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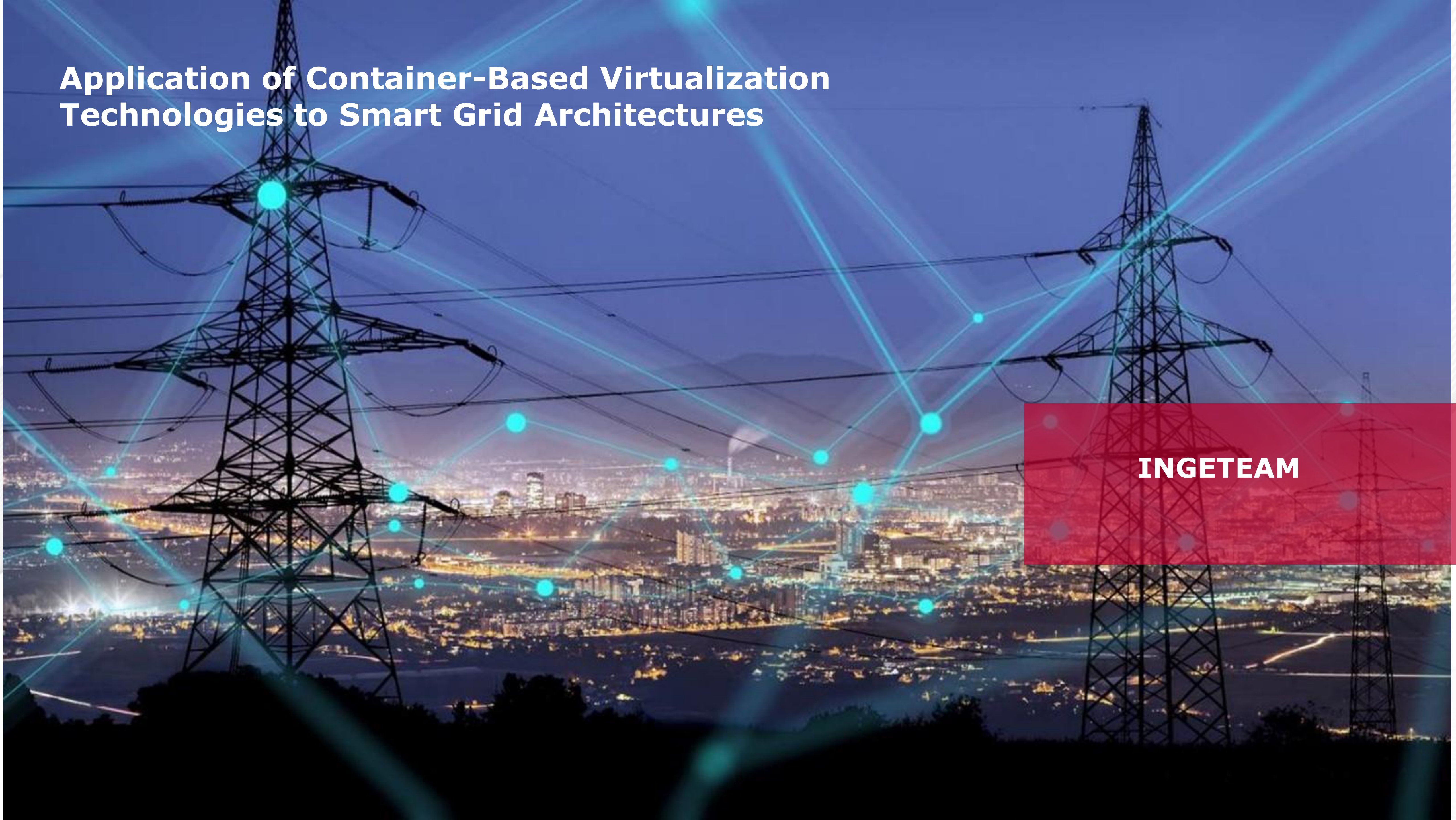
ELECTRIFYING
A SUSTAINABLE FUTURE

Application of Container-Based Virtualization Technologies to Smart Grid Architectures



INGETEAM

WHO WE ARE

Ingeteam is an international technology company specialized in the conversion of electrical energy, with advanced technology in rotating electric machines, power electronics, automation and control.

We strive to meet the needs of our customers, to offer the best and most competitive products, systems and services.

Our staff is the key to our success.

We apply continuous improvement in operations, processes and organization, to remain agile and competitive.

Our aspiration is to be a benchmark in the generation and conversion of electrical energy in the target business sectors.

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Main magnitudes

Present in
16 countries
and new markets.

5.5%
of the turnover, invested in R&D
+500 engineers in R&D

+3,500 employees
In the world.

+80 years
in the electrical sector.

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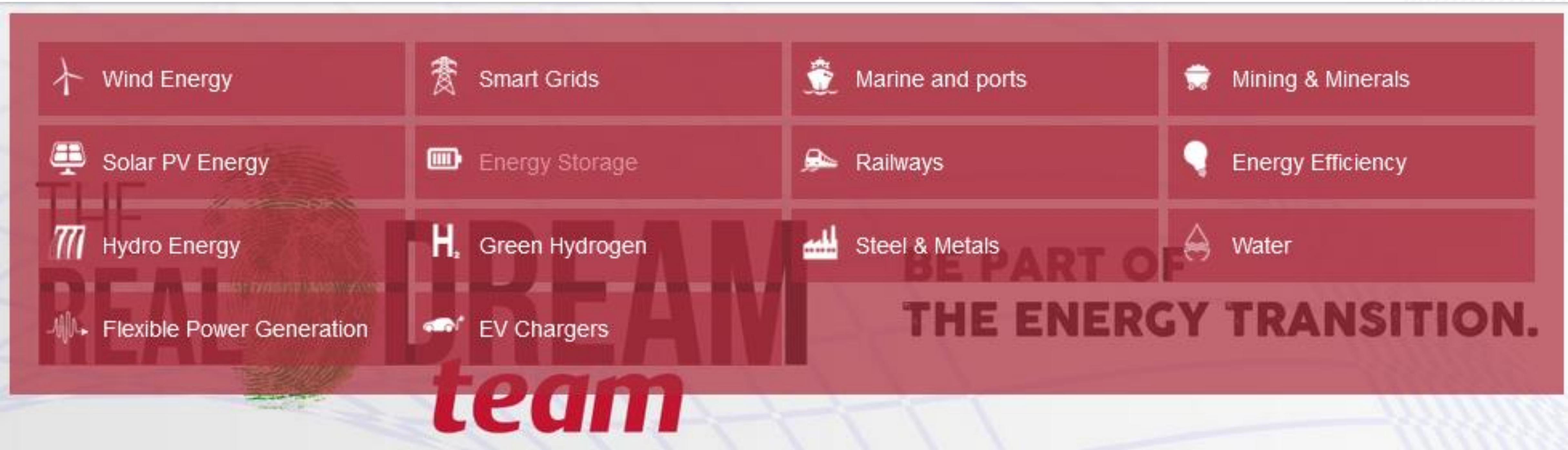
Wind Energy
Smart Grids
Marine and ports
Mining & Minerals
Solar PV Energy
Energy Storage
Railways
Energy Efficiency
Hydro Energy
Green Hydrogen
Steel & Metals
Water
Flexible Power Generation
EV Chargers
THE REAL DREAM team
BE PART OF
THE ENERGY TRANSITION.


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TRANSMISSION & DISTRIBUTION Sector
Smart Grids

+50 years
of experience

+10,000
automated substations up to 500 kV

+33 GW
of exported renewable power

+130,000
Intelligent Electronic Devices installed

+3 GWh
of storage (BESS) installed in distribution and generation substations

- FACTS solutions power electronics-based (STATCOM, SSSC, SOP).
- Synchronous Condensers SYNCON.
- Storage Solutions (BESS) and hybrids (SYNCON + STATCOM+ BESS).
- Substation automation, protection & control.
- Grid distribution automation.
- PC&M E-House modular buildings.

Topics

SMART GRID INTRO

VIRTUALIZATION TECHNOLOGIES

USE CASES AND PROJECTS

CHALLENGES

Smart Grid Technologies

SMART GRID INTRO

What is Smart Grid?

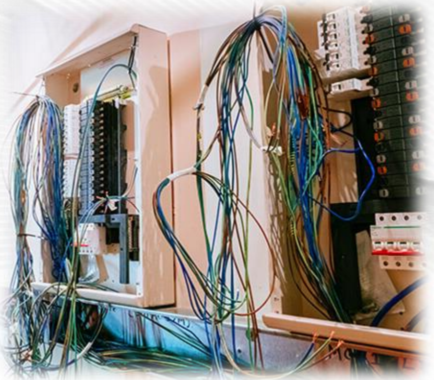
A Smart Grid is an advanced electrical power system that integrates **digital** communication technology to manage electricity supply and demand in a **sustainable**, **reliable**, and **efficient** manner.

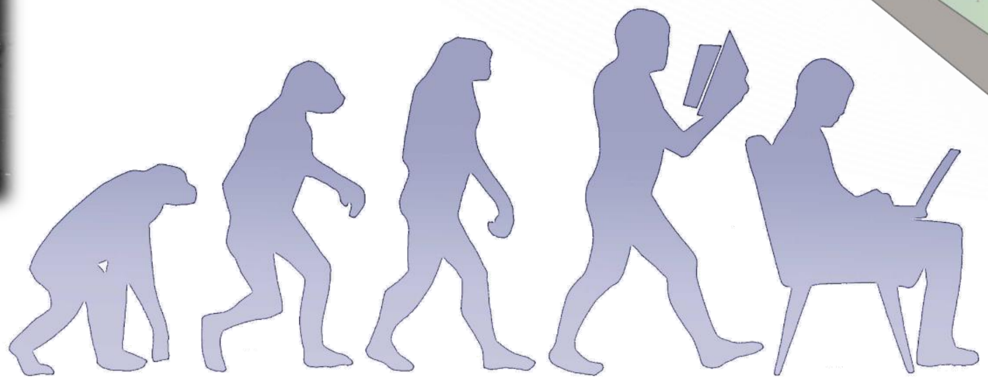
Some characteristics…

- **Communication (nearly among every device)**
- **Real time monitoring and control of the Grid**
- **Consumers can be both users or producers of energy**
- **Dynamic pricing and demand response**
- **Decarbonization**
- **Energy efficiency**

Electrical Power Grid Evolution

The impact of digitalization on the evolution of the electrical power network is profound and multifaceted. Digital technologies are transforming energy systems to become more **connected**, **intelligent**, **efficient**, **reliable**, and **sustainable**.





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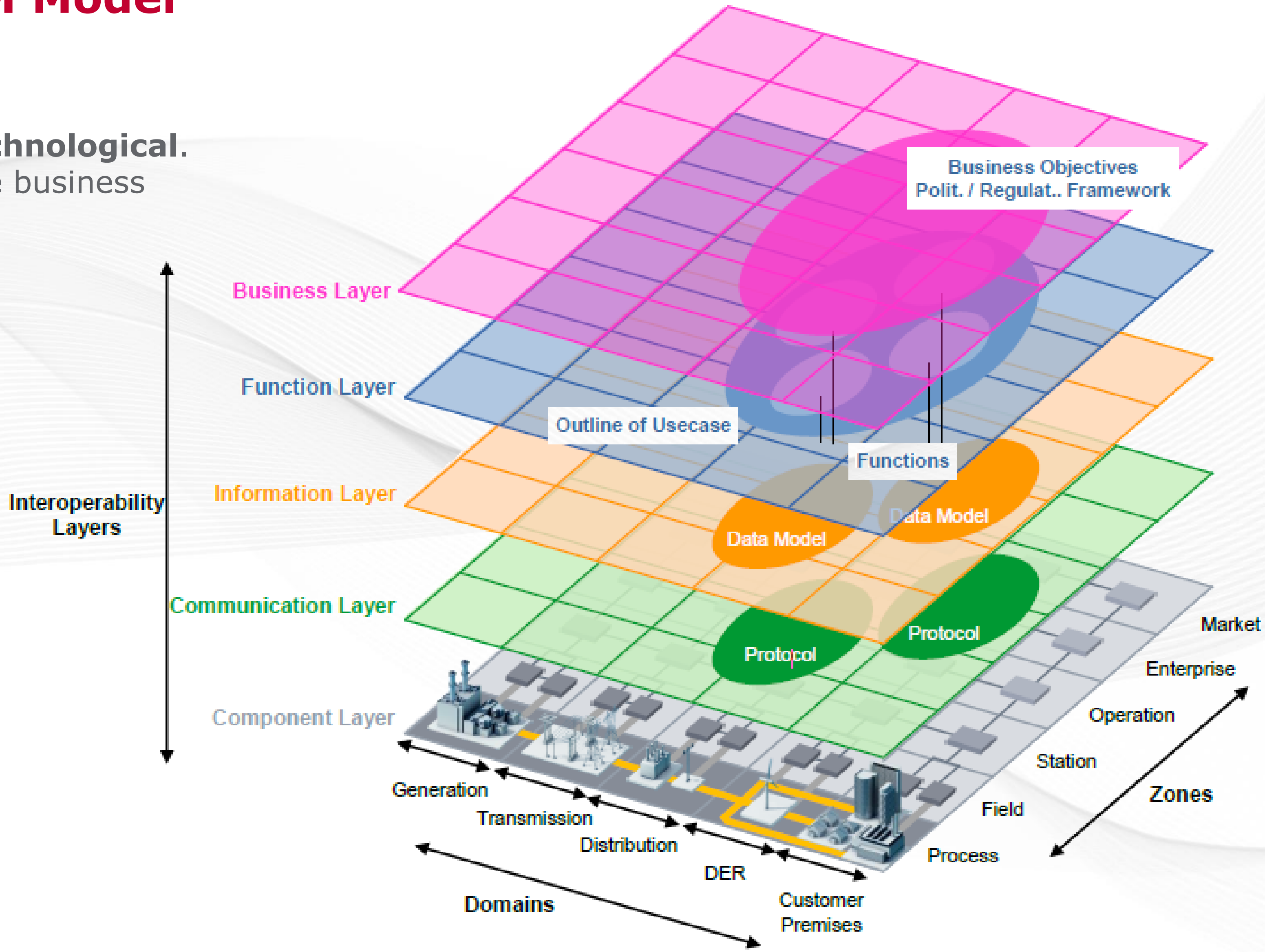
Smart Grid: SGAM Model

The change is **not only technological**. It is a transformation of the business model as a whole.



