Communication Protocols for DER

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Acronyms

- DER: Distributed Energy Resources
- DERMS: DER Management System
- DNP3: Distributed Network Protocol (IEEE 1815)
- IEC: International Electrotechnical Commission
- SEP2: Smart Energy Profile 2.0 (IEEE 2030.5)
- Resources ≠ Race Horses

Agenda

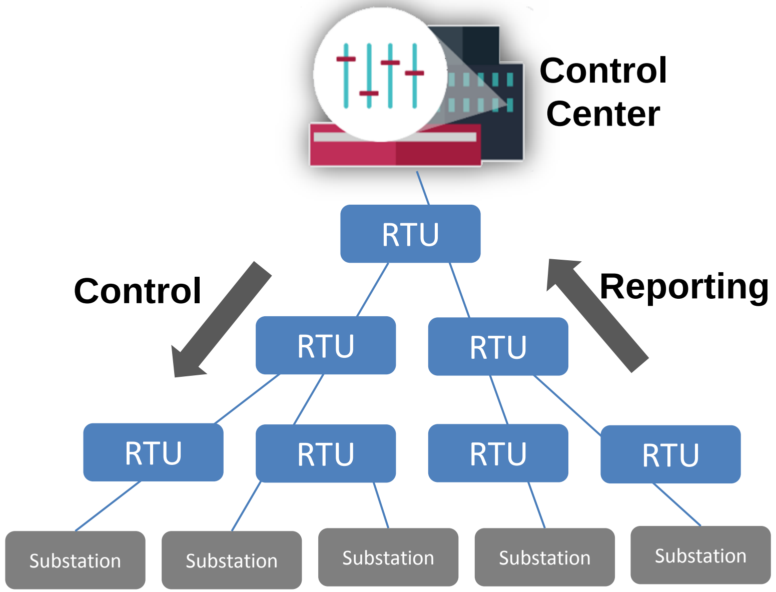
- Control system communications background
- DER functionality & requirements
- Data Models
- Protocols for DER

Take-Home Lessons

- Different approaches & requirements:
  - Engineered SCADA systems that are highly customizable
  - Standardized DER functionality for highly scalable and secure systems
  - Indirect for autonomous deployment DER communications (relaxed timing requirements)
  - Direct for controlled (dispatch) deployment DER communications (fast response)

Traditional SCADA Communication

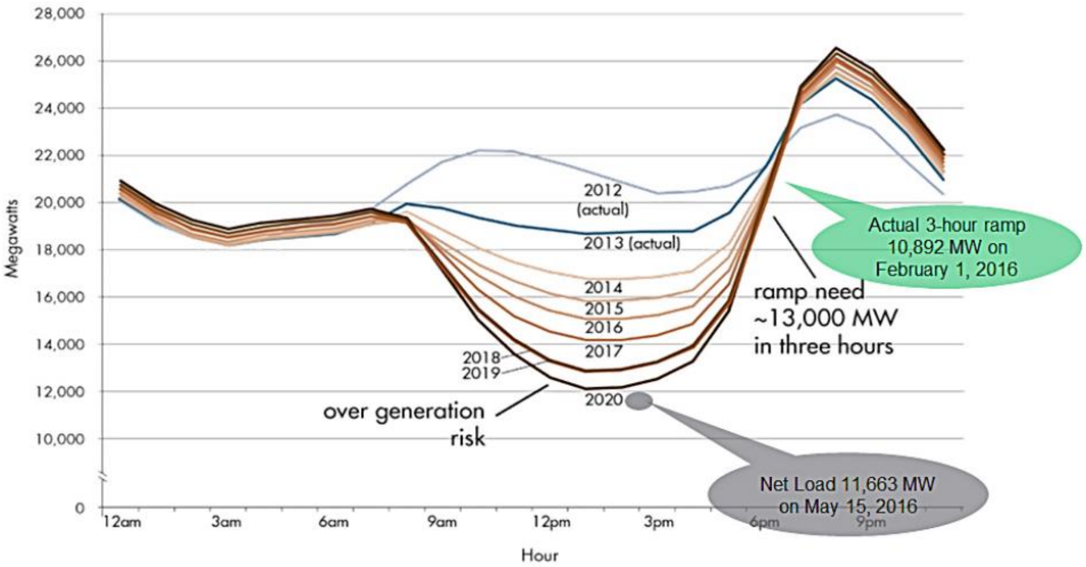
- All About Reliability:
  - Report events in order
  - Control equipment reliably
  - Time stamps, quality bits
- Scalability:
  - Systems can scale up to 1,000's of devices
  - Scale is usually met with hierarchy
- Security:
  - Assumed to run over secure network
  - Security features (authentication) added later



DER Challenges

- Large fleet
  - Millions of devices
  - Scale up to address the “Duck Curve”
- Built in security

CAISO Net Load Curve (Duck Curve)



Source: CAL ISO 2016 Report

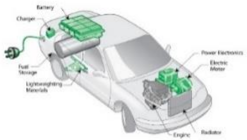
Non-Utility DER

Rooftop PV

- Produces power; impacts grid
- Interconnected with Inverters
- Not coordinated; little utility experience managing

DR/Load Management

- Decrease (Increase) Load
- No inverters (typically); no power production
- Well-developed programs and practices

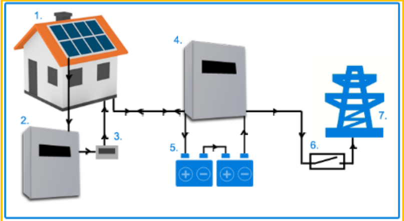


EV Batteries: G2V or V2G

- Decrease (Increase) Load
- Produces power; impacts grid
- Not coordinated; little utility experience managing
- Mobile batteries

Behind-the-Meter Storage

- Not coordinated; little utility experience managing
- Interconnected with Inverters (if connected)
- Stores or produces power; impacts grid



Primary Protocols / Standards

- IEEE 1547-2018
- IEC 61850 (-7-420, -90-7)
- IEEE 1815 (DNP3) AN2018-001
- IEEE 2030.5 (SEP2)
- OpenADR 2.0
- SunSpec Modbus

