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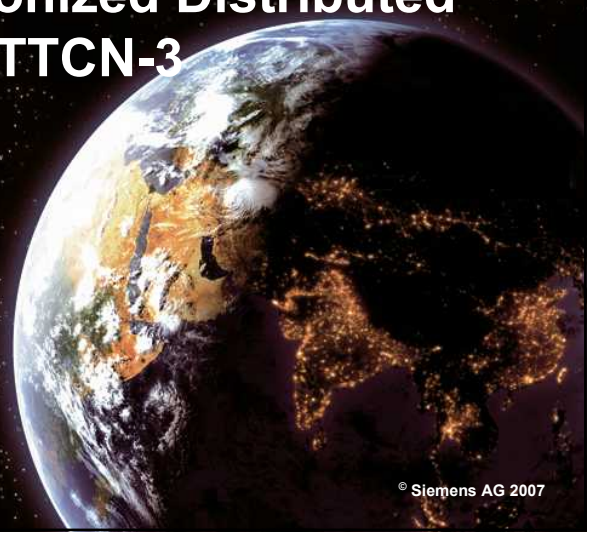
GPS Synchronized Distributed Tests using TTCN-3

Power Transmission
and Distribution



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Agenda

Part 1: Introduction to Siemens PTD EA
- What are the products of Siemens PTD EA
- What are test cases for these products

Part 2: Distributed testing with TTCN-3

Part 3: The Test Setup and the Results
- Test purpose
- Using TTCN-3 distributed testing
- Results
- Extension of TTCN-3 for Testing of communication in process automation

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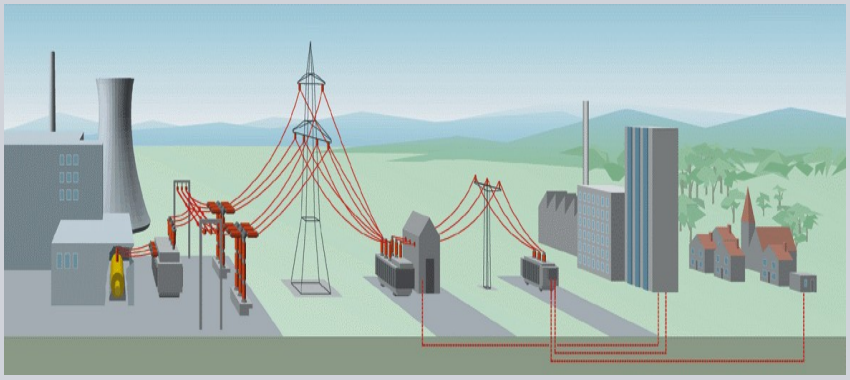
Protection systems are essential for a safe and reliable energy system

Generation
Generator protection
Transformer protection

Transmission
Distance protection
Line protection
Feeder protection
Busbar protection

Distribution
Transformer protection
Line protection
Overcurrent protection



As in other industries, digitalization totally changed the way protection devices work

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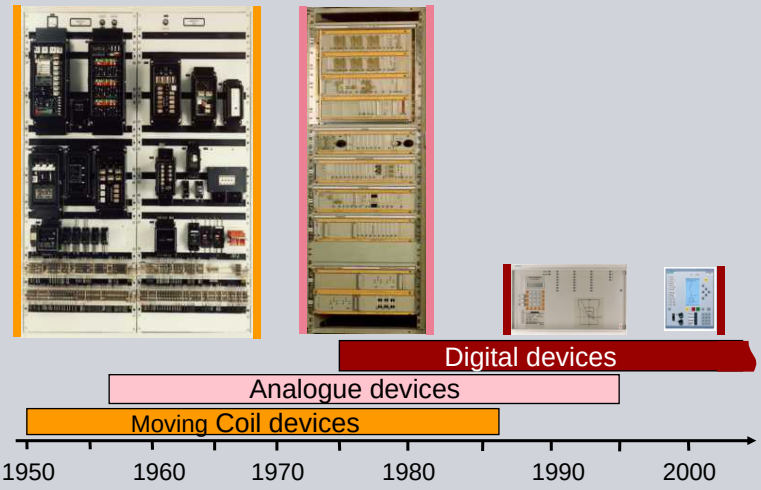

