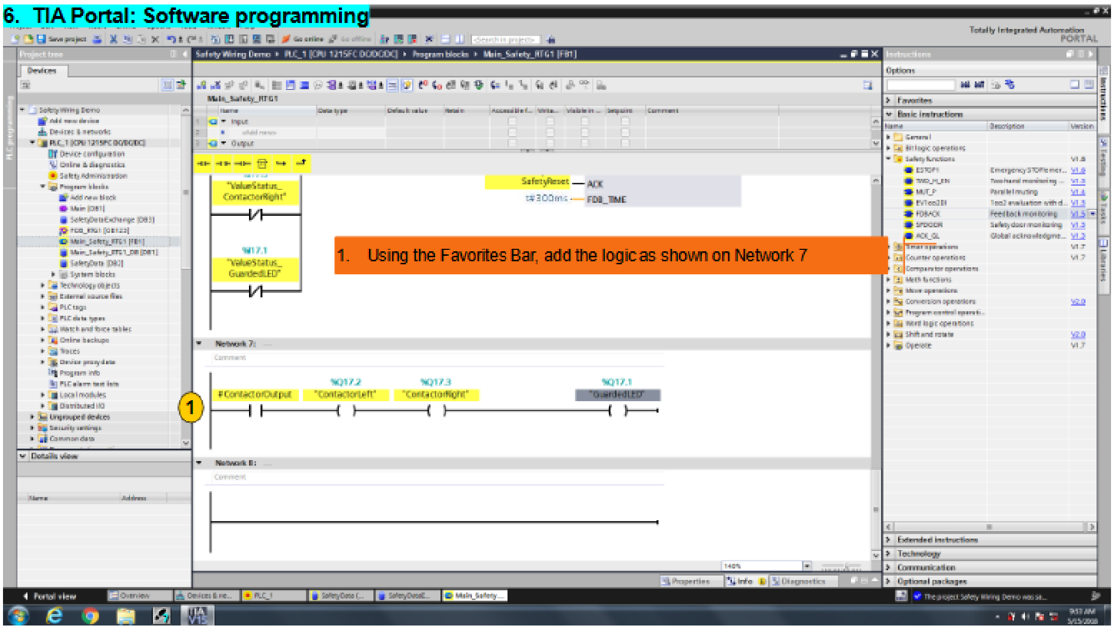

6. TIA Portal: Software programming
1. Drag "ESTOP1" from the Safety Functions Folder and place it on Network 4 as shown.
2. Fill in tags as shown.
Note: Be sure to use the Multi-Instance option for the Instance Data when prompted during insertion the ESTOP1 block. Define the Variable as "GuardStatus"


6. TIA Portal: Software programming
1. Drag "ESTOP1" from the Safety Functions Folder and place it on Network 4 as shown.
2. Fill in tags as shown.
Note: Be sure to use the Multi-Instance option for the Instance Data when prompted during insertion the ESTOP1 block. Define the Variable as "GuardStatus"


6. TIA Portal: Software programming
1. Drag "FDBACK" from the Safety Functions Folder and place it on Network 6 as shown.
2. Fill in tags as shown. (Be sure to change the FDB_Time = t#300ms)
Note: Be sure to use the Multi-Instance option for the Instance Data when prompted during insertion the FDBACK block. Define the Variable as "Contactors"
Note: We are adding a new variable, "ContactorOutput", we will define it on the next slide.
Note: Be sure to add the Feedback Time input to the block.
#Contactors
FDBACK
ContactorOutput
t#300ms
Call options
Multiple instance


6. TIA Portal: Software programming
1. Right-click on the "ContactorOutput" variable and select "Define tag…"
2. Change the Section to "Local Static", press "Define"
Note: By using local static memory, this bit is stored with the Instance Data for this FB, but is available globally if needed.
#Contactors
FDBACK
Define tag
ContactorOutput
Local Static
Bool
Define
Cancel


6. TIA Portal: Software programming
1. Return to Network #2 and add logic as shown
1. #Contactors.ERROR
ESTOP1



6. TIA Portal: Software programming

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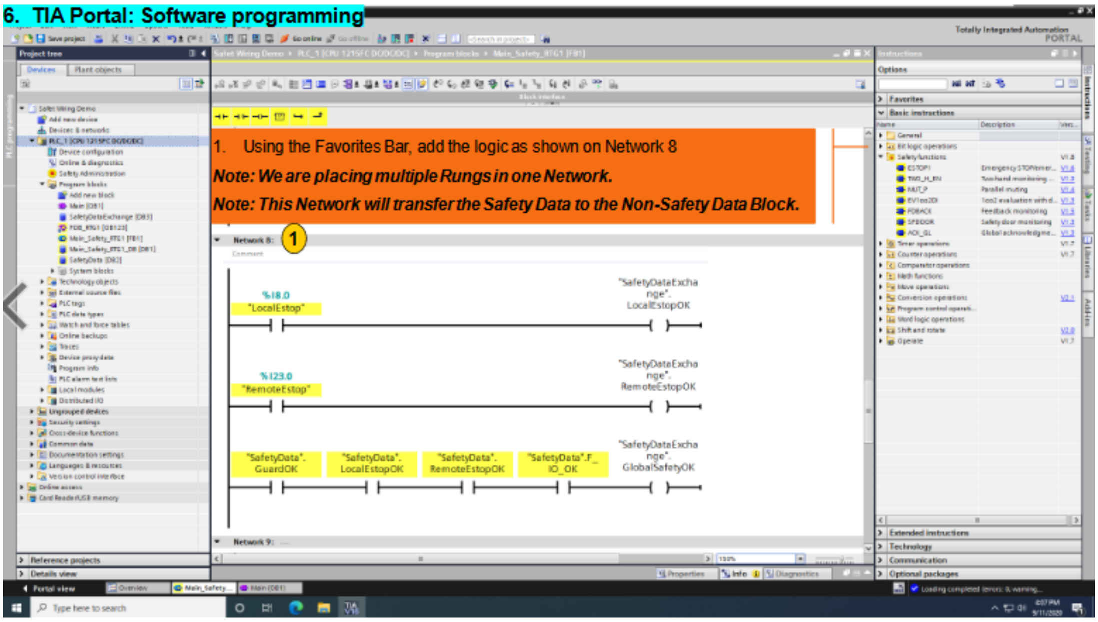
6. TIA Portal: Software programming – Technical Info