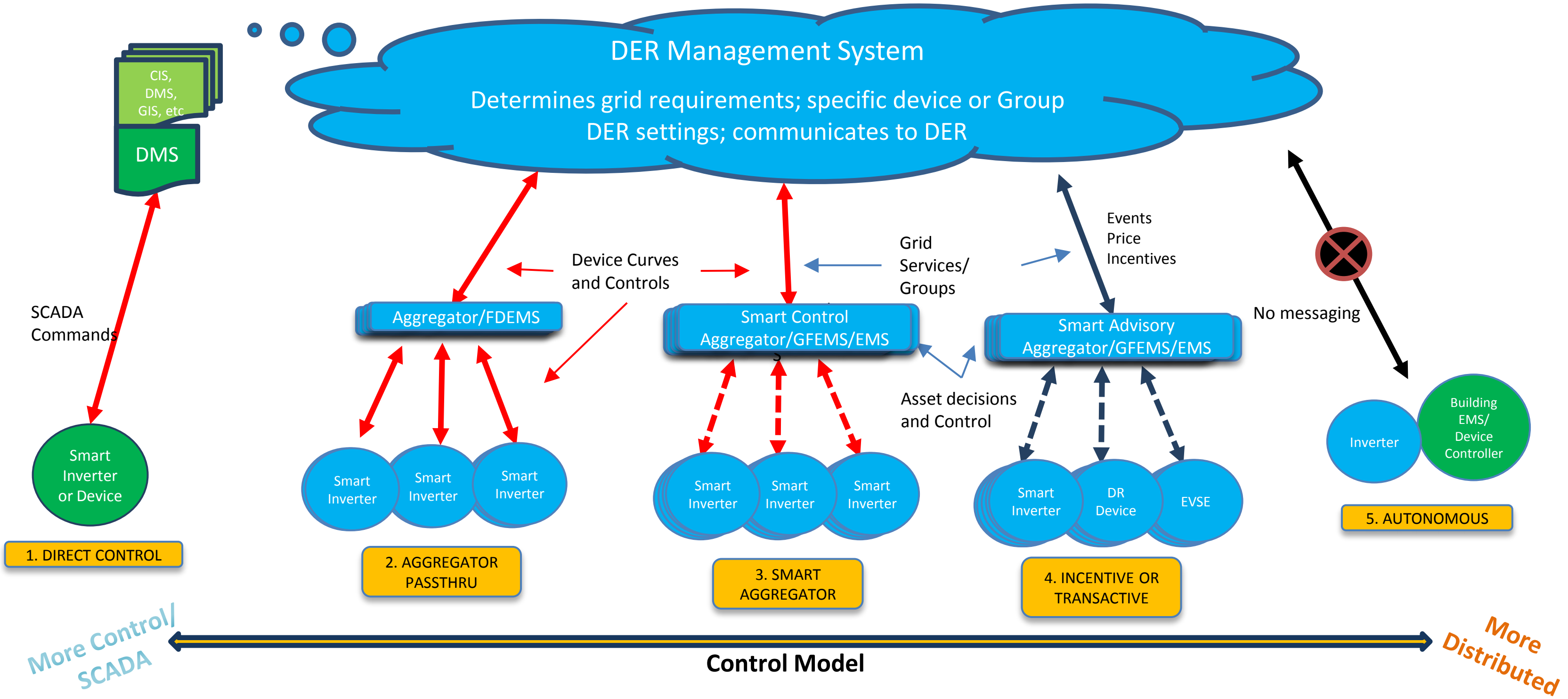
DER Communication

DER Messaging

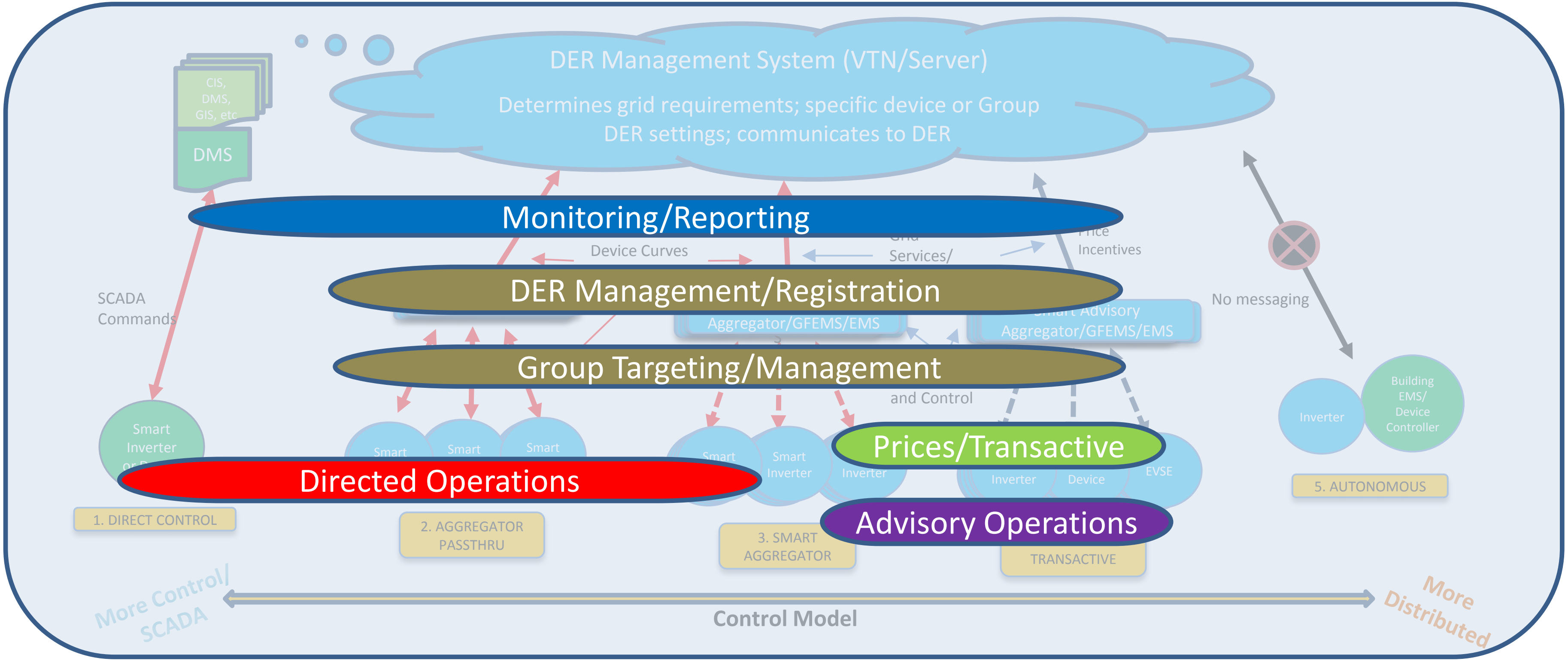
- **Directed operations**
  - Emergency dispatch
  - Notifications/Alarms
  - Behavior profiles/schedules
- **Advisory operations**
  - Requests/prices/incentives
  - Schedules
- **Reporting/Monitoring**
  - DER information/status
  - Configuration
  - Metering/performance

- **DER management**
  - Enrollment/Registration
  - Asset owners/Utility Programs
  - Discrete devices
- **Targeting/Groupings**
- **Prices/Transactions**
  - Price signals
  - Bids
  - Negotiations/forecasting
  - Transactions/settlements

