Agidens

Toepassing van IEC61511 in de praktijk

De lifecycle van een veiligheidskring: van risico-analyse tot onderhoud

Industriële Veiligheid

online kennisdagen | 21-22 april 2021

Agenda

- Even voorstellen
- Doel van de presentatie
- Definities
- Aan de slag
- Vragen

Even voorstellen | Agidens

- Actief in Oil & Gas, Food & Beverage, (Fijn)chemie, Life Sciences en Infrastructure
- Divisie O&G vooral focus op
  - Tankterminals
  - (Petro)chemie
- Disciplines
  - Technical consulting (FS, ATEX, Hazop)
  - Process engineering
  - Hardware engineering
  - Software engineering
  - Site-activiteiten
- +/-15 Tuv-certified engineers

Even voorstellen | Bald Peeters

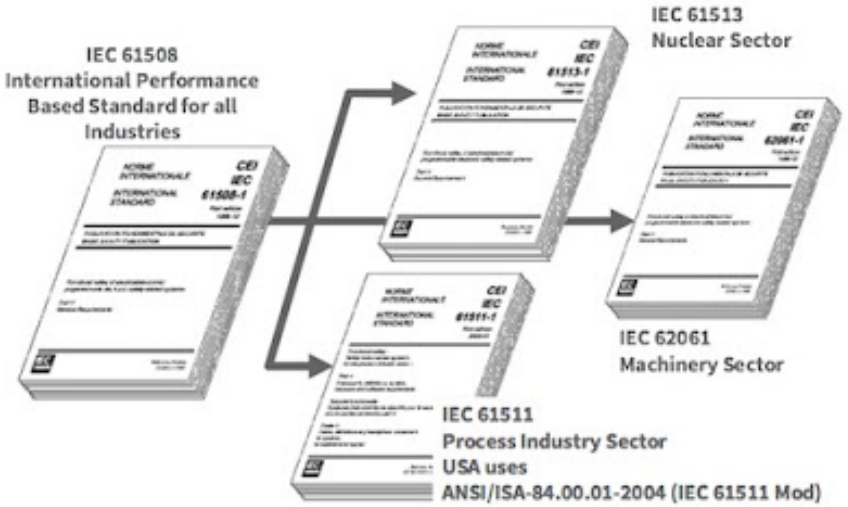
- Operational Manager Oil & Gas
  - Al 23 jaar bij Agidens
  - +/-15 jaar ervaring met Functional Safety

Doel van de presentatie

Toelichten van de opeenvolgende stappen
in de lifecycle van de veiligheidsfunctie.

Definities

- IEC 61511 is een technische standaard, specifiek voor de procesindustrie, die specificatie, ontwerp, installatie, operatie en onderhoud van instrumentele veiligheidssystemen beschrijft. Deze standaard valt over de overkoepelende IEC61508-standaard en is gericht op de gebruikers van veiligheidssystemen.



