Modern ICT/Automation Approaches for Smart Grids and Industrial Environments

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Content

- Background and Motivation
- From Passive to Active Power Grids
- Smart Grid ICT and Automation
- Selexted Examples

This project has received funding from the H2020 programme of the European Union under GA No. 952140

Background and Motivation

› Challenges and drivers

- Climate change
- Deep decarbonisation
- Energy transition

- Industrial competitiveness
- Business Innovation
- Digitalisation

- Urban Transformation
- Infrastructure needs
- Societal changes

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Background and Motivation

- Global policy
  - *Paris Agreement (COP21):* long-term, limit temperature increase to 1.5°C
  - *UN Sustainable Development Goals:* pathway for future research and innovation activities
  - *Mission Innovation:* global initiative to accelerate clean energy innovation
- Europe policy
  - *European Green Deal:* climate-neutrality by 2050
  - *EC Roadmap Low-Carbon Economy 2050:* EU GHG emissions towards an 80% domestic reduction
  - *EC Hydrogen Strategy and Sector Integration:* renewable hydrogen electrolysers

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Background and Motivation

- Planning and operation of the energy infrastructure becomes more complex
  - Large-scale integration of renewable sources (PV, wind, etc.)
  - Controllable loads (batteries, electric vehicles, heat pumps, etc.)
- Trends and future directions
  - Digitalisation of power grids
  - Deeper involvement of consumers and market interaction
  - Linking electricity, gas, and heat grids for higher flexibility and resilience

Source: AIT

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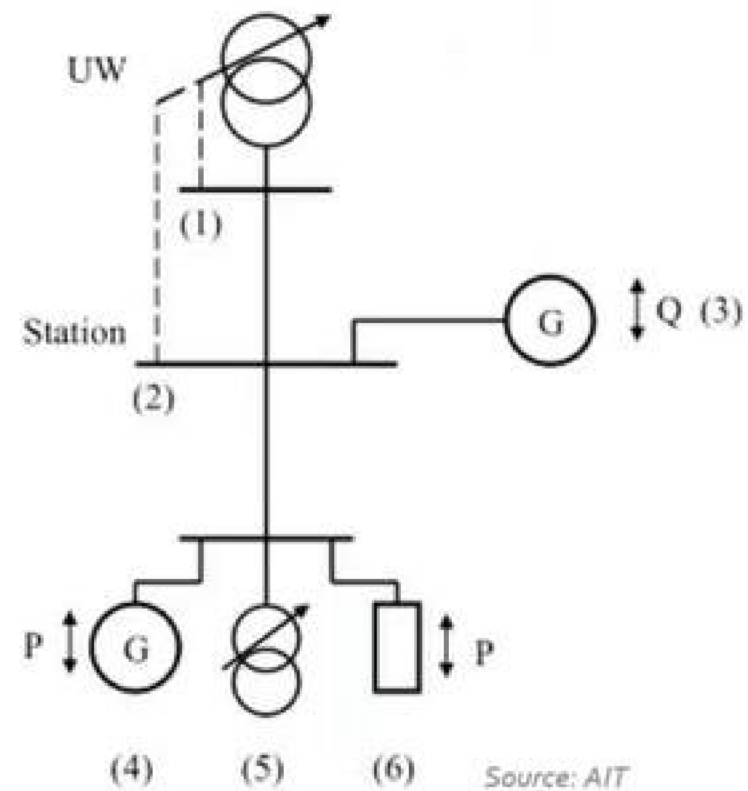
From Passive to Active Power Grids

- What can be influenced in smart power distribution grids?
  - On-load Tap Changer (OLTC) (1,2)
  - Generators (3,4)
  - Adjustable transformers (low voltage) (5)
  - Demand Side Management (DSM) (6)



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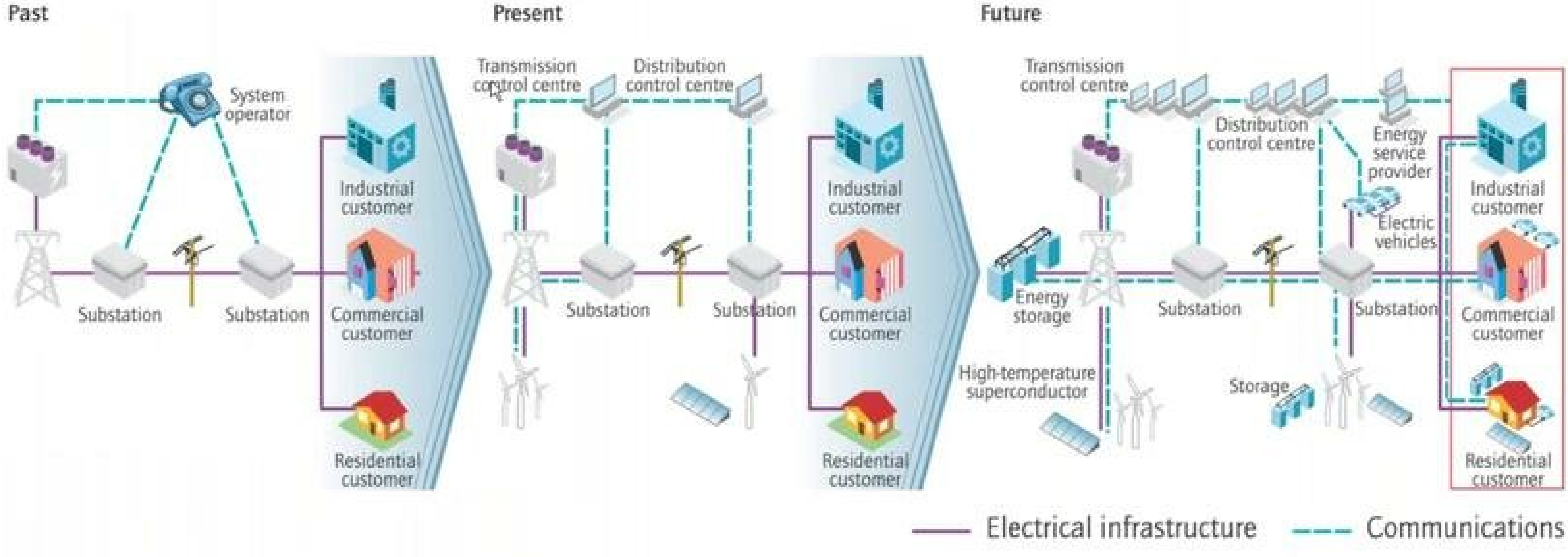
From Passive to Active Power Grids

› Historical development and future trends



Source: IEA

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From Passive to Active Power Grids

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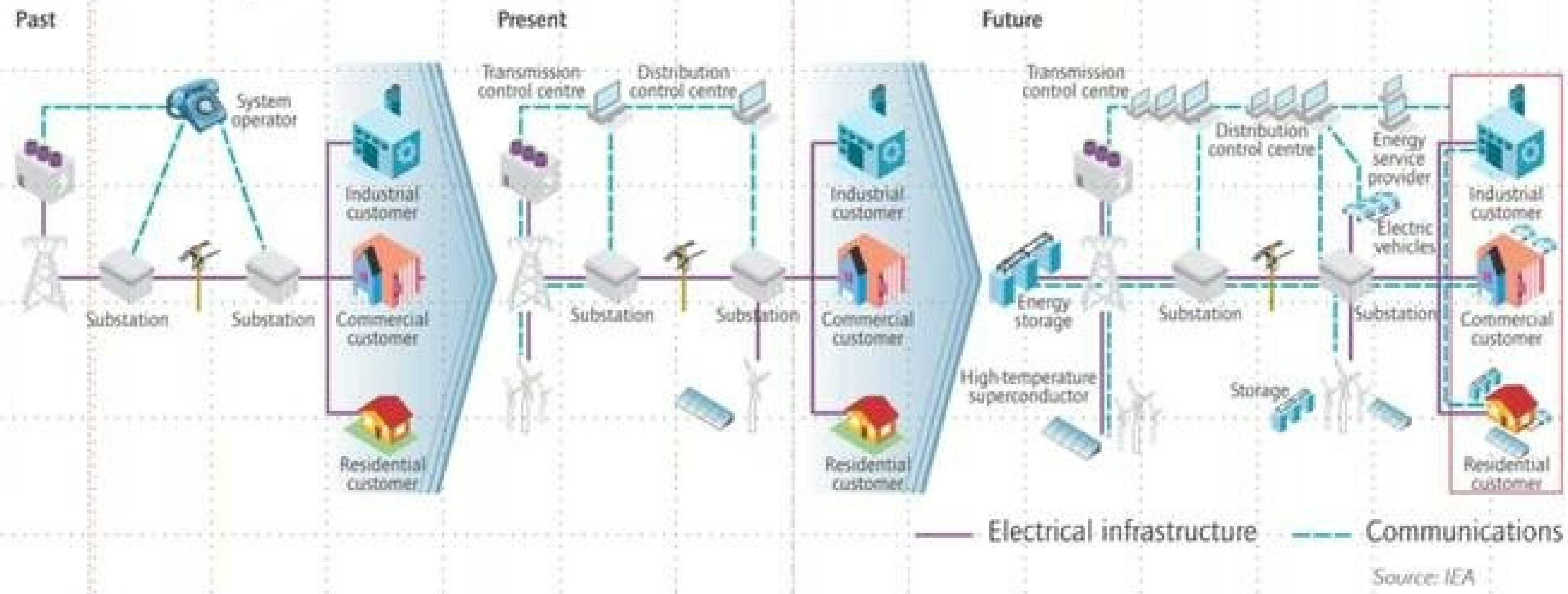

