Outline

• Brief Review of Several Protocols
  • Modbus
  • DNP3
  • DLMS/COSEM
  • ANSI C.12
  • IEC 61850
  • ICCP-TASE.2
  • OpenADR

• Impact on Smart Grid Applications
  » Demand Response
  » Distributed Renewable Integration
  » Utility Analytics
  » Wide Area Protection
Modbus

• The simplest protocol in use in utilities:
  » Master/Slave network access
  » Most Basic protocol:
    • Station Address
    • Function Code (read and write)
    • Data + Length
    • Checksum
  » Multiple Link Types
    • RS-232, RS-485 and TCP/IP-Ethernet
  » Simple data types
    • Integer, floating point, boolean, integer of booleans
  » No reporting
  » No time stamps
  » No quality
  » No authentication
  » User group supports specification
DNP3 and IEC 60870-5

- Widely used protocol in electric energy industry
  - Master/Slave network access
  - Multiple Link Types
    - RS-232, RS-485 and TCP/IP-Ethernet
  - 3 bytes to describe data:
    - Object #: binary input static, integer, control output, float, etc.
    - Variation #: With status, without status, time stamped, etc.
    - Index #: Refers to a specific instance of an object.
  - SBO and direct control operations
  - Polling and Report by exception, Sequence of Events and more.
  - Formalized method of expressing mapping to IEC 61850 models
  - Authentication options available
  - DNP3 Users Group supports standard and interoperability test set.

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ANSI C.12 Metering Protocols

- Specific purpose protocols for AMI
  - Read and Write of ANSI C.12.19 defined tables
    - data types related to common AMI functions like energy count, demand, min/max, etc. (floats, integers and characters)
  - Standardized date/time representations
  - Definitions for the configuration of these tables
  - Standardize table formats
  - Manufacturer tables
- Unsolicited Device Events
  - C.12.18, C12.21, C.12.22 provide mappings of these tables to a variety of link types:
    - Modems, IP Based networks, (TCP/UDP), etc.
  - Authentication and encryption options
  - Registrars for registering devices unique IDs.
  - Individual test labs providing testing services.

<table>
<thead>
<tr>
<th>Mfg Table Property*</th>
<th>Required</th>
<th>Global Default Table Property Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>number</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>label</td>
<td>No</td>
<td>Table name</td>
</tr>
<tr>
<td>type</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>role</td>
<td>No</td>
<td>&quot;UNDEFINED&quot;</td>
</tr>
<tr>
<td>associate</td>
<td>No</td>
<td>Scope of the TDL or decade where defined</td>
</tr>
<tr>
<td>atomic</td>
<td>No</td>
<td>&quot;false&quot;</td>
</tr>
<tr>
<td>accessibility</td>
<td>No</td>
<td>&quot;READWRITE&quot;</td>
</tr>
<tr>
<td>deprecated</td>
<td>No</td>
<td>&quot;false&quot;</td>
</tr>
<tr>
<td>metrological</td>
<td>No</td>
<td>&quot;false&quot;</td>
</tr>
<tr>
<td>volatile</td>
<td>No</td>
<td>&quot;AUTO AS PER ROLE&quot;</td>
</tr>
<tr>
<td>Class</td>
<td>No</td>
<td>&quot;STD&quot;</td>
</tr>
</tbody>
</table>

TYPE TABLE_IDA_BFLD = BIT FIELD OF UINT16
  TBL_PROC_NBR : UINT(0..10);
  MFG_FLAG : BOOL(11);
  PENDING_FLAG : BOOL(12);
  EUDT_FLAG : BOOL(13);
  FLAG2 : BOOL(14);
  FLAG3 : BOOL(15);
END;
**DLMS/COSEM**

- AMI metering protocol in widespread usage outside of NA.
  - Supports client/server and unsolicited communications using two-party-application association model similar to ICCP and IEC 61850 as well as connectionless data transfer.
  - Uses COSEM Interface classes and Object Identification Systems (OBIS) over Device Language Messaging System (DLMS) to implement metering functions. OBIS objects are collected into tables not unlike ANSI C12.
  - Support for serial (HDLC), ATM, Ethernet, LAN and WAN IP based networks.
  - Authentication and encryption supported.
  - DLMS Users Association defines OBIS, conformance and interoperability testing.
  - Protocols specified by IEC.

