



Advanced DER Functions

***Generator, Storage, and Inverter
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 DER Generation and Storage

Benefits of DER to Utility Operations #1

- **Increase generation capacity / decrease load:**
 - 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
- **Improve energy efficiency:**
 - Provide energy close to loads, thus minimizing losses
 - Provide voltage support along feeders in place of voltage regulators, so that voltage levels from the feeder substation could be lowered, while still remaining within the nominal limits
 - Provide VAr support to improve power efficiency
 - Support load-following of local loads to improve power efficiency
 - Counteract any large non-conforming loads of the DER owner, thus providing a more stable load profile to utilities

Benefits of DER to Utility Operations #2

- **Increase reliability**
 - Provide spinning or operational reserve for local areas
 - Support intentional islanding for campuses, housing developments, and industrial/commercial areas if normal energy supply is not available
- **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 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

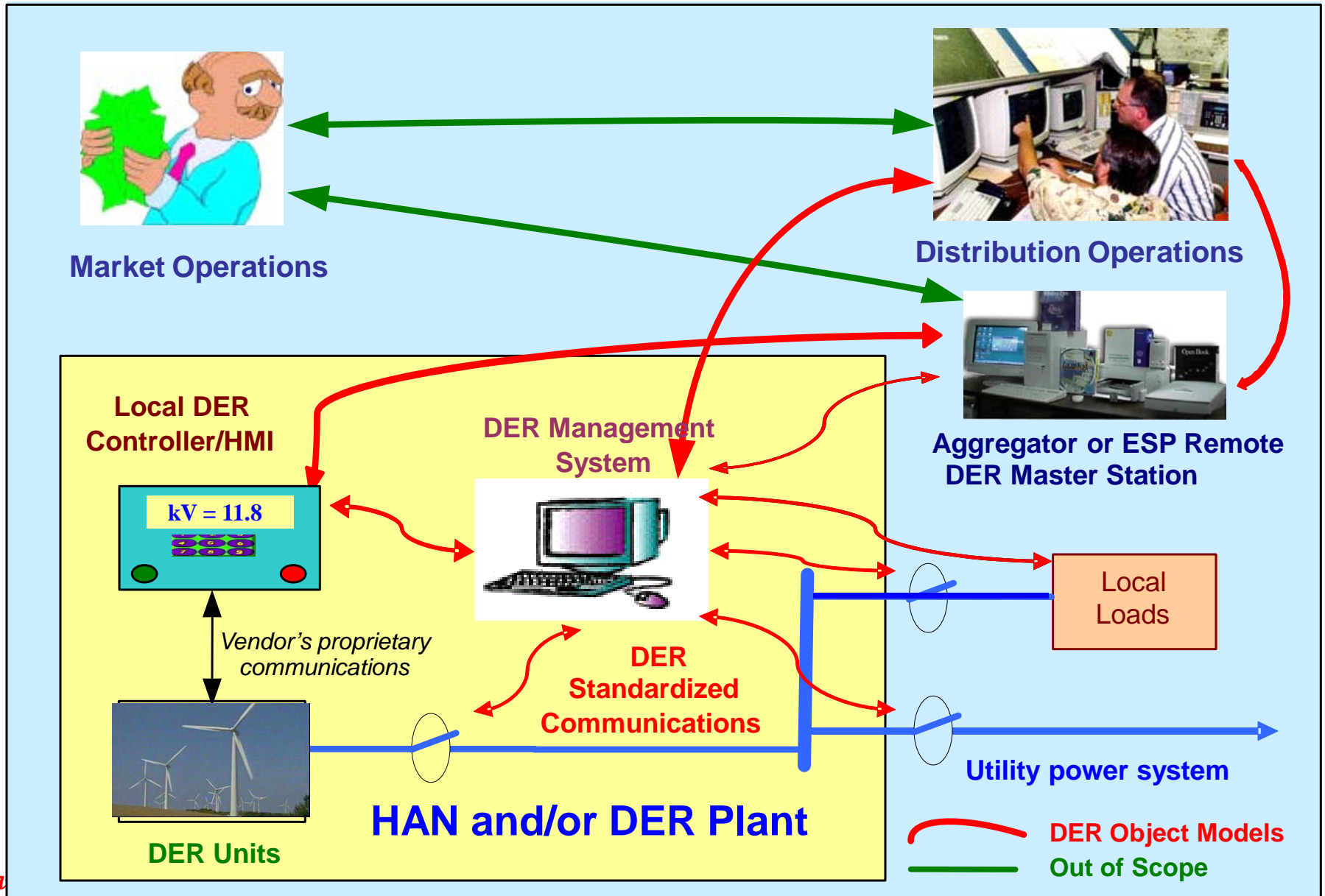
Benefits of DER for Society

- **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 portfolios:**
 - 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”