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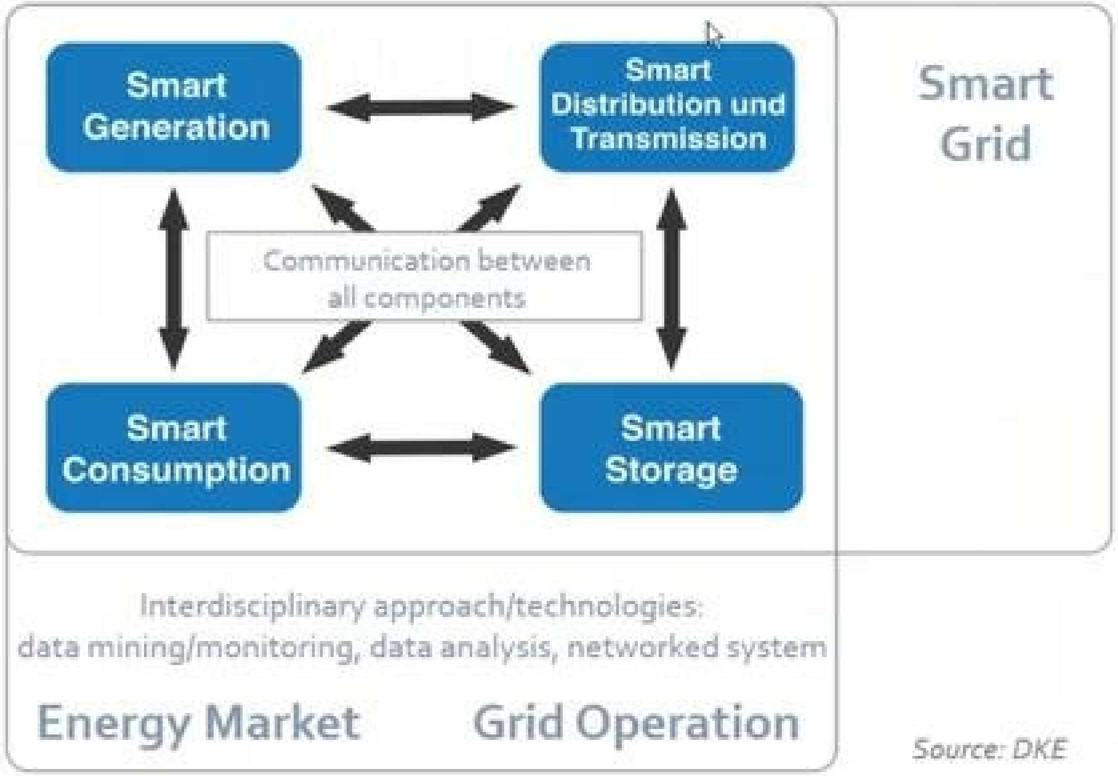
From Passive to Active Power Grids

- Interaction between different players
  - Information exchange
  - Integration of different players/devices
  - Interaction between different players/devices



Source: DKE

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From Passive to Active Power Grids

- Smart grids on different levels
  - Transmission system (e.g., Trans-European demand/supply matching)
    - → Super Grids (offshore wind farms in northern Europe – hydro storages in the Alps – large scale solar/PV systems in southern Europe/Africa)
  - Medium Voltage (MV)/Low Voltage (LV) distribution system
    - → Smart Grids (active distribution grids, integration of distributed generators and storage systems)
  - Local energy system (e.g., for buildings or small areas; low voltage systems)
    - → Micro Grids (islanding, grid-connected)

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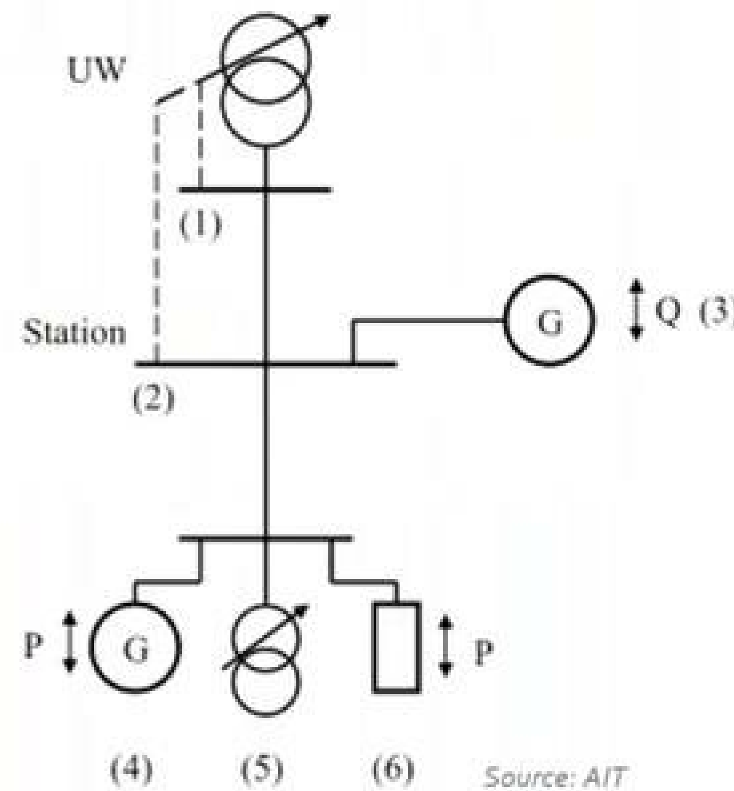

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From Passive to Active Power Grids

› Automation functions of smart grids

Function	Description
Self-healing	Automatic restoration of grid operation in case of faults/errors
Self-optimization	Ability to optimize the grid operation due to fluctuating renewables
Self-monitoring and diagnostics	Advanced monitoring and state estimation capability
Condition dependent maintenance	Preventive maintenance using component condition and life-time
Automatic grid (topology) reconfiguration	Automatic adjustment of the grid topology for grid optimization
Adaptive protection	Automatic adaption of protection equip. settings due to grid condition
Demand response support	Advanced energy management using distributed generation and controllable loads
Distributed management	Distributed control with automatic decision finding process and
Distributed generators with ancillary services	Possibility to use ancillary services (e.g., voltage/frequency control)
Advanced forecasting support	Forecasting of generation and load profiles for grid optimization

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From Passive to Active Power Grids

- Necessary technologies
  - Internet of Energy
    - Energy grids/infrastructure + ICT Network
    - Bi-directional energy and communication flow
  - Operation of Smart Grids requires innovative ICT technologies
    - Advanced automation concepts and algorithms
    - Advanced communication concepts
    - Intelligent grid components (inverters, controllers, meters, etc.)
    - Interoperability of systems and components (most important requirement!!!)

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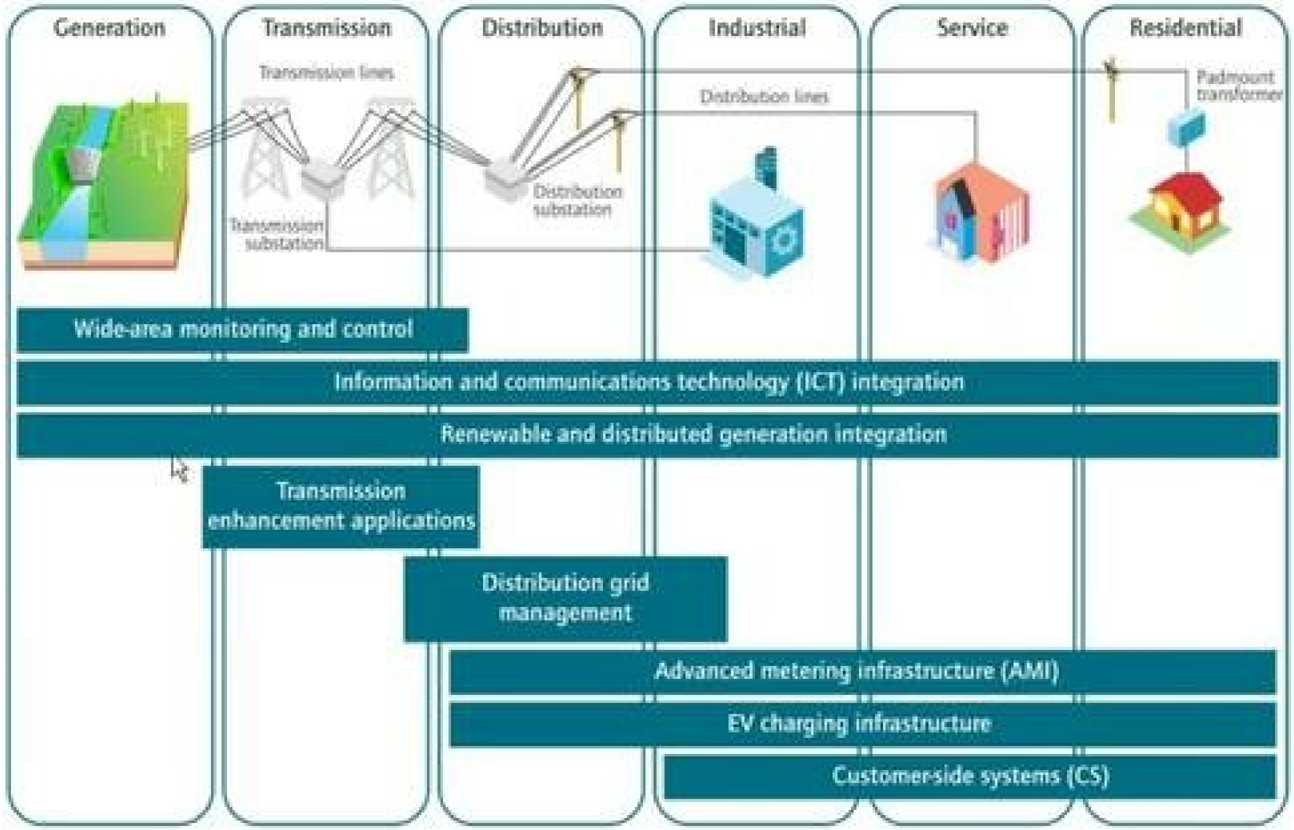
From Passive to Active Power Grids