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IEC 61850: A New Approach to Power System Communications

» Standardized Device, Object and Service/Behavior Modeling

» Standardized Communications Protocols and Profiles for Specific Use Cases:
   › Station Level Monitoring and Control (substation SCADA) (TCP/IP)
   › Protection and Control – Multicast GOOSE over Ethernet
   › Sampled Values – Process Bus over Ethernet
   › Wide Area Measurement Protection and Control (WAMPAC): GOOSE and process bus using secure IP Multicast

» Read, Write, buffered reporting, controls, logging, files, etc.

» Formalized engineering process to configure power system functions and create interoperable configuration files for IEDs using Substation Configuration Language.

» UCAIug and IEC Users Group supports conformance/interoperability testing and user feedback

Specifications supported by the IEC.
ICCP-TASE.2

- Protocol originally developed for control center to control center data exchange.
  - Client/server communications over TCP/IP
  - Bilateral configuration to enable each side to control data exchanged
  - Tag name based point addressing with data sets and client configured reporting.
  - Polling, report by exception and controls.
  - Specifications supported by the IEC.
  - Smart Grid Applications?
    - Power plant dispatching
    - **Negative power plant dispatching** (a.k.a. Demand Response)
OpenADR

• Open Automatic Demand Response standardizes the message format used for Auto-DR to support price and reliability signals in a uniform and interoperable fashion.
  » http and XMPP transport profiles (IP based). XMPP provides discovery services
  » Application profile specifies mandatory and option parameters for web service messaging:
    • Registration
    • Enrollment
    • Market Contexts
    • Event
    • Quotes/Dynamic Prices
    • Reporting/Feedback
    • Availability
    • Override direct signalling.
  » OpenADR alliance supports the specifications and conformance/interoperability testing
OpenADR for Demand Response

• A good platform for implementation of local control systems based on real-time pricing signals
  » organizational support
  » testing program
  » Support by products

• Problematic for many utilities to implement real-time pricing policies to take advantage of distributed control systems responding via OpenADR.
  » Regulatory and political hurdles to be cleared.
Demand Response using OpenADR

Generation/Demand Management

Positive Dispatching

ICCP

Negative Dispatching

Demand Aggregator

OpenADR

Demand Response Approach

Generation Dispatch Approach
Impact on Renewables
Integration
Distributed Solar
Renewable Integration - Solar

• Sun Spec Alliance has developed a Modbus based communication protocol for grid connected inverters.

• At a 2010 industry event a Sun Spec representative told me:
  » IEC 61850 was too complex for grid connected inverters.
  » Modbus was simple and easy to implement.
  » Even DNP3 was too complex (Sun Spec is now working on a DNP3 Transport Mapping).

• Let’s look at how simple grid connected inverters are using Modbus
### Modbus mapping from non-Sun Spec product

