



DPC: 23 / 30472052 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 28 March 2023

Origin: International

Latest date for receipt of comments: 16 May 2023

Project No. 2023/00716

Responsible committee: PEL/57 Power systems management and associated information exchange

Interested committees:

Title: BS EN IEC 62746-4 Systems interface between customer energy management system and the power management system

Part 4: Demand Side Resource Interface

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

**WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD.
THIS DRAFT IS NOT CURRENT BEYOND 16 May 2023**

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop <http://shop.bsigroup.com> or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from <http://standardsdevelopment.bsigroup.com>

Responsible Committee Secretary: **Ms Andreea Vieru (BSI)**
Direct tel: **0208 996 7432**
E-mail: **andreea.vieru@bsigroup.com**

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER:

IEC 62746-4 ED1

DATE OF CIRCULATION:

2023-03-24

CLOSING DATE FOR COMMENTS:

2023-06-16

SUPERSEDES DOCUMENTS:

57/2520/NP, 57/2574/RVN

IEC TC 57 : POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE

SECRETARIAT:

Germany

SECRETARY:

Mr Heiko Englert

OF INTEREST TO THE FOLLOWING COMMITTEES:

SC 23K

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC☐ ENVIRONMENT☐ QUALITY ASSURANCE☐ SAFETY

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (See [AC/22/2007](#) or [New Guidance.doc](#)).

TITLE:

**Systems interface between customer energy management system and the power management system – Part 4:
Demand Side Resource Interface**

NOTE FROM TC/SC OFFICERS:

Copyright © 2023 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

CONTENTS

FOREWORD	4
INTRODUCTION	6
1 Scope	7
1.1 Scope of full standard	7
1.2 Scope of this document	7
2 Normative references	7
3 Terms, definitions, and abbreviations	9
3.1 Abbreviation and Acronym Definitions	9
3.2 Term Definitions	9
4 Reference and Information Models	11
4.1 General Approach	11
4.2 Reference Communication Model	12
4.3 Information Model	15
5 Core Modelling & Shared Enumerations	26
5.1 Master Resource Identifiers	26
5.2 Compound Classes	26
5.3 Shared Data Types	33
6 Message Profiles	39
6.1 Market DER Profile	39
6.2 Reference Energy Curve Profile	44
6.3 Bid/Offer Curve Profile	48
6.4 Dispatch Profile	56
6.5 Commodity Price Exchange Profile	61
7 Message Sequences	64
7.1 General	64
7.2 Inform	66
7.3 Incentivise	66
7.4 Plan	66
7.5 Schedule	66
7.6 Report	66
7.7 Evaluate	67
Annex A: Use Case: Energy Management of Groups of Buildings based on Financial Incentives from Electricity Markets	68
a. Scope and Objectives	68
b. Actors	70
c. Process Overview	71
d. Process Details	72
e. Possibilities for control parameters	79
f. Implementation using CIM Profiles defined in this document	80
Annex B: Profile UML Diagrams	81
a. MarketDER	81
b. ReferenceEnergyCurve	82
c. MarketDERBidOffer	83
d. MarketDERInstruction	84
e. CommodityPriceExchange	84
Annex C: XML Schemas	85
Annex D: Sample XML	86

Figure 1: IEC 62746-4 Representation	11
Figure 2: SPS-CEMS Communication Logical Model	12
Figure 3: SPS-AEMS-CEMS Communications Logical Model	13
Figure 4: Example of “Stacked” Aggregators	14
Figure 5: Resource Model	15
Figure 6: Location Model	16
Figure 7: Node Mapping.....	17
Figure 8: Connectivity & Pricing / Nodes & Zones	18
Figure 9: Capacity & Qualification Model	19
Figure 10: Energy Schedule Model	20
Figure 11: Price-Based Versus Self-Schedule	22
Figure 12: Price-Sensitive Offers/Bids	23
Figure 13: Dispatch Model	23
Figure 14: Commodity Model	24
Figure 15: Price Model.....	25
Figure 16: MarketDER Schema.....	40
Figure 17: Resource Capacity Sub-Schema	42
Figure 18: Resource Certification Sub-Schema	43
Figure 19: Reference Energy Curve Schema	44
Figure 20: Resource Time Series Sub-Schema	45
Figure 21: Time Points Sub-Sub-Schema.....	47
Figure 22: Bid/Offer Curve Schema	48
Figure 23: Product Bid Sub-Schema	50
Figure 24: Price-Sensitive Bid/Offer Sub-Sub-Schema	51
Figure 25: BidPriceCurve Sub-Sub-Schema	52
Figure 26: CurveDatas Sub-Sub-Schema	53
Figure 27: BidSelfSched Sub-Sub-Schema	54
Figure 28: TimePoints Sub-Sub-Schema.....	55
Figure 29: Dispatch Schema	56
Figure 30: Distributed Resource Actual Event Sub-Scheme	57
Figure 31: Instruction Clearing Sub-Schema	58
Figure 32: Market Occurrence Sub-Schema	60
Figure 33: Commodity Price Exchange Schema	61
Figure 34: Commodity Price Schema	63
Figure 35: Sequence Diagram.....	65
Figure 36: Examples of Energy Values for Demand Response Exchanges	67
Table 1: List of Acronyms	9
Table 2: List of Definitions	9
Table 3: ScheduleKind	21
Table 4: Unit Symbol & Unit Multiplier Data Types	33
Table 5: Yes/No, Priority & Currency.....	34
Table 6: Market-Related Enumerations	35
Table 7: Price-Related Enumerations	36
Table 8: Resource-Related Enumerations	37
Table 9: Scheduling-Related Enumerations.....	38

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SYSTEMS INTERFACE BETWEEN CUSTOMER ENERGY MANAGEMENT SYSTEM AND THE POWER MANAGEMENT SYSTEM –

Part 4: Demand Side Resource Interface

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62746-4 ED1 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this document the stability date is **20XX..**

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

INTRODUCTION

This document is one of the IEC 62746 series which define interface between the Smart Grids and residential and commercial building and industrial energy management systems.

The principal objectives of the IEC 62764 series of standards is to leverage the management of customer energy resources. These resources may be a combination of load and generation resources that can be managed to respond to signals provided by grid and/or market operators. These resources may be identified and managed as individual resources with specific capabilities, or as virtual resources with an aggregated set of capabilities.

This document describes CIM profiles corresponding the Use Case described in Annex A.

