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PROTECTION & AUTOMATION

Paper 10852

How to Test Virtual Protection, Automation and Control Systems (vPACS)

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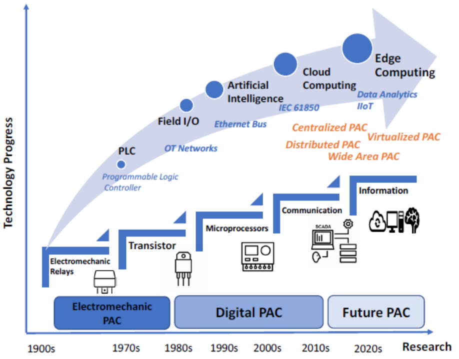
Summary

- The next stage in the evolution of PACS: software-defined grid;
- A historical analysis of power protection systems;
- Exploring the tests requirements: physical IEDs vs. virtual IEDs;
- Investigating tests in vPACS contexts: physical test sets vs. virtual test sets;
- The use of COMTRADE files vs. PCAP files.

Introduction

- Evolution line of protection systems:



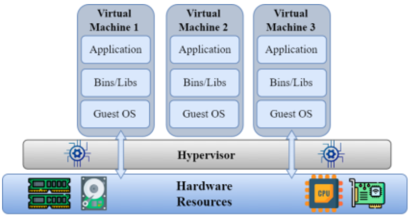
- Evolution of protection systems and test tools:

Eras of Protection Systems Evolution

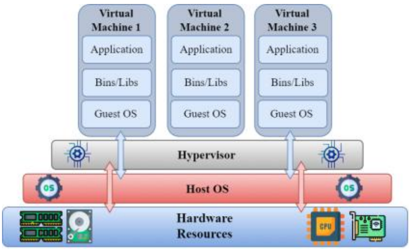
	Electromechanical	Static	Microprocessed	IED	vPACS
Protection Relay	• Single protection functions; • Single-Phase; • Protection functions with low precision and complexity	• Single protection functions; • Single-Phase; • Protection functions with moderate precision	• Multiples protection functions; • Three or Six phases; • Protections functions with high precision and complexity.	• Multiples protection functions; • Three or Six phases; • Protections functions with high precision and complexity; • IEC-61850 Standard: • Embedded Intelligence	To discuss...
Test Tools	• Gen. channels with Single-phase and high power Source; • Relay Settings tests; • Longer comissioning time.	• Gen. channels with Single-phase and low power Source; • Relay Settings Tests.	• Gen. channels with three or six phases and low power Source; • System-based tests; • Increased number of digital IOs.	• Gen. channels with three or six phases and low power Source; • Network evaluation and troubleshooting Tests; • System-based tests.	

Basic concepts of virtualization mechanisms

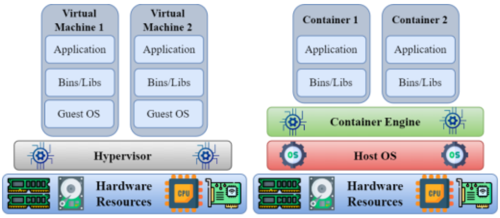
- Type 1 (bare-metal) hypervisor:



- Type 2 (hosted) hypervisor:



- Comparison: Type 1 hypervisor vs. container:



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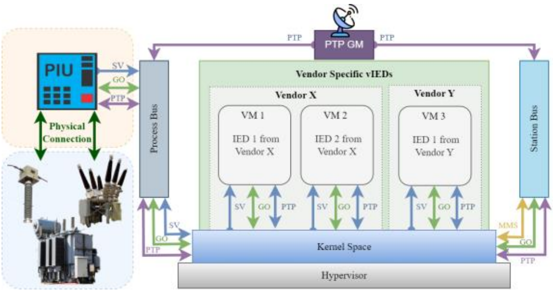
- Comparison summary: Type 1 hypervisor vs. container:

Aspects	Hypervisor Virtualization	Container Virtualization
Isolation	More robust, has a virtual machine-level isolation.	Less isolation, it shares host OS kernel resources.
Overhead	It has higher overhead due to running full operating systems on each VM.	It has less overhead, as it shares the OS kernel and uses memory spaces more efficiently.
Efficiency	It's less efficient in terms of computing resources since it consumes more memory and disk space.	It's more efficient as it requires fewer resources to run applications and startup is faster.
Portability	In VMs, applications can be portable between different hypervisors.	Containers can run on any host that supports the technology.
Performance	Performance is similar to Containers, but hardware resources are isolated and individual between VMs.	Performance is similar to VMs, but the use of Host resources is shared between containers.
Scalability	VM's applications depend on the Guest operation system and they need memory space to allocate their libraries and the OS's files. Therefore, its size is larger than containers, and this can make VM scalability difficult.	Containers use a software architecture that runs the application based on its base image that can be easily updated from the cloud. This way, the applications can be used on any machine that has a container engine installed.
Security	A lot safer, as it is more difficult for a contaminated VM to infect others, considering that its functional system is quite isolated from each other.	Less secure, due to containers sharing the same host's hardware resources.