Source: CEN-CENELEC-ETSI

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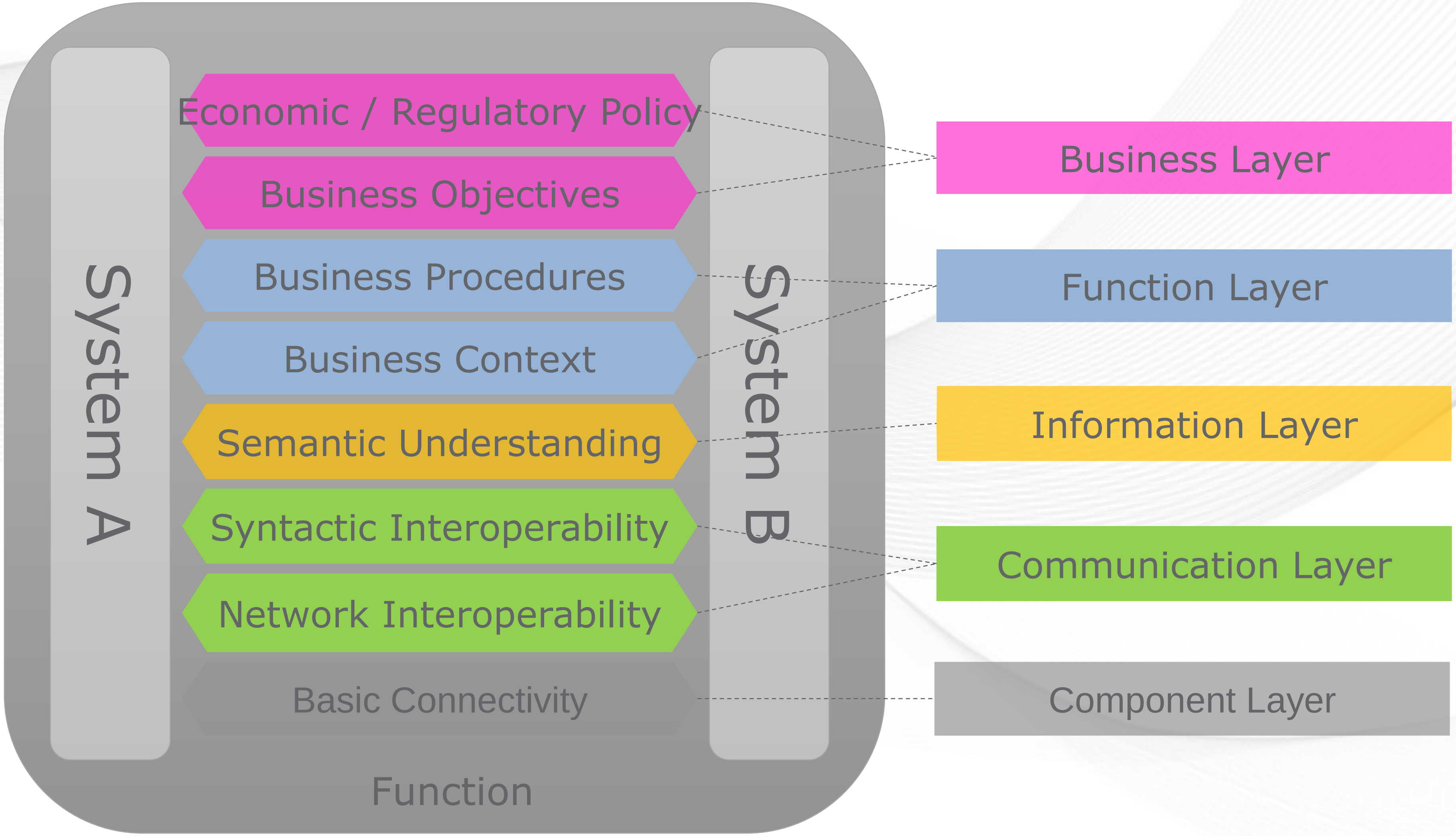
Smart Grid: SGAM Model

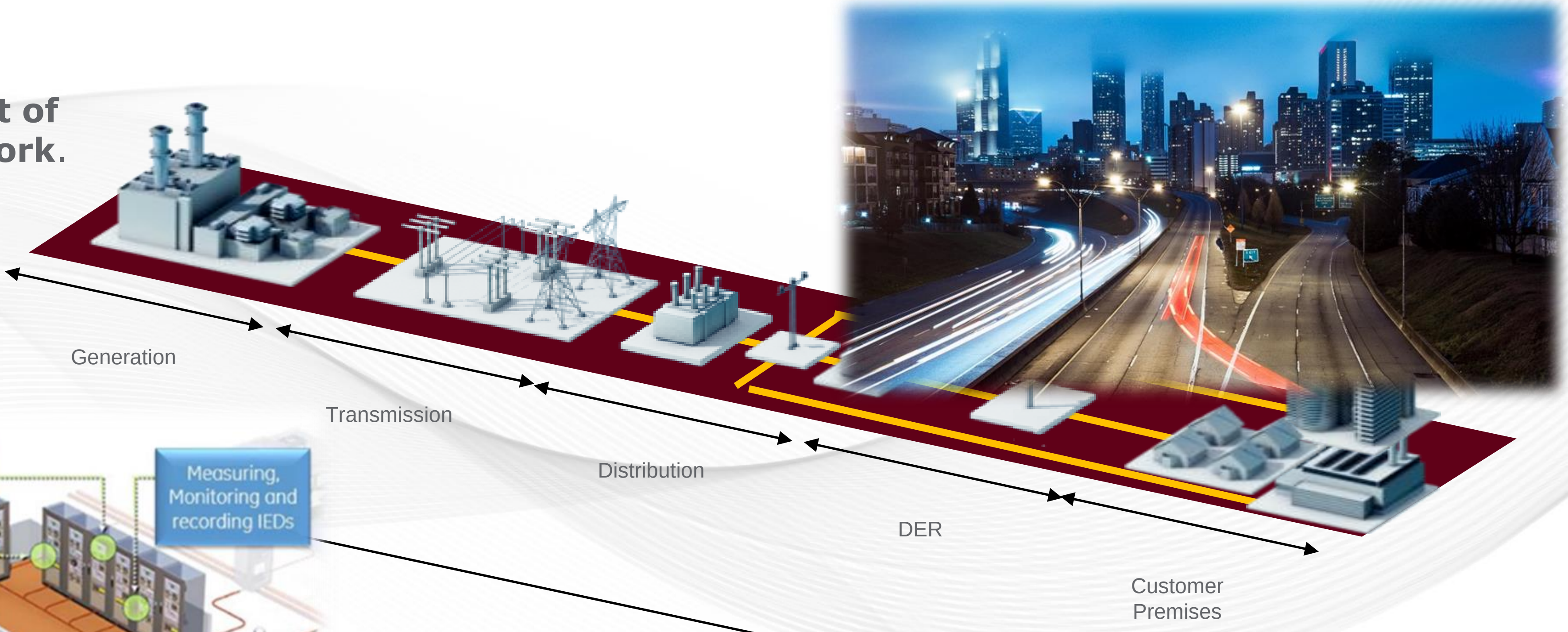
It covers **every aspect** of the Smart Grid.

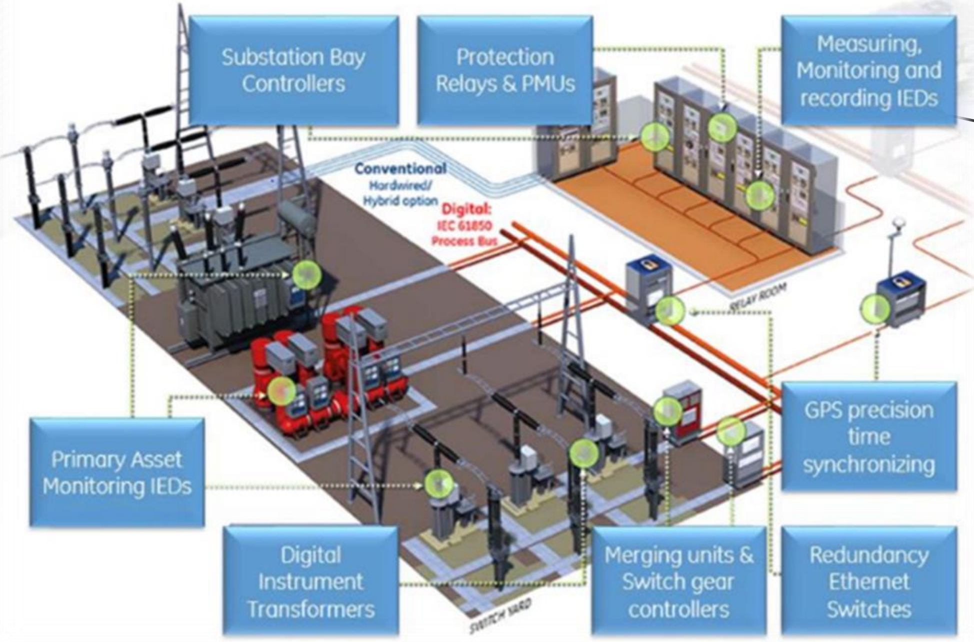


Source: CEN-CENELEC-ETSI

Smart Grid

And it also covers **every part of the Electrical Power Network**.





Source: CEN-CENELEC-ETSI

Facing new challenges and enabling new opportunities (e.g. renewables, mesh power injection, flexibility and many more…)

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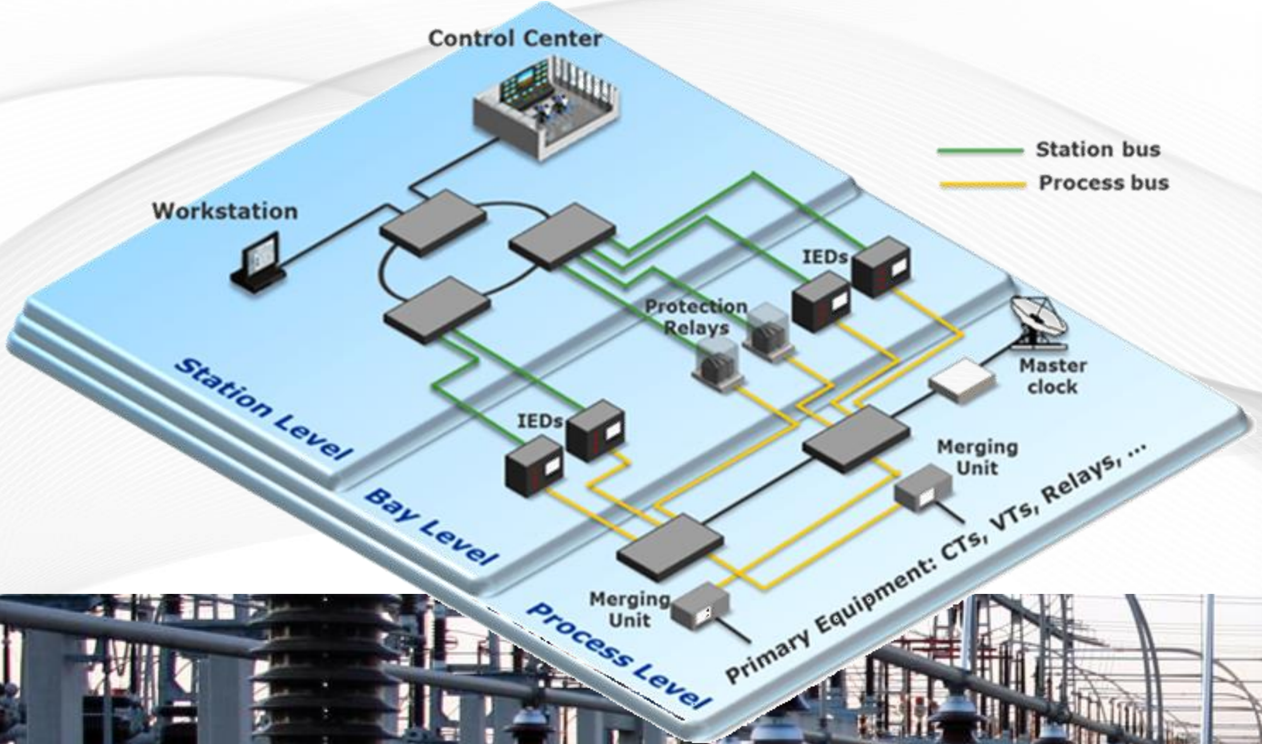
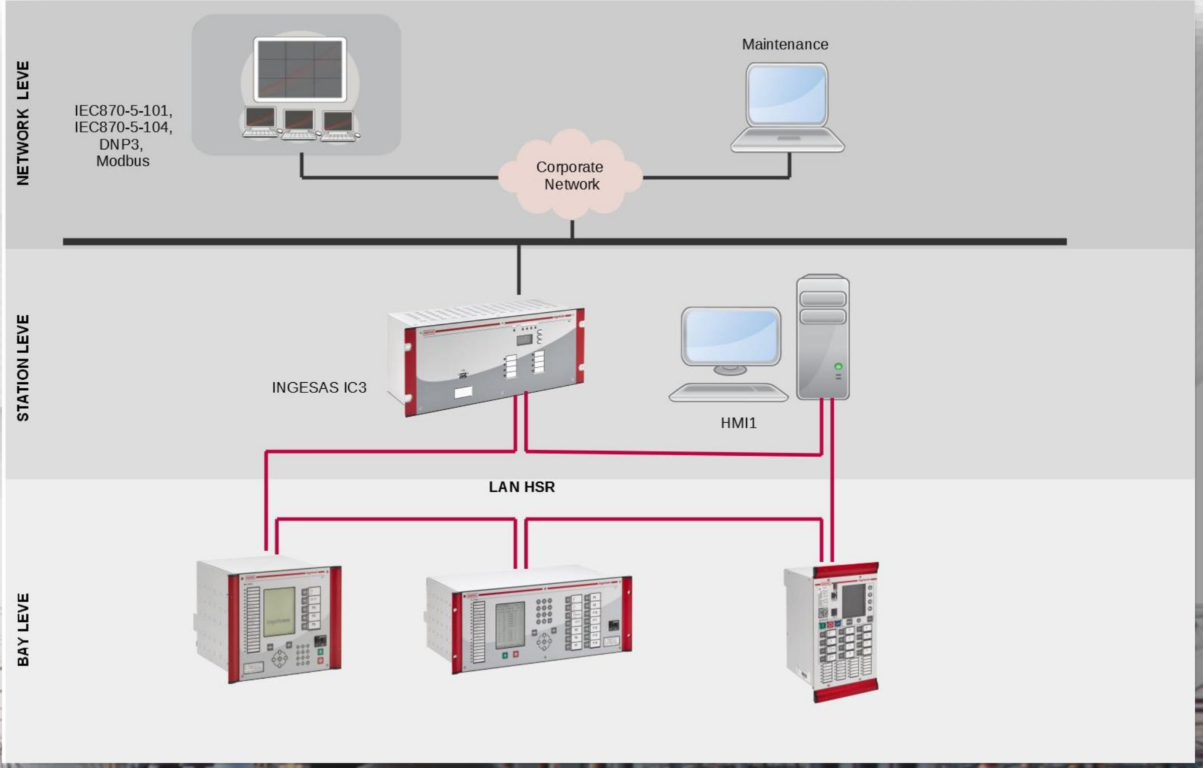
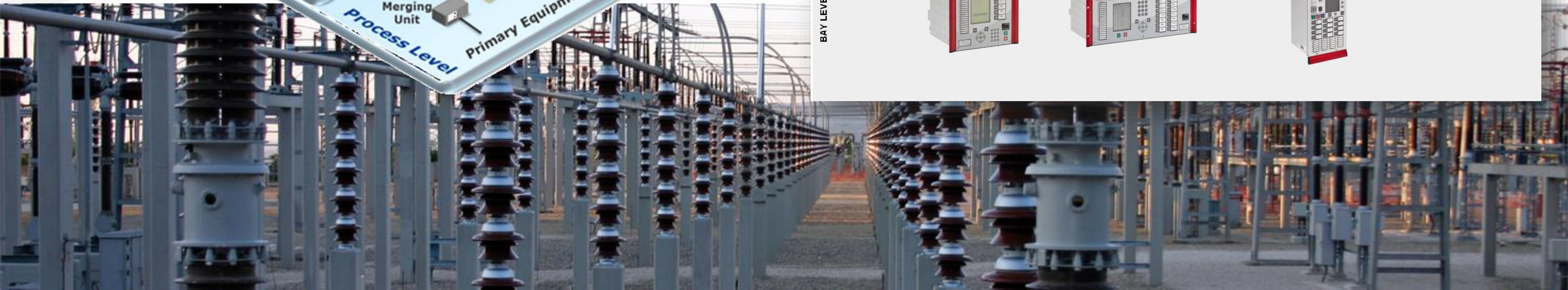
Smart Grid Scenarios

