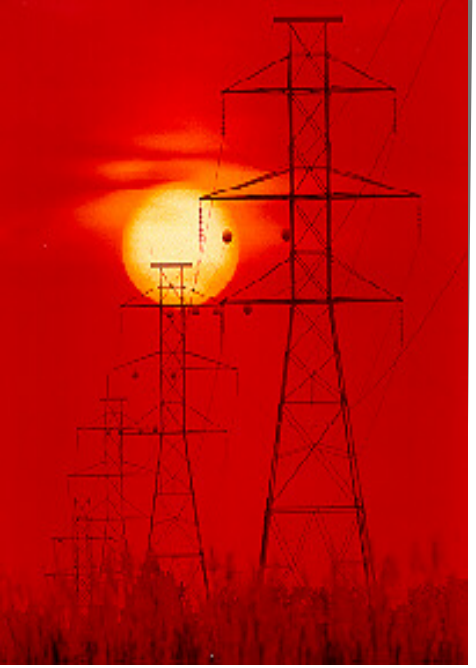


PV/Storage Inverter Functions

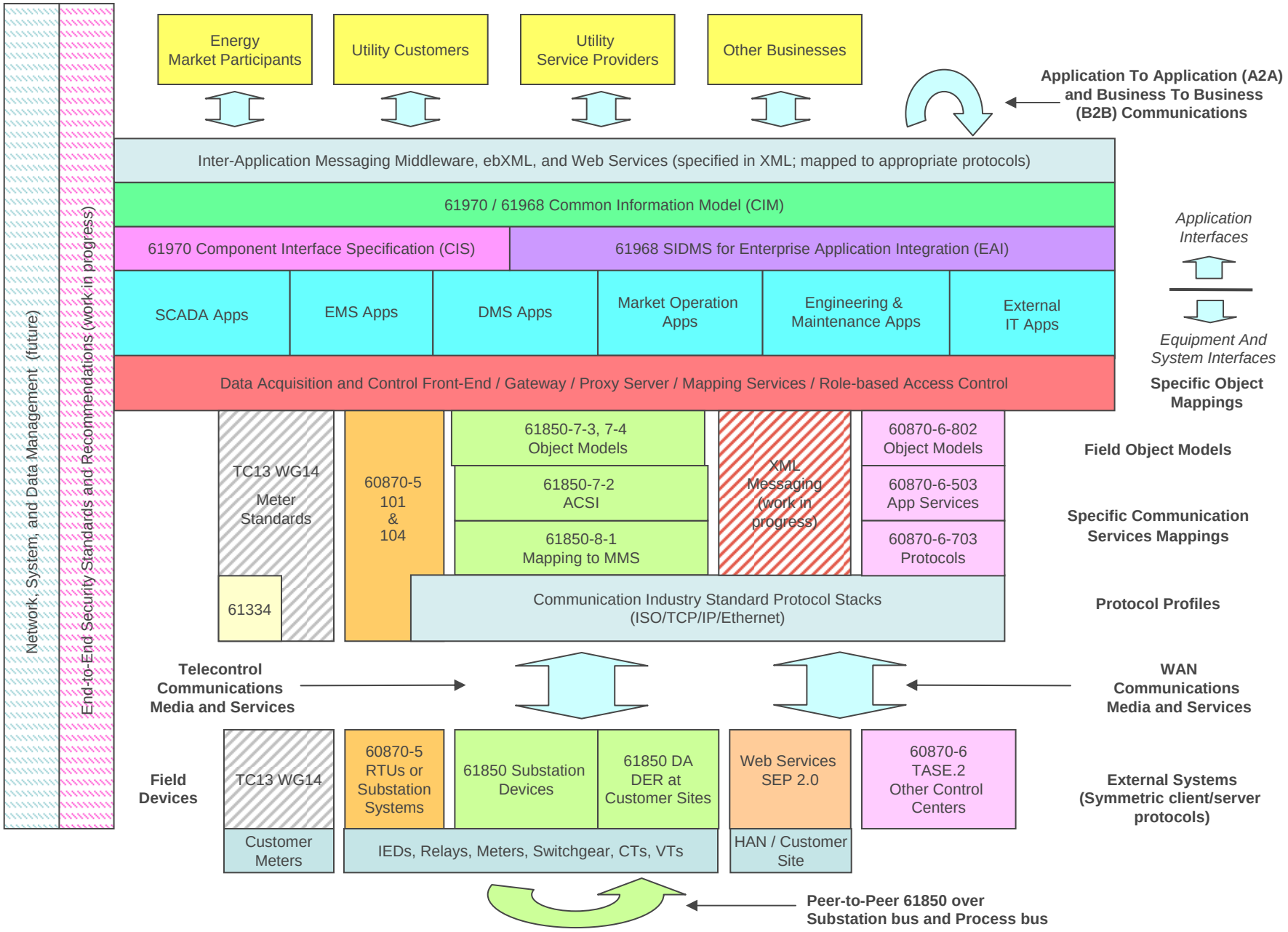
EPRI Project and NIST Priority Action Plan: PAP 7