Definities

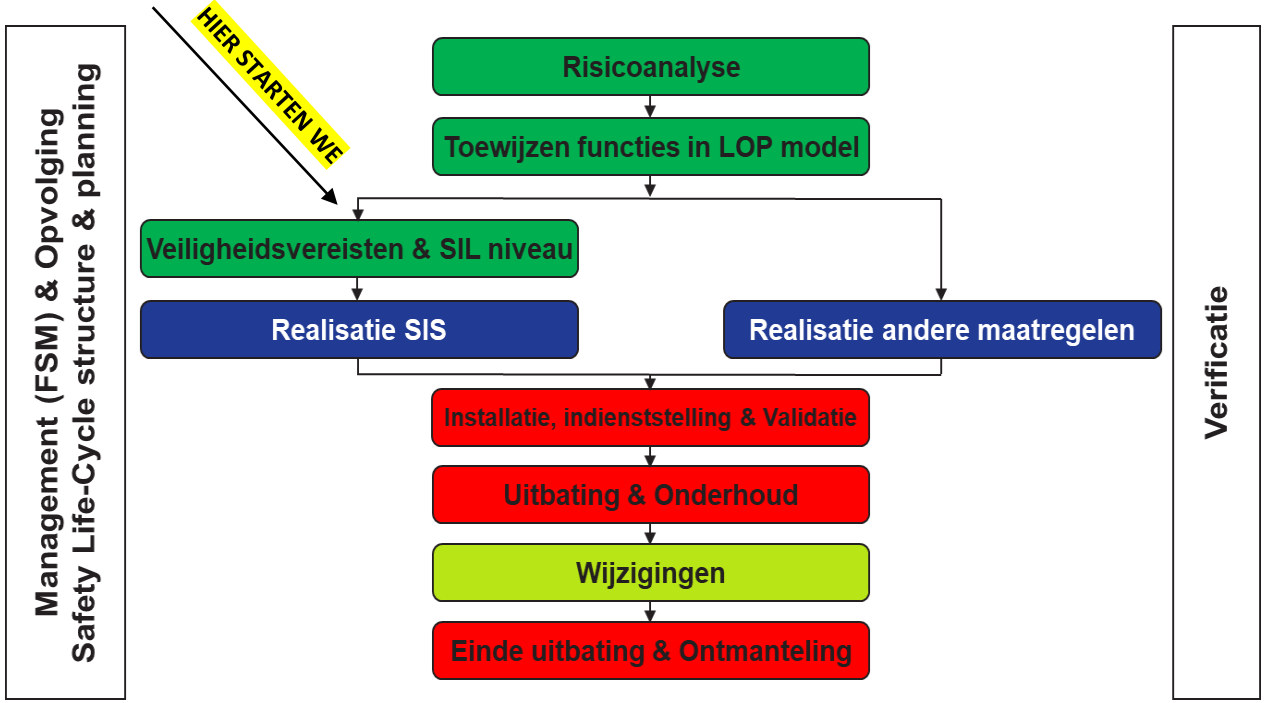
- SIF (Safety Instrumented Function) is een *'automatische'* functie die een proces naar een veilige toestand brengt bij optreden van een oorzaak. Een SIF bestaat steeds uit een 'sensor', een 'logic solver' en een 'final element'.
- SIL (Safety Integrity Level) is een kwantitatieve waarde die het niveau van performantie van de veiligheidsfunctie bepaalt.
- SRS (Safety Requirement Specification) beschrijft de SIF in detail. Dit is het referentiedocument voor alle stakeholders die met de veiligheidsfuncties te maken hebben.

Definities

- SAT-protocol is het testprotocol dat gebruikt wordt bij een eerste inbedrijfname van een SIF.
- Prooftest-protocol is het testprotocol dat gebruikt wordt tijdens de periodieke testen van een SIF.

Aan de slag | Uitwerken van veiligheidskring in de verschillende stappen

IEC61511 Life cycle



Stap 1 | Data-analyse

- Analyse uitgevoerde risicoanalyse (Hazop/LOPA)
  - Overzicht maken SIF's met correcte tag-nummers
  - Voting sensoren en final elements
- Nakijken procedures van klant
  - SIF-identificatie
  - Scheidinglagen
  - Bypass-filosofie
  - Reset-filosofie
  - Alarmfilosofie
- Standaardlijst toegepaste veiligheidsinstrumenten van klant
- Proof of concept berekening (SIL-calculatie)
  - Architectural constraints (voting)!

Stap 2 | Opmaak SRS

- Referentie naar
  - IEC61511
  - P&ID's
  - Klantprocedures
  - Process data (Process safety time)
  - Risico-analyse (Hazop/LOPA)
  - …

Reference documents

	Title	Document nu
[1]	International standard - Functional safety - Safety instrumented systems for the process industry sector (parts 1 through 3)	IEC-61511-1/-2
[2]	P&ID	101186-P33-5(
[3]	P&ID Demolition	EC.009.TW.10
[4]	HAZOP	HAZOP LOPA 05-02-2021
[5]	Drawings VSD	7.1_Drawings S Frequentierege

Stap 2 | Opmaak SRS

- Beschrijving en werking SIF
- Beschrijving in- & outputs en toegepaste voting
- Beschrijven bijkomende risico's
- Beschrijving scenario's uit Hazop/LOPA
- Proof test
  (interval, duur, coverage, documentatie, ..)
- Response time
  (Process safety time & allowed response time)
- SIL-niveau & Operating Mode
- Ranges & Trippoints
- Trip mode
- Reset
- Failure mode
- Opstart
- Interfacing
- Bypass procedure
- Repair time
- Specifieke requirements voor hardware
- Specifieke requirements voor software applicatie
- Cyber security

