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IEC 61968-5 Distributed Energy Optimization to Open Field Message Bus (OpenFMB) Mapping



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ABSTRACT

The International Electrotechnical Commission (IEC) 61968-5 Distributed Energy Optimization standard defines a series of message exchanges between a distributed energy resource management system (DERMS) and other utility enterprise systems such as a Distribution Management System (DMS), Geospatial Management System (GIS), or Outage Management System (OMS). Some functions that are present in these systems may be included in a single "advanced" DMS, hence, ADMS.

Open Field Message Bus, or OpenFMB as it is commonly called, is a logical bus which may use various Internet of Things (IoT) protocols such as Data Distribution Service (DDS), Message Queue Telemetry Transport (MQTT), or Extensible Messaging and Presence Protocol (XMPP) and publish/subscribe integration patterns so that devices, such as those located in a microgrid, can "talk" to each other. Both OpenFMB and the IEC 61968-5 can be used in the DER management domain, and it's possible that an enterprise system utilizing the IEC 61968-5 for DER group management would have to be translated due to individual DER devices communicating through another protocol such as DNP3, IEC 61850, or OpenFMB.

This research seeks to map the two protocols together. Although a complete mapping cannot be made between the two protocols, enough overlap exists in their current forms that messages can be translated between a system using the common information model (CIM) and another system utilizing OpenFMB. This report seeks to illustrate the different implementations of DER group management in the CIM, and how they could be represented in the OpenFMB specification.

Keywords

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KEY RESEARCH QUESTION

Open Field Message Bus (OpenFMB) is a logical bus that may use various Internet of Things (IoT) protocols in a publish/subscribe integration pattern to allow devices such as those in a microgrid to talk to each other. An enterprise system using the Common Information Model (CIM) for its Distributed Energy Resource Management System (DERMS) could be used to send messages to individual DER devices that communicate using various protocols such as DNP3, IEC 61850, or OpenFMB. This report explores how mapping between the IEC 61968-5 and OpenFMB might be accomplished.

RESEARCH OVERVIEW

This research sought to show how a message following the IEC 61968-5 standard could be mapped to OpenFMB. To complete this research, EPRI's 61968-5 Test Script was used to illustrate different use cases for issuing DER Group messages. For OpenFMB, software artifacts such as protocol buffer files and extensible schema definition (XSDs) files were used to determine how messages could be mapped to the CIM. Due to different payloads being utilized by the IEC 61968-5 and OpenFMB examples, the underlying data model itself was typically referenced in tables that would map the two different standards.

KEY FINDINGS

- Key parts of the OpenFMB data model can be mapped to the CIM.
- For attributes that cannot be mapped directly, there are still other ways to proceed with the mapping using more general "description" fields.
- Although the payload of both data models is expressed differently (XML for CIM, and protocol buffers for OpenFMB), the two protocols can still be mapped due to the language agnostic architecture of a DERMS.
- OpenFMB is continuing to grow, and what may not exist in the model today could be there tomorrow.

WHY THIS MATTERS

Different protocols and standards make different design trade-offs to optimize for the domain of their intended use. However, when information needs to span domains; in this example from the enterprise to a domain such as a microgrid where OpenFMB might come into play, mapping between these protocols needs to occur to minimize data loss, while maximizing the benefits of each protocol. It is therefore important to make sure that a message can be understood and properly conveyed in the event that the DERMS is issuing commands

to DERs that utilize different protocols. Having a reference to map between different standards can help systems achieve interoperability between these different protocols. Prior research has shown that standards help to hold down maintenance costs and promote innovation. The mapping between these two standards maximizes the benefits of both.

HOW TO APPLY RESULTS

A DERMS could be implemented using several communication protocols, such as IEC 61850, DNP3, OpenFMB, IEEE 2030.5, and others. The purpose of this report is to map the enterprise communications following the IEC 61968-5 standard to systems that use OpenFMB to control their DER communications.

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1
INTRODUCTION

Open Field Message Bus (OpenFMB) is a logical bus which may use various Internet of Things (IoT) protocols such as Data Distribution Service (DDS), Message Queue Telemetry Transport (MQTT), or Extensible Messaging and Presence Protocol (XMPP). The OpenFMB logical bus utilizes publish/subscribe integration patterns so that devices, such as those located in a microgrid, can "talk" to each other. The power of OpenFMB is that it facilitates distributed intelligence making decisions closer to the point of need, rather than being limited by the latency of status being sent all the way to central station, waiting on an operator decision, and then having the resulting control signal sent from central station to an affected device. As the number of devices capable of distributed intelligence and communication and the use of microgrids continues to rise, the effective management of the grid will require a greater amount of decision-making that can be made closer to the "action."

This is not to say that the role of central station has been eliminated. It has not. While decision making can be distributed, central station still needs to be aware of status changes as they occur. Additionally, devices in a microgrid may be only locally aware. Central station has the view of the entire grid and this broader understanding may inform distributed intelligent devices. For example, as broader situational intelligence is acted upon, central station will need to be able to send control signals to the distributed devices, for example, ramp rates curves, that tell devices what energy levels they need to match at points in time to optimize frequency, voltage, or current. Additionally, systems operators do not want to manage thousands of devices individually. There needs to be a way to aggregate resources so that a single command can be issued to many devices. This is the role of a distributed energy resource management systems (DERMS).

Role of DERMS

The IEC 61968-5 Distributed Energy Optimization defines a series of message exchanges between a DERMS and other utility enterprise systems such as a Distribution Management System (DMS), Geospatial Management System (GIS), or Outage Management System (OMS). Some functions that are present in these systems are sometimes included in a single "advanced" DMS, hence, ADMS.

At a high level a DERMS can be thought of providing four services to the operation:

- Aggregate - DERMS should take the services of many individual DER and present them as a smaller, more manageable, number of aggregated virtual resources.
- Simplify - DERMS should handle the granular details of DER settings and present simple grid-related services
- Optimize - DERMS should optimize the utilization of DER within various groups to get the desired outcome at minimal cost and maximum power quality.

- Translate - Individual DER may speak different "languages" (use different protocols or information models), depending on their type and scale. DERMS should handle these diverse languages, and present to the upstream calling entity in a cohesive way.

> It should be noted that OpenFMB is transport agnostic. While several IoT protocols are listed here, regardless of transport method, the important unifying aspect is the underlying information model. Much like the CIM, also agnostic to transport (regardless of whether JMS, SOAP, REST, XMPP are used), the unifying aspect of CIM is its information model.

These messages might also be between the utility and third parties, for example, that may host DERMS functionality. Figure 1-1 below illustrates how the DERMS is agnostic to architecture. However, the specification does not specify how the DERMS does the work of managing the aggregation of individual DER, or how messages to individual DER are managed. The scope of IEC 61968-5 is only the enterprise system messages. To understand the message requirements to individual DER, one must reference the specification, be that OpenFMB (technically North American Standards Board (NAESB), RMQ.26, within the Version 3.1 publication of the NAESB Retail Markets Quadrant Model Business Practices), DNP, IEC61850, ModBUS, and so on.

For a comprehensive list of DERMS functions, see the EPRI report *Common Functions For DER Group Management, Third Edition*[1]. Not all functional requirements have been implemented in the IEC 61968-5 standard at this time, but rather a subset:

- DER group creation and maintenance
- DER group status and event monitoring
- DER group forecast
- DER group dispatch
- DER group connect/disconnect
- DER group capability discovery
- DER group voltage ramp rate

This report, while not defining how a DERMS may implement such features, does seek to add clarity to the mapping between two of the standards, IEC 61968-5 and the OpenFMB specification. This will illustrate one possible implementation that DERMS vendors could use to understanding how to map between enterprise IEC 61968-5 messages and field messages to individual DER.

It should also be noted that DERMS is a logical grouping of capabilities. The IEC 61968-5 specification details the messages that are exchanged with other enterprise systems or other business entities. Thus, a DERMS could be an edge system similar to how an Advanced

[1] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008215

Metering Infrastructure (AMI) Head-End system is used to communicate with meters, or it could be subsumed into an ADMS, or it could be a hosted capability provided by a third-party vendor in the cloud, or even a "DERMS in a box", located in a substation managing more localized control, or even, a logical node within an OpenFMB microgrid, managing communication back to central station (See Figure 1-1 below).

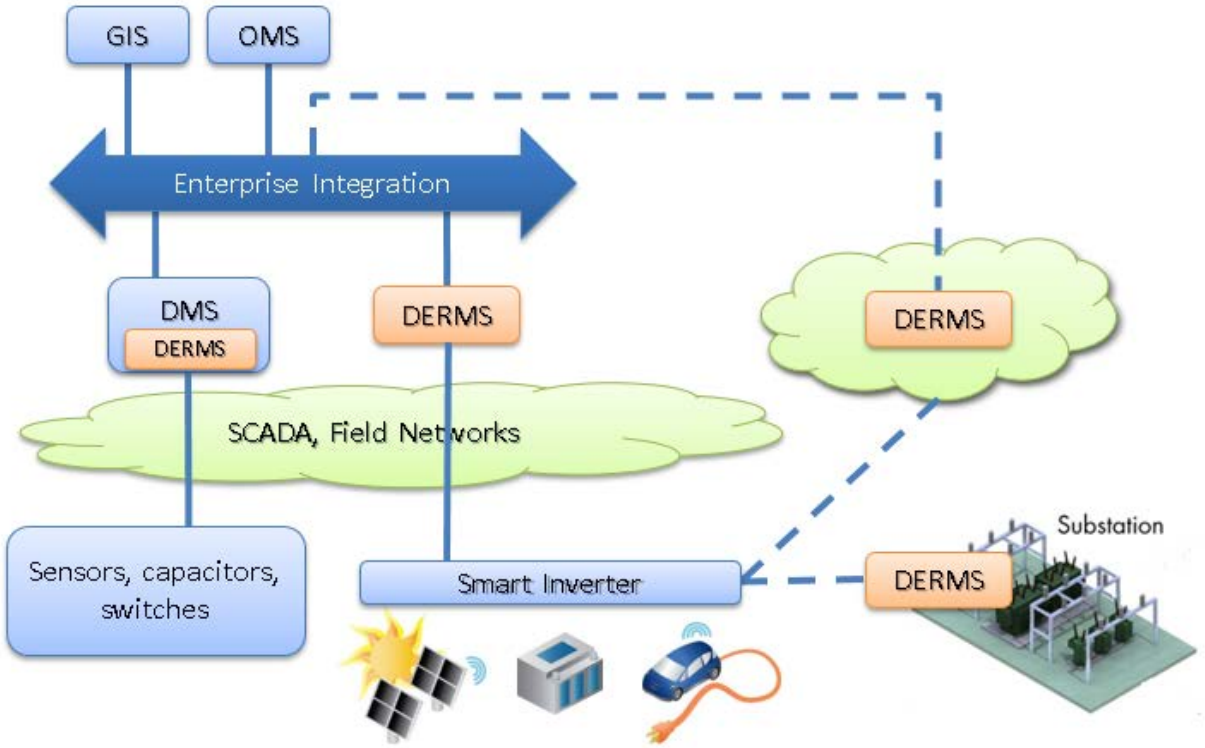


Figure 1-1
DERMS architectural options

To better understand the DERMS consider the architecture diagram below in Figure 1-2. Enterprise DERMS messages are exposed as web services (on the left). While IEC 61968-5 specifies the eXtensible Schema Definitions (XSD) for the messages, they could be implemented in a variety of ways such as SOAP over HTTP, JMS, or REST. Internally the DERMS would probably require some local storage to log states, events, and group membership and the respective changes over time. While a DERMS could support all the functions defined in the EPRI report regarding DER group management, only a couple examples are shown in this diagram. On the right side of the DERMS architecture diagram the DER comms function lists the individual protocols that might be supported for communication to the individual DER.