› Technology areas



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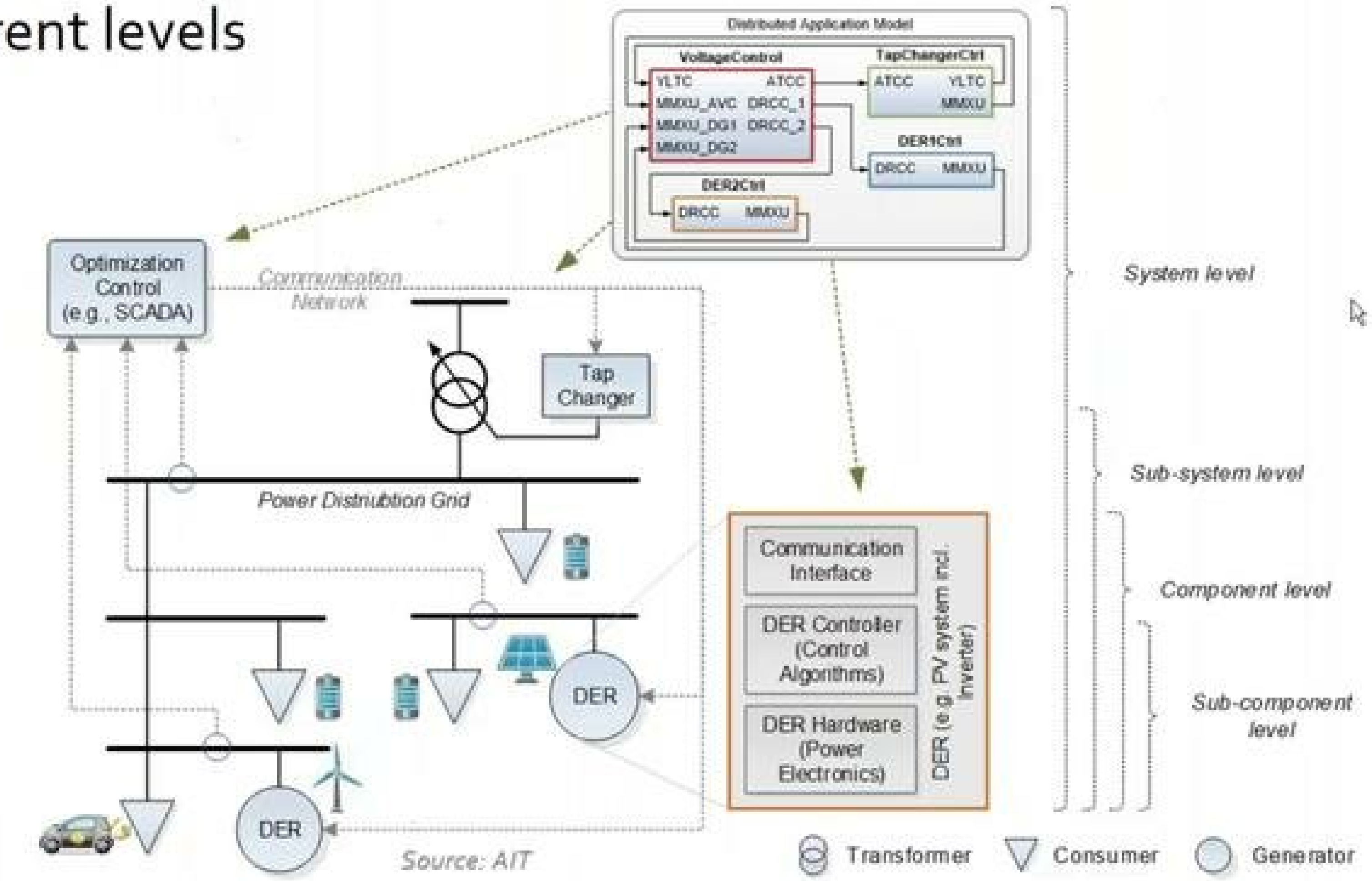
Smart Grid ICT and Automation

- Intelligence on different levels
  - System
  - Sub-system
  - Component
  - Sub-component



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Smart Grid ICT and Automation

› Important ICT-based standards (IEC view)

IEC 62357	• Reference Architecture – SOA • Energy Management Systems, Distribution Management Systems
IEC 61970/ IEC 61968	• CIM (Common Information Model) • EMS, DMS, DA, SA, DER, AMI, DR, E-Storage
IEC 61850	• Substation Automation, Power Utility Automation • EMS, DMS, DA, SA, DER, AMI
IEC 62351	• Security
IEC 62056	• Data exchange for meter reading, tariff and load control
IEC 61508	• Functional safety of electrical/electronic/programmable electronic safety-related systems

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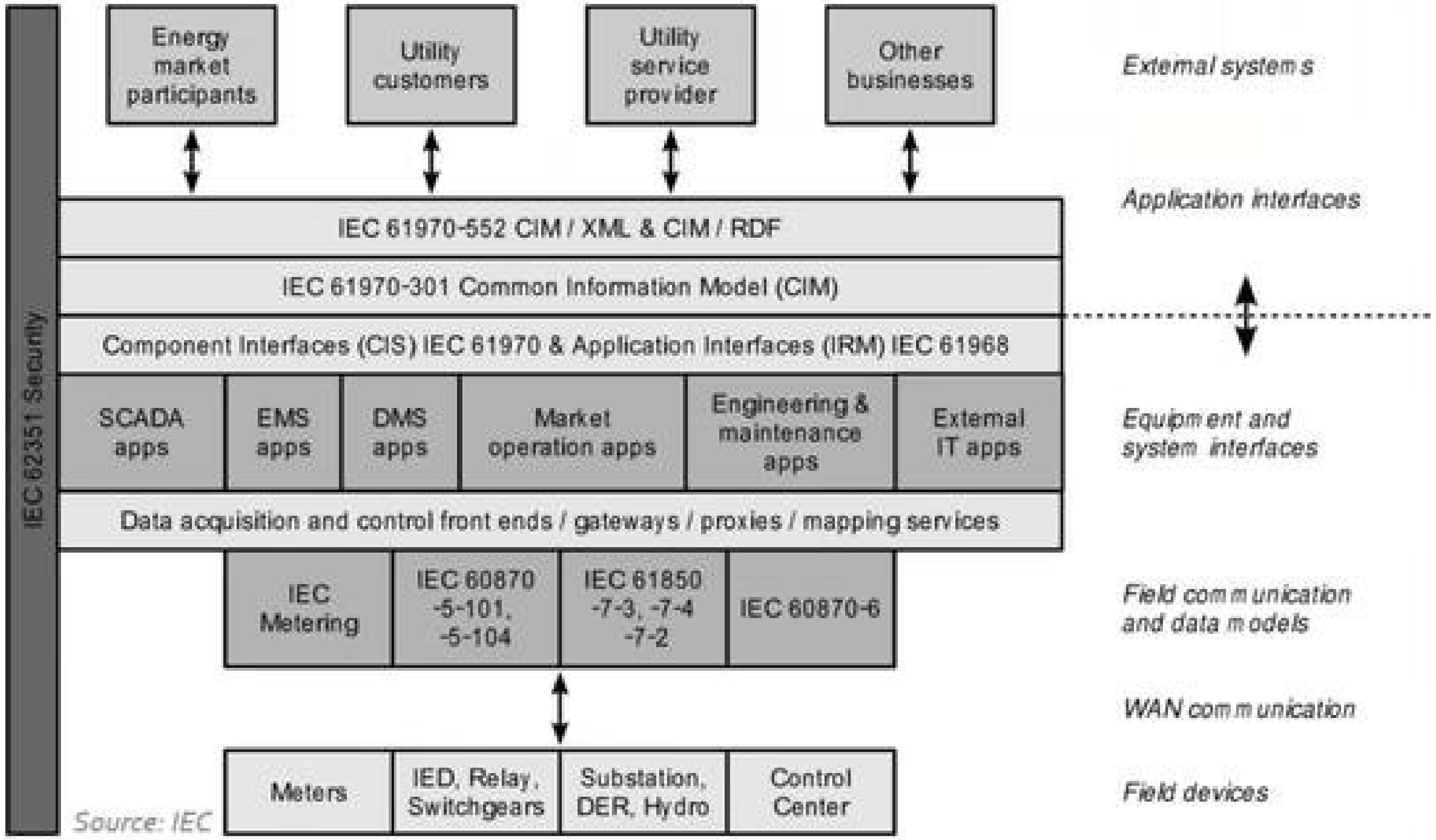
Smart Grid ICT and Automation