Today, energy management relies on communication technology

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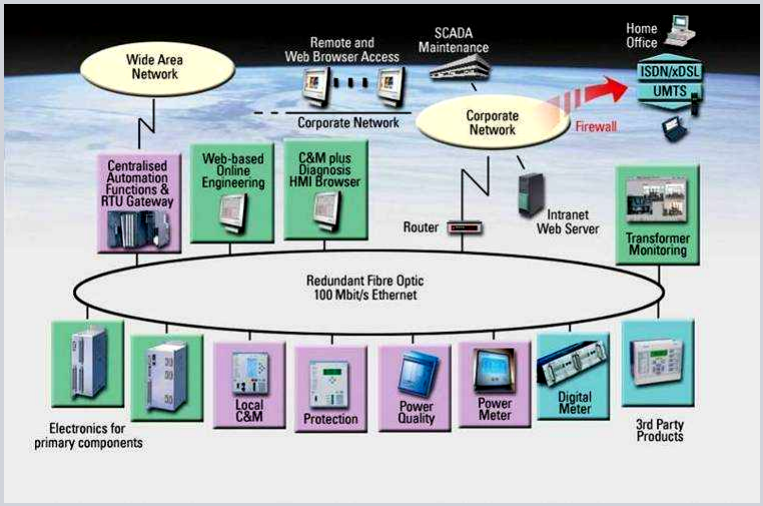

A typical test case: the protection setup for a busbar

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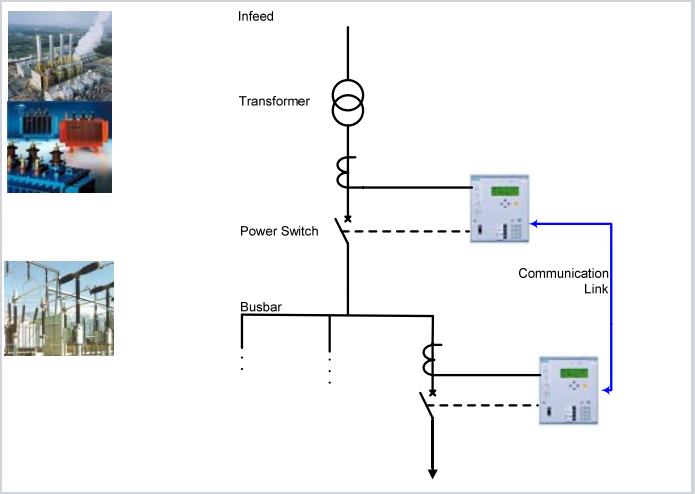

When a fault occurs, the protection device A turns off the power switch

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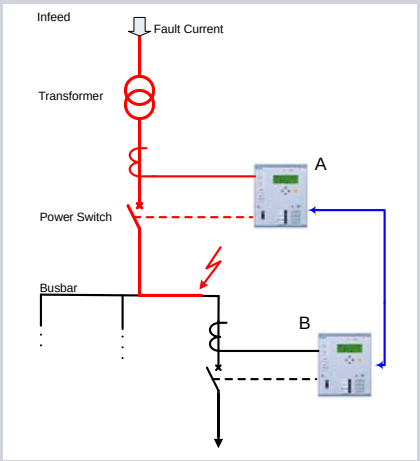

Procedure:

- A fault occurs, e.g. due to strike of lightning
- A fault current flows
- Device A detects the current
- Device A sends a command to the power switch after 50ms
- The power switch is opened
- The current flow is disrupted

An external fault should not lead to switching off the power switch assigned to device A