This report will explore how the mapping between IEC 61968-5 and OpenFMB might be accomplished, considering the characteristics of the respective message payloads.

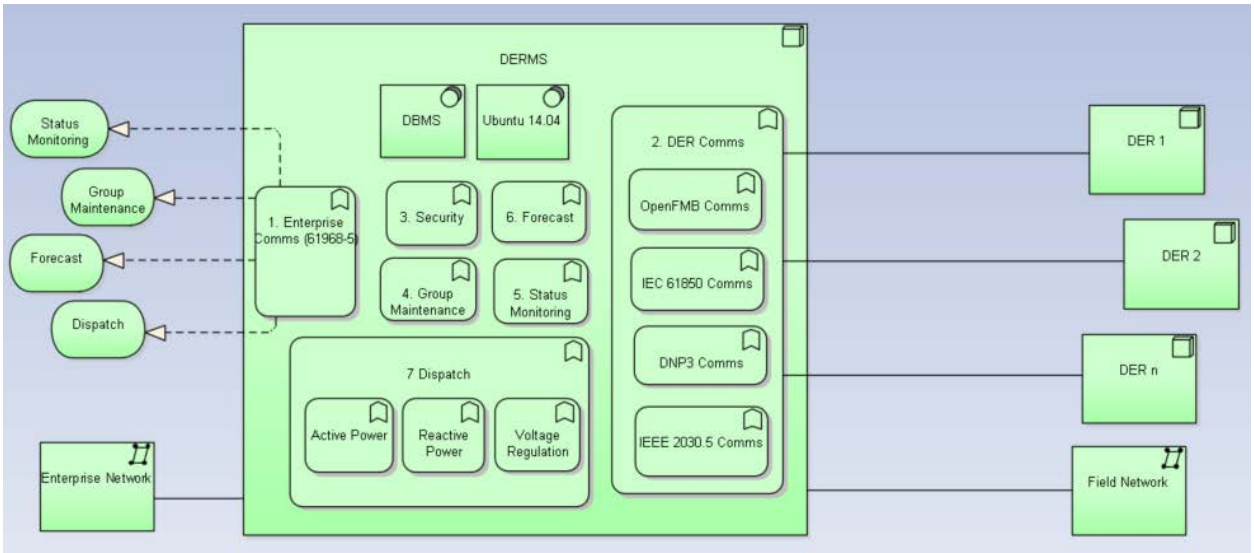


Figure 1-2
Example technology architecture diagram for a DERMS

A more abstract way to view the same diagram is below in Figure 1-3. For the purposes of this report, one could think of a DMS asking the DERMS to perform some actions on its behalf. The "conversation" between utility enterprise systems, is based on the IEC 61968 family of standards. In this case, IEC 61968-5 Distributed Energy Optimization, defines the messages to support the various DER grouping use cases. The interaction also leverages IEC standard 61968-100:2013 Application Integration for defining the integration using web services, in this case, using Simple Object Application Protocol (SOAP) over the Hypertext Transfer Protocol (HTTP); essentially the same protocol used by the world-wide web (WWW).

The DERMS, in turn, sends out commands to the individual DER. Several protocols and standards could be used such as IEC 61850, DNP3, or Modbus. However, this report is focused on using OpenFMB for DERMS to individual DER communications.

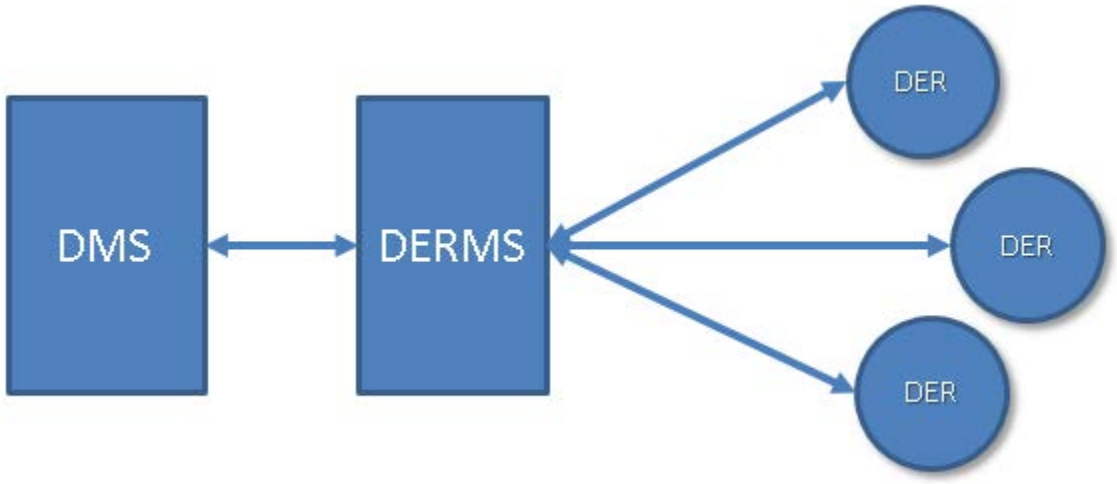


Figure 1-3
Abstract version of DMS to DERMS interactions

Further, in the domain of enterprise communications, both between utility systems such as a DERMS, DMS, or other enterprise system, or externally with third-party aggregators, perhaps hosting DERMS providers, is the realm of the Common Information Model (CIM) family of standards. Specifically, for distribution systems, the family of standards is IEC 61968. One must also keep in mind that the CIM is the unified modeling language (UML) representation of the objects, attributes, and relationships between objects. The standards discuss the use cases for a domain and leverage profiles of the CIM (subsets of the model) to illustrate these use cases or represent data exchange between systems.

The draft standard that covers DER group related communications with other enterprise systems is IEC 61968-5 Distributed Energy Optimization (currently in the IEC standardization process as a Final Draft International Standard [FDIS]).

Payload Differences 61968-5 and OpenFMB

When comparing IEC 61968-5 and OpenFMB, it should be noted that the standards use different payloads (XML versus protocol buffers, respectively) and different transport protocols (exclusively SOAP for 61968-5 while OpenFMB utilizes various other HTTP protocols such as XMPP, DDS, MQTT and more) in the examples used for this report. Sample XMLs from the 61968-5 test script[2] will be used to show CIM functions, while OpenFMB will be referenced either by the UML model or by the sample protocol buffer (.proto) files.

Header Mapping

The IEC 61968-5 follows the standard for Headers as outlined in the 61968-100. Typically, this results in a message that at a bare minimum contains a *Noun*, *Verb*, *MessageID*, *CorrelationID*, and *Timestamp*. In OpenFMB, similar information is conveyed through a MessageInfo class (e.g. the SolarReadingProfile contains a ReadingMessageInfo class) that consists of *name*, *mRID*, *description*, and *messageTimeStamp* fields. This is almost exactly the same as the CIM, where the *description* field in OpenFMB could be used to define the actions that the CIM defines using *verb* and *noun*. However, only one *mRID* field exists in the OpenFMB data model, which would most likely be matched to the *messageID* field in the CIM. This leaves only the *CorrelationID* without a direct mapping.

The CIM header can contain optional fields that are not currently represented by OpenFMB's MessageInfo class. These fields include *ReplyAddress*, *User*, *Context*, *AsyncReplyFlag*, *Comment* and others. For the purposes of this report, these will not be included in the header mapping.

[2] https://www.epri.com/#/pages/product/000000003002014703/?lang=en-US

2
IEC 61968-5 FIRST EDITION

Creation and Maintenance of DER Groups

To manage DER in aggregate, this presumes the ability to create, and do updates to, groups of DER. Hence, in the IEC 61968-5 standard the first use case that was developed was to provide for the creation, update of, or deletion of DER groups. Once a group has been formed, then actions can be performed by referencing the group, with the DERMS handling communication to the individual members. The rough equivalent for groups in OpenFMB is the RequestedInterconnectionScheduleProfile or perhaps the RequestedOptimizerScheduleProfile. Both modules within the OpenFMB model provide one-to-many functionality, while the SolarModule and ESSModules that handle DER functionality are used primarily for individual storage systems, PV installations, reclosers, etc.

Both IEC 61968-5 and OpenFMB make use of a Globally Unique Identifier (GUID) to uniquely identify classes in their respective information models. This is an important feature of this harmonization in that a unique class used in aggregation of DER, can be specifically mapped to the unique member of a specific DER that is being communicated with via OpenFMB. For example, the figure below depicts the organization of the DERgroups.xsd used by IEC 61968-5 for the creation and maintenance of DERgroups.

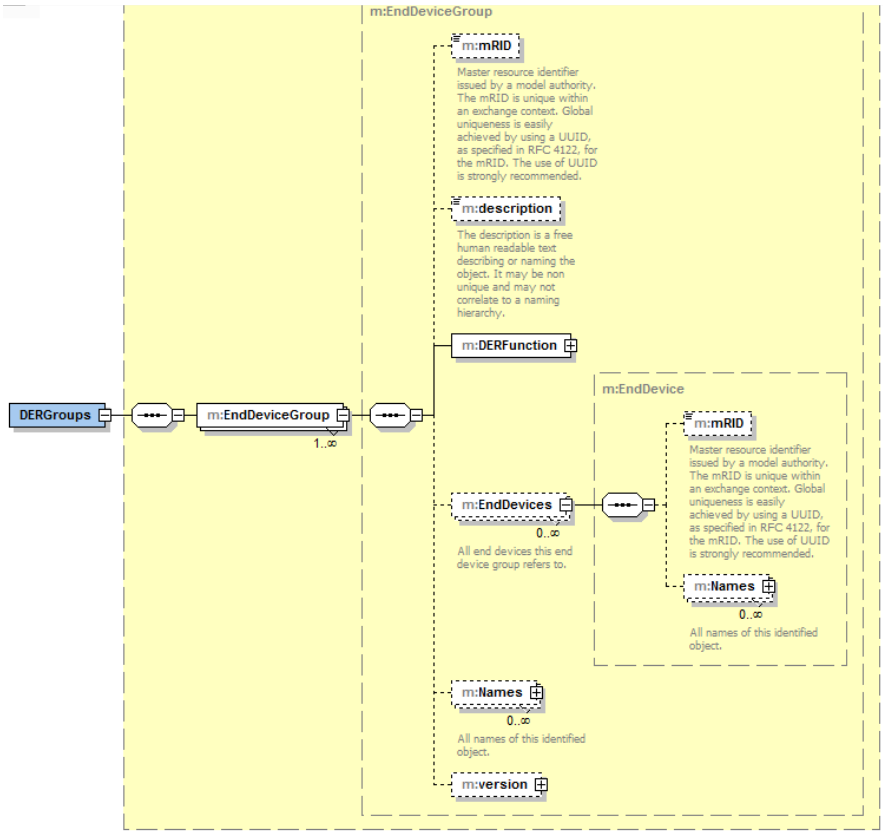


Figure 2-1
IEC 61968-5 DERgroups.xsd schema view

First, a convention should be noted in how the CIM is used in the construction of these profiles. “DERGroups” is the name of the profile, and an abstraction of the CIM class, EndDeviceGroups. The EndDevices class (seen in the center of the diagram), is the generic class used for distribution devices. For example, an electric meter is one type of device, premise area network, another type of device, and it follows that EndDevices is an abstraction for DER (or more specifically, the smart inverter connected to the DER).

