OpenFMB™ Working Group
SEPA Grid Evolution Summit – In Person Meeting
Agenda

• Welcome
• OpenFMB Overview
• SEPA OpenFMB Roadmap Discussion
• OpenFMB Industry updates
• OpenFMB Task Force updates
• New Business
• Adjourn
Welcome

Meet the Chairs:

Dr. Stuart Laval
Director, Technology Development
Duke Energy

Stuart McCafferty
VP, EnergyIoT
Hitachi Microgrids

Dr. Robby Simpson,
System Architect
GE Grid Solutions
OpenFMB Overview
OpenFMB™: The Catalyst for Interoperability

- Open Field Message Bus (OpenFMB™) is a reference architecture and framework for distributed intelligence and grid-edge interoperability
- Leverages existing standards to federate data between field devices and harmonize them with centralized systems
  - Utility industry standardized semantic models
    - IEC’s Common Information Model (CIM) used in first reference implementation
    - Harmonization of IEC 61850 with CIM in progress for current implementation
    - Other standards/platforms being considered (e.g. Volttron, OpenADR, etc)
  - Industrial Internet of Things (IoT) publish/subscribe protocols
    - DDS: Data Distribution Service
    - MQTT: Message Queue Telemetry Transport
    - AMQP: Advanced Message Queue Protocol
    - Other IoT pub/sub standard protocols being considered
- Scales operations independently, without a system-wide rollout
  - Flexible integration of renewables and storage with the existing grid
  - Accelerates ability to stack operational benefits
- OpenFMB™ RMQ.26 standard was ratified in March 2016 by the North American Energy Standards Board (NAESB)
OpenFMB: Relevant Publications

SEPA’s Open Field Message Bus (OpenFMB): Internet of Things (IoT) Interoperability Framework

DOE PNNL’s Grid Architecture 2.0: Laminar Coordination Framework (LCF)

NAESB RMQ.26 Version 3.1
Please contact naesb@naesb.org

PNNL-25480 (Courtesy of JD Taft)
Available at http://gridarchitecture.pnnl.gov/
### OpenFMB: Enhancing Grid Edge Integration

**Key Observations:**

1. **Single-Purpose Functions**
2. Proprietary & Silo’ed systems
3. Latent, Error-prone Data
4. OT/IT/Telecom Disconnected
5. **No Field Interoperability!**

**Arrows and Node Diagram:**

- **Vendor A Solution**
  - Head End A
  - Private Carrier
  - Modbus

- **Vendor B Solution**
  - Head End B
  - Proprietary Network
  - C12.22 or CoAP

- **Vendor C Solution**
  - Head End C
  - Public Carrier
  - 900MHz ISM

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**Key Observations:**

1. **Multi-Purpose Functions**
2. Modular & Scalable HW&SW
3. End-to-End Situational Awareness
4. OT/IT/Telecom Convergence
5. **True Field Interoperability!**

**Arrows and Node Diagram:**

- **Open Field Message Bus**
  - 3G, LTE, Wi-Fi, Fiber, Ethernet, RF ISM, or PLC
  - MESA DNP3

- **Enterprise Service Bus**
  - 61850+CIM IoT Pub/Sub

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**Node Details:**

- **Node**
  - Any Medium
  - 61850 GOOSE
OpenFMB: Federated Message Exchanges

- Periodic Readings - Pub every few secs or near-real-time
- Data-Driven Events – on status change in near-real-time

**Pub/Sub - Readings**
- KW A/B/C
- KVAR A/B/C
- V A/B/C
- I A/B/C
- Phase Angle A/B/C
- KWh
- TimeStamp
- State of Charge

**Pub/Sub - Events, Alarms, and Control**
- Trip / Open
- TimeStamp

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Open Field Message Bus

- PV
- Battery
- Security/Network Policy Manager
- DER/Microgrid Optimizer
- Recloser / Switch
- Meter
- Grid Edge analytics
OpenFMB: OT/IT Abstraction Process

- **Use-Case App(s) or Policies**
- **Analytics**
- **Messaging**
  - DDS, MQTT, AMQP, Other
  - OPEN FIELD MESSAGE BUS
  - 61850 & CIM Data model
- **Security**
- **Transformation**
  - Data Model
  - Profiling
- **Translation**
  - Head-End
  - DNP3 & GOOSE
  - Modbus
  - Other
- **OT System or Device**
  - DMS, Sandbox, Pi
  - FCI line Sensor
  - Intelligent Switch
  - Cap Bank
  - Smart Meter
  - Battery/PV Inverters
  - Transformer
  - Telco Router
SEPA OpenFMB Framework Life Cycle

