



Event driven maintenance for IEC 61850 Substations

Periodic comparison of GOOSE data flow and of automatic post-fault analysis results

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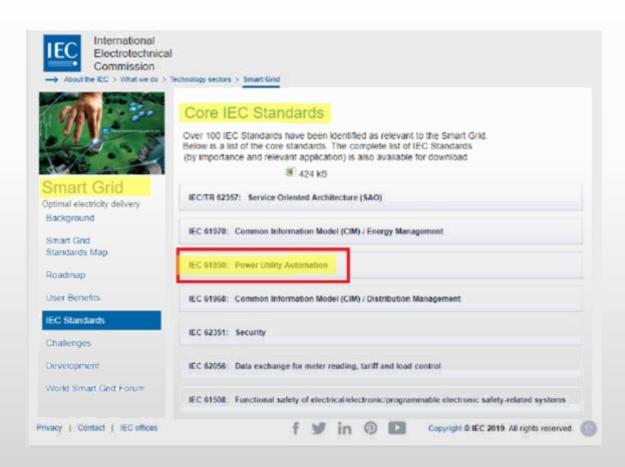






IEC 61850 – Standardized Digital Power System Technology – Smart Grid

IEC 61850 has to do with the standardized digitalisation of the electrotechnical technology -> Smart Grid



IEC 61850 is one of the core standards for Smart Grid, according to IEC





How to address a new technology?

When using a new technology ...





... the methods and procedures used in the past cannot always be directly extrapolated from the new technique...

... The new methods will allow to achieve the same goals of the previous methods (routines)...

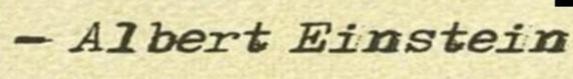
... it is necessary to understand the purpose of the previous procedures...

... and see how the new technique can be used to get the same purpose.



How to address a new technology?

If you always do what you always did, you will always get what you always got.

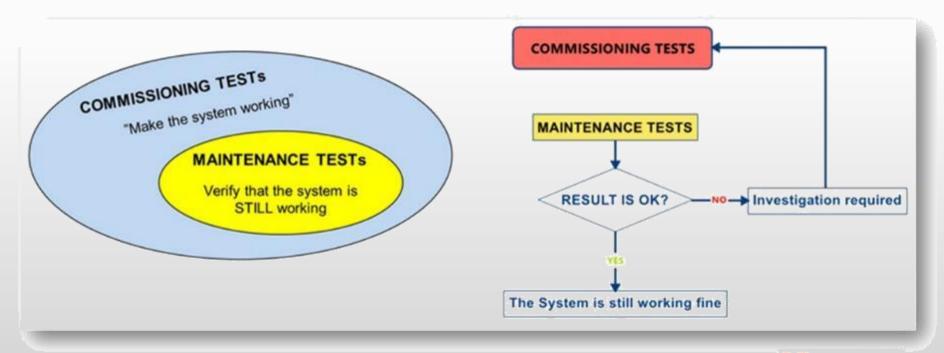




Purpose of Commissioning / Maintenance Tests

Commissioning tests are performed to set-up the system until its functionality is confirmed.

Maintenance tests are to verify that the system is still running correctly and are therefore a more restrictive subset of the commissioning tests.





20 To 22 How can we verify that the system is LYON "still running well"?

The IEC 61850 system is a (standardized) numerical system...





...it makes sense to use the numerical technology to get information about the status of the system and to get solution to assess the status.



Non-Invasive comparison actions

Compare the previous proven correct status of the system with the current "unknown" status





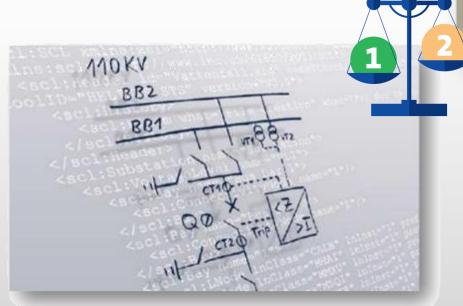
the key is to SELECT the parts of the system that are able to give a reasonable representation of its status.