Verificatie van de SRS door onafhankelijke FS engineer

Stap 2 | Opmaak SRS

Key word	Description/value
SIF tag	» SI-342
Function description	» When the pressure at the pressure side of the pump is too high, the pump will be stopped

Key word	Description/value
Inputs (multiple possible)	» 36-PT-620-003
Output (multiple possible)	» 36-P-620-001_E

Proof test interval	» Sensor and actuator: 1 Ye » Logic solver: 10 Years
Proof test duration	» 2h
Proof test coverage	» Sensor >= 50% » Logic solver >= 90% » Actuator >= 50%
Possible failures occurring during proof test	» Pump not running at the b » Pressure transmitter calibr » Pressure transmitter or pu » Process valve and transm not locked open after test
Status of the process during the test (batch – continuously)	» Batch
Failure prevention	» Use of calibrated test equi » Use of test protocol » 4 eyes principle

Key word	Description/value
Reset conditions after trip	» 36-PT-620-003 < 4,5 Barg » Manual reset via hardware button software button by operator to re-a after the cause has been eliminate » The safety function has no faults

Key word	Description/value
Possible hazards due to the safe state of the SIF	» Pumping against closed valves » Water hammer

Key word	Description/value
Process safety time	» 1 min
Allowed response time	» 45 s

Key word	Descripti
SIL to be achieved	» 2
Operating mode	» Low d
Demand rate	» Less t
Mission Time	» 20 yea

ey word	Description/value
re resistance valves	» NA
ow long can the valves remain open in case of fire	» NA
ype of field cabling	» Power cables mus

Sensor (+ interface module)	» Diagnostic error or break down of the se trip. » Wire break or short circuit in the cabling leads to a trip
Compensating measures	» Spare material available in stock ETT » Replacement of faulty apparatus is a me for maintenance
Logic	» Diagnostic failure or error of PLC » Error on AI card => leads to trip of th connected to the card » Error on CPU => leads to trip of the s » Error on DO card => High priority ala immediate intervention with procedur

Key word	Description/value
Safe state	» The pump has stopped, the electrical power to the pump motor is interrupted, so no pressure build-up in the lines at pressure side.

Key word	Description and frequency
Expected source of activation (sources of demand) **EXTRACT FROM LOPA**	» Node: 5. Laden train (topverlading) vanuit pomp P-620 (liquid) » 1. 36-GATE-620-002 (ernst 5 omwille dichtbij truckverlading waar mogelijk n personen aanwezig zijn) ● 6. Drukopbouw boven ontwerp leid Schade en vrijzetting bij aanvang b Mogelijke vorming explosief mengs brand/explosie » 1. 36-GATE-620-002 ● 7. Drukopbouw boven ontwerp leid Schade en vrijzetting bij aanvang b Grondvervuiling. Milieuscenario » 1. 36-MOV-PD-001 faalt dicht (ernst 5 locatie - dichtbij truckverlading waar m meerdere personen aanwezig zijn) ● 8. Drukopbouw boven ontwerp leid Schade en vrijzetting, mogelijk aar Mogelijke vorming explosief mengs

Key word	Description/value
Sensor (+ interface module)	» De-energize to trip
Logic	» De-energize to trip
Actuator (+ interface module)	» De-energize to trip

Stap 3 | SRS approval

- Formele goedkeuring SRS door stakeholders
- Bij wijzigingen na goedkeuring steeds impact op de hele flow

Stap 4A | Hardware design

- E&I Hardware concept met SRS ALTIJD als referentiedocument
- E&I Detailed design (bedradingstekeningen, datasheets, …)
- Aankoop instrumenten & componenten voor de SIF's
- Controle door FS engineer van Safety Manuals & SIL-certificaten/data t.o.v. SRS
- Verificatie door FS engineer van design t.o.v. SRS

Stap 4B | Software design

- Functioneel ontwerp met SRS steeds als referentiedocument
- Software specificaties/bibliotheek van klant (of fabrikant S-PLC)
- Ontwikkeling software conform Safety manual van S-PLC
- Visualisatie (SCADA / HMI)
- Alarmmanagement / prioriteiten
- Bypass filosofie
- Reset filosofie
- Interne testen (test evidence!)
- Verificatie door FS engineer van design t.o.v. SRS