Note the use of mRID. This is the “Master Resource ID” and is a GUID data type and used throughout the CIM to uniquely identity classes. The Names hierarchy of classes (also shown) also serves this purpose, but the focus for the CIM to OpenFMB harmonization will be mRID.

Both the DERGroup and the individual DER (EndDevice) have an mRID. This is so that both the group and its members can be uniquely identified. When a member is added to a DERGroup, the mRID of the member should specifically match the identifier for the DER represented or communicated with using OpenFMB. This is what ties the two models together.

Shown below is an example taken from the 61968-5 test script for the creation of DER Groups. This test case, DERG-1a, is used when a client requests creation of a DER Group.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:CreateDERGroups xmlns="http://iec.ch/TC57/2017/DERGroups#"
xmlns:msg="http://iec.ch/TC57/2011/schema/message"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupsMessage"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupsMessage DERGroupsMessage.xsd">
  <tns:Header>
    <msg:Verb>create</msg:Verb>
    <msg:Noun>DERGroups</msg:Noun>
    <msg:Timestamp>2017-05-31T13:55:27-06:00</msg:Timestamp>
    <msg:MessageID>bc9b3eaa-bdc0-4d61-9577-0c78515fee65</msg:MessageID>
    <msg:CorrelationID>bb9a2075-e2e1-43ba-a234-e5d800bfff6e</msg:CorrelationID>
  </tns:Header>
  <tns:Payload>
    <DERGroups>
      <EndDeviceGroup>
        <mRID>a20c559c-dda3-41e5-98b7-41afeb63ae5b</mRID>
        <description>DER Group 1</description>
        <DERFunction>
          <connectDisconnect>true</connectDisconnect>
          <frequencyWattCurveFunction>false</frequencyWattCurveFunction>
          <maxRealPowerLimiting>false</maxRealPowerLimiting>
          <rampRateControl>false</rampRateControl>
          <reactivePowerDispatch>false</reactivePowerDispatch>
          <realPowerDispatch>true</realPowerDispatch>
          <voltageRegulation>false</voltageRegulation>
          <voltVarCurveFunction>false</voltVarCurveFunction>
          <voltWattCurveFunction>false</voltWattCurveFunction>
        </DERFunction>
        <EndDevices>
          <mRID>23cbd502-128a-4c4e-b7cd-5eaf6d9ae275</mRID>
        </EndDevices>
        <EndDevices>
          <mRID>7fc50292-2e8a-4e9c-80ae-9105f50ce3ea</mRID>
        </EndDevices>
        <EndDevices>
          <mRID>63d092b7-baed-4bfe-ad97-5709f2ce4ec9</mRID>
        </EndDevices>
        <Names>
          <name>DG1</name>
        </Names>
        <version>
          <date>2017-05-31T13:55:01-06:00</date>
          <major>1</major>
          <minor>0</minor>
          <revision>0</revision>
        </version>
      </EndDeviceGroup>
    </DERGroups>
  </tns:Payload>
</tns:CreateDERGroups>
```

In the above figure, there are multiple mRIDs provided: one for the DER Group that is to be created, and then three more for each device that will be added to that group. The individual devices listed under each EndDevices tag already exist and it is only the DER Group that is being created in this request. This message also provides the DER Functions to be supported by this group, in this case Real Power Dispatch. Setting the connectDisconnect tag to true shows that this DER Group is connected to the grid.

CIM-to-OpenFMB Mapping

Mapping this message to OpenFMB will make use of several classes (see Appendix C for OpenFMB class definitions). Note that OpenFMB does not contain the verb – noun usage that the CIM utilizes and instead provides a description field. In this mapping, one or more immediate parent classes will be included to avoid ambiguity.

For example, the mRID of an EndDeviceGroup in the CIM found under <Payload><DERGroups><EndDeviceGroup> would be abbreviated as DERGroups.EndDeviceGroup.mRID. However, since EndDevices falls under EndDeviceGroup only, its mRID would only be represented as EndDeviceGroup.EndDevice.mRID.

Table 2-1
Creation and Maintenance of DER Groups

Creation and Maintenance of DER Groups	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERFunction	crvPts
DERFunction.connectDisconnect	crvPts.state
DERFunction.frequencyWattCurveFunction	crvPts.frequencySetPointEnabled
DERFunction.maxRealPowerLimiting	
DERFunction.reactivePowerDispatch	crvPts.reactivePrSetPointEnabled
DERFunction.realPowerDispatch	crvPts.realPwrSetPointEnabled
DERFunction.voltageRegulation	crvPts.voltageSetPointEnabled
DERFunction.voltVarCurveFunction	
DERFunction.voltWattCurveFunction	

In addition, the attributes listed above, OpenFMB only supports one solar inverter per SolarControlProfile message, as opposed to the zero-to-many EndDevices that can appear for an EndDeviceGroup in the CIM. Without making changes to the underlying data model, one potential workaround is to simply create multiple SolarControlProfiles (one for each DER).

Status and Event Monitoring

In the CIM, DER group status is reported using the DERMonitorableParameter class (see Appendix B for a full class definition). One or more of these parameters may be passed in a message, each with a specific DERParameter, and optionally, a set of corresponding DERCurveData for the respective DERParameter. This is a “get” request where the client lists the name or mRID of the DER group it wants information about, and then the server responds with details about the groups. The example below shows both the request and reply from DERGS-1a from the 61968-5 test script.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:DERGroupStatusQueriesRequestMessage
xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:obj2="http://iec.ch/TC57/2017/DERGroupStatusQueries#"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupStatusQueriesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupStatusQueriesMessage
DERGroupStatusQueriesMessage.xsd">
  <tns:Header>
    <Verb>get</Verb>
    <Noun>DERGroupStatuses</Noun>
    <Timestamp>2017-06-12T15:54:29-06:00</Timestamp>
    <MessageID>9e78323f-7ae5-4aee-aaa7-53130f5da8dd</MessageID>
    <CorrelationID>125981da-6a49-4e14-9f9c-c4aa3bafaf08</CorrelationID>
  </tns:Header>
  <tns:Request>
    <obj2:DERGroupStatusQueries>
      <obj2:EndDeviceGroup>
        <obj2:Names>
          <obj2:name>DG2</obj2:name>
        </obj2:Names>
      </obj2:EndDeviceGroup>
    </obj2:DERGroupStatusQueries>
  </tns:Request>
</tns:DERGroupStatusQueriesRequestMessage>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:DERGroupStatusQueriesResponseMessage
xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xml="http://www.w3.org/XML/1998/namespace"
xmlns:m="http://iec.ch/TC57/2017/DERGroupStatuses#"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupStatusQueriesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupStatusQueriesMessage
DERGroupStatusQueriesMessage.xsd">
  <tns:Header>
    <Verb>reply</Verb>
    <Noun>DERGroupStatuses</Noun>
    <Timestamp>2017-06-12T15:54:36-06:00</Timestamp>
    <MessageID>d996b1c0-1d5a-45b9-9ad0-2457e2615244</MessageID>
    <CorrelationID>125981da-6a49-4e14-9f9c-c4aa3bafaf08</CorrelationID>
  </tns:Header>
  <tns:Reply>
    <Result>OK</Result>
    <Error>
      <code>0.0</code>
    </Error>
  </tns:Reply>
  <tns:Payload>
    <m:DERGroupStatuses>
      <m:EndDeviceGroup>
        <m:mRID>String</m:mRID>
        <m:DERMonitorableParameter>
          <m:DERParameter>activePower</m:DERParameter>
          <m:yMultiplier>k</m:yMultiplier>
          <m:yUnit>W</m:yUnit>
          <m:DERCurveData>
            <m:nominalYValue>41.2</m:nominalYValue>
            <m:timeStamp>2017-12-06T15:54:35-06:00</m:timeStamp>
          </m:DERCurveData>
        </m:DERMonitorableParameter>
        <m:Names>
          <m:name>DG2</m:name>
        </m:Names>
      </m:EndDeviceGroup>
    </m:DERGroupStatuses>
  </tns:Payload>
</tns:DERGroupStatusQueriesResponseMessage>
```

CIM-to-OpenFMB Mapping

When mapping the CIM message for status and event monitoring to an OpenFMB message, the mapping is going to match up more easily due to OpenFMB's usage of the UnitSymbolKind and UnitMultiplierKind classes that are based on the CIM. Though not an exact mapping, CIM's DERMonitorableParameter class is mapped to OpenFMB's solarControlFSCC class since it contains most of the same data.

Table 2-2
Status and Event Monitoring

Status and Event Monitoring	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERMonitorableParameter	solarControlFSCC
DERMonitorableParameter.DERParameter	SolarControlScheduleFSCH.ValDCSG.crvPts
DERMonitorableParameter.yMultiplier	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.multiplier
DERMonitorableParameter.yUnit	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.SIUnit
DERMonitorableParameter.DERCurveData	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts
DERCurveData.nominalYValue	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yVal
DERCurveData.timeStamp	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.xVal.seconds
EndDeviceGroup.Names.name	solarControl.name

DER Group Forecast

The IEC 61968-5 standard describes the DER Group Forecast method as a means by which forecasts of DER availability may be exchanged between software applications. This function only addresses the exchange of the forecast of DER availability (e.g. real, reactive, and apparent power).