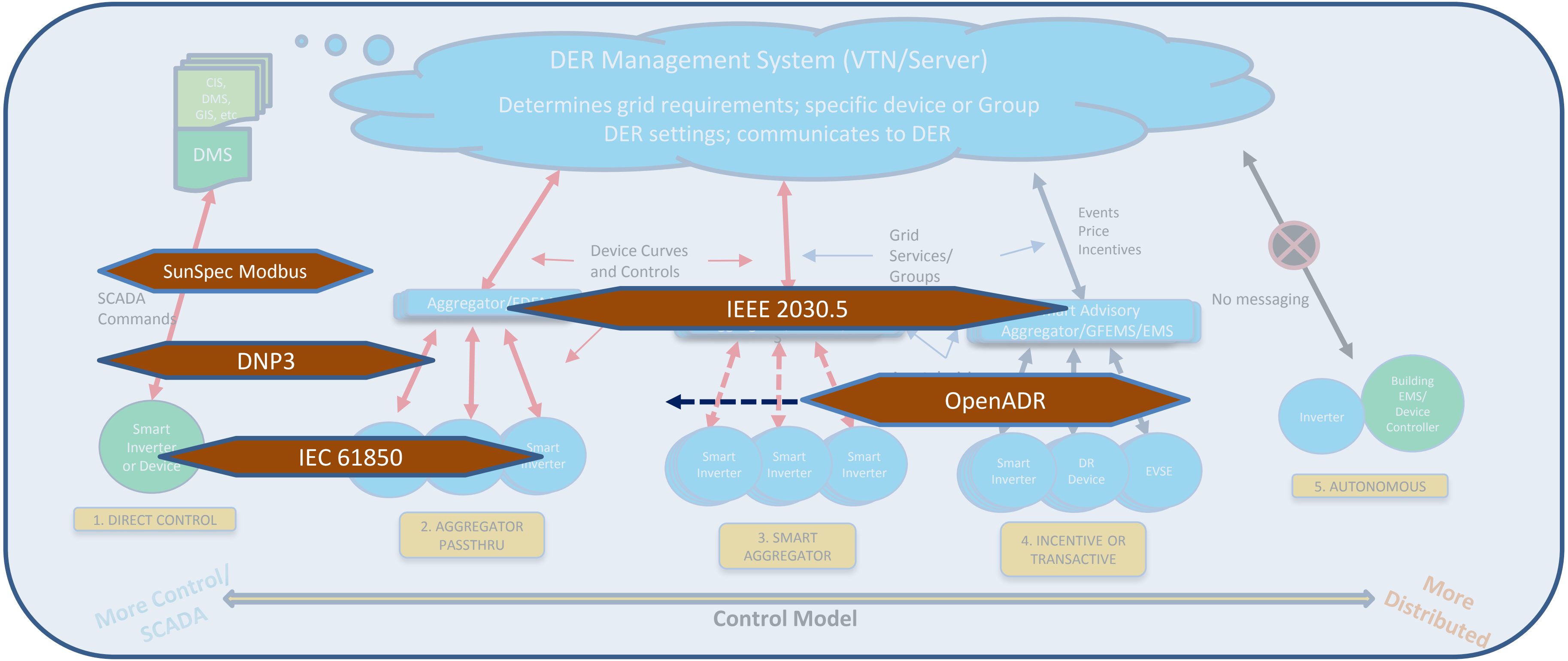
Primary DER Messaging Use Cases



Primary DER Messaging Use Cases



Standards for DER Messaging



Standards for DER Messaging

Protocol	Protocol	Protocol
OpenADR 2.0	OCHP (EV)	Open SG Protocol
IEEE 2030.5 (1547)	OCPI (EV)	TeMIX
IEC 61850-8-2	OCPP (EV)	CTA 2045
DNP3 (1547)	OICP (EV)	ETSI TS 104.001
SunSpec (1547)	OSCP (EV)	FAN USEF
MESA	Green Button	ASHRAE 201/2030.5
IEC 61850-90-8	Orange Button	PowerMatcher
ISO/IEC 15118	OpenFMB	IEC 61968-5
eMIP (EV)	IEC 61850-4-720	

Industry priority   Also of interest   Just added

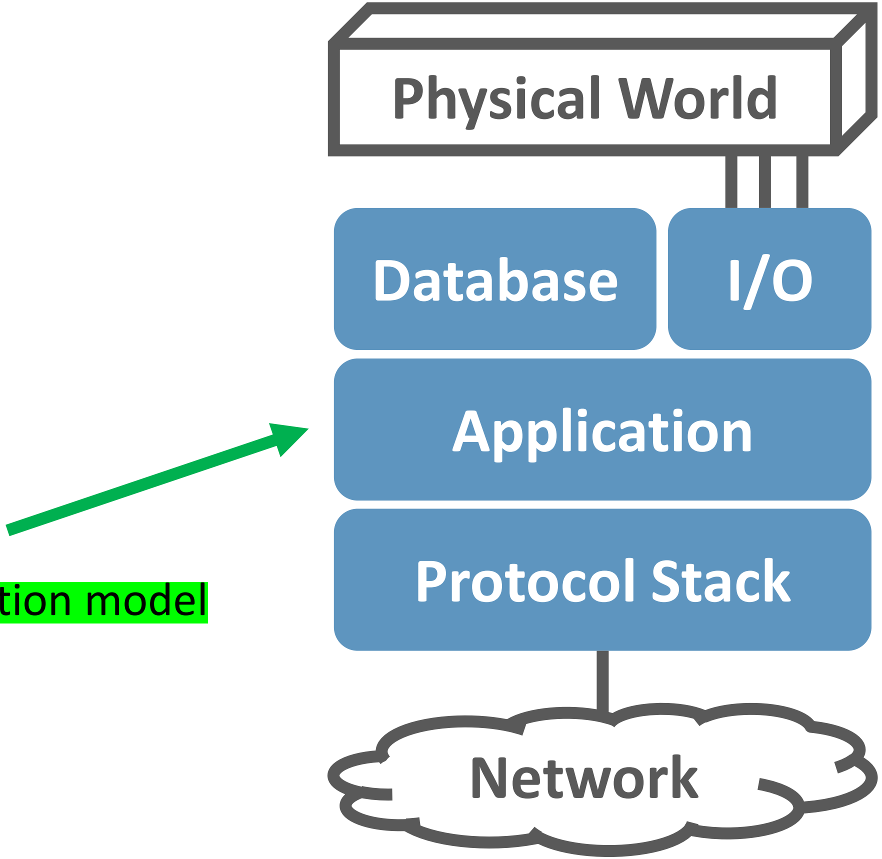
Information Models

Messaging Protocol	DER Data Model
IEC 61850-8-2	IEC 61850-7-420 and -90-7
IEEE 2030.5 (SEP 2)*	IEC 61850-7-420
SunSpec*	IEC 61850-7-420 and -90-7
IEEE 1815 (DNP3)*	IEC 61850-7-420 and -90-7
OpenADR 2.0	*Energy Interop/61968 (CIM)*
IEC 61968-5	*CIM DER*

* Named protocols in IEEE 1547.1

Information Models

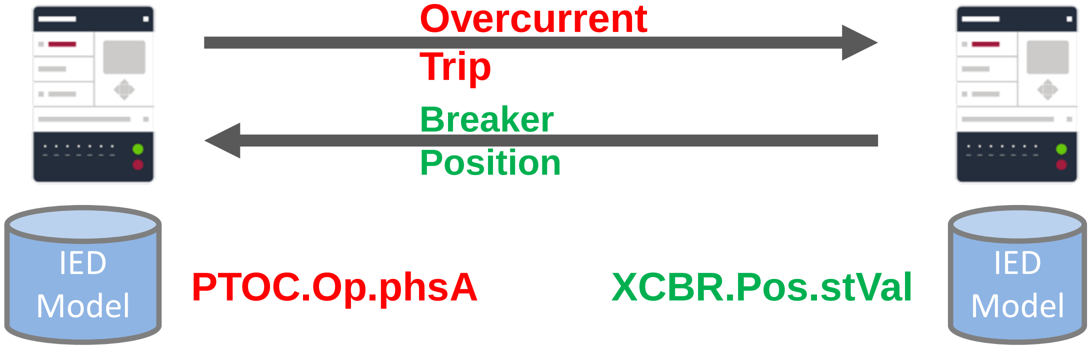
- A way to represent information such as:
  - → Measurements
  - → Status values
  - → Alarms
  - → Controls / commands
  - → Configuration / capabilities
- Application uses the information model
- Communication protocol allows information model to be shared with other devices



