Communication Protocols for DER

Andrew West, Regional Technical Director, SUBNET Solutions
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
Non-Utility DER

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

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

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

Mobile batteries
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
PRESS RELEASE

New Standard Communication Model Enables Grid Operators to Enhance Performance, Value of Distributed Energy Resources

JANUARY 14, 2019

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

DER Management System
Determined grid requirements; specific device or Group DER settings; communicates to DER

1. DIRECT CONTROL
2. AGGREGATOR PASSTHRU
3. SMART AGGREGATOR
4. INCENTIVE OR TRANSACTIVE
5. AUTONOMOUS

Control Model

- SCADA Commands
- More Control/SCADA
- More Distributed

DER Messaging System

- Smart Inverter or Device
- Aggregator/FDEMS
- Smart Control Aggregator/GFEMS/EMS
- Smart Advisory Aggregator/GFEMS/EMS
- Building EMS/Device Controller
- Inverter
- DR Device
- EVSE

Device Curves and Controls
Grid Services/Groups
Events
Price Incentives

No messaging
Primary DER Messaging Use Cases

DER Management System (VTN/Server)
- Determines grid requirements; specific device or Group
- DER settings; communicates to DER

Monitoring/Reporting

DER Management/Registration

Group Targeting/Management

Directed Operations

1. DIRECT CONTROL
2. AGGREGATOR/PASSTHRU
3. SMART AGGREGATOR

Advisory Operations

Prices/Transactive

More Control/SCADA

Control Model
Standards for DER Messaging

DER Management System (VTN/Server)
Determines grid requirements; specific device or Group
DER settings; communicates to DER

1. DIRECT CONTROL
2. AGGREGATOR PASSTHRU
3. SMART AGGREGATOR
4. INCENTIVE OR TRANSACTIVE
5. AUTONOMOUS

SunSpec Modbus
IEC 61850
DNP3
IEEE 2030.5
OpenADR

SCADA Commands
Device Curves and Controls
Grid Services/Groups
Events Price Incentives
No messaging

Aggregator/FDEMS
Smart Inverter
Smart Inverter
Smart Inverter
Smart Inverter
Smart Advisory
Aggregator/GFEMS/EMS

Smart Inverter
Smart Inverter
Smart Inverter
Smart Inverter
Smart Inverter

Inverter
DR Device
EVSE
Building EMS/Device Controller

1. More Control/SCADA
2. More Distributed

IEC 61850
SunSpec
Modbus
DNP3
IEEE 2030.5
OpenADR

IEEE 2030.5
IEC 61850
SunSpec
Modbus
DNP3

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## Standards for DER Messaging

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

- **Yellow**: Industry priority
- **Blue**: Also of interest
- **Green**: Just added
## Information Models

<table>
<thead>
<tr>
<th>Messaging Protocol</th>
<th>DER Data Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850-8-2</td>
<td>IEC 61850-7-420 and -90-7</td>
</tr>
<tr>
<td>IEEE 2030.5 (SEP 2)*</td>
<td>IEC 61850-7-420</td>
</tr>
<tr>
<td>SunSpec*</td>
<td>IEC 61850-7-420 and -90-7</td>
</tr>
<tr>
<td>IEEE 1815 (DNP3)*</td>
<td>IEC 61850-7-420 and -90-7</td>
</tr>
<tr>
<td><em>OpenADR 2.0</em></td>
<td>Energy Interop/61968 (CIM)</td>
</tr>
<tr>
<td>IEC 61968-5</td>
<td>CIM DER</td>
</tr>
</tbody>
</table>

* 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
• 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
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)

Also defines how DER should react to:

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

How do we model this information?
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

- DOPM Mode Control
  - DRCC PF Setpoint
  - DRCC VAR Setpoint
  - DGSM Volt-VAR
  - DGSM Watt-VAR
  - DGSM High/Low V Ride-Through
  - FMAR Curve
  - FMAR Curve
  - FMAR Curve
# IEC 61850 Model Hierarchy Example