Below is test case DERGF-1a of the 61968-5 test script.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:DERGroupForecastQueriesRequestMessage
xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:obj2="http://iec.ch/TC57/2017/DERGroupForecastQueries#"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupForecastQueriesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupForecastQueriesMessage
DERGroupForecastQueriesMessage.xsd">
  <tns:Header>
    <Verb>get</Verb>
    <Noun>DEGroupForecasts</Noun>
    <Timestamp>2017-06-14T13:03:09-06:00</Timestamp>
    <MessageID>8e13f6fe-27a8-4686-bcaa-5176ce460486</MessageID>
    <CorrelationID>12668dce-4005-4acf-bcc0-d81194a5d3f1</CorrelationID>
  </tns:Header>
  <tns:Request>
    <obj2:DERGroupForecastQueries>
      <obj2:DERMonitorableParameter>
        <obj2:DERParameter>activePower</obj2:DERParameter>
      </obj2:DERMonitorableParameter>
      <obj2:DispatchSchedule>
        <obj2:curveStyleKind>straightLineYValues</obj2:curveStyleKind>
        <obj2:numberOfIntervals>4</obj2:numberOfIntervals>
        <obj2:startTime>2017-06-15T15:00:00-06:00</obj2:startTime>
        <obj2:timeIntervalDuration>15</obj2:timeIntervalDuration>
        <obj2:timeIntervalUnit>m</obj2:timeIntervalUnit>
      </obj2:DispatchSchedule>
      <obj2:EndDeviceGroup>
        <obj2:mRID>228650bf-7f77-44fa-9576-db4bbce8a07f</obj2:mRID>
      </obj2:EndDeviceGroup>
    </obj2:DERGroupForecastQueries>
  </tns:Request>
</tns:DERGroupForecastQueriesRequestMessage>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:DERGroupForecastQueriesResponseMessage
xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xml="http://www.w3.org/XML/1998/namespace"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:obj1="http://iec.ch/TC57/2017/DERGroupForecasts#"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupForecastQueriesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupForecastQueriesMessage
DERGroupForecastQueriesMessage.xsd">
  <tns:Header>
    <Verb>reply</Verb>
    <Noun>DERGroupForecasts</Noun>
    <Timestamp>2017-06-14T13:03:19-06:00</Timestamp>
    <MessageID>3c6f308f-653b-49cd-92b0-620cbb5a7169</MessageID>
    <CorrelationID>12668dce-4005-4acf-bcc0-d81194a5d3f1</CorrelationID>
  </tns:Header>
  <tns:Reply>
    <Result>OK</Result>
    <Error>
      <code>0.0</code>
    </Error>
  </tns:Reply>
  <tns:Payload>
    <obj1:DERGroupForecasts>
      <obj1:DERGroupForecast>
        <obj1:mRID>035ab91a-a826-4b8b-86fd-fb28da52514c</obj1:mRID>
        <obj1:predictionCreationDate>2017-06-14T13:03:19-
06:00</obj1:predictionCreationDate>
        <obj1:EndDeviceGroup>
          <obj1:mRID>228650bf-7f77-44fa-9576-db4bbce8a07f</obj1:mRID>
          <obj1:DERMonitorableParameter>
            <obj1:DERParameter>activePower</obj1:DERParameter>
            <obj1:yMultiplier>k</obj1:yMultiplier>
            <obj1:yUnit>W</obj1:yUnit>
            <obj1:DispatchSchedule>
              <obj1:curveStyleKind>straightLineYValues</obj1:curveStyleKind>
              <obj1:startTime>2017-06-15T15:00:00-06:00</obj1:startTime>
              <obj1:timeIntervalDuration>15</obj1:timeIntervalDuration>
              <obj1:timeIntervalUnit>m</obj1:timeIntervalUnit>
              <obj1:DERCurveData>
                <obj1:intervalNumber>1</obj1:intervalNumber>
                <obj1:maxYValue>145.0</obj1:maxYValue>
                <obj1:minYValue>100.0</obj1:minYValue>
                <obj1:nominalYValue>134.5</obj1:nominalYValue>
              </obj1:DERCurveData>
              <obj1:DERCurveData>
                <obj1:intervalNumber>2</obj1:intervalNumber>
                <obj1:maxYValue>147.0</obj1:maxYValue>
                <obj1:minYValue>100.0</obj1:minYValue>
                <obj1:nominalYValue>135.3</obj1:nominalYValue>
              </obj1:DERCurveData>
              <obj1:DERCurveData>
```

```
                <obj1:intervalNumber>3</obj1:intervalNumber>
                <obj1:maxYValue>141.0</obj1:maxYValue>
                <obj1:minYValue>98.0</obj1:minYValue>
                <obj1:nominalYValue>129.5</obj1:nominalYValue>
              </obj1:DERCurveData>
              <obj1:DERCurveData>
                <obj1:intervalNumber>4</obj1:intervalNumber>
                <obj1:maxYValue>145.0</obj1:maxYValue>
                <obj1:minYValue>100.00</obj1:minYValue>
                <obj1:nominalYValue>135.2</obj1:nominalYValue>
              </obj1:DERCurveData>
              <obj1:DERCurveData>
                <obj1:intervalNumber>5</obj1:intervalNumber>
                <obj1:maxYValue>153.0</obj1:maxYValue>
                <obj1:minYValue>105.00</obj1:minYValue>
                <obj1:nominalYValue>139.7</obj1:nominalYValue>
              </obj1:DERCurveData>
            </obj1:DispatchSchedule>
          </obj1:DERMonitorableParameter>
          <obj1:Names>
            <obj1:name>DG2</obj1:name>
          </obj1:Names>
        </obj1:EndDeviceGroup>
      </obj1:DERGroupForecast>
    </obj1:DERGroupForecasts>
  </tns:Payload>
</tns:DERGroupForecastQueriesResponseMessage>
```

CIM-to-OpenFMB Mapping

Much of the mapping in this test case is like the Status and Event Monitoring section above, with the exception of several missing elements in OpenFMB such as setting a minimum or maximum Y-value. Currently there is also no way to represent DER Group Dispatches. The closest match to that would be the ControlScheduleFSCH class which provides a way to set a start time, value, and schedule parameter type (e.g. VA_net_mag). However, should support for some of these attributes be added, certain attributes are already defined in the CommonModule. These are highlighted in the table below.

Table 2-3
DER Group Forecast

DER Group Forecast	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERMonitorableParameter	solarControlFSCC
DERMonitorableParameter.DERParameter	SolarControlScheduleFSCH.ValDCSG.crvPts
DERMonitorableParameter.yMultiplier	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.multiplier
DERMonitorableParameter.yUnit	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.SIUnit
DERMonitorableParameter.DispatchSchedule	
DispatchSchedule.curveStyleKind	
DispatchSchedule.numberOfIntervals	
DispatchSchedule.startTime	CommonModule.SchedulePoint.startTime
DispatchSchedule.timeIntervalDuration	CommonModule.DateTimeInterval
DispatchSchedule.timeIntervalUnit	CommonModule.UnitSymbolKind
DERMonitorableParameter.DERCurveData	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts
DERCurveData.nominalYValue	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yVal
DERCurveData.maxYValue	
DERCurveData.minYValue	
DERCurveData.intervalNumber	
DERCurveData.timeStamp	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.xVal.seconds
EndDeviceGroup.Names.name	solarControl.name

Dispatch

Dispatches are defined in the 61968-5 test script as a control command issued to or by a Distributed Resource Management System (DERMS) to cause a certain level of active, reactive, or apparent power to be provided to the grid by a DER group. In addition to this functionality, it can also be used to set voltage ramp rate curves. This section is thus divided into two subsections, one for active (real) power, and the other for reactive power. Because these commands are nearly identical, the bulk of this section will be contained in the DER Group Real Power (Active) Dispatch subsection, with the DER Group Reactive Power Dispatch subsection being provided only to show examples.

DER Group Real Power (Active) Dispatch

To send a message in the CIM that sets the level of active power provided to the grid, the DERGroupDispatches class is utilized in combination with the DispatchSchedule and DERCurveData classes. The DispatchSchedule class allows the user to specify when to set the rates of power being provided to the grid, in addition to how long to do so. The DERCurveStyle class and curveStyleKind are best described by the test script's documentation, placed here for convenience:

> The IEC 61968-5 profiles utilize the DERCurveData class to convey values of DER Monitorable Parameters both for a single point in time (in the DERGroupStatuses profile) as well as for a series of points in time (in the DERGroupForecasts and DERGroupDispatches profiles). For the case of a series of points in time, the curveStyleKind element specifies the way in which the time series data points are to be interpreted:
>
> - a curveStyleKind of "straightLineYValues" indicates that data over a time interval is to be linearly interpolated between the Y value at the start of the time interval and the Y value at the end of the time interval.
> - a curveStyleKind of "constantYValue" indicates that data over a time interval remains at the Y value at the beginning of the time interval and takes a step change to a new value at the end of the time interval (which is also the start of the next time interval).
>
> (Note: Interval numbering starts at 1. For curveStyleKind = "straightLineYValues", to specify n intervals, it is necessary to specify n+1values, with the (n+1)th y-value being for the start time of the (n+1)th interval. For curveStyleKind = "constantYValue", to specify n intervals, it is only necessary to specify n values, with each y-value being the value at both the start and end of the interval.)

Here is an example Real Power Dispatch command DERGD-1 from the 61968-5 test script.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:CreateDERGroupDispatches xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:m="http://iec.ch/TC57/2017/DERGroupDispatches#"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupDispatchesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupDispatchesMessage
DERGroupDispatchesMessage.xsd">
  <tns:Header>
    <Verb>create</Verb>
    <Noun>DERGroupDispatches</Noun>
    <Timestamp>2017-06-16T16:23:33-06:00</Timestamp>
    <MessageID>d463ff88-7625-46f7-b8f4-64665b7484b2</MessageID>
    <CorrelationID>5d0a1857-9e68-405a-afbe-9b5f6d3165d3</CorrelationID>
  </tns:Header>
  <tns:Payload>
    <m:DERGroupDispatches>
      <m:DERGroupDispatch>
        <m:mRID>016cf0c9-4eb6-4e6c-b6d8-d50e5746f54e</m:mRID>
        <m:EndDeviceGroup>
          <m:DERMonitorableParameter>
            <m:DERParameter>activePower</m:DERParameter>
            <m:yMultiplier>k</m:yMultiplier>
            <m:yUnit>W</m:yUnit>
            <m:DispatchSchedule>
              <m:curveStyleKind>straightLineYValues</m:curveStyleKind>
              <m:startTime>2017-06-16T17:00:00-06:00</m:startTime>
              <m:timeIntervalDuration>15</m:timeIntervalDuration>
              <m:timeIntervalUnit>m</m:timeIntervalUnit>
              <m:DERCurveData>
                <m:intervalNumber>1</m:intervalNumber>
                <m:nominalYValue>190.0</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>200.0</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>3</m:intervalNumber>
                <m:nominalYValue>200.0</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>4</m:intervalNumber>
                <m:nominalYValue>180.0</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>5</m:intervalNumber>
                <m:nominalYValue>175.0</m:nominalYValue>
              </m:DERCurveData>
            </m:DispatchSchedule>
          </m:DERMonitorableParameter>
```

```
          <m:Names>
            <m:name>GD-20170616-029</m:name>
          </m:Names>
        </m:EndDeviceGroup>
        <m:Names>
          <m:name>DG2</m:name>
        </m:Names>
      </m:DERGroupDispatch>
    </m:DERGroupDispatches>
  </tns:Payload>
</tns:CreateDERGroupDispatches>
```

The reply message to this is simply an acknowledgement that the message was received. A separate event message is sent autonomously by the server later once the dispatch has run its course.

CIM-to-OpenFMB Mapping

Mapping a Real Power Dispatch request from CIM to OpenFMB runs into some of the same issues that are encountered when attempting to map DER Group Forecasts. Attributes that can be represented by the CommonModule in OpenFMB are highlighted in yellow in the table below.

Table 2-4
DER Group Real Power Dispatch

DER Group Real Power Dispatch	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERMonitorableParameter	solarControlFSCC
DERMonitorableParameter.DERParameter	SolarControlScheduleFSCH.ValDCSG.crvPts
DERMonitorableParameter.yMultiplier	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.multiplier
DERMonitorableParameter.yUnit	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.SIUnit
DERMonitorableParameter.DispatchSchedule	
DispatchSchedule.curveStyleKind	
DispatchSchedule.numberOfIntervals	
DispatchSchedule.startTime	CommonModule.SchedulePoint.startTime
DispatchSchedule.timeIntervalDuration	CommonModule.DateTimeInterval
DispatchSchedule.timeIntervalUnit	CommonModule.UnitSymbolKind
DERMonitorableParameter.DERCurveData	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts
DERCurveData.nominalYValue	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yVal
DERCurveData.intervalNumber	

DER Group Reactive Power Dispatch

DER Group Reactive Power Dispatch commands are like their real power counterpart. This example is provided to show their similarity while also pointing out the few things that do change (the DER Parameter and yUnit).