Information Models

- Standardization of information improves interoperability
- System configuration is easier
- Consistent mapping between protocols

IEC 61850 Example



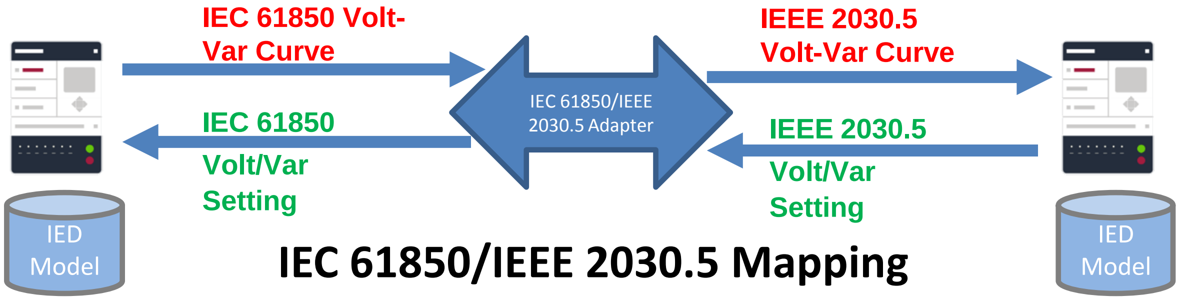
Need context for data:
Which phase?
What kind of fault?
When did it start?
What other IEDs detect it?
Was there a failure?

Information Models

- Scaling DER management requires standard models for end device functions
  →Example: Functions in IEEE 2030.5 for IEEE 1547 functionality

- Integration with multiple protocols in a system is faster and easier
  →Example: SunSpec mapping to IEEE 2030.5 and DNP3

- Accelerate interoperable DER management systems
  →Example: IEEE 2030.5 control functions and inverter groupings



IEC 61850/IEEE 2030.5 Mapping

How are the models being standardized?

- Industry has agreed on 61850-7-420
- Leading protocols are using it or are in the process of standardizing on it

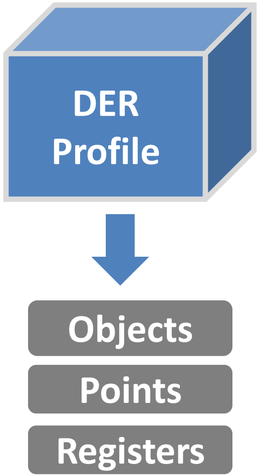
Information Model Approaches

Scalability: Pre-defined, fixed models for end devices

- IEEE 2030.5 CSIP (Common Smart Inverter Profile)
- SunSpec Modbus Profile
- DNP3 DER Profile (AN2018-001)

Flexibility: Building block objects

- IEC 61850 objects, DNP3 points or Modbus registers without a profile



Pre-defined models can allow greater scalability and data interoperability

IEEE 1547 Communications & Info Model

Requirements came from Smart Inverter Working Group and UL 1741 SA

Defines interconnection capabilities that DER shall support:

- Constant power factor mode (default)
- Voltage-reactive power mode (Volt-VAR)
- Active power-reactive power mode (Watt-VAR)
- Constant reactive power mode
- Voltage-active power mode (Volt-Watt)

How do we model this information?

Also defines how DER should react to:

- Power system faults, anti-islanding, reclosing
- Voltage and frequency ride-through

IEEE 1547 Communications & Info Model

Defines "Local DER Interface" required to be either:

- IEEE 2030.5
- IEEE 1815 (DNP3) - TCP/IP only
- SunSpec Modbus – TCP/IP or serial

Information Model:

- IEEE 1547 uses information models from IEC 61850-7-420

IEC 61850 DER Information Models

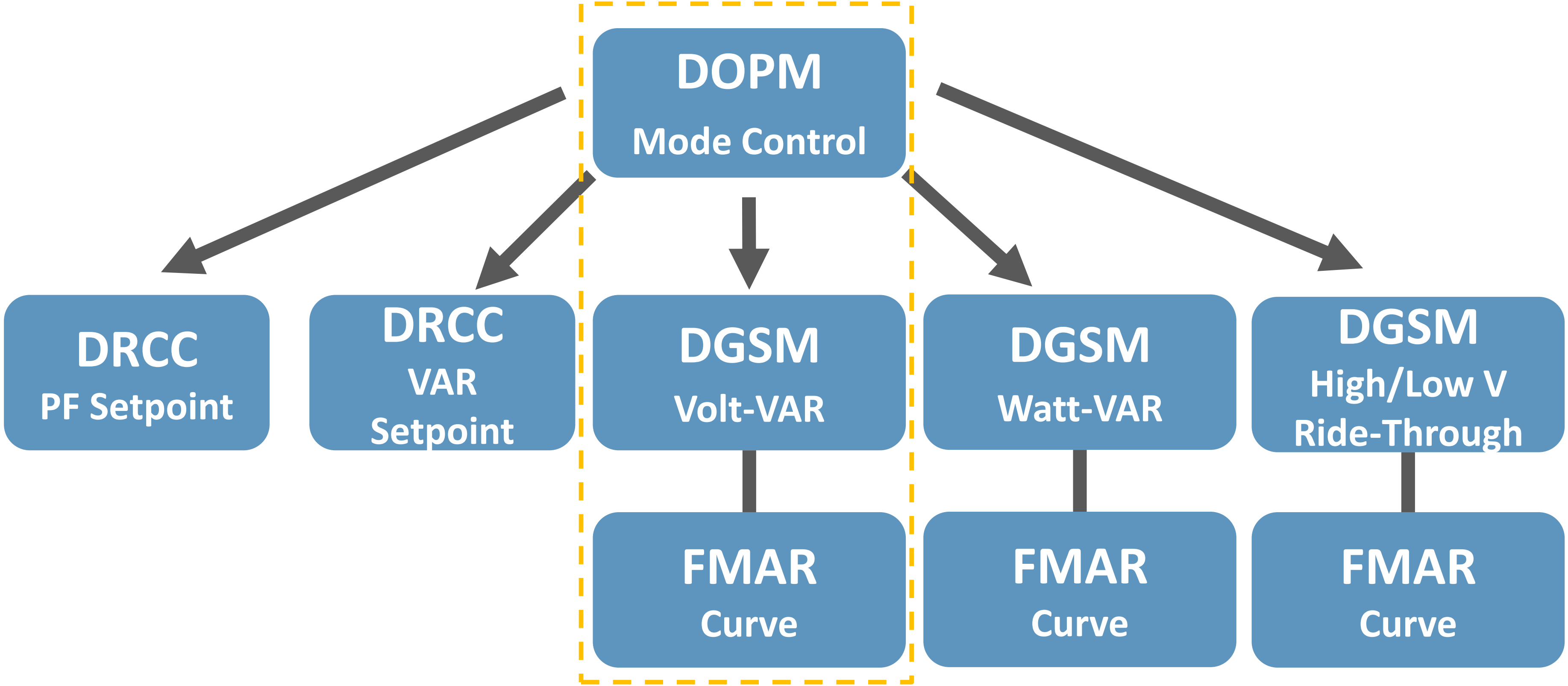
IEC 61850-7-420 Standard

- DER information models defined in IEC 61850-7-420 Standard
- Some DER models updated with IEC 61850-90-7 Technical Report

What is included in -7-420?