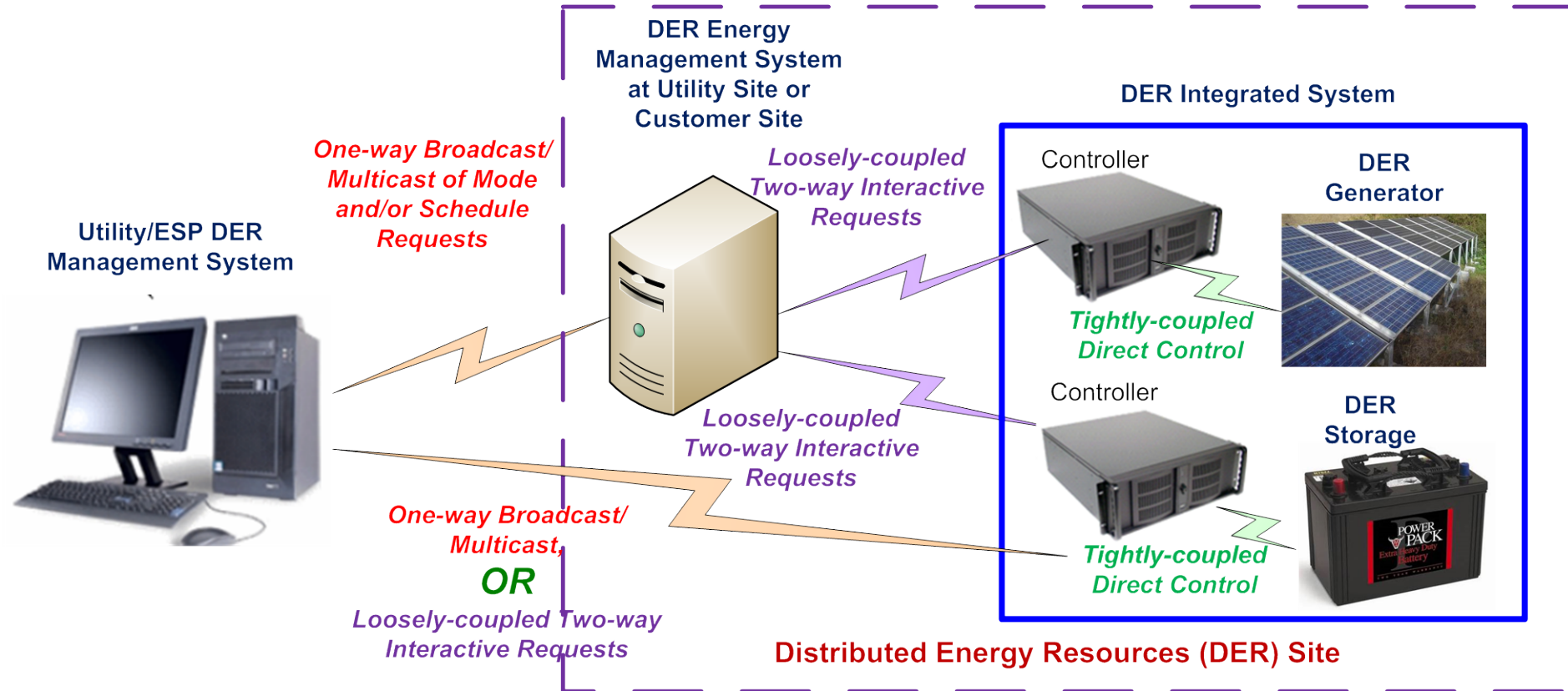
Distributed Energy Resources: Stakeholders and Interactions