- Functional and non-functional requirements
- Interaction and sequencing

Business Case
- Business-driven solutions

Use Case
- Profile of applicable, existing data model

UML
- Common software definitions and language

XSD and IDL and Protobuf
- Software tools to allow actors to interoperate

Apps and Adapters
- System integration and validation testing

Test and Field
- Updates and versioning

Maintenance
OpenFMB: Security Analytics Framework

- **Describe**: Identifying Normal Behavior & Good Actors: Commissioning, Updating & Operating.
- **Define**: Profiles, Topics, Semantics, Behavior: Operational Functions & Security Policies
- **Messaging**: White-listed & Encrypted Payloads: DDS Secure on top of the UDP/IP or TCP/IP
- **Transport**: Transport Layer Security (TLS) 1.2 or Plug-ins
- **Security Behavior Analysis**: Intrusion Detection & Machine Learning: Domain Knowledge: Detect, Isolate, Restore
OpenFMB: Logical Reference Architecture

Layered Security Approaches

Application Layer

Field Applications

Client/Server Adapters
(Modbus, DNP3, IEC 61850 GOOSE/MMS, C37.118, ANSI C12, CoAP, XMPP, Others)

Interface Layer

OpenFMB™ Interface Layer
(Data Models and Profiles, Configurations, Interaction Patterns, Security)

Pub/Sub Layer

AMQP  DDS  MQTT  Other Pub/Sub Middleware

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OpenFMB: Management Services Architecture

Middleware

Configurations

Applications

Adapters

Defense in Depth

Layered Security Approaches

OpenFMB™ Management Services Layer
(Plug-ins, Updates, Installation, Health Monitoring, Alerting, Auditing)

OpenFMB™ Interface Layer
(Data Models and Profiles, Configurations, Interaction Patterns, Security)

DDS
AMQP
MQTT
Other Pub/Sub Middleware Clients

Middleware Broker
Middleware Client
Management Services Administration

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OpenFMB Roadmap

Path Forward

• Roadmap

• Architectural Relationships

• Testing and Certification Program

• Open Source Foundation Relationship
### OpenFMB: Past Accomplishments

<table>
<thead>
<tr>
<th>Year</th>
<th>Event/Activities</th>
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<tbody>
<tr>
<td>2015</td>
<td>SGIP &amp; NAESB kick-off OpenFMB task forces, SGIP publishes DER circuit segment mgmt use-cases w/ IEC CIM UML, DOE NREL INTEGRATE OpenFMB microgrid demos at Duke Energy &amp; CPS Energy.</td>
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<tr>
<td>2017</td>
<td>SGIP launches OpenFMB.io website &amp; Open-source repository.</td>
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**Legend:**
- SGIP: Smart Grid Interoperability Panel
- NAESB: North American Energy Standards Board
- UML: Unified Modeling Language
OpenFMB: Proposed Roadmap

--- 2017 ---

- SGIP/SEPA Merger Complete
- OpenFMB UML Data Model Harmonizing IEC CIM + 61850
- OpenFMB Conformance Test Harness at DOE Lab
- OpenFMB User’s Group Launched & NAESB RMQ.26 Standard Updates
- SDGE, Avista, Entergy, APS, & others initiate plans for OpenFMB pilots
- OpenFMB Distributed Cybersecurity Reference Architecture
- OpenFMB Open-source Foundation Project Assessment
- OpenFMB Commercially Certified Solutions

--- 2018 ---

- Utility OpenFMB Pilots & Test bed Demos
OpenFMB Architectural Relationships

IEEE P2030.7: Example Hierarchy in Microgrid Controls

Source: IEEE
IEEE P2030.7 Con’t: Example Functional Hierarchy

Function Assignment

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Device Level Control Functions</th>
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<tbody>
<tr>
<td></td>
<td>(Voltage/Frequency Control, Reactive power Control, Electric Vehicle Control, Energy Storage Control, Load Control, Generation Control, Islanding Detection, Fault Protection)</td>
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<thead>
<tr>
<th>Block 2</th>
<th>Local Area Control Functions</th>
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<tbody>
<tr>
<td></td>
<td>(Sequence Logic/Status control, Load Management, Building Energy Management, Plant Controller, AGC, Fast Load Shedding, Resynchronization, Disturbance Recording)</td>
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<tr>
<th>Block 3</th>
<th>Supervisory Control Functions</th>
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<tr>
<td></td>
<td>(Forecasting, Data management and Visualization, Optimization [e.g. Volt/VAR, Economic dispatch], Dispatch, State Estimation, Emergency Handling, Generation Smoothing, Spinning Reserve, Topology Change Management, Black Start, Protection Coordination)</td>
</tr>
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<tr>
<th>Block 4</th>
<th>Grid Interactive Control Functions</th>
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<tr>
<td></td>
<td>(Area EPS control, Spot Market, DMS, TSCADA, Connection to adj. Microgrid)</td>
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</table>