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>CompoWay/F Type Code</th>
<th>Modbus Type Code</th>
<th>Variable Identifier</th>
<th>KPCCCL (CompoWay/F &amp; Modbus)</th>
<th>KP100G (CompoWay/F)</th>
<th>KP40G (CompoWay/F)</th>
<th>Model Name</th>
<th>Model Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>04</td>
<td>11a</td>
<td>Country setting</td>
<td>0x01: Italy</td>
<td>0x02: Italy</td>
<td>0x00: Italy</td>
<td>SI2-DC-OD-1</td>
<td>SI2-DC-OD-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x02: France</td>
<td>0x03: Spain</td>
<td>0x04: Korea</td>
<td>SI2-DC-OD-2</td>
<td>SI2-DC-OD-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x05: Germany</td>
<td>0x06: Italy</td>
<td>0x04: PP</td>
<td>SI2-DC-OD-3</td>
<td>SI2-DC-OD-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x07: Greece</td>
<td>0x08: Italy</td>
<td>0x05: PC</td>
<td>SI2-DC-OD-4</td>
<td>SI2-DC-OD-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x09: Czech Republic</td>
<td>0x0A: Italy</td>
<td>0x06:瑞士</td>
<td>SI2-DC-OD-5</td>
<td>SI2-DC-OD-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x0B: Turkey</td>
<td>0x0C: Spain</td>
<td>0x07: FF</td>
<td>SI2-DC-OD-6</td>
<td>SI2-DC-OD-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x0D: Portugal</td>
<td>0x0E: Spain</td>
<td>0x08: EF</td>
<td>SI2-DC-OD-7</td>
<td>SI2-DC-OD-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x0F: Switzerland</td>
<td>0x10: Italy</td>
<td>0x09: FF</td>
<td>SI2-DC-OD-8</td>
<td>SI2-DC-OD-8</td>
</tr>
</tbody>
</table>

| 0001    | 1a                  | 11a               | The number of DC input | 0x01: 1 input | 0x02: 1 input | 0x03: 3 inputs | 0x04: 4 inputs | 0x05: 6 inputs |
|         |                      |                  |                     | 0x06: 8 inputs | 0x07: 10 inputs | 0x08: 12 inputs | 0x09: 14 inputs | 0x0A: 16 inputs |
|         |                      |                  |                     | 0x0B: 18 inputs | 0x0C: 20 inputs | 0x0D: 22 inputs | 0x0E: 24 inputs | 0x0F: 26 inputs |

| C1      | 0000                | 5500              | Setting value of overvoltage (OV) | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex |
|         | 0001                | 5502              | Setting value of undervoltage (UV) | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex | 0x00:000000 to 0x00000D hex |

| 0002    | 5500                | 5502              | Setting value of overfrequency (OF) | 0x00:000034 to 0x00000D hex | 0x00:000034 to 0x00000D hex | 0x00:000034 to 0x00000D hex | 0x00:000034 to 0x00000D hex | 0x00:000034 to 0x00000D hex |

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## 4-Secure Dataset Read Response

<table>
<thead>
<tr>
<th>Start Offset</th>
<th>End Offset</th>
<th>Size</th>
<th>R/W</th>
<th>Name</th>
<th>Label</th>
<th>Type</th>
<th>Units</th>
<th>SF</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R</td>
<td>ID</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
<td>A well-known value 4. Uniquely identifies this as a SunSpec Secure Dataset Read Response Model</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1</td>
<td>R</td>
<td>L</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
<td>Variable # of 16 bit registers to follow : 60+N*1</td>
</tr>
</tbody>
</table>

### 4 Secure Dataset Read Response Fixed Block (60)

<table>
<thead>
<tr>
<th>Start Offset</th>
<th>End Offset</th>
<th>Size</th>
<th>R/W</th>
<th>Name</th>
<th>Label</th>
<th>Type</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
<td>R</td>
<td>RqSeq</td>
<td>Request Sequence</td>
<td>unit16</td>
<td></td>
<td>Sequence number from the request</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1</td>
<td>R</td>
<td>Sts</td>
<td>Status</td>
<td>unit16</td>
<td></td>
<td>Status of last read operation</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>1</td>
<td>R</td>
<td>X</td>
<td>X</td>
<td>unit16</td>
<td></td>
<td>Number of values from the request</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>1</td>
<td>R</td>
<td>Val1</td>
<td>Value1</td>
<td>unit16</td>
<td></td>
<td>Copy of value from register Off1.</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>1</td>
<td>R</td>
<td>Val2</td>
<td></td>
<td>unit16</td>
<td></td>
<td>Unused values shall return 0xFFFF</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>1</td>
<td>R</td>
<td>Val3</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>1</td>
<td>R</td>
<td>Val4</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>1</td>
<td>R</td>
<td>Val5</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>1</td>
<td>R</td>
<td>Val6</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>1</td>
<td>R</td>
<td>Val7</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>1</td>
<td>R</td>
<td>Val8</td>
<td></td>
<td>unit16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There are 75 tabs on this spreadsheet.
Renewable Integration - Solar

• In California:
  » There are 2,164 different models of inverters from 151 different manufacturers that are approved for grid connection of solar panels.

