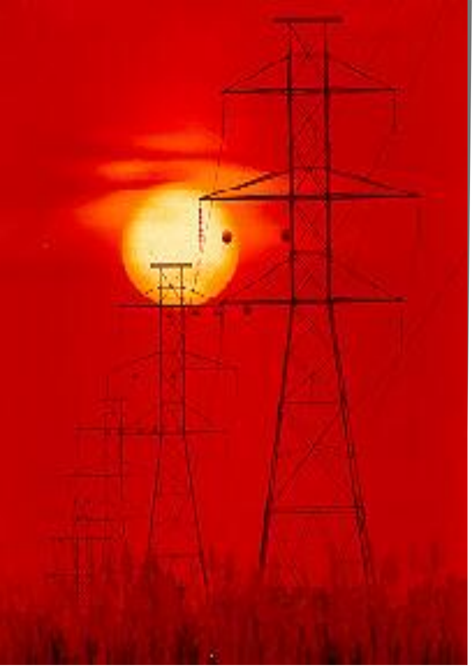

International Standards for Integrating Distributed Energy Resources (DER)

Advanced DER Functions and Information Models using IEC 61850

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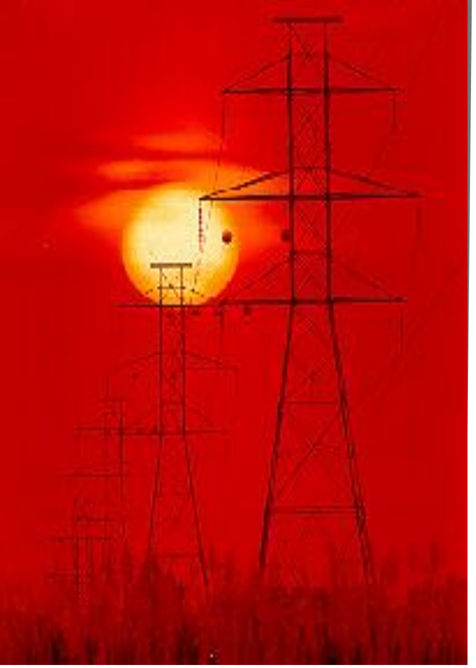
Topics

- Benefits of DER Generation and Storage
- Distributed Energy Resources (DER) Stakeholders and Interactions
- Inverter Functions, Concepts, and Models
- IEC 61850-7-420: Generator and Storage Models
- IEC 61850-90-7: Additional Models for Inverter Functions



Benefits of Distributed Energy Resources (DER) Generation and Storage

Including:

- ***Photovoltaic Systems, Fuel Cells, Diesel Generators, Biomass, etc.***
- ***Energy Storage***
- ***Electric Vehicles (EVs, PEVs, PHEVs)***

Benefits of DER to Utility Operations #1

- **Improve energy efficiency:**
  - Provide **voltage/var support** to improve power efficiency (mandated in Europe)
  - Provide **peak shaving capability** through generation/storage combinations
  - Support **load-following** of non-conforming loads to improve power efficiency
- **Increase power system reliability:**
  - Provide **dynamic grid support** with var management to minimize likelihood of outages (mandated in Europe)
  - Provide **low/high voltage ride** through during voltage fluctuations
  - Support **intentional islanding** for campuses, housing developments, and industrial/commercial areas if normal energy supply is not available
- **Increase renewable generation capacity to meet RPS requirements**
  - Provide energy to offset load within a customer site
  - Provide energy with net metering and feed-in tariffs
  - Provide energy within a substation for local generation

Benefits of DER to Utility Operations #2

- **Decrease costs**
  - Defer construction of distribution facilities through DER generation, which acts as negative load, provides peak shaving, and supports voltage and VArs on the feeder
  - Directly control DER generation to provide peak shaving to minimize start-up of costly peaker generation
  - Use Demand Response or market incentives to increase DER generation during peak times
- **Improve power quality**
  - Provide smooth transitional VAr support by DER in place of switched capacitor banks to minimize harmonics

Benefits of DER to Customers #1

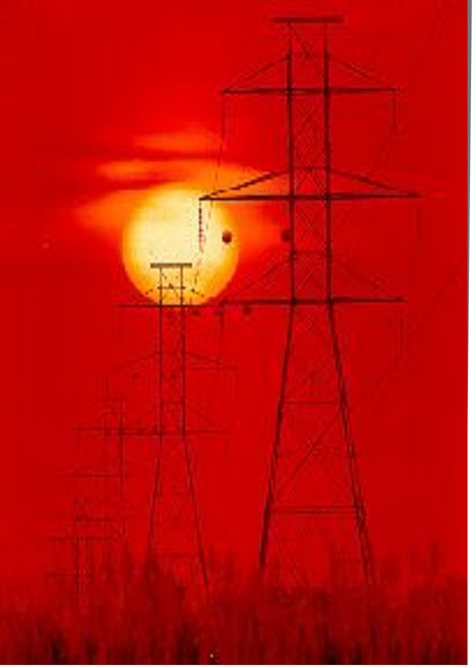
- **Provide shared cost-savings for utilities and customers**:
  - Through net metering, to reduce overall electricity usage and costs
  - Through different types of tariffs such as Demand Response
  - Directly through direct market participation and/or dynamic pricing tariffs
  - Indirectly through overall lower electricity costs due to utility gains in efficiency
- **Provide emergency backup generation**
  - Customers can install DER for emergency power to their critical loads
  - Customers can sell emergency power into a microgrid island which was formed due to a loss of utility power

Benefits of DER to Customers #2

- **Use by-products from customer industrial processes to generate and sell electricity:**
  - Use heat to generate electricity through Combined Heating and Power (CHP) systems, thus off-setting some of the customer’s costs.
  - Provide biomass as source of gas, production of hydrogen as transportable energy.
- **Participate in carbon trading:**
  - If and when carbon trading becomes a reality, customers can “trade” their low-carbon DER generation

Benefits of DER for Society

- **Minimize carbon and pollution production:**
  - Renewable DER units produce less carbon dioxide, thus helping in the battle against global climate change
  - Efficient re-use of “waste heat” or other by-products of industry improve the overall efficiency of energy usage
  - Many DER units, including burning biomass and CHP, can also minimize non-carbon pollutants
- **Meet mandated renewable portfolio standards:**
  - Many states have legislated renewable portfolios that mandate increasing use of renewable sources of energy. Most renewables to-date are small generators
- **Provide “green power” for socially conscious people**
  - Many people are willing to pay extra for power or to off-set their carbon “footprint”



