Megger

SIEMENS

Closed-loop relay testing with digital twins opens the door for relay engineers

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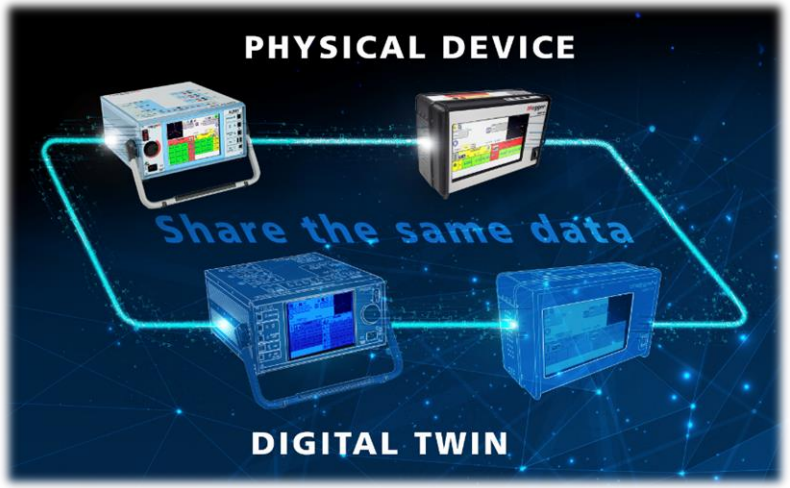
EXPERIENCE THE CONNECTION

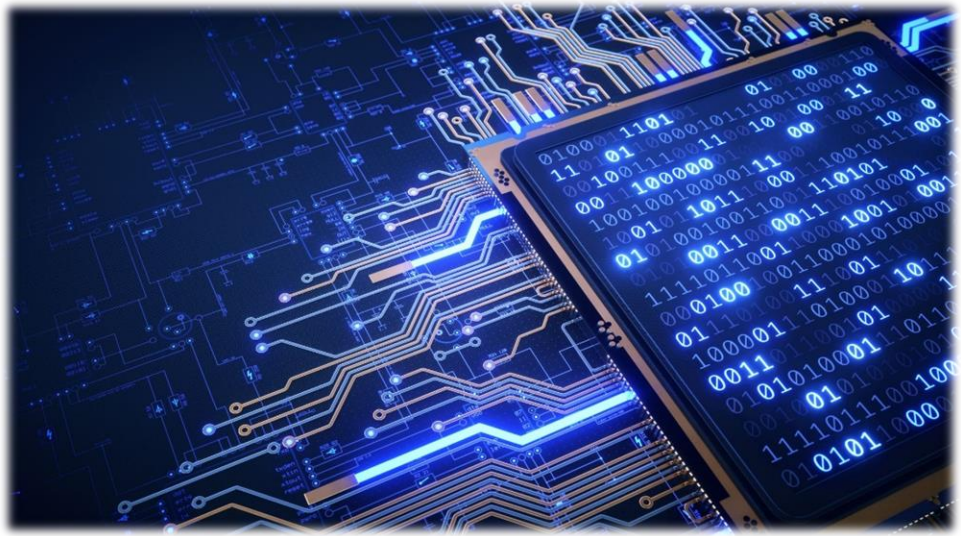
Digital twin definition

- Virtual representation of physical device or process
- Synchronized at a specified frequency and fidelity
  - Real-time and historical data
  - Represent the past and present
  - Simulate predicted futures
- Key elements
  - Share the same data
  - Get the same behaviour



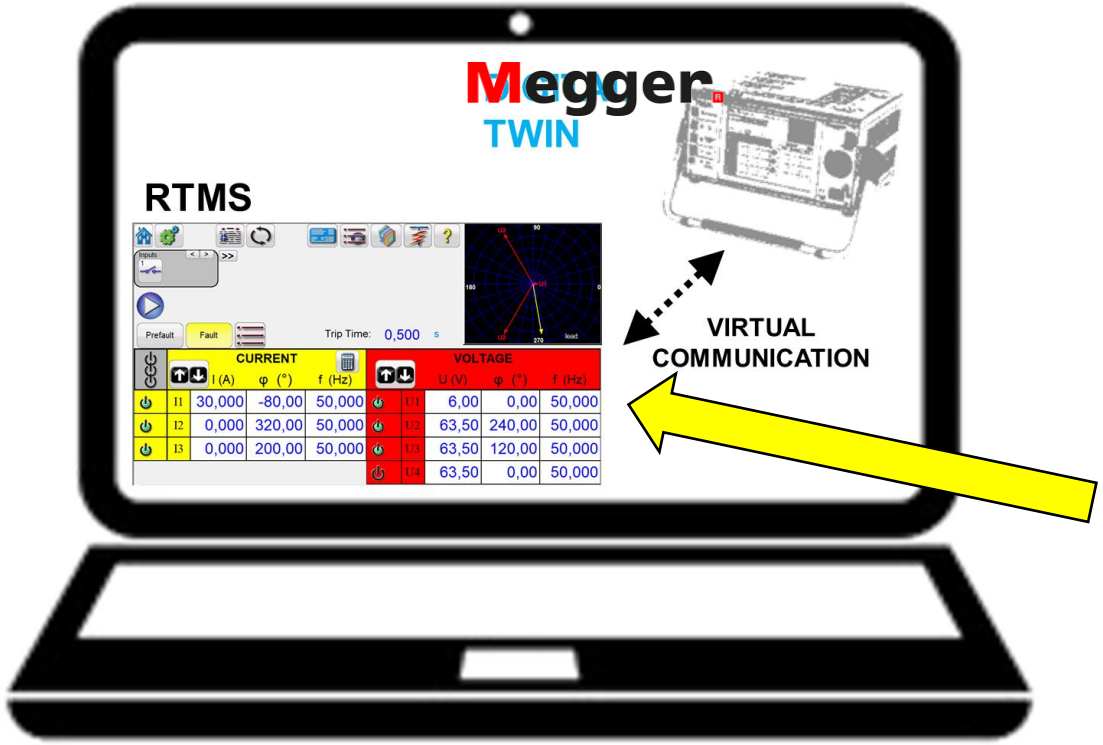
Functional digital twins – High fidelity simulation only by OEM's