Scope of IEC 61850-7-420 DER Information Exchanges



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

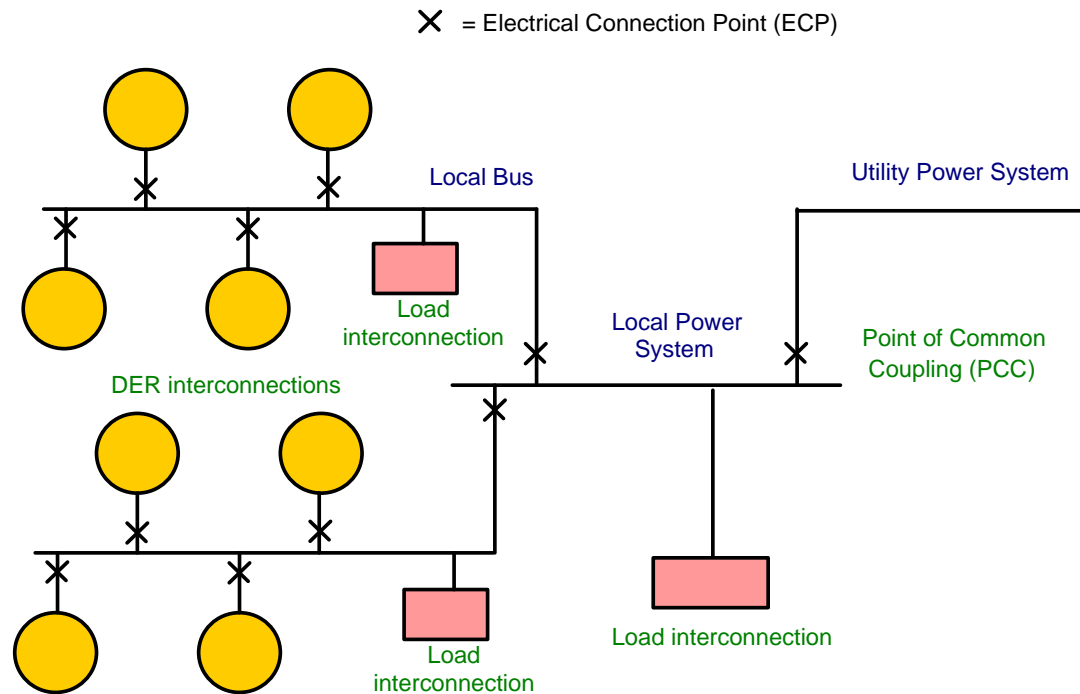
- **Direct, tightly-coupled control commands** (*Do exactly this and I will monitor the results*)
 - Between inverter controller and ES-DER device
 - Between Customer EMS and multiple ES-DER devices in a building, subdivision, or campus
- **Interactive two-way monitoring and control** (*I know your capabilities, 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

Functions for DERs with Inverters (and even for Loads)