Distributed Energy Resources: Stakeholders and Functions

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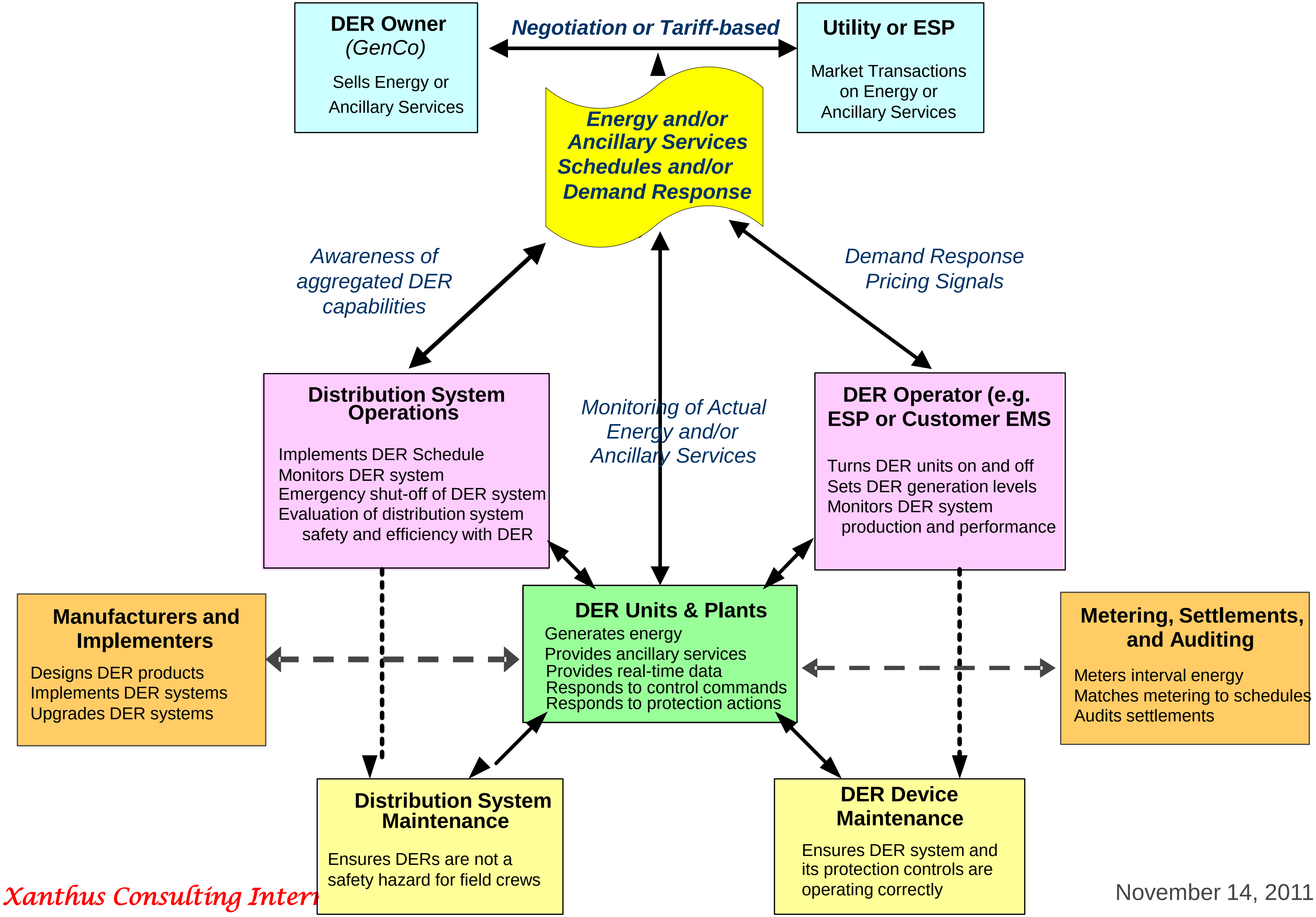
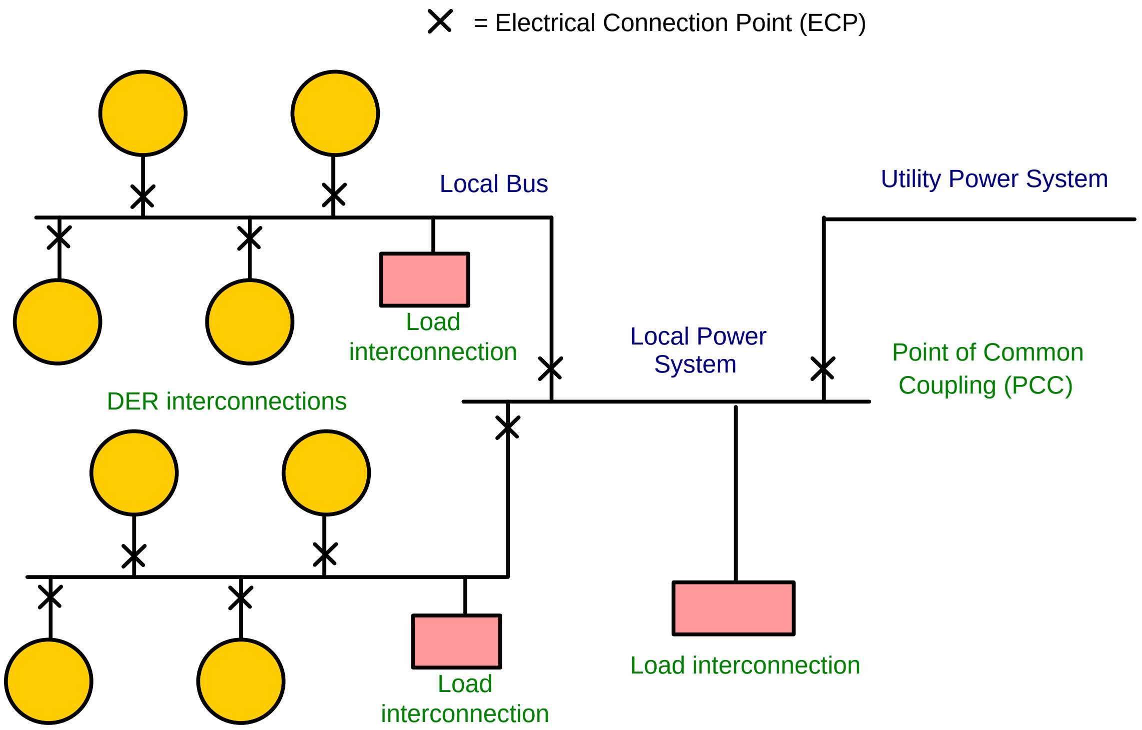
DER Stakeholders