Compare GOOSE traffic with its SCD description

SENTORARE,COM

Compare the GOOSE traffic





with its description on the substation master SCD file.



Multimeter yesterday GOOSE sniffer tomorrow

Conventional Multimeter

IEC 61850 GOOSE sniffer







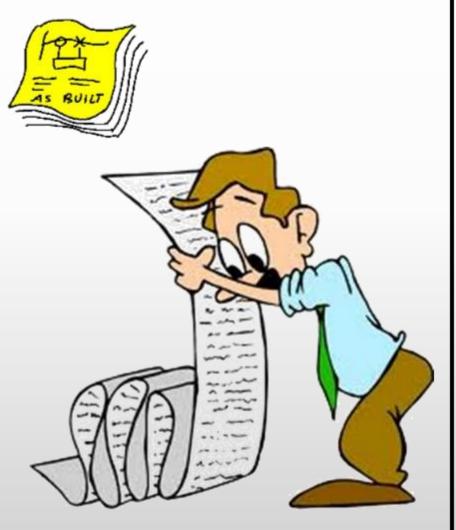






"as built drawing" yesterday SCD file tomorrow

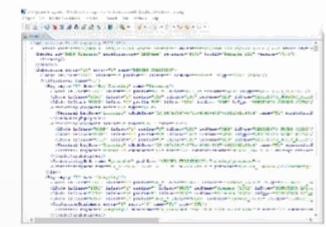
Reading the "as built" drawing

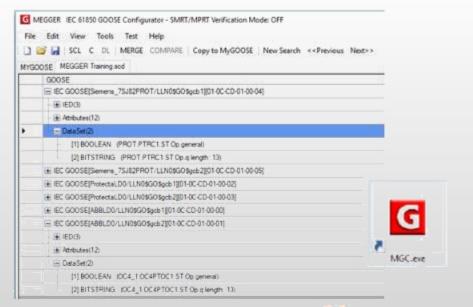


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Reading the "as built" SCD file









How it works in practice: TODAY!