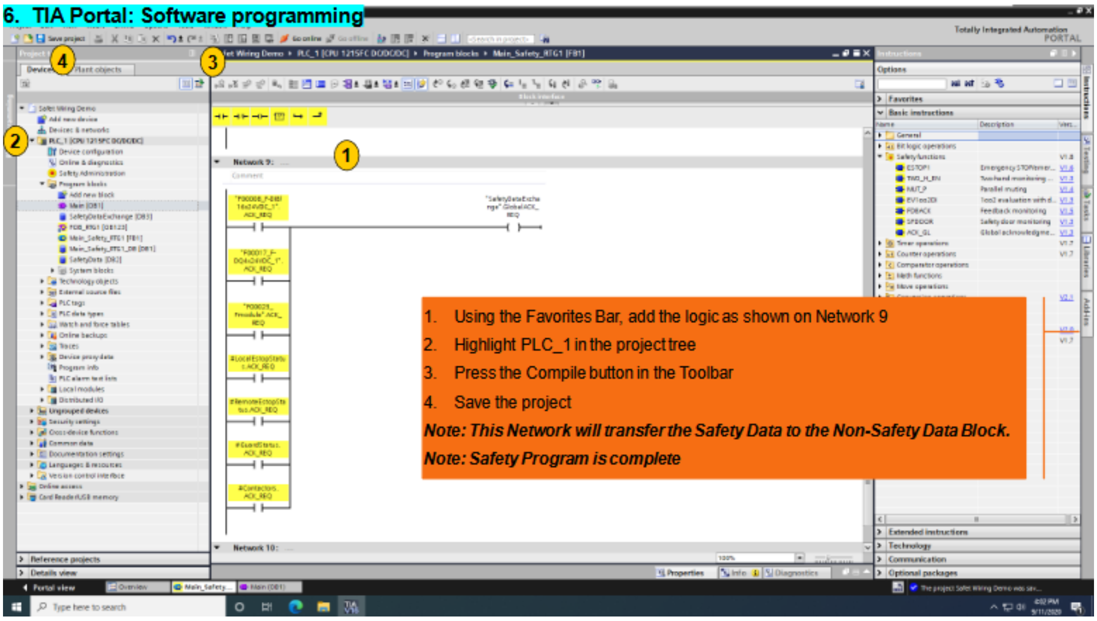
Safety data transfer to non-safe DB

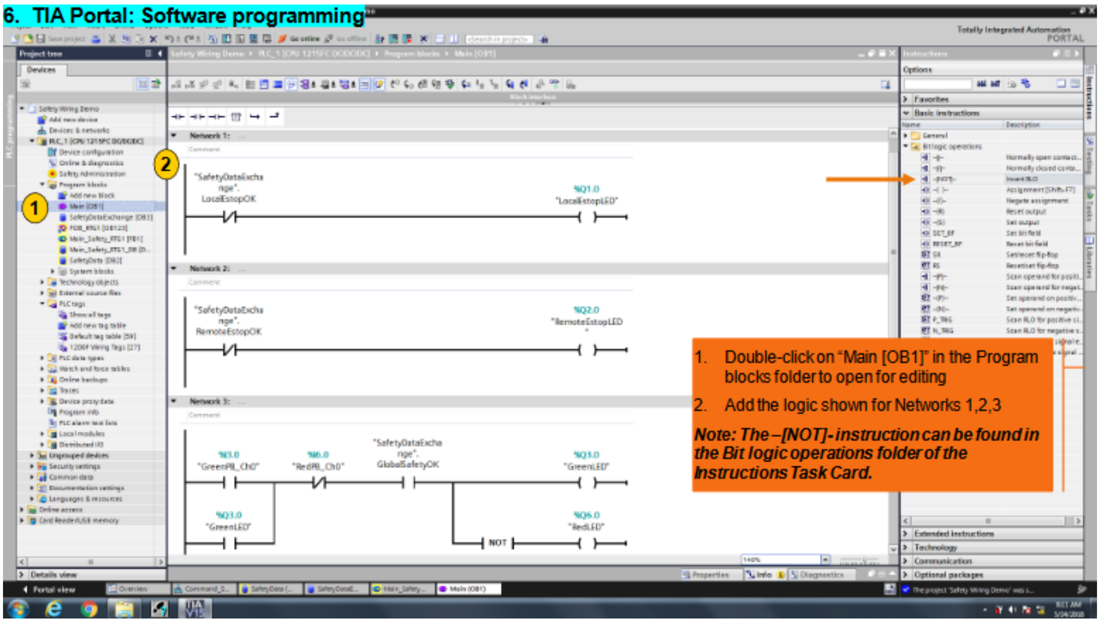
Advantages of using Data-coupling DB:

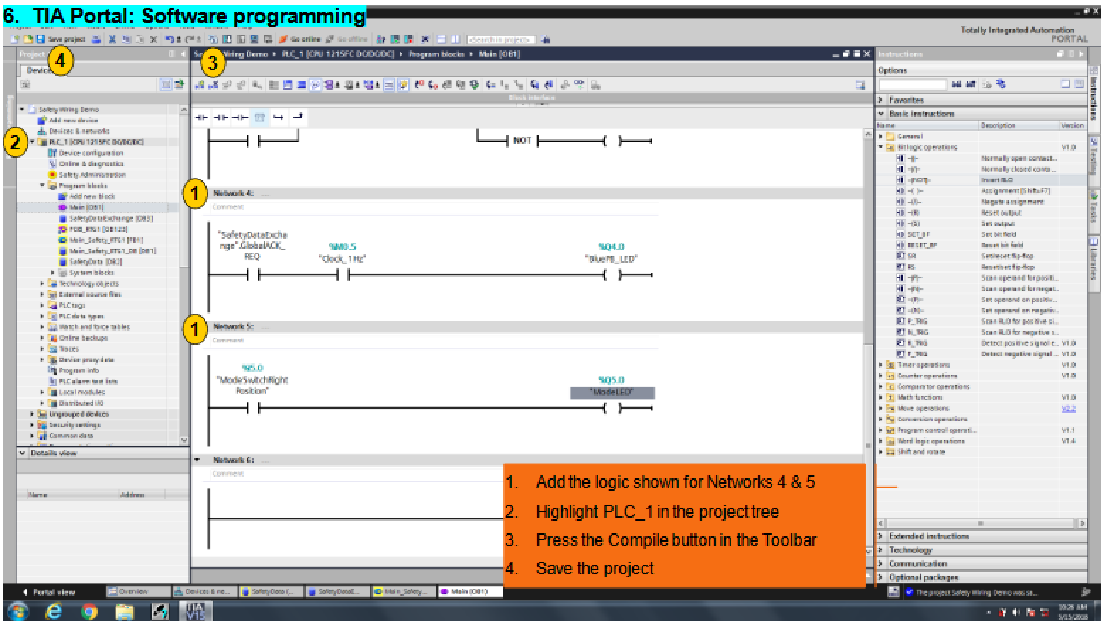
- Lean F-runtime group
- Better overview of the exchanged data
- Changes of the diagnostic and signaling concept in the standard user program do not affect the safety program's signature
- Minimized risk of downtimes caused by data corruption due to write access to the safety program
- Simplified typing of F-blocks
- Changes to the standard user program can be loaded without stopping the CPU
- Standard user program and safety program can be created independently of each other, provided that interfaces have already been defined

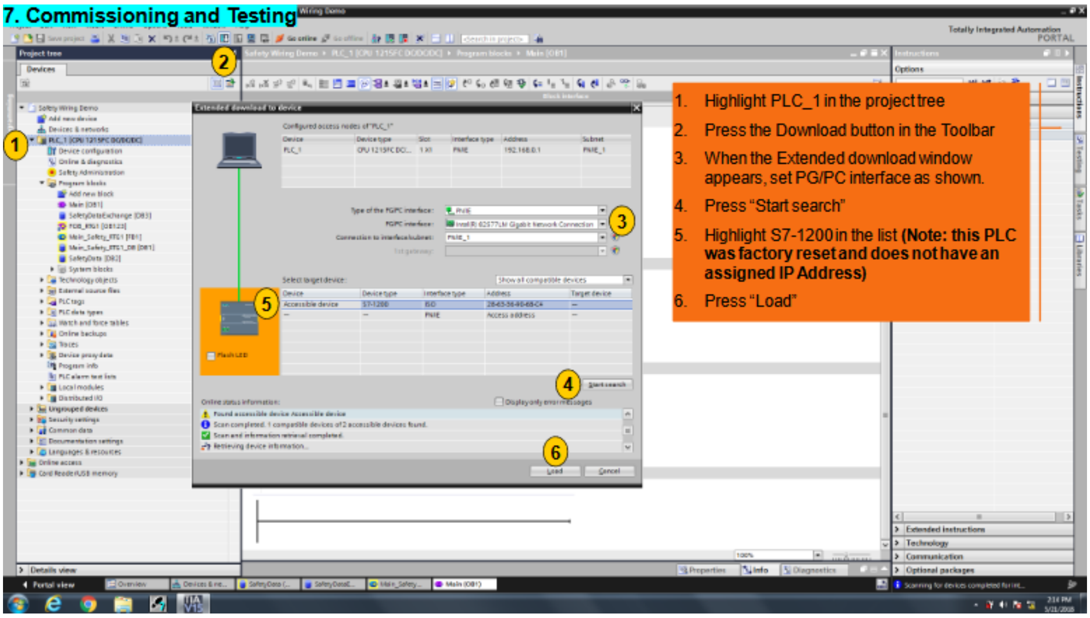
Refer to S7-1200F/1500F programming guideline:
https://support.industry.siemens.com/cs/us/en/view/109750255