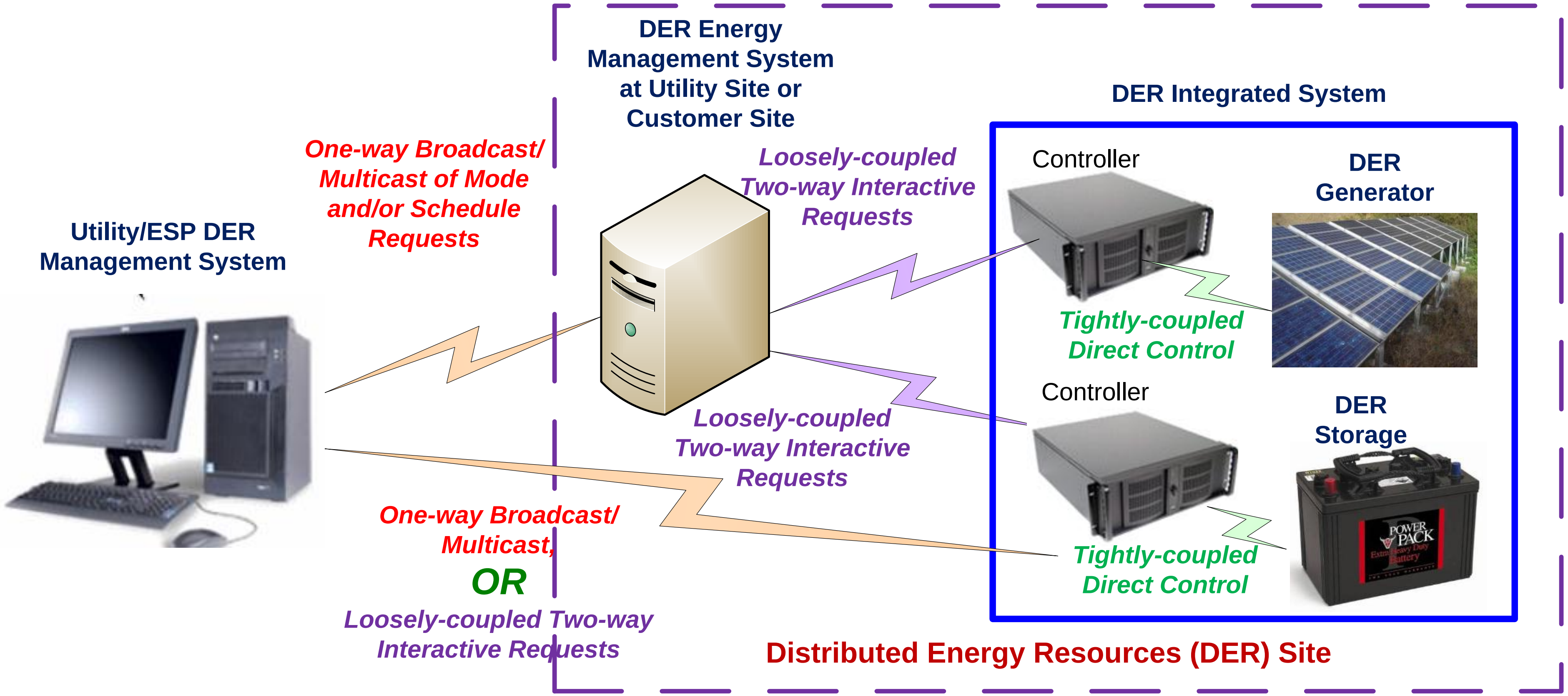
DER Management at Electrical Connection Points (ECPs)

- Multiple DERs within a residential subdivision, campus, industrial plant, or virtual power plant, each having its own Electrical Connection Point (ECP)
- The ECP at the connection to the utility grid is the IEEE 1547 Point of Common Coupling (PCC)
- DER management can be at the PCC and at each of the ECPs



Different Levels of Autonomous Management of DER Generation and Storage Functions

DER Interactions / Configurations: ***Autonomous, Tightly-coupled, Loosely-coupled, Broadcast/Multicast***

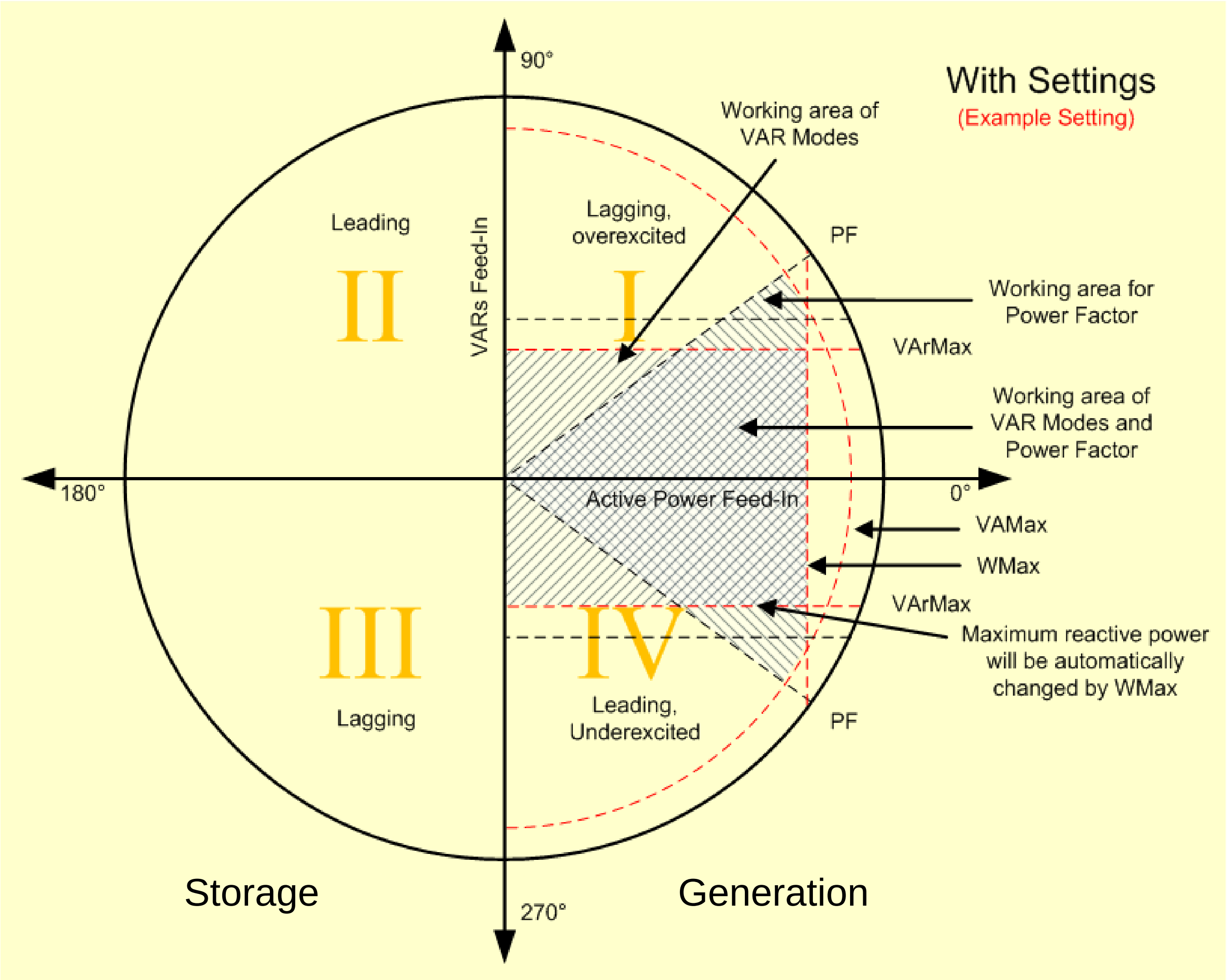


DER Management: Interactions between Components

Three Levels of Stakeholder Interactions with DER

- **Direct, tightly-coupled control commands** (*Do exactly this and I will monitor the results*)
  - Between inverter controller and ES-DER device
  - Between Customer EMS and multiple ES-DER devices in a building, subdivision, or campus
- **Interactive two-way monitoring and control** *(I know your capabilities, so do this if you can)*
  - Between ISO/RTO and ES-DER system whose bid has been accepted
  - Between Customer EMS and multiple ES-DER systems with their own (sophisticated) controllers
- **Broadcast/multicast one-way “pricing” or “request” signals** (*I don’t know who is out there, but here are some pricing signals and/or mode requests, so you decide*)
  - Between utility and Customer EMS
  - Between aggregator and ES-DER systems