Frances Cleveland

Xanthus Consulting International

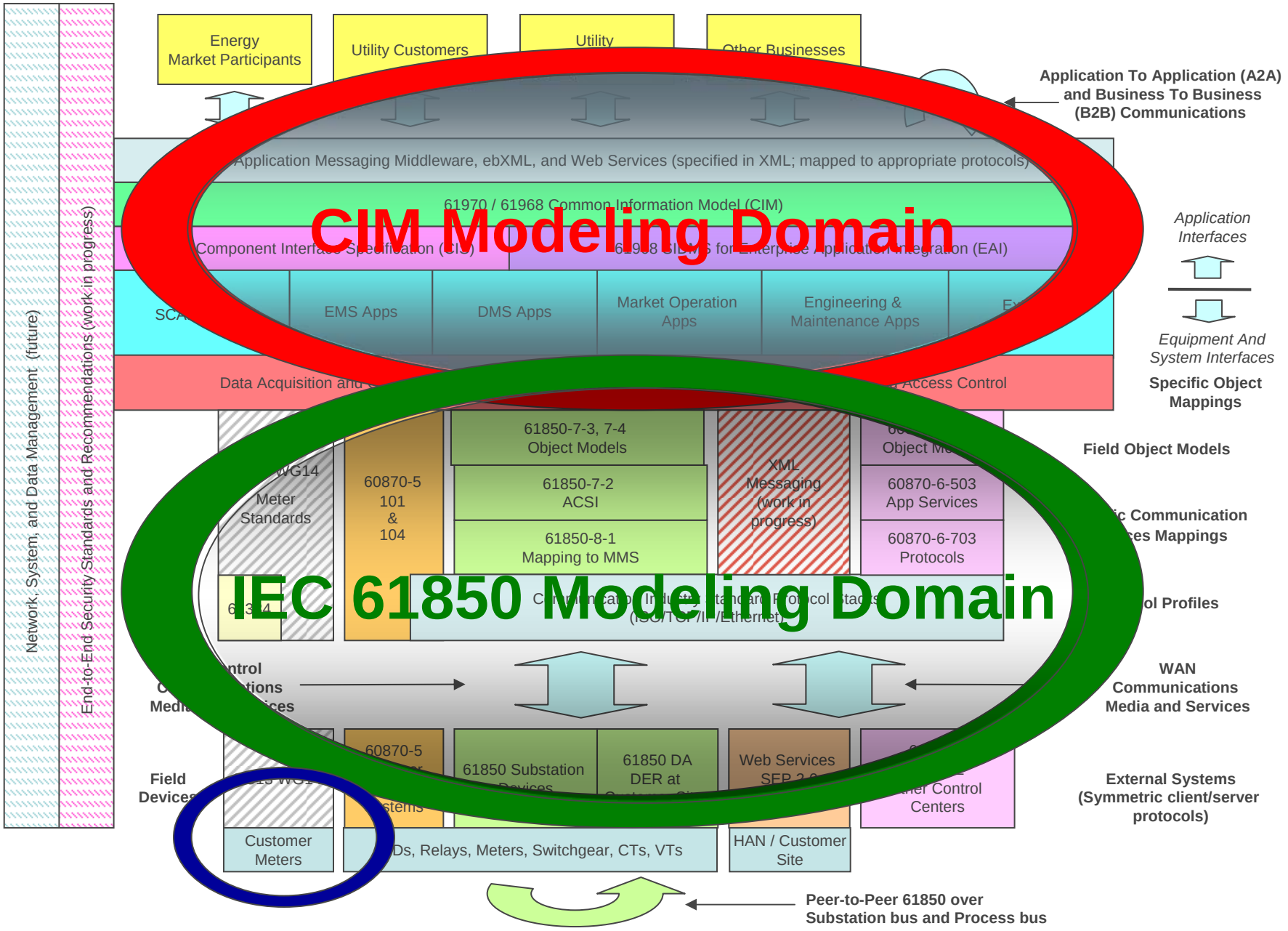
Xanthus
Consulting International

Current TC57 Reference Architecture – Scope and Layers



Notes: 1) Solid colors correlate different parts of protocols within the architecture.
2) Non-solid patterns represent areas that are future work, or work in progress, or related work provided by another IEC TC.