Generation / Transmission Substation







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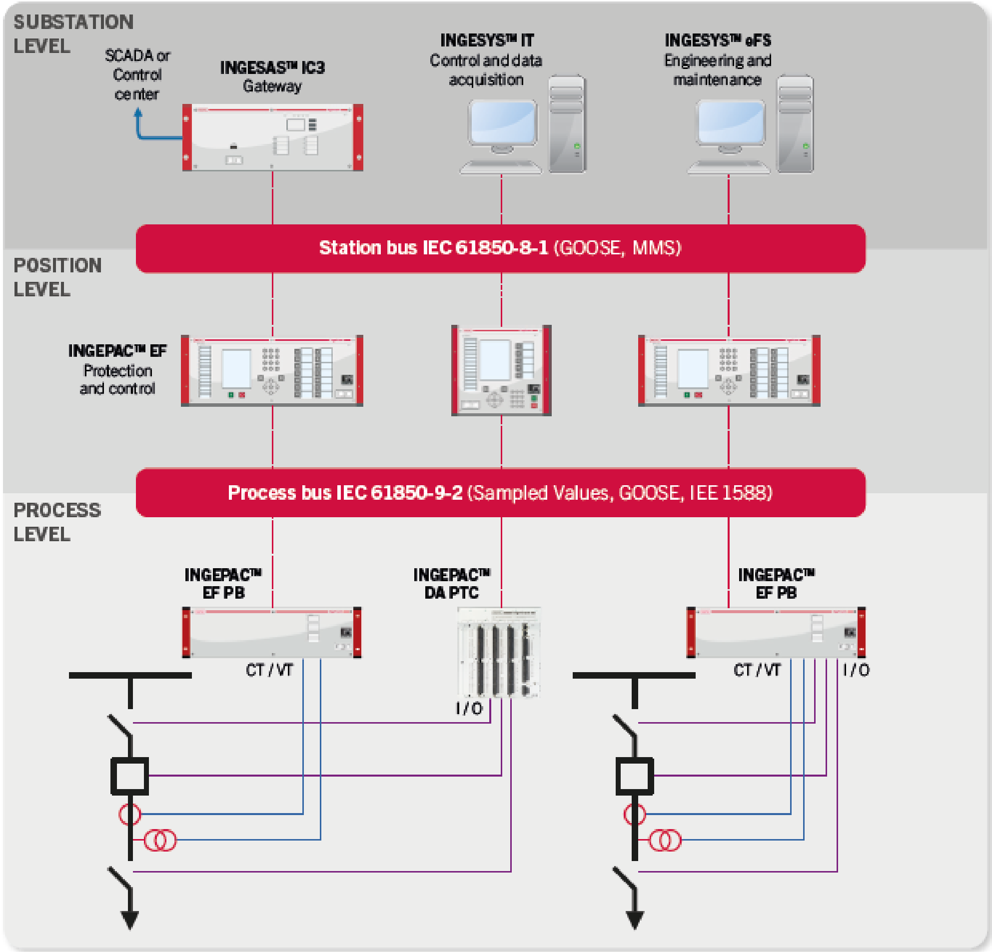
Smart Grid Scenarios

Generation / Transmission Substation Example

The **process bus** is a communications network that allows the connection between the protection, measurement and control IEDs INGEPACTM EF and the primary switchyard equipment.

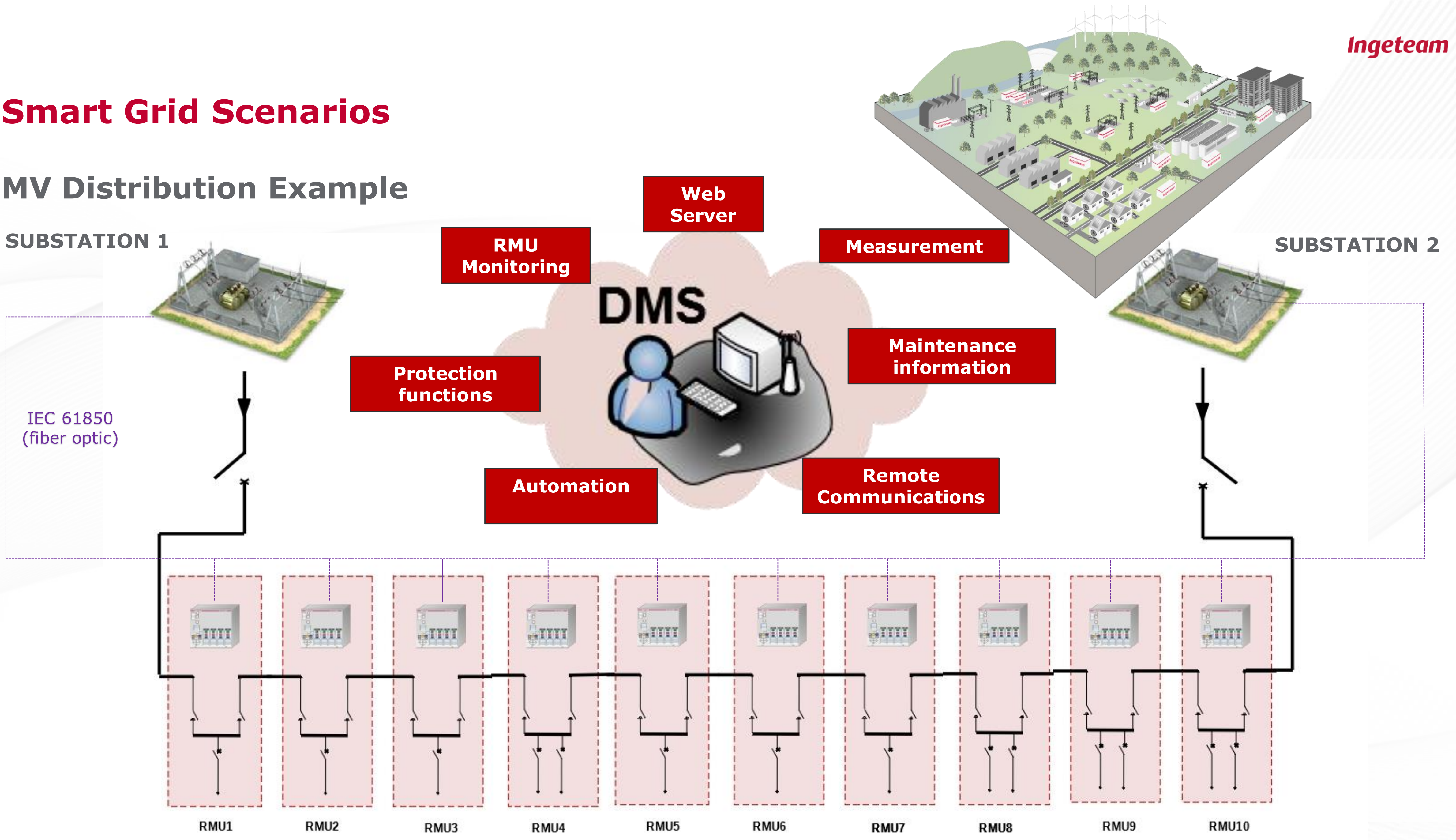
Process bus installation helps to reduce copper wiring, simplifies the engineering and maintenance of Substations and improve safety

- Acquisition of sampled values as per IEC 61869-9 (Non Conventional Transformers) or IEC61850-9-2 (merging Units) standards.
- Reception and transmisión of GOOSE messages as per EC 61850-8-1 standard.
- IEEE1588v2 synchronisation



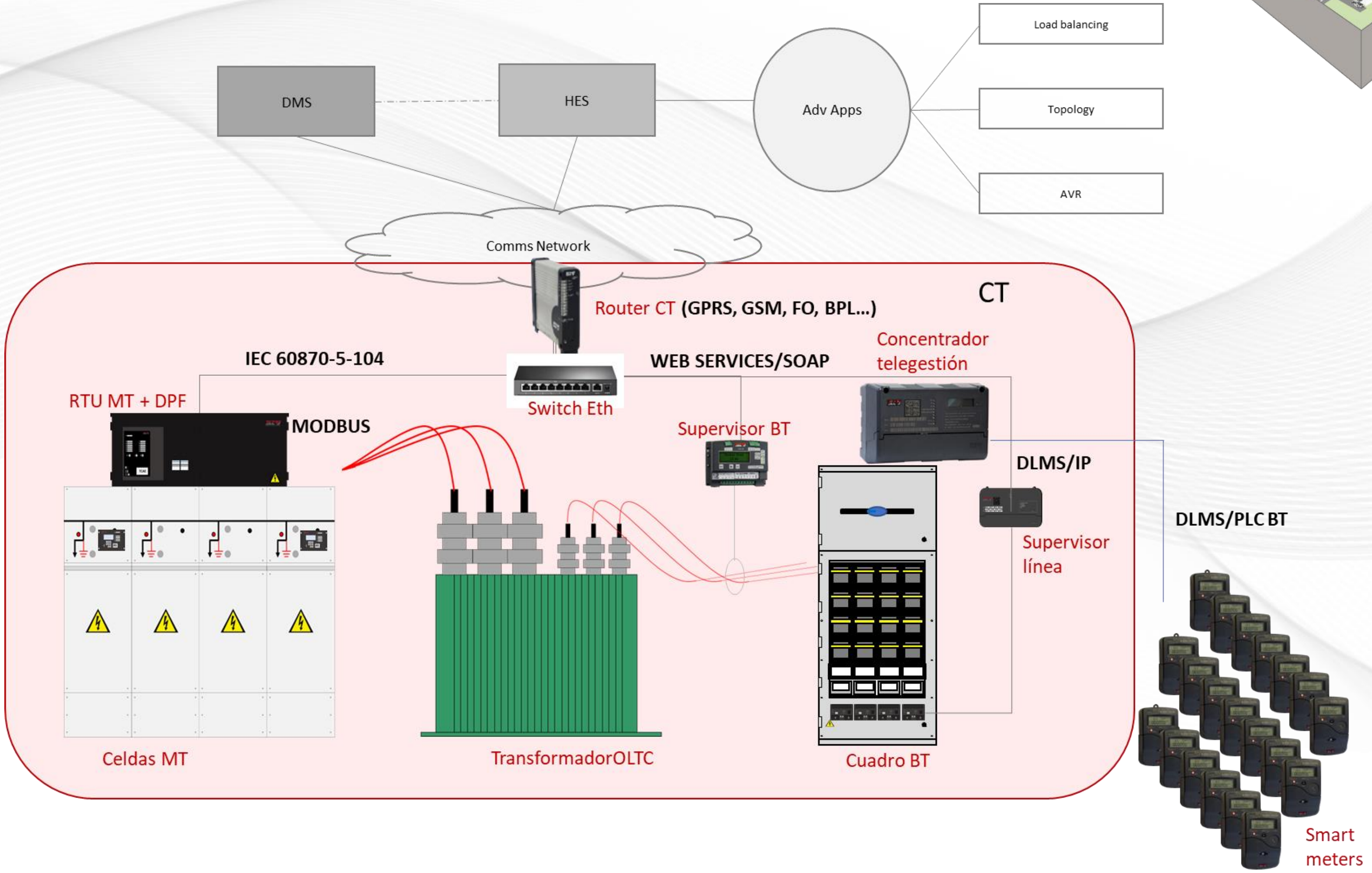
Smart Grid Scenarios

MV Distribution Example



Smart Grid Scenarios

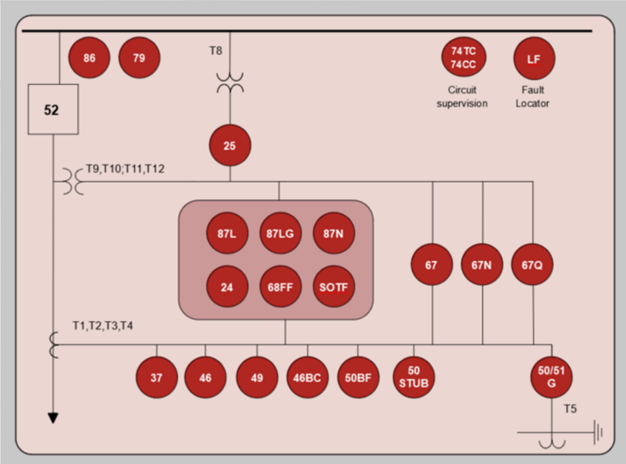
LV Network Example



Smart Grid Devices (IED)