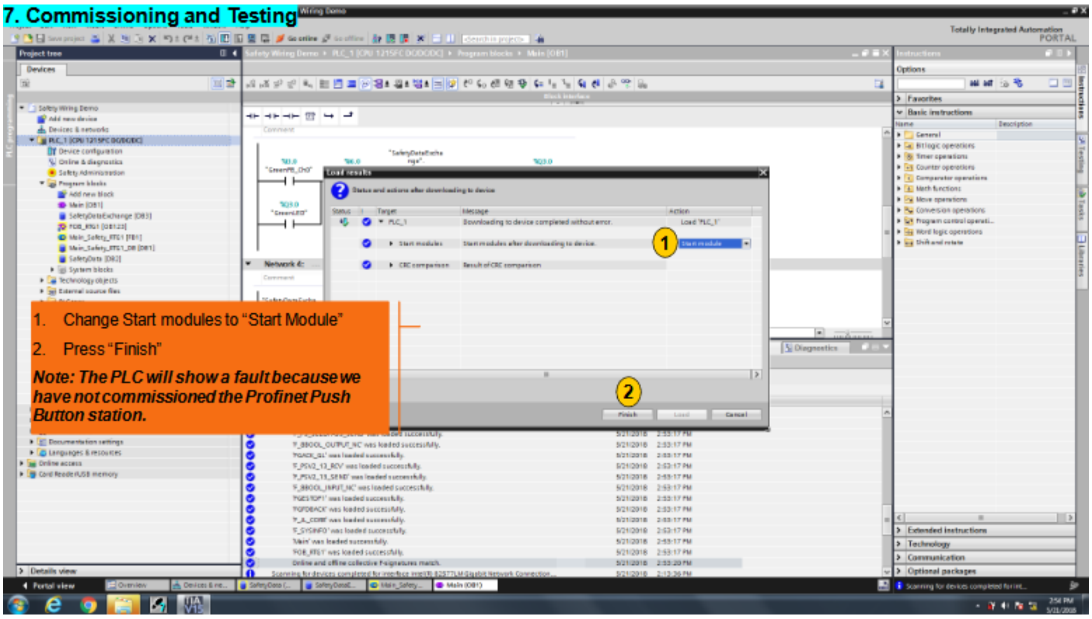


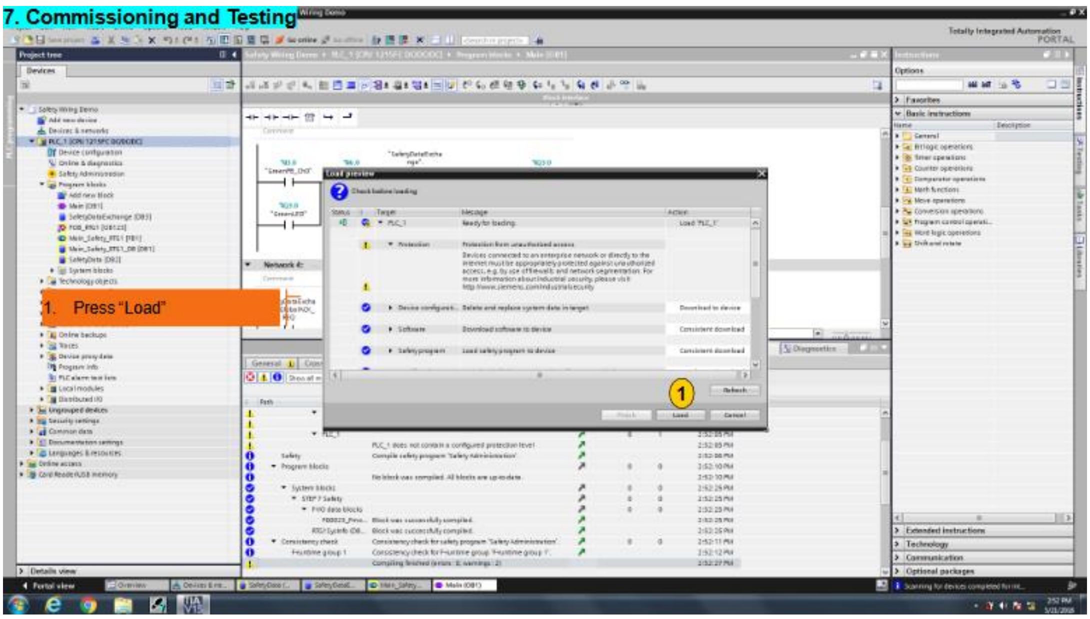

6. TIA Portal: Software programming
1. Using the Favorites Bar, add the logic as shown on Network 9
2. Highlight PLC_1 in the project tree
3. Press the Compile button in the Toolbar
4. Save the project
Note: This Network will transfer the Safety Data to the Non-Safety Data Block.
Note: Safety Program is complete