<table>
<thead>
<tr>
<th>IED</th>
<th>PV Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEAS</strong></td>
<td><strong>CTRL</strong></td>
</tr>
<tr>
<td>MMXU</td>
<td>DOPM</td>
</tr>
<tr>
<td>DOPM</td>
<td>DGSM</td>
</tr>
<tr>
<td>DGSM</td>
<td>FMAR</td>
</tr>
<tr>
<td>PhV.PhpsA</td>
<td>OpModVVar</td>
</tr>
<tr>
<td>OpModVVar</td>
<td>ModEna</td>
</tr>
<tr>
<td>ModEna</td>
<td>PairArray</td>
</tr>
<tr>
<td>CMV</td>
<td>SPC</td>
</tr>
<tr>
<td>SPC</td>
<td>SPC</td>
</tr>
<tr>
<td>SPC</td>
<td>CSG</td>
</tr>
<tr>
<td>cVal</td>
<td>ctlNum</td>
</tr>
<tr>
<td>q, t</td>
<td>stVal</td>
</tr>
<tr>
<td>ctlNum</td>
<td>stVal</td>
</tr>
<tr>
<td>stVal</td>
<td>numPts</td>
</tr>
<tr>
<td>q, t</td>
<td>crvPts</td>
</tr>
<tr>
<td>xUnit, yUnit</td>
<td></td>
</tr>
</tbody>
</table>
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 increasing VARs (%/minute)
### DER Volt-VAR Example

**Voltage** (p.u. of nominal)

<table>
<thead>
<tr>
<th>Point</th>
<th>X Value</th>
<th>Y Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>50.0</td>
</tr>
<tr>
<td>1</td>
<td>0.97</td>
<td>50.0</td>
</tr>
<tr>
<td>2</td>
<td>0.99</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>1.01</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>1.03</td>
<td>-50.0</td>
</tr>
<tr>
<td>5</td>
<td>2.00</td>
<td>-50.0</td>
</tr>
</tbody>
</table>

**FMAR.PairArray.crvPts**

- **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

<table>
<thead>
<tr>
<th>Data structure</th>
<th>Types</th>
<th>Example (phase A voltage)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IEEE 2030.5</strong></td>
<td>XML tags</td>
<td>&lt;value&gt; (value)</td>
</tr>
<tr>
<td></td>
<td>URI paths</td>
<td>&lt;uom&gt; = 29 (unit of measure = voltage)</td>
</tr>
<tr>
<td></td>
<td>Programs</td>
<td>&lt;phase&gt; = 128 (phase = A)</td>
</tr>
<tr>
<td></td>
<td>Function Sets</td>
<td>&lt;start&gt; (start time for measurement)</td>
</tr>
<tr>
<td></td>
<td>Objects</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Register Offset</th>
<th>Value</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21365</td>
<td>SunSpec ID</td>
</tr>
<tr>
<td>1</td>
<td>28243</td>
<td>SunSpec ID</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Model ID</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Length</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>Device Address</td>
</tr>
<tr>
<td>65</td>
<td></td>
<td>Pad</td>
</tr>
<tr>
<td>0</td>
<td>126</td>
<td>Model ID</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>2</td>
<td>1-N</td>
<td>Active Curve</td>
</tr>
<tr>
<td>3</td>
<td>0/1</td>
<td>Mode Enable</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Length - 1</td>
<td>0/1</td>
<td>Curve Read Only</td>
</tr>
<tr>
<td>0</td>
<td>xFFFF</td>
<td>End of model</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Length</td>
</tr>
</tbody>
</table>
Modbus – Discovery of Device Model

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

### Inverter Model

<table>
<thead>
<tr>
<th>Register Offset</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SunSpec ID</td>
</tr>
<tr>
<td>1</td>
<td>SunSpec ID</td>
</tr>
<tr>
<td>0</td>
<td>Model ID (1)</td>
</tr>
<tr>
<td>1</td>
<td>Length = 66</td>
</tr>
<tr>
<td>65</td>
<td>Last Registers</td>
</tr>
<tr>
<td>0</td>
<td>Model ID (126)</td>
</tr>
<tr>
<td>1</td>
<td>Length = 152</td>
</tr>
<tr>
<td>151</td>
<td>Curve Read Only</td>
</tr>
<tr>
<td>0</td>
<td>End of model</td>
</tr>
<tr>
<td>1</td>
<td>Length</td>
</tr>
</tbody>
</table>

- Start - read base register 40,001
- Read base + 2
- Read base + 2 + 66
- Read base + 2 + 66 + 152
- Stop – end of model
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

<table>
<thead>
<tr>
<th>Object group</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary Inputs</td>
<td>Status, alarms</td>
</tr>
<tr>
<td>Binary Outputs</td>
<td>Set modes</td>
</tr>
<tr>
<td>Counters</td>
<td>Energy Flow</td>
</tr>
<tr>
<td>Analog Inputs</td>
<td>Measurements, status, protection events</td>
</tr>
<tr>
<td>Analog Outputs</td>
<td>Curves, modes, set points, events</td>
</tr>
</tbody>
</table>
### Example - Control DER Operating Modes