Stap 5 | Safety Manual

Opstellen van Safety manual voor gehele installatie

- Beschrijft
  - Hoe de installatie veilig gebruikt moet worden;
  - Hoe aanpassingen moeten gebeuren;
  - Hoe er getest moeten worden
- Moet bij elke aanpassing/uitbreiding een update krijgen
- Omvat alle disciplines & stakeholders

Stap 6 | FAT (Factory Acceptance Test)

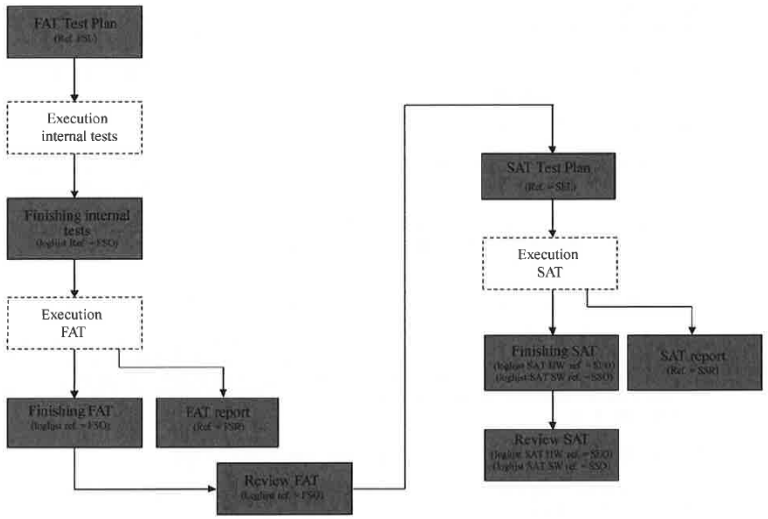
- FAT procedure & protocollen voor FS hard- & software
  - Hardware (panelen)
  - Software (S-PLC, SCADA)
  - Integratie testen
- Rekening houden met
  - Safety manuals
  - Nieuw of aanpassing op site
  - Zijn alle componenten beschikbaar voor de hardware FAT
  - Is er een testsysteem beschikbaar voor de software FAT
- Logging afname testen en open issues
- Bijkomende FAT-run voor verificatie open issues

Stap 6 | FAT (Factory Acceptance Test)

Voorbeeld: FATPLAN /testprotocol veiligheidsfunctie

1.4 Test proceedings

A diagram of the proceeding and follow-up of the different tests.



	Steps (Actions)	Expected test results and acceptance criteria	Success (Y / N) (Y / N)	Log Ref.	Evd. Ref.. Ref.
[1]	Write down the safety function to be tested	Safety function : 1000 - SI - 001	Y		
[2]	Write down the CRC code of the application	CRC code is : 318 2BA5	Y		
[3]	Take a copy of the approved C&E. Write the protocol number of this protocol and proof reference "A" down on the copy	A copy of the approved C&E is available. The protocol number and required test evidence reference "A" are written down on the copy	Y		
[4]	Take a copy of the approved SRS. Write down the protocol number of this protocol and proof reference "B" down on the copy	A copy of the approved SRS is available. The protocol number and required test evidence reference "B" are written down on the copy	Y		
[5]	Put all causes not in trip condition and reset the function and acknowledge the alarms of the function	Function is not in trip, outputs are high, no alarms of this function.	Y		

Stap 7 | Installatie, Indienststelling, Validatie

- SAT procedure & protocollen voor FS hard- & software
  - Hardware
    - Inspecties
    - Statische testen
    - Onder spanning brengen van panelen/kringen
    - Integratietesten (netwerkverbindingen, derden, overige systemen
    - I/O-testen
  - Functionele test veiligheidsfunctie (eerste inbedrijfname) met witnessing door klant
  - Test met alle equipment in dienst (ook derden/ communicatie/…)
- Alle test documenten te ondertekenen door alle betrokken partijen
- Logging open issues met prioriteit