Current TC57 Reference Architecture – Scope and Layers

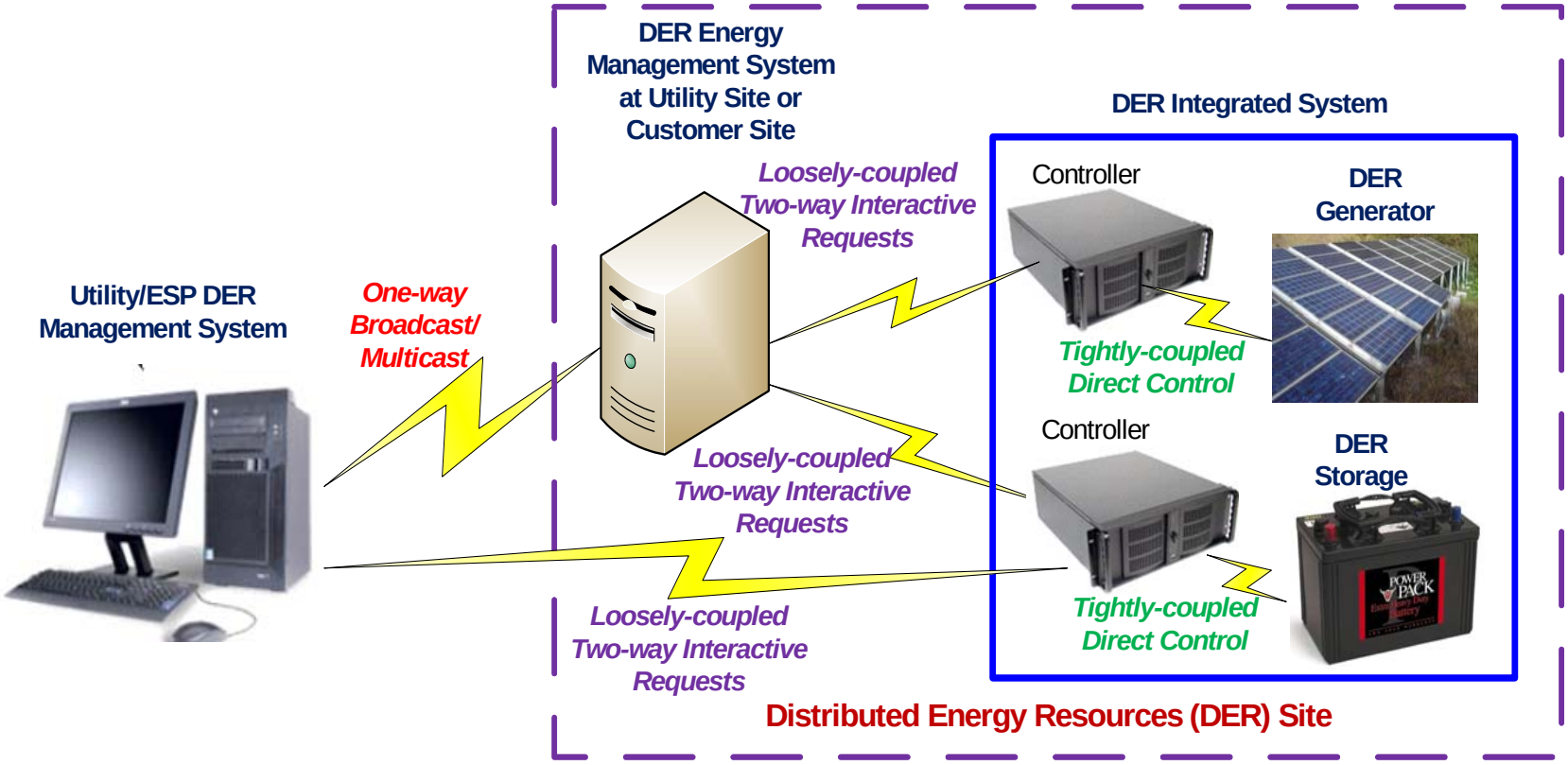


Notes: 1) Solid colors correlate different parts of protocols within the architecture.
2) Non-solid patterns represent areas that are future work, or work in progress, or related work provided by another IEC TC.

DER (Generation and Storage) Functions and Interactions

- DERs will provide:
  - Energy (real power) from generators and from storage units
  - Reactive power support (volt/var support) to both distribution and transmission efficiency and stability
  - Combined generation and storage can provide rapid response to mitigate intermittent renewable resources like wind and solar
  - Low voltage ride-through, emergency reserves, harmonic-damping
  - Rapid response to frequency deviations
- DER will be managed:
  - By customers for their own exclusive use
  - Through direct control by utilities or aggregators
  - Through market-driven bids, with direct control by utilities
  - Through market-driven, tariff-based demand response

Different DER Interactions: Direct Control, Interactive Requests, Broadcast/Multicast



DER Management: Interactions between Components

DER Key Use Cases Must Cope with Many Different Configurations

- Direct, tightly-coupled control
  - 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
  - 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
  - Between utility and Customer EMS
  - Between aggregator and ES-DER systems

PV/Storage Inverter-based System Phase 1 Functions and Interactions

Phase 1 Functions

- Connect/Disconnect from grid
- Limit maximum generation
- Set power factor
- Var settings, based on voltage
- Var settings, based on watts
- Storage charge / discharge rate (fast PEV chargers??)
- “Pricing” signal
- Event / history logging
- State / status reporting
- Time synchronization

Interaction

- Direct command
- Immediate request
- Change settings
- Schedule of settings based on time
- Schedule of settings based on temperature