- Other simulations in the power industry
  - IEC 61850 – SCL Model simulators
  - IEC 61850 – Simulation of GOOSE and SV
  - Real time power system simulators
- Functional digital twins made by OEM
  - Shared software with physical device
  - Same settings and algorithms
  - Internal hardware processes are simulated
  - Digital twin – functionally type tested



High fidelity simulation only by OEM's

The Megger Digital Twin is a digital replica of a real relay test set with identical behaviour and characteristics



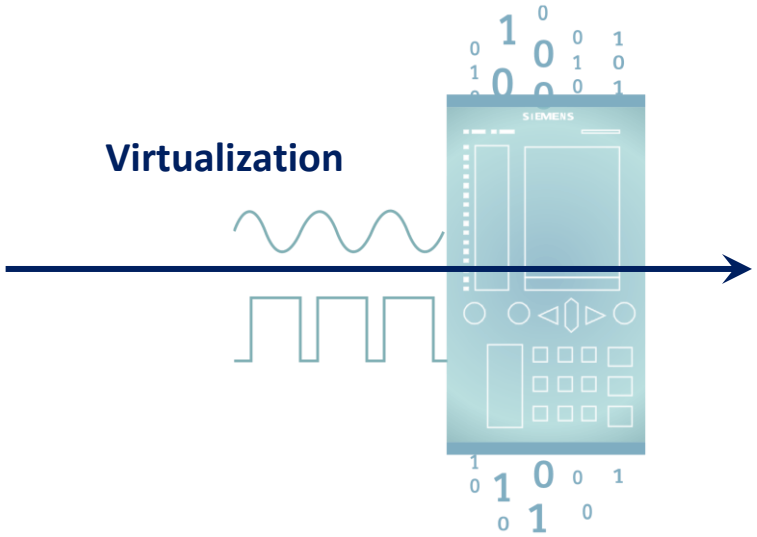
Test set software (RTMS) contains the test to be performed.
It connects to the FREJA 546 Digital Twin test set (in this example)

- Same user interface as conventional testing – the DT test set connects through a virtual Ethernet connection
- The entire real test set is virtualized: FW, algorithms, hardware and software configurations, parameters,…

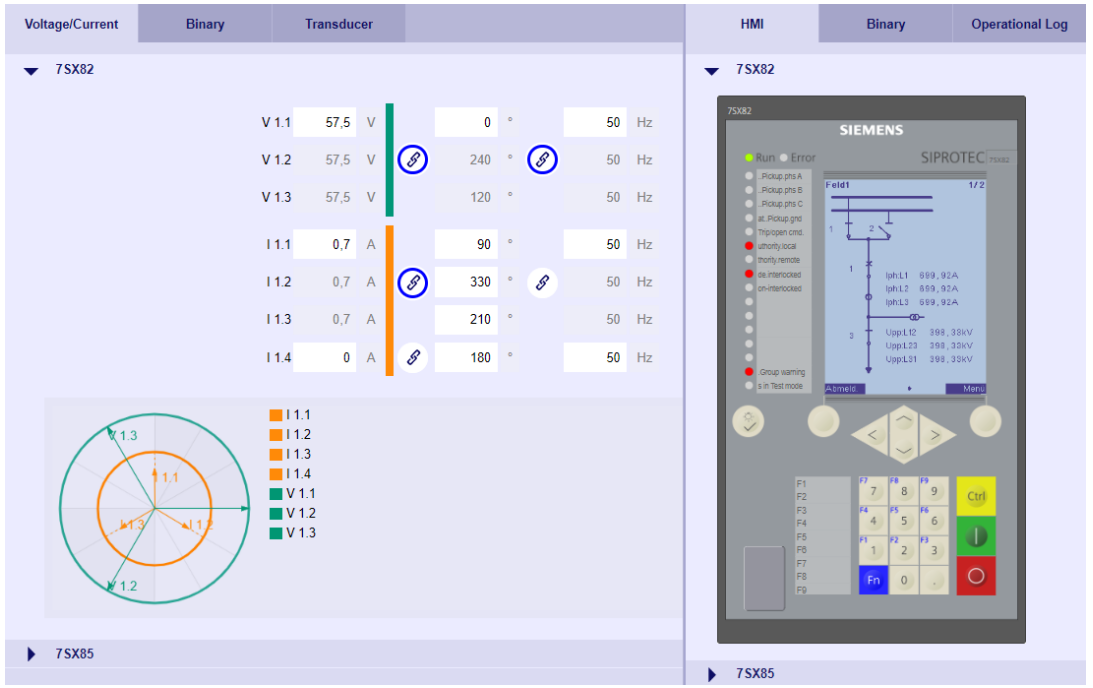
The SIPROTEC DigitalTwin is a digital replica of a real protection relay with identical behavior and characteristics