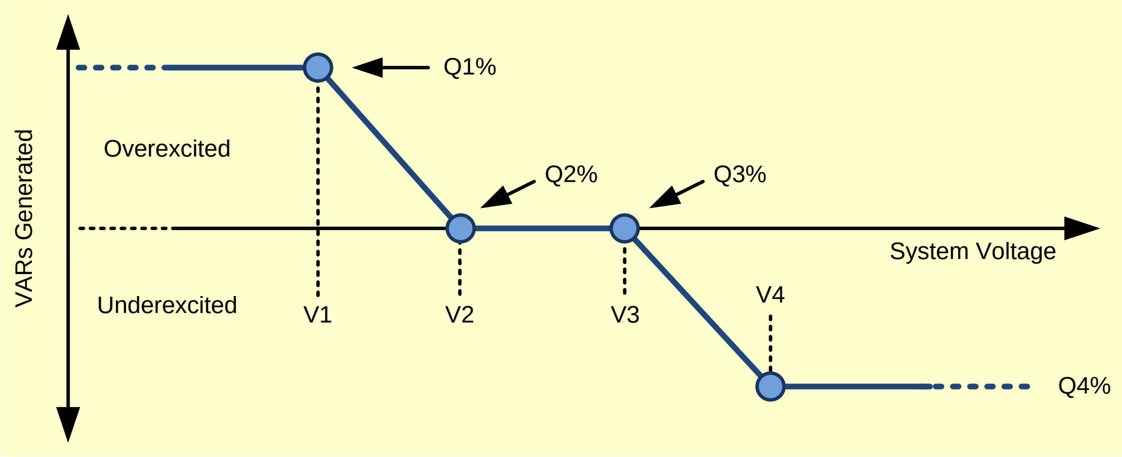
Inverters: Four Quadrant Capabilities

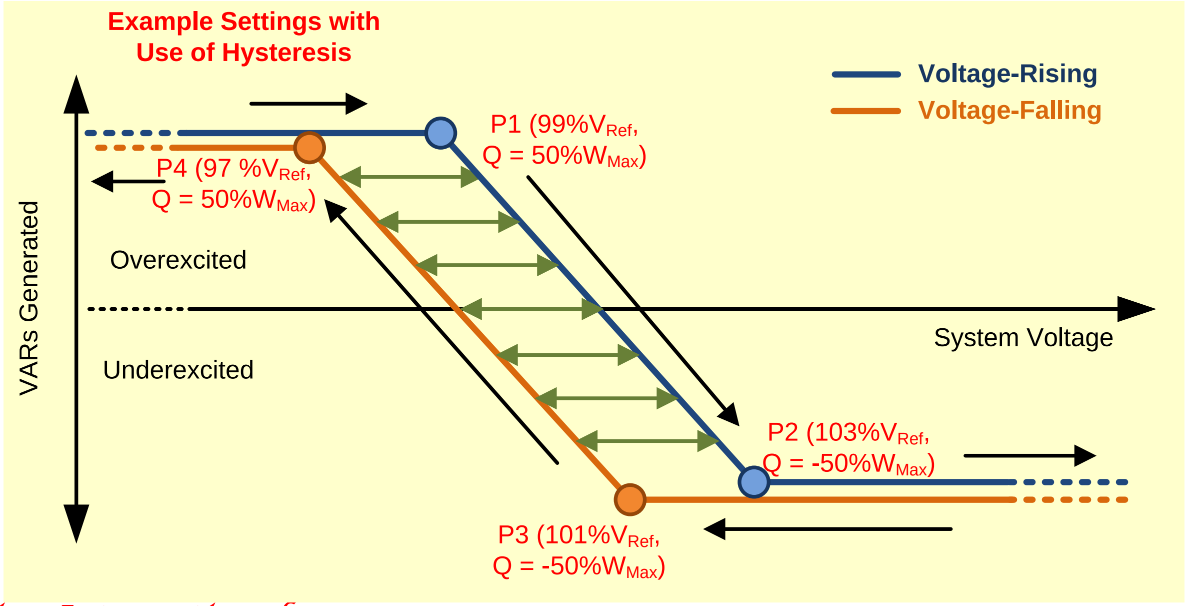


Functions for DERs with Inverters

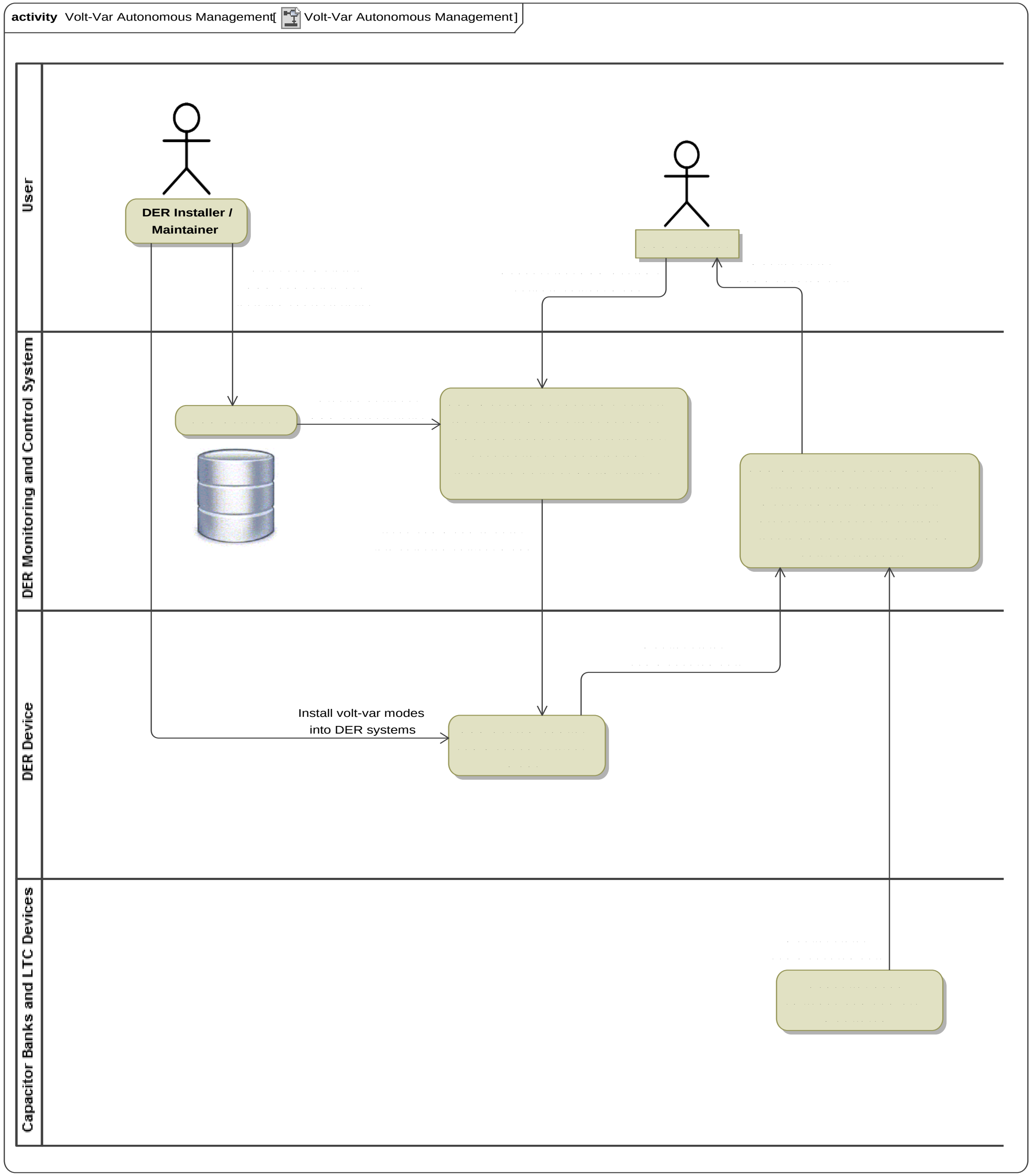
- **Immediate commands** for inverter-based DER functions:
  - Turn on/off
  - Limit maximum watts output
  - Peak shaving to increase generation/storage output during peaks
  - Status and event log information
- ”**Modes**” for pre-established behaviour autonomous :
  - Volt-var curves to modify vars (absorb or supply) based on voltage
  - Frequency curves to modify watts output
  - Dynamic grid support through var management
  - Low/high voltage ride-through
  - Temperature-var control (equivalent to capacitor banks)
- **Schedules** for hourly, daily, weekly, and/or seasonal actions:
  - Modes
  - Commands

