A Framework to Demonstrate a DNP3 Interface with a CIM-based Data Integration Platform

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Introduction

Background:

- Increasing speed of changes introduced by distributed energy resources (DERs) compels distribution system operators (DSOs) to deploy fast-sampled distribution-level synchrophasor devices and smart meters.
- Distributed Network Protocol (DNP3) are commonly used in distribution networks, where legacy devices exchange data within the grid service area. It involves a “master” and “outstation” communication.

Objective:

- Utilities need applications and software services that take advantage of all available data to implement advanced methods that operate and control IEDs and RTUs.

Contributions:

- Development and deployment of a DNP3-Master service based on the Common Information Model (CIM) that interfaces with a standard-based open-source platform called GridAPPS-D and the advanced distribution management system (ADMS) test bed at the National Renewable Energy Laboratory (NREL).
- DNP3 workflow between GridAPPS-D acting as the “Master” and the ADMS test bed at NREL simulating the “Outstation.” A Colorado distribution feeder with 425 DERs, including 300 photovoltaics (PVs) and 125 battery systems, is simulated using OpenDSS. Setup includes SEL RTAC and GridAPPS-D.

GridAPPS-D Overview

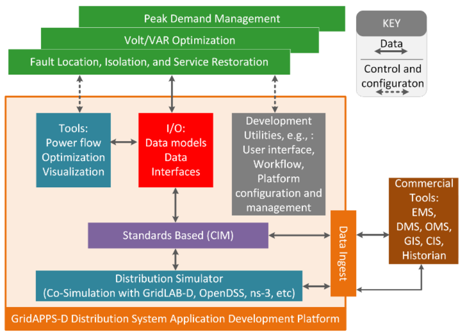


Fig. Conceptual GridAPPS-D Architecture diagram

GridAPPS-D uses Common Information Model (CIM) to standardize the representation of distribution feeder models important features:

- Helps manage various network models, related information, and data that change over time
- Co-simulation, which lets application developers simulate different behaviors in distribution systems
- "Data Ingest," - makes it easy to exchange data with existing systems like Energy Management Systems , (EMS), Distribution Management Systems (DMS), Outage Management Systems (OMS), Geographic Information Systems (GIS), and data storage systems.
- “Data Ingest” function acts as a service that can take in data from external devices or management systems.
- This implementation focuses on one of the use cases for the application service: how GridAPPS-D exchanges data with an external distribution system simulation within the ADMS test bed. This test bed is hosted separately from the main GridAPPS-D platform.

DNP3-Master Service

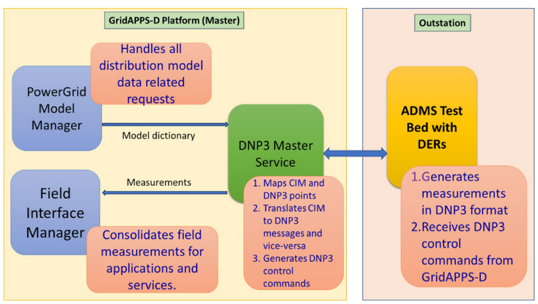


Fig. Architecture for integrating the DNP3-Master service.

PowerGridModel Manager

- ➢ Core component of the GridAPPS-D platform that is responsible for handling all distribution model data-related requests
- ➢ Receives a request from the DNP3-Master service to generate a CIM dictionary for the requested distribution model identification (ID)

Field Interface Manager

- ➢ The introduction of an FI enhances modularity, ensures compliance with the data model, and provides a solid foundation for future updates.
- ➢ Receives the field measurements from device protocol services such as the DNP3-Master service, consolidates them, and publishes them to field output topics for other applications.

DNP3-Master Service

- ➢ Subscribes to DNP3 messages originating from the test bed or field devices
- ➢ Every 60 seconds, the Master polls the NREL’s ADMS Testbed (Outstation)
- ➢ The service code (python based) is responsible for parsing the CIM and DNP3 data from outstation to master and vice-versa.
- ➢ Table I summarizes the data type, group, and variation of DNP3 points. These specifications adhere to the DNP3 standards, ensuring a consistent framework for communication.