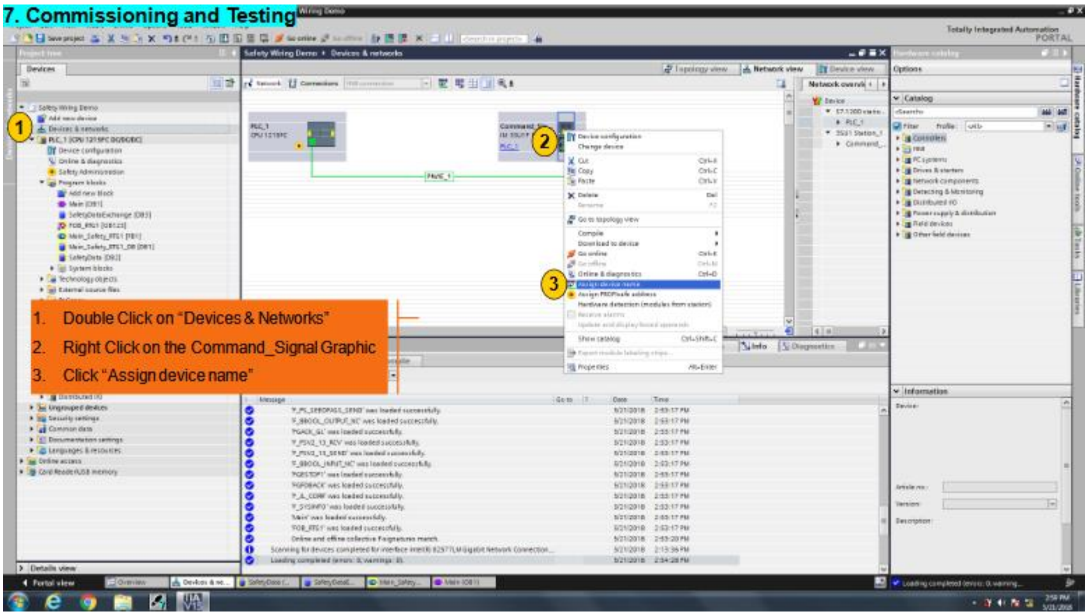

6. TIA Portal: Software programming
1. Double-click on "Main [OB1]" in the Program blocks folder to open for editing
2. Add the logic shown for Networks 1,2,3
Note: The –[NOT]- instruction can be found in the Bit logic operations folder of the Instructions Task Card.

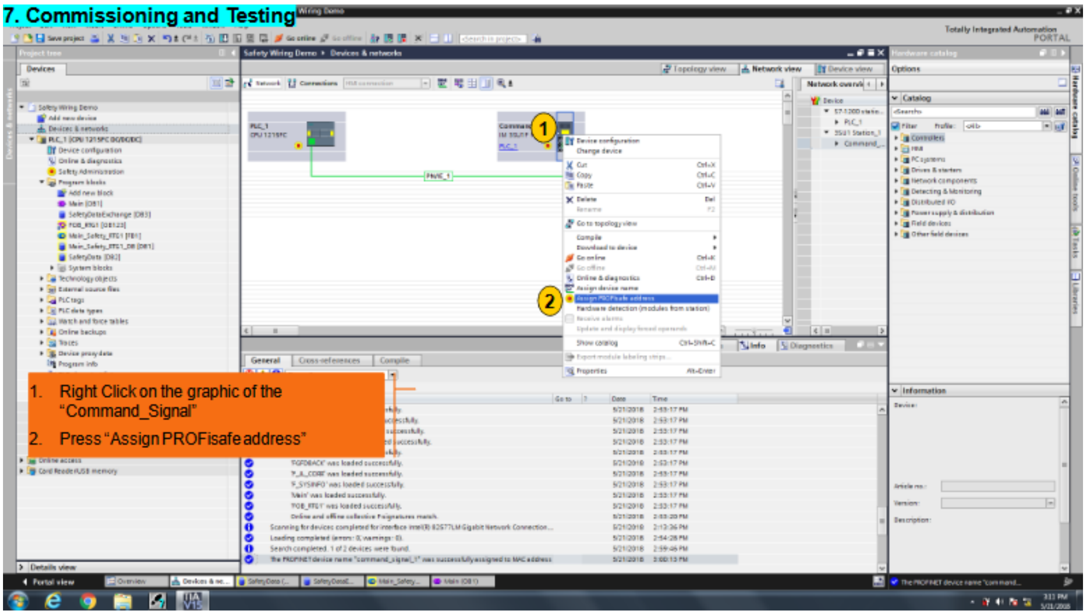

6. TIA Portal: Software programming
1. Add the logic shown for Networks 4 & 5
2. Highlight PLC_1 in the project tree
3. Press the Compile button in the Toolbar
4. Save the project