Virtual protection, automation and control systems

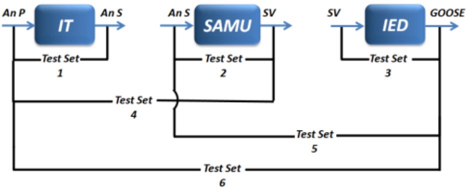
- IEC 61850 communication protocols: GOOSE, SV, PTP and MMS -> software-defined PACS;
- vPACS: centralized protection system through vIEDs, with specifications of each vendor -> "Vendor Specific vIEDs";
- Virtualization mechanisms to achieve vPACS requirements: Type 1 hypervisor or container.



- Challenges of vPACS: interoperability, performance, scalability and security;
- vPACS must achieve the generic requirements: selectivity, speed, simplicity, reliability and economy;
- vPACS must be tested by independent testing solutions during commissioning and maintenance.

Protection tests on vPACS

- In the generic context of digital substation: in relation to testing, the process bus can be approached in a segmented manner:



- Summary of segmented test system:

DUT	Injection	Measurement
IT	Primary V/I	Secondary V/I
SAMU	Multiple V/I (Secondary)	SV
IED	SV	GOOSE
IT + SAMU	Primary V/I	SV
SAMU + IED	Multiple V/I (Secondary)	GOOSE
IT + SAMU + IED	Primary V/I	GOOSE

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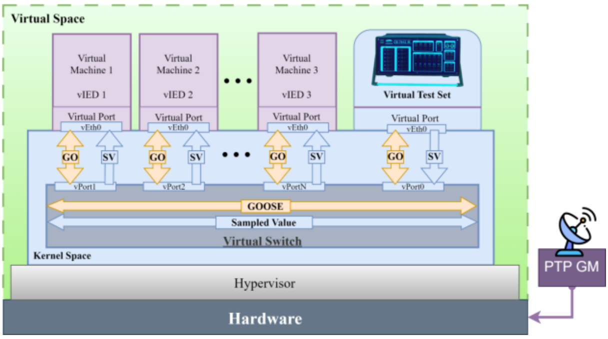
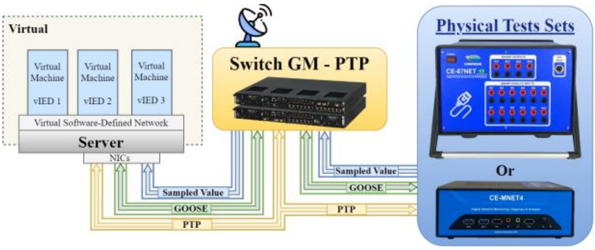
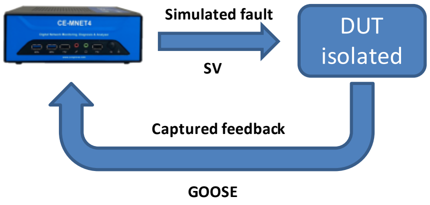
- vPACS testing solutions: physical tests set vs. virtual tests set;
- Physical tests set: valuable in testing the complete protection system chain, covering primary and secondary tests, along with protection algorithms;
- Virtual tests set: valuable in the stage of protection system tests chain related to protection algorithms;
- In vPAC paradigm: virtualized network architecture is implemented, including virtual Switch to allow the traffic of the IEC 61850 communication protocols;
- All aspects of traffic forwarding management, security, access control, and traffic isolation can also be implemented in the virtual switch;
- vPACS with virtual tests set:



- vPACS with physical tests sets:



- Just as with the physical IEDs, the commissioning (FAT and SAT) and maintenance tests must be performed with the virtual IEDs;
- General steps for testing:



- Examples of tests that can be performed in the virtual environment are: characteristics searching, shots faults simulations and transients reproduction;
- The mode and behavior configurations, as defined in IEC 61850-7-4, can be applied to the vIED: duplicated traffic in the virtual network -> projected bandwidth must support this traffic.

Conclusions

- This paper aimed to set the groundwork related to test vPACS;
- A comprehensively knowledge base was established;
- It was conducted a historical analysis about the protection systems, including the tests requirements;
- Some basic concepts of virtualization mechanisms were addressed;
- Generic basic requirements and implementation challenges of vPACS were also approached;
- It was explored the evolution of the testing tools and IEDs;
- The testing requirements in the vPACS environment were verified, along with the implementation of the test configuration;
- Some benefits of virtualization: improved safety, reliability and intelligence within the substation;
- Through this paper, it is expected to pave the way for the effective implementation of vPACS;
- Testing tools must evolve with modernized features to meet the demands of the software-defined grid in the vPACS context.