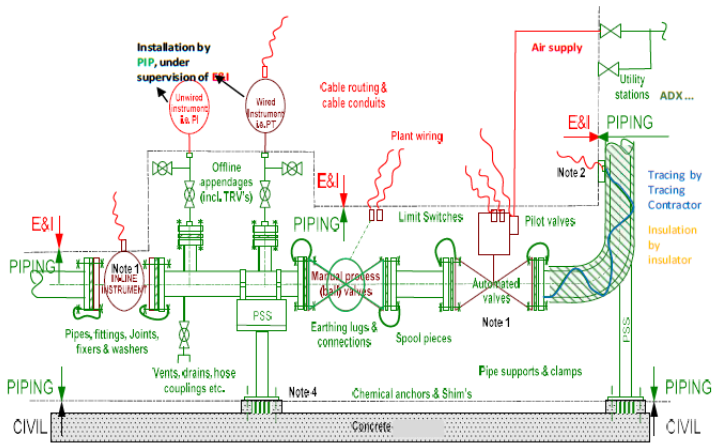
Stap 7 | Installatie, Indienststelling, Validatie

SIL-berekening (validatie)

- Via professionele software (bv. exSILentia)
- Informatie nodig om SIL-berekening op te stellen
  - Safety certificaten/betrouwbaarheidscijfers gebruikte componenten
  - OF ervaringscijfers klant (route 2H - architectural constraints)
  - OF generieke cijfers
- Test frequenties
- Proof test coverage
- Mission time
- MTTR
- …

Stap 7 | Installatie, Indienststelling, Validatie

Voorbeeld: Hook-up/ individuele equipment test



Test Procedure

Pressure transmitter test and configuration	Result	Remarks
Visual test PT housing is not damaged	OK	
Visual test Manifold is not damaged	OK	
Visual test process tubing is not damaged	OK	
Visual test Gland is not damaged	OK	
Visual test Gland is tightly secured	OK	
Visual test Cable is not damaged	OK	
Visual test Tagnumber on instrument	NOK	GEEN GELE ACHTER
Visual test Tagnumber on cable	NOK	NIET AAWEZIG GROEN
Note calibrated range of instrument	0 - 100 bar	RODE TAG OP MANIFOLD
Note output range of instrument	4 - 20 mA	ONTBREEKT
Calibrated range is according to calibration sheet	OK	
Calibrated range is according to RATS list	NOK	
Burn out is correct configurated for instrument, value = 22,10	HIGH	
Manifold of instrument is closed to process and opened to vent	V	
Pressure tester is connected to correct test connection of manifold	V	
Pressure tester is set to minimum range 0% => Range on SCADA is minimum 0% EU range. 0 bar	0,07 bar	
Pressure tester is set to range 25% => Range on SCADA is 25% EU range. 5 bar	5,03 bar	
Pressure tester is set to range 50% => Range on SCADA is 50% EU range. 10 bar	10,03 bar	
Pressure tester is set to range 75% => Range on SCADA is 75% EU range. 12 bar	12,11 bar	
Pressure tester is set to range 100% => Range on SCADA is 100% EU range. 10 bar	10,03 bar	
Pressure tester is set to range 75% => Range on SCADA is 75% EU range. 5 bar	5,13 bar	
Pressure tester is set to range 50% => Range on SCADA is 50% EU range. 0 bar	0,03 bar	
Pressure tester is set to range 25% => Range on SCADA is 25% EU range.		

Stap 7 | Installatie, Indienststelling, Validatie

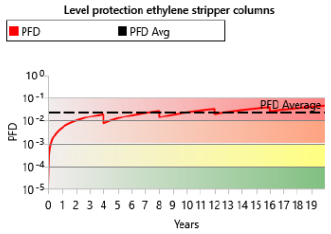
Voorbeeld: Prooftest document /SIL-berekening

Test conditions	:		Checked (OK)
Hardware	:	The cabinet is fully powered up All connections to instruments are done (process, electrical, and air)	Ok
Software	:	Plc and Scada system are running without faults No forcing is active in safety PLC for this safety function No system alarms in safety PLC	OK
Equipment	:	All equipment of safety function is loop tested and functioned correctly	OK
Utilities	:	All utilities are available (air, power, steam, etc…)	OK
Installation	:	The installation is ready for functional test no works on component of safety function are out standing	OK

	Steps (Actions)	Expected test results and acceptance criteria	Success (Y / N)	Log Ref.	Evd. Ref.
[1]	Write down CRC code of safety PLC on this procedure	CRC code = D606DC6	Y		

The SIF operates in the Low demand mode.