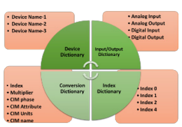


Fig. Schema for the model dictionary

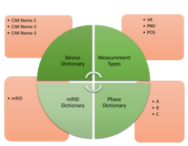


Fig. Schema for the conversion dictionary

Example Application And Results

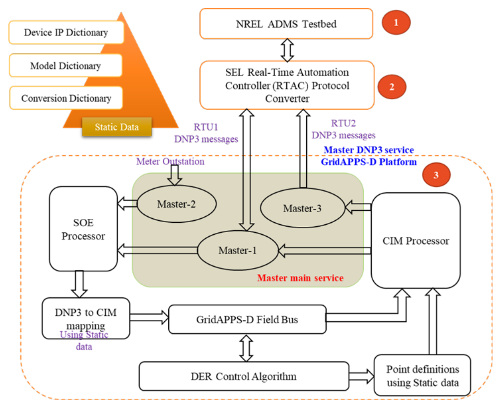


Fig. Flow of data/messages for co-simulation at NREL

TABLE I
DATATYPE, GROUP, AND VARIATION OF THE DNP3 POINTS

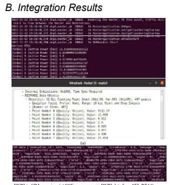
Data Type	Group	Variation	Examples	Control/ Status	*Sent From*
Analog Output	42	3	Solar Panel, Capacitors, Regulators	Control (Update set points)	Master to Outstation
Analog Input	30	1	AC Line Segment	Measure-ment Values	Outstation to Master
Digital Output	12	1	Switches, Reclosers, Regulators	Control, Enable, Disable	Master to Outstation
Digital Input	1	2	Breakers	Status	Outstation to Master

A. ADMS Integration

Fig. shows the flow of data/messages of the DNP3-Master service inside GridAPPS-D in a co-simulation setup at NREL, consisting of three stages: the ADMS test bed, the SEL RTAC, and GridAPPS-D.

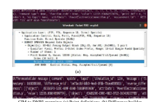
- **ADMS Test Bed**: NREL’s ADMS Test Bed, funded by the U.S. Department of Energy, employs multi timescale co-simulation (using HELICS [9]) to evaluate grid control architectures. It integrates hardware seamlessly, collecting data through various communication protocols and aiding the power industry in testing existing/future control systems.
- **SEL RTAC**: The SEL RTAC serves as a protocol converter with cybersecurity features. In the ADMS test bed setup, OpenDSS is used for power flow simulation.
- As OpenDSS lacks the required communication protocols, the SEL RTAC protocol converter enables the DNP3-Master service for demonstration.
- **DNP3-Master Service in GridAPPS-D**: This setup involves the preparation of static data in a CSV file and the assignment of names/indexes to the measurements (analog/digital) of the RTAC devices (RTU1, . . . , RTUn.

B. Integration Results



DNP3 to CIM mapping: (a) SOE processor raw DNP3 data from SEL RTAC, (b) CIM message.

Fig shows raw DNP3 data from SOE Handler and RTAC.



CIM to DNP3 mapping: (a) Point definitions, (b) Difference builder message.

Point definitions are as shown. Subsequently, the GridAPPS-D python builder generates forward- and reverse-difference CIM messages. as shown in Fig.

The evaluation used a configuration polling every minute for integrity, without assessing latency. The latency for a collocated system is in the milliseconds, minimizing the impact to the optimization performance with a time step of one second.

Summary

- With these successfully demonstrated examples, we believe the DNP3-Master service offers flexibility in configuring and scaling the integration of numerous DERs and legacy devices, with minimal file configurations. This could involve real-world field trials and real-time assessments.
- We plan to extend this work to integrate an EMS (GE e-terra) with GridAPPS-D.

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