Phase 2 Functions

- Low voltage ride-through!!
- Counteracting frequency deviation
- Other

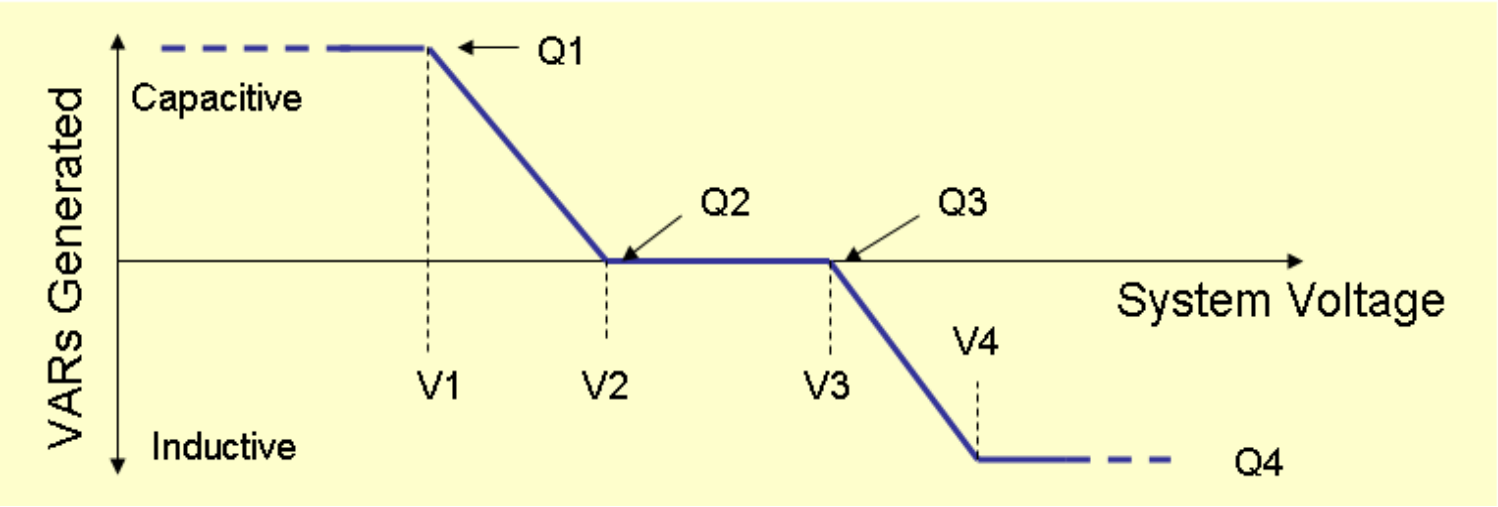
One PV/Storage Inverter Mode

Mode PV1 – Normal Energy Conservation Mode

Example Settings

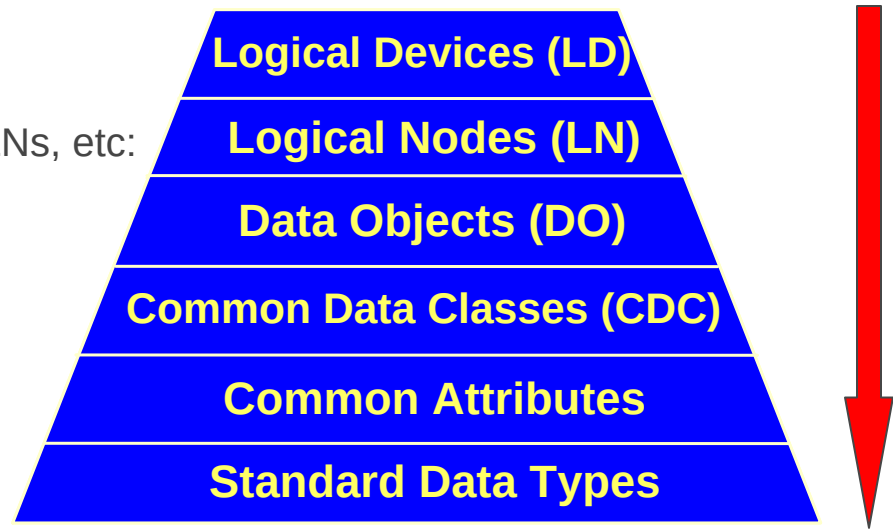
Voltage Array		VAR Array (%)	
V1	115	Q1	100
V2	118	Q2	0
V3	122	Q3	0
V4	126	Q4	-100