Comments:



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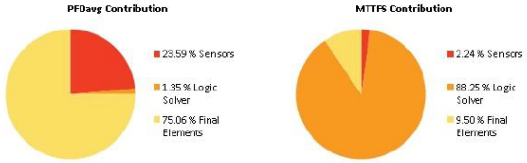
Given the reliability data and SIL verification selections and assumptions described in the subsequent subsections in this report the 8000-SI-003 Level protection ethylene stripper columns Safety Instrumented Function achieves the functional safety performance as displayed in the Functional Safety Performance table.

Table 20 Functional Safety Performance

PFDavg	RRF	Achieved SIL (PFDavg)	Achieved SIL (Arch. Constraints IEC 61508)	Achieved SIL (Systematic Capability)	MTTFS (years)
2.37E-02	42.1	1	1	N/A	8.65



Stap 8 | Uitbating & onderhoud

- Beheer as-built documents
- Beheer proof testen
  - Plannen
  - Uitvoeren (proof test protocols)
  - Archiveren
- Vervangen componenten door identieke component (defect)
  - IO-test van vervangen component
  - Controle versies/firmware
    - Bij verschil: zie stap 9 (Wijziging)

Stap 8 | Uitbating & onderhoud

Voorbeeld: Proof test document/ equipment testdocument

[2]	Put function in not activated state (No LSH activated) • LSH-1140-SIS no alarm No push button activated • HSE-1170-SIS no alarm Logged in as operator in SCADA	• EEV-1105-SIS : OPEN • No lamps lit on block L1 on ESD panel • Buzzer off on ESD panel • No alarm on SCADA • No colouring of box on main overview (grey) • No colouring of box on detail view (grey) • No colouring of flag on detail view (white)	OK	①	
[3]	No bypass is activated • HSE-8141-1-SIS not on • Bypass on SCADA not on	• EEV-1105-SIS : OPEN • No lamps lit on block L1 on ESD panel • Buzzer off on ESD panel • No alarm on SCADA • No colouring of box on main overview (grey) • No colouring of box on detail view (grey) • No colouring of flag on detail view (white)	OK	①	
[4]	Put level switch in alarm and time the closing time of the valve ECV-1105-SIS • LSH-1140-SIS alarm	• EEV-1105-SIS : CLOSED • Closing time valve is between 1 and 60s • Closing time of ECV-1105-SIS : 57 • Red lamp lit on block L1 on ESD panel • Buzzer on ESD panel ON • Alarm LSH-1140-SIS on SCADA • Colouring of box on main overview (Red) • Colouring of box on detail view (Red) • Colouring of flag on detail view (Red)	OK	①	

Area	..... GL	SIS-System	~~9000-XC-6150-SIS~~ / 9000-XC-8250-SIS
Location	.....	Description	.....
Tagnumber	P-12.03-1.0-STOP-2-SIS		
Function	Digital Output interface relay		

UA VERVANGEN DOOR SPARE

Test Procedure

Stop signal to motor/VSD	Result	Remarks
Visual test interface relay is not damaged	OK	
Visual test interface relay wires are not damaged	OK	
Visual test interface relay wires are tightly fastend	OK	
De-activate the interface relay (correct output = "0")	OK	
De-energize the contact circuit (MCC de-activate the breaker of the control loop)	OK	
Test there is no voltage over terminal 7 and terminal 6	OK	
Put measuring equipment on continuity	OK	
Measure between terminal 7 and 8 => continuity (fuse relay is ok)	OK	
Measure between terminal 7 and TP1 => no continuity (internal relay K1 is open)	OK	
Measure between terminal TP1 and TP2 => no continuity (internal relay K2 is open)	OK	
Measure between terminal TP2 and 6 => no continuity (internal relay K3 is open)	OK	