Real SIPROTEC 5 Relay

Virtualization



SIPROTEC DigitalTwin



- The virtualization process is quick and easy (less than a minute) and requires no additional engineering effort
- The entire real relay is virtualized: FW, algorithms, hardware and software configurations, CFC logics, parameters,…

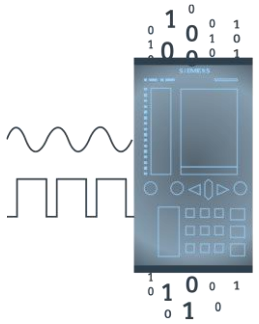
SIPROTEC DigitalTwin – Features and functionalities

SIPROTEC DigitalTwin local control panel (HMI) operates in the same way as the real relay.

Primary devices (Circuit breakers, disconnectors and OLTC) are simulated by SIPROTEC DigitalTwin

In terms of communication, DigitalTwin behaves exactly like the real relay (no difference seen from the communication partner). Supported protocols:

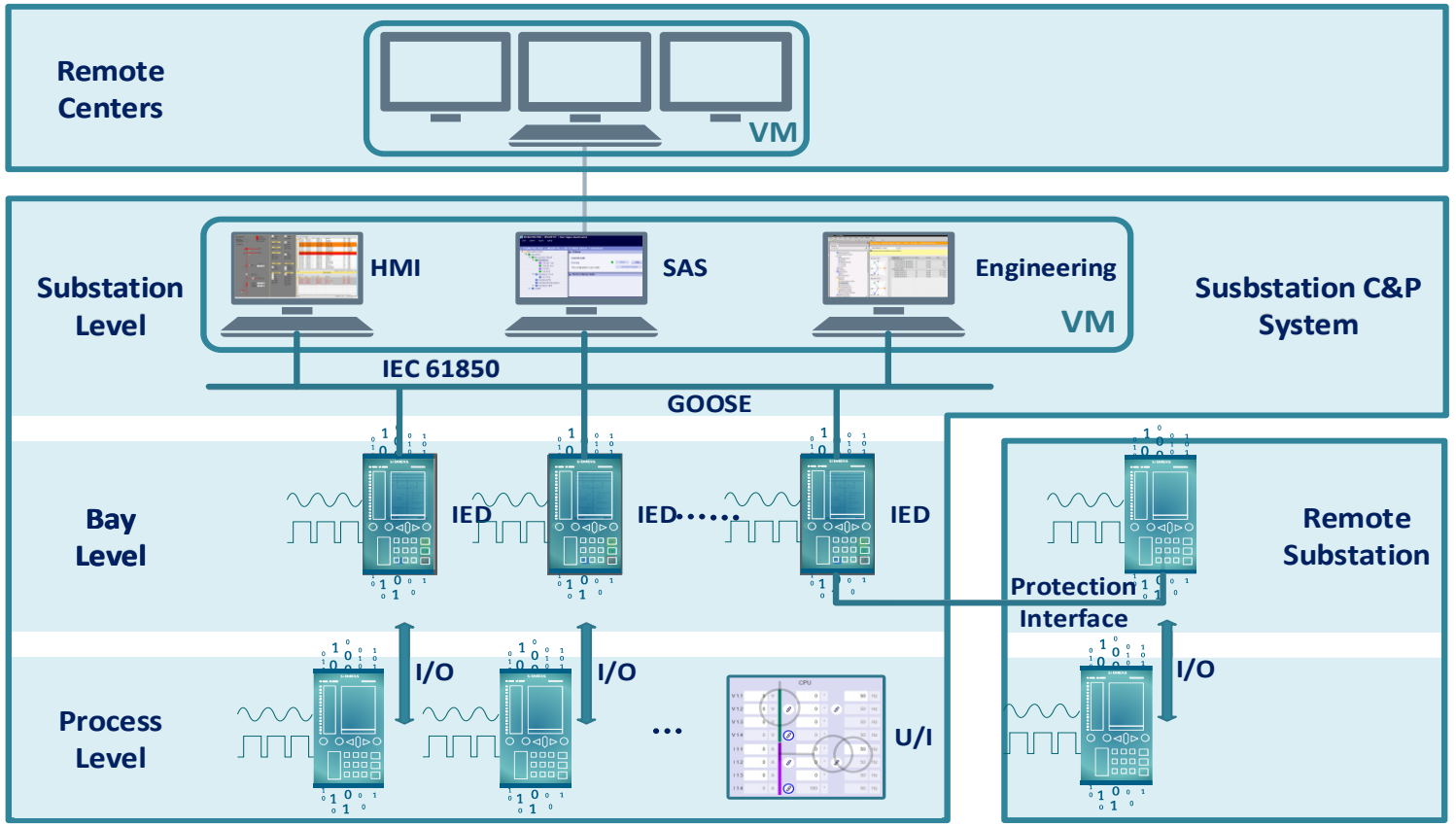
- IEC 61850 (Goose, SV, MMS)
- IEC 60870-5-104
- DIGSI 5, Web browser, Differential Protection Interface
- Modbus TCP, Profinet