"Reading the network" IEC 61850 GOOSE sniffer

MYGOOSE Digital Capture Viewer Capture GOOSE ■ IEC GOOSERS RILDOLLNOSGOSociA S POSTO1-0C-CD-01-00-017 # IEC GOOSE|L5 R1LD0LLN08G08gd8 S_POS[01-00-0D-01-00-02] ₩ IEC GOOSERS, R2LDOLLNOSGOSqxbGOOSE, ALBLK, START(01-00-03) WIEC GOOSEILS RILDOLLNOSGOSpeaA S POSIDI-0C-CD-01-00-04] #IEC GOOSEJLE R1LD01LN0\$GO\$ub8 S POSJ01-0C-CD-01-00-05] # IEC GOOSEILE R2LDOLLNOSCOSpcbGOOSE AL BLK_START[01:00:00:01:00:08] # IEC GOOSETTI FILDOLLNOSGOSocbA_S_POS[01-0C-CD-01-00-07 ■EC GOOSEIT1 R1LD0/LLN05GOSoctB S POSI01-0C-CO-01-60-08 EC GOOSEITI_RILDO/LLN0\$GO\$qcbVCTRij01-0C-CD-01-00-09 ■IEC GOOSETT R2LD0LLN05G05qtbLOCK_T1_130_SUB2_PHHFT0[61-0C-CD-01-00-10] # IEC GOOSEIT2 RILDUILLN05GOSocbA S POSI01-0C-CD-01-00-TI ⊞IEC GDOSEIT2 RILDOLLNOSGOSactB S POSB01-0C-CD-01-00-12 # IEC GOOSEIT2 R2LD04LN05GOSqxb8LOCK_T2_130_SUB2_PHHFT0]01-0C-CD-01-00-140 ₩1EC GOOSEIN1_R1LD0LLN0\$GOSgdrOC_BLOCK[01-9C-CD-91-90-15] RIEC GOOSEN2_RILDOLLNOSGOSocbOC_BLOCKTEDT-0C-CD-01-00-160 ■ IEC GOOSEIL 19 FILDUILL NOSGOSuchA S POSII01-00-00-01-00-22 # IEC GOOSEIL19 R1LDBLLN05GOSoct8 S POS[01-00-00-01-00-23] # IEC GOOSEIL19: R1L001LN05GO5acbb63E01-0C-CD-01-00-24E # IEC GOOSEIL 19_RTLD01LN0\$GO50cbPHASESELECTION[01-0C-CD-01-00-25] ₩ IEC GOOSEIL19 F2L80(LN0\$GO\$ocbbk3@1+0C-CD-81-00-26) ★ IEC GOOSEE 19 R2LD0 LLN05GOSqcbGOOSE_AL_BLK_START[I01-0C-CD-01-00-27] ■ IEC GOOSER 19 R2LD0/LEN05GOSocbPHASESELECTION[01-0C-CD-01-00-28] # IEC GOOSEIL9_R1LD0/LIN0\$GOSqcbA_S_POS[[01-00-01-00-28]] # IEC GOOSEIL9 RILDULLNOSGOSocial S POSII01-0C-CD-01-00-30! # IEC GOOSEIL9_R TLDO/LLN05GOSqcbbli3[01-0C-CD-01-00-31] ■ IEC GOOSEJL9_R1LD01LN0\$GO5gcbPHASESELECTIONJ01-0C-CD-01-00-32 WIEC GOOSEIL9: R2LD0ILLN0SGOSacbbk3851-0C-C5-01-00-33[■ IEC GOOSER9 R2LD0LLN05GO5qcbGOOSE AL BLK START[01-00-00-01-00-34] # IEC GOOSEIL# ROLDOLLNOSGOSGSPHASESELECTION[61-90-05-61-00-35] * IEC GOOSEIL14 R1LDGLLN0SGOSgcbA 5 POSE01-0C-CD-01-00-368 ■ IEC GOOSEJL14 R1LD01LN0\$GO\$qdaB S POSIJ01-0C-CD-01-06-37 ★ IEC GOOSEIL14_R1LD01LN0\$GO\$qubbk3[01-00-01-00-38] ★ IEC GOOSEIL14: R1LD0LLN0\$GO\$gdbPHASESELECTION[01:00:GD:01:00:30] # IEC GOOSEIL14 R2LDQLLN0\$GO\$qubb#3[01-0C-CD-01-00-40] * IEC GOOSEL 14 R2LDGLLN0SG0SgcbG00SE AF BLX :START[I01-0C-CD-01-00-41] ★ EC GOOSEIL14 R2LDOLLNOSGOSgopPHASESELECTION(8) 40C 6D-01-00-42[

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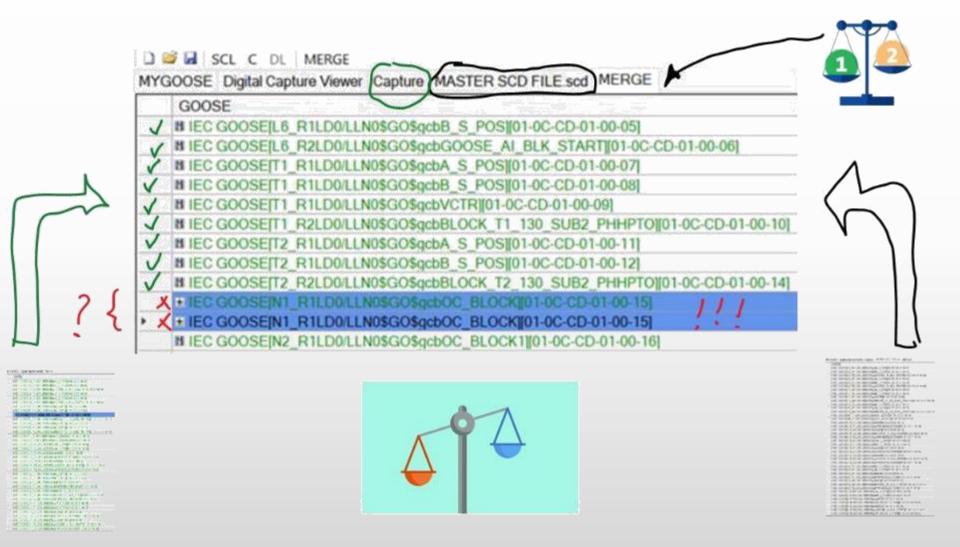
Reading the as built IEC 61850 SCD file