Stap 9 | Wijziging

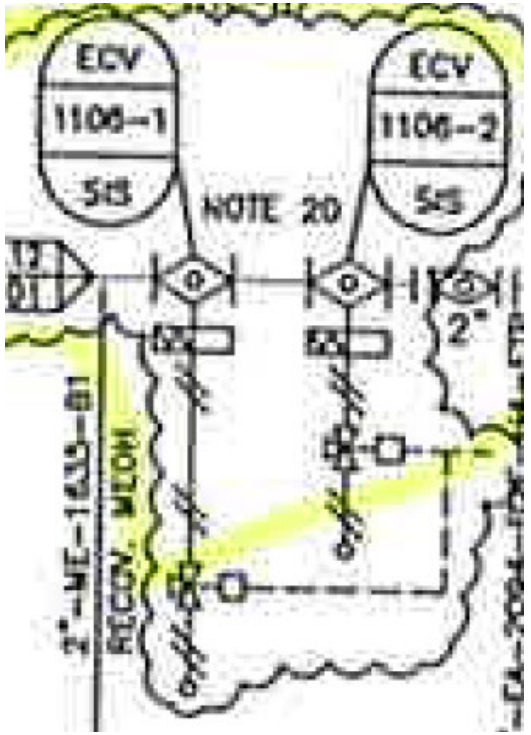
- MOC uitvoeren (risico-analyse vereist of niet)
- Goedkeuring en verificatie alvorens de wijziging uit te voeren (Audit)
- Elke wijziging te beschouwen als project (stap 1 t.e.m. stap 8), met aandacht voor versiebeheer
- MOC bepaalt welke stappen van toepassing zijn voor de wijziging
- Toelating voor aanpassing aan SIS in bestaande installatie (specifieke procedure/vergunning voor wijziging aan SIS)

Stap 9 | Wijziging

Voorbeeld: document versiebeheer/ P&Id

Revision history

Version	Date	Author	Details
1.0	Feb 2016	NP	First issue
2.0	May 2016	NP	After discussion with client
3.0	July 2016	NP	Update with information from Sweco
4.0	August 2016	NP	Update after internal testing and FAT and with addition of appendix of Sweco
5.0	March 2016	NP	Update Appendix Sweco
6.0	August 2019	NP	Update after FAT 8000-SI-011 (same sensors) Discrepancy alarm against median of 3 sensor and not each other



Stap 9 | Wijziging

Voorbeeld: document voor aanpassing / documentwijzigingen oud-nieuw S-PLC programma

Tags:	LT-1124
Identificatie safety PLC:	8000-XC-8150-SISL1
Omschrijving van aanpassing:	RANGE AANPASSEN ⇒ 0-54 mBAR
MOC van desbetreffende aanpassing (referentie):	16 00 65 LT-1124-SIS LEVEL AANPA
Risicoanalyse (referentie):	NO
Operationele Impact van aanpassing:	→ ALARMEN OP DCS
Mogelijke risico's en maatregelen tijdens de uitvoering van de werken	→ ALARMEN OP DCS → FOUT OP SIS PLC.
Fall back scenario:	OUDE RANGE
Bypass procedure van toepassing: J (N)	-
Systeemalarmen aanwezig: J (N)	-