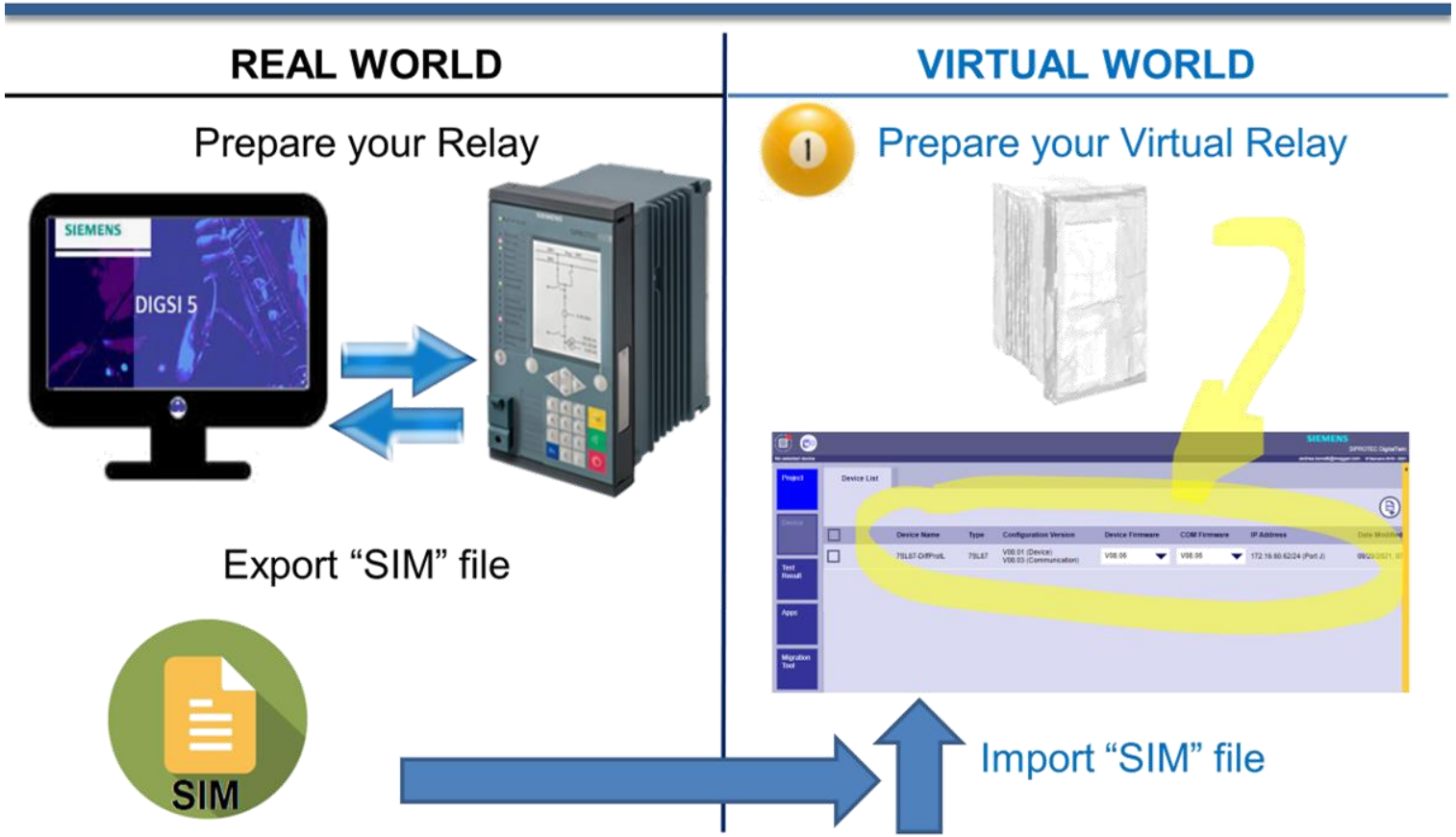
Interaction with the DigitalTwin through a simulation environment allowing:

- Binary Input forcing
- Current / Voltage injection
- COMTRADE file and test sequence replay
- Virtual binary I/O wiring