- Overview of IEC 61850 information modeling
- DER specific Logical Nodes, Data Objects, Common Data Classes
- How the information model relates to DER systems

DER Control Example



IEC 61850 Model Hierarchy Example

IED	PV Inverter			
Logical Devices	MEAS	CTRL		
Logical Nodes	MMXU	DOPM	DGSM	FMAR
Data Objects	PhV.PhsA	OpModVVar	ModEna	PairArray
Common Data Classes	CMV	SPC	SPC	CSG
Data Attributes	cVal q, t	ctlNum stVal q, t	ctlNum stVal q, t	numPts crvPts xUnit, yUnit

IEC 61850 – Control Operating Mode

DOPM – Operating Mode

- OpModConPF – constant fixed PF mode
- OpModConW – constant real power mode
- OpModConVAR – constant VAR mode
- OpModLimW – limit maximum real power
- OpModVvar – Volt/VAR control mode
- OpModFrt – frequency ride-through mode

IEC 61850 – Curve Based Mode (Autonomous Functions)

DGSM – Issue Mode Command

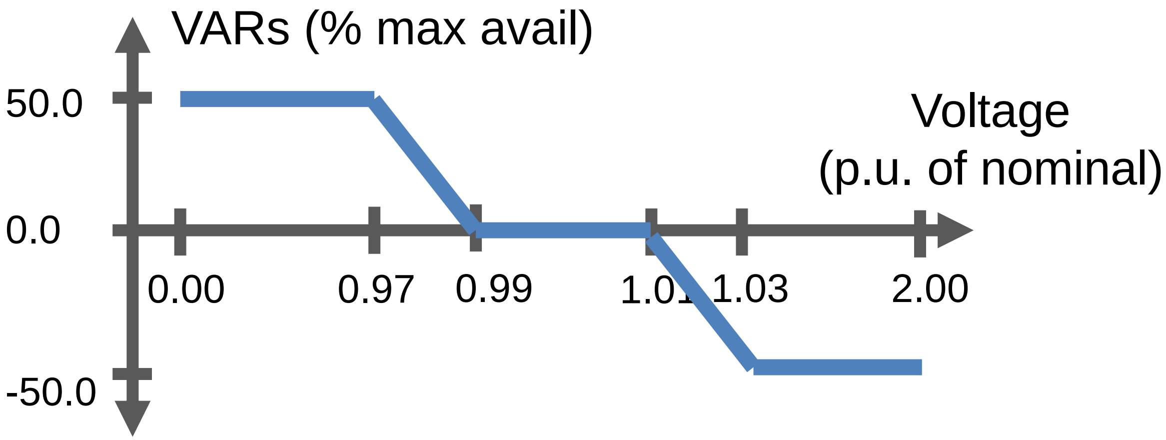
- ModEna – control activating/deactivating mode for curve
- InCurve – reference to curve (defined in FMAR)
- ModTyp (2 = Volt-VAR modes)
- WinTms – time window to randomly execute command (seconds)
- RvrtTms – timeout to revert to default operation when communications lost
- RmpTms – ramp time to transition to new operation mode

IEC 61850 Curve Settings

FMAR – Mode curves and parameters

- PairArray (CSG) -
  - numPts – number of x-y pairs of points
  - crvPts – array of xVal and yVal FLOAT32 values for each curve point
- IndpUnits (29 = Voltage)
- DeptRef (3 = VArAval) - VARs as percent of maximum available VARs)
- RmpDecTmm – max rate for reducing VARs (%/minute)
- RmpIncTmm – max rate for incresing VARs (%/minute)

DER Volt-VAR Example



FMAR.PairArray.crvPts

Point#	X Value	Y Value
0	0.00	50.0
1	0.97	50.0
2	0.99	0.0
3	1.01	0.0
4	1.03	-50.0
5	2.00	-50.0

DOPM
Mode Control

→

DGSM
Volt-VAR

→

FMAR
Curve

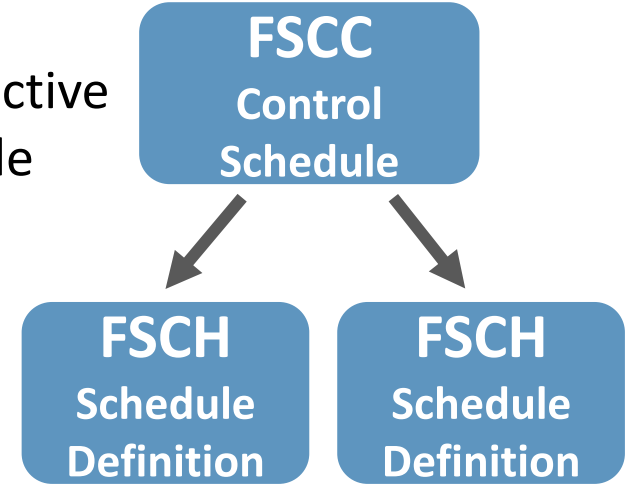
IEC 61850 Scheduling DER Functions

DSCC/FSCC (-90-10) – Control Schedule

- ActWSchdSt – indication of which schedule is active
- ActWSchd – control to activate specific schedule

DSCH/FSCH (-90-10) – Define Schedule

- SchSt – status of this schedule
- SchdId – ID of the schedule
- SchdVal – type of values (2 = VAR)
- SchdAbsTm – array of values and absolute times
- SchdRelTm – array of values and relative times



IEEE 2030.5 - Information Models

- IEEE 2030.5 information model designed into protocol
- Uses standard models for end devices and system level configuration
- CA Rule 21 CSIP Guide references IEEE 2030.5 information model
- Defines information model using UML with classes, objects, and links
- Data in messages are in XML

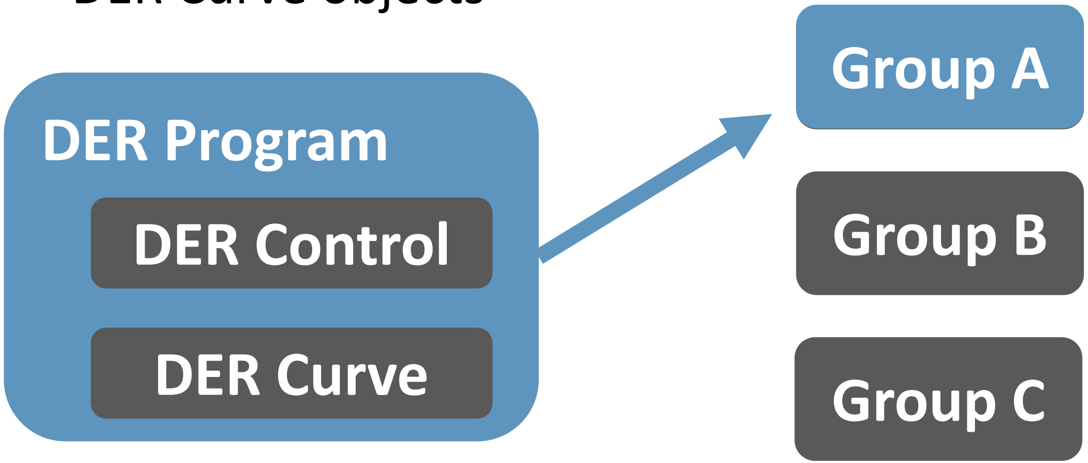
	Data structure	Types	Example (phase A voltage)
IEEE 2030.5	XML tags URI paths	Programs Function Sets Objects	<value> (value) <uom> = 29 (unit of measure = voltage) <phase> = 128 (phase = A) <start> (start time for measurement)