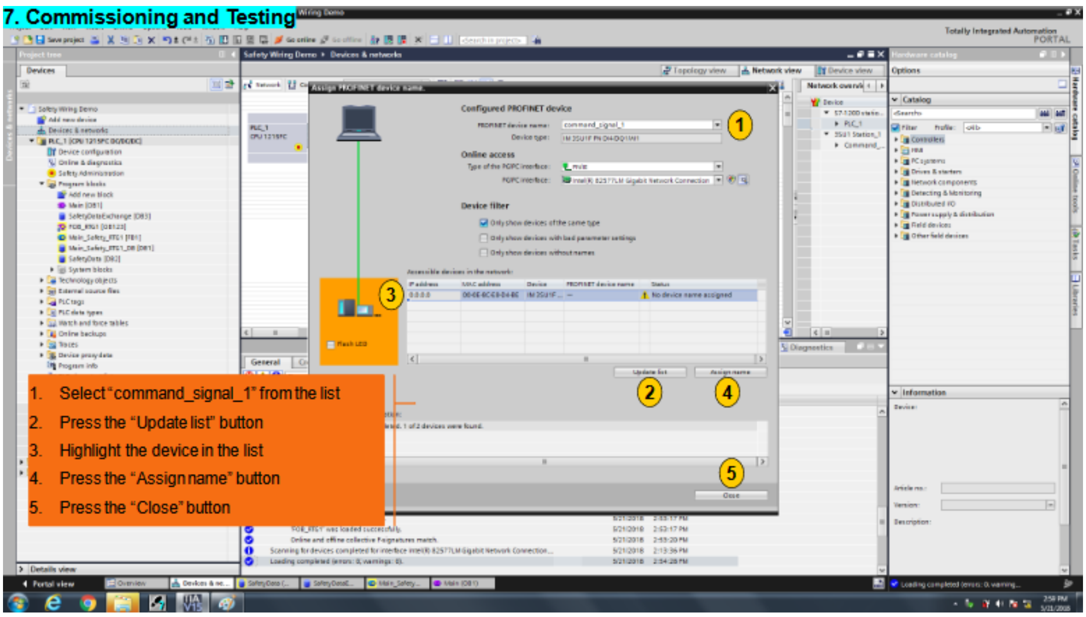

7. Commissioning and Testing
1. Highlight PLC_1 in the project tree
2. Press the Download button in the Toolbar
3. When the Extended download window appears, set PG/PC interface as shown.
4. Press "Start search"
5. Highlight S7-1200 in the list (Note: this PLC was factory reset and does not have an assigned IP Address)
6. Press "Load"

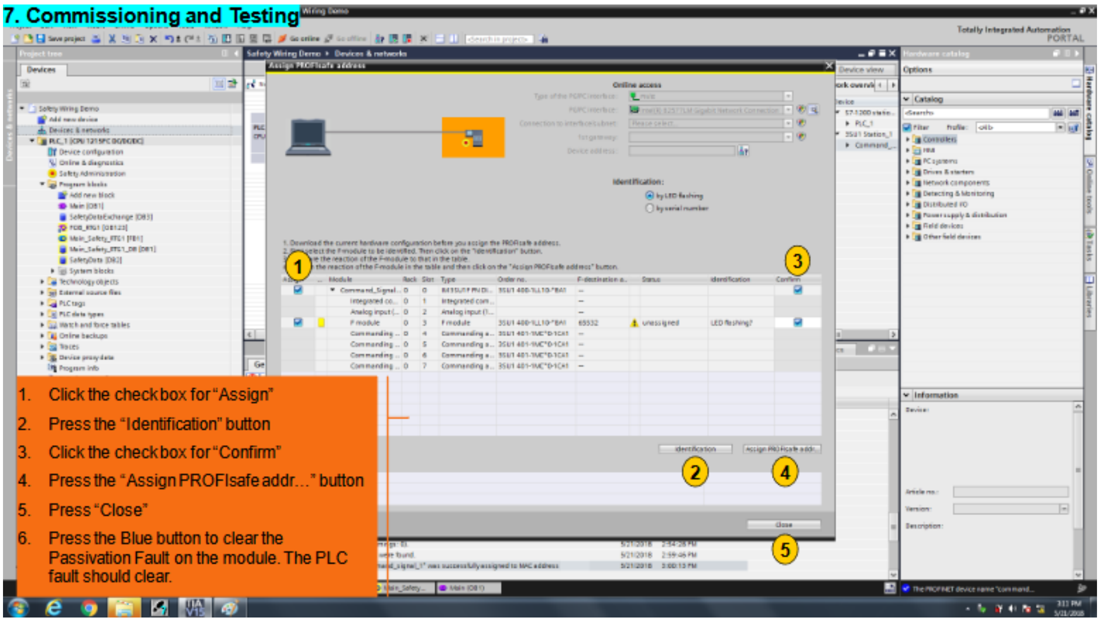

7. Commissioning and Testing
1. Change Start modules to "Start Module"
2. Press "Finish"
Note: The PLC will show a fault because we have not commissioned the Profinet Push Button station.


7. Commissioning and Testing
1. Press "Load"


7. Commissioning and Testing
1. Double Click on "Devices & Networks"
2. Right Click on the Command_Signal Graphic
3. Click "Assign device name"


7. Commissioning and Testing
1. Right Click on the graphic of the "Command_Signal"
2. Press "Assign PROFisafe address"


7. Commissioning and Testing
1. Select "command_signal_1" from the list
2. Press the "Update list" button
3. Highlight the device in the list
4. Press the "Assign name" button
5. Press the "Close" button



Article from Control Design Magazine on Use of E-Stops:

"Standards guide the use of e-stops
Jan. 9, 2023
Wireless and remote e-stops are allowed but must follow strict guidelines for location and design
Anna Townshend

This is an article that is based on reader questions regarding e-stop design with answers from industry leaders:

"A Control Design reader writes: I'm seeing new technologies available for wireless e-stops, remote e-stops and touchscreen e-stops. Are these allowable? Are there regulations governing the use of anything besides a physical red button? What machine applications would these be used for? What does the Occupational Safety and Health Administration (OSHA) say about them? And where is the reset to resume operation?

Answers

Pushbutton standards specify physical requirements

Yes, wireless e-stops and remote e-stops are allowable but must be compliant with the following:

- International Organization for Standardization (ISO) 13849—Safety of Machinery Package
- ISO 13850:2015 Safety of Machinery—Emergency Stop Function—Principles for Design
- American National Standards Institute (ANSI) B65.1-2005—Graphic Technology—Safety Standard—Printing Press
- International Electrotechnical Commission (IEC) 60204-1:2005 Safety of Machinery—Electrical Equipment of Machines—Part 1: general requirements
- IEC 62745 Safety of Machinery—Requirements for Cableless Control Systems of Machinery. This standard aims to define the guidelines of how wireless remote-control systems must be designed to comply with the minimum requirements of machine design and safety.

For touchscreen e-stops, graphical representations of a button—an icon—on an HMI or flat panel display are not an option. The same standards do not permit flush or membrane-style switches or touchscreen buttons/icons.