- Day	GOOSE
	# IEC GOOSEES, R1LD0LLN08G08qxbA, S, POSE01-0C-CD-01-00-01[
	* IEC GOOSEILS RILDOLLNOSGOSQUBB S POSITOLOC CD-01-00-021
	# IEC GOOSEILS ROLDGILINOSGOSGOGGOOSE AL BLK STARTIOT-OC-CD-01-00-03
3	# IEC GOOSEJLE R1LDGLLNOSGOSgobA S POSEO1 OC CD-01-00-04]
	# IEC GOOSEJLS_R1LDOLLNOSGOSqubS_S_POSJO1 OC-CD-01-00-05)
	# IEC GOOSEJLS RZLDGŁLNOSOOSgabGOOSE AL BLK STARTJO1-0C-CD-01-06-08]
	# IEC GDOSE[T1_R1LDQLLN0\$GO\$qdbA_S_POS[01-00-01-00-07]
3	# IEC GOOSE[T1_R1LD01LN0\$GO\$qdb8_S_POS[01-00-00-01-00-08]
	# IEC GOOSEJT1_R1LD0LLN05GOSgdtVCTRg01-0C-CD-01-00-00]
3	# IEC GDOSE[T1_R2LD01LN05G05q:b8L0CX_T1_130_SU82_PHHPT0[01-6C-CD-01-60-16
3	# IEC GOOSEJTZ_RTLDOLLMOSGOSQ:bA_S_POSJJ01-0C-CD-01-00-11]
	# IEC GOOSEJT2_R1LD0LLN0\$GO\$gds8_S_POSJJ01-8C-CD-81-60-12J
	# IEC GOOSEJT2_R2LD01LN05GO5g:b8LOCK_T2_130_SUB2_PHHPT0J01-0C-CD-01-00-14
	# IEC GOOSE[N1_R1LD0LLN05GO5gdbOC_BLOCK[J01-6C-CD-01-06-15]
	# IEC GDOSEJI, 16_R1LD0LLN0\$G0\$qxtelk3[j01-0C-CD-01-00-17]
	* IEC GOOSEJL16_R1LD01LN0\$GO\$qcbPHASESELECTION[01-0C-CD-01-00-18]
	# IEC G005Ejt.16_R2LD0LLN05G05gdbbk3jj01-0C-CD-01-06-19j
	* IEC GOOSEJL 16_R2LD01LN0\$GO\$qcbGOOSE_AL_BLX_STARTJJ01-0C-CD-01-00-20J
į	* IEC GOOSEJL18_R2LD01LN0\$GO\$gcbPHASESELECTION[01-0C-CD-01-00-21]
	# (EC GOOSE)L19_R1LD0LLN0\$GO\$qcbA_S_POS(01-0C-CD-01-00-22)
	# IEC GOOSEJL19_R1LD0LLN0\$GO\$qxb8_5_POSJJ01-0C-CD-01-00-23j
	* IEC GOOSEJL 19_R1LD0LLN0SGOSgcbbk3[01-0C-CD-01-00-24]
	* IEC GOOSEIL 19_R1LD0LLN0\$GO\$qcbPHASESELECTION[[01:00:CD:01:00:25]
	* IEC GOOSEJI. 19_R2LD01LN0\$GO\$qcbbik3Jj01-0C-CD-01-00-26J
	* IEC GOOSEJI, 19_RZLDOLLNISGOSgcbGOOSE_AL_BLX_STARTJJ01-0C-CD-01-00-27]
	* IEC GOOSEJL 19_RZLDOLLNOSGOSgcbFHASESELECTION(IO1-0C-CD-01-00-28)
	* IEC GOOSE L9_R1LD01LN08G08g0bA_S_POS 01-0C-CD-01-00-29
	* IEC GOOSE L9 R1LD0LLN0\$GO\$qxb8 S POS 01 0C CD 01 00 30
	* IEC GOOSEJL9_R1LD01,LN0\$GO\$qxtelkJIJ01 0C CD 01 00 31]
	* IEC GOOSEJL9_R1LD0LLN0\$GO\$qubPHASESELECTIONJJ01-0C-CD-01-00-32]
	* IEC GOOSEJL9_R2LD01,LN0\$GO\$qctels/Jg01 8C CD 61-00-33)
	* IEC GOOSEJL9_RQLDOLLNOSGOSgobGOOSE_AL_BLK_STARTJJ01-0C-CD-01-00-34[
	* IEC GOOSEJL9_RZLD0LLN0\$GO\$gdPHASESELECTIONJ01-0C-CD-01-00-35J
	* IEC G005E3L14_R1LD01LN0\$G0\$q:bA_S_P05[[01-00-00-01-00-36]
	* IEC GOOSEJL14 R1LD01LN05GO5qcb6 S_POSJ(01 0C CD 01 00 37)
	* IEC GOOSEJI, 14, R11LD01, LN05GOSgc20003[01-00-00-01-00-38]
	* IEC GOOSEJL14, R1LDOLLNOSGOSGOPHASE SELECTIONIJO1 OC CD-01 00:39J
	IÉC GOOSEJI, 14 RZLDOLLNOSGOSqcbckOJJ01 OC CD-01 00-40;
	* IEC GOOSEJL14_RZLDOLLNOSGOSGOGOOSE_AL_BLX_STARTJO1-0C-CD-01 ***
	* IEC GOOSER 14 RZLDOLLNOSGOSGOGOGOSE AL BLK, STARTROLOC CD-01 ** ** * IEC GOOSER 14 RZLDOLLNOSGOSGORHASESELECTIONROLOC CD-01 80-4