- **Immediate commands** for inverter-based DER functions:
 - Turn on/off
 - Limit maximum output
 - Status and event log information
- **”Modes”** for pre-established autonomous behaviour:
 - Volt-Var control
 - Frequency-Watt control
 - Volt-Watt control
 - Low voltage ride-through
 - Temperature-var control
- **Schedules** for hourly, daily, weekly, and/or seasonal actions:
 - Modes
 - Commands

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





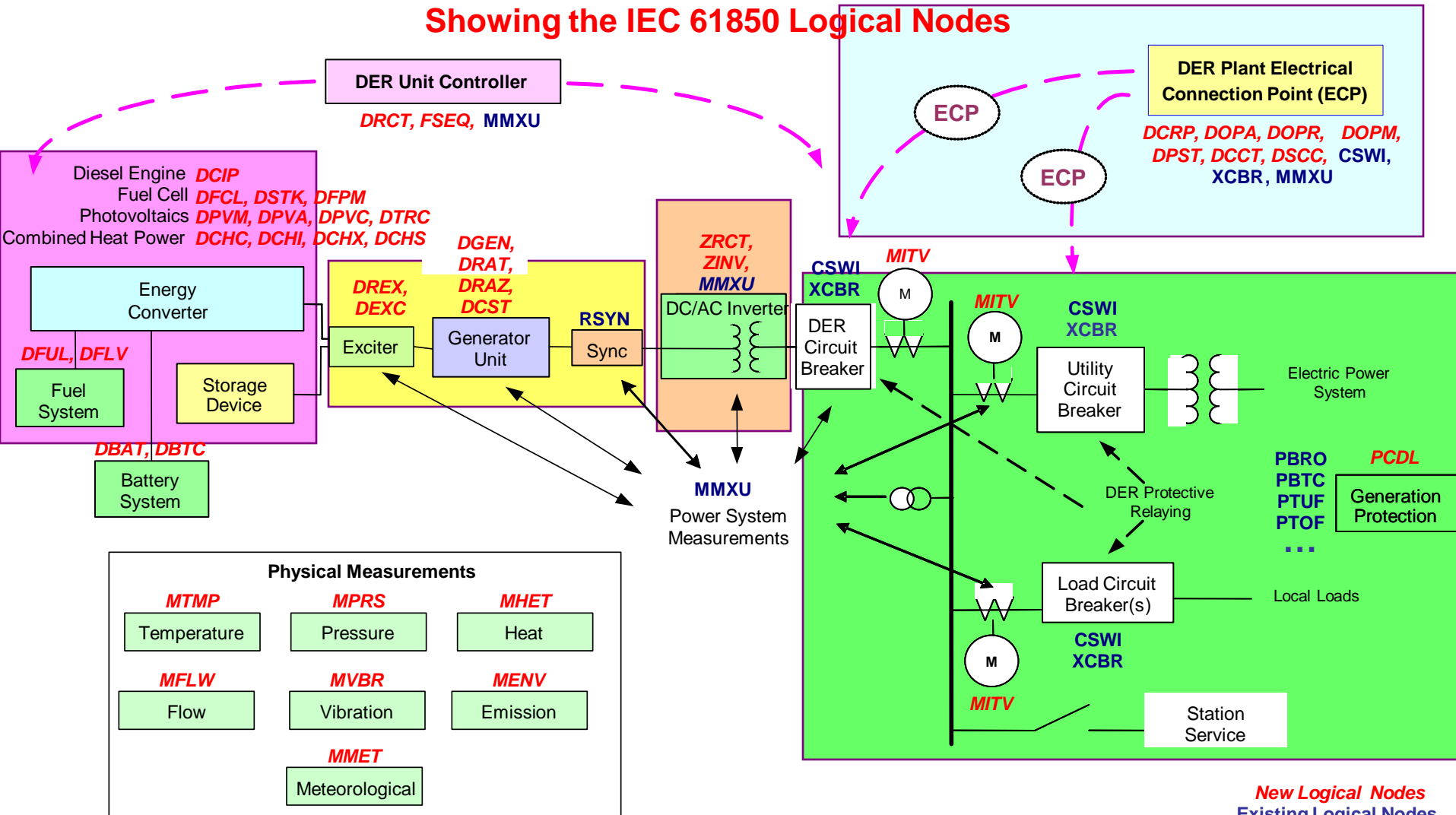
Inverter Functions, Concepts, and Models