Tertiary Control

Secondary Control

Primary Control

Source: IEEE
IEEE P2030.7 Con’t : Example Microgrid Controller Options
OpenFMB Testing & Certification

Benefits of Certification:

• Provides a level of certainty in the market for customers, implementers, and product vendors

• Increases value by establishing thresholds

• Gives implementers confidence of interoperability with other implementations
OpenFMB Testing & Certification Con’t

Testing and Certification Roles:

• **ITCA** – Interoperability Testing Certification Authority
  • Develops, maintains, owns certification program requirements.
  • Posts and maintains certifications, markets the certification program, and is a resource for Accreditation Bodies

• **SDO** – Standards Development Organization
  • Develops, maintains, and owns standard specification

• **TL** - Test Lab
  • Performs certification test against requirements

• **CB** - Certification Body:
  • Manages certification process, reviews test lab reports, issues and maintains compliance certificates

• **AB** - Accreditation Body
  • Accredits certification bodies and test labs
Example Testing and Certification Program Development Process

Develop Implementation Agreements
- Conformance Statements
- Application Profiles
- Standards Updates

Develop Test Requirements
- Requirements Breakdown
- Requirements Verification
- Test Procedures

Select Participating Firms
- Certification Body
- Accreditation Body
- Test Labs

Develop Process
- Certification Mark
- Certification Process
- Authorize Certification Bodies
Next Steps:

- Develop SEPA Testing and Certification business plan, support processes, and Testing and Certification processes

- Develop conformance statements for NAESB RMQ.26

- Convene team to write implementation Agreements, Application Profiles, Testing Requirements and PICS

- Solicit firms to participate in OpenFMB Testing and Certification
Open-Source Foundation Relationship

• Exploring the benefits of establishing an ‘Energy Working Group’ with an Open-Source foundation to manage code within a potential “OpenFMB project”:
  • Intellectual property due diligence
  • Code management and governance
  • Facilitate a developer’s forum and ecosystem

• SEPA will be documenting requirements and having discussions with multiple foundations to determine value and feasibility.
OpenFMB Industry Updates

Utility Testbed activities
• Duke Energy
• CPS Energy
• Arizona Public Service (APS)
• San Diego Gas & Electric (SDG&E)

Department of Energy (DOE) projects
• ABB
• RTI
• Oak Ridge National Labs
First OpenFMB Reference Implementation: Duke Energy Microgrid Test Site in Mount Holly, NC
Second OpenFMB Reference Implementation: Duke Energy Rankin / Mount Holly Microgrid Pilot Circuit

Planned use-cases:
- Microgrid Islanding/Reconnection
- Circuit Segment Optimization
- DER Circuit Segment Management
- PKI Management (new)

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CPS Energy OpenFMB Reference Implementation

• CPS Energy
  • Largest Municipal Electric and Natural Gas Utility

• OpenFMB Implementation
  • Microgrid at Fort Sam Houston

• Proposed OpenFMB Projects
  • Anderson VVO and FLISR
    • Low latency DA telemetry data
    • Coordinated P&C with DMS
  • Microgrid Load Management
    • Partnership with UTSA
  • Air Sensor Deployment
    • Data creation for data analytics effort
APS: Possible OpenFMB Demo Site

Need for visibility and control

Tap-changing Transformer

Inverter

Radio Enclosure

Capacitors

Regulators

BESS

APS Operations

PQM

Cell Modem Enclosure
APS: 2 MW / 2 MWH Battery Energy Storage System (BESS)

https://vimeo.com/user31717259/review/219005262/cf8509a7d7
SDG&E OpenFMB Evaluation and Demonstration

- SDG&E EPIC 2 Project 3 – Monitoring, Communication, and Control Infrastructure for Power System Modernization
SDG&E EPIC2 OpenFMB Test Scope

SDG&E Applications (SCADA, ADMS, DERMS)

OpenFMB Test System

OpenFMB Interface layer

Power System Components (Distribution Circuit Devices)

- DNP3.0
- Modbus
- IEC 61850
- SEP 2.0
- XMPP
- CoAp
- Custom
- Future

OpenFMB Test System

OpenFMB Interface layer

Publish / Subscribe Protocols
- DDS
- AMQP
- MQTT
- Other (OPC UA)
DOE CEDS Grant: Multi-layered Resilient Microgrid Networks

Project Summary:
• Develop and demonstrate a cyber-physical resilient P&C architecture for future deployment of multiple microgrids, as well as retrofitting the existing distribution grids by additional DER deployment