SIPROTEC DigitalTwin – Virtualized Control and Protection Test platform

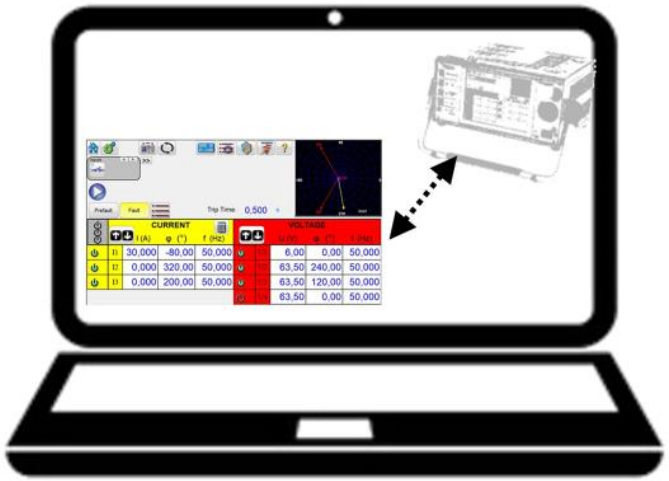


Relay testing – real vs virtual world – step 1



Relay testing – real vs virtual world – step 2

REAL WORLD	VIRTUAL WORLD
Prepare your test,	2 Prepare your test



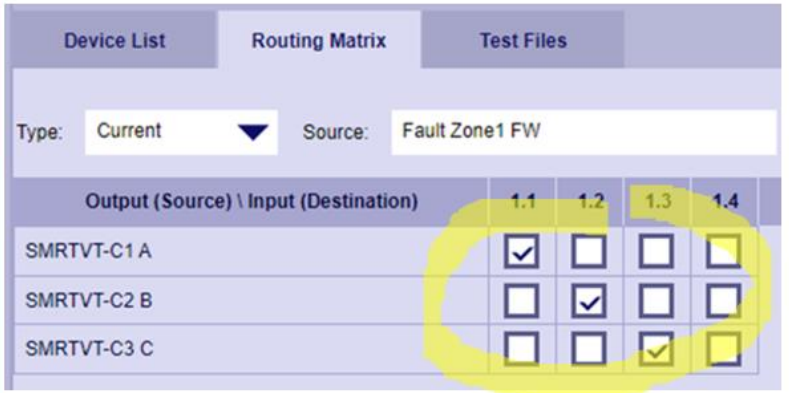
Relay testing – real vs virtual world – step 3

REAL WORLD

Connect relay to the test set

VIRTUAL WORLD

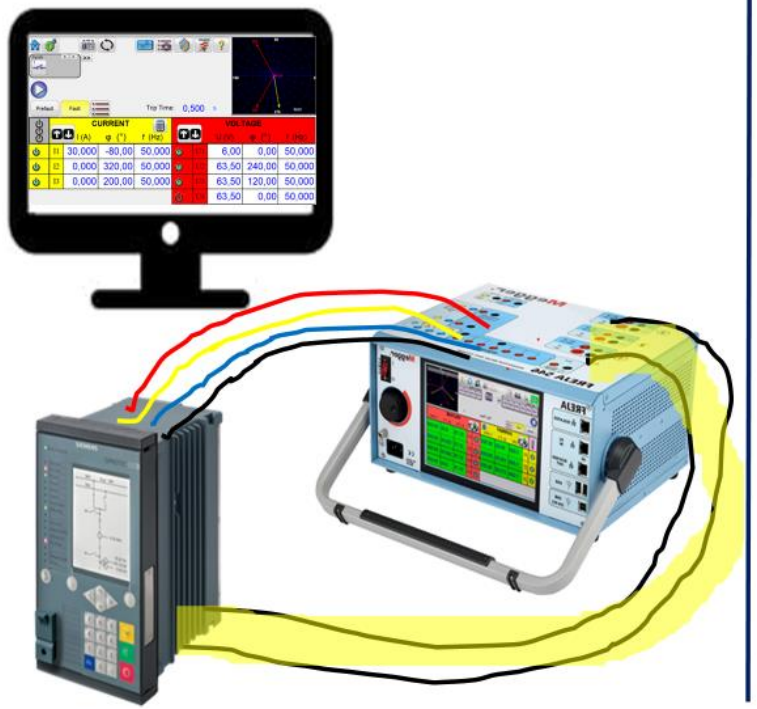
3 MAP the test signals to virtual analog inputs of the relay



Relay testing – real vs virtual world – step 3

REAL WORLD

Connect relay to the test set



VIRTUAL WORLD

3 MAP the relay outputs to the virtual binary inputs of the test set

Device List | Routing Matrix | Test Files | Files for Apps

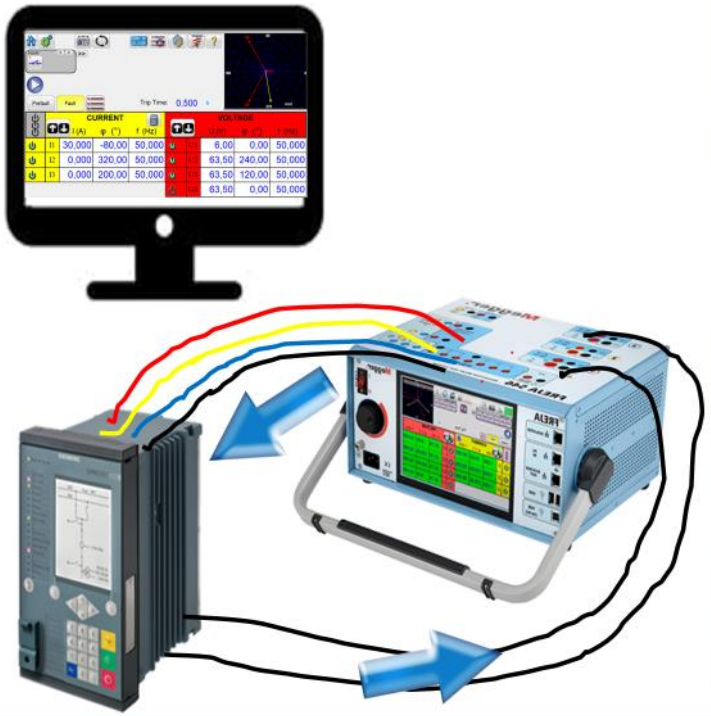
Type: Binary Source: 7SA86 Destination: ApiReferenceFile