How it works in practice: TODAY!

Comparing (MERGING) "SCD GOOSE" with "Sniffed/scanned" GOOSE

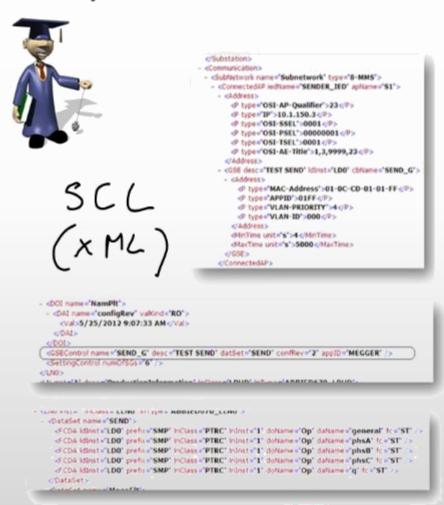




How it works in practice: TODAY!

Manual comparison of traffic (Wireshark/Ethereal) with XML (SCL) is too difficult and requires too much competence





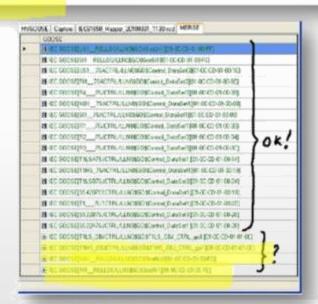


First comparison at FAT / SAT



Example of IEC 61850 FAT where the MERGE algorithm has been used

Αı	nnex2. Analysis of the SCD file for the معمودة substation ("IEC61850_السهر ما معمودة المعالمة على المعالمة ا
	Annex2, Point 1. Verify that the substation file (SCD) contains all the installed IEDs
	Conclusion (actions needed)25
	Annex2; Point2: Verify that all GOOSE messages available on the SCD file are also available "online" on the network
	Conclusion (actions needed)



Conclusion (actions needed).