• Sun Spec Alliance:
  » 18 manufacturers with Sun Spec certified Modbus interfaces.

• According the LA times:
  » There are > 230,000 solar homes in California

• Will it be “simple” to integrate these homes with utility scale applications to build an intelligent grid leveraging solar resources using Modbus?

• Good news: they are mapping this DNP3.

• Bad news: they are only just NOW mapping this to DNP3.
Why Does This Happen?

- Assuming product implementation complexity results in application complexity
- Assuming that technology constraints today will be valid over the life of the product
- Assumption that user configuration is reasonable because it is understandable
- Cynically: User effort costs less than development
Where should the complexity be handled?

- **Power System Functions**
  - Measurements:
    - Phase A Voltage
    - Phase B Voltage
    - Phase C Voltage
  - Controls:
    - Local/Remote Status
    - Breaker Position
    - Blocked Open
  - Protection:
    - Activate Phase A
    - Activate Phase B
    - Activate Phase C

- **Modbus**
  - R400040
  - R400041
  - R400042
  - R400043
  - R400044
  - R400045
  - R400046
  - R400047
  - R400048
  - R400049
  - R40004A
  - R40004B

- **Applications**
  - 230,000 mappings developed by users

- **Devices**
  - 2,154 mappings developed by mfgers.
Impact on Utility Analytics

AMI Analytics
AMI Protocols

- Metering network media dictates solutions:
  - Very large number of end points
  - Large variety of media available
  - Variety of meter types, brands, styles

- Both ANSI C.12 and DLMS/COSEM exhibit similar characteristics

- Widespread use of “AMI Head-Ends” and/or MDMs that collect data via protocols and present meter data in an application oriented context to applications.

- Proprietary, MultiSpeak, and CIM IEC 61968-9 messaging and RDBMS are used.

- Not considering CIM, data models used by analytics tend to be user driven
Typical Approach for Analytic Data Modeling

• Each group looks at its own application needs and develops a data model that is optimized for its own use:
  » Only data needed for its application is considered.
  » New data model elements are added as needed based on needs of individual applications.

• The “Ad-Hoc” Approach
Impact of Ad Hoc Approach for Application Data Models

- Each Application has its own data model.
- Each application defines the same objects differently.
- Impact of cross-organizational integration and data sharing ignored.
What breaks it? Change

• Addressing change becomes too difficult when each application uses its own incompatible data modeling:
  » Business needs demand organizational changes and new levels of data sharing and integration.
  » New technology must be addressed (e.g. renewables, DER, “deregulation”, etc.

• Result: Application rewrites, reintegration, project delays, barriers to data sharing.

• The “Bigger” the data, the more the negative impact will be of not using a consistent common data model.
Why Does This Happen?

- Misunderstanding the Use Case
- Is this really the use case that should drive choices?
Here is a Real Use Case
How To Address the Real Use Case

• There is no need to develop a solution for every integration point. This is not possible.

• Ignoring everything other than the small handful of use cases that need to be addressed immediately will not result in a scalable system.

• The architecture needs to utilize a process by which the integration of each element is based on a common approach where shared data models are leveraged not redefined.

• Model-Driven Integration
Common Information Model (CIM)

- Encompasses all aspects of power systems
  - Planning
  - Operations
  - Transmission
  - Distribution
  - Markets

UML – Unified Modeling Language
Model-Driven Data Using CIM

- CIM is flexible to accommodate:
  - Extensions for non-standard business needs
  - Eliminate the complexity of unused models
- Profiles are created based on use cases to address specific needs
- Instances created to relate existing data to the CIM Profile schema
- Model can be used to configure analytics.
- Analytics use models to access data eliminating custom tag name dependency.
CIM Data Models Deliver Flexibility

- Multiple uses cases can be addressed with one profile.
- Multiple profiles can be supported for use cases that can’t share a profile.
- A disciplined modeling process with CIM provides models optimized for all applications.
CIM Helps Manage Change

- The model driven process captures change and creates incremental updates.