Here is an example Active Power Dispatch command DERGD-1c from the 61968-5 test script.

```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2015 rel. 4 sp1 (x64)
(http://www.altova.com)-->
<tns:CreateDERGroupDispatches xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:m="http://iec.ch/TC57/2017/DERGroupDispatches#"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupDispatchesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupDispatchesMessage
DERGroupDispatchesMessage.xsd">
  <tns:Header>
    <Verb>create</Verb>
    <Noun>DERGroupDispatches</Noun>
    <Timestamp>2017-06-16T17:11:22-06:00</Timestamp>
    <MessageID>993e3047-5bc4-4d50-b31e-8f5850d99be7</MessageID>
    <CorrelationID>a613a3d1-c880-4f73-a90b-2c7d3f524ba1</CorrelationID>
  </tns:Header>
  <tns:Payload>
    <m:DERGroupDispatches>
      <m:DERGroupDispatch>
        <m:mRID>cf78aff3-afcf-4304-8e70-72de5ff98801</m:mRID>
        <m:EndDeviceGroup>
          <m:DERMonitorableParameter>
            <m:DERParameter>reactivePower</m:DERParameter>
            <m:yMultiplier>k</m:yMultiplier>
            <m:yUnit>VAr</m:yUnit>
            <m:DispatchSchedule>
              <m:curveStyleKind>straightLineYValues</m:curveStyleKind>
              <m:startTime>2017-06-16T18:00:00-06:00</m:startTime>
              <m:timeIntervalDuration>1</m:timeIntervalDuration>
              <m:timeIntervalUnit>h</m:timeIntervalUnit>
              <m:DERCurveData>
                <m:intervalNumber>1</m:intervalNumber>
                <m:nominalYValue>415.7</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>439.5</m:nominalYValue>
              </m:DERCurveData>
            </m:DispatchSchedule>
          </m:DERMonitorableParameter>
        </m:EndDeviceGroup>
        <m:Names>
          <m:name>DG3</m:name>
        </m:Names>
      </m:DERGroupDispatch>
      <m:DERGroupDispatch>
```

```
        <m:mRID>c646bd5c-9ca1-4d31-8e8e-33aba6ee2ab4</m:mRID>
        <m:EndDeviceGroup>
          <m:DERMonitorableParameter>
            <m:DERParameter>voltage</m:DERParameter>
            <m:yMultiplier>k</m:yMultiplier>
            <m:yUnit>V</m:yUnit>
            <m:DispatchSchedule>
              <m:curveStyleKind>constantYValue</m:curveStyleKind>
              <m:startTime>2017-06-16T18:00:00-06:00</m:startTime>
              <m:timeIntervalDuration>1</m:timeIntervalDuration>
              <m:timeIntervalUnit>h</m:timeIntervalUnit>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>12.20</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>12.35</m:nominalYValue>
              </m:DERCurveData>
            </m:DispatchSchedule>
          </m:DERMonitorableParameter>
        </m:EndDeviceGroup>
        <m:Names>
          <m:name>DG4</m:name>
        </m:Names>
      </m:DERGroupDispatch>
    </m:DERGroupDispatches>
  </tns:Payload>
</tns:CreateDERGroupDispatches>
```

CIM-to-OpenFMB Mapping

Mapping for this command would be like the DER Real Power Dispatch detailed in the above subsection.

Table 2-5
DER Group Reactive Power Dispatch

DER Group Reactive Power Dispatch	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERMonitorableParameter	solarControlFSCC
DERMonitorableParameter.DERParameter	SolarControlScheduleFSCH.ValDCSG.crvPts
DERMonitorableParameter.yMultiplier	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.multiplier
DERMonitorableParameter.yUnit	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.SIUnit
DERMonitorableParameter.DispatchSchedule	
DispatchSchedule.curveStyleKind	
DispatchSchedule.numberOfIntervals	
DispatchSchedule.startTime	CommonModule.SchedulePoint.startTime
DispatchSchedule.timeIntervalDuration	CommonModule.DateTimeInterval
DispatchSchedule.timeIntervalUnit	CommonModule.UnitSymbolKind
DERMonitorableParameter.DERCurveData	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts
DERCurveData.nominalYValue	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yVal
DERCurveData.intervalNumber	

3
IEC 61968-5 SECOND EDITION

As the 61968-5 standard evolved, a second edition of the 61968-5 Test Script was created to provide use cases for three new functions:

- DER Group Voltage Ramp Rate Dispatch
- DER Group Capability Discovery
- DER Group Connect/Disconnect

These functions leveraged updates to the 61968-5 standard while also incorporating the use of existing normative IEC 61968-9:2013 (Meter Reading and Control) messages to support the connection/disconnection of DER groups from the grid. These messages make use of the profiles regarding DER Group Dispatches, DER Groups, and EndDeviceControls in the CIM.

When mapping these to OpenFMB, similar steps can be taken to the previously defined messages since these classes are not completely new.

DER Group Voltage Ramp Rate Dispatch

In the CIM, voltage ramp rates are sent via DER Group Dispatch messages. An example of this can be found in the 61968-5 Test Script under the name DERGD-1c. In this use case, a client requests the creation of a DER Group Dispatch and the server replies that it was a success. This makes use of the DERMonitorableParameter, DERCurveData, and DERGroupDispatches classes from the CIM.

The test case below has been modified to only display the relevant ramp rate dispatch for voltage.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:CreateDERGroupDispatches xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:m="http://iec.ch/TC57/2017/DERGroupDispatches#"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupDispatchesMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupDispatchesMessage
DERGroupDispatchesMessage.xsd">
  <tns:Header>
    <Verb>create</Verb>
    <Noun>DERGroupDispatches</Noun>
    <Timestamp>2017-06-16T17:11:22-06:00</Timestamp>
    <MessageID>993e3047-5bc4-4d50-b31e-8f5850d99be7</MessageID>
    <CorrelationID>a613a3d1-c880-4f73-a90b-2c7d3f524ba1</CorrelationID>
  </tns:Header>
  <tns:Payload>
    <m:DERGroupDispatches>
      <m:DERGroupDispatch>
```

```
        <m:mRID>c646bd5c-9ca1-4d31-8e8e-33aba6ee2ab4</m:mRID>
        <m:EndDeviceGroup>
          <m:DERMonitorableParameter>
            <m:DERParameter>voltage</m:DERParameter>
            <m:yMultiplier>k</m:yMultiplier>
            <m:yUnit>V</m:yUnit>
            <m:DispatchSchedule>
              <m:curveStyleKind>constantYValue</m:curveStyleKind>
              <m:startTime>2017-06-16T18:00:00-06:00</m:startTime>
              <m:timeIntervalDuration>1</m:timeIntervalDuration>
              <m:timeIntervalUnit>h</m:timeIntervalUnit>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>12.20</m:nominalYValue>
              </m:DERCurveData>
              <m:DERCurveData>
                <m:intervalNumber>2</m:intervalNumber>
                <m:nominalYValue>12.35</m:nominalYValue>
              </m:DERCurveData>
            </m:DispatchSchedule>
          </m:DERMonitorableParameter>
        </m:EndDeviceGroup>
        <m:Names>
          <m:name>DG4</m:name>
        </m:Names>
      </m:DERGroupDispatch>
    </m:DERGroupDispatches>
  </tns:Payload>
</tns:CreateDERGroupDispatches>
```

CIM-to-OpenFMB Mapping

Even though this use case was new for the second addition of 61968-5, it was not a major change from existing dispatch requests. The mapping for this use case thus reflects the one for real and reactive power dispatch. The table is listed below for reference.

Table 3-1
DER Group Voltage Ramp Rates Dispatch

DER Group Voltage Ramp Rates Dispatch	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERMonitorableParameter	solarControlFSCC
DERMonitorableParameter.DERParameter	SolarControlScheduleFSCH.ValDCSG.crvPts
DERMonitorableParameter.yMultiplier	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.multiplier
DERMonitorableParameter.yUnit	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yUnits.SIUnit
DERMonitorableParameter.DispatchSchedule	
DispatchSchedule.curveStyleKind	
DispatchSchedule.numberOfIntervals	
DispatchSchedule.startTime	CommonModule.SchedulePoint.startTime
DispatchSchedule.timeIntervalDuration	CommonModule.DateTimeInterval
DispatchSchedule.timeIntervalUnit	CommonModule.UnitSymbolKind
DERMonitorableParameter.DERCurveData	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts
DERCurveData.nominalYValue	solarControlFSCC.controlScheduleFSCH. ValACSG.crvPts.yVal
DERCurveData.intervalNumber	

DER Group Capability Discovery

The DER group capability profile is for obtaining information regarding the installed capabilities of individual DER, and the intelligence to translate this into the functions supported by the group. At some point in time, a separate application, such as a Distribution Management System (DMS) seeks to understand the supported functions of a group of DER, and this message is utilized.

Based on a request for supported functions, a DERMS would pass a set of Boolean values for the following functions:

- connectDisconnect
- frequencyWattCurveFunction
- maxRealPowerLimiting
- rampRateControl
- reactivePowerDispatch
- realPowerDispatch
- voltageRegulation
- voltVarCurveFunction
- voltWattCurveFunction

This functionality is covered by the “get DERGroups” message, shown by test case DERG-5a in the test script.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:DERGroupQueriesRequestMessage xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:obj2="http://iec.ch/TC57/2017/DERGroupQueries#"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupQueriesMessage"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupQueriesMessage
DERGroupQueriesMessage.xsd">
  <tns:Header>
    <Verb>get</Verb>
    <Noun>DERGroups</Noun>
    <Timestamp>2017-06-02T13:22:38-06:00</Timestamp>
    <MessageID>836a18cd-d8f9-4c34-a144-7d3f59f34229</MessageID>
    <CorrelationID>37d7b6e7-8098-4960-a297-4b2cb49ca81f</CorrelationID>
  </tns:Header>
  <tns:Request>
    <obj2:DERGroupQueries>
      <obj2:EndDeviceGroup>
        <obj2:Names>
          <obj2:name>DG2</obj2:name>
        </obj2:Names>
      </obj2:EndDeviceGroup>
    </obj2:DERGroupQueries>
  </tns:Request>
</tns:DERGroupQueriesRequestMessage>
```