Example: How to map IEC 61850 DOPM

<table>
<thead>
<tr>
<th>Obj. Group (index)</th>
<th>Data Contained</th>
<th>IEC 61850 Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>BO (2)</td>
<td>Set constant fixed PF mode</td>
<td>DOPM.OpModConPF</td>
</tr>
<tr>
<td>BO (1)</td>
<td>Set constant real power mode</td>
<td>DOPM.OpModConW</td>
</tr>
<tr>
<td>BO (10)</td>
<td>Set constant VAR mode</td>
<td>DOPM.OpModConVAR</td>
</tr>
<tr>
<td>BI (0)</td>
<td>Status constant fixed PF mode</td>
<td>DOPM.OpModConPF</td>
</tr>
<tr>
<td>BI (54)</td>
<td>Status constant VAR mode</td>
<td>DOPM.OpModConVAR</td>
</tr>
</tbody>
</table>
Example - Set Mode for a Curve (Autonomous Functions)

Example: How to map IEC 61850 DGSM

<table>
<thead>
<tr>
<th>Obj. Group (index)</th>
<th>Data Contained</th>
<th>IEC 61850 Object [LN Inst. #]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BO (11)</td>
<td>Enable VoltVAR Curve 1</td>
<td>DGSM.ModEna [1]</td>
</tr>
<tr>
<td>BO (12)</td>
<td>Enable VoltVAR Curve 2</td>
<td>DGSM.ModEna [2]</td>
</tr>
<tr>
<td>AO (62)</td>
<td>VoltVAR Curve 1 ID</td>
<td>DGSM.InCurve [1]</td>
</tr>
<tr>
<td>AO (85)</td>
<td>VoltVAR Curve 1 Time Window</td>
<td>DGSM.WinTms [1]</td>
</tr>
<tr>
<td>AO (87)</td>
<td>VoltVAR Curve 2 ID</td>
<td>DGSM.InCurve [2]</td>
</tr>
<tr>
<td>AO (110)</td>
<td>VoltVAR Curve 2 Time Window</td>
<td>DGSM.WinTms [2]</td>
</tr>
</tbody>
</table>
## Example - Defining a Volt/VAR Curve

### Example: How to map IEC 61850 FMAR

<table>
<thead>
<tr>
<th>Analog Output</th>
<th>Data Contained</th>
<th>IEC 61850 Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>Volt/VAR Curve ID</td>
<td>DGSM.InCurve</td>
</tr>
<tr>
<td>63</td>
<td>Number of points</td>
<td>FMAR.PairArray.NumPts</td>
</tr>
<tr>
<td>65</td>
<td>Point 1 Volts (% nom)</td>
<td>FMAR.PairArray.CrvPts[0].xVal</td>
</tr>
<tr>
<td>66</td>
<td>Point 1 VARS (% nom)</td>
<td>FMAR.PairArray.CrvPts[0].yVal</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>83</td>
<td>Point 9 Volts (% nom)</td>
<td>FMAR.PairArray.CrvPts[9].xVal</td>
</tr>
<tr>
<td>84</td>
<td>Point 9 VARS (% nom)</td>
<td>FMAR.PairArray.CrvPts[9].yVal</td>
</tr>
</tbody>
</table>
**Example - Define a Schedule**

**Example: How to map IEC 61850 FSCH**

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

Utility ADMS/DERMS

Direct Utility-DER Communications

Utility-GFEMS Communications

Generating Facility EMS (GFEMS)

DER Aggregator

Aggregator-Mediated Communications

Smart Inverter Control Unit (SMCU)

Communications

Direct Utility-DER Communications

Communications

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Where do DER Protocols Work Best?

Utility scale PV/Storage
- Direct Control

DER Aggregator
- IEEE 2030.5, SunSpec, MESA, DNP3, OpenFMB or Proprietary

DR Aggregator
- OpenADR, IEEE 2030.5, DNP3, OpenFMB or Proprietary

Utility DERMS
- CIS, DMS, GIS, etc

Utility DRMS
- IS0/RTO DRMS

ISO/RTO Protocol
- OpenADR

Substation
- DMS
- DNP3, IEC 61850

Building EMS
- Proprietary or BACnet, OpenADR, SunSpec, MESA, DNP3, OpenFMB or Proprietary

Smart Inverter
- Managed DER

DR Device
- EVSE

Storage Only
- Managed Charging

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