Yes, regulations are governing the use of anything besides a physical red button. For emergency-stop pushbuttons to be compliant, they must be designed as follows:

- with direct opening operation
- as self-latching and must be reset manually
- with mushroom-head shape to make it easy to push
- to remain unguarded
- to be located at each operator control station and at any other location where an emergency stop would be required
- colored red and mounted on a bright yellow background. The yellow background must be a minimum of 3 mm beyond—surrounding—the mounting collar and visible beyond the control actuator—the button itself—according to ANSI B65.1-2005.

A common application where wireless e-stops are superior to wired e-stops is during crane operations. This allows greater operator freedom for their positioning to view crane movements, and lower costs for system implementation. The wiring alone, in a traditional wired e-stop system, can be a significant portion of the cost and complexity of an e-stop-based safety system implementation.

OSHA and relevant standards such as IEC 60204-1 state that an e-stop must be readily accessible to the operator. Additionally, it should be unobstructed—no collars or actuation restrictions—and easily accessible without having to reach over, under or around to actuate. Machine-building standards such as ANSI B11, B11-19 and National Fire Protection Agency (NFPA) 79 also address specifics in regard to safety devices such as an e-stop.

OSHA and relevant standards such as IEC 60204-1 further state that resetting of the e-stop alone shall not resume operation. A second deliberate action is needed, such as the pressing of a reset button. This could include twisting the mushroom button and allowing it to spring back up or pulling the button back up to reset. It cannot automatically reset.

Michael Warren / product manager—safety components and safety controllers / Omron

Wireless e-stops enhance maintenance safety

After looking through OSHA regulations and other global standards, I could not find anything that specifically says wireless e-stops are not allowed. In fact, there is an offering for a wireless e-stop that actually meets ISO 13849 Category 3 specifications for functional safety systems. There isn't much in the way of where an e-stop button should be located and what it should look like other than "easily accessible and within arm's length," red button on a yellow background and requiring only a manual reset.

OSHA uses NFPA and other global standards, such as ISO, to form its standards. NFPA 79—Electrical Safety Standard for Industrial Machinery—sets out what is allowable for emergency-stop buttons. This includes pull-cord-operated, foot-operated, push-bar-operated and rod-operated switches. NFPA 79 does not allow emergency stops to be flat switches or a graphical/digital representation. So, while wireless e-stops would be allowable, touchscreen e-stops would not be.

Any machine or process could theoretically use a wireless e-stop. More specifically, imagine a scenario where a technician has to be physically inside a machine or is working on a section of the machine where the e-stop might be just out of reach. Having a wireless button that can stop the machine from anywhere would be a great benefit. Another scenario could be operators that keep wireless buttons on their person for potential need. They see someone who shouldn't be operating or performing maintenance on a machine. It takes time to get to the nearest button to e-stop the machine so being able to press one that's currently with them on hand could potentially save a life or limb.

The wireless button would need to have a manual reset, whether that be a twist-to-release or a pull-to-release function. Once that's done, assuming the safety system is a manual/manual, monitored setup, the resume operation would be as usual. Press the reset button. If the safety system is an automatic reset, manually releasing the e-stop button would reset the safety system to a ready state. Most likely, the machine itself will need to be rehomed and/or have the process reset/acknowledge button pressed to restart the production process.

Noah Greene / product specialist—safety / Phoenix Contact USA

E-stop differs from an emergency-off switch

The short answer is yes. Wireless and remote e-stops are allowed with very strict regulations. The standards that dictate how an e-stop switch works are ISO 13850:2015, Safety of Machinery – Emergency Stop Function—Principles for Design; and IEC 60947-5-5, Low-Voltage Switchgear and Controlgear—Part 5.5: Control Circuit Devices and Switching Elements—Electrical Emergency Stop Device with Mechanical Latching Function.

These standards require a physical e-stop that opens a contact and, at the same time, latches. This means no latching without opening the contact and no opening without latching is allowed. ISO 13850 is the so-called machinery directive, which lists several other requirements for operating and resetting an e-stop.

It is important to note that there must be a physical e-stop, no matter what (Figure 1). A physical e-stop, which must open a physical contact, could be connected to a wireless or remote technology to activate it. It sends a signal, and the physical freeze of a machine is activated. It's also important to note the difference between an e-stop and an emergency-off switch. While an e-stop freezes the machine, an emergency-off shuts off the power, which is not necessarily the case for e-stops.

When it comes to resetting or resuming operation, there are safety regulations and protocols in place. For example, you are allowed to connect a normal-stop switch in a way that, if you push it, the machine stops or freezes. Once you release it, the machine runs again. That is for a normal-stop switch. However, with an e-stop, once you press it, the machine freezes and stops. If you release the emergency-stop switch, the machine must not run, it will stay stopped. For safety reasons, there must be another separate mechanism to restart the machine.

Reinhard Kalla / principal product manager / EAO

Touchscreen e-stops are not allowed

E-stops shall be located at each operator control station. In addition, other locations can be considered according to a risk analysis, including entrance and exit location. See ISO 13850-4, Safety Requirements; 3, Terms and Definitions; and 2, Normative References. In case of e-stop activation, locally or remotely, the machinery shall be inspected in order to detect the reason for activation.