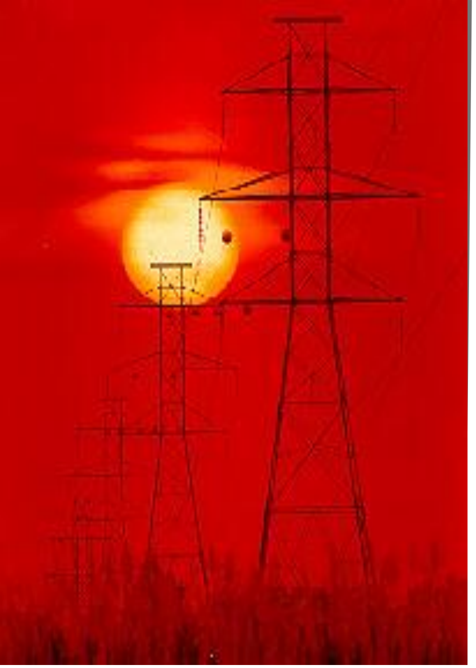
Volt-Var Curves: Basic Curve and with Hysteresis





Use Case of Autonomous Volt-Var Management





IEC 61850-90-7 Inverter Information Models

Defining the communication interactions of inverter functions as abstract IEC object models

Mapping these IEC 61850 models to DNP3, SEP 2.0, web services, or other protocols

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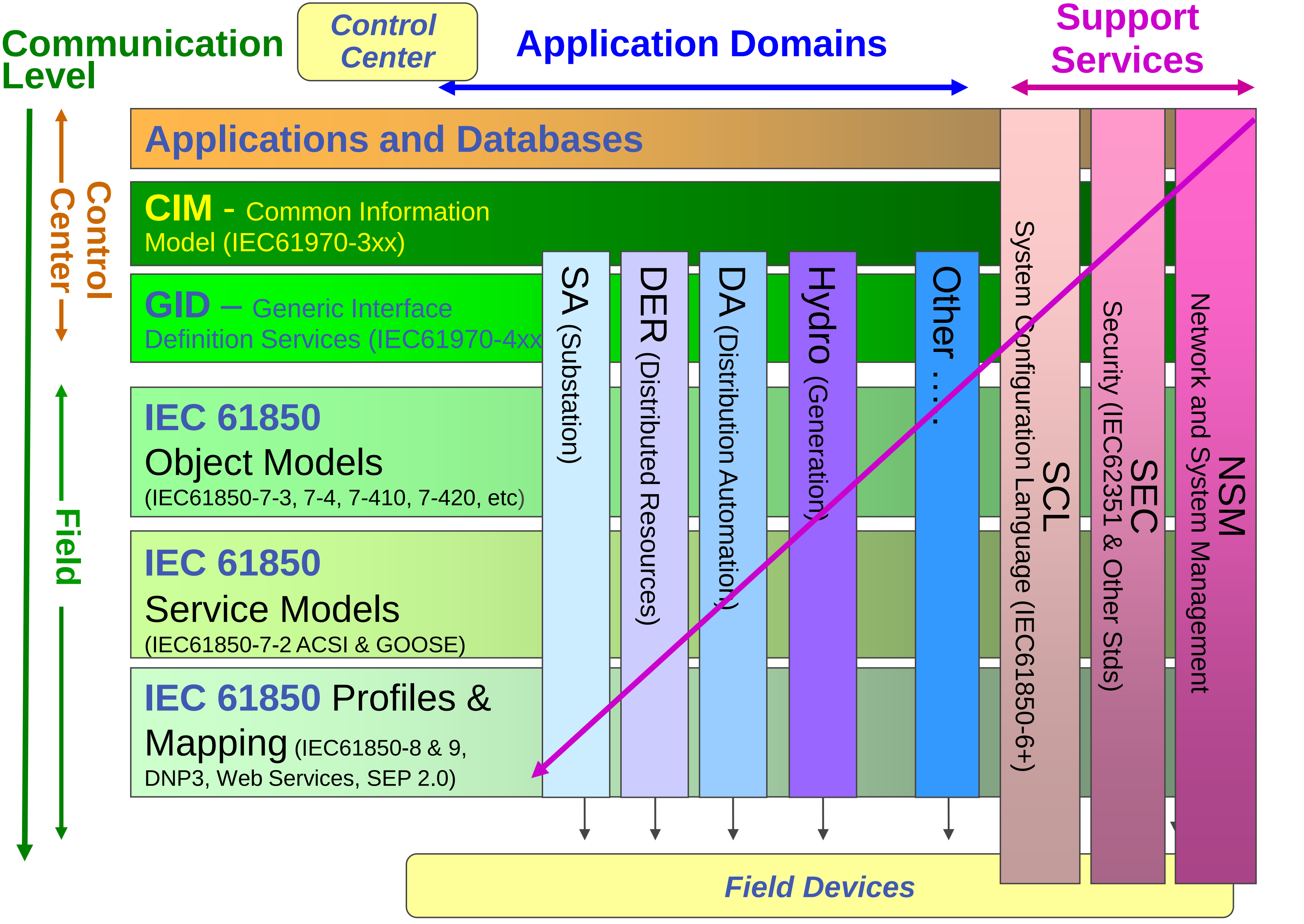
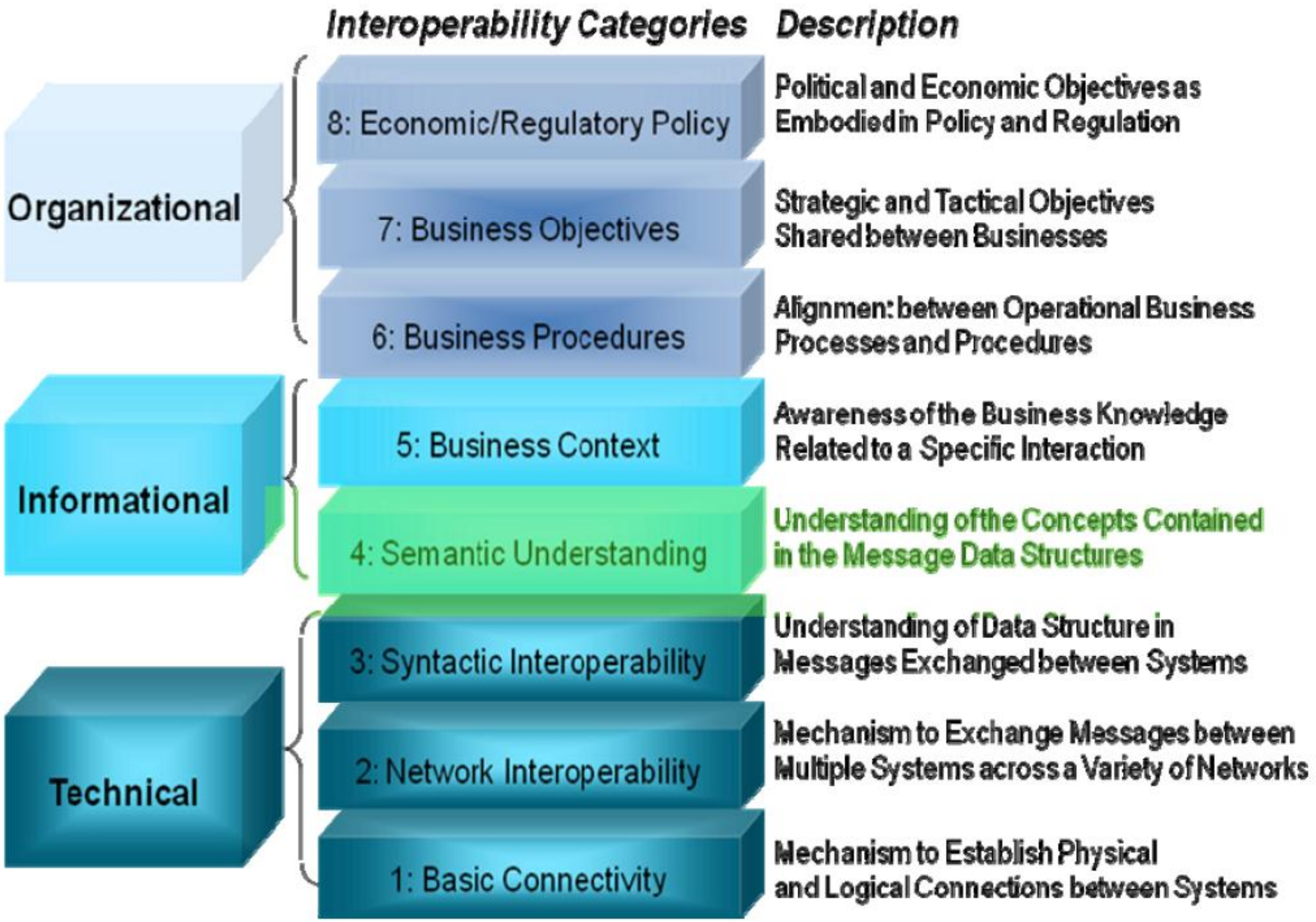
IEC 61850 Models and the Common Information (CIM) Model