IED Example

INGEPAC™ EF LD0 Functions



- ✓ T1: Phase A Current
- ✓ T2: Phase B Current
- ✓ T3: Phase C Current
- ✓ T4: Neutral Current
- ✓ T5: I polarization current
- ✓ T8: Synchronism voltage
- ✓ T9: Neutral Voltage
- ✓ T10: Phase A voltage
- ✓ T11: Phase B voltage
- ✓ T12: Phase C voltage

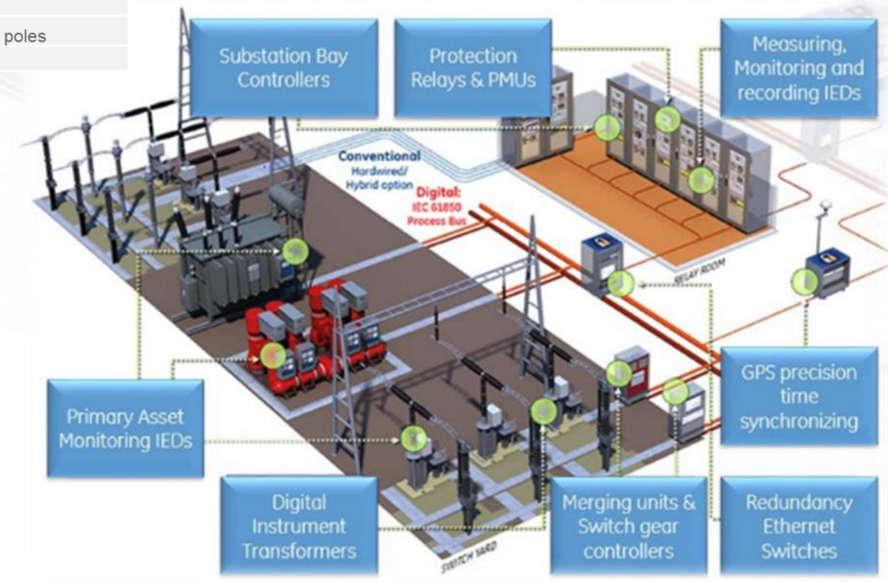
Differential functions
87: Line differential protection (Instantaneous and percentage)
Second harmonic restraint and blocking (Cross blocking)
87LG: Ground differential protection
87N: Restricted earth
24 Overexcitation V/f
5º harmonic level Overexcitation
Directional supervision
Saturation detector
Load compensation
86 function

Protection functions
SOTF Switch onto fault
Undervoltage
3x50/51 (67)
50N/51N (67N)
50G/51G. Earthing overcurrent
46TOC (67Q), 46IOC(67Q)
46BC Broken conductor
50CSC 2º harmonic restraint
50CSC Second and fifth harmonic restraint
37 Undercurrent
49 Thermal image
49T Overtemperature RTD

Suprevision units
68FF Fuse failure
Fault locator
Breaker Supervision
kI2 breaker monitoring per pole
74TC/CC Closing and trip circuit monitoring
Excessive number of trips
Open pole/Dead line detector
Breaker status logic
Pole discordance
Breaker Failure (50BF)
Breaker failure with monopolar/tripolar trip
Breaker failure with low load
Automatisms
Synchronism
Recloser one/three poles
Coupling

Protocols and Redundancy

- **IEC 61850 Edition 2**
- **DNP 3 (serial or TCP-IP)**
- **IEC 60870-5-104 (TCP-IP)**
- **IEC 60870-5-103 (serial)**
- **PROCOME (serial and TCP-IP)**
- **Modbus server (serial and TCP-IP)**
- **Modbus RTU. Master**
- **SNMP**
- **IEEE 1588 v2 (PTP)**
- **SNTP**
- **Parallel Redundancy Protocol (PRP)**
- **High-Availability Seamless Redundancy (HSR)**
- **D-link redundancy**
- **Switch mode**



Cybersecurity


Virtualization Technology
VIRTUALIZATION TECHNOLOGIES

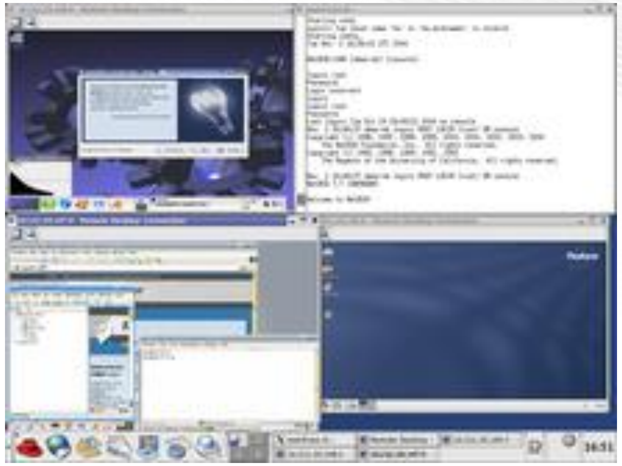
What is Virtualization

First Approach

Virtualization is technology that you can use to **create virtual representations** of servers, storage, networks, and other physical machines.

Virtual software **mimics the functions of physical hardware** to run **multiple virtual machines simultaneously** on a single physical machine.

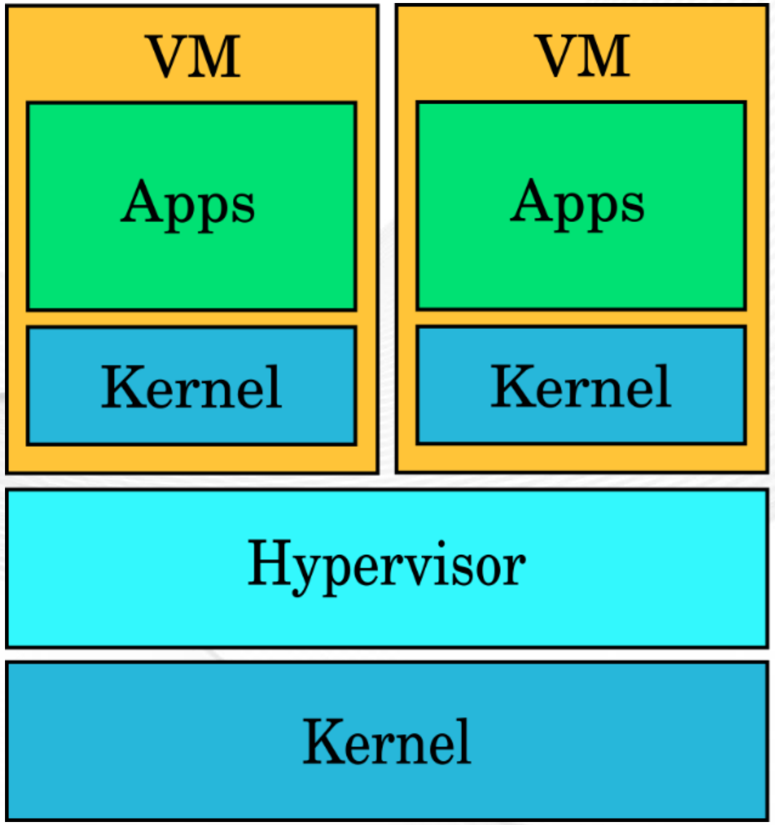
The benefits of virtualization include greater **efficiency, scalability, flexibility,** among others.



Virtualization

Types of Virtualization Techniques

- Type 0 (FW)
- Type 1 – Native Hypervisor:
  - VMWare ESXi, Proxmox VE.
- Type 2 – Hosted Hypervisor:
  - VirtualBox, VMware Workstation and Fusion, Parallels Desktop.



Virtualization

Other 'Virtualization' Techniques

Paravirtualization - Technique in which the guest operating system is modified to work in cooperation with the VMM to optimize performance (e.g. Xen).

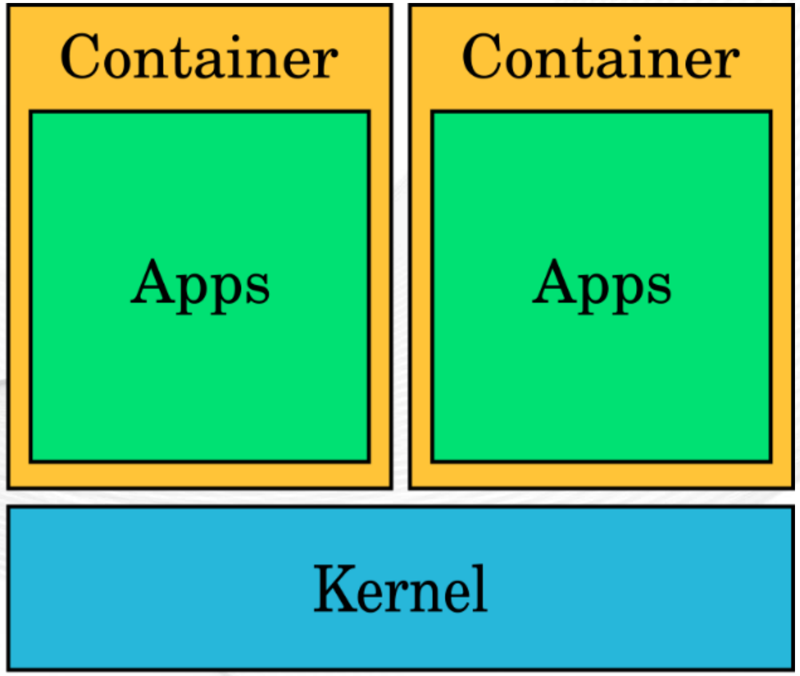
Programming-environment virtualization (e.g. Oracle Java and Microsoft.Net)

Emulators (e.g. QEMU)

Application containment - Not virtualization at all but rather provides virtualization-like features by segregating applications from the operating system, making them more secure and manageable.

Encapsulation / Packaging examples:

- Docker, Podman, LXD.



Virtualization

Some Benefits

Isolation: Host system protected from VMs, VMs protected from each other. Interaction provided though shared resources (via shared file system volume, network communication)--> architecture design.

Flexible management: Freeze, suspend, running VM. Snapshot of a given state. Clone by creating copy and running both original and copy (backup and recovery operations). Allows to run multiple, different OSes on a single machine.

Useful for DevOps: Improving system development efficiency. Consolidation, app dev, testing, deployment advantages.

Replication and Templating: Easy to write a template to create multiple instances for deployment.

Incident response / backup and recovery: It is possible to move a running VM from one host to another (with no interruption of user access).

Easy integration in cloud computing environments. Using APIs, programs tell cloud infrastructure (servers, networking, storage) to create new guests, VMs, virtual desktops.

Virtualization

What technology is the best?

Every one of them has its advantages/disadvantages. Some of them are shown below:

- Type 0 / Type 1:
  - Allow close to physical partitioning of the HW.
  - They usually need some features from the host OS.
  - …
- Type 2:
  - The guest OS runs as a process: it cannot take advantages of some HW features (not so good in performance).
  - It doesn’t require changes to the host OS (easy to maintain).
  - …
- Containment:
  - Achieve some goals of virtualization, such as segregation of apps, performance and resource management, easy start, stop, move, management.
  - Allows a more dynamic usage of the existent resources.
  - Less predictive.
  - …

Virtualization in Smart Grid

USE CASES AND PROJECTS

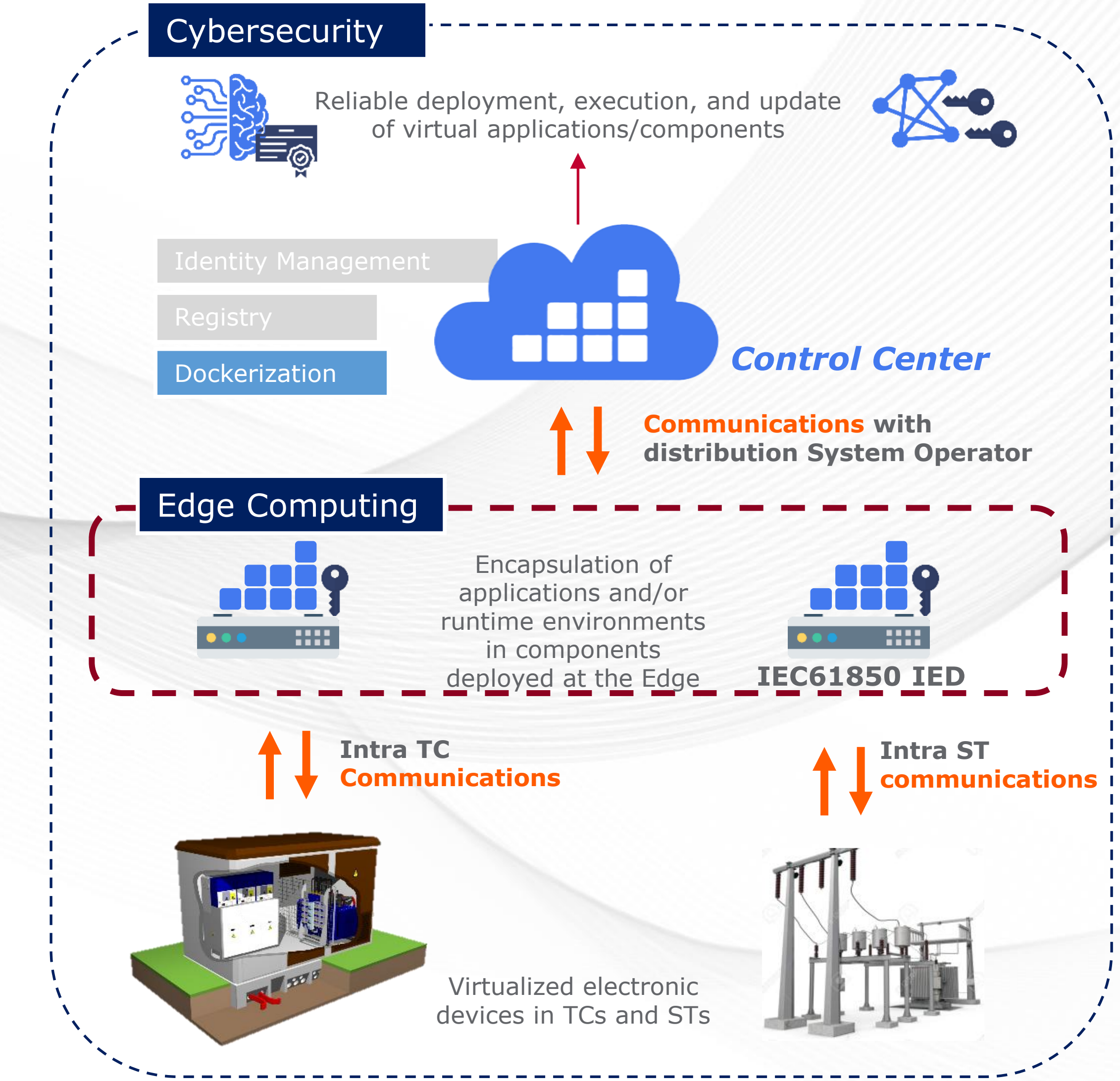
VIRTGRID Virtualization Project

Project funded by the Department of Economic Development, Sustainability and Environment of the Basque Government (ELKARTEK 2022 Programme).