Technical Approach:
- **System Resilience**: microgrid systems provide enhanced resilience to anomalous power system events and cyber attacks
- **Holistic** cyber security and engineering strategies
- Evaluate control commands for **correctness** with respect to system physics as well as the protocol semantics
- IEC 61850/CIM/OpenFMB extended **semantic models** for self-description and aggregation
- OpenFMB for microgrid to microgrid communications
DOE SBIR Phase 2 Grant: OpenFMB Node Configuration & Monitoring

DOE Program Manager: Chris Irwin

Project Summary:
• Open, Scalable Remote Node Management Capability for OpenFMB
  • Device Configuration & Updates
    • Containers, Applications, Security
  • Real-Time Device Health Status Monitoring
  • Certificate Provisioning & Management
• In Collaboration with the OpenFMB Working Group
  • Aligned with NAESB RMQ.26 (OpenFMB Mgmt Services Layer)
  • Reference Implementation Will Be Part of OpenFMB Distribution
DOE SBIR Phase 2 Grant: OpenFMB Node Configuration & Monitoring Con’t

Technical Approach:
• Device & Operating System Agnostic
  • Hardware vendor and device agnostic
  • Software platform independent
• Standards-Based
  • Built upon mature open standards-based software
• Demonstration planned
  • Year 1: 100+ node lab-based system
  • Year 2: Utility testbed(s)

Industry Collaboration:
• Forming an advisory board consisting of utilities, research labs, technology providers, and other stakeholders.
ORNL: OpenFMB Planned Activities

• Develop technical specifications and reference implementations of the DOE GMLC architecture with OpenFMB cyber security framework
• Develop & implement OpenFMB cyber security profiles
• Develop & implement OpenFMB compliance validation test-harness
• Develop a VOLTTRON/OpenFMB interface for DER transactive controls
• Field validation of advanced adaptive protection relays for distributed microgrids as flexible assets
• Porting of ORNL’s CSEISMIC open-source microgrid controller to support OpenFMB and deploy on low-cost secure hardware
• Architect an OpenFMB DDS bus to federate topics among sensors (µPMUs), devices (smart inverters, microgrid controllers, intelligent adaptive relays), analysis tools (traditional and AI-based), and services (data backup/repository).
• Investigate how to incorporate OpenFMB with AMQP and ZeroMQ.
OpenFMB Task Force Updates

- OpenFMB Data Model Task Force
- OpenFMB Cybersecurity Task Force
- OpenFMB Management Services Task Force
OpenFMB Data Model Task Force Update

- The data exchanged between the devices and systems are modeled in UML Class Diagrams based on standards.
OpenFMB Data Model Task Force Update Con’t

• OpenFMB Data model
  • Use of 61850/CIM harmonization model: include Logical node (LN)
  • Model structure: Common module & individual modules
  • Restricted data types: Enumerations and Specialization
  • Model management (centralized server proposed)

• Use 61850/CIM harmonization with MeasurementValueSource & MeasurementValue as profile foundation

• Specialization:
  • Specialized IED at root (e.g. ResourceReadingIED)
  • Specialized MeasurementValue (e.g. ResourceReadingMeaValue)
  • Specialized IEC61850 LN (e.g. ResourceReadingMMXU)
  • Specialized data types (e.g. MV, BCR and etc.)

• Common module package
OpenFMB Data Model Task Force Update Con’t

• Use of IEC61850 (draft for discussion)
OpenFMB Cybersecurity Task Force Update

• Analyzed DER circuit segment management use-case

• Network Segment Security
  • Isolation
  • Behavioral Analytics

• OpenFMB Node Security
  • Physical Security
  • Identity
  • Secure Boot Stack
  • Operating System
  • Data At Rest
  • Services:
    • Isolation, Identify
    • Integrity, Data Assurance
  • Communications
    • Inter-Service Communications
    • Ingress and Egress Filtering
OpenFMB Cybersecurity Task Force Next Steps

• SGIP Smart Grid Testing and Certification Committee (SGTCC) created the Smart Grid Interoperability Process Reference Manual (ANSI/NEMA SG-IPRM 1-2016)

• To support OpenFMB certification, the task force is preparing conformance statements including security for:
  • Publish/Subscribe Communications
  • Node Characteristics
  • Management Services
Objectives

- Develop a management services layer information model
- Define the actors involved in the Management Services layer and how they interact
- Identify, prioritize, and create high priority use cases, such as:
  - Health Metrics Time Series (Counter, Gauge, Related Statistics)
  - Alerts (Current or imminent user impact, Otherwise undetected, Actionable)
  - OpenFMB Updates (OpenFMB Applications, Interface Layer, Pub/Sub Layer, Administration)
  - OpenFMB Node Installation (Node Inventory, Configuration Definition, Lab Test Configuration, On-Site Installation)
New Business
New Business

• 2017 Fall In Person Meeting – Date/Location TBD
• Potential leadership elections in Q3 2017
• Other?