Name	Description	CRC DL	Version DL	CRC CG	Version CG	CRC Comparison
/sys/fm.config	License	16#2cb07810	V2	16#2cb07810	V2	ok
/sys/lc.config	Logic Solver Configuration	16#6c074ed	V3	16#690e0dc5	V3	-
/sys/fs/Program.config	Program Parameters	16#7c7f5913	V3	16#74f2ce44	V3	-
/sys/fs/Program.bin	Program Binary File	16#5e0d88e	V2	16#5a80bbc5	V2	-
8000-SI-001	Function Block Type FBD	16#79800b05	V2	16#79800b05	V2	ok
8000-SI-001 diagnostic I Air	Function Block Type FBD	16#8c754729	V2	16#8c754729	V2	ok
8000-SI-002	Function Block Type FBD	16#2635c16f	V2	16#2635c16f	V2	ok
8000-SI-003	Function Block Type FBD	16#f5f7dad8	V2	16#f5f7dad8	V2	ok
8000-SI-004	Function Block Type FBD	16#3c365216	V2	16#3c365216	V2	ok
8000-SI-005	Function Block Type FBD	16#4ca3bd90	V2	16#4ca3bd90	V2	ok
8000-SI-006	Function Block Type FBD	16#7443c6e2	V2	16#7443c6e2	V2	ok
ARRAY_5xWORD	Array	16#5291d9c5	V2	16#5291d9c5	V2	ok
ARRAY_10xINT0RD	Array	16#315a3203	V2	16#315a3203	V2	ok
ARRAY_20xINT0RD	Array	16#ad80d2a	V2	16#ad80d2a	V2	ok
ARRAY_32xINT0RD	Array	16#a321d5dd	V2	16#a321d5dd	V2	ok
ARRAY_35xINT0RD	Array	16#96c7ccc0	V2	16#96c7ccc0	V2	ok
ARRAY_39xINT0RD	Array	16#a723c819	V2	16#a723c819	V2	ok
ARRAY_69xINT0RD	Array	16#b0efa2e5	V2	16#b0efa2e5	V2	ok
COMM_DCS	Function Block Type FBD	16#8e94bd13	V2	16#8e94bd13	V2	ok
FB_DI_SCADA	Function Block Type FBD	16#51114e4f	V2	16#51114e4f	V2	ok
FB_DO_SCADA	Function Block Type FBD	16#1d80ad4d	V2	16#1d80ad4d	V2	ok
FB_FDB_CHK_PC	Function Block Type FBD	16#4988cae	V2	16#4988cae	V2	ok
FB_FDB_CHK_PLC	Function Block Type FBD	16#9e866bca	V2	16#9e866bca	V2	ok
FB_MOTOR1_CHK	Function Block Type FBD	16#dc615700	V2	16#dc615700	V2	ok
GENERAL L1	Function Block Type FBD	16#4e7f15e4	V2	16#4e7f15e4	V2	ok
Global Variables	Global Variables	16#9a8061dd	V2	16#9a8061dd	V2	ok
ILK-1113/ILK-1105	Function Block Type FBD	16#ec3a2a88	V2	16#ec3a2a88	V2	ok
L1_Evaporators	Function Block Type FBD	16#17d6f3b9	V2	16#17d6f3b9	V2	ok
L1_Main_Process	Function Block Type FBD	16#5c37bbca	V2	16#c0072317	V2	-
L1_MaDAC_Recov	Function Block Type FBD	16#7e1ef439	V2	16#7ba1cf98	V2	ok
L1_MeOH_Recov	Function Block Type FBD	16#780c1b5d	V2	16#780c1b5d	V2	ok
L1_VAC_Recov	Function Block Type FBD	16#f1d49dc6	V2	16#f1d49dc6	V2	ok
Program	Program	16#413894f7	V2	16#413894f7	V2	ok
SYSTEM_HW	Function Block Type FBD	16#146d50e9	V2	16#146d50e9	V2	ok
SYSTEM_SW	Function Block Type FBD	16#4354826f	V2	16#4354826f	V2	ok
X_Bool_8	Function Block Type FBD	16#4005e5e8	V2	16#4005e5e8	V2	ok
X_BoolToWord	Function Block Type FBD	16#a240ed95	V2	16#a240ed95	V2	ok
X_BytsToBool	Function Block Type FBD	16#a046a715	V2	16#a046a715	V2	ok
X_Debounce	Function Block Type FBD	16#e4f240ae	V2	16#e4f240ae	V2	ok
X_Flasher	Function Block Type FBD	16#775cb198	V2	16#775cb198	V2	ok
X_Hz_AI	Function Block Type FBD	16#35628f27	V2	16#35628f27	V2	ok
X_LimH	Function Block Type FBD	16#b09e00c3	V2	16#b09e00c3	V2	ok
X_UTC	Function Block Type FBD	16#80541095	V2	16#80541095	V2	ok
X_WordToBool	Function Block Type FBD	16#48d65058	V2	16#48d65058	V2	ok
/sys/fs/Program_force.config	Application Force Data	16#c658d7c5	V2	16#c658d7c5	V2	ok
/sys/fs/Program_retain.config	Application Retain Data	16#2d12bc54	V2	16#2d12bc54	V2	ok
/sys/pp.config	Configuration Connections	16#ff533379	V4	16#ff533379	V4	ok

Stap 10 | Einde uitbating uitrusting

Deze stap kan gezien worden als een wijziging met enkele extra aandachtspunten

- *Verwijzingen naar obsolete documenten*
- *Gemeenschappelijk gebruikte software (deel)programma's*
- *VOID-aanduidingen indien documenten niet worden verwijderd*

Stap 10 | Einde uitbating uitrusting

Voorbeeld: VOID-aanduiding SRS

4.1 Level protection Vac receiving tank

This SIF is taken out of service in September 2016

Key word	Description/value
Function typical	8000-SI-006
Function description	If the level in the Vac receiving tank is too high, the supply valve to the tank is closed
Safe state	Supply valve to Vac receiving tank is closed.
Possible influence on other process parts of safe state	» Supply of Vac is stopped (1 day buffer) » Pumping against closed valve (pump is equipped to run against closed valves) » Water hammering
Permissible response time	60s

Vragen?

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