› IEC seamless integration architecture (service-oriented approach)



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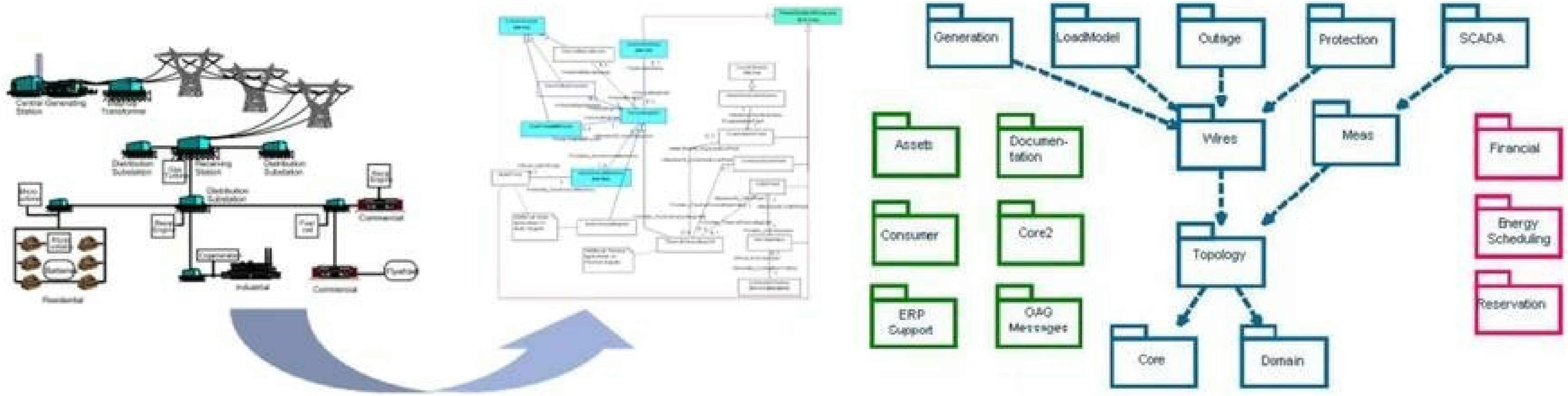
Smart Grid ICT and Automation

- IEC 61970/61968 – Common Information Model (CIM)
  - Object-oriented information model of the power system
  - Kind of domain ontology



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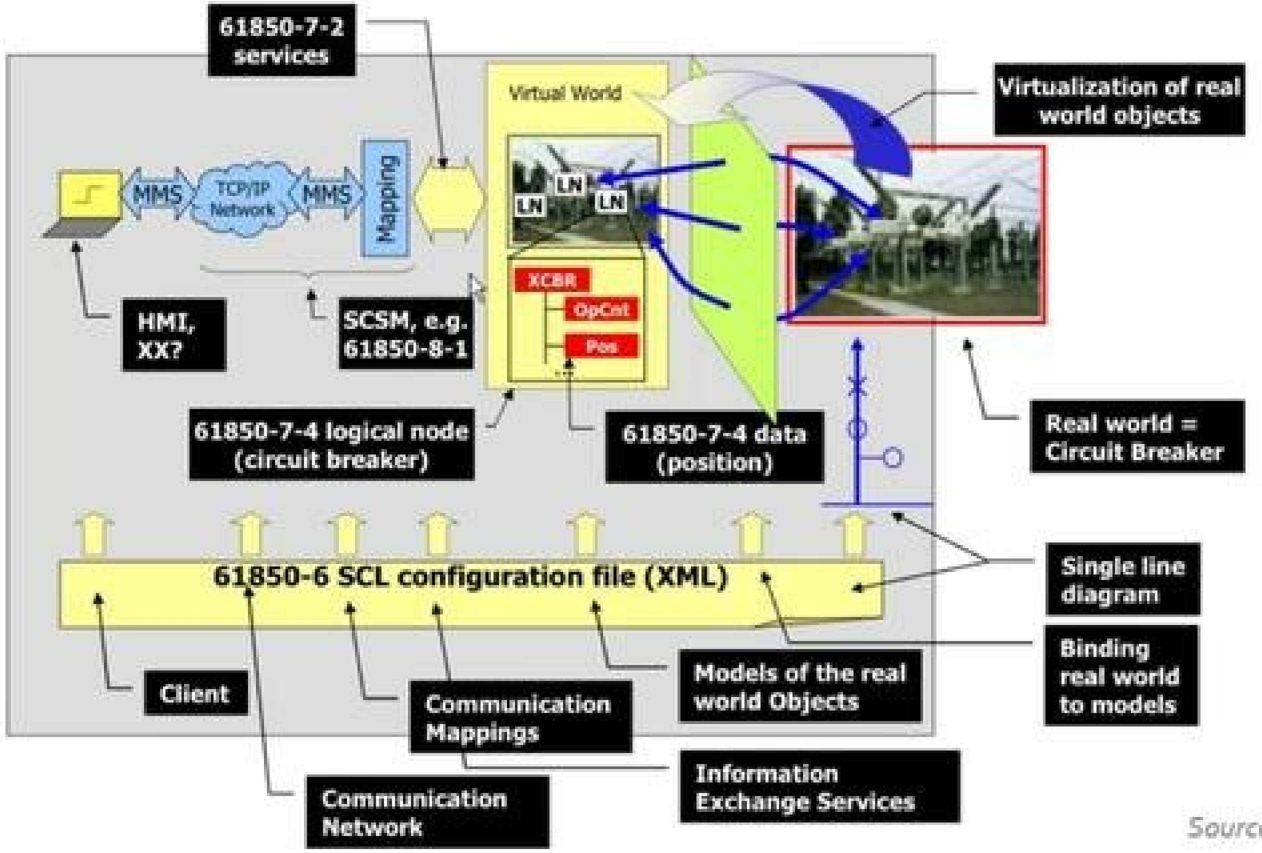
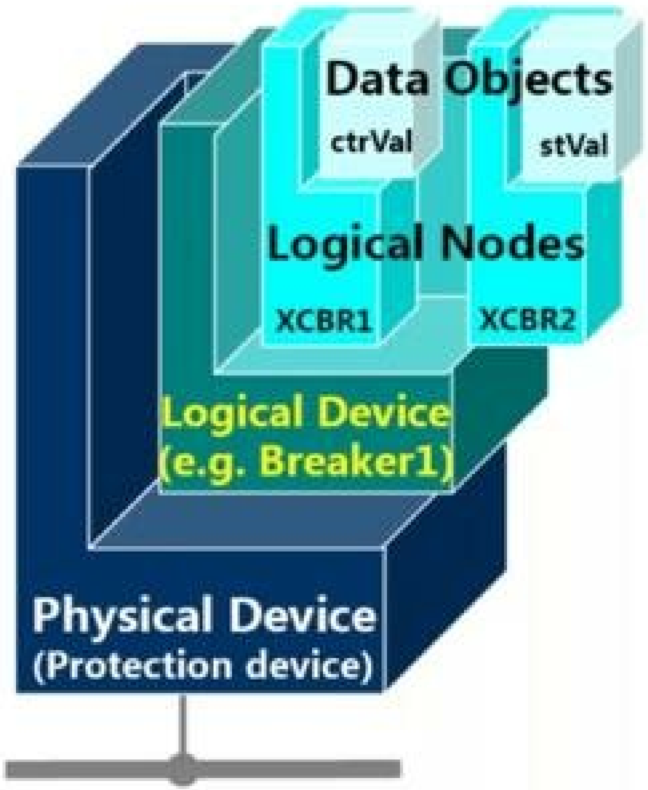
Smart Grid ICT and Automation