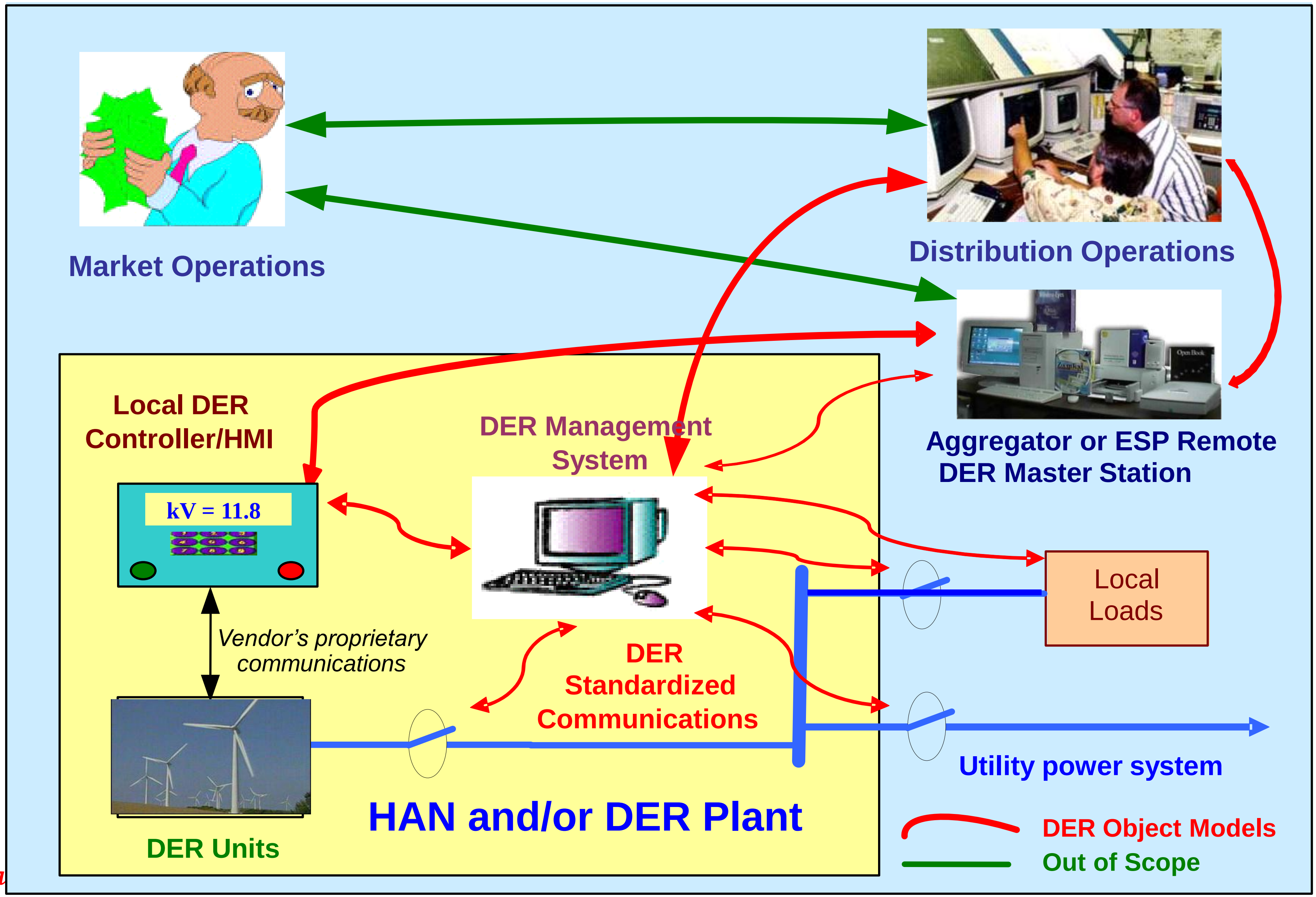


GWAC Stack



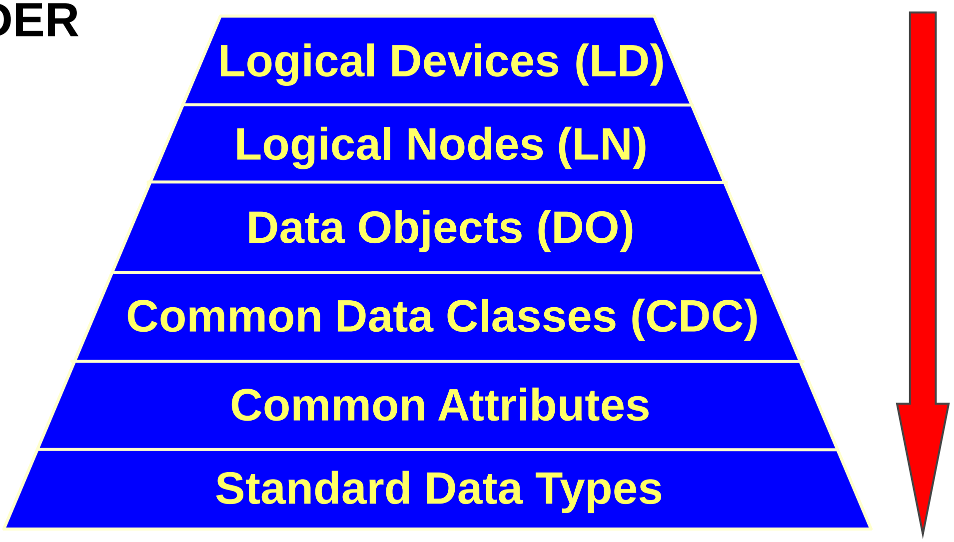
Interoperability Categories
Description
Organizational
Informational
Technical
8: Economic/Regulatory Policy
Political and Economic Objectives as Embodied in Policy and Regulation
7: Business Objectives
Strategic and Tactical Objectives Shared between Businesses
6: Business Procedures
Alignment between Operational Business Processes and Procedures
5: Business Context
Awareness of the Business Knowledge Related to a Specific Interaction
4: Semantic Understanding
Understanding of the Concepts Contained in the Message Data Structures
3: Syntactic Interoperability
Understanding of Data Structure in Messages Exchanged between Systems
2: Network Interoperability
Mechanism to Exchange Messages between Multiple Systems across a Variety of Networks
1: Basic Connectivity
Mechanism to Establish Physical and Logical Connections between Systems