IEEE 2030.5 - DER Programs and Groups

A DER Program is a high level object that links to:

- DER Control objects
- DER Curve objects

A DER Program can target a group of end devices (inverters for example)



Can be grouped by:

- Substation
- Feeder
- Segment
- Transformer
- Service Point

IEEE 2030.5 – How to control DER modes

Class DER Control:

- Links to Event and Event Status classes
  - For scheduling events
- Immediate controls
  - opModFixedW
  - opModFixedPF
  - opModFixedVAr
  - opModFixedFlow
- Curve-based controls (autonomous)
  - opModVoltVAr
  - opModVoltWatt
  - opModWattPF

Similar to information in IEC 61850 DOPM

- OpModConPF
- OpModConW
- OpModConVAR
- OpModLimW
- OpModVvar
- OpModFrt

IEEE 2030.5 – How to define a curve

Class DER Curves:

- DERCurve
  - curveType
  - rampDecTms
  - rampIncTms
- CurveData
  - xvalue
  - yvalue
- DERCurveListLink

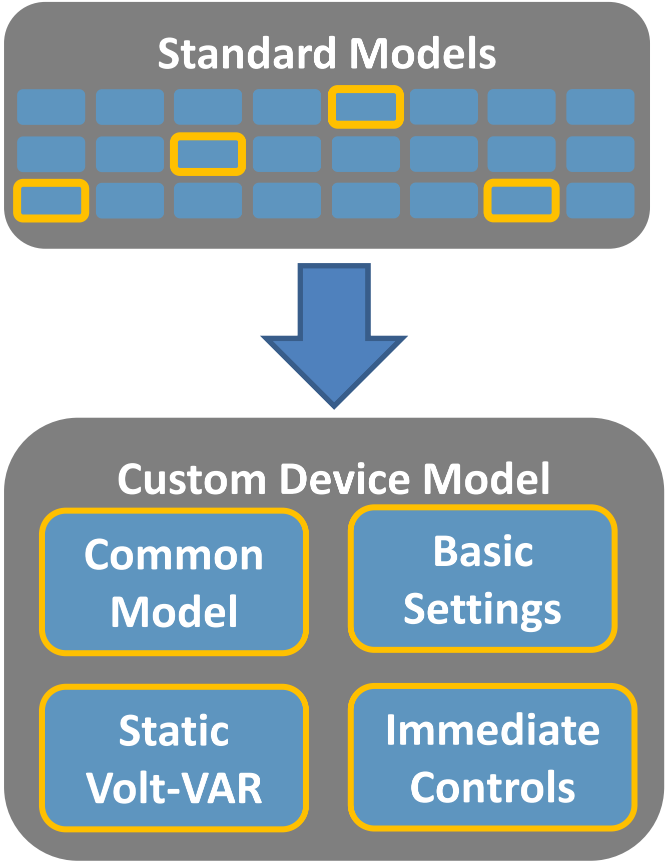
Similar to information in IEC 61850 DGSM and FMAR

- FMAR.PairArray
  - numPts
  - crvPts
- FMAR.RmpDecTmm
- FMAR.RmpIncTmm
- DGSM.ModTyp
- DGSM.InCurve
- DGSM.ModEna

SunSpec Modbus Profile

Way to build an interoperable device model:

- Profile for how registers should be indexed
- Defines standard modeling blocks
- Scaling factors to get around 16 bit limits
- Defines basic types built with 16 bit registers:
  - Signed/unsigned integers (16, 32, 128)
  - 32 bit floating points
  - Strings



Examples of SunSpec Standard Models

Inverter Single Phase – measurements/status (Model 101)
Nameplate (Model 120)
Basic Settings - Inverter control (Model 121)
Immediate Controls (Model 123)
Static Volt-VAR (Model 126)
Basic Scheduling (Model 133)

SunSpec Example Inverter Model

Start at base register 40,001

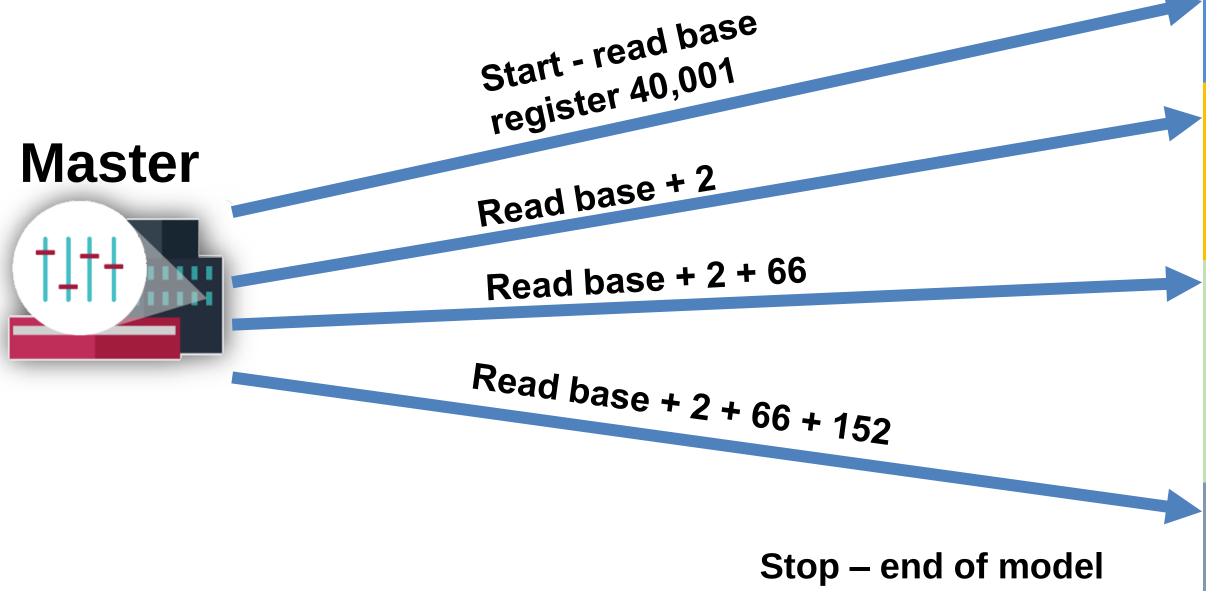
Common Model

Static Volt-VAR

Register Offset	Value	Use
0	21365	SunSpec ID
1	28243	SunSpec ID
0	1	Model ID
1	66	Length
…	…	…
64		Device Address
65		Pad
0	126	Model ID
1	Variable	Length
2	1-N	Active Curve
3	0/1	Mode Enable
…	…	…
Length - 1	0/1	Curve Read Only
0	xFFFF	End of model
1	0	Length