Why are Inverters Important?

- Inverters, those devices that convert DC to AC, are needed on almost all types of generators (*except for bulk power “synchronous” generators*), and absolutely all storage devices. Most generators either:
 - Produce DC (like Photovoltaic Systems) so must convert to AC
 - Or do not spin at 60 cycles per second (like diesel generators) so must convert first to DC, then back to 60 Hz AC
- Inverters are now “software-driven” and have some amazing capabilities to shift what they are doing:
 - They can manage Watts (energy) so long as they remain within the capabilities of the DER device
 - More importantly, they can manage Vars and provide capabilities like volt-var control and low voltage ride-through

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

Showing the IEC 61850 Logical Nodes



New Logical Nodes
Existing Logical Nodes

Logical Device

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

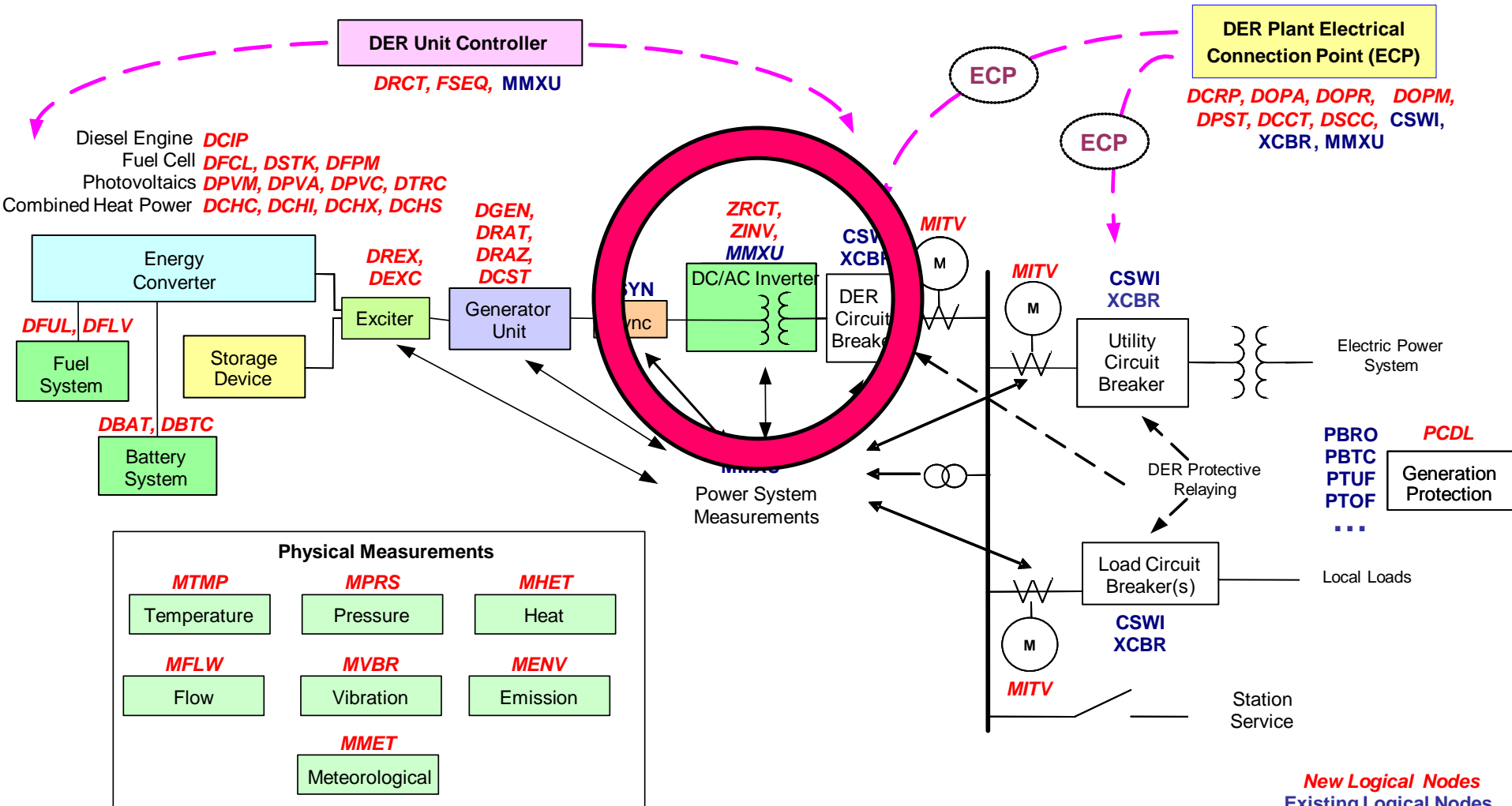
Storage Device = Battery, Pumped Hydro, Superconducting Magnetic Energy Storage, Flywheels, Micro-flywheels