Scope of IEC 61850-7-420 DER Information Exchanges



Structure of IEC 61850 Models

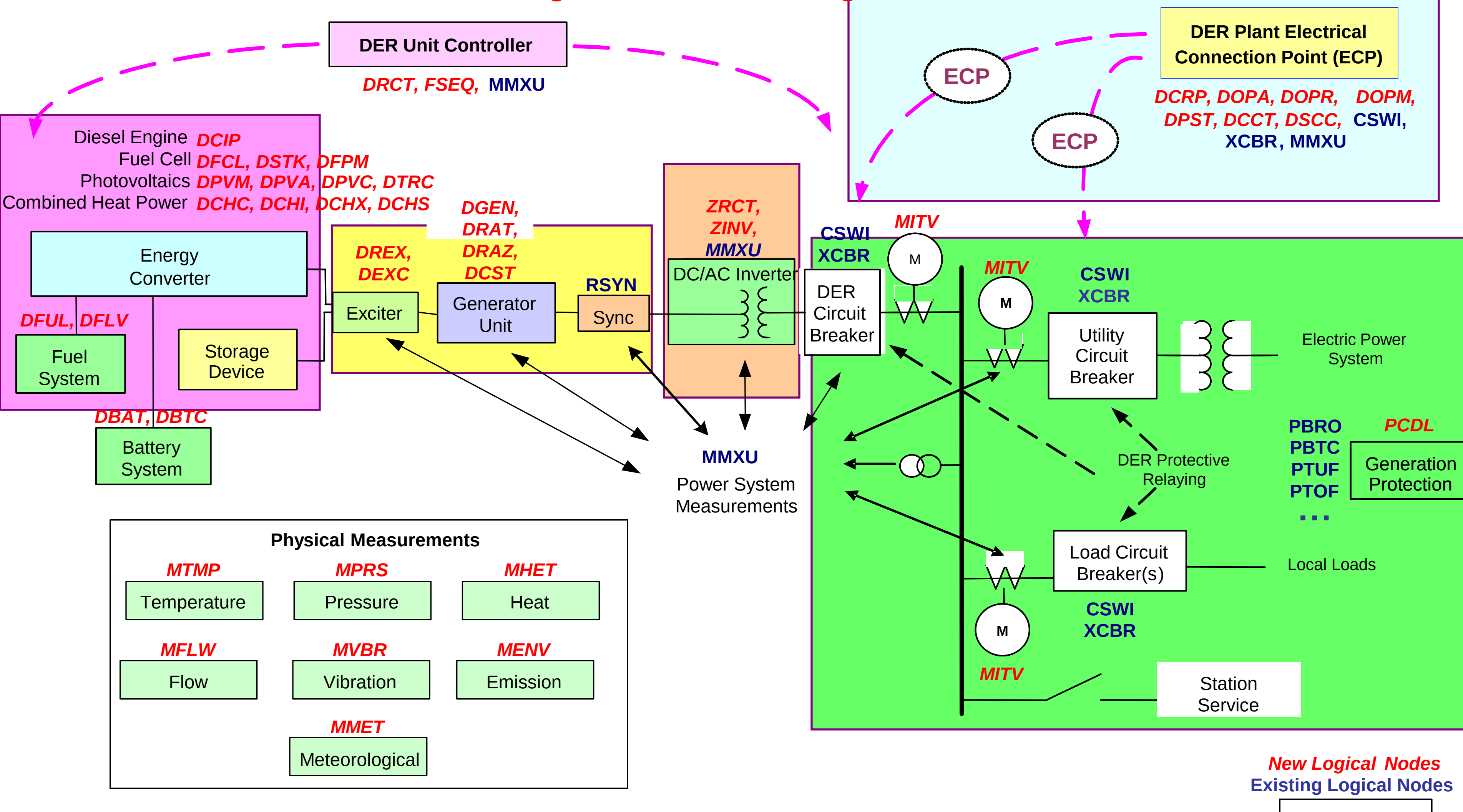
- **IEC 61850-7 (basic) and 7-420 for DER**
  - Provide the information model of **"Nouns"**
  - Use the IEC 61850 constructs of:



- Covers:
  - **General DER management**
  - **Photovoltaic systems**
  - **Fuel cells**
  - **Diesel generation**
  - **Combined heat and power**
  - **Wind power** is modeled in IEC 61400-25
  - **Inverters** in IEC 61850-90-7
- **IEC 61850-7-2, plus mappings, cover the "Verbs"**
  - Services define when and how to exchange messages
  - Mappings convert abstract standards to "bits and bytes"
  - **Mappings exist to MMS, DNP3, Web Services, OPC/UA, and working on SEP 2.0**

Overview: Logical Devices and Logical Nodes for Distributed Energy Resource (DER) Systems

Showing the IEC 61850 Logical Nodes



Energy Converter = Microturbines, Fuel Cell, Photovoltaic System, Wind turbines, Diesel Generators, Combustion Turbines

Storage Device = Battery, Pumped Hydro, Superconducting Magnetic Energy Storage, Flywheels, Micro - flywheels

Converter = DC to AC, frequency conversion, voltage level conversion

Auxiliaries = Battery, Fuel Cell

Information Modeling Constructs: Commands and Modes

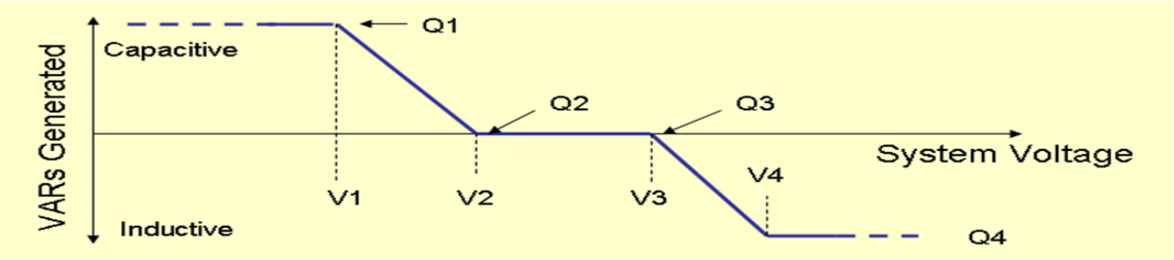
- Simple commands (e.g. on/off)
- Mode commands:
  - Arrays of volt-var settings
  - Ramp rate to move from one mode to another
  - Time window with randomized start
  - Time-out period in case of loss of communications