The response message supplied by the server then reveals the DER functions that are supported by the DER group DG2.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:DERGroupQueriesResponseMessage xmlns="http://iec.ch/TC57/2011/schema/message"
xmlns:m="http://iec.ch/TC57/2017/DERGroups#"
xmlns:xml="http://www.w3.org/XML/1998/namespace"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:tns="http://iec.ch/TC57/2017/DERGroupQueriesMessage"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xsi:schemaLocation="http://iec.ch/TC57/2017/DERGroupQueriesMessage
DERGroupQueriesMessage.xsd">
  <tns:Header>
    <Verb>reply</Verb>
    <Noun>DERGroups</Noun>
    <Timestamp>2017-06-02T13:22:45-06:00</Timestamp>
    <MessageID>16f37e9e-be26-40be-a9b8-4d7855391565</MessageID>
    <CorrelationID>37d7b6e7-8098-4960-a297-4b2cb49ca81f</CorrelationID>
  </tns:Header>
  <tns:Reply>
    <Result>OK</Result>
    <Error>
      <code>0.0</code>
    </Error>
  </tns:Reply>
  <tns:Payload>
    <m:DERGroups>
      <m:EndDeviceGroup>
        <m:mRID>228650bf-7f77-44fa-9576-db4bbce8a07f</m:mRID>
        <m:description>DER Group 2</m:description>
        <m:DERFunction>
          <m:connectDisconnect>true</m:connectDisconnect>
          <m:frequencyWattCurveFunction>false</m:frequencyWattCurveFunction>
          <m:maxRealPowerLimiting>false</m:maxRealPowerLimiting>
          <m:rampRateControl>false</m:rampRateControl>
          <m:reactivePowerDispatch>false</m:reactivePowerDispatch>
          <m:realPowerDispatch>true</m:realPowerDispatch>
          <m:voltageRegulation>false</m:voltageRegulation>
          <m:voltVarCurveFunction>false</m:voltVarCurveFunction>
          <m:voltWattCurveFunction>false</m:voltWattCurveFunction>
        </m:DERFunction>
        <m:EndDevices>
          <m:mRID>46029b51-8d94-4a06-b242-74d4a3fc2390</m:mRID>
        </m:EndDevices>
        <m:EndDevices>
          <m:mRID>13a801e1-b45d-4dbe-960f-84f04ef39fcb</m:mRID>
        </m:EndDevices>
        <m:EndDevices>
          <m:mRID>7a02c3a5-606e-4d0e-adaf-0e1b98757512</m:mRID>
        </m:EndDevices>
        <m:Names>
          <m:name>DG2</m:name>
        </m:Names>
        <m:version>
          <m:date>2017-06-02T12:30:21-06:00</m:date>
```

```
          <m:major>1</m:major>
          <m:minor>1</m:minor>
          <m:revision>0</m:revision>
        </m:version>
      </m:EndDeviceGroup>
    </m:DERGroups>
  </tns:Payload>
</tns:DERGroupQueriesResponseMessage>
```

CIM-to-OpenFMB Mapping

As with the Creation and Maintenance mapping, a few changes would need to be made to the OpenFMB data model to fully map it to the CIM, such as having multiple SolarInverters per SolarControlProfile object in order to represent multiple EndDevices in the CIM. However, since OpenFMB is designed more for device-level communications than group-level communications, it is likely that this aspect of OpenFMB will remain as-is. This is especially likely because OpenFMB uses the publish-subscribe model for communication instead of the client-server approach. Note that in addition to the attributes in the below graph, there is currently no support in OpenFMB for versioning, nor would there be an expectation of such. Versioning of a group is a function within the DERMS to track changes to a grouping of DER over time, for example, if a new DER is added to a group, or if a DER is taken out of service.

Table 3-2
DER Group Capability Discovery

DER Group Capability Discovery	
CIM Attribute	**OpenFMB Attribute**
EndDeviceGroup	solarControl
EndDeviceGroup.mRID	solarControl.mRID
EndDeviceGroup.description	solarControl.description
EndDeviceGroup.DERFunction	crvPts
DERFunction.connectDisconnect	crvPts.state
DERFunction.frequencyWattCurveFunction	crvPts.frequencySetPointEnabled
DERFunction.maxRealPowerLimiting	
DERFunction.reactivePowerDispatch	crvPts.reactivePrSetPointEnabled
DERFunction.realPowerDispatch	crvPts.realPwrSetPointEnabled
DERFunction.voltageRegulation	crvPts.voltageSetPointEnabled
DERFunction.voltVarCurveFunction	
DERFunction.voltWattCurveFunction	

DER Group Connect/Disconnect

To connect or disconnect a DER group from the grid in the CIM, the EndDeviceControls profile from 61968-9 is utilized. To show an example of this, test case DERGCD-1a will be used. In DERGCD-1a, the client requests the disconnection of a DER group and the server replies. Note that in the reply, the server's response indicates that it received the message and will attempt to disconnect the DER, but it does not indicate whether the connection of each device was successful. The message informing the client whether the disconnect is later (usually almost immediately) sent asynchronously as an event message. Note that the disconnect is sent using a 4-digit reference code in the EndDeviceControlType field.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:CreateEndDeviceControls xmlns="http://iec.ch/TC57/2011/EndDeviceControls#"
xmlns:msg="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/EndDeviceControlsMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/EndDeviceControlsMessage
EndDeviceControlsMessage.xsd">
  <tns:Header>
    <msg:Verb>create</msg:Verb>
    <msg:Noun>EndDeviceControls</msg:Noun>
    <msg:Timestamp>2017-06-20T11:24:04-06:00</msg:Timestamp>
    <msg:MessageID>aab72e66-d8b4-406c-8e18-4df2864cf947</msg:MessageID>
    <msg:CorrelationID>3a913c02-bc54-4a63-b82a-b255ffa0b7da</msg:CorrelationID>
  </tns:Header>
  <tns:Payload>
    <EndDeviceControls>
      <EndDeviceControl>
        <mRID>2b928834-b538-4244-9daf-6db54f700a76</mRID>
        <EndDeviceControlType ref="2.31.0.18"/>
        <EndDeviceGroups>
          <Names>
            <name>DG2</name>
          </Names>
        </EndDeviceGroups>
      </EndDeviceControl>
    </EndDeviceControls>
  </tns:Payload>
</tns:CreateEndDeviceControls>
```

The server then replies with the following message that simply acknowledges that it received the message.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:EndDeviceControlsResponseMessage
xmlns="http://iec.ch/TC57/2011/EndDeviceControls#"
xmlns:xml="http://www.w3.org/XML/1998/namespace"
xmlns:msg="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xmlns:tns="http://iec.ch/TC57/2017/EndDeviceControlsMessage"
xsi:schemaLocation="http://iec.ch/TC57/2017/EndDeviceControlsMessage
EndDeviceControlsMessage.xsd">
```

```
  <tns:Header>
    <msg:Verb>reply</msg:Verb>
    <msg:Noun>EndDeviceControls</msg:Noun>
    <msg:Timestamp>2017-06-20T11:24:12-06:00</msg:Timestamp>
    <msg:MessageID>e7bdb90c-17cb-42fe-a559-19022b72a130</msg:MessageID>
    <msg:CorrelationID>3a913c02-bc54-4a63-b82a-b255ffa0b7da</msg:CorrelationID>
  </tns:Header>
  <tns:Reply>
    <msg:Result>OK</msg:Result>
    <msg:Error>
      <msg:code>0.0</msg:code>
    </msg:Error>
  </tns:Reply>
</tns:EndDeviceControlsResponseMessage>
```

The server then sends messages asynchronously to the client notifying it of each meter that was disconnected. In this case, it was a successful disconnect.