EUSKO JAURLARITZA
GOBIERNO VASCO
EKONOMIAREN GARAPEN, JASANGARRITASUN ETA INGURUMEN SAILA
DEPARTAMENTO DE DESARROLLO ECONÓMICO, SOSTENIBILIDAD Y MEDIO AMBIENTE

Research in digital technologies (Edge Computing, Cloud Computing, IoT, Big Data and associated Cybersecurity) and their application to the virtualization of electronic devices in substations (ST) and transformer substations (CT).

DIGITAL TECHNOLOGIES FOR VIRTUALIZATION AND INTEROPERABILITY OF FUNCTIONS IN SMART GRIDS



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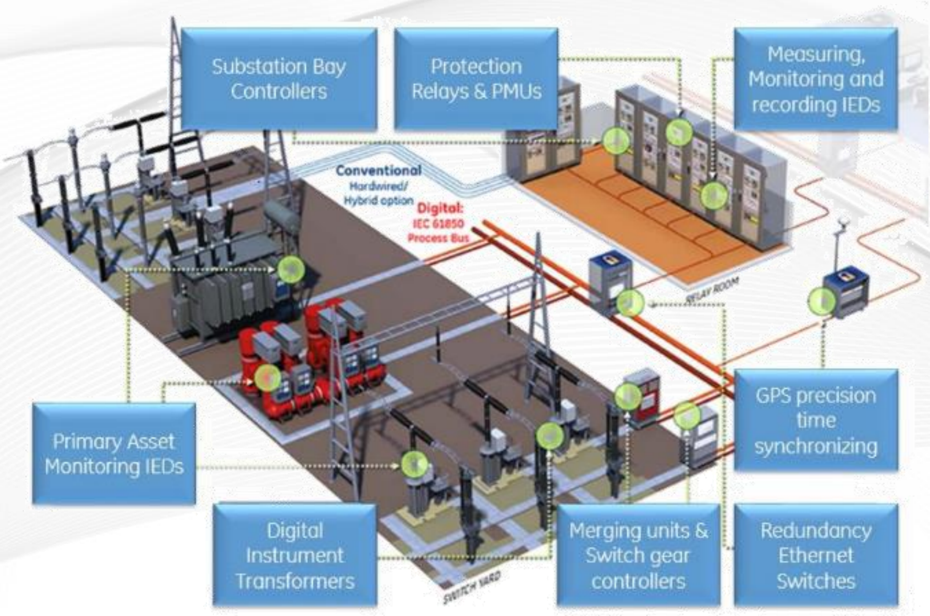
Virtualization in Smart Grid

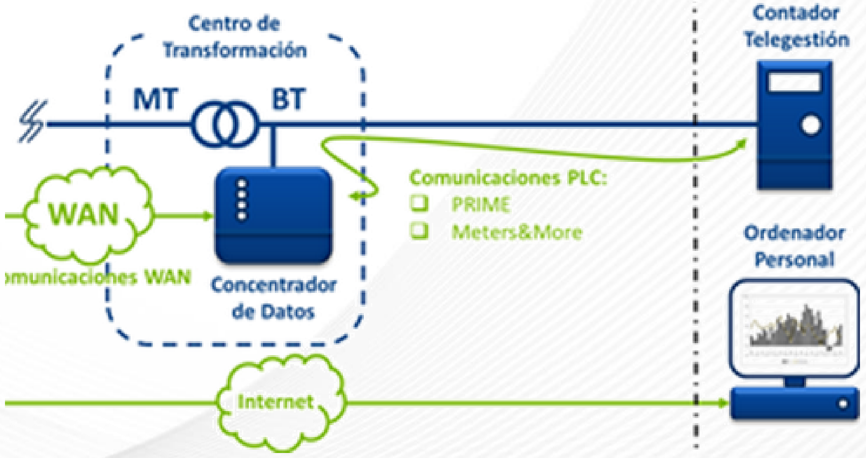
There is not 'one size fits all' solution…

- Network Location
- Functionality
- Criticality
- TSO/DSO policies
- …

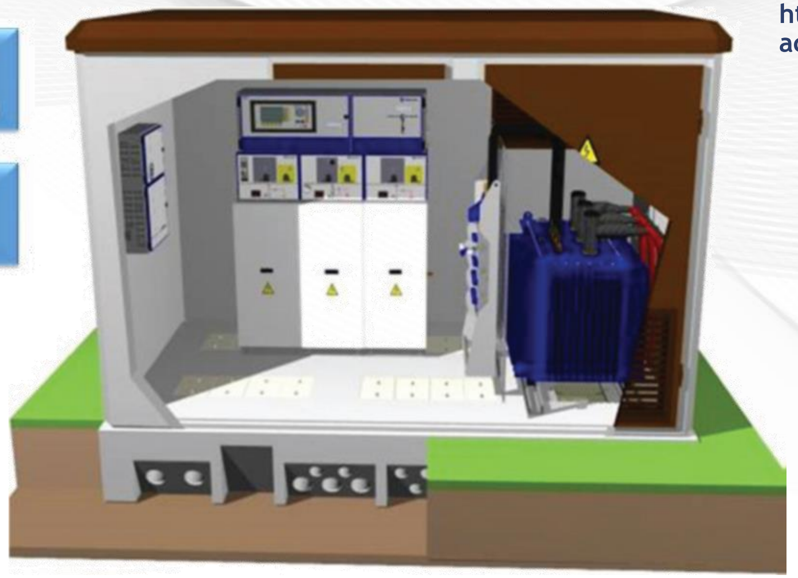
Virtualization in Smart Grid

Different scenarios: ST/TC/LV





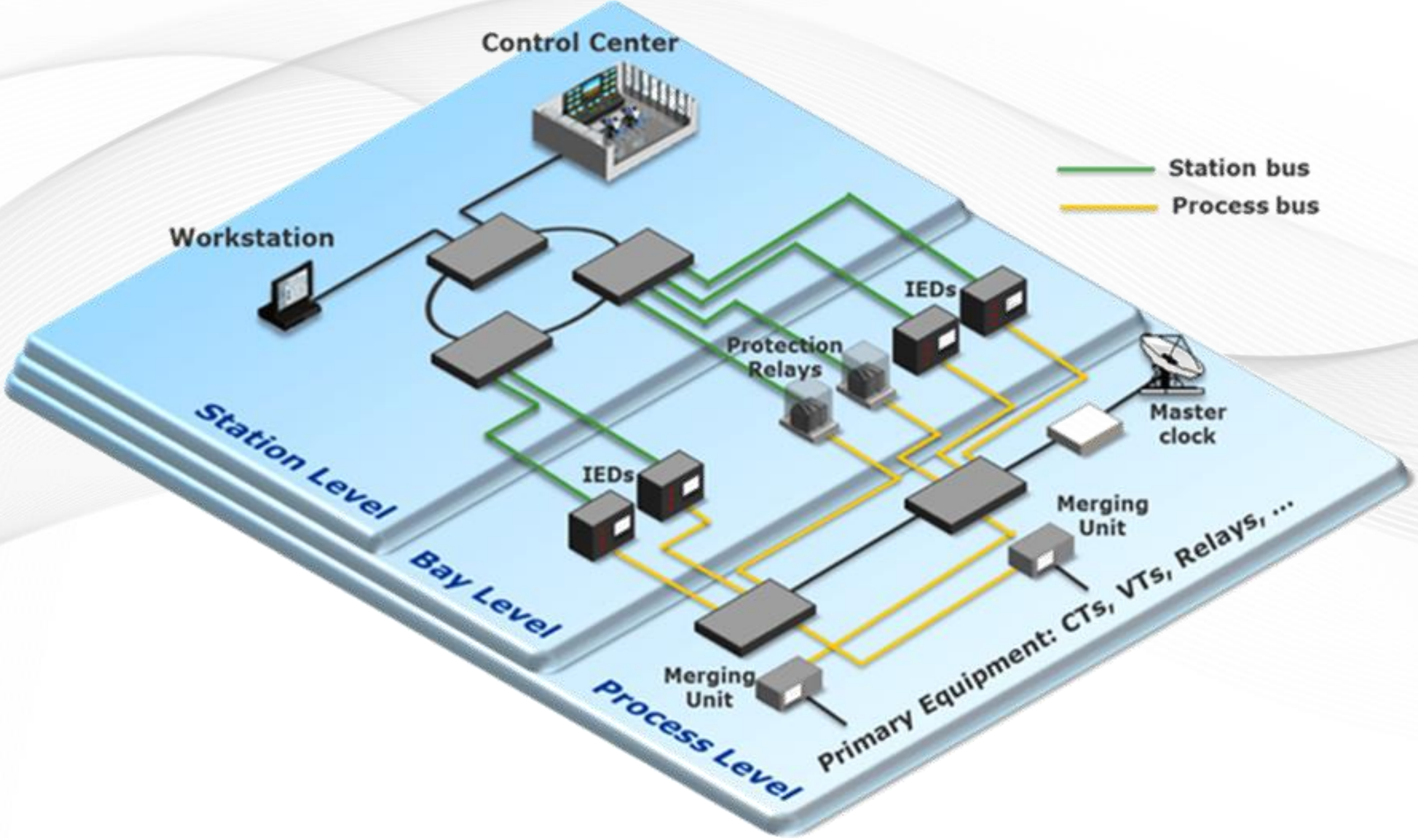
https://www.smartgridsinfo.es/comunicaciones/comunicacion-actualidad-uso-informacion-contador-telegestion



Source: Centro de transformación Inteligente (FutuRed 2020)

Virtualization in Smart Grid

There is not 'one size fits all' solution… let's focus on Substations



Possible solutions:

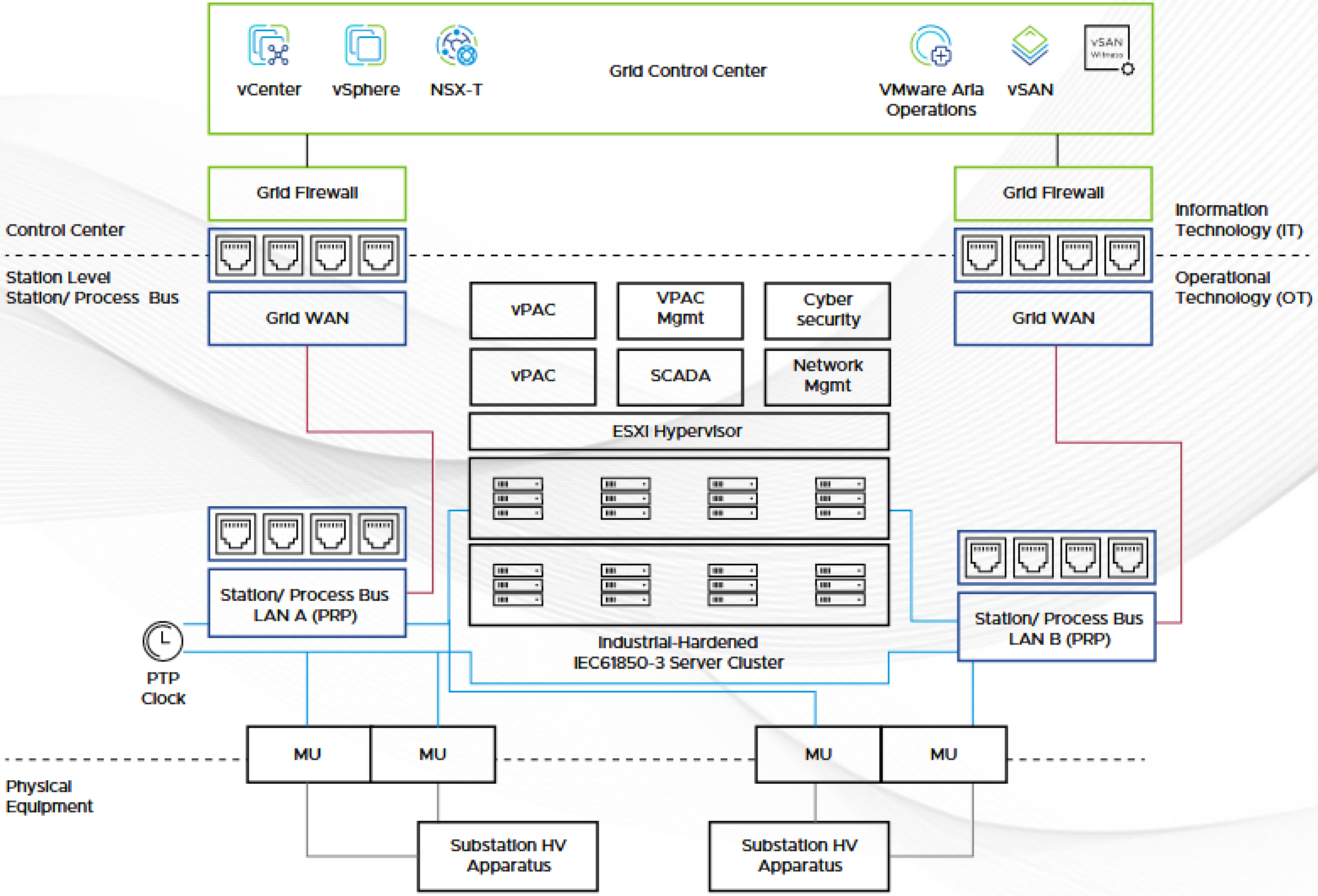
- SCADA System: **Type 2 Hypervisor** (VirtualBox, VMWare) or **Docker**
- Real Time P&C Devices → **Type 1/2 Hypervisor + Docker**
- Test environment → **QEMU**.