Statements have been added to certain figures, tables, schemas, and enumerations throughout the document that indicate that they are reproduced with the permission of the UCA International User Group (UCAIug). These items are derived from the Common Information Model (CIM).

SYSTEMS INTERFACE BETWEEN CUSTOMER ENERGY MANAGEMENT SYSTEM AND THE POWER MANAGEMENT SYSTEM

Part 4 Ed.1: Demand Side Resource Interface

1 Scope

1.1 Scope of full standard

The IEC 62746 series describes the interface between Customer Energy Management Systems (CEMS) and the grid management systems includes those within Distribution System Operators (DSOs) and Transmission System Operators (TSOs). Each CEMS is designed to control resources associated with a residential, commercial, or industrial facility with the potential for a hierarchy of energy management systems.

Initial focus is on demand response and support for demand side management; later developments are expected to include storage resources as well as grid support services from new demand-side resources. The interface may also be applied to many types of communications, for example among multiple aggregators, or among an aggregator and multiple customers.

1.2 Scope of this document

This document is Part 4 of the IEC 62746 series and describes CIM profiles for Demand side Resource Interface, which is based on the Use Case shown in Annex A of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Demand Side Resource Interface, Edition 1, available at:
<https://hdl.handle.net/20.500.14284/DemandSideResourceInterfaceV1>

IEC 62746-2:2015, Systems Interface between Customer Energy Management System and the Power Management System – Part 2: Use Cases and Requirements

IEC TS 62746-3:2015, Systems interface between customer energy management system and the power management system - Part 3: Architecture

IEC 61968-11:2013, Application integration at electric utilities - System interfaces for distribution management - Part 11: Common information model (CIM) extensions for distribution

IEC 61968-100:2013, System interfaces for distribution management – Part 100: Implementation Profiles

IEC 61970-301:2016, Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base

IEC 62325-301 Framework for energy market communications - Part 301: Common information model (CIM) extensions for markets.

- 53 IEC 62361-100, Power systems management and associated information exchange
54 Interoperability in the long term – Part 100: CIM profiles to XML schema mapping
55

3 Terms, definitions, and abbreviations

3.1 Abbreviation and Acronym Definitions

For the purposes of this document, the following abbreviations and acronyms apply:

Table 1: List of Acronyms

Acronym	Phrase
AEMS	Aggregator Energy Management System
CEMS	Customer Energy Management System
DER	Distributed Energy Resource
SPS	Service Procurement System
UML	Unified Modeling Language
XML	Extensible Markup Language
XSD	XML Schema Definition

3.2 Term Definitions

For the purposes of this document the following term definitions apply:

Table 2: List of Definitions

Term	Definition
Aggregation	Aggregation is the collection of the capabilities of multiple resources into a single virtual resource. A common use of aggregation is to collect many small resources and offer their capabilities in the form of a single larger resource to a market (IEC 62746-3)
Aggregator Energy Management System	A collection of hardware and/or software components which together act as an intermediary between a Service Procurement System and multiple Customer Energy Management Systems
Customer Energy Management System	A collection of hardware and/or software components which together coordinate the electricity usage and production among various Distributed Energy Resources
Distributed Energy Resource	Generators (with their auxiliaries, protection, and connection equipment), including loads having a generating mode (such as electrical energy storage systems), connected to a low-voltage or a medium-voltage network [www.electropedia.org]
Operator Role	The “upper” side of the DER communication chain, representing the entity which is responsible for procuring services and distributing operational controls and prices.
Resource Role	The “lower” side of the DER communication chain, representing the entity which is responsible for providing services and responding to operational controls and prices

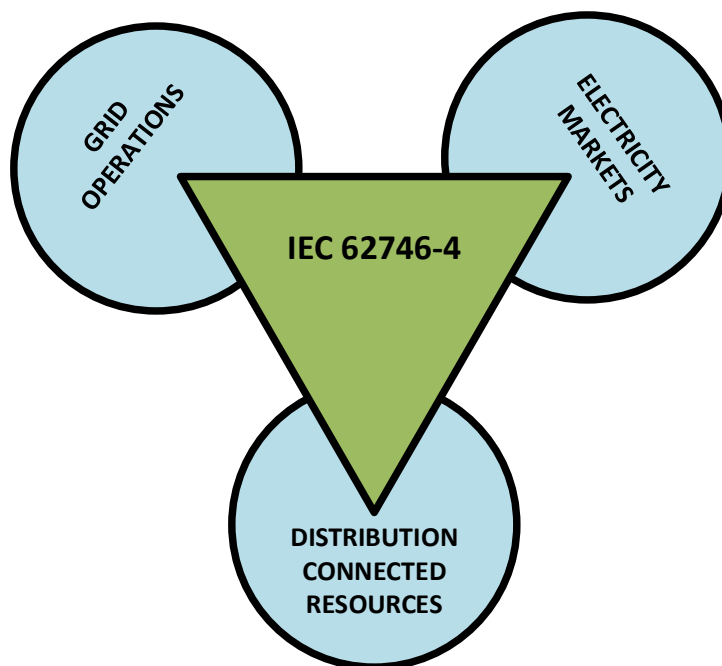
Service Procurement System	A collection of hardware and/or software component which together procure services to make the electrical grid more reliable and/or less costly.
Technical Role	Actors defined by use cases have assigned roles with associated responsibilities. Technical roles are those roles that identify responsibilities associated with participation within information exchanges with other actors. Technical roles are physically realized through software and associated systems integration infrastructure. (IEC 62746-3)
Virtual Resource	A set of one or more physical resources that is represented as a single, aggregated resource. This may be comprised of multiple entities that may be geographically distributed. Virtual Resources can be an aggregated model of many types of load, generation and storage, such as VPP, PV, factory, building, home, etc. Since the Virtual Resource can include both energy consumer and energy provider, the related “net load curve” can be positive (in this case the Virtual Resource acts as a consumer which consumes electrical power), or negative (in this case the Virtual Resource acts as generation assets to produce electrical power). (IEC 62746-3)

4 Reference and Information Models

4.1 General Approach

Communications between electricity markets and grid operations are enabled by shared modelling among three series of standards: IEC 61968, IEC 61970, and IEC 62325. However, none of these standards extend into the domain of controllable resources deployed on the distribution grid, and specifically to those resources “behind” the customer electricity meter. IEC 62746 remedies this situation by providing a set of message profiles designed to convey grid instructions, grid conditions, pricing signals, and resources capabilities among multiple parties within the emerging Distributed Energy Resource (DER) space.