Wireless e-stops are allowed, but, according to the IEC 60204-1, the wireless e-stop shall not be the sole means to initiate an emergency stop. In addition, according to ISO 13850, a wireless e-stop shall comply with Subsection 4.3.8, Subsection 4.3.9, Subsection 4.6.2 and a minimum of safety level PLC, according to ISO 13849, and/or SIL 1, according to IEC 62061. The safety level shall be consistent with a risk analysis of the machine. IEC 62745 deals with wireless control systems for electrical equipment of machinery, and, since March 2021, it is now harmonized for machinery directive in Europe.

Touchscreen e-stop is not allowed, because ISO 13850 and IEC 60947-5-5 require that the emergency-stop device shall comply with IEC 60947-5-1, Annex K, a direct opening action of the electrical contact. A touchscreen is not compliant with this requirement.

According to NFPA 79 10.7.2.3, emergency-stop switches shall not be flat switches or graphic representations based on software applications.

In Europe, in compliance with Machinery Directive, in Annex 1, Subsection 1.2.4.3, emergency-stop machinery must be fitted with one or more emergency-stop devices to enable actual or impending danger to be averted.

The following exceptions apply for:

- machinery in which an emergency-stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken
- portable handheld and/or hand-guided machinery.

For the e-stop, the NFPA standard is more suitable than OSHA regulations. The main requirements of the e-stop are defined in NFPA 79 standard for machinery. The requirements from NFPA 79 are based on IEC 60204-1 with some few specificities for the e-stop.

In case of e-stop activation, locally or remotely, the reset button shall be located in general in the machine, because the machine shall be inspected to detect the reason for activation.

Eric Domont and Sébastien Chaigneau / standardization manager, e-stop expert and creation manager, safety expert / Schneider Electric

End of article on E-Stop Design.

Next, an article from Control Design Magazine on Robotic E-Stops:

How machines stop in emergency situations
Aug. 2, 2024
Safety configurations for Category 0, Category 1 and Category 2 stops
Tobey Strauch

As robots become more advanced, the Association for Advancing Automation, which includes what was once the Robot Industries Association (RIA), has encouraged more decisive risks analysis for safety. Many machine builders go straight to RIA 15.06 as a standard because its more comprehensive than having two standards, one for robotic machines and one for non-robotic machines. This is a go-to for motion-control applications. However, it does not stand alone. Why? In any safety configuration, one must consider how the machine is going to stop and in which instances.

National Fire Protection Association (NFPA) 79 is an industrial machine safety regulation and defines stops in categories. Category 0 is an uncontrolled stop by immediate removal of power to the machine actuators. This requires non-retentive relays. A reset to initial state is required. Category 1 is a controlled stop with power to the machine actuators to achieve a stop and removed power when the stop is achieved. Category 2 is a controlled stop with power left available to the machine actuators."

The article continues with examples of category 0, 1 and 2 applications:

"Emergency stops or conditions are the "darn it" buttons and require quick stops. This is a Category 1 type stop. Category 2 would be an instance when a stop requires power to remain on a circuit. Hydraulic oil may need to keep circulating for an auxiliary power unit (APU) response, even if a machine is stopped. E-stops are not Category 2 stops, but a machine stop can be Category 2.

Category 1, quick stops after short amount of time, are used for high inertia machines where an immediate stop would harm people or machine, and the safe way to stop is to allow a time to slow down before removing power. Removing power from the machine in a hard stop, would require a timed slow down and then removal of power. This is discerned by the application. Things to consider are time to stop, damage in not waiting for a controlled stop, risks between controlled stop and depowered stop regarding people.

In automated assembly lines, a Category 1 stop is crucial for safely halting operations. For instance, if a sensor detects an obstruction or a malfunction, the system initiates a controlled deceleration of the conveyor belts and robotic arms before cutting off power.

Computer numerical control (CNC) machines, which are used for precise cutting, milling and drilling, often employ Category 1 stops. When an emergency stop is activated, the machine decelerates in a controlled manner to avoid damaging the workpiece or the cutting tool, and then power is cut off.

Automated guided vehicles (AGVs) used in warehouses and manufacturing plants rely on Category 1 stops to ensure safety. If an obstacle is detected in the vehicle’s path, the AGV will decelerate smoothly before stopping completely, reducing the risk of collisions and damage.

In packaging lines, Category 1 stops are used to prevent damage to both the machinery and the products being packaged. For example, if a jam is detected, the machine will decelerate before stopping, allowing operators to clear the jam safely.

High-speed printing presses use Category 1 stops to avoid damage to the printing plates and paper. When an emergency stop is triggered, the press decelerates in a controlled manner before stopping, ensuring that the print quality is maintained and the equipment is protected.

Cold mills hold high tension with dangerous metal sheets. When a Category 1 stop is made the tension can be decreased on a set ramp to allow safe maneuvering of metal sheeting on a roll. This saves the material and the people. A hard depowered stop would leave tension on the sheet and risk a break and possible equipment damage.

Would a stop due to fire be a Category 1 stop? No. That is a Category 0 stop. Why? Fire hazard. Get out now.

Category 2 stops are like pushing the stop button in manual mode but keeping the power on because the drive should be ready for a “jog” function.

In conclusion, there are three types of category stops for machine builders: categories 0, 1 and 2. The most extreme is a hard-stop Category 0. The least extreme is a soft stop, which is Category 2, and Category 2 may not be an emergency stop.

Understanding what the machine does on a stop and how it should operate is critical for machine functionality. Why? Safety is not just about human safety but machine usability. The risk assessment should define the type of stop, the reason and what power is cut off for each stop. For Category 2 stops, the timing until the power is shut off should be known so that it can be briefed to operations.”