Virtualization in Smart Grid

VPAC Alliance

vPAC alliance

https://vpacalliance.com/



Shared Process/Station Bus Architecture example

https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/docs/vmw-utility-substation-virtual-protection-automation-and-control-ready-infrastructure.pdf

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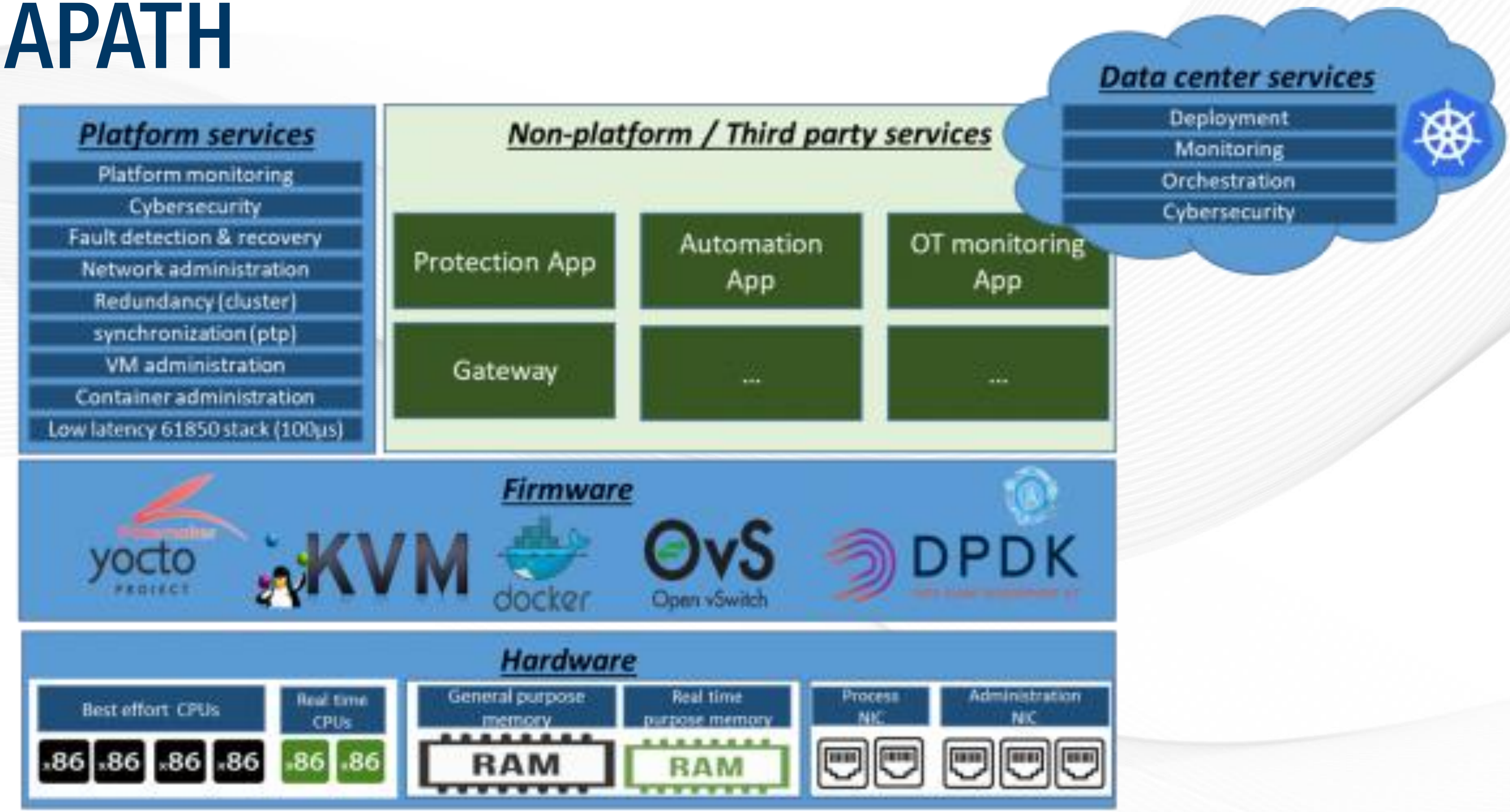
Virtualization in Smart Grid

SEAPATH

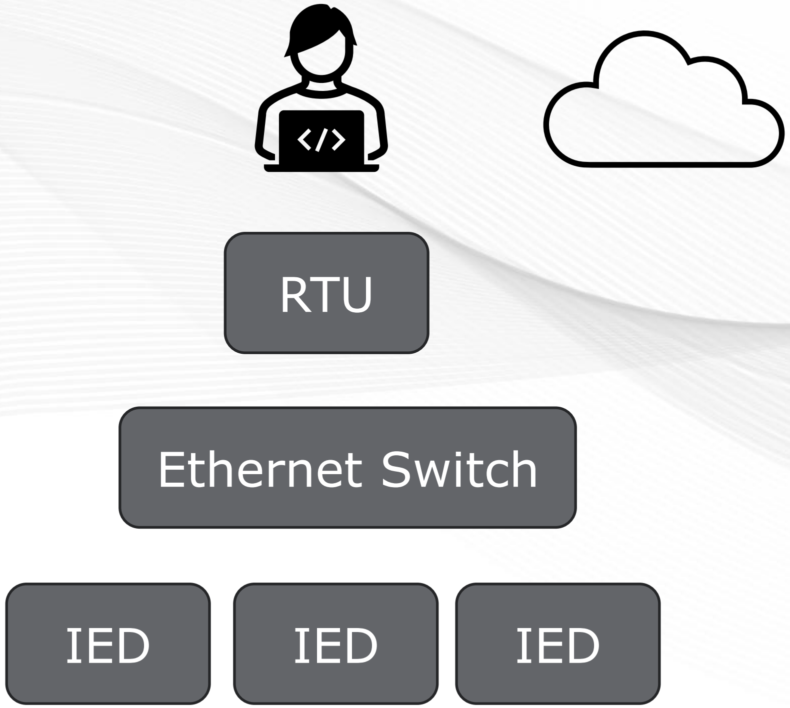
TSOs and DSOs require a **new generation of Digital Substation Automation Systems** (DSAS) that could provide more complex, dynamic, and **adaptative** automation functions at grid nodes and edge, as well as **enhanced orchestration from central systems**, in both **flexible** and **scalable** manner. Virtualization is seen as a key innovation in order to fulfill these needs.



https://lfenergy.org/projects/seapath/

Virtualization in Smart Grid

There is not 'one size fits all' solution… let's focus on Transformation Centres



Possible solutions:

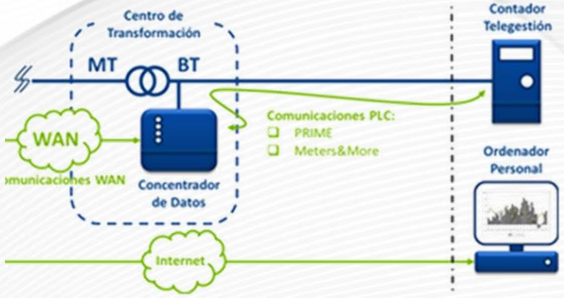
RTU: **Docker**

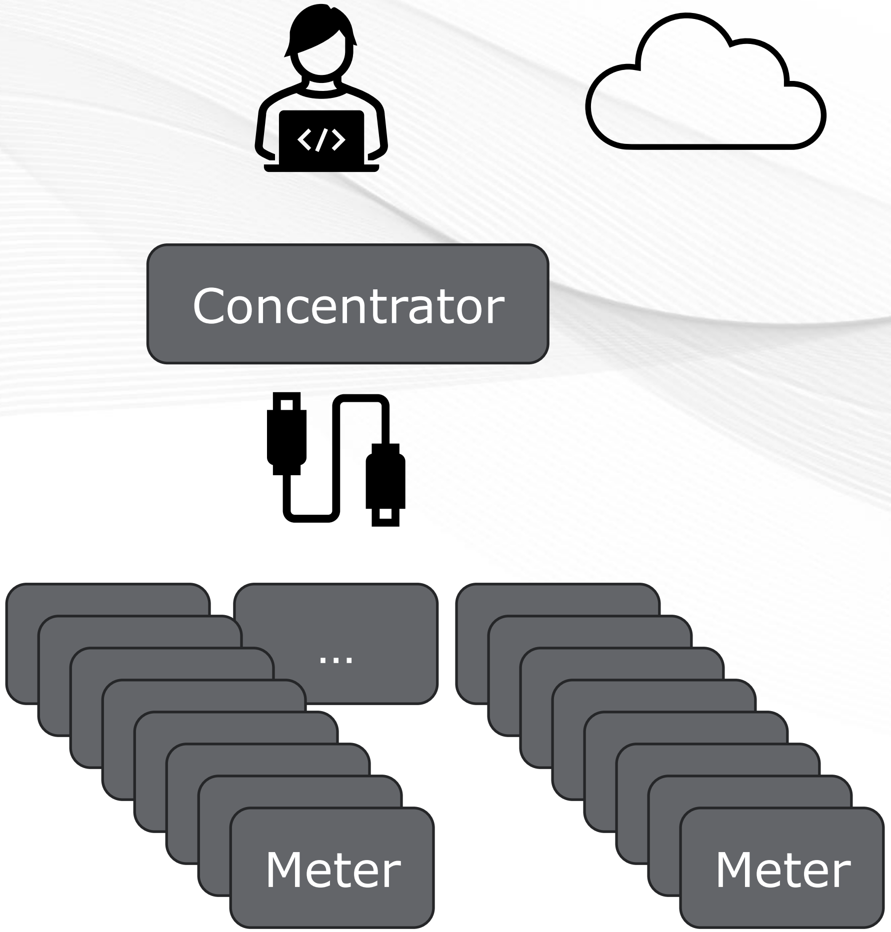
Real Time P&C Devices → **Type 1/2 Hypervisors or Docker**

Cloud enabled solution.

Virtualization in Smart Grid

There is not 'one size fits all' solution… let's focus on Low Voltage Network





Possible solutions:

Concentrator: **Docker**

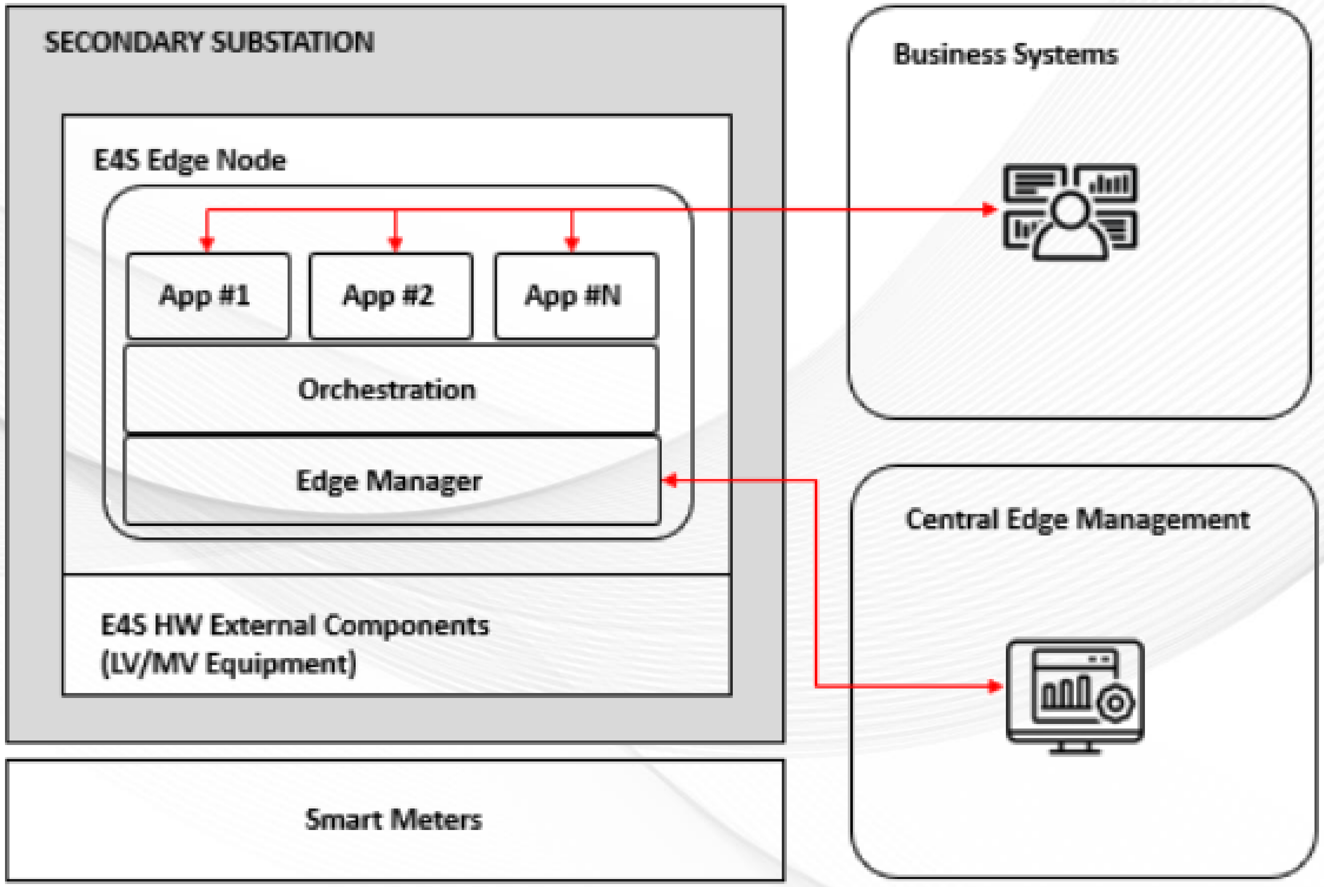
Meter: No virtualization

Cloud enabled solution

Virtualization in Smart Grid

E4S Alliance

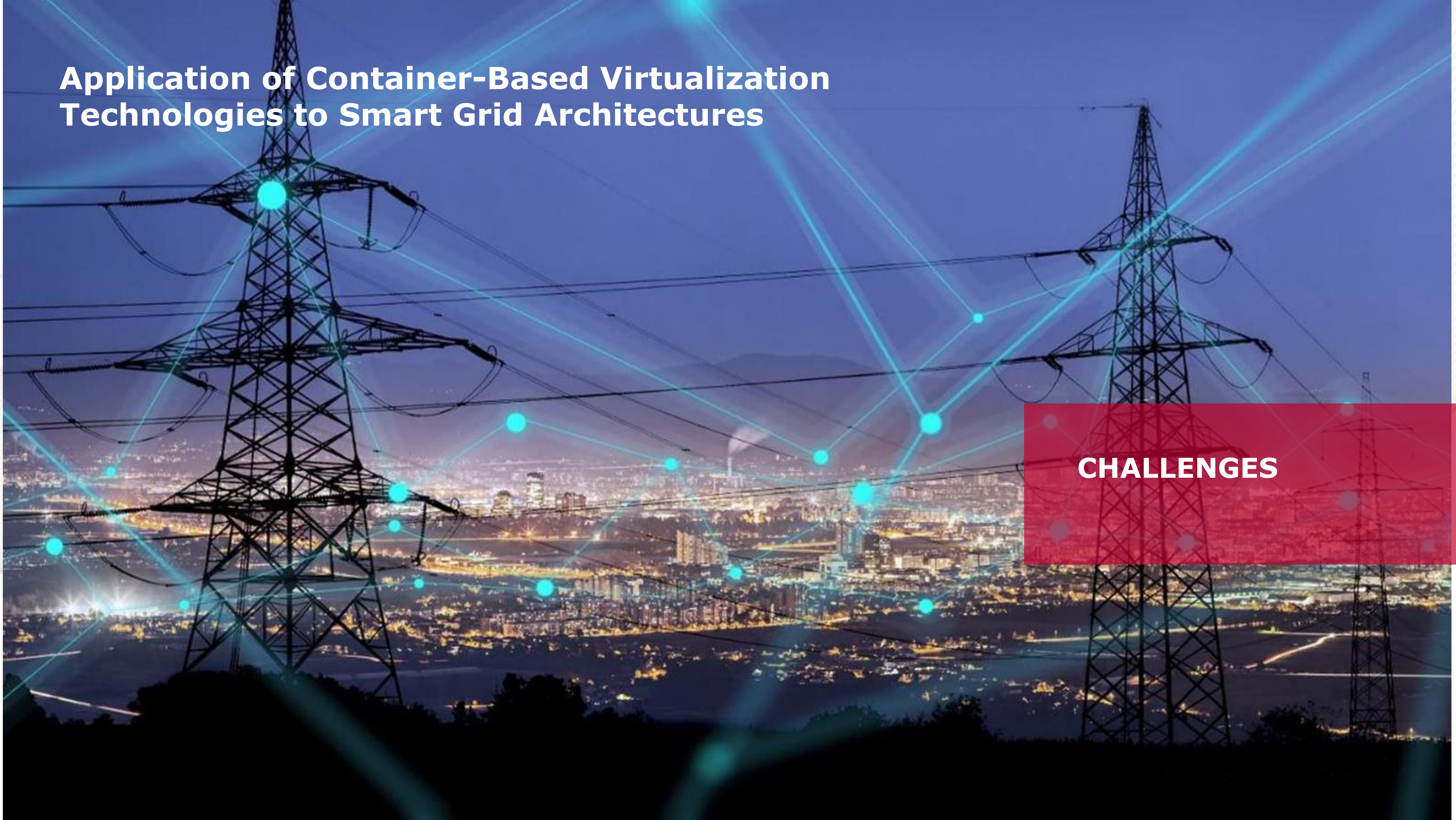
Adaptive "smart" grid control is crucial to enable operators to manage demand for power and reliability across the board. To deliver electricity **reliably**, we need to build the **next-generation smart grid**. The industry has created the Edge for Smart Secondary Substations (E4S) Alliance accelerates the **creation of standards-based flexible, manageable, and interoperable platforms**



https://www.e4salliance.com/data/files/wipe4s-specificationv1.2-summary-v3-vcedit121622.pdf

https://www.e4salliance.com/

Application of Container-Based Virtualization Technologies to Smart Grid Architectures



CHALLENGES

Virtualization in Smart Grid Challenges

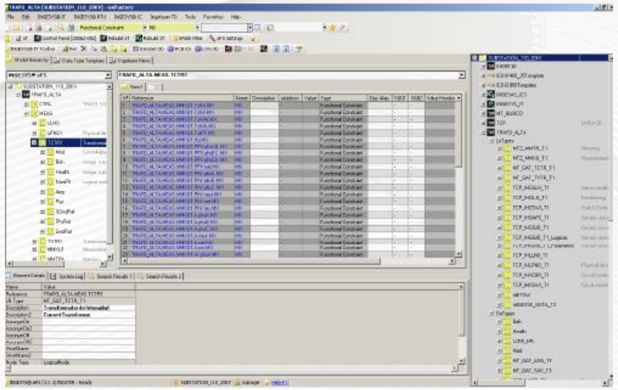
There are advantages, but we can identify some disadvantages or caveats

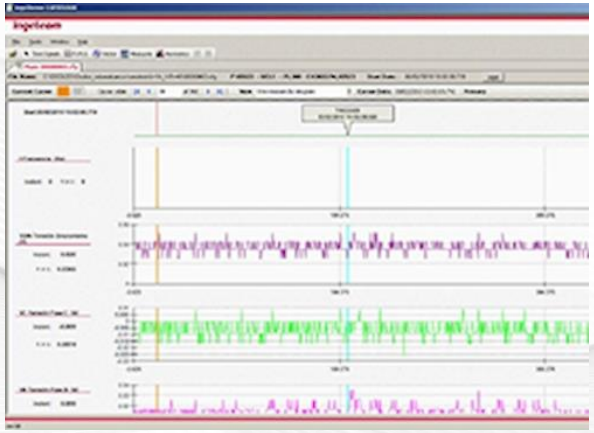
Let’s discuss some examples

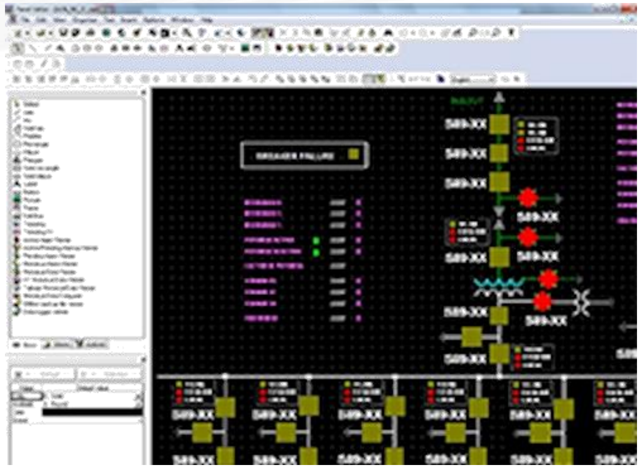
Advantages	Caveats
Cost Reduction	Initial Cost
Flexibility	Technology dependency
Cybersecurity	Failure Risk
Availability	Latency
Scalability	Resource Management

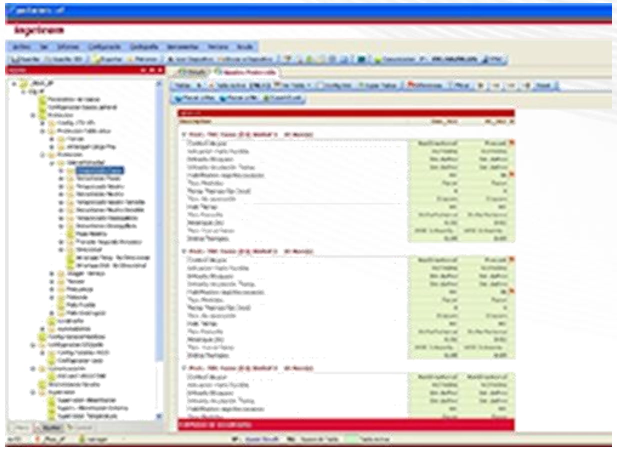
Virtualization in Smart Grid Challenges

IED and System Configuration







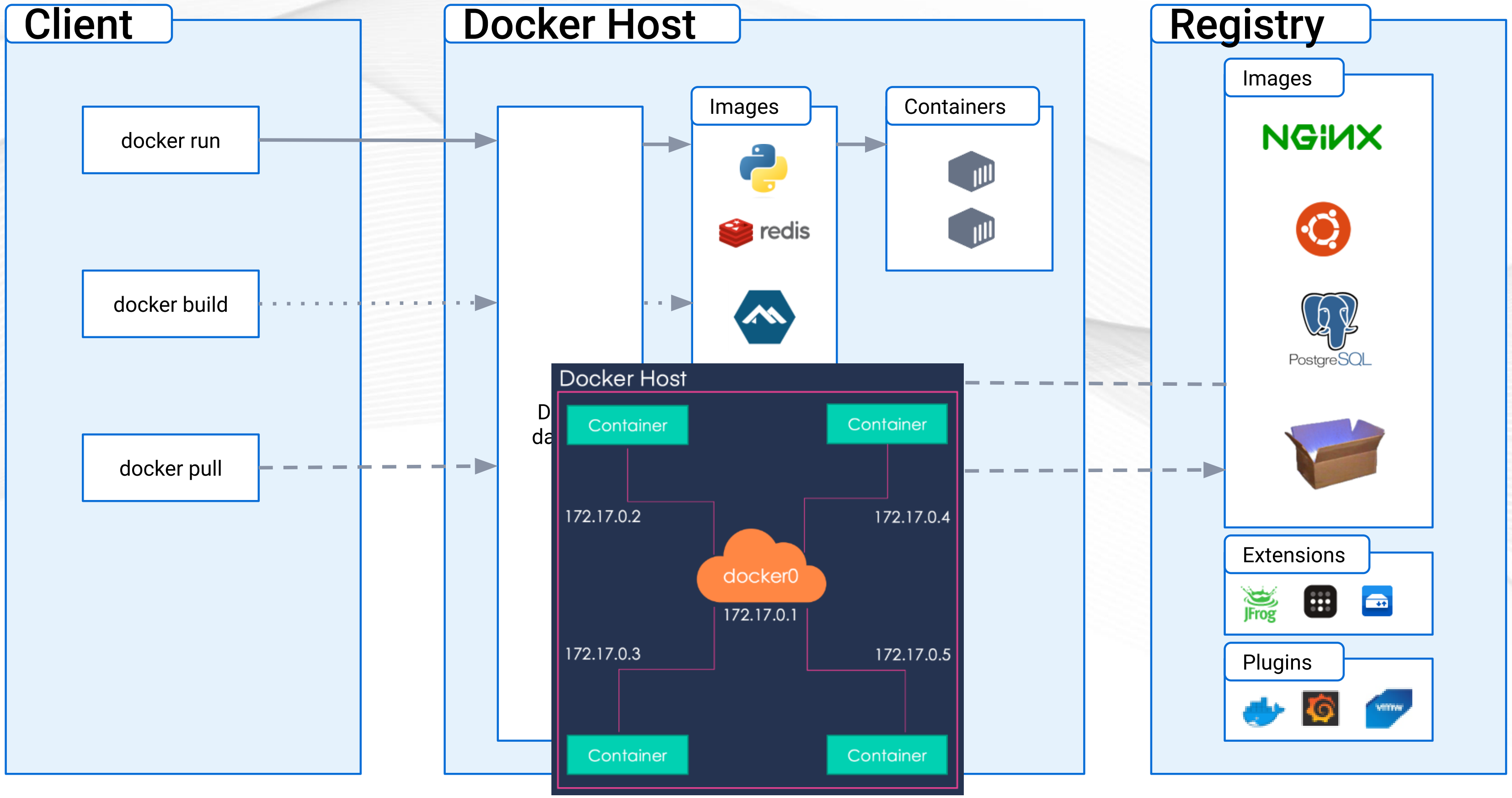


The configuration of the IED devices and the engineering process required for building a Smart Grid case (ST, TC) requires a **high degree of expertise and the use of advanced SW tools**.

The new virtualized scenario will be a **big change**.

Virtualization in Smart Grid Challenges

Required Network Ecosystem



The devices integrated in a docker based network system **don't run alone**.

There will be a **new whole ecosystem of tools and services** spread all over the network for leveraging the opportunities that container-based solutions enable.