Modbus – Discovery of Device Model

- No concept of integrity poll or discovery in Modbus
- Master can use SunSpec registers to “discover” model



Inverter Model

Register Offset	Use
0	SunSpec ID
1	SunSpec ID
0	Model ID (1)
1	Length = 66
65	Last Registers
0	Model ID (126)
1	Length = 152
151	Curve Read Only
0	End of model
1	Length

DNP3 Application Note 2018-001
Profile for Advanced Photovoltaic Generation and Storage

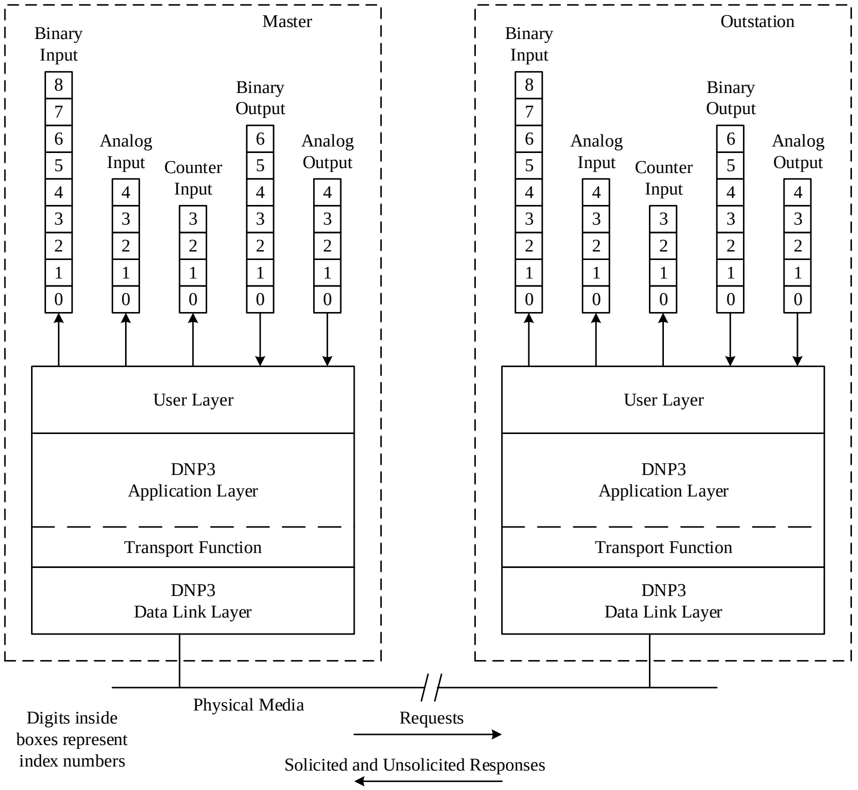
What does this profile cover?

- DNP3 data points for implementing IEC 61850-7-420 model
- DNP3 services for implementing functions specified by IEC 61850-90-7 and EPRI Common Functions for Smart Inverters
- Uses guidelines from IEEE 1815.1 for mapping DNP3 to IEC 61850
- Protocol Implementation Conformance Statement (PICS)

Work commenced to make this into a new standard: IEEE 1815.2

DNP3 Data Model

- One-dimensional arrays of simple data types: 1- & 2-bit binary inputs, analog inputs, counter input, binary and analog outputs
- Data identified by:
  DNP3 Device Address +
  Data Type +
  Index in type array
  - First entry is index 0
- Counters & Frozen counters both supported
- Reporting format (integer, float, etc.) independent of underlying data storage



DNP3 DER Profile - Data Mapping to IEC 61850

- Defines how to map DNP3 points to IEC 61850
- Uses IEEE 1815.1 - DNP3 to IEC 61850 mapping standard

Object group	Purpose
Binary Inputs	Status, alarms
Binary Outputs	Set modes
Counters	Energy Flow
Analog Inputs	Measurements, status, protection events
Analog Outputs	Curves, modes, set points, events

Example - Control DER Operating Modes

Example: How to map IEC 61850 DOPM

Obj. Group (index)	Data Contained	IEC 61850 Object
BO (2)	Set constant fixed PF mode	DOPM.OpModConPF
BO (1)	Set constant real power mode	DOPM.OpModConW
BO (10)	Set constant VAR mode	DOPM.OpModConVAR
BI (0)	Status constant fixed PF mode	DOPM.OpModConPF
BI (54)	Status constant VAR mode	DOPM.OpModConVAR

Example - Set Mode for a Curve (Autonomous Functions)

Example: How to map IEC 61850 DGSM

Obj. Group (index)	Data Contained	IEC 61850 Object [LN Inst. #]
BO (11)	Enable VoltVAR Curve 1	DGSM.ModEna [1]
BO (12)	Enable VoltVAR Curve 2	DGSM.ModEna [2]
AO (62)	VoltVAR Curve 1 ID	DGSM.InCurve [1]
AO (85)	VoltVAR Curve 1 Time Window	DGSM.WinTms [1]
AO (87)	VoltVAR Curve 2 ID	DGSM.InCurve [2]
AO (110)	VoltVAR Curve 2 Time Window	DGSM.WinTms [2]

Example - Defining a Volt/VAR Curve

Example: How to map IEC 61850 FMAR

Analog Output	Data Contained	IEC 61850 Object
62	Volt/VAR Curve ID	DGSM.InCurve
63	Number of points	FMAR.PairArray.NumPts
65	Point 1 Volts (% nom)	FMAR.PairArray.CrvPts[0].xVal
66	Point 1 VARS (% nom)	FMAR.PairArray.CrvPts[0].yVal
…	…	…
83	Point 9 Volts (% nom)	FMAR.PairArray.CrvPts[9].xVal
84	Point 9 VARS (% nom)	FMAR.PairArray.CrvPts[9].yVal

Example - Define a Schedule

Example: How to map IEC 61850 FSCH

Obj. Group (index)	Data Contained	IEC 61850 Object
BO (29-40)	Schedule 1-12 ready	FSCH.SetReady
AO (36-59)	Schedule 1-12 status	FSCH.SchSt
AO (312)	Schedule 1 ID	FSCH.SchId
AO (315)	Schedule 1 # Points	FSCH.numPts
AO (338)	Schedule 1 Type of values	FSCH.SchdVal
AO (317-336)	Schedule 1 time/values	FSCH.SchdVal.tmOffset / val
AO (339-365)	Schedule 2 points	Repeat above like schedule 1