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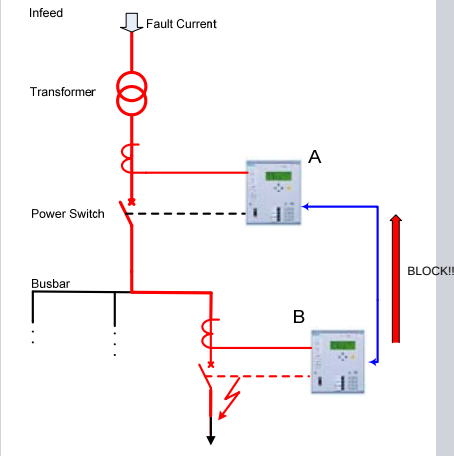

Procedure:

- A fault occurs e.g. due to strike of lightning
- A fault current flows
- Device A detects the current
- Device B detects the current
- Device B sends a blocking command to device A
- Device A does not switch off the power switch
- Device B switches off the power switch immediately

The timing is very important when a blocking scheme is used for protection

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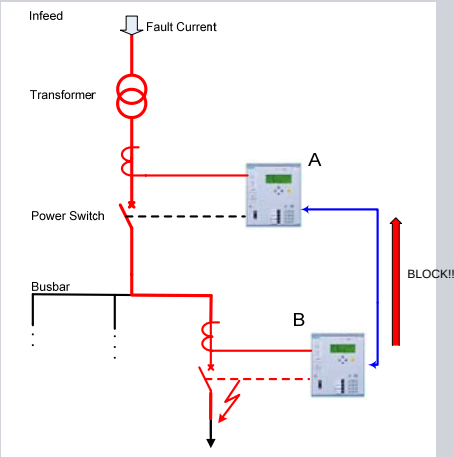

Timing:

- Detection of a fault current: *approx. 20ms*
- Switch-off of external faults: *0 ms after detection*
- Switch-off of busbar faults: *50 ms after occurrence*

The blocking signal has to be sent, transmitted and received within a *window of 30 ms*

In our test we want to show that this happens even under heavy load. !

A lot of communication sources should be used simultaneously to perform a load test

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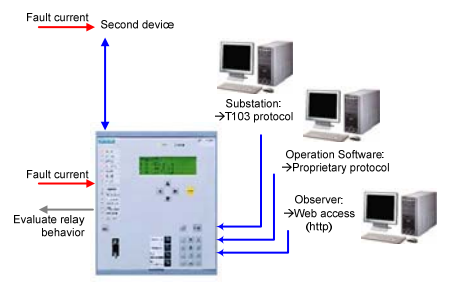

Test case description:

- Generate a fault current
- Within 30ms after fault occurrence:
  - Send a T103 telegram
  - Send a http request
  - Send an operational request

In order to perform these tests:
- A distributed test system with 3 test machines is needed
- The test machines have to be synchronized

Summary

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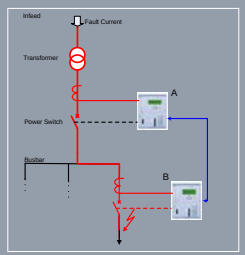
Load testing of a blocking scheme with two protection devices – **Challenges**



Sending messages to a system under test from 3 test computers

The test computers have to be synchronized with each other

The analogue signal generator has to be synchronized with the test machines

The test machines have to support different protocols

Our "synchronicity" requirement for this scenario is: ***"Within an interval of 10 ms"*** !