Figure 1: IEC 62746-4 Representation



The communication requirements are challenging given the wide range of communicating parties, including:

- Electricity market operators,
- Transmission system operators (TSOs),
- Wholesale electricity service providers,
- Wholesale electricity service consumers,
- Distribution grid operators (DSOs),
- Service aggregators, and
- Electricity consumers

Additionally, there is a wide range of business processes which are established as well as many new models being devised. These processes include the communication of the time-varying changes in:

- Resource composition by grid location(s)
- Resource capability by market service

- Economic thresholds for service delivery/procurement
- Resource instructions/dispatches

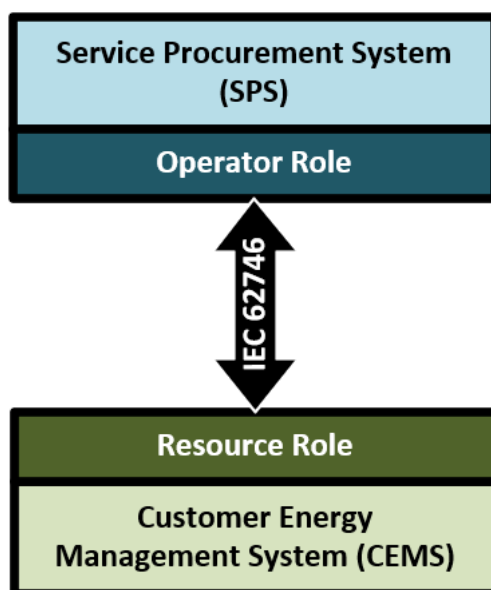
The challenge of communicating with DERs (or their aggregators) can be visualized as a more complex permutation of the communication with traditional bulk-power electricity generation stations. Therefore, IEC 62746-4 leverages the IEC 62325 set of standards which are currently in use to standardize bulk-power market exchanges.

4.2 Reference Communication Model

This reference model has two Technical Roles: the Operator Role and Resource Role. The Operator Role, in the simplest configuration, is performed by a grid operator with any number of applications which are used to track, manage, forecast, incentivise, control, and monitor DERs. This collection of software we group as a single collection labelled the Service Procurement System (SPS), as it has the responsibility of procuring grid services to make the grid more reliable and/or make electricity costs lower. The distribution customer who owns a DER takes on the Resource Role, with the collection of software controlling the customer's facility termed the Customer Energy Management System (CEMS). Figure 2 illustrates the logical model for these communications in this base configuration.

Figure 2: SPS-CEMS Communication Logical Model

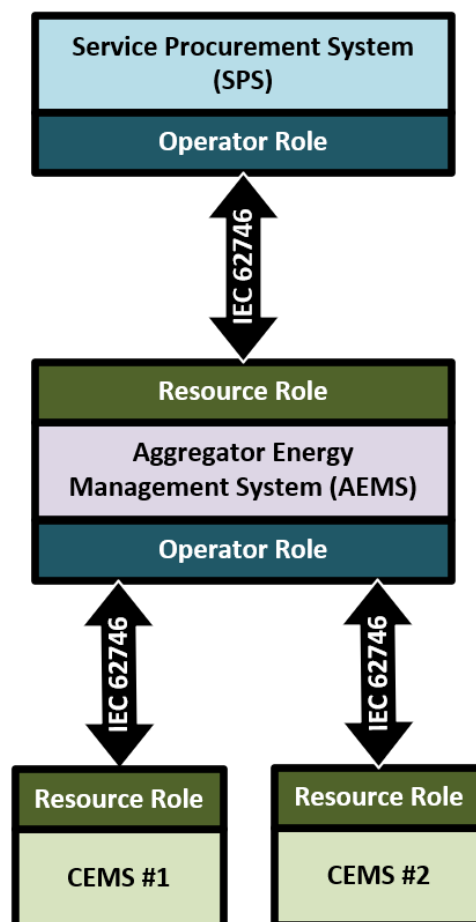
Reproduced with the permission of UCAIug



Individual DERs may not be large enough to warrant direct participation in grid operations and may be better served as members of a DER aggregation. When Aggregation is introduced into the communication chain, the Aggregator Energy Management System (AEMS) acts as intermediary for communications between the SPS and many CEMSs. However, the AEMS is not simply a broker of information; the AEMS performs aggregation functions (such as adding together individual CEMS capabilities to pass to the SPS) and allocation functions (such as dividing dispatch signals across the participating CEMSs). IEC 62746-4 is used on both ends of the exchange, with the AEMS performing the Resource Role when communicating with the SPS and the Operator Role when communicating with each CEMS, as shown in Figure 3. Thus, the AEMS appears to the SPS as a Virtual Resource.