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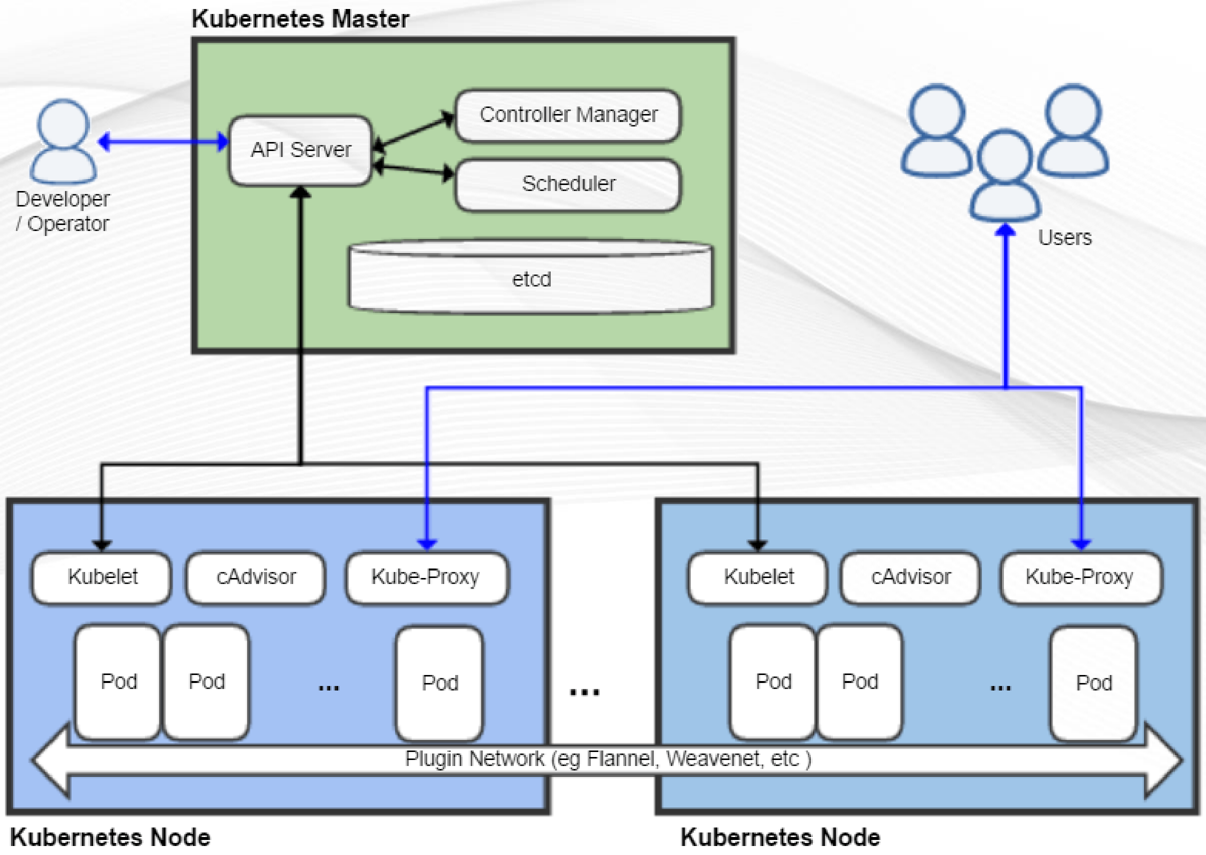
Virtualization in Smart Grid Challenges

Resource Management



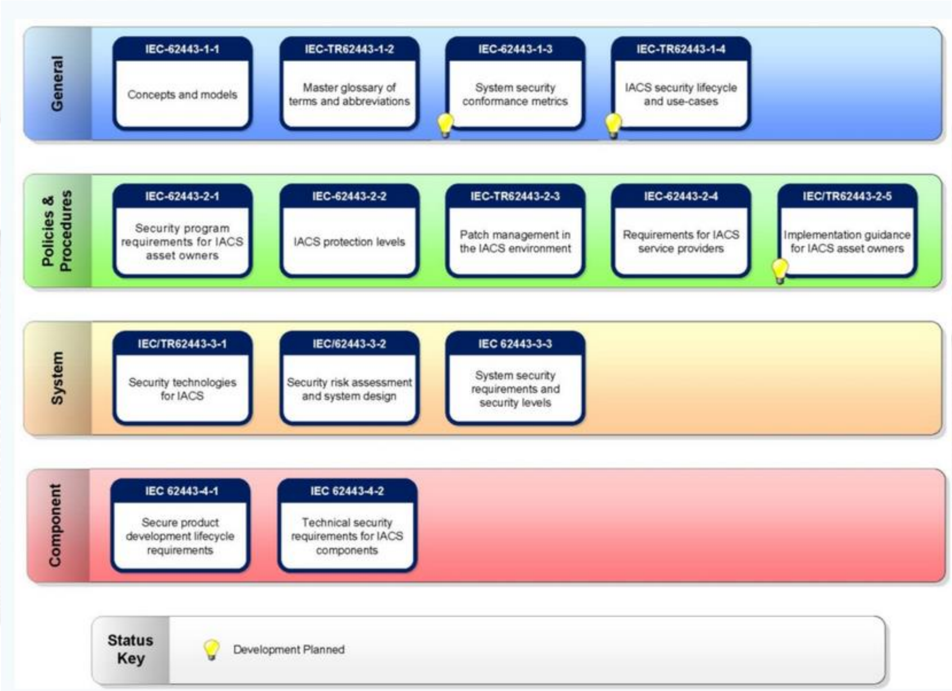
https://upload.wikimedia.org/wikipedia/commons/b/be/Kubernetes.png

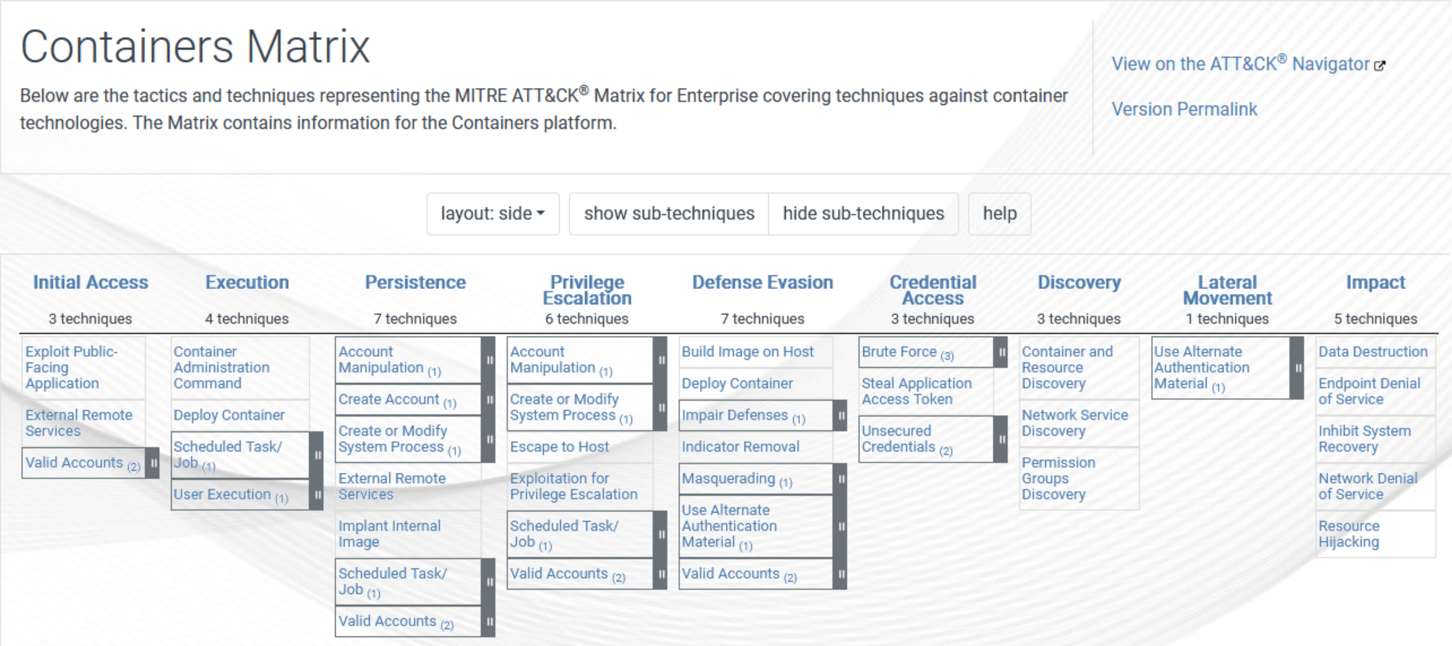
We cannot forget we are speaking about devices and systems running a **critical infrastructure with real time capabilities.**

The management of resources present in current docker networks are **not designed for this scenario.**

Virtualization in Smart Grid Challenges

Cybersecurity





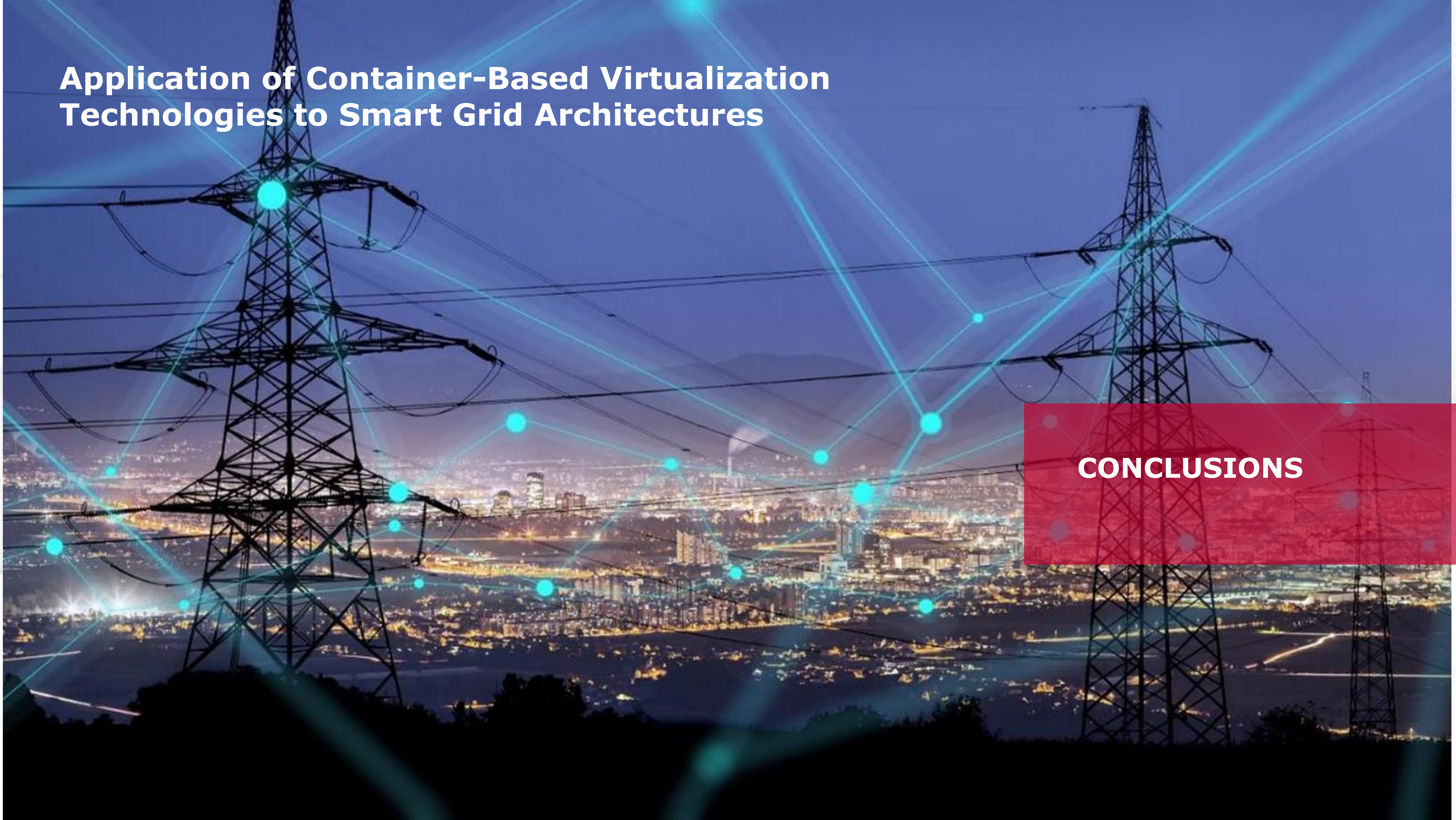
https://syc-se.iec.ch/deliveries/cybersecurity-guidelines/security-standards-and-best-practices/iec-62443/

https://attack.mitre.org/matrices/enterprise/containers/

The docker solution should **comply with industrial cybersecurity standards.**

Cybersecurity measures need to be aware of **new threats and attack vectors** related to this virtualized environment.

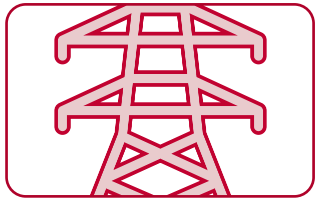
Application of Container-Based Virtualization Technologies to Smart Grid Architectures



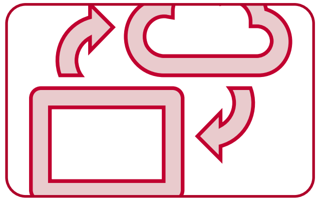
CONCLUSIONS

Virtualization in Smart Grid

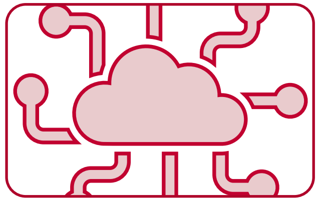
Conclusions



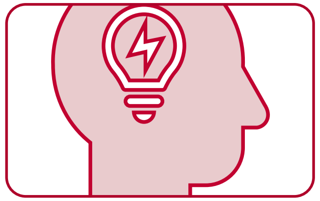
Smart Grid
- Complex Network System
- Different requirements / approaches
- Critical Sector



Virtualization
- Multiple solutions / Technologies
- Many benefits
- New Opportunities



Virtualization in Smart Grid
- ST, TC, LVN
- Cloud enabled solution
- Real projects working on it



Some Challenges
- IED/System configuration
- Required ecosystem
- Adapted Orchestration
- Cybersecurity

Ingeteam

Questions

Acknowledgements

The authors gratefully acknowledge the support from the Basque Government VIRTGRID Project (Elkartek KK-2022/00069) . Project funded by the Department of Economic Development, Sustainability and Environment of the Basque Government (ELKARTEK 2022 Programme).

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