› IEC 61850 - communication networks and systems for power utility automation



Source: IEC



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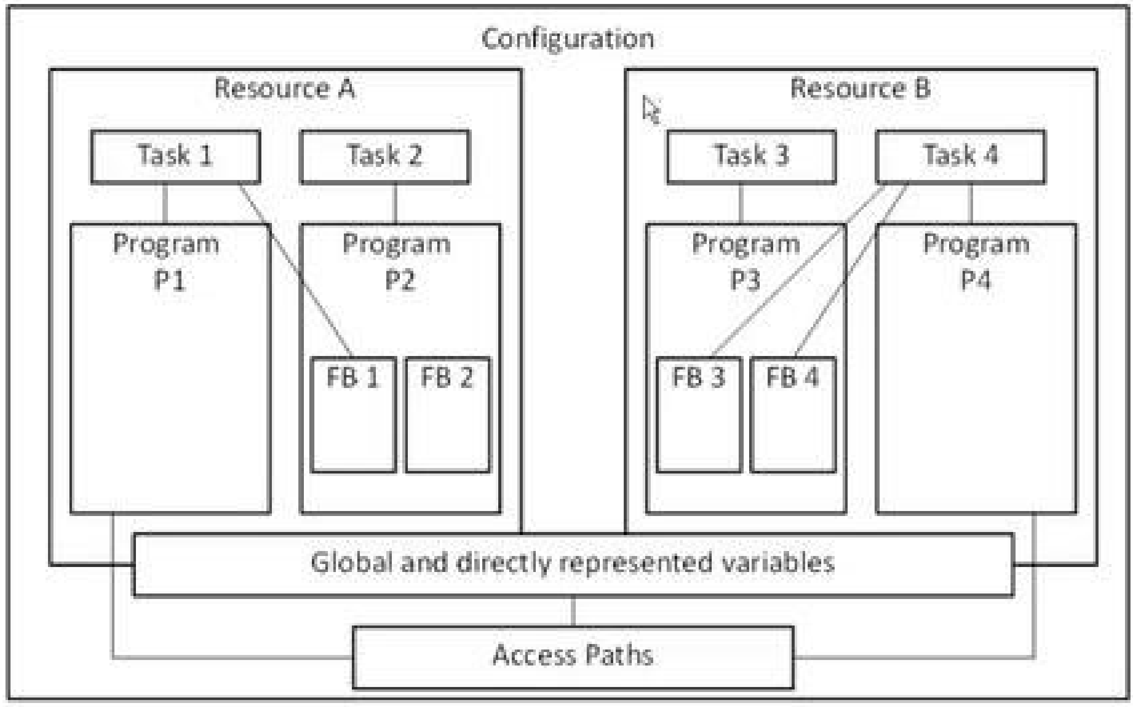
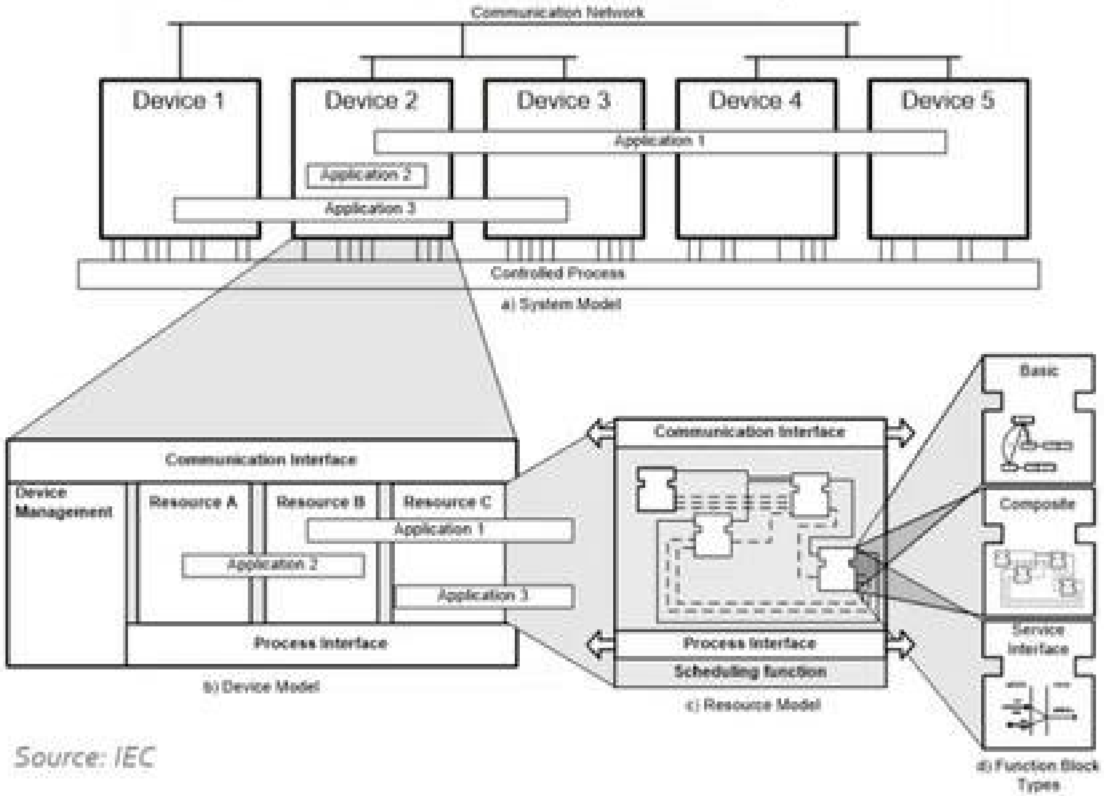
Smart Grid ICT and Automation

› IEC 61131 and IEC 61499 – implementation of control code

IEC 61131 Programable Logic Controller (PLC)



IEC 61499 Distributed Control System (DCS)



Source: IEC

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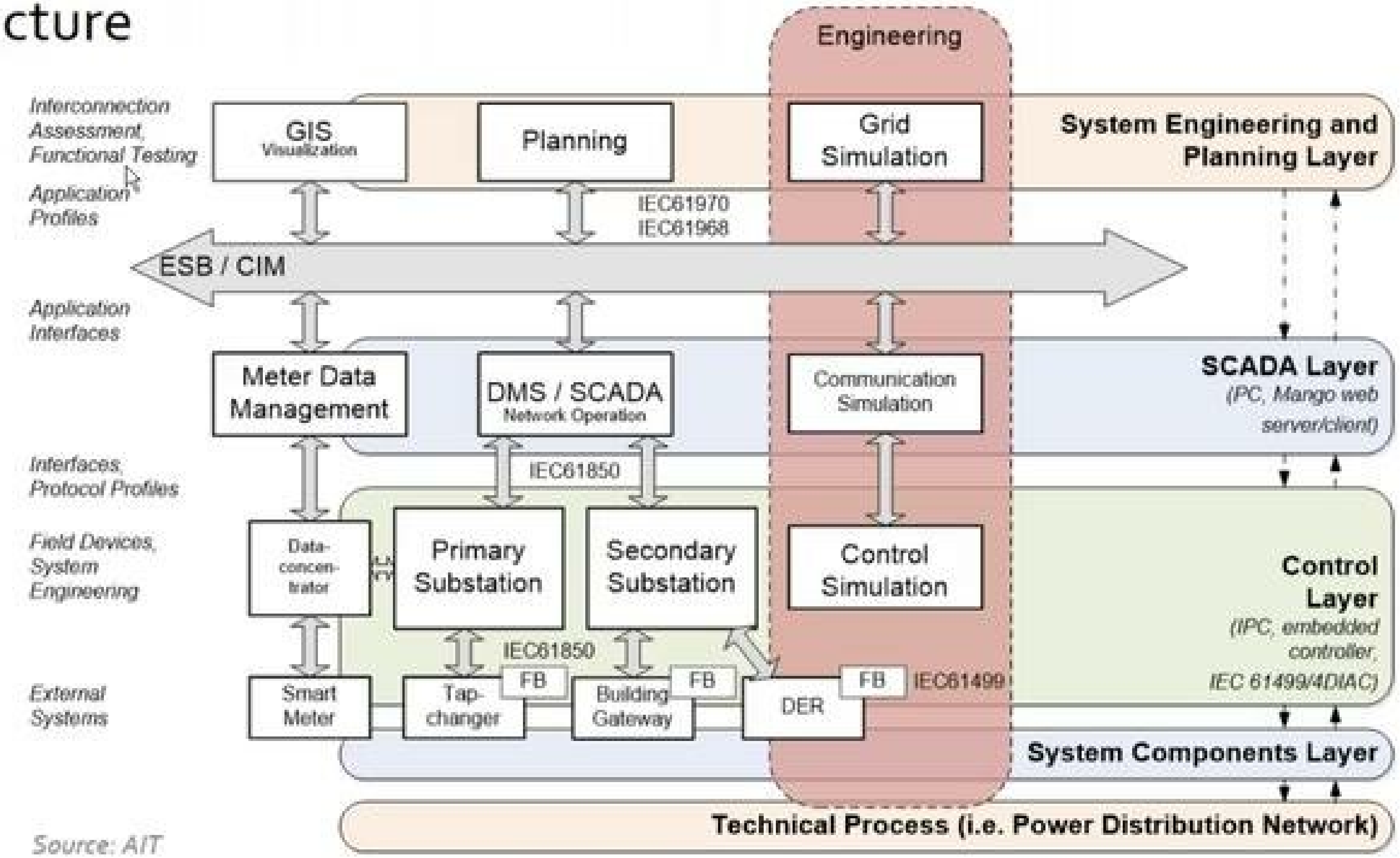
Selexted Examples