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

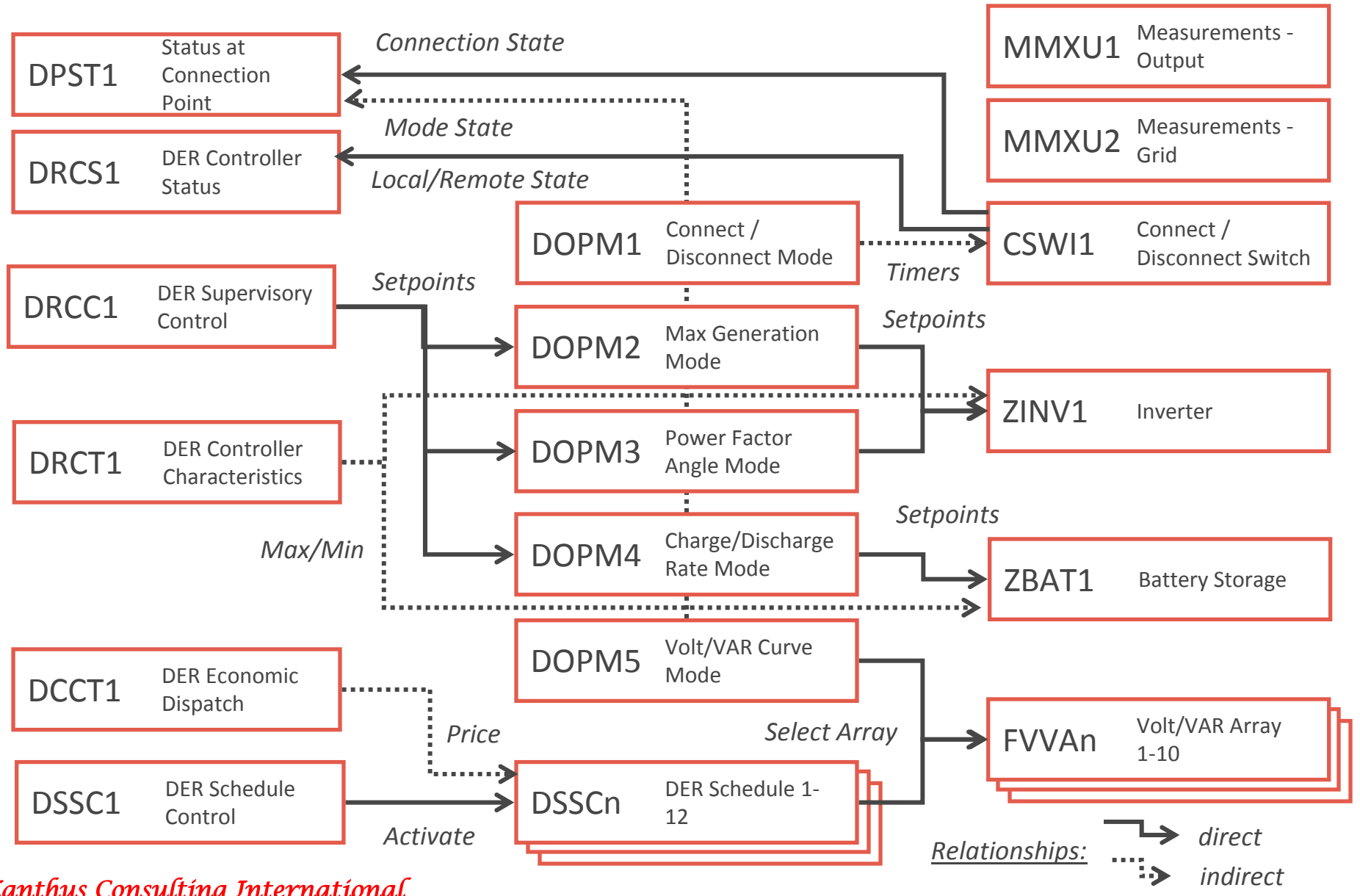


IEC 61850-7-420 for DER

- IEC 61850 – Interface Standard of Object Models for Utility Industry
  - Very modular
  - Establishes “well-known” standardized names, data formats, and services
  - Initially focused on substation automation, but now being expanded
- IEC 61850-7-420 for DER
  - Addresses only the “Nouns”
  - IEC 61850 object modeling constructs of LNs, etc:
- Covers:
  - General DER management
  - Photovoltaic systems
  - Fuel cells
  - Diesel generation
  - Combined heat and power
  - Wind power is handled separately (IEC 61400-25)
- Currently status is Final Draft International Standard (FDIS)
  - Due to become International Standard (IS) by mid-2008