Output (Source) \ Input (Destination)	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
BO 1.1 (Trip/open cmd.- U)	☑	☐	☐	☐	☐	☐	☐	☐
BO 1.2 (Line 1.85-21Perm.u	☐	☐	☐	☐	☐	☐	☐	☐
BO 1.4 (Circuit breaker 1.	☐	☐	☐	☐	☐	☐	☐	☐
BO 1.5 (Line 1.Group indica	☐	☐	☐	☐	☐	☐	☐	☐
LifeContact	☐	☐	☐	☐	☐	☐	☐	☐

Relay testing – real vs virtual world – step 4

REAL WORLD

Run the test

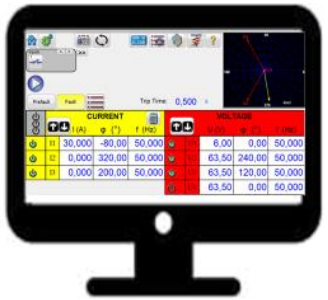
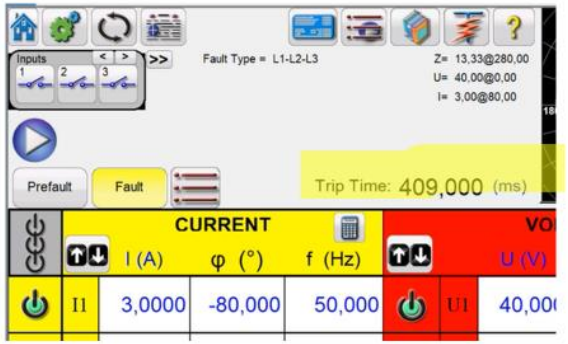


VIRTUAL WORLD

4

Run the test and ask for
“CLOSED LOOP TEST”
From the Digital Twin test set

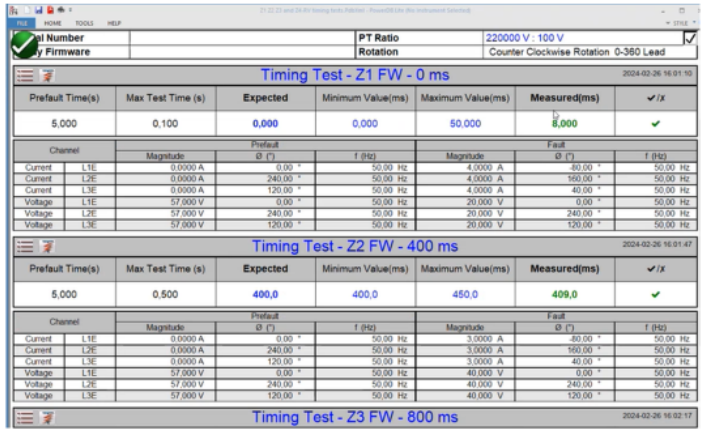
Relay testing – real vs virtual world – step 5

REAL WORLD	VIRTUAL WORLD
Assess the test results	5 Assess the test results from the virtual test set
 From the test set	
 Additionally From the relay data (Event Recorder, HMI, Disturbance Recorder)	 Additionally From the relay data (Event Recorder, HMI, Disturbance Recorder)

Relay testing – real vs virtual world – step 5

REAL WORLD

Get report from the software.



		PT Ratio	220000 V : 100 V
		Rotation	Counter Clockwise Rotation 0-360 Lead

Timing Test - Z1 FW - 0 ms — 2024-02-26 16:01:10

Prefault Time(s)	Max Test Time (s)	Expected	Minimum Value(ms)	Maximum Value(ms)	Measured(ms)	✔/✘
5,000	0,100	0,000	0,000	50,000	8,000	✔

Channel		Prefault Magnitude	Prefault Ø (°)	Prefault f (Hz)	Fault Magnitude	Fault Ø (°)	Fault f (Hz)
Current	L1E	0,0000 A	0,00 °	50,00 Hz	4,0000 A	-80,00 °	50,00 Hz
Current	L2E	0,0000 A	240,00 °	50,00 Hz	4,0000 A	160,00 °	50,00 Hz
Current	L3E	0,0000 A	120,00 °	50,00 Hz	4,0000 A	40,00 °	50,00 Hz
Voltage	L1E	57,000 V	0,00 °	50,00 Hz	20,000 V	0,00 °	50,00 Hz
Voltage	L2E	57,000 V	240,00 °	50,00 Hz	20,000 V	240,00 °	50,00 Hz
Voltage	L3E	57,000 V	120,00 °	50,00 Hz	20,000 V	120,00 °	50,00 Hz

Timing Test - Z2 FW - 400 ms — 2024-02-26 16:01:47

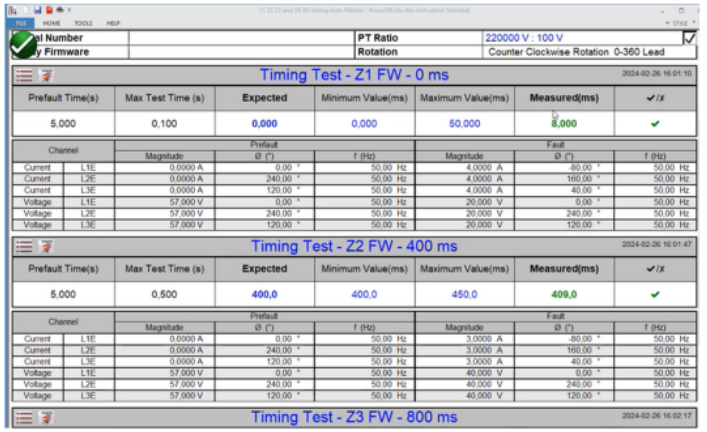
Prefault Time(s)	Max Test Time (s)	Expected	Minimum Value(ms)	Maximum Value(ms)	Measured(ms)	✔/✘
5,000	0,500	400,0	400,0	450,0	409,0	✔