- ICT-based integration architecture
  - IEC standard-compliant
  - Virtual environment + real devices



Source: AIT

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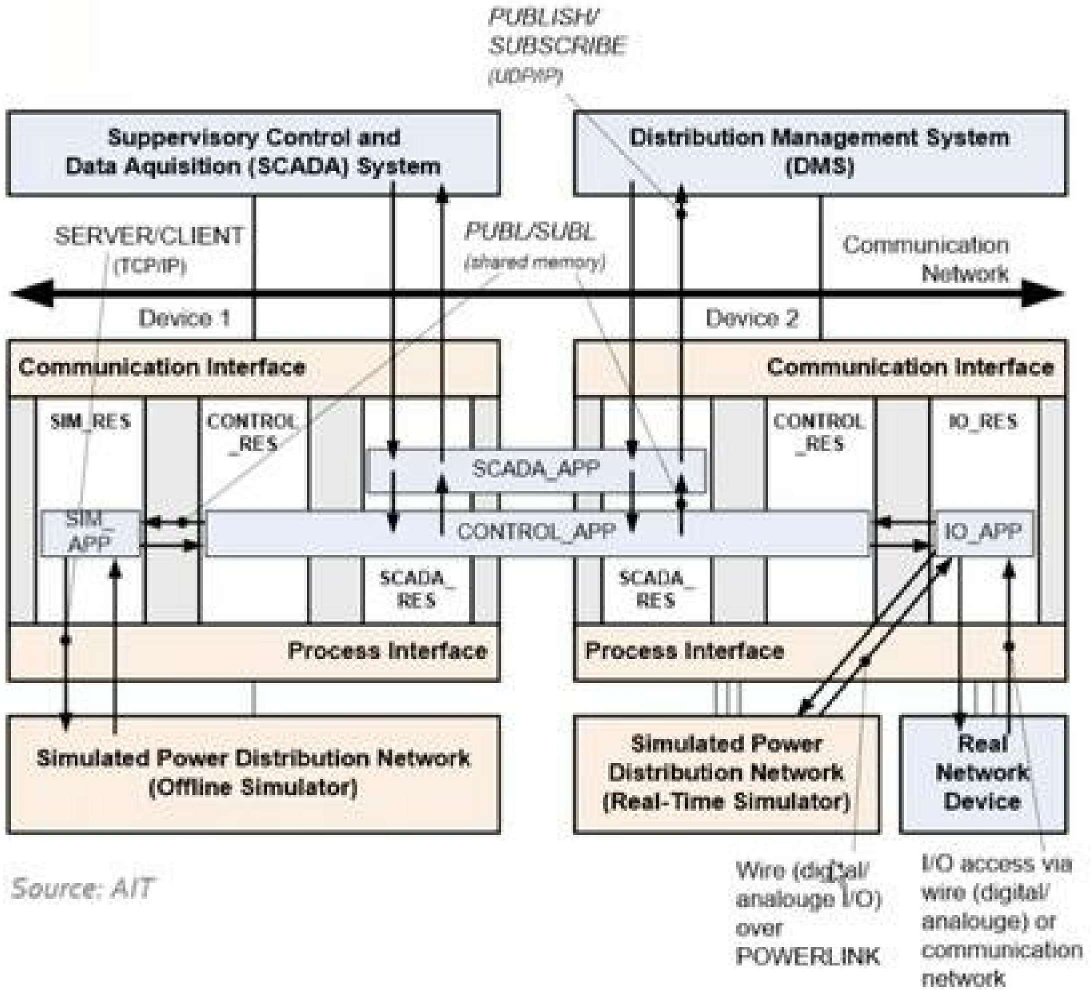
Selexted Examples

- ICT-based integration architecture
  - IEC 61850/IEC 61499 system architecture and generic communication interfaces
    - Multiple systems
      (SCADA/DMS, controllers, simulators)
    - Independent applications
      (control application(s), communication application(s))



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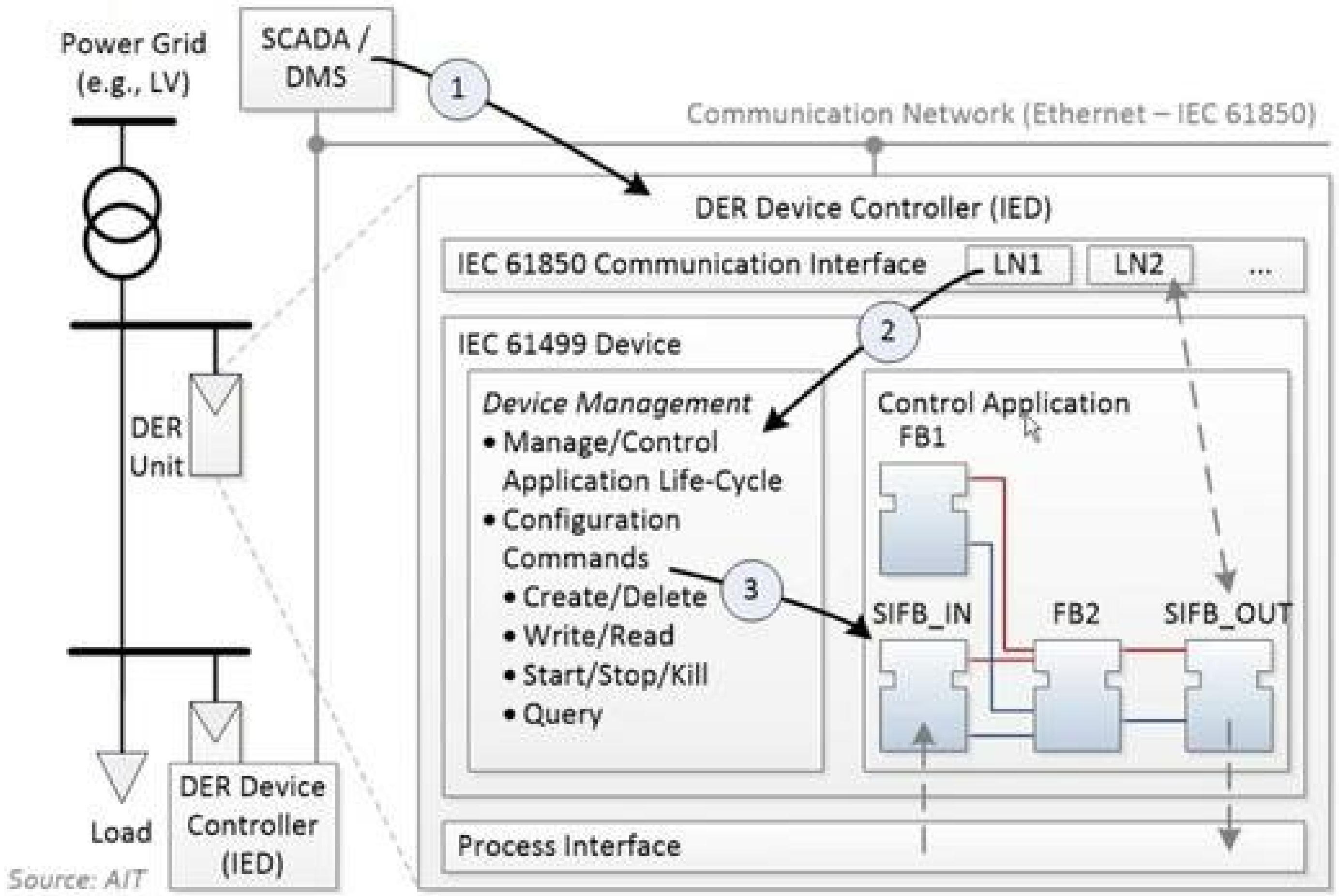
Selexted Examples

- DER device controller
  - IEC 61850 communication interface
  - IEC 61499 implementation of control algorithms
  - Usage of IEC 61850/IEC 61499 configuration interfaces for on-line adaptation of functions