Figure 3: SPS-AEMS-CEMS Communications Logical Model

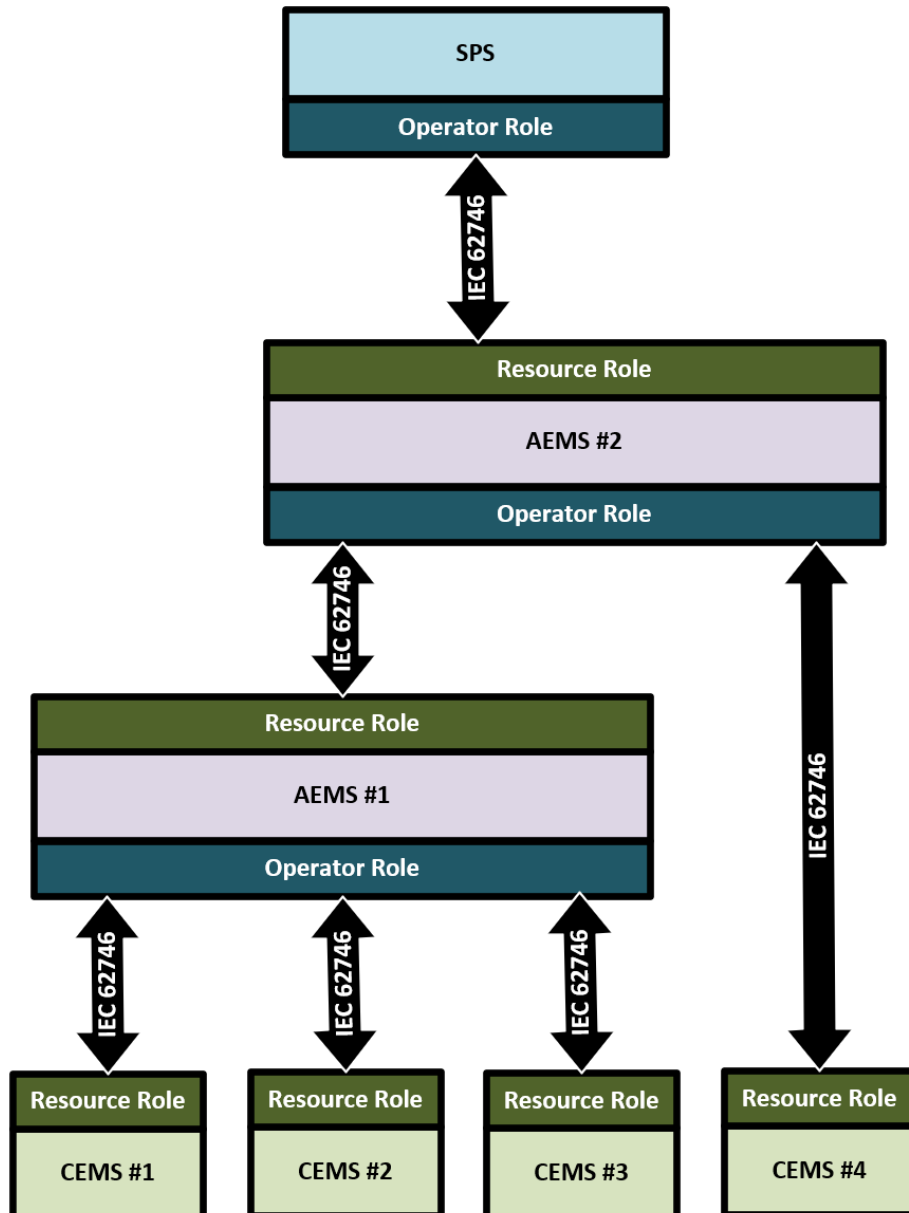
Reproduced with the permission of UCAIug



The communication model may be expanded to any number of AEMS instances connected to any number of CEMS instances, including configurations where “aggregators of aggregators” are established. An example of this more complex configuration is shown in Figure 4.

Figure 4: Example of “Stacked” Aggregators

Reproduced with the permission of UCAIug



4.3 Information Model

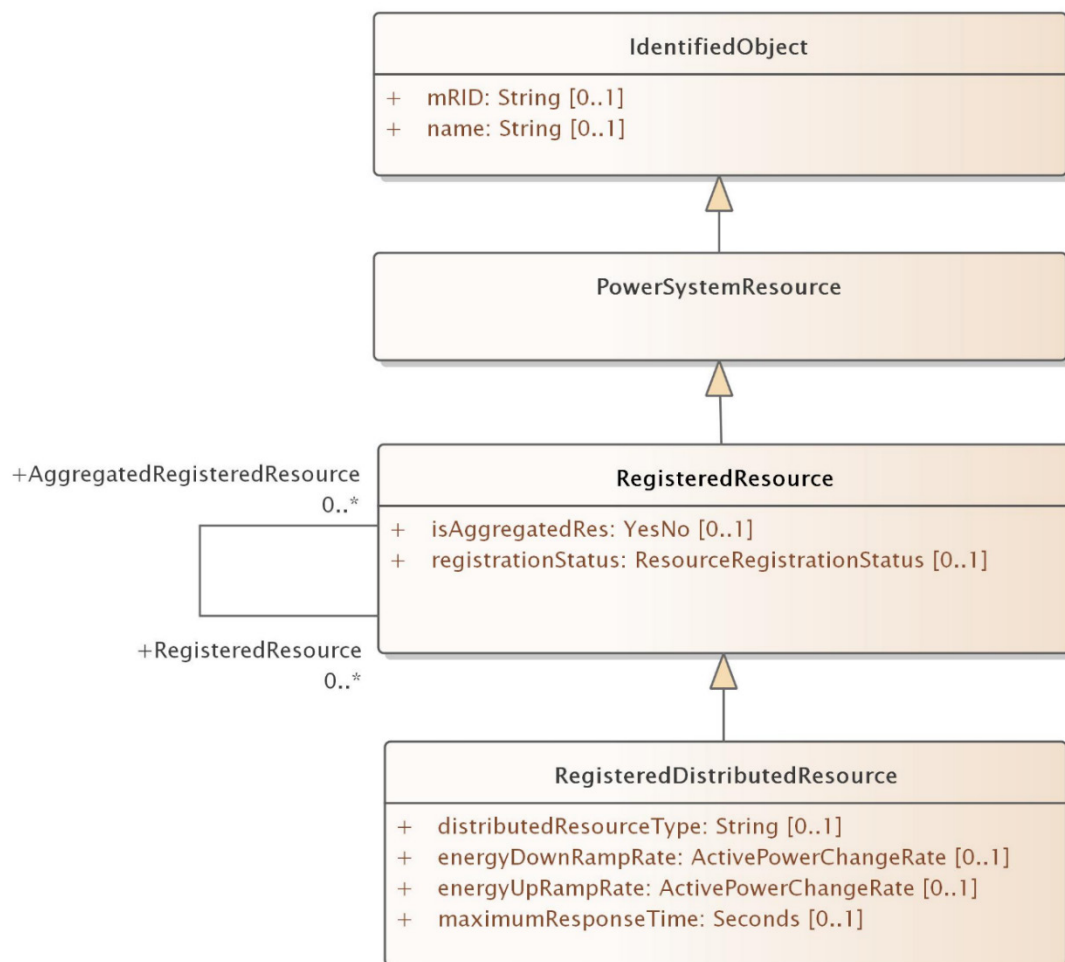
This section is intended to provide an overview of the modelling concepts illustrated with the most important classes in the Common Information Model UML for DERs, along with several of the key attributes in each class and several of the key relationships among classes. To keep diagrams focused on the concepts, detailed features have been removed from the diagrams, including package names, relationship end-names, and attributes not relevant to the DER model. Complete UML diagrams are provided in Section 5 as they are selected for use in IEC 62746 exchange profiles.