Mode PV1 – Normal Energy Conservation Mode

Example Settings

Voltage Array		VAR Array (%)	
V1	115	Q1	100
V2	118	Q2	0
V3	122	Q3	0
V4	126	Q4	-100

VAR Ramp Rate Limit – fastest allowed change in VAR output in response to either power or voltage changes	50 [%/second]
Randomization Interval – time window over which mode or setting changes are to be made effective	60 seconds



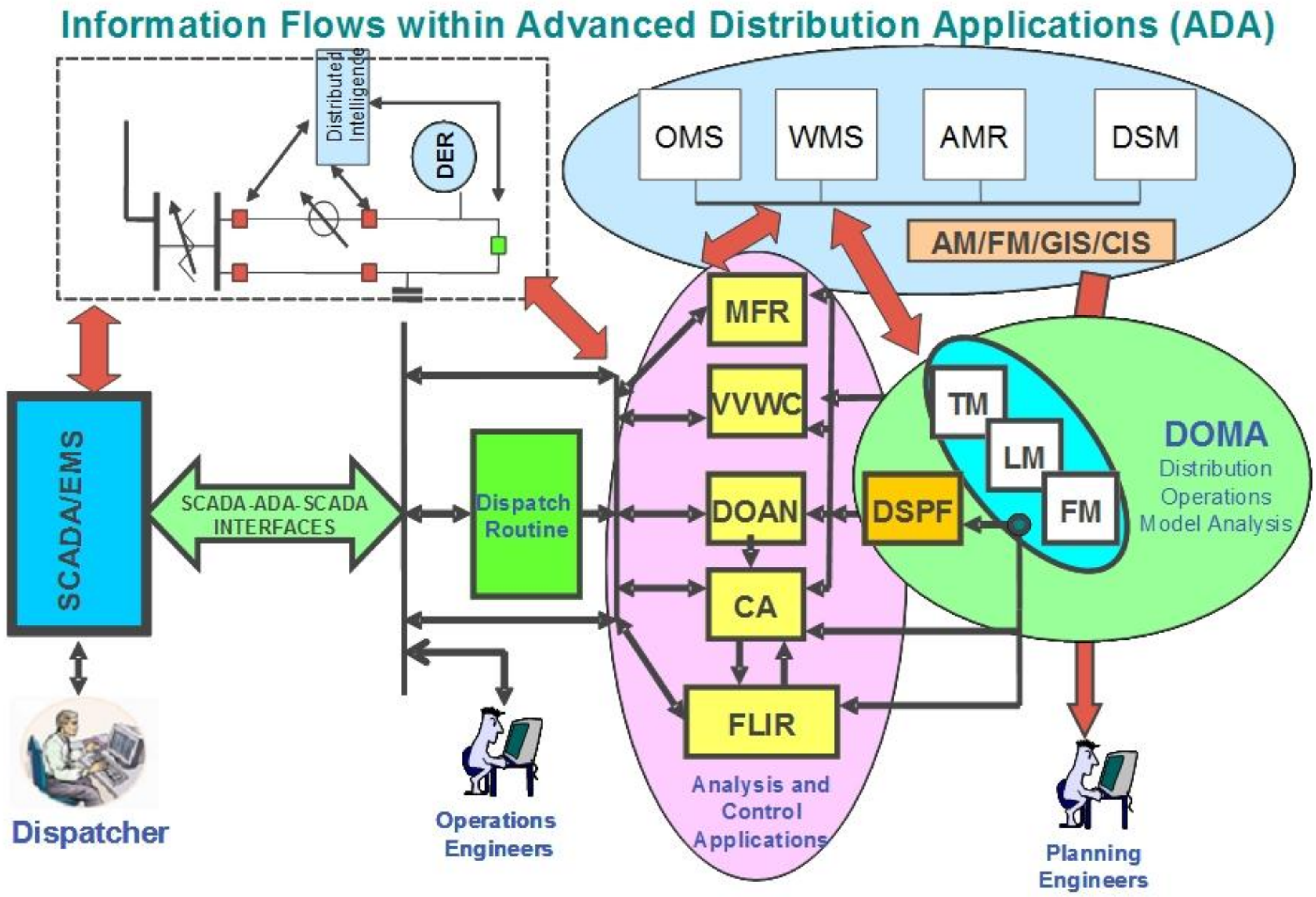
Information Modeling Constructs: Schedules and Pricing

- Schedules:
  - Time-based schedules for going into specific modes
    - From 6am to noon, turn on and use mode 3
    - From noon to 5:30, use mode 5
    - From 5:30 to 7:15, use mode 8
    - At 7:15, turn off
    - Repeat schedule every weekday during the summer
  - Schedules can be overridden by emergencies or other commands
- Pricing signals to DER generation/storage systems for demand response
  - Pricing signals can be $$, or tariff-based tiers, or High/Med/Low, or ….
  - Pricing signals can be different for different functions
    - Pricing curve for volt-var control
    - Pricing curve for frequency control
  - Demand response signal would indicate which part of the pricing signal graph to invoke

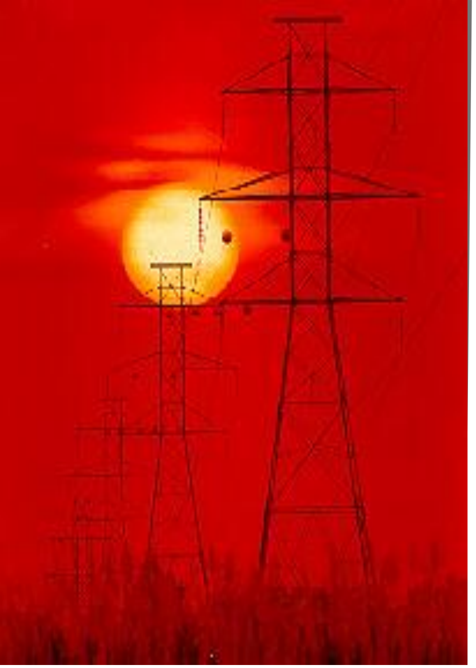
Background and Status of IEC 61850-90-7

- Initially based on an **EPRI project**
  - Weekly teleconferences for over 9 months during 2010 and now 2011
  - 80+ participants
  - Utilities, inverter manufacturers, generator and storage manufacturers, integrators, national labs
- Information modeling
  - IEC 61850 experts modeled functions into **IEC 61850 abstract models**
  - Mapping IEC 61850 models to **DNP3** and **SEP 2.0**
- Submitted to **NIST / SGIP PAP 7**
- Submitted to **IEC TC57 WG17**
  - Additions by European manufacturers
    - Many of these functions are **mandated by different European countries** to be implemented within 2 years
  - Fast-track approach
  - **Expect IEC 61850-90-7 released by IEC in Q4 2011**
- **New NIST/SGIP DEWG: Distributed Renewable, Generation, Storage**

Managing DER Systems – Advanced Distribution Applications for Optimizing DER Usage



TM - Topology Model; LM - Load Model; FM - Facility Models; DSPF – Distribution System Power Flow; MFR – Multi-Level Feeder Reconfiguration; VVWC – Volt/Var/Watt Control; DOAN – Distribution Operations Analysis; CA – Contingency Analysis; FLIR – Fault Location, Fault Isolation, and Service Restoration;



Questions?

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