- The individual hierarchies can be updated and kept synchronized with each other.
CIM Is The Only Choice for the Model-Driven Utility

- Developing your own comprehensive utility data model to replace CIM will take many decades of effort.
  - How many experts can your utility hire to design this from scratch?
- CIM is specifically designed to be adapted to fit the needs of individual utility use cases:
  - Extensions
  - Profiles/subsets
  - Messages
  - Integration Patterns
- New applications can extend independently yet share the existing models where needs overlap without breaking existing applications and integration.
CIM vs. Protocols (IEC 61850)

IEC61970/68 CIM
- Power System Models
- Metering, trading, etc.

IEC61850
- Power System Models
- Device Models

Measurements

WG19 Harmonization
CIM vs. Protocols (DNP3)

IEC 61970/68 CIM
- Power System Models
- Metering, trading, etc.

DNP3
- Obj#, Var#, Index#
- IEC 61850 Device Models

Measurements

MAPPING
CIM vs. Protocols (ICCP-TASE.2)

IEC61970/68 CIM
- Power System Models
- Metering, trading, etc.

ICCP-TASE.2
- Bilateral Tables
- SCADA data & controls

Edition 3 of ICCP

Measurements
CIM vs. Protocols (OpenADR)

IEC61970/68 CIM
- Power System Models
- Metering, trading, etc.

Possibility of future support for native CIM messaging

OpenADR
- R/T Pricing
- Demand Response

Measurements

MAPPING

MAPPING
CIM vs. Protocols (ANSI C.12 – DLMS/COSEM)

IEC61970/68 CIM
- Power System Models
- Metering, trading, etc.

AMI Protocols
- Tables
- OBIS – Table Data

Measurements

Headend
Wide Area Protection
Centralized Remedial Action Systems
Why RAS is Needed

- Long lines separating load and generation need protection to prevent damage from generation tripping.

- Increasing reserve margins to protect lines reduces available energy.

- Maintaining system stability during anomalous conditions challenges operators to respond quickly to prevent cascade failure.

- More transmission capacity in the same corridor is subject to the same contingencies and results in increasing reserve margins.
Individual Remedial Action Schemes and Special Protection Systems (RAS/SPS)

- Protects lines from damage during anomalous conditions.
- Individual RAS are available using traditional approaches involving hardwired devices within local areas.
Multiple Individual RAS

- Deploying multiple individual RAS practical because little interaction between RAS.
- Difficult to maintain and update as number of RAS increases.
Integration of Multiple Individual RAS into a Distributed RAS

- Addressing system stability requires integration of multiple RAS over a wide area.
- Information sharing and interactions between individual RAS using traditional techniques increases complexity and cost beyond what is practical.
Centralized Remedial Action Systems (C-RAS)

- Centralized control reduces complexity of information sharing making implementation feasible.
- Centralization of control requires a network architecture to support very reliable high speed communications of events and controls.
C-RAS Architecture

Web Services Using CIM

IEC 61850 GOOSE
C-RAS Architecture

Web Services Using CIM

IEC 61850 GOOSE

50 Millisecond Round Trip Fault to Mitigation
Protocol Usage Enables Solution

- **IEC 61850 GOOSE:**
  - High-speed reliable multicast messaging delivers fault data to control centers quickly
  - Use of VLANs and Priority tagging enables implementation of complex interconnection VLAN networks.
  - Ability to use XML definition of data objects to convey context inherent in the messaging.

- Simply not possible with master/slave protocols like Modbus or even DNP3.
Summary

• Protocol characteristics can have a significant impact on application performance, capability, maintainability, and scalability.

• Simple protocols are not necessarily always the best choice because system complexity is not necessarily reduced by using very simple devices.
Thank You For Your Attention

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