Possible Inverter Logical Device

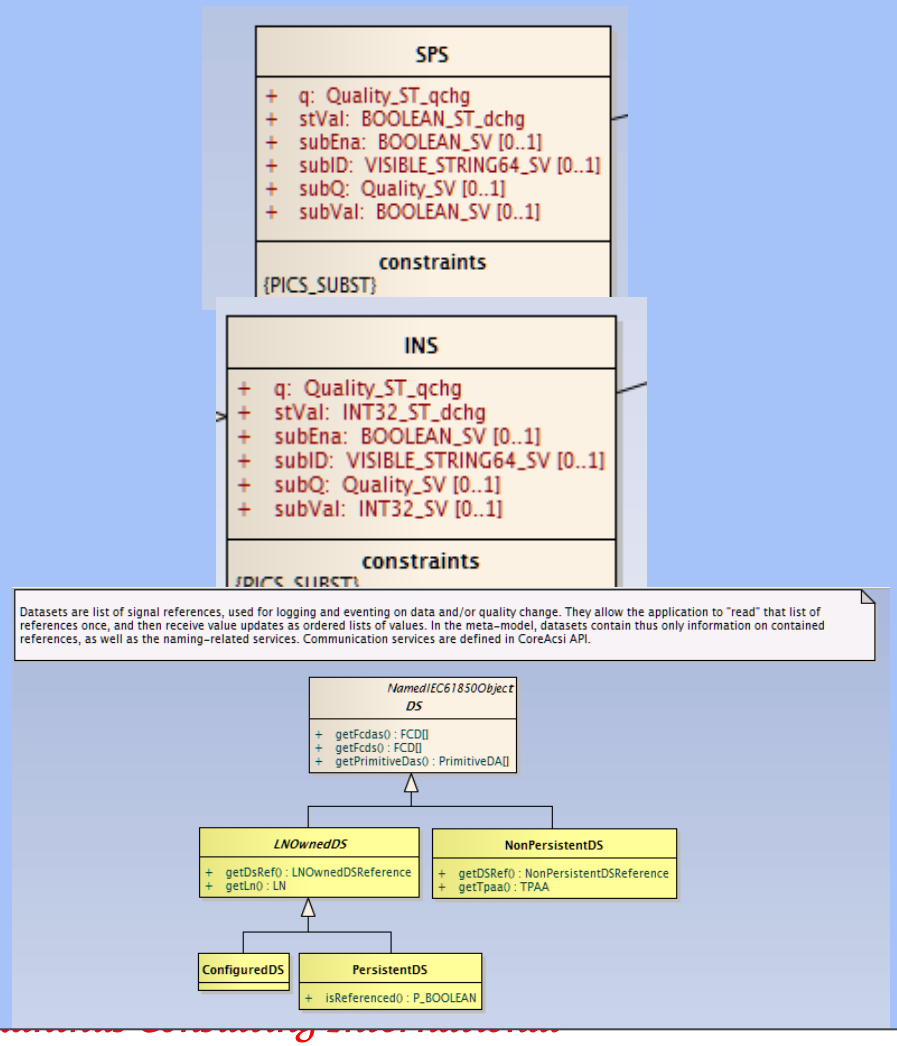


Mapping to DNP3

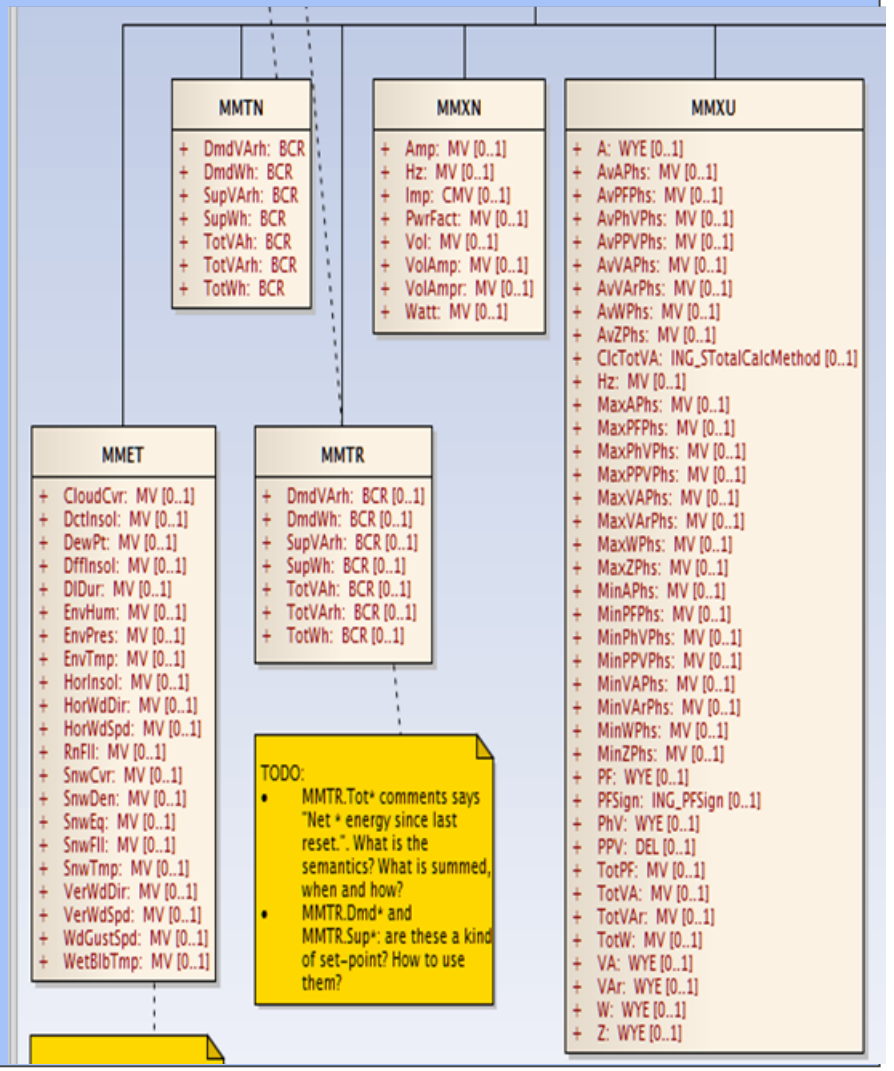
3	LN	Inst	Data Object	CDC	IEC 61850 Description	T	M/O	New?	PV?	Fn	DNP3?	PV Description
4	CSWI	1		LN					Y	PC1	Y	Connect/Disconnect Switch
7	CSWI	1	Pos	DPC	Switch, general		M		Y	PC1	Y	Connect status - status of the device's connect/
13	DOPM	1		LN					Y	PC1	Y	Operating Mode - Connect/Disconnect
28	DOPM	1	WinTms	ING	Time window within which to randomly		O	Y	Y	PC1	Y	Time window for Connect/Disconnect
29	DOPM	1	RevtTms	ING	Timeout period - revert to defaults		O	Y	Y	PC1	Y	Timeout period for Connect/Disconnect
31	DOPM	2		LN					Y	PC2	Y	Operating mode - Maximum Generation
43	DOPM	2	OpModWLim	SPC	Mode of operation - limited Watts, as p		O	Y	Y	PC2	Y	Mode of operation - limited Watts
46	DOPM	2	WinTms	ING	Time window within which to randomly		O	Y	Y	PC2	Y	Time window for limited Watts mode
47	DOPM	2	RevtTms	ING	Timeout period - revert to defaults		O	Y	Y	PC2	Y	Timeout period for limited Watts mode
48	DOPM	2	RmpTms	ING	Ramp time		O	Y	Y	PC2	Y	Ramp time for limited Watts mode
49	DOPM	3		LN					Y	PC3	Y	Operating mode - Power Factor Angle
55	DOPM	3	OpModPFAng	SPC	Mode of operation – power factor angle		O	Y	Y	PC3	Y	Mode of operation - maintaining fixed power fa
64	DOPM	3	WinTms	ING	Time window within which to randomly		O	Y	Y	PC3	Y	Time window for fixed power factor angle mode
65	DOPM	3	RevtTms	ING	Timeout period - revert to defaults		O	Y	Y	PC3	Y	Timeout period for fixed power factor angle mo
66	DOPM	3	RmpTms	ING	Ramp time		O	Y	Y	PC3	Y	Ramp time for fixed power factor angle mode
67	DOPM	4a		LN					Y	PC4a	Y	Operating Mode - Charge or Discharge Rate
80	DOPM	4a	OpModWRte	SPC	Mode of operation - charge or discharge		O	Y	Y	PC4a	Y	Mode of operation - charge or discharge rate
82	DOPM	4a	WinTms	ING	Time window within which to randomly		O	Y	Y	PC4a	Y	Time window for charge or discharge rate mode
83	DOPM	4a	RevtTms	ING	Timeout period - revert to defaults		O	Y	Y	PC4a	Y	Timeout period for charge or discharge rate mo