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

Auxiliaries = Battery, Fuel Cell

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

Focus on the Inverter Functions



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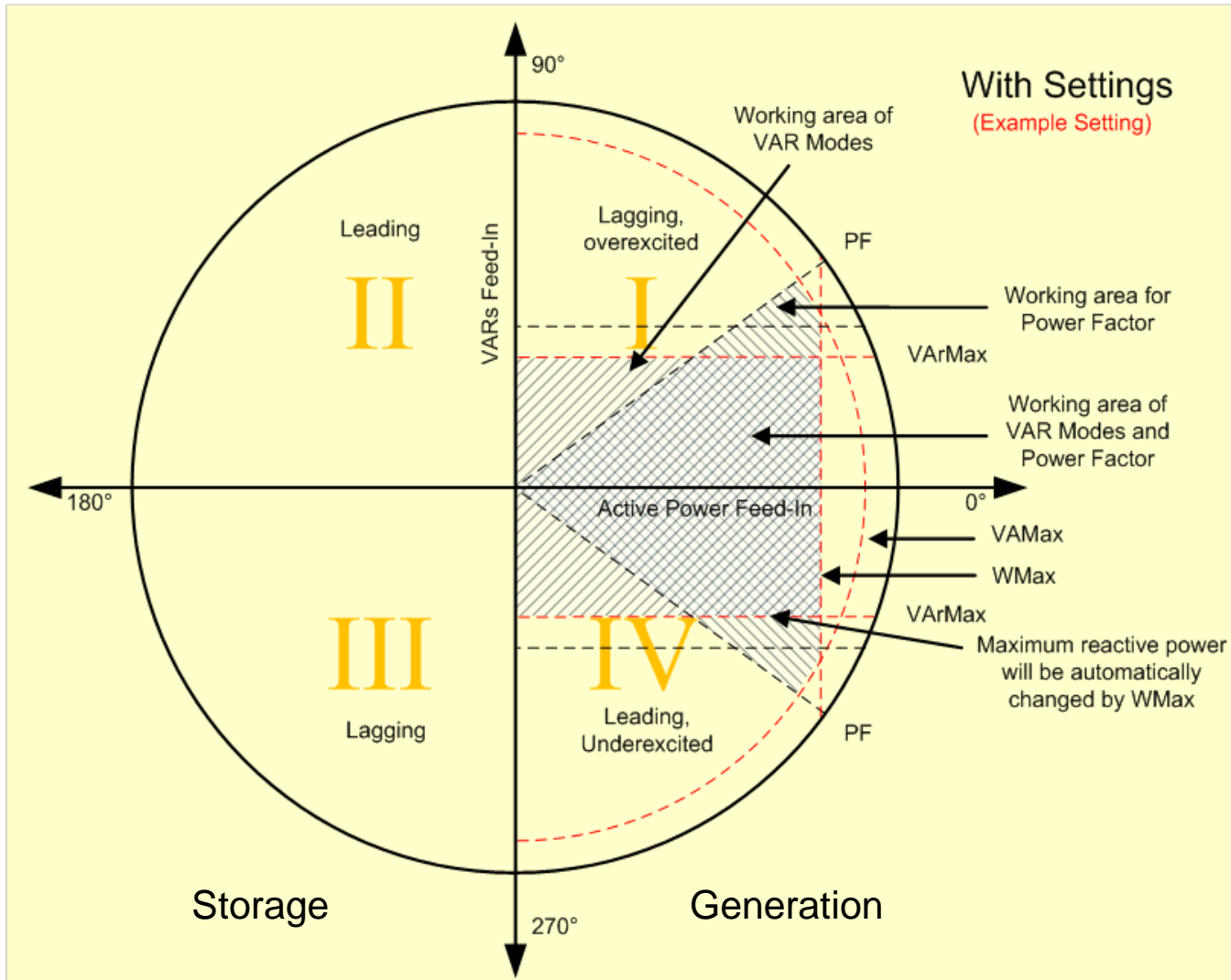
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New Logical Nodes
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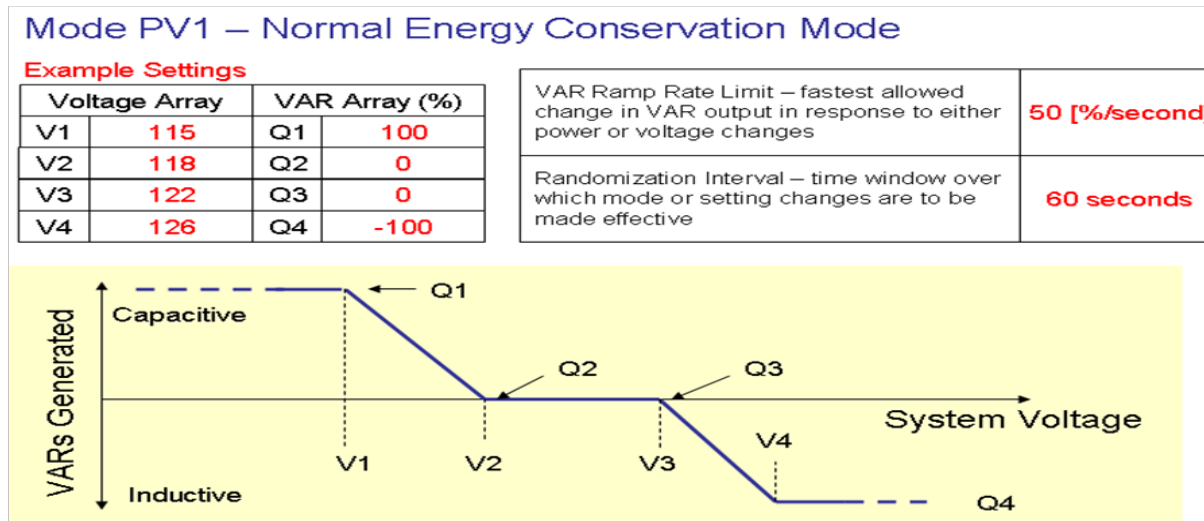
Logical Device