4.3.1 Resource Modelling

The class central to the DER model is the *RegisteredDistributedResource*, a specialization of the *RegisteredResource* class, based on the IEC 61970 *PowerSystemResource*, which in turn is a specialization of the *IdentifiedObject* class. These inheritances are shown in Figure 5 along with several of the more important attributes of these classes.

Figure 5: Resource Model

Reproduced with the permission of UCAIug



The *IdentifiedObject* class is the parent to almost all classes in the Common Information Model, where a globally unique identifier called the master record identifier (*mRID*) is assigned, along with a name (which may be omitted during the profiling process). In the context of a DER, the *mRID* is assigned when the DER is instantiated and persists through the life of the DER. The *mRID* is used for each future information exchange to tie exchanged information to that specific DER.

From *RegisteredResource*, several features document the core DER parameters as a market resource, namely the:

- *registrationStatus*: Status can be set to Planned, Active, or Decommissioned
- *isAggregatedRes*: Aggregation flag can be set on/off

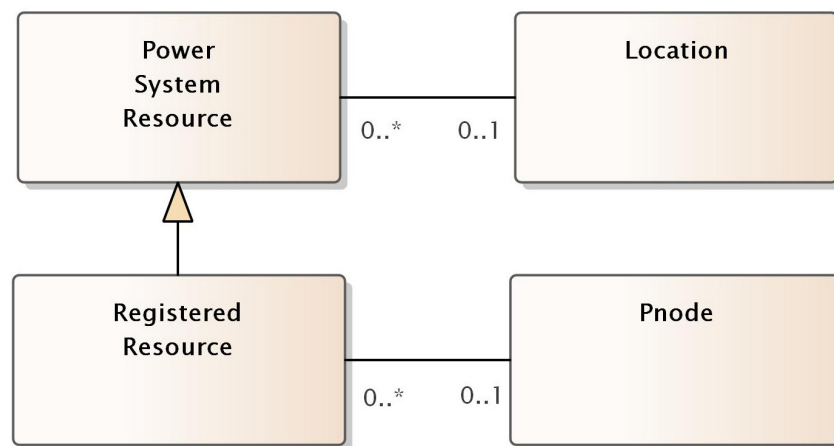
If aggregation is flagged, the self-reference within *RegisteredResource* (the loop relationship on the left side of the diagram) is utilized to identify the *AggregatedRegisteredResource* to which the individual *RegisteredResource* belongs.

4.3.2 Resource Location Modelling

IEC 62746 also leverages existing associations in IEC 61970 and IEC 62325 to identify the physical and logical locations of each resource, as shown in Figure 6. The *Location* class is associated with the *PowerSystemResource* class and represents a physical location of the DER. The *Location* class allows for multiple reference systems, including street address and geospatial coordinates, among other options.

Figure 6: Location Model

Reproduced with the permission of UCAIug

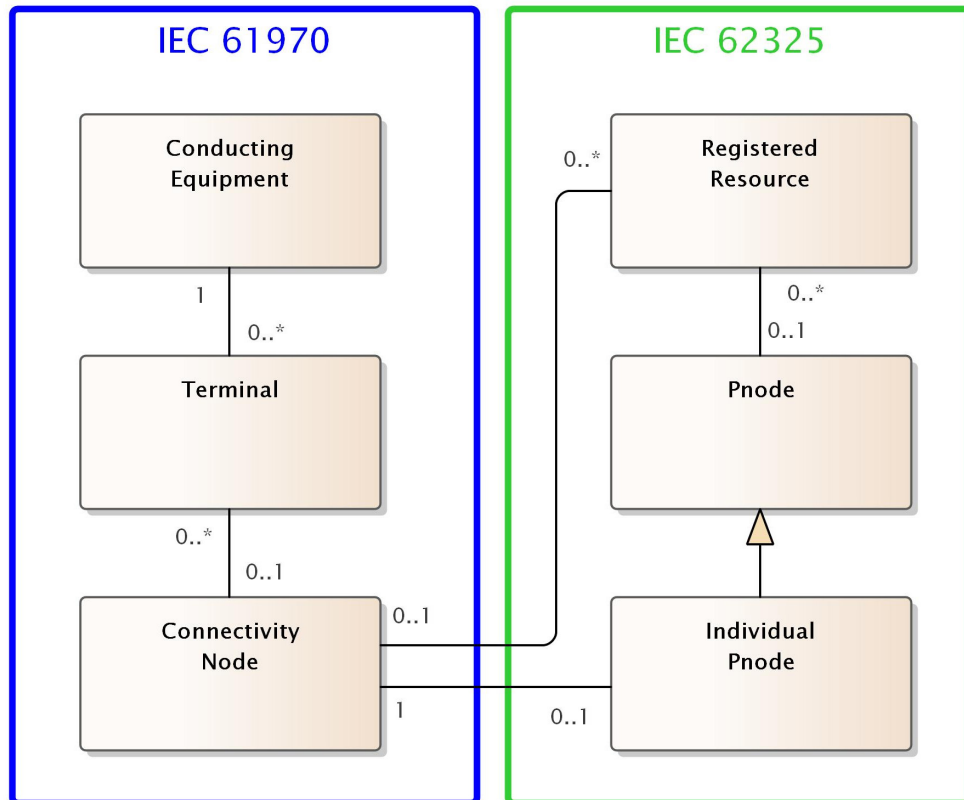


Pricing Nodes, or P-Nodes, are modelled in the *Pnode* class and are associated with the *RegisteredResource* class to represent the logical location of the DER in the market topology model. P-Nodes represent locations on the grid where prices are set for the delivery and/or consumption of energy services. Traditionally, individual P-Nodes have been associated with physical equipment on the grid with the P-Node itself associated to a Connectivity Node, or C-Node. C-Nodes are used to establish electrical connections among terminals on different pieces of conducting equipment, as a set forming a representation of an electrical grid.

The bridging of the grid representation (using IEC 61970) to the market representation (using IEC 62325) is shown in Figure 7. The linkage between market representation and grid representation is a critical one, as grid operators need to understand how DERs will affect grid reliability and knowing exactly where “on the grid” the DERs exist is essential. This importance will increase as the DERs’ role of reliability service providers increases.