```
<?xml version="1.0" encoding="UTF-8"?>
<tns:CreatedEndDeviceEvents xmlns="http://iec.ch/TC57/2011/EndDeviceEvents#"
xmlns:msg="http://iec.ch/TC57/2011/schema/message"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:tns="http://iec.ch/TC57/2017/EndDeviceEventsMessage"
xmlns:n1="http://www.altova.com/samplexml/other-namespace"
xsi:schemaLocation="http://iec.ch/TC57/2017/EndDeviceEventsMessage
EndDeviceEventsMessage.xsd">
  <tns:Header>
    <msg:Verb>created</msg:Verb>
    <msg:Noun>EndDeviceEvents</msg:Noun>
    <msg:Timestamp>2017-06-20T11:24:31-06:00</msg:Timestamp>
    <msg:MessageID>ca8fe4d0-00b7-4276-a185-f53e113f5802</msg:MessageID>
    <msg:CorrelationID>3a913c02-bc54-4a63-b82a-b255ffa0b7da</msg:CorrelationID>
  </tns:Header>
  <tns:Payload>
    <EndDeviceEvents>
      <EndDeviceEvent>
        <mRID>02a4d91f-6727-4005-8f60-b523729afd16</mRID>
        <createdDateTime>2017-06-20T11:24:28-06:00</createdDateTime>
        <Assets>
          <mRID>46029b51-8d94-4a06-b242-74d4a3fc2390</mRID>
        </Assets>
        <EndDeviceEventType ref="2.31.0.42"/>
      </EndDeviceEvent>
    </EndDeviceEvents>
  </tns:Payload>
</tns:CreatedEndDeviceEvents>
```

CIM-to-OpenFMB Mapping

The OpenFMB model isolates a similar value to its crvPoints.mode tag. Mode has a setVal tag that is an enumerated value, containing multiple specific values for DERs. The table below lists the possible values for this GridConnectModeKind type.

Table 3-3
OpenFMB's GridConnectModeKind

Name	Description
CSI	Current-source inverter (CSI)
UNDEFINED	Undefined
VC_VSI	Voltage-controlled voltage-source inverter (VC-VSI)
CC_VSI	Current-controlled voltage-source inverter (CC-VSI)
none	Not applicable/unknown
other	
VSI_PQ	Voltage source inverter regulating to P and Q references (VSI PQ)
VSI_VF	Voltage source inverter regulating to voltage and frequency references paralleling other generation and not grid forming (VSI VF).
VSI_ISO	Voltage source inverter regulating to voltage and frequency references as primary grid forming generation (VSI ISO).

The OpenFMB documentation at this time doesn't specify whether *none* or *undefined* should be used to represent disconnected status. The CIM equivalent to these codes does not exist in terms of pure connect/disconnect functionality, nor does OpenFMB have an equivalent reference code like the "2.31.0.42" in the CIM use case. Another possible value in OpenFMB to indicate connection to the grid is the crvPts.state tag, which can be set as *on*, *off*, or *standby*.

4
REFERENCES

1. NAESB (2016, March 17). *NAESB Ratifies OpenFMB*. Available [Online] http://www.greenenergycorp.com/2016/03/17/naesb-ratifies-openfmb/
2. EPRI (2016, November, 4). *Common Functions for DER Group Management*, Third Edition. Electric Power Research Institute, Palo Alto, Product ID: 3002008215. Available [Online]: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000030020082155

A
61968-5 TEST SCRIPT PROFILES

The IEC 61968-5 test script currently comprises nearly a hundred different use cases for DER group management. These are currently separated into ‘change or delete’, ‘create’, and ‘get’ profiles. For a more comprehensive look at these profiles, consult the 61968-5 test script for examples of each. More profiles could emerge as additions are made to the 61968-5 standard.

Change or Delete

The change or delete profiles are used to modify existing DER Groups in the CIM. The 61968-5 test script includes the following profiles currently:

- DERGroups.xsd
- DERGroupsMessage.xsd
- DERGroupsOperationSetMessage.xsd
- DERGroupStatuses.xsd
- DERGroupStatusesMessage.xsd
- Message.xsd

Get

In the CIM, get profiles are used to query existing data without making changes to it, similar to querying for data using Select statements in a SQL database. Most of the XSDs in the ‘get’ profiles are easily identifiable by the word queries being present in the name of the XSD file itself. The below files are present in the ‘get’ profile as of the third edition of the 61968-5 test script.

- DERGroupForecastQueries.xsd
- DERGroupForecastQueriesMessage.xsd
- DERGroupForecasts.xds
- DERGroupQueries.xsd
- DERGroupQueriesMessage.xsd
- DERGroups.xsd
- DERGroupStatuses.xsd
- DERGroupStatusQueries.xsd
- DERGroupStatusQueriesMessage.xsd

- Message.xsd

Create

The 61968-5 ‘create’ profiles in the test script handle the creation of DER Groups, DER Group Forecasts, DER Group Dispatches, and EndDeviceControls. The following profiles are used for the 61968-5 test script.

- DERGroupDispatches.xsd
- DERGroupDispatchesMessage.xsd
- DERGroupForecasts.xsd
- DERGroupForecastsMessage.xsd
- DERGroups.xsd
- DERGroupsMessage.xsd
- EndDeviceControls.xsd
- EndDeviceControlsMessage.xsd
- EndDeviceEvents.xsd
- EndDeviceEventsMessage.xsd
- Message.xsd

B
CIM DATA MODEL

The Common Information Model's data model has reached a high level of maturity and covers a variety of topics such as metering, maintenance and construction, customer information systems, distributed energy optimization, and others. This appendix serves simply as an overview of the classes within the 61968-5 and further information about them can be obtained directly from the IEC 61968-5. The tables presented here are not intended to be enough to completely construct the data model of the CIM; rather it serves as a general overview of each class.

CIM payload

The CIM payload currently is represented through XML via SOAP, although the standard will eventually support other language agnostic representations such as JSON or protocol buffers. This appendix does not go into detail about the XML payload themselves, but instead provides a quick reference to parts of the API that are used in this document or tie in with the OpenFMB model.

DEROverview

The DEROverview module within the CIM is the primary part of the 61968-5 standard. It contains data models representing DER functions (e.g. real power dispatch), dispatch schedules, monitorable parameters and more. This section will provide quick reference tables to the different pieces of the data model that comprise the 61968-5 standard.

DERFunction

The DERFunction class contains a list of boolean attributes that describe the functions that the DER is capable of handling. It is most similar to the SolarPoint module in OpenFMB. The DERFunction class is part of *DERGroups.xsd*.

Table B-1
DERFunction class

Data Type	Attribute
Boolean	connectDisconnect
Boolean	frequencyWattCurveFunction
Boolean	maxRealPowerLimiting
Boolean	rampRateControl
Boolean	reactivePowerDispatch
Boolean	realPowerDispatch
Boolean	voltageRegulation
Boolean	voltVarCurveFunction
Boolean	voltWattCurveFunction

DERMonitorableParameter

The DERMonitorableParameter class is used to report DER group status, typically used together with the DERCurveData and DispatchSchedule class.

Table B-2
DERMonitorableParameter class

Data Type	Attribute
DERParameterKind	DERParameter
flowDirectionKind	flowDirection
UnitMultiplier	yMultiplier
DERUnitSymbol	yUnit
Float	yUnitInstalledMax
Float	yUnitInstalledMin
DispatchSchedule	DispatchSchedule
DERCurveData	DERCurveData

DispatchSchedule

The DispatchSchedule class is used to handle active, reactive, and apparent power dispatch requests, as well as the voltage ramp rate curve dispatches. It is a subclass of the DERMonitorableParameter class and also contains its own DERCurveData subclass.

Table B-3
DispatchSchedule class

Data Type	Attribute
PerCent	confidence
CurveStyle	CurveStyleKind
Integer	numberOfIntervals
DateTime	startTime
Integer	timeIntervalDuration
TimeIntervalKind	timeIntervalUnit
DERCurveData	DERCurveData

DERCurveData

The DERCurveData class is used in together with the DERMonitorableParameter and DispatchSchedule class.

Table B-4
DERCurveData class

Data Type	Attribute
Integer	intervalNumber
Float	maxYValue
Float	minYvalue
Float	nominalYValue
dateTime	timestamp

DERParameterKind

DERParameterKind is an enumerated class (i.e. restricted to specific string values) representing which DER parameter is being acted upon in a DER group messages. This particular class is limited to the string values listed below.

- apparentPower
- activePower
- reactivePower
- highFilterBiDirectionalRegulation
- lowFilterBiDirectionalRegulation
- highFilterUpRegulation
- lowFilterUpRegulation
- highFilterDownRegulation
- lowFilterDownRegulation
- increasingRampRate
- decreasingRampRate
- voltage

DERUnitSymbol

DERUnitSymbol is an enumerated class that can be almost directly mapped to the UnitSymbolKind class in OpenFMB's CommonModule. Because OpenFMB directly bases their UnitSymbolKind class off of the CIM, the table in this section includes a reference to whether an OpenFMB counterpart exists for each Attribute. The following table shows the DERUnitSymbol

class as defined in the 61968-5 standard, its description, and whether an equivalent exists in OpenFMB.

Table B-5
DERUnitSymbol class

Attribute	Description	OpenFMB?
A	Current in Ampere.	yes (Amp)
Ah	Ampere-hours, Ampere-hours.	yes
As	Ampere seconds (A·s).	
Btu	Energy, British Thermal Unit.	
Hz	Frequency in Hertz (1/s).	yes
V	Electric potential in Volt (W/A).	yes
VA	Apparent power in Volt Ampere (See also real power and reactive power.)	yes
rhVAh	Apparent energy in Volt Ampere hours.	
VAr	Reactive power in Volt Ampere reactive. The “reactive” or “imaginary” component of electrical power (VIsin(phi)). (See also real power and apparent power).	yes
VArh	Reactive energy in Volt Ampere reactive hours.	yes
VPerVA	Power factor, PF, the ratio of the active power to the apparent power. Note: The sign convention used for power factor will differ between IEC meters and EEI (ANSI) meters. It is assumed that the data consumers understand the type of meter being used and agree on the sign convention in use at any given utility.	
VperVAr	Power factor, PF, the ratio of the active power to the apparent power. Note: The sign convention used for power factor will differ between IEC meters and EEI (ANSI) meters. It is assumed that the data consumers understand the type of meter being used and agree on the sign convention in use at any given utility.	
Vh	Volt-hour, Volt hours.	
Vs	Volt second (Ws/A).	
W	Real power in Watt (J/s). Electrical power may have real and reactive components. The real portion of electrical power (I^2R or VIcos(phi)), is expressed in Watts. (See also apparent power and reactive power.)	yes
WPerA	Active power per current flow, watt per Ampere.	
WPers	Ramp rate in Watt per second.	yes (wPerS)
Wh	Real energy in Watt hours.	yes
deg	Plane angle in degrees.	yes
degC	Relative temperature in degrees Celsius.	yes
h	Time, hour = 60 min = 3600 s.	yes (hour)
min	Time, minute = 60 s.	yes
ohm	Electric resistance in ohm (V/A).	yes
ohmPerm	Electric resistance per length in ohm per metre ((V/A)/m).	
ohmm	resistivity, Ohm metre, (rho).	
onePerHz	Reciprocal of frequency (1/Hz).	
therm	Energy, Therm	

Common Module

The CIM Common module contains similar classes to OpenFMB. In fact, OpenFMB directly attributes some of its classes in its CommonModule to the CIM. The following classes are inherited by multiple components of the CIM data model and are part of the Common class.

IdentifiedObject

According to the CIM documentation, IdentifiedObject "is a root class to provide common identification for all classes needing identification and naming attributes."

Table B-6
IdentifiedObject class (CIM)

Data Type	Attribute
String	aliasName
String	description
String	mRID
String	name

Name

According to the CIM documentation, "the Name class provides the means to define any number of human readable names for an object. A name is not to be used for defining inter-object relationships. For inter-object relationships instead use the object identification 'mRID'."

Table B-7
Name class (CIM)

Data Type	Attribute
String	name

NameType

According to the CIM documentation

> *Type of name. Possible values for attribute 'name' are implementation dependent but standard profiles may specify types. An enterprise may have multiple IT systems each having its own local name for the same object, e.g. a planning system may have different names from an EMS. An object may also have different names within the same IT system, e.g. localName as defined in CIM version 14. The definition from CIM14 is:*
>
> *The localName is a human readable name of the object. It is a free text name local to a node in a naming hierarchy similar to a file directory structure. A power system related naming hierarchy may be: Substation, VoltageLevel, Equipment etc. Children of the same parent in such a hierarchy have names that typically are unique among them.*

Table B-8
NameType class (CIM)

Data Type	Attribute
String	description
String	name

NameTypeAuthority

According to the CIM documentation, NameTypeAuthority is the "authority responsible for creation and management of names of a given type; typically, an organization or an enterprise system." It contains the same fields as its parent's class, NameType.

Table B-9
NameTypeAuthority class (CIM)

Data Type	Attribute
String	description
String	name

EndDeviceControls