84	DOPM	4a	RmpTms	ING	Ramp time		O	Y	Y	PC4a	Y	Ramp time for charge or discharge rate mode

UML Diagrams of IEC 61850 – CDCs, Data Sets, and Logical Nodes – Being Used for Mapping to SEP 2.0

Common Data Classes



Logical Nodes



IEC 61850-7-420 Abstract Information Models

(*Italic indicates new DO)*

DOPM

DOPM class (existing in IEC 61850-7-420)				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
Settings				
WinTms	ING	Time window (in seconds) within which to randomly execute a command. If the time window is zero, the command will be executed immediately		O
RevtTms	ING	Timeout period (in seconds), after which the device will revert to its default status, such as closing the switch to reconnect to the grid		O
RmpTms	ING	Ramp time, in seconds, for moving from current operational mode settings to new operational mode settings		O
Controls				
OpModWLim	SPC	Mode of operation – limited watts, as percentage of nominal watts – in SPC: • ctlVal = off (FALSE) | on (TRUE)		O
OpModPFAng	SPC	Mode of operation – maintaining fixed power factor – in SPC: • ctlVal = off (FALSE) | on (TRUE)		O

DRCC

DRCC class (existing in IEC 61850-7-420)				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
Settings				
MaxLimWPct	ING	Percent of nominal watts as maximum allowed watts output – in ING: • setVal = percentage value between minVal and maxVal • minVal = 0% (or larger number) • maxVal = 100%		O

New LN: FVVA – Scheduling with Pairs of Volt/Var Settings

FVVA class (new, to be added to IEC 61850-7-420)				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
Settings				
VolVArId	ING	Identity of this paired volt/var array		M
VolVArSet	CSG	Paired array of voltage values and var percent of Qmax: For crvPts: xVal = voltage values yVal = var percent of Qmax		M
WinTms	ING	Time window (in seconds) within which to randomly execute the command using this array. If the time window is zero, the command will be executed immediately		O
RmpTms	ING	Ramp time, in seconds, for moving to the var settings in the volt/var array		O