Figure 7: Node Mapping

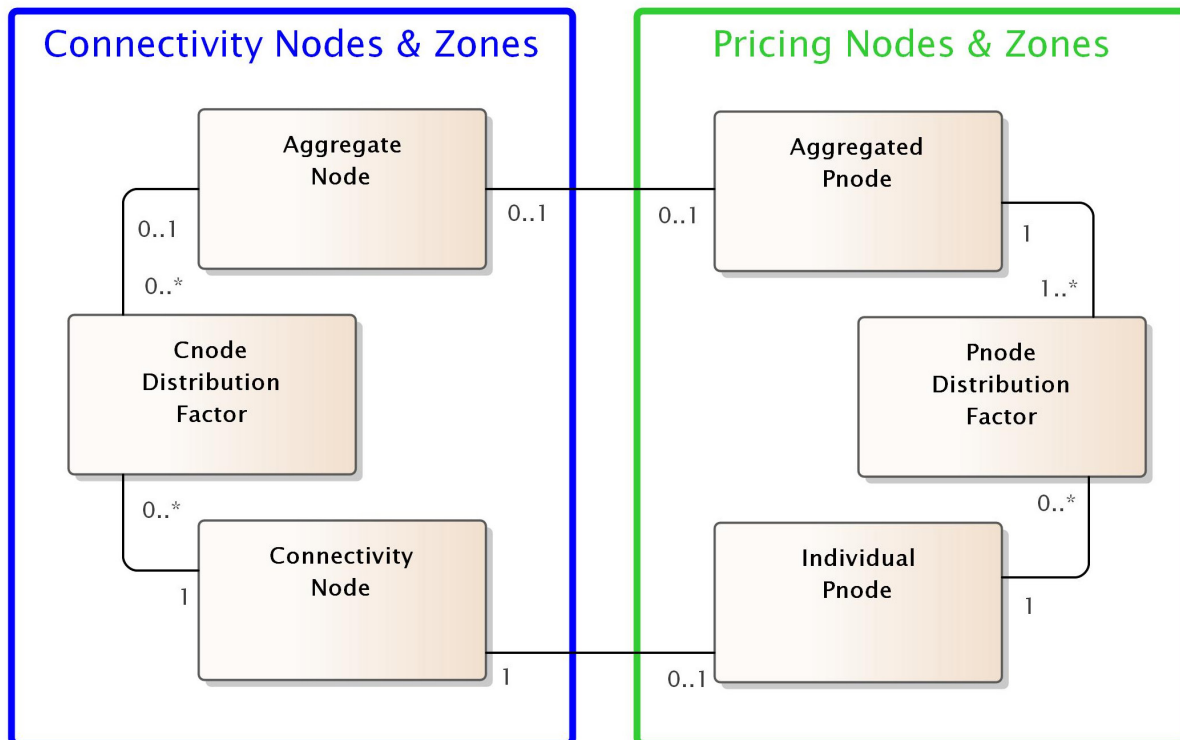
Reproduced with the permission of UCAIug



While traditional generation facilities have well-defined locations and hence both physical locations on the earth and logical locations in the grid and market topology models, DERs may not. Some DERs may be relatively large resources connected to the distribution; however, many DERs are likely to be aggregations of small resources located across a section of the distribution grid. For this reason, collections of pricing nodes called Aggregate Pricing Nodes (also called Pricing Zones) can be used to define the “fuzzy” location for DERs and DER aggregations. As opposed to an individual P-Node which maps to one (and only one) C-Node, an Aggregate P-Node can be mapped to multiple P-Nodes, using non-unity distribution factors if desired, just as aggregations of C-Nodes nodes can be grouped together into Aggregate C-Nodes. This concept is illustrated in Figure 8.

Figure 8: Connectivity & Pricing / Nodes & Zones

Reproduced with the permission of UCAIug



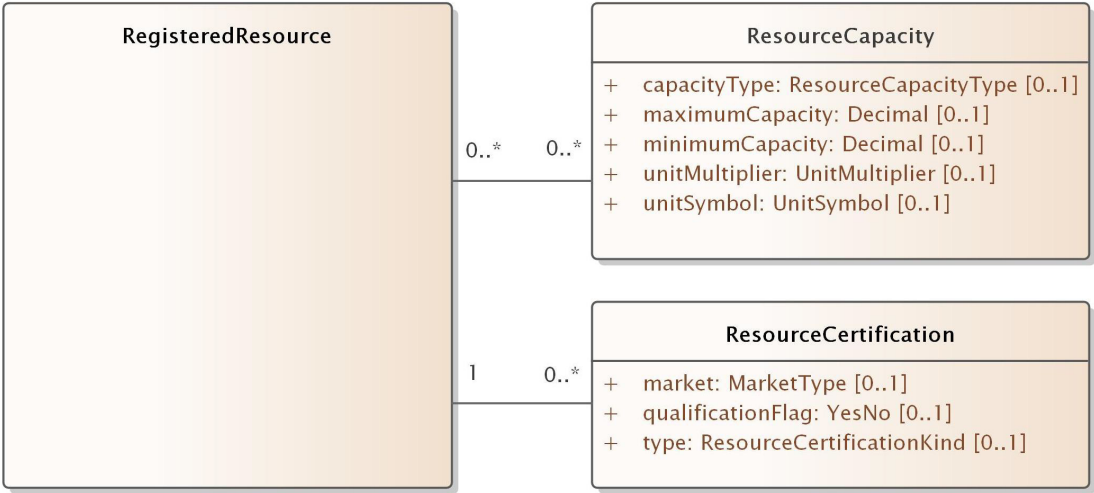
Aggregate P-Node modelling is especially important for DERs, as small resources will be aggregated into larger resources, and the aggregate resources may span multiple P-Nodes. Aggregate P-Nodes may be established by the grid operator and changed very rarely, for example a collection of individual P-Nodes which historically see little to no congestion among their shared electrical paths; or Aggregate P-Nodes may be dynamic, for example the specific set of P-Node at which an aggregator has DERs on the grid for a specific month.

4.3.3 Resource Capability & Qualification Modelling

Figure 9 shows two classes associated with the *RegisteredResource* class along with several of their key attributes which are used to document a DER’s capability to provide grid services. The *ResourceCapacity* class documents the amount of service that the DER can provide, using a *maximumCapacity* and an optional *minimumCapacity*. The *capacityType* attribute allows for different capacities for different services, for example 1 MW of power, in this case leveraging the same UnitSymbol (W) but two different UnitMultiplier (k vs. M).