Channel		Prefault Magnitude	Prefault Ø (°)	Prefault f (Hz)	Fault Magnitude	Fault Ø (°)	Fault f (Hz)
Current	L1E	0,0000 A	0,00 °	50,00 Hz	3,0000 A	-80,00 °	50,00 Hz
Current	L2E	0,0000 A	240,00 °	50,00 Hz	3,0000 A	160,00 °	50,00 Hz
Current	L3E	0,0000 A	120,00 °	50,00 Hz	3,0000 A	40,00 °	50,00 Hz
Voltage	L1E	57,000 V	0,00 °	50,00 Hz	40,000 V	0,00 °	50,00 Hz
Voltage	L2E	57,000 V	240,00 °	50,00 Hz	40,000 V	240,00 °	50,00 Hz
Voltage	L3E	57,000 V	120,00 °	50,00 Hz	40,000 V	120,00 °	50,00 Hz

Timing Test - Z3 FW - 800 ms — 2024-02-26 16:02:17

VIRTUAL WORLD

5 Get report from the software.



		PT Ratio	220000 V : 100 V
		Rotation	Counter Clockwise Rotation 0-360 Lead

Timing Test - Z1 FW - 0 ms — 2024-02-26 16:01:10

Prefault Time(s)	Max Test Time (s)	Expected	Minimum Value(ms)	Maximum Value(ms)	Measured(ms)	✔/✘
5,000	0,100	0,000	0,000	50,000	8,000	✔

Channel		Prefault Magnitude	Prefault Ø (°)	Prefault f (Hz)	Fault Magnitude	Fault Ø (°)	Fault f (Hz)
Current	L1E	0,0000 A	0,00 °	50,00 Hz	4,0000 A	-80,00 °	50,00 Hz
Current	L2E	0,0000 A	240,00 °	50,00 Hz	4,0000 A	160,00 °	50,00 Hz
Current	L3E	0,0000 A	120,00 °	50,00 Hz	4,0000 A	40,00 °	50,00 Hz
Voltage	L1E	57,000 V	0,00 °	50,00 Hz	20,000 V	0,00 °	50,00 Hz
Voltage	L2E	57,000 V	240,00 °	50,00 Hz	20,000 V	240,00 °	50,00 Hz
Voltage	L3E	57,000 V	120,00 °	50,00 Hz	20,000 V	120,00 °	50,00 Hz

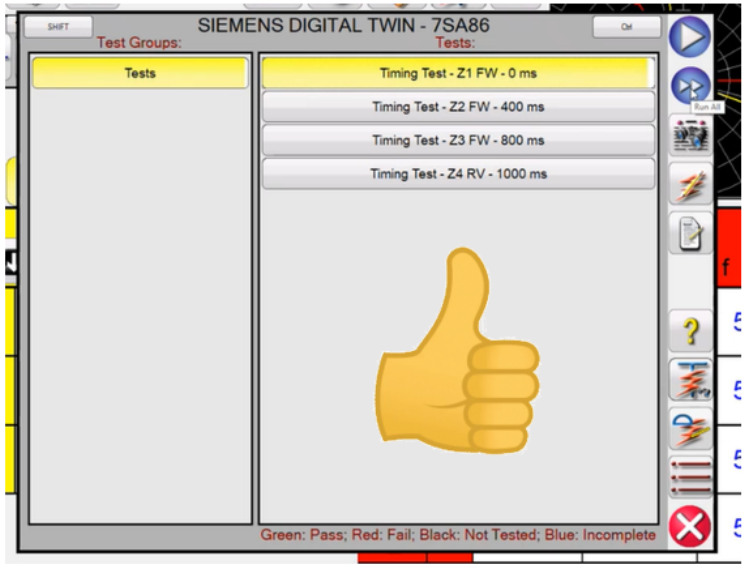
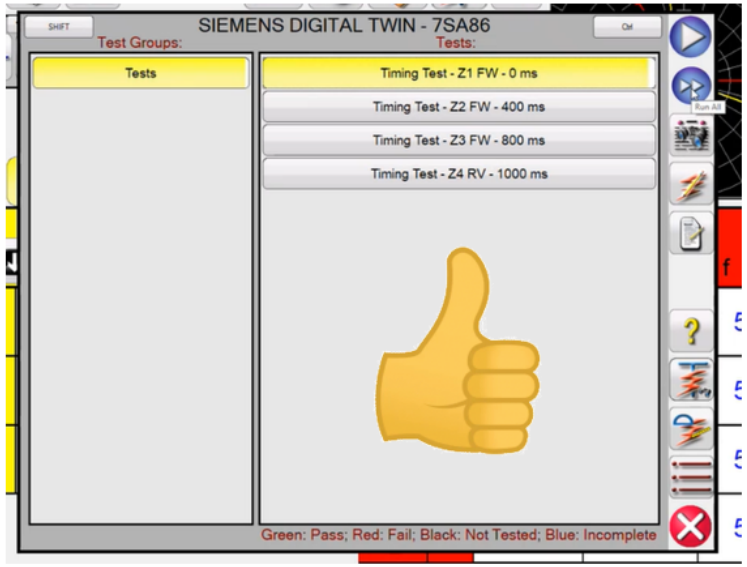
Timing Test - Z2 FW - 400 ms — 2024-02-26 16:01:47