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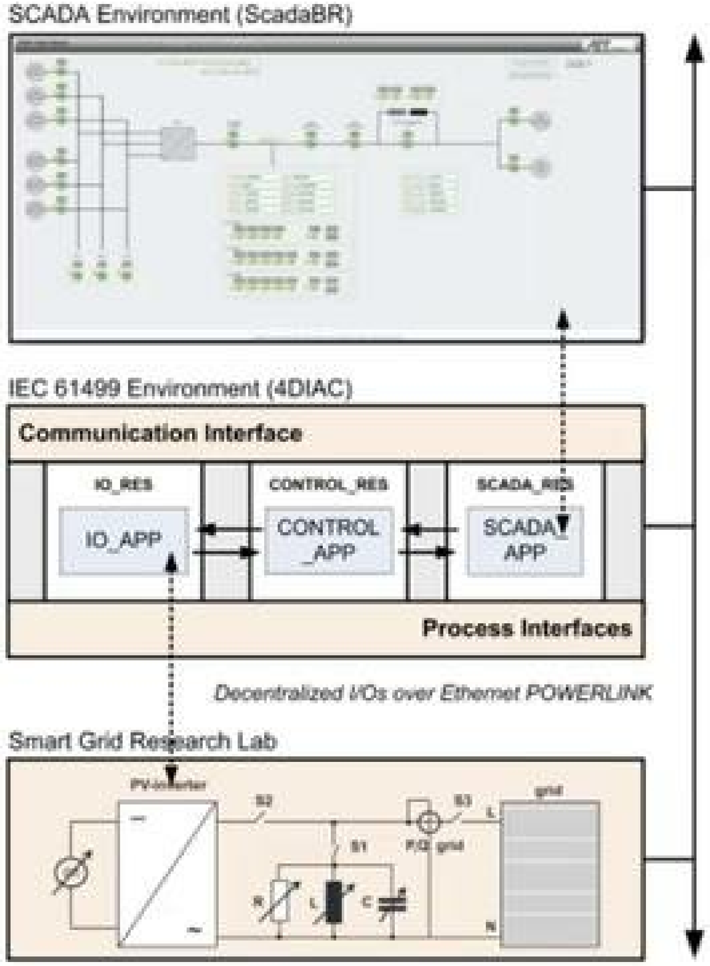
Selexted Examples

- Smart grid lab automation
  - AIT SmartEST laboratory



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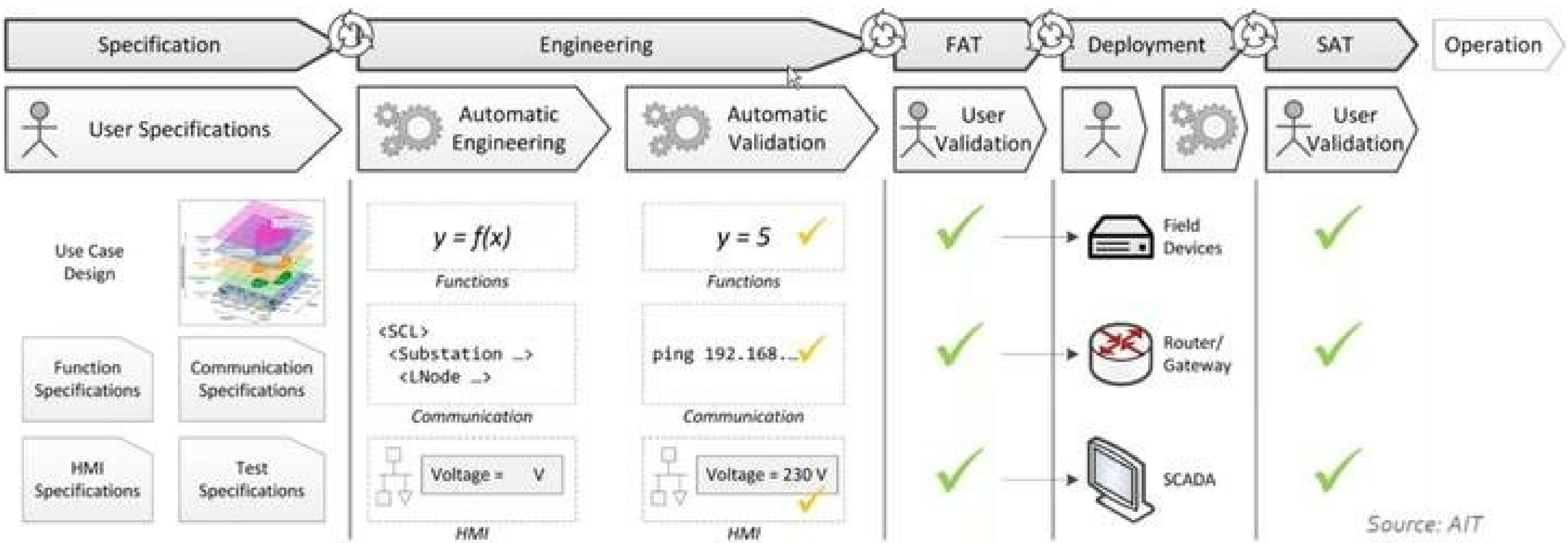
Selexted Examples

- Engineering and validation support system
  - Model-based framework
  - Supports engineers in the development and validation of smart grid automation applications



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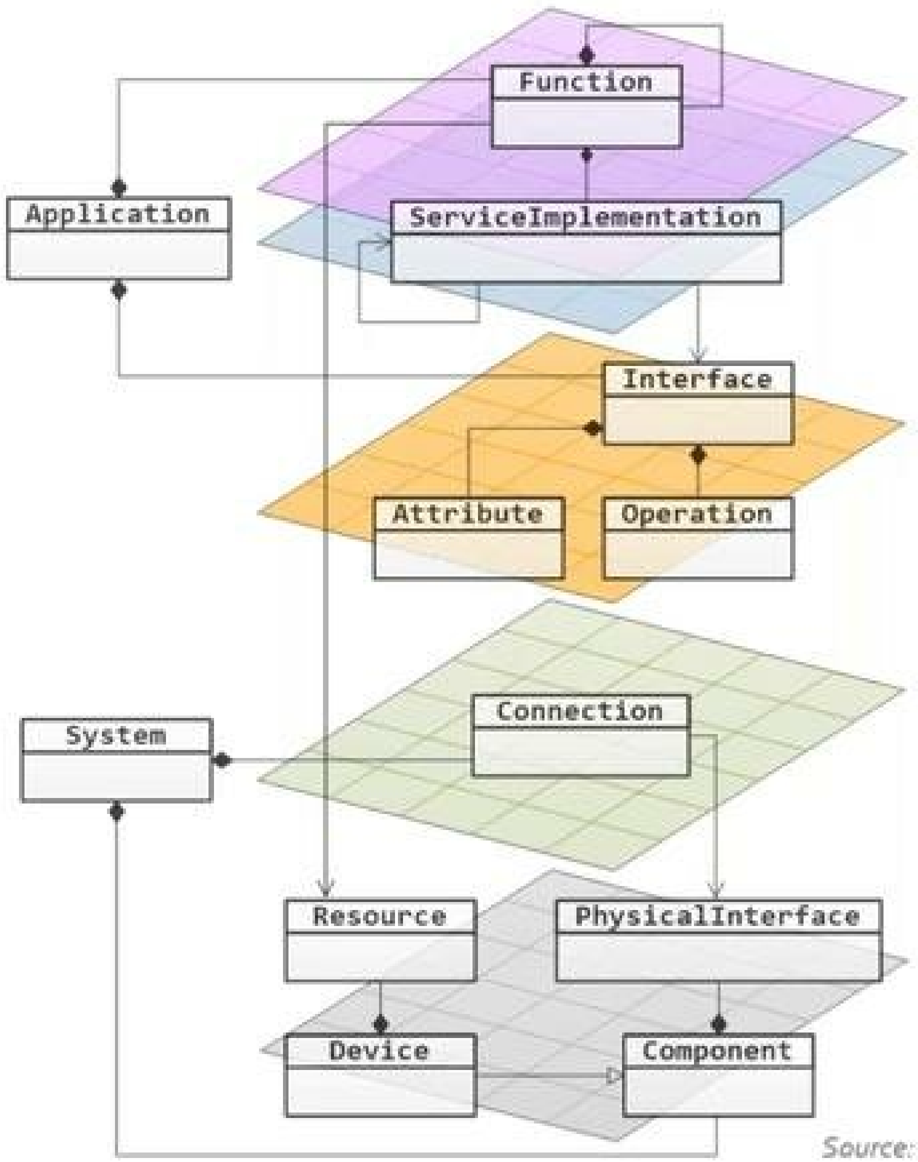
Selexted Examples

- Engineering and validation support system
  - *Main element:* Power System Automation Language (PSAL)
  - Domain-specific Language (DSL) mainly based on CIM, IEC 61850 and IEC 61499

```
application VoltageControl {
  function VoltVArCtrl at DSOComputer.VoltVAr {
    requests Field.Controls fieldControls
  }
  module Field {
    interface Controls {
      attribute float32 activePowerSetpoint
}}}
```

```
system DistributionSystem {
  device DSOComputer {
    ethernet eth0 {ip = "10.0.0.1"}
    resource VoltVAr
  }
  router StationRouter
  generator DER

  connect DSOComputer.eth0 with StationRouter
}
```