The GOOSE engineering for the IEDs "N01_L, 1" and "RI1_L, 1" is missing in the SCD file and it should be added.

For the $\frac{c}{2} = \frac{c}{2} = 1$ IEDs nothing can be said as their description is corrupted in the xml file itself. Anyway there are two $\frac{c}{2} = \frac{c}{2} =$



Maintenance tests: Identification of differences in the GOOSE traffic

Identified issues so far with the (manual) merge/compare algorithm:

- ETH Switch replaced with wrong settings. Wrong VLAN settings. Some GOOSE disappeared (more black than green) and some GOOSE dropped (lost) their VLAN tag.
- IED reconfigured and differently engineered Some green GOOSE didn't get merge because of different CONFIG REVISION
- IED out of service or disconnected Some green GOOSE disappeared
- New IED inserted Some new green GOOSE appeared, SCD file has not been updated





Disturbance recording and data collection

Disturbance recorder files from protection devices and/or dedicated devices are becoming more and more important in power system operation and maintenance.

A systematic post-fault or post-event analysis allows to:

- Detect incorrect relay settings and give facts supporting their improvement
- Verify relay coordination
- Verify relay performances
- Determine the position of the fault (fault location)
- Perform asset condition monitoring

Retrieving the disturbance files has been a complex task in the past: proprietary vendor software was necessary to retrieve the information, proprietary communication protocol, lack of fast and reliable communication structure to transmit the disturbance files to a central location...



IEC 61850 provides Easier access to data for Post-Fault Analysis!

Thanks to the IEC 61850 standard today:

We know the communication protocol for file transfer (FTP or MMS)

We know how to communicate (Ethernet, 100 Mbit/s or 1 Gbit/s)

We know how the files look like (COMTRADE)

We **know where the file are stored** in the IEDs (folder /COMTRADE)

COMTRADE:

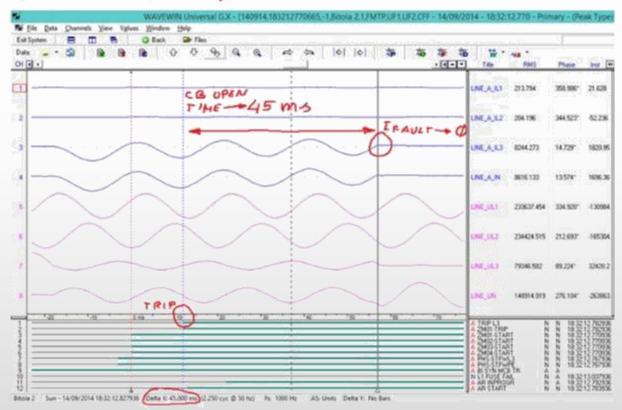
COMmon format for TRansient Data Exchange for power systems





Asset condition monitoring CB Operating time

Considering some 3...4 ms for the TRIP binary output to close, we can reasonably state a circuit breaker opening time of approx. 40 ... 41 ms (at least <= 45 ms).



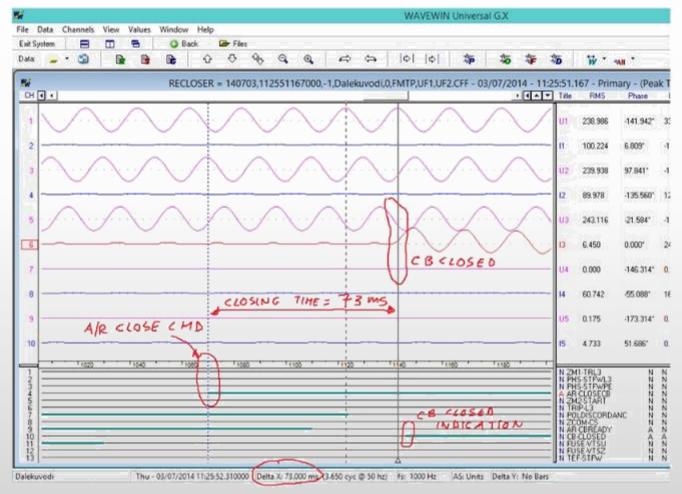






20 to 22 Asset condition monitoring **CB Closing Time**

Let's measure the time from when the autorecloser CLOSE command is issued to when the circuit breaker has closed...