Figure 9: Capacity & Qualification Model

Reproduced with the permission of UCAlug



Capacity levels for resources may not be symmetric, meaning the “up” capacity may be different from the “down” capacity – and hence *capacityType* may be defined for each direction – for example regulation up (“RU”) and regulation down (“RD”). With the *ResourceCertification* class, the DER market’s *qualificationFlag* can be set on/off for any combination of type (as above: energy, reserve, regulation, etc.) but also for a given market timeframe, generally either a Day-Ahead Market (DAM) or a Real-Time Market (RTM).

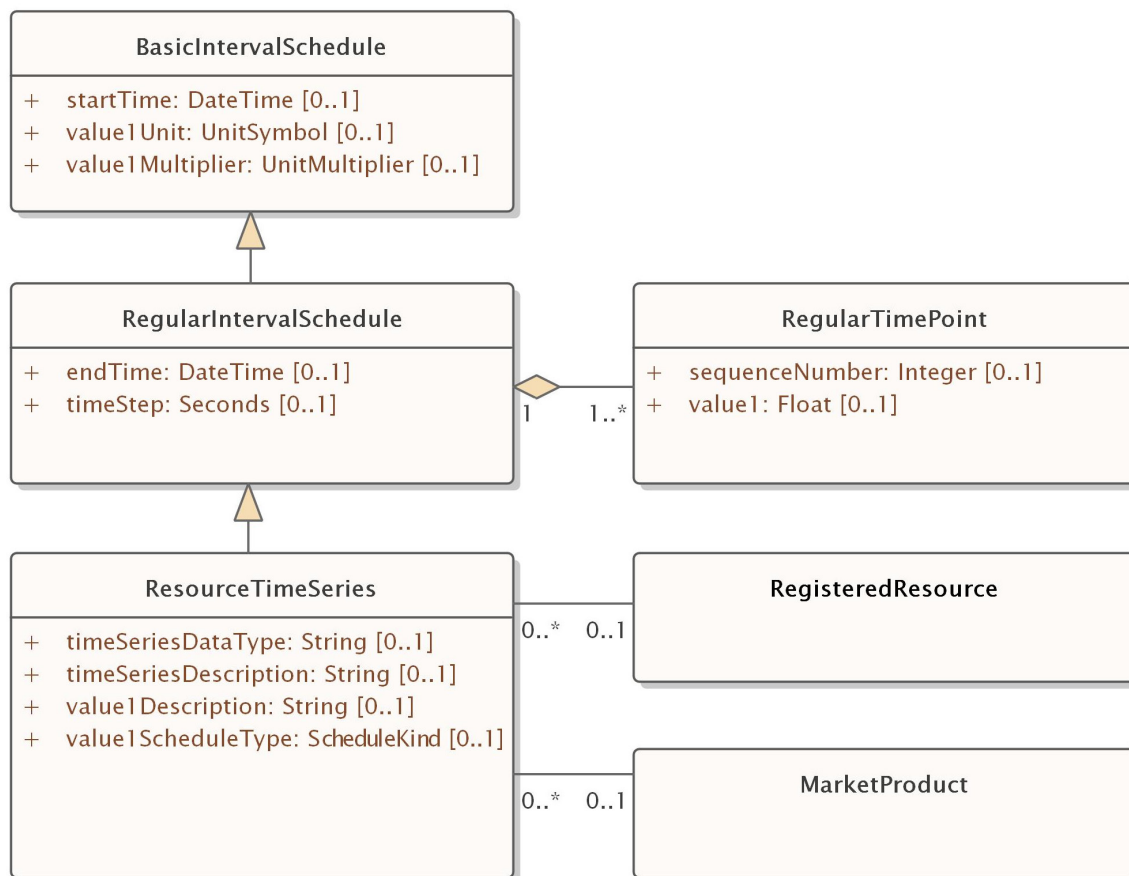
There is a correlation between the *ResourceCapacity* and the *ResourceCertification*; however, this relationship is specific to the business process of market certification, potentially having multiple *marketTypes* constrained by a single *ResourceCapacityType*.

4.3.4 Energy Schedule Modelling

An energy curve is any sort of energy-related quantity mapped over time. Energy curves can be used to track meter data, thresholds, expected energy consumption levels, production schedules, and so on. IEC 62746 uses the *ResourceTimeSeries* class as a base class, which inherits from both the *RegularIntervalSchedule* and *BasicIntervalSchedule*, as shown in Figure 10.

Figure 10: Energy Schedule Model

Reproduced with the permission of UCAIug



The energy curve is defined in time by specifying a *startTime* and *endTime*, along with a *timestep* which determines how many intervals will be documented. The item being quantified is specified using the *value1Unit*, *value1Multiplier*, *value1Description*, and *value1ScheduleType*. As discussed in previous sections, the energy curve can be associated with a *RegisteredResource* and/or a *MarketProduct*.

Since it is common to send multiple but related datasets in a single exchange, the standard allows for optional *value2* and *value3* fields (which mirror the *value1* attributes in the diagram but are not shown for simplicity). One example of multiple values would be to use *value1* for a baseline consumption level and *value2* for the actual/metered consumption level. Another would be to use *value1*, *value2*, and *value3* for minimum, average, and maximum consumptions levels, respectively.

The series of data points for *value1* and optionally *value2* and *value3* are associations to multiple *RegularTimePoint* instances. A common example would be to instantiate twenty-four *RegularTimePoints*, each for an hourly value during a single day, assigning a *sequenceNumber* of 1 through 24 to represent the “hour ending” for each interval.

The *scheduleType* attribute is unique to DERs and is necessary to identify how the DER is offering and/or consuming services. *scheduleType* is as a human-understandable enumeration (documented in Table 3) intended to help DER owners and aggregators submit bid/offer information and clearly understand two key features (a) the energy flow convention for a positive number as either production or consumption of service and (b) the sense of how the bid/offer amount is used as either a target or setpoint or as a relative change to a defined level.

Table 3: ScheduleKind

Reproduced with the permission of UCAIug

Enumeration	Description
generation	The DER operates primarily as a generation resource, where a positive amount corresponds to an injection of energy (or support service) to the grid; the amount is an absolute level understood to be a <u>production setpoint</u> .
load	The DER operates primarily as a load resource, where a positive amount corresponds to a withdrawal of energy (or support service) from the grid; the amount is an absolute level understood to be a <u>consumption setpoint</u> .
loadIncrease	The DER operates primarily as a variable load, where a positive amount corresponds to a <u>relative load increase</u> , effectively as an offset to a reference level such as current usage or a baseline usage.
loadReduction	The DER operates primarily as a curtailable load, where a positive amount corresponds to a <u>relative load reduction</u> , effectively as an offset to a reference level such as current usage or a baseline usage.