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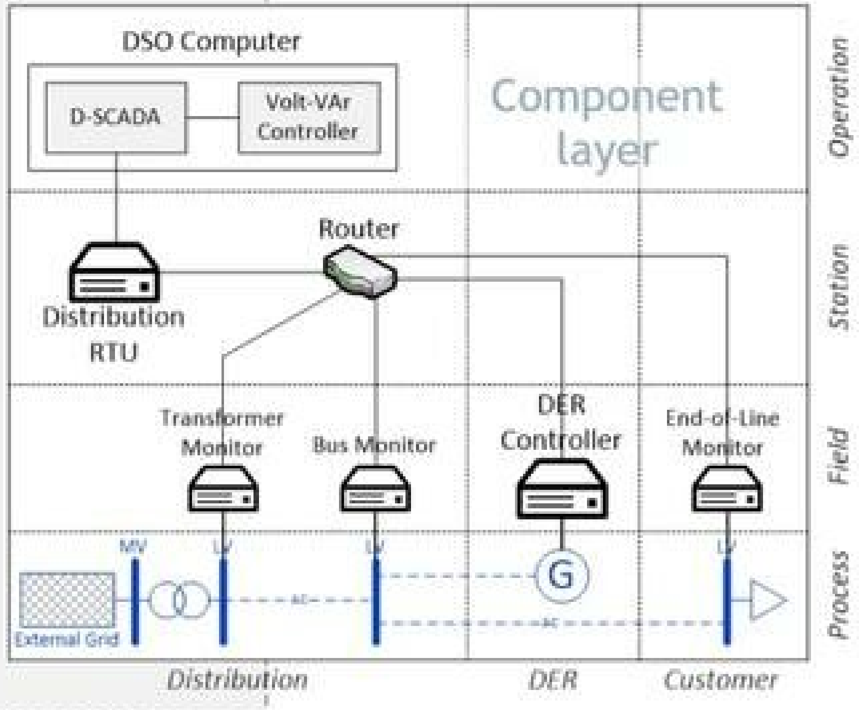
Selexted Examples

- Engineering and validation support system
  - Application example

```
application VoltVArControlCentralized {
  function DERController at DERController.AncillaryServices {
    provides Measurements.GridMeasurements measurements
    requests DERCtrlInterfaces.DERDirectControls derDirectControls
    …
  }
  function VoltVArController {…}
  function DSCADA {…}
  function DistributionRTU {…}
  function DERGenerator {…}
  function TransformerMonitor {…}
  function BusMonitor {…}
  function EndOfLineMonitor {…}

  module Measurements {
    interface GridMeasurement {…}
    eventtype AggregatedMeasurement {…}
  }
  module DERCtrlInterfaces {…}

  connect DERController.derDirectControls
          with DERGenerator.directControls
  …
}
```



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Selexted Examples

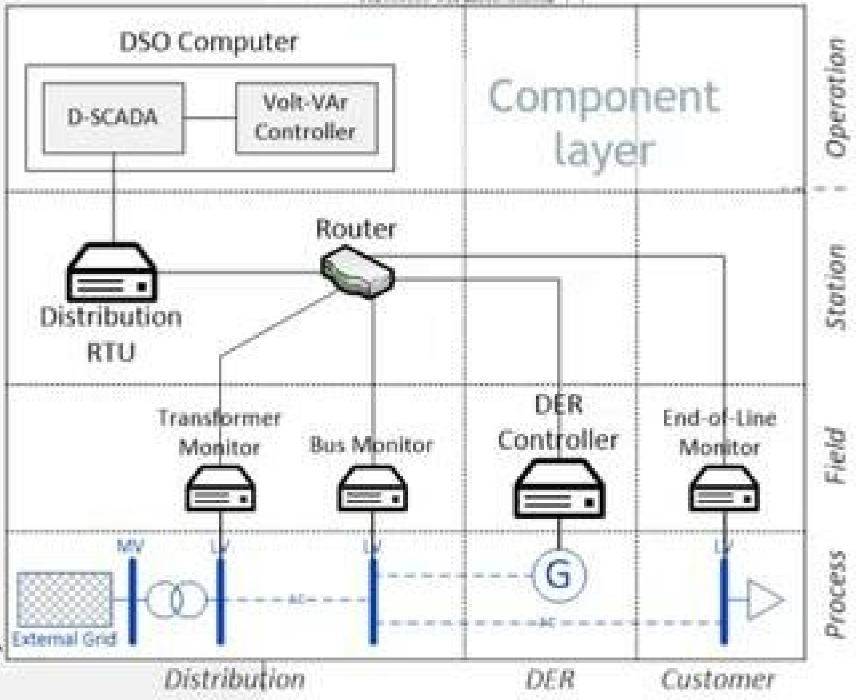
› Engineering and validation support system

› System example

```
system DistributionSystemVV {
  @DER @Field
  device DERController {
    ethernet eth0 {ip = "10.0.0.1"}
    ethernet eth1 {ip = "192.168.0.2"}
    resource AncillaryServices
  }
  device DSOComputer {…}
  device DistributionRTU {…}
  router StationRouter
  device TransformerMonitor {…}
  device BusMonitor {…}
  device EndOfLineMonitor {…}
  generator ExternalSystem {…}
  busbar MVBus {…} …
  generator DERGenerator {
    ethernet eth0 {ip = "192.168.0.1"}
    terminal LVBus2
    resource DERResource
  }
  …
  connect DERController.eth1 with DERGenerator.eth0
  connect DERGenerator.LVBus2 with LVBus2.DERGenerator
}
```

```
application VoltVArControlCentralized {
  function DERController at DERController.AncillaryServices {
    provides Measurements.GridMeasurements measurements
    requests DERCtrlInterfaces.DERDirectControls derDirectControls
    …
  }
  function VoltVArController {…}
  function DSCADA {…}
  function DistributionRTU {…}
  function DERGenerator {…}
  function TransformerMonitor {…}
  function BusMonitor {…}
  function EndOfLineMonitor {…}

  module Measurements {
```



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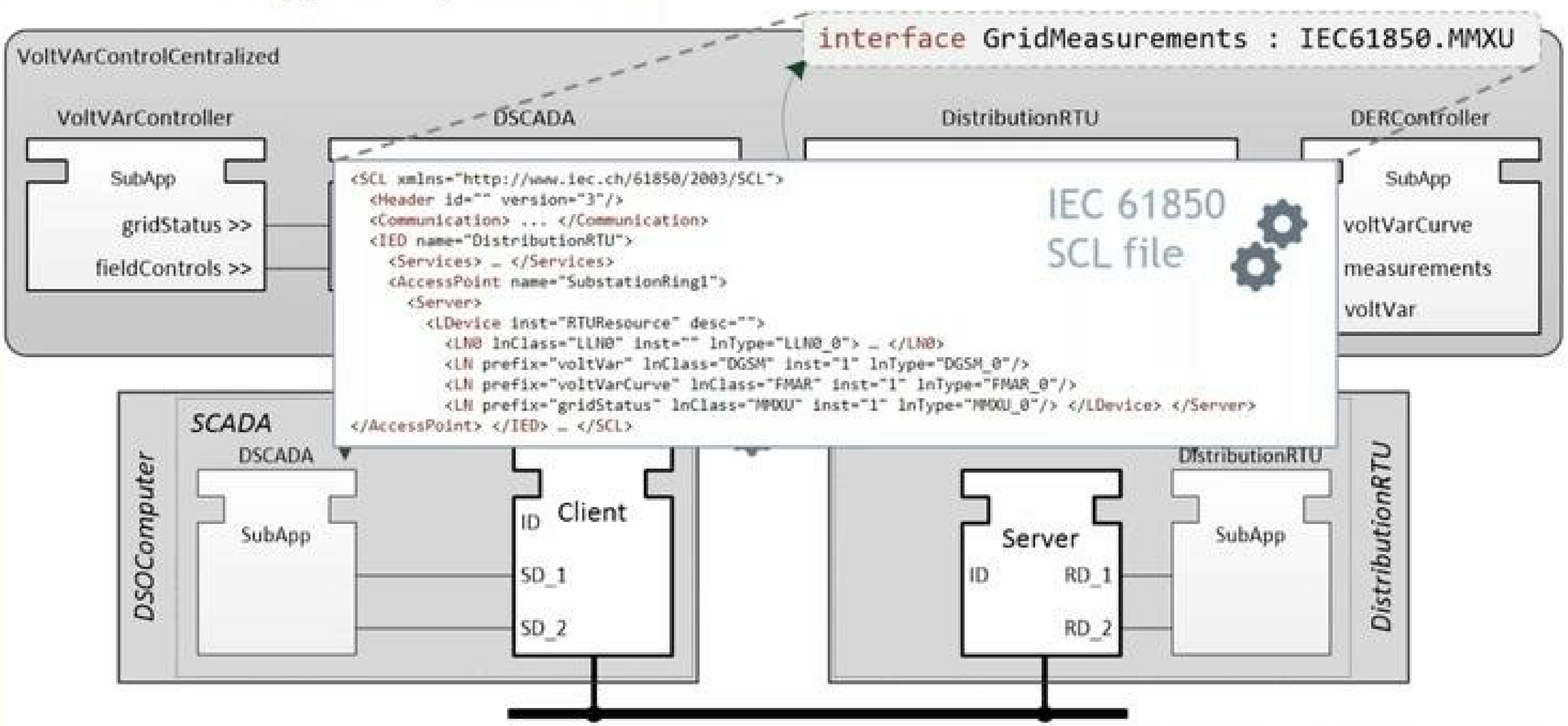
Selexted Examples

- Engineering and validation support system
  - Generation of IEC 61850 specifications
  - Generation of IEC 61499 code fragments



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