Prefault Time(s)	Max Test Time (s)	Expected	Minimum Value(ms)	Maximum Value(ms)	Measured(ms)	✔/✘
5,000	0,500	400,0	400,0	450,0	409,0	✔

Channel		Prefault Magnitude	Prefault Ø (°)	Prefault f (Hz)	Fault Magnitude	Fault Ø (°)	Fault f (Hz)
Current	L1E	0,0000 A	0,00 °	50,00 Hz	3,0000 A	-80,00 °	50,00 Hz
Current	L2E	0,0000 A	240,00 °	50,00 Hz	3,0000 A	160,00 °	50,00 Hz
Current	L3E	0,0000 A	120,00 °	50,00 Hz	3,0000 A	40,00 °	50,00 Hz
Voltage	L1E	57,000 V	0,00 °	50,00 Hz	40,000 V	0,00 °	50,00 Hz
Voltage	L2E	57,000 V	240,00 °	50,00 Hz	40,000 V	240,00 °	50,00 Hz
Voltage	L3E	57,000 V	120,00 °	50,00 Hz	40,000 V	120,00 °	50,00 Hz

Timing Test - Z3 FW - 800 ms — 2024-02-26 16:02:17

Relay testing – real vs virtual world – step 5

REAL WORLD	VIRTUAL WORLD
Save the tests, repeat them…	5 Save the tests, repeat them…
	
	AS ”USUAL” ….

The digital twins has the same roles as in reality

DT TEST SET responsibility

- Generate the test quantities Voltages currents, binary signals.
- Provide test methods pseudo-continuous ramps, ramps of shots, sequences of shots, standardized according to IEC 60255-1xx series or not.
- Measure the relay response from relay binary outputs, provide test reports, handle test files, repeat tests etc.

DT RELAY responsibility

- Measure the test quantities that simulate different power system conditions
- Take protection decision, operation or not, based on the protection algorithms
- Report the relay behaviour Information on local HMI, Disturbance recorder, event recorder, etc.

Use cases and benefits

Use case A: Virtual FAT

- Virtual devices – Logistics, temporary installation, panel production, additional hardware and temporary wirings avoided
- Remote and parallel work – No travel => CO2 emissions, available experts, convenience, increased speed => meet delivery time

Use case B: Training

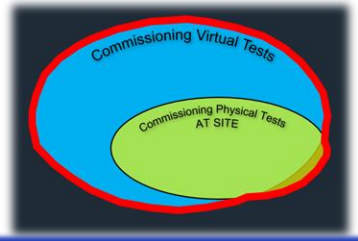
- Safety, availability, cost reduction, familiar environment.

Use case C: Remote support

- Enable quick solutions, convenient

Benefits

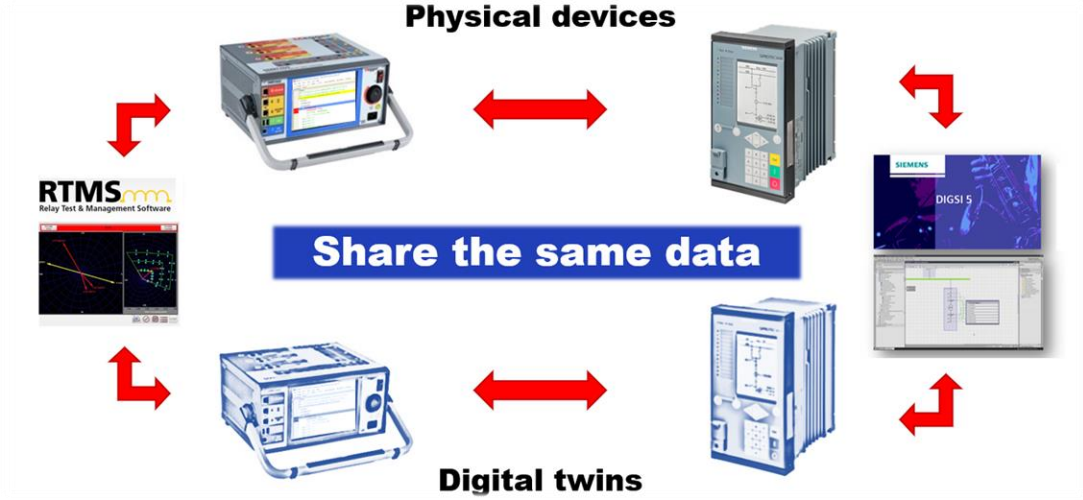
- Test files and settings files are reused in reality
- Verified settings files and test files will work
- Environment familiar
  - Gives confidence in troubleshooting
- Repeat a subset of the tests at commissioning
  - Verify connections, hardware and correct settings file



Less stress in a project phase with high time pressure

Conclusion

- Functional digital twins working together gives benefits
  - Cost saving
  - Time saving
  - Trained staff
  - Safety
- High fidelity digital twins from OEMs
  - Accurate functional simulation
  - Performance confirmed virtual
  - A few prepared tests repeated in reality
- Closed loop testing
  - Two digital twins interacting
  - The digital twins has same role as in reality
  - Makes digital twins available to ‘regular’ users



- Coming steps
  - Sequencer tests in closed-loop testing
  - Standardization