DFR Courtesy of





Asset condition monitoring CB Operating time



EXAMENSARBETE INOM ELEKTROTEKNIK, GRUNDNIVÅ, 15 HP STOCKHOLM, SVERIGE 2019

Automatic post-fault analysis is one important contribution to maintenance routines.

Automatic post-fault analysis based on disturbance data stored in substation devices Automatisk analys av felhändelser baserad på störningsdata lagrad i ställverksenheter

Approach towards the preventive maintenance Tillvägagångssätt för förebyggande underhåll

MIROSLAV UROSEVIC

RIAD YALDA

We have the data, let's put resources on analyzing it!





Automated reading of COMTRADE files

- Multiple files for the same disturbance (configuration and data)
- Several versions of COMTRADE standard
- Data files in both ASCII and binary format

Configuration file

```
Station 1,1,2013
10,7A,3D
1,INE_A_ILI,,, A,0.230458300000,0.0,0.0,-99998,2.0000000+0001,0000000+000,P
2,LINE_A_ILI,,, A,0.022459250000,0.0,0.0,-99998,2.00000000+0001,0000000+000,P
3,LINE_A_ILI,,, A,0.021235850000,0.0,0.0,-99998,2.0000000+003,1.0000000+000,P
4,LINE_A_IN,,, A,0.218090100000,0.0,0.0,-99998,99998,2.0000000+003,1.0000000+000,P
5,LINE_ULI,,, V,3.244896000000,0.0,0.0,-99998,99998,1.0000000+003,1.1000000+002,P
6,LINE_ULI,,, V,3.28785000000,0.0,0.0,-99998,99998,4.0000000+005,1.1000000+002,P
7,LINE_UL3,,, V,3.212939000000,0.0,0.0,-99998,99998,4.0000000+005,1.1000000+002,P
1,PMS-STFWL1,,,0
2,PMS-STFWL2,...0
3,PMS-STFWL2,...0
3,P
```

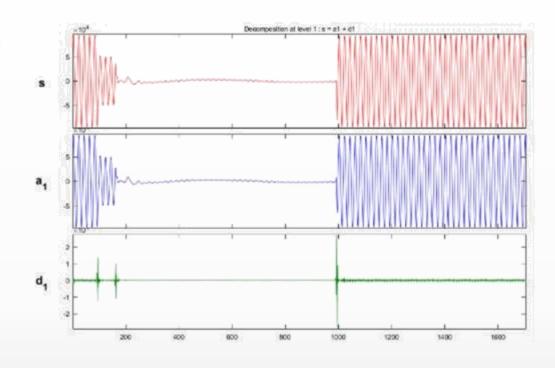
Data file

```
1,0,8965,-62316,-31781,-36,93572,-73193,-17368,0,0,0
2,1000,9112,-37506,-59397,-14,99558,-50577,-47178,0,0,0
3,2000,8340,-8860,-81030,12,95795,-23074,-72432,0,0,0
4,3000,6749,20605,-94751,28,82603,6888,-90591,0,0,0
5,4000,4482,48183,-99544,6,61234,36040,-99857,0,0,0
6,5000,1777,71171,-94494,6,33862,61757,-99350,0,0,0
7,6000,-1082,87244,-80043,43,3173,81428,-89112,0,0,0
8,7000,-3857,94661,-57667,52,-27906,93146,-70068,0,0,0
9,8000,-6271,92648,-29603,28,-56180,95787,-44200,0,0,0
10,9000,-8077,81589,1254,-8,-79021,89084,-14035,0,0,0
11,10000,-9083,62798,32006,-17,-94267,73625,17529,0,0,0
12,11000,-9209,38079,59878,16,-100297,51090,47400,0,0,0
13,12000,-8429,9363,81794,19,-96505,23457,72664,0,0,0
14,13000,-6825,-20155,95680,25,-83251,-6405,90773,0,0,0
15,14000,-4570,-47604,100283,31,-61959,-35619,100031,0,0,0
16,15000,-1862,-70574,94960,6,-34606,-61271,99533,0,0,0
```