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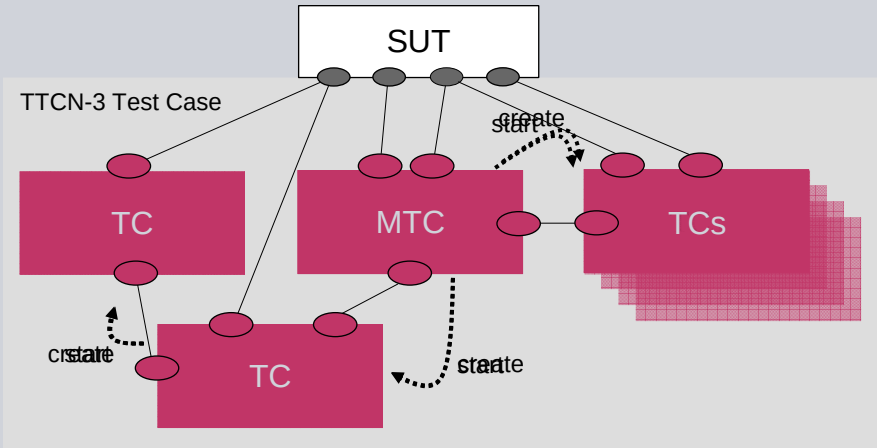
Dynamic Test Configurations in TTCN-3



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Test purpose

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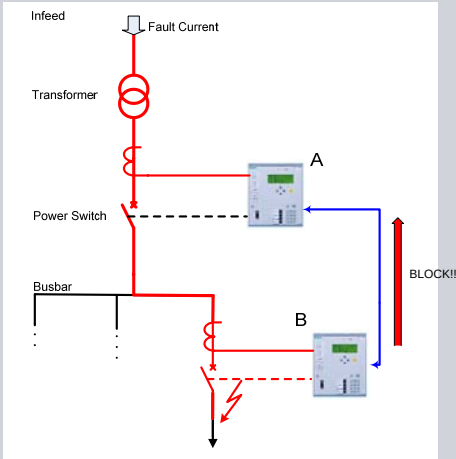

Test purpose

The blocking signal has to be transmitted within *30 ms* even if the it is stressed by max. 5 clients which connect “simultaneously” to the protection device B (server)

Simultaneousness means that all messages “connect” from all clients have to be transmitted within a time window of 10 ms. !

Using TTCN-3 distributed testing where 3 clients are simulated and deployed on 3 PCs

Challenges and Solution

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Challenges:	Solution:
▪ Test adapters for communication protocol IEC 61850 not available	✓ Programming the Test adapters
▪ All Components of a distributed test system have to be timely synchronized	✓ Time Synchronisation with GPS
▪ Synchronization of send operations at 3 Clients in TTCN-3 is not successful. Absolute time is needed	✓ Extention of send operation in system adapter with synchronization methods. Absolute time of operation system
▪ Real-Time behavior not available (Windows/JAVA)	✓ It's not good, but can be acceptable for the given test purpose

Synchronization of the send operation at all 3 Clients

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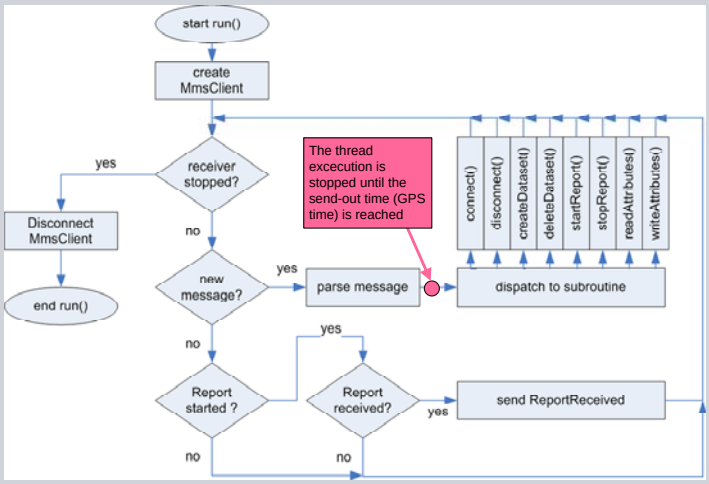