The EndDeviceControls class from part 9 is used to send connect/disconnect messages in the 61968-5 test script. For the purposes of this appendix, the various parts attributes of an EndDeviceControl will not be described in detail; they will be listed here for reference only. EndDeviceControls inherits the IdentifiedObject class, meaning that in addition to the fields listed below it contains all of those in the IdentifiedObject class, such as the mRID.

Table B-10
EndDeviceControls class

Data Type	Attribute
EndDeviceControlType	EndDeviceControlType
EndDevice	EndDevice
EndDeviceGroup	EndDeviceGroup
UsagePointGroup	UsagePointGroup
Integer	drProgramLevel
Boolean	drProgramMandatory
String	issuerID
FloatQuantity	priceSignal
EndDeviceTiming	primaryDeviceTiming
String	reason
DateTimeInterval	scheduledInterval
EndDeviceTiming	secondaryDeviceTiming

EndDeviceControlType

In the connect/disconnect use case, the EndDeviceControlType is used to reference a code that means “disconnect the DER group from the grid”. The EndDeviceControlType inherits the IdentifiedObject class and is listed below in detail.

Table B-11
EndDeviceControlType class

Data Type	Attribute
String	domain
String	eventOrAction
String	subDomain
String	type

EndDeviceGroup

The EndDeviceGroup class inherits the IdentifiedObject class and has no additional attributes in the part 9 profile, however, in the part 5 profile it gains three additional attributes in addition to the InheritedObject.

Table B-12
EndDeviceGroup class

Data Type	Attribute
Status	status
String	type
Version	version

C
OPENFMB DATA MODEL

Similar to the Common Information Model, the OpenFMB data model consists of multiple modules related to various parts of grid communication. The data model is not meant to be described in full detail in these tables; rather this section serves as a reference to the relevant classes that might be used to map to the IEC 61968-5 messages.

OpenFMB Payload

Although the OpenFMB payload can be interpreted using XML or JSON, OpenFMB currently uses protocol buffers to represent its payload instead of XML as used in the 61968-5 test script. This leads to a JSON-like representation of the data that is simpler to read, smaller in size, and 20 to 100 times faster to process than XML. Like XML payloads, protocol buffers are language agnostic and can utilized by software written in Java, C++, Python, and more.

This appendix does not serve as a comprehensive description of the OpenFMB data model as represented by protocol buffers, but rather as a quick reference to parts of the API that relate in some way to the IEC 61968-5 standard. However, if a particular class has extra attributes that are not utilized by the CIM, these attributes are still included in the table for that class.

SolarControlModule

OpenFMB's SolarModule contains multiple messages relating to solar inverters, photovoltaics, and the like. The following tables list each message within the SolarModule protocol buffer, listing its type, name, and description per the documentation. The SolarModule would be most similar to the EndDeviceGroup in the 61968-5 model, however, it falls just short due to its constraint of only allowing one solarInverter (in the case of the 61968-5, the EndDevice) object.

SolarInverter

The SolarInterter class inherits the NamedObject class and is limited to one per SolarControlProfile.

IED

The IED class inherits the IdentifiedObject class and is limited to one per SolarControlProfile.

SolarPoint

The SolarPoint message in OpenFMB is used for point definitions

Table C-1
SolarPoint class

Data Type	Attribute	Description
commonmodule.ControlDPC	frequencySetPointEnabled	Enable frequency point
commonmodule.ENG_GridConnectModeKind	Mode	Grid connect mode
Float	pctHzDroop	Black start enable
Float	pctVDroop	Black start enable
commonmodule.RampRate	rampRates	Ramp rates
commonmodule.ControlDPC	reactivePwrSetPointEnabled	Enable reactive power set point
commonmodule.ControlDPC	realPwrSetPointEnabled	Enable real power set point
commonmodule.ControlDPC	reset	Reset device
commonmodule.Optional_Statekind	state	ESS state
commonmodule.ControlDPC	voltageSetPointEnabled	Enable voltage set point
commonmodule.ControlTimestamp	startTime	x-axis value (Unix time)

SolarCSG

The SolarCSG message is used for curve shape setting and has only one defined attribute. The “repeated” typing in Google protocol buffers is defined as being able to repeat any number of times (including zero) in a well-formed message.

Table C-2
SolarCSG class

Data Type	Attribute	Description
repeated SolarPoint	crvPts	The array with multiple points specifying a curve shape.

SolarPointStatus

The SolarPointStatus message, similar to SolarPoint defined above, is for point definitions.

Table C-3
SolarPointStatus class

Data Type	Attribute	Description
commonmodule.ControlDPC	frequencySetPointEnabled	Enable frequency point
commonmodule.ENG_GridConnectModeKind	mode	Grid connect mode
Float	pctHzDroop	Black start enable
Float	pctVDroop	Black start enable
commonmodule.RampRate	rampRates	Ramp rates
commonmodule.ControlDPC	reactivePwrSetPointEnabled	Enable reactive power set point
commonmodule.ControlDPC	realPwrSetPointEnabled	Enable real power set point
commonmodule.Optional_Statekind	state	ESS state
commonmodule.ControlDPC	voltageSetPointEnabled	Enable voltage set point

CommonModule

OpenFMB's CommonModule is similar in many ways to CIM's *Message.xsd* profile. Within the CommonModule profile, many common attributes that are shared across profiles are kept. Note, for instance, that the vast majority of the SolarModule definitions are actually defined in the CommonModule profile. In this Appendix, parts of the CommonModule that are used in SolarModule or in other ways relate to the IEC 61968-5 standard are listed for reference.

IdentifiedObject

The IdentifiedObject class is a root class to provide common identification for all classes that need both identification and naming attributes.

Table C-4
IdentifiedObject class (OpenFMB)

Data Type	Attribute	Description
String	description	description of the Names object
String	mRID	master resource identifier issued by a model authority. The mRID must semantically be a UUID as specified in RFC 4122. The mRID is globally unique.
String	name	the name is any human-readable and possibly non-unique text identifying an object.

NamedObject

Within OpenFMB, NamedObject is a root class similar to Identified Object but without the mRID, similar to the CIM Names class. These two classes are separated because the mRID may need to be defined as a separate key field for technology such as the DDS implementation.

Table C-5
NamedObject class

Data Type	Attribute	Description
String	description	description of the Names object
String	name	the name is any human-readable and possibly non-unique text identifying an object.

UnitSymbolKind

OpenFMB's UnitSymbolKind class is directly taken from the CIM and is used to define multiple units. It is an enumerated class with the following values. The name for each of these is *UnitSymbolKind_* followed by the name, e.g. *UnitSymbolKind_degC*. Within the CIM these values are used for functions such as real power dispatch, reactive power dispatch, and others. Although OpenFMB uses this same class, the data model is not set up to use this class in places that the CIM uses them, such as when setting ramp rates.

Table C-6
UnitSymbolKind class (OpenFMB)

Attribute	Description
none	dimensionless quality, e.g. count, per unit, etc.
meter	length in meter
gram	mass in gram
Amp	current in ampere
deg	plane angle in degrees
rad	plane angle in radians
degC	relative temperature in degrees Celsius. To distinguish degrees Celsius from the coulomb the symbol used in the UML is degC.
Farad	capacitance in farad
sec	time in seconds
Henry	inductance in Henry
V	voltage in volt
ohm	resistance in ohm
Joule	energy in joule
Newton	force in Newton

Table C-6 (continued)
UnitSymbolKind class (OpenFMB)

Attribute	Description
Hz	frequency in hertz
W	active power in watt
Pa	pressure in pascal (n/m2)
m2	area in square meters
Siemens	conductance in siemens
VA	apparent power in volt ampere
VAr	reactive power in volt ampere reactive
wPerVA	power factor
VAh	apparent energy in volt ampere hours
Wh	real energy in watt hours
VArh	reactive energy in volt ampere reactive hours
hzPerS	hertz per second
wPerS	watts per second
other	other enum not listed
Ah	amp hour
min	time in minutes
hour	time in hours
m3	volume in cubic meters
wPerM2	watts per square meter
degF	relative temperature in degrees fahrenheit
mph	miles per hour

UnitMultiplierKind

Like UnitSymbolKind, UnitMultiplierKind is also taken directly from the CIM. Each variable name is prefaced with *UnitMultiplierKind_*, e.g. *UnitMultiplierKind_centi*.

Table C-7
UnitMultiplierKind class

Attribute	Description
none	no multiplier or equivalently multiply by 1
other	other enum not listed
centi	10**-2
deci	10**-1
Giga	10**9
kilo	10**3
Mega	10 **6
micro	10**-6
milli	10**-3
nano	10**-9
pico	10**-12
Tera	10**12

ActivePower

The ActivePower class within OpenFMB's CommonModule contains three variables. These would be set alongside other fields if wanting to mirror something similar to CIM's DER Group Dispatch function.

Table C-8
ActivePower class

Data Type	Attribute
Optional_UnitMultiplierKind	multiplier
Optional_UnitSymbolKind	unit
Float	value

The *multiplier* and *unit* behave like a class object in most programming languages, i.e. *multiplier* can be any of the UnitMultiplierKind possibilities. It would be the responsibility of the vendor system or message translator to catch whether valid options were used for those variables.

RampRate

Ramp rate comprises four total variables defining how the ramp rate can be set. Unlike the CIM where the UnitSymbolKind and UnitMultiplierKind values are used to set the ramp rate, OpenFMB has four defined values for setting ramp rate, meaning a conversion would be needed if the system using the CIM is using different values instead of minutes, for example.

Table C-9
RampRate class

Data Type	Attribute
Float	negativeReactivePowerKVArPerMin
Float	negativeRealPowerKWPerMin
Float	positiveReactivePowerKVArPerMin
Float	positiveRealPowerKWPerMin

ControlDPC

The ControlDPC class is documented as a specialized DPC 61860 CDC class. It contains only one variable: the Boolean *ctlVal*, which is described in the documentation as a "service parameter that determines the control activity ('false' for off, 'true' for on)." For the purposes of this report, this is primarily used to represent the true/false value for enabling reactive power, real power, frequency set points, and voltage set points.

ControlTimeStamp

ControlTimeStamp represents UNIX time; that is, it represents UTC time with the epoch of midnight on January 1, 1970. ControlTimeStamp specifically is a timestamp for a future time point, and as a result does not contain the same time quality as the normal Timestamp data type.

Table C-10
ControlTimeStamp class

Data Type	Attribute	Description
uint32	fraction	fractional of the current second when the value of time stamp has been determined. It shall be calculated as (SUM from i=0 to 31 of bi*2**-(i+1))
uint64	seconds	number of seconds since epoch (1970-01-01T00:00:00Z)

MessageInfo

The MessageInfo class contains generic control message info and can be directly mapped to the CIM header tag. It contains the **IndentifiedObject** (comprising name, MRID, and description) class, and a **Timestamp** object, correlating to CIM's Timestamp tag for when a message is sent. The MessageInfo class is typically an inherited class, such as in the SolarControlProfile's ControlMessageInfo class, which uses messageTimeStamp from MessageInfo, in addition to all parts of the IdentifiedObject class (mRID, name, and description).

GridConnectModeKind

OpenFMB's GridConnectModeKind class is defined as "power system connect modes to the power grid." These are all defined as *GridConnectModeKind_* followed by the name, e.g. *GridConnectModeKind_other*. These values are all specific to different types of DER connections.

Table C-11
GridConnectModeKind class

Attribute	Description
CSI	Current-source inverter (CSI)
UNDEFINED	Undefined
VC_VSI	Voltage-controlled voltage-source inverter (VC-VSI)
CC_VSI	Current-controlled voltage-source inverter (CC-VSI)
none	Not applicable/unknown
other	
VSI_PQ	Voltage source inverter regulating to P and Q references (VSI PQ)
VSI_VF	Voltage source inverter regulating to voltage and frequency references paralleling other generation and not grid forming (VSI VF).
VSI_ISO	Voltage source inverter regulating to voltage and frequency references as primary grid forming generation (VSI ISO).

OptimizerModule

One of the closest equivalent emulating CIM's DER Groups is through OpenFMB's OptimizerModule. The OptimizerModule contains the RequestedOptimizerScheduleProfile class, which inherits from MessageInfo to convey similar information to the Header in CIM while also containing the capability to contain a list of any OpenFMB profile. In other words, if the SolarControlProfile is used to represent a DER Group, then the OptimizerModule would be used to represent one-to-many of those. Below is a snippet of the data model for the RequestedOptimizerScheduleProfile.

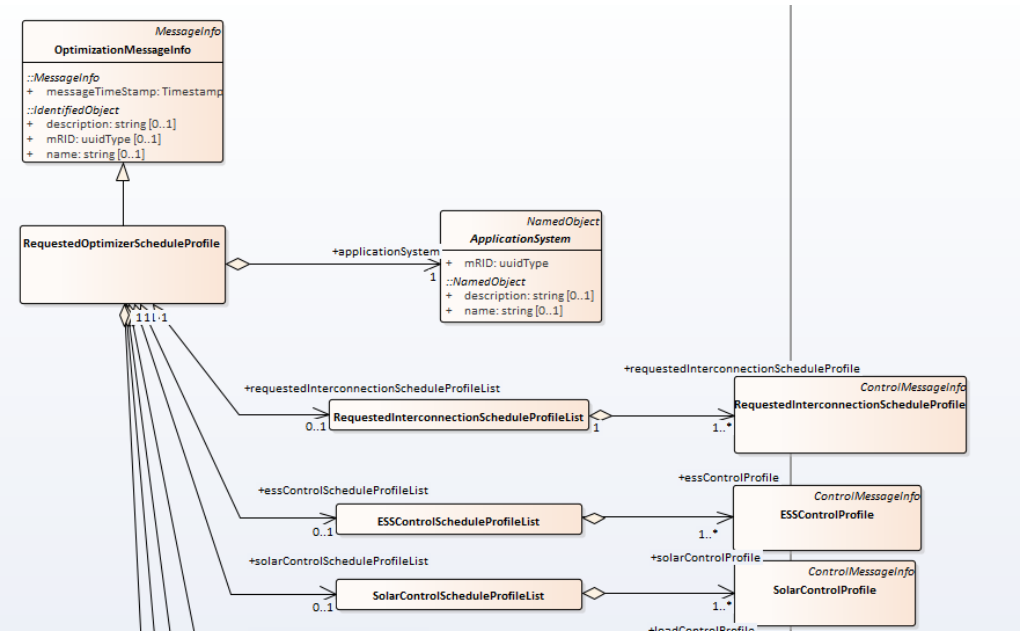


Figure C-1
OptimizerModule data model

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