Communication Protocols and Networks for Power Systems-
Current Status and Future Trends
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Introduction

Legacy Protocols
- Modbus
- DNP3

New Generation: IEC 61850
- Overview
- Data Structure using Logical Nodes
- Communication Services
- Advantages over Legacy Protocols

Communication outside Substations
- Upstream: ICCP
- Downstream: DNP3

Future Trends
- IEC 61850 beyond Substations
- IEC 61850 for Peer-to-Peer Communications

Concluding Remarks
Introduction
Communication Protocols and Standards

- Communication protocols and standards were introduced in 1970’s to industry
- Quickly adopted in power industry and replaced proprietary counterparts.

Main objectives:
- Open access
- Interoperability
- Flexibility
- Upgradability
- Future proof
- Effective data sharing among applications
Introduction

Current Status
Legacy Protocols
Modbus

- Developed in 1979 for process control systems
- Positioned at layer 7 of OSI model
- Used for client/server communication
- Messages are of the types:
  - Query/response
  - Broadcast/no response
  - Report by Exception (RBE) (in Modbus TCP)

<table>
<thead>
<tr>
<th>Protocol Data Unit (PDU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Data Unit (ADU)</td>
</tr>
<tr>
<td>1 Byte</td>
</tr>
<tr>
<td>Address Field</td>
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</tbody>
</table>
Legacy Protocols

Modbus
Legacy Protocols
DNP3

- Defines communications between client stations, RTU’s and IED’s.
- Developed based on IEC 60870-5, made public in 1993.
- Originally designed for SCADA, but today it has applications in many electrical, water, oil and gas industries.

- Communication media:
  - RS232 for short distance point-to-point communication
  - RS422 bidirectional extension to 232
  - RS485 for multi-point communications
  - Over Ethernet for larger geographic areas
Legacy Protocols
DNP3

User Application Data (if required)

ASDU  ASDU

APDU (Fragment)

APCI  APCI

TSDU

2048

TPDU

TH  TH  TH

1  249

LPDU (Frame)

LH  LH  LH

Data + CRCs  Data + CRCs  Data + CRCs

292 Bytes  250 + 2*16

8 Bit Data + 1 Start Bit + 1 Stop Bit
IEC 61850 is a standard specifically designed for implementing substation automation (SA) systems.

The main features of the standard are:

- **Data Modeling**- Object oriented platform-independent modeling of all the functions.
- **Fast Transfer of Events and Messages**- GOOSE and GSSE for the peer-to-peer communication mode.
- **Setting Groups**- Control blocks allow the user to switch from any active group of setting values to another.
- **Sampled Value**- Transfer of sampled values from modern switchgear and nonconventional CT/VTs.
- **Data Storage and Representation**- Configured data of the substation is stored in XML format using the Substation Configuration Language (SCL).
New Generation: IEC 61850 Substation Automation Topology
New Generation: IEC 61850
Data Structure based on Logical Nodes

Picture recreated from http://www.bitswiz.co.kr
New Generation: IEC 61850 Communication Modes

- Client/Server
- Peer-to-Peer Services
  - GOOSE: multicast transmission of high priority information like trip commands or interlocking information
  - Sampled Value (SV): quantities digitized at the source to be transmitted to the substation
New Generation: IEC 61850
Communication Services
New Generation: IEC 61850
Substation Configuration Language (SCL)

- XML based language used for representation and configuration of the substation automation system.
- Enhances communication capabilities between the IEDs
- Enables sharing of IED configuration among users
New Generation: IEC 61850
Advantages over Legacy Protocols

- Provides 100+ LNs with 2000+ data attributes
- More easily expandable
- Uses hierarchical names, instead of indexed addressing
- Supports quality, time stamp, cause of transmission (similar to DNP3)
- The data (LNs, attributes) are more self-descriptive
- More flexible at parameter setting control
- Means for transmitting substation events (GOOSE/GSSE)
- More flexible in selecting the data for reporting, enabling/disabling the communication control objects, reporting/logging behavior
- Complete description of device configuration available in XML
- Fully supports vendor independent engineering tools for development
Communications Outside Substations
Upstream: ICCP

- Inter-Control Center Communication Protocol (ICCP), also known as TASE.2 is used for communications between control centers.
- Client/server model
- Works with OSI or TCP/IP model
- Types of requests:
  - Single requests
  - Request for periodic transfer
  - Request for Return by Exception (RBE)
Communications Outside Substations
Upstream: ICCP
Communications Outside Substations
Downstream: DNP3

- Between the substation and the control center
- Implementation on TCP/IP allows for transferring the data over WAN
- Currently main protocol used for feeder automation applications
Future Trends
IEC 61850 Beyond Substations

**Feeder Automation**

- Extending the IEC 61850 standard to feeder automation applications
- This ensures the interoperability of all components participating in distribution automation, from the distribution substation to the point of interface with the end users.
- Can be in the form of using some of the logical nodes in the current standard, or applying the same messaging techniques such as GOOSE and SV.
- Can cover applications such as Var control, power quality enhancement, information exchange with metering devices (AMI) or control of devices such as network protectors, switches, circuit breakers, fault detectors/locators.
Future Trends
IEC 61850 Beyond Substations

Communication with Control Centers

- Extending the IEC 61850 standard to include the link to the control centers
- Might need defining new logical nodes or implementing additional logical connections.
- It is generally believed that this integration can be done in the following ways:
  - Map IEC 61850 data model content to a traditional SCADA protocol such as DNP3. May result in loss of some information or speed.
  - Provide a proxy server for IEC 61850 data in the substation, as a single point of access for the 61850 data model content.
Future Trends
IEC 61850 for Peer-to-Peer Communications

- Example: employ GOOSE messaging concept for applications beyond substations, for example for fast transfer of sensitive information at the transmission level between:
  - Protective relays (e.g. trip commands or outage detection)
  - PMUs (e.g. over/under-voltage indications or current flows close to stability/thermal limits)
Concluding Remarks

- Standard protocols were adopted by the industry to implement efficient control and automation systems.
- The need for more platform-independent and interoperable protocols led to the introduction of IEC 61850 standard for communication networks and systems in substations.
- IEC 61850 is a future proof and adaptable communication protocol, capable of providing interoperability in a multi-vendor environment and with a highly advanced object oriented modeling approach.
- In addition to the efforts to provide an advanced solution for substation automation systems, there is also a need for extending the “automation” benefits to beyond the substations.
- This paper presented an overview of IEC 61850 to be used in the next generation of substations.
- Possible future trends for extending the scope of the standard and using its capabilities for other applications within the distribution system were also discussed.