Inverters: Four Quadrant Capabilities



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

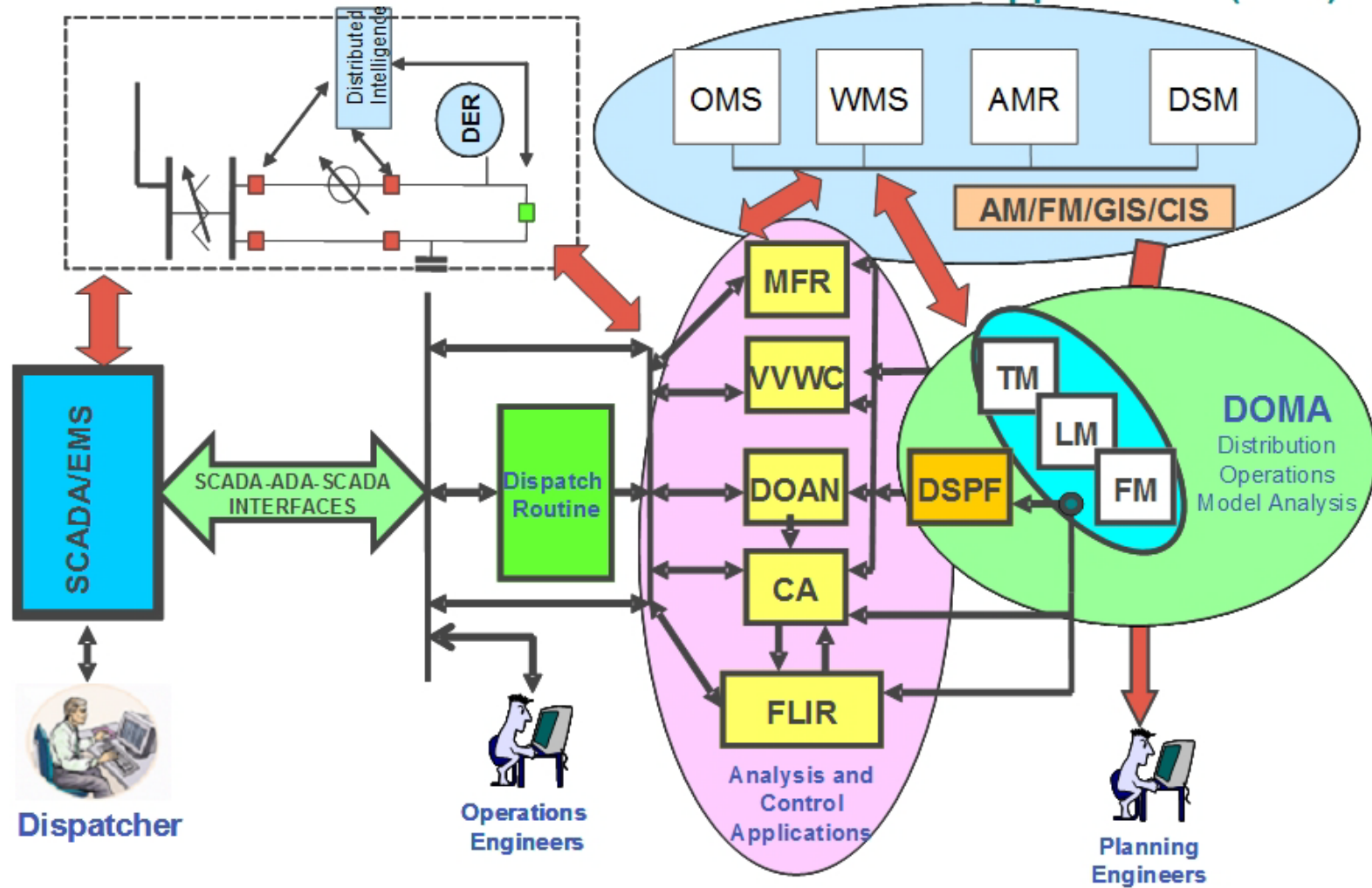


Information Modeling Constructs: Schedules and Graphs

- 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 signal-based “graphs” to respond to demand response**
 - **Pricing signals can be \$\$, or tariff-based tiers, or High/Med/Low, or**
 - **Pricing signals can be different for different functions**
 - **Pricing graph for volt-var control**
 - **Pricing graph for watt-frequency control**
 - **Demand response signal would indicate which part of the pricing signal graph to invoke**

Diagram of ADA Information Flows

Information Flows within Advanced Distribution Applications (ADA)



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;