The code snippet demonstrates how the synchronization is programmed in TTCN-3

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```
function DistributedConnect() runs on MTCType{
        ConnectIECDevice( Connect: { IP_ADDRESS, 102, 55000 } ) ;
                if( getverdict() == fail )
                        DisconnectIECDevice();
        }
type component MTC{}
testcase distributed() runs on MTC system  TestComponent{
        var MTCType Component1, Component2, Component3;
        Component1 := MTCType.create;
        Component2 := MTCType.create;
        Component3 := MTCType.create;
        map(Component1: iec61850, system: iec61850);
        map(Component2: iec61850, system: iec61850);
        map(Component3: iec61850, system: iec61850);
        Component1.start(DistributedConnect());
        Component2.start(DistributedConnect());
        Component3.start(DistributedConnect());
        all component.done;
}
```


In another setup the delay between three synchronized test computers was measured

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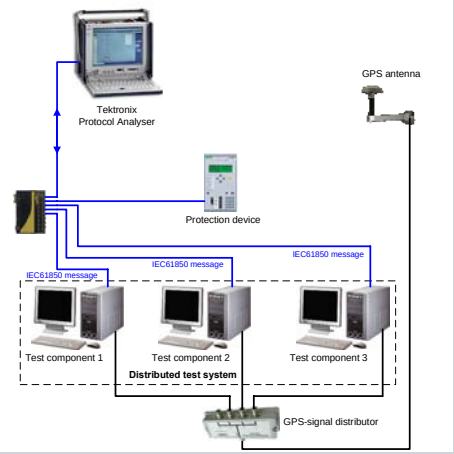

Test description:

- At a determined time all three test computers send a message to the protection device
- The protocol analyzer records all three messages

In this test we measured the delay between:

- The first and
- The last arriving message

The measurements show that the synchronicity of the distributed tests meets our requirements

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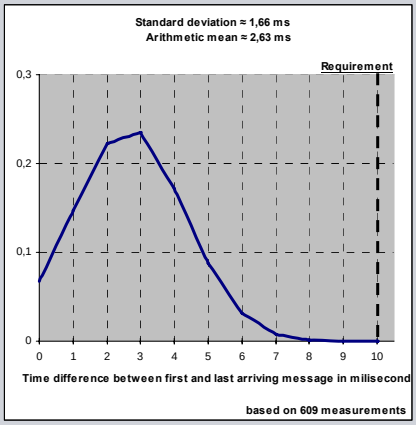

Result:

- The average difference between the arriving messages was 2,6 ms
- No test showed a difference of more than 8 ms

The synchronicity requirement ***"Within an interval of 10 ms"*** is fulfilled.

Requirements of distributed testing in energy automation (process automation)

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- All test component can process absolute time which is needed for processing received informations (indication or measured valued)
- All test component and the SUT are time synchronized
- All operations of a test component are processed in real-time. That means they are processed in a deterministic time window
-

Our Modification of TTCN-3 test system architecture

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- Extension of the system adapter (SA) so that it can process absolute time which is retrieved from the GPS Adapter by using an API
- Extension of the system adapter (SA) with a synchronization operation

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What we expect from TTCN-3 distributed testing

- The Platform Adapter (PA) should offer operations for handling absolute time
- The Component Handler (CH) should support time synchronization or test system architecture should be extended by a time synchronization interface
- For high performance real-time distributed testing all operations of the TTCN-3 test system should have deterministic time behavior. This can be realized by using real-time operation system (e.g. Solaris SPARC) and real-time programming (e.g. JRTS) for developing TTCN-3 test system

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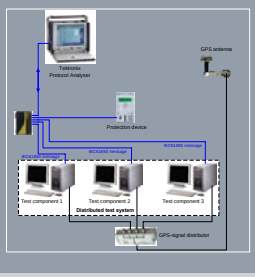
Summary

Synchronization of three TTCN-3 test computers with GPS – **Results**



- TTCN-3 distributed testing was successfully applied
- TTCN-3 test system architecture was modified for time synchronization and processing absolute time
- The test application fulfills the requirements
- TTCN-3 should support absolute time and time synchronization
- High performance real-time distributed testing doesn't have to be standardized but it can be implemented if necessary

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Questions?

Thank you for your attention!