DSCH Schedule by Temperature Range

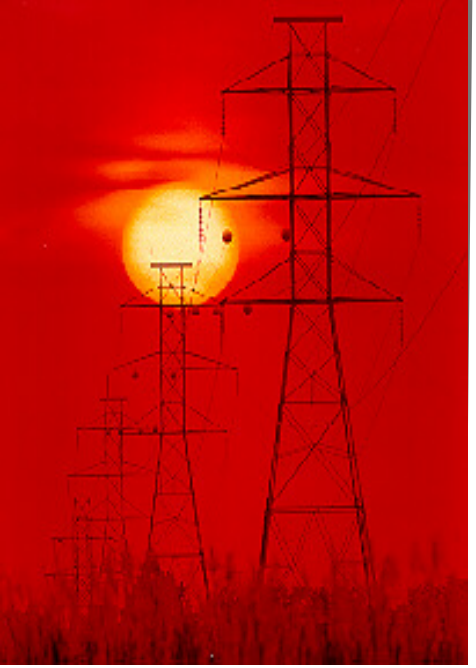
<table>
<tr><th colspan="5">DSCH class</th></tr>
<tr><th>Data Object Name</th><th>Common Data Class</th><th>Explanation</th><th>T</th><th>M/O/C</th></tr>
<tr><td colspan="5">Settings</td></tr>
<tr><td>SchdId</td><td>ING</td><td>Non-zero identity of the schedule</td><td></td><td>M</td></tr>
<tr><td>SchdTmp</td><td>CSG</td><td>Array of energy targets for each temperature range:
For crvPts:
xVal = energy target values (SchdVal)
yVal = temperature range (yVal(n) > yVal(n-1) for yVal(0..n)</td><td></td><td>M</td></tr>
<tr><td>SchdVal</td><td>ING</td><td>Meaning of the val parameter in the SCA or SCR:
<table>
<tr><th>Value</th><th>Explanation</th></tr>
<tr><td>0</td><td>Not applicable / Unknown</td></tr>
<tr><td>1</td><td>Active power</td></tr>
<tr><td>2</td><td>Reactive power</td></tr>
<tr><td>3</td><td>Power factor</td></tr>
<tr><td>4</td><td>Voltage</td></tr>
<tr><td>5</td><td>Price for active power</td></tr>
<tr><td>6</td><td>Price for reactive power</td></tr>
<tr><td>7</td><td>Heat</td></tr>
<tr><td>8</td><td>Volt/Var array identifier</td></tr>
<tr><td>99</td><td>Other</td></tr>
</table></td><td></td><td>O</td></tr>
</table>

SCR – Relative time schedule settings

SCR Class					
Data Object Name	**Attribute type**	**FC**	**TrgOp**	**Value/value range**	**M/O/C**
DataName	Inherited from data class (see IEC 61850-7-2)				
DataAttribute					
setting					
numPts	INT16U	SP		Length of array >= 1	AC_NSG_M
val	ARRAY 1..numPts OF FLOAT32	SP	dchg	1 to numPts values	AC_NSG_M
rmpTyp	ARRAY 1..numPts OF ENUMERATED	SP	dchg	1 to numPts values: 1=Fixed, 2=Ramp, 3=Average	AC_NSG_C
tmsOffset	ARRAY 1..numPts OF UINT24	SP	dchg	1 to numPts of time offsets in seconds	AC_NSG_M
configuration, description and extension					
cur	VISIBLE STRING3	CF		Currency as 3-character string as per ISO 4217	O
occPer	Enumerated	CF		Repeat period (Hour, Day, Week, Month, Year)	O
valUnits	Unit	CF		Units of val	O
valEq	ENUMERATED	CF		Equation for val: 1 = SI units, 2 = Currency as per ISO 4217 per SI unit, 3 = SI unit per currency	O
valD	VISIBLE STRING255	DC		Description of val	O
valDU	UNICODE STRING255	DC		Description of val in Unicode	O
d	VISIBLE STRING255	DC		Description of instance of data	O

Activation of Schedules

DSCC class				
Status information				
ActWSchdSt	INS	Indication of which energy schedule is active – schedule 0 indicates no schedule		M
ActAncSchdSt	INS	Indication of which ancillary services schedule is active – schedule 0 indicates no schedule		M
Controls				
ActWSchd	ENC	Activate specific energy schedule, using TimeActivatedOperate (see IEC 61850-7-2) to establish start time for schedules using relative time and if start time is in the future. ctrVal: 0 = deactivate, 1 = activate		M
ActAncSchd	SPC	Activate specific ancillary services schedule, using TimeActivatedOperate to establish start time for schedules using relative time and if start time is in the future. ctrVal: 0 = deactivate, 1 = activate		M
ActTmpSchd	ENC	Activate temperature-based schedule: ctrVal: 0 = deactivate, 1 = activate, time-activated		O
ActPriceSchd	ENC	Activate pricing signal-based schedule: ctrVal: 0 = deactivate, 1 = activate		O



Discussions??? !!!