Background and Status of IEC 61850-90-7

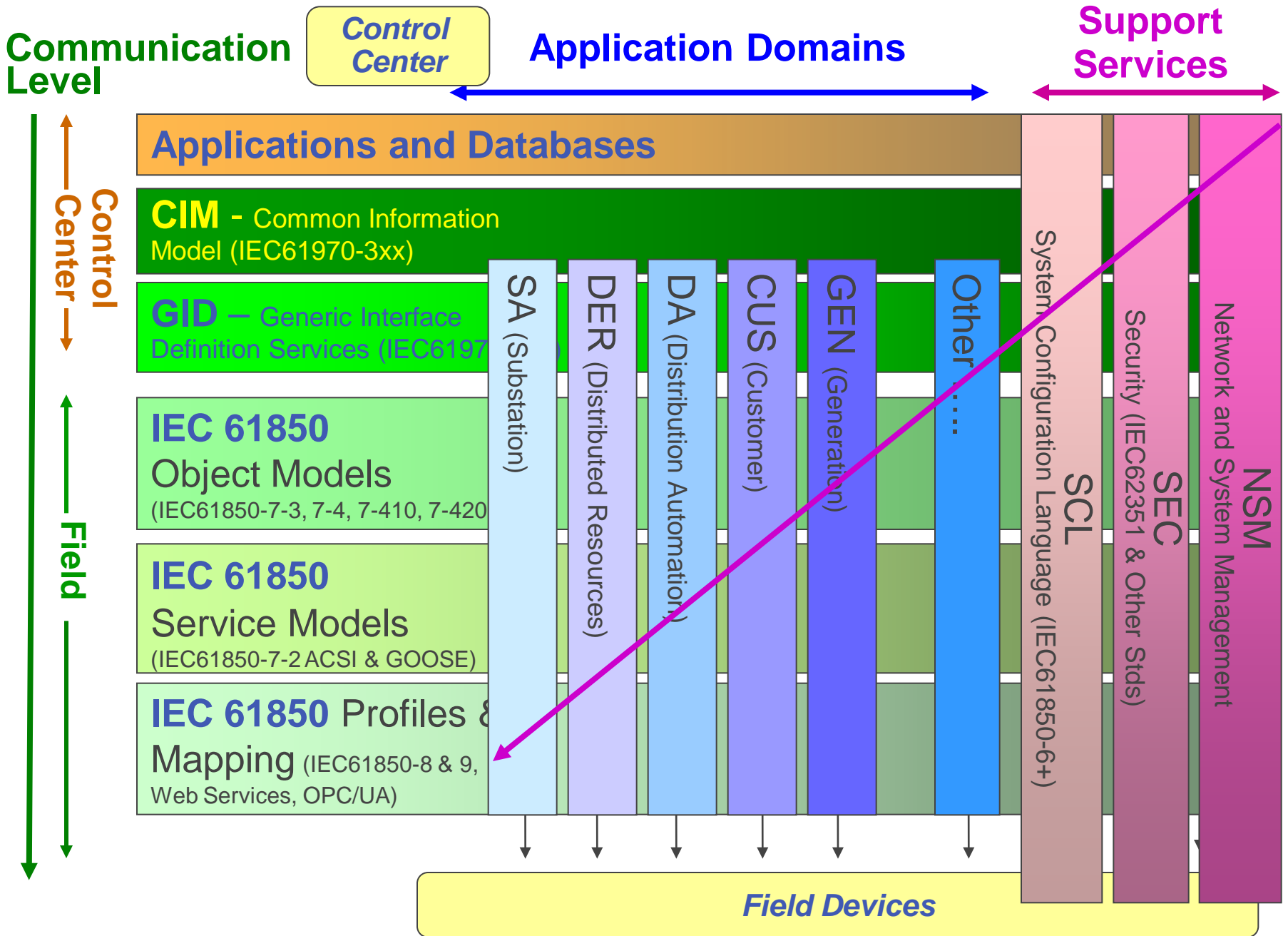
- Initially based on an **EPRI project**
 - Weekly teleconferences for over 9 months during 2010
 - 30+ participants
 - Utilities, inverter manufacturers, generator and storage manufacturers, integrators, national labs
- Information modeling
 - IEC 61850 experts modeled functions into **IEC 61850 abstract models**
 - Mapping IEC 61850 models to **DNP3** and **SEP 2.0**
- Submitted to **NIST / SGIP PAP 7**
 - Additional review and input from the ISO/RTOs
- 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
 - Technical Report: IEC 61850-790-7 for 6 month informative standardization cycle, rapid implementations, and feedback
 - Parallel Edition 2 of IEC 61850-7-420 for 2 year normative standardization cycle, taking advantage of feedback
 - **Expect IEC 61850-90-7 by Summer 2011**



Defining the DER Functions in the IEC 61850 Information Model

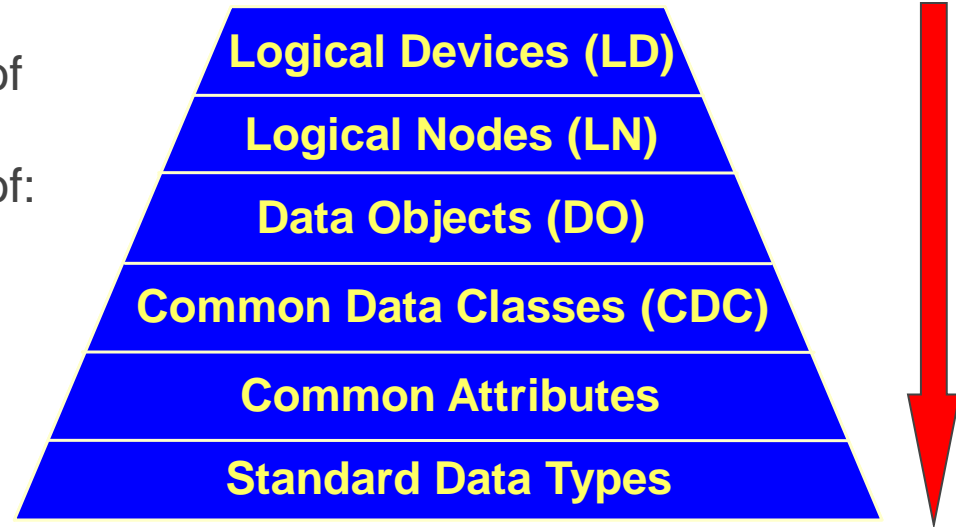
Mapping to DNP3, SEP v2, and Web Services

IEC 61850 Models and the Common Information (CIM) Model



IEC 61850-7-420 for DER Information Models

- IEC 61850-7-420 for DER
 - Provides the information model of **“Nouns”**
 - Uses 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**





Questions?