DNP3 DER Use Case

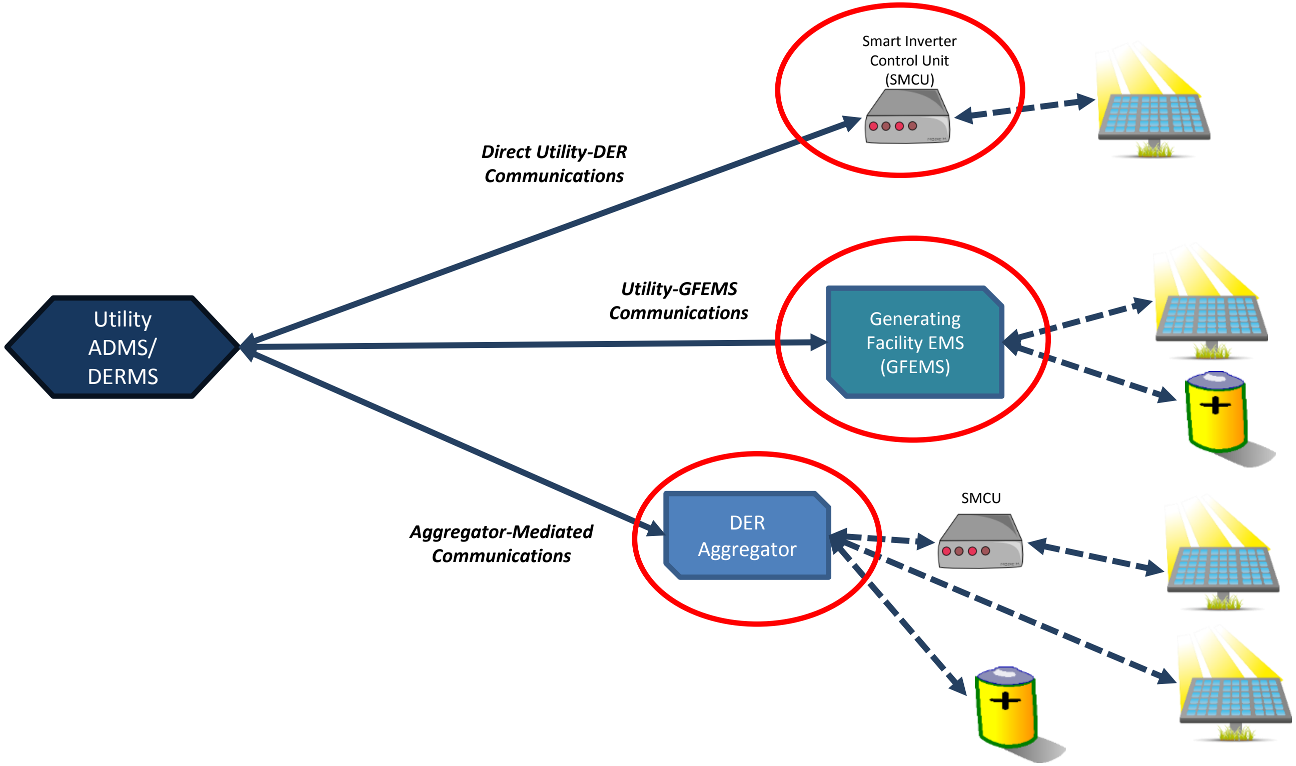
- Interfaces directly with existing utility SCADA systems
- AN2108-001 provides a consistent DNP3 interface for DER systems and devices
  - A template approach allows ready instantiation of a large fleet of DERs
  - The modeling approach can allow a single connected DER to actually aggregate a fleet of smaller DER systems and resent them to the SCADA master as a single resource with the combined capabilities of the fleet
  - The scheduling capabilities allow for pre-planned autonomous operation
  - Various volt/var modes of operation permit management of the DER to best support utility requirements
  - Multiple modes may be active with prioritization of which mode takes precedence depending on operating conditions
  - Primarily intended to allow utility to set operating characteristics and allow DER to manage its own operation, with the ability to rapidly update the operating characteristics

CA Rule 21

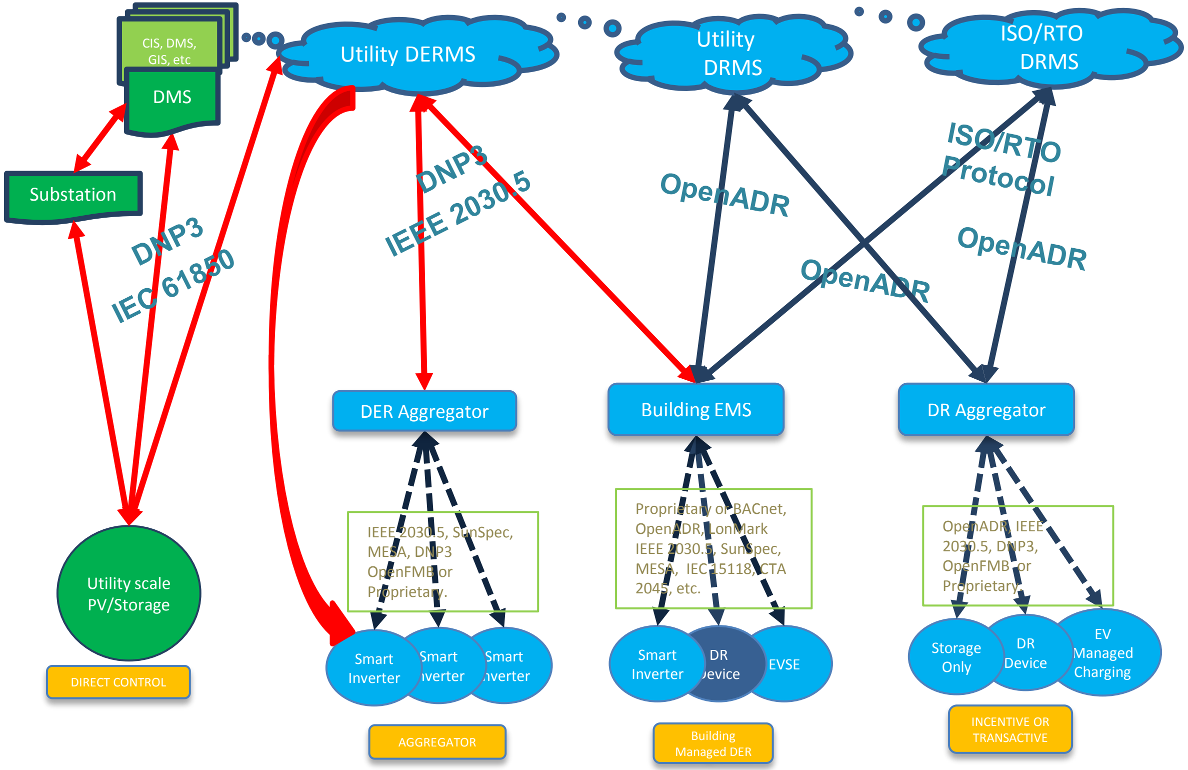
- Standardizing functionality and communications with DERs
- Phase 2, “Recommendations for Utility Communications with Distributed Energy Resources (DER) Systems with Smart Inverters”, appr. June 23, 2016
- Specifies requirements for interconnection including:
  - “The default Application Level protocol shall be the IEEE 2030.5.”
  - Allows utilities to use alternatives by agreement
- Common Smart Inverter Profile – implementation guide for Rule 21 using 2030.5 protocol (CSIP*)

*IEEE 2030.5 Common California IOU Rule 21 Implementation Guide for Smart Inverters, V1.0, August 31, 2016. V2 published March, 2018

What are Rule 21 Phase 2 Use Cases?



Where do DER Protocols Work Best?



Q&A / Contact Details

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