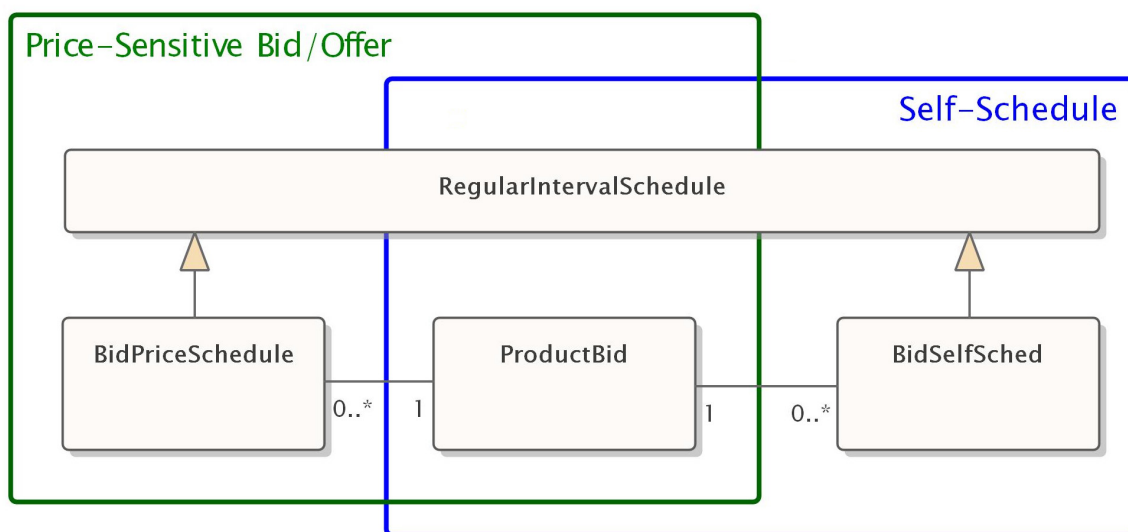
Many DER types are easy to classify; for example, a distribution-connected wind turbine would mostly likely choose a *scheduleType* of “generation” whereas a residential demand response resource would mostly likely choose “*loadReduction*”. A storage resource, however, could choose any number of options and having well-defined definition for each *scheduleType* should eliminate ambiguity. For example, a stand-alone battery might choose “generation” if it has capacity available to discharge to the grid or “load” if it needs energy to charge; a battery coupled with a load might choose “loadReduction” if the battery offsets the associated load at the service meter, or “loadIncrease” if the battery desires to increase load from the grid to charge the battery. The standard makes no claims to which models should be used for which resources, rather provides the set of all four possible options and should be constrained by business rules for a given implementation.

4.3.5 Bid/Offer Modeling

Once qualified for market participation, resources can inform their grid operator and/or aggregator of **offers** to produce grid services and/or **bids** to consume grid services. There are two basic models for how a DER might interact with a market. One is to convey a set of expected production and/or consumption levels for one or more services, also known as a “self-schedule”. The second is a set of price-sensitive levels. Both are modelled using the *ProductBid* class, as shown in Figure 11, with an association to either a *BidSelfSched* (for self-scheduling) or a *BidPriceSchedule* (for price-sensitive offers/bids).

Figure 11: Price-Based Versus Self-Schedule

Reproduced with the permission of UCAIug

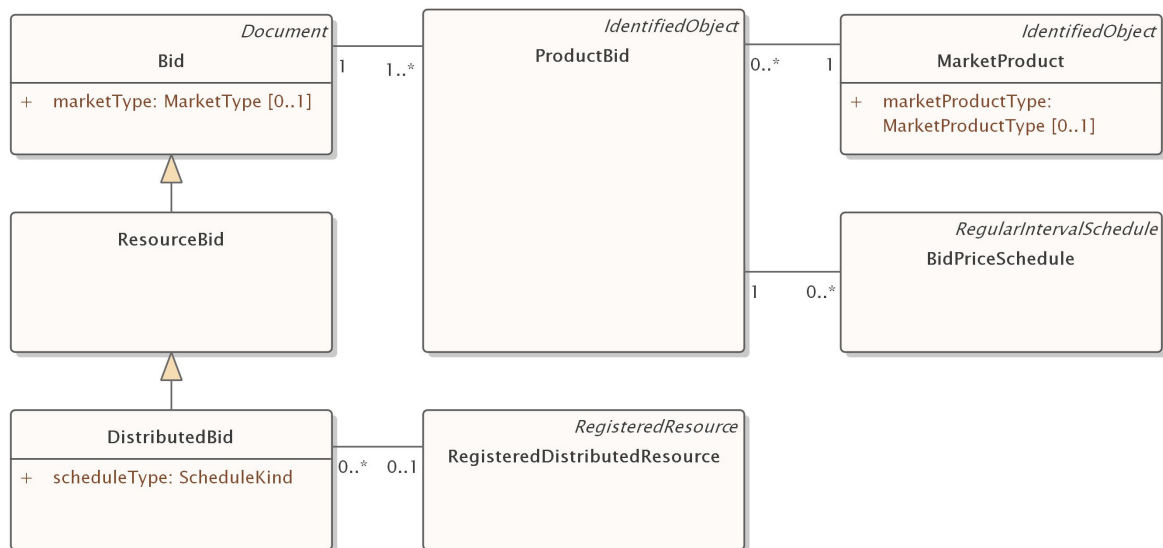


The remainder of this section describes the modelling for price-sensitive offers and bids. The self-schedule model can be derived by simply replacing *BidPriceSchedule* with *BidSelfSched*. Both classes are based on the *RegularIntervalSchedule* class, with the *BidSelfSched* being form of an energy curve, as described in Section 4.3.4.

As shown in Figure 12, the resource’s overall price-sensitive offer/bid is shown on the left and pertains to a specific *marketType*, again generally the DAM/RTM designation. The *Bid* is associated with one or more *ProductBid* instances. Any specific resource may be capable of offering and perhaps even supplying different commodities simultaneously, sometimes referred to as “