Automated analysis of COMTRADE files

Wavelet transform analysis:



Other algorithms implemented to identify analog "changes": RMS, delta values, zero sequence components etc

- RMS variations
- 2. Phase angle variations
- 3. Sequence components variations

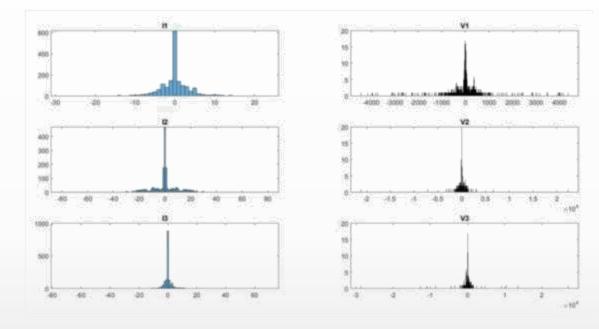




Automated analysis of COMTRADE files

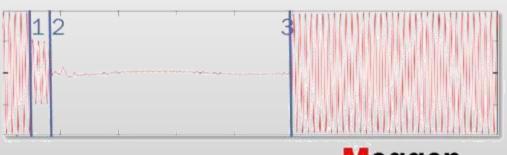
Final fault event points chosen by a probabilistic decision on many

coefficients:



Fault events identified from analog channels:

- 1. Fault start
- 2. Circuit breaker opening
- 3. Circuit breaker closing





Automated analysis of COMTRADE files

Software tested using COMTRADE files from the same substation containing shunt faults on 110 kV transmission lines

Fault date	Relay operate time [s]	Protection chain total operate time [s]	Circuit breaker operating time [s]	Circuit breaker closing time [s]		
Bay Q1 Main protection						
[2018-03-25	0.018	0.068	0.05	0.068		
[2018-8-06	0.018	0.068	0.05	0.078		
[2018-08-07	0.016	0.068	0.052	0.078		
[2018-08-13	0.017	0.068	0.051	0.074		
Bay Q1 Backup protection						
[2018-03-25	0.018	0.078	0.06	0.077		
[2018-08-06	0.018	0.068	0.05	0.078		
[2018-08-07	0.016	0.068	0.052	0.064		
[2018-08-13	0.015	0.068	0.053	0.083		
Bay Q2 Main prote	Say Q2 Main protection					
[2018-08-12	0.017	0.076	0.059	0.077		
[2018-08-12	0.015	0.076	0.061	0.079		
[2018-08-12	0.017	0.068	0.051	0.073		
[2018-08-16	0.014	0.068	0.054	0.075		

Warnings are generated if calculated operate times are above a threshold

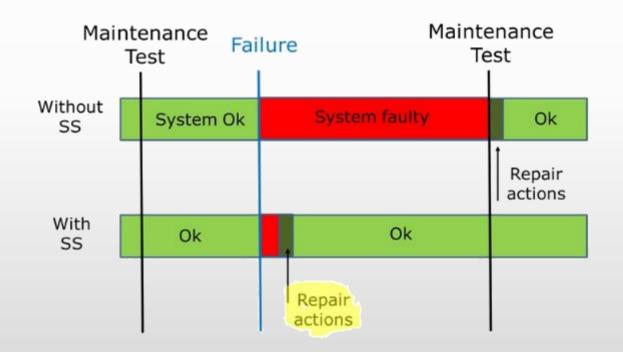
Future goal is to compare the calculated operate times with previously calculated times and generate warnings if there is a substantial difference



The tools need today manual efforts but the concept can be improved and performed automatically, for example once every day...

Reduced MTTR: information about failures in the communication between two particular IED available as soon as the problem occurs

event oriented maintenance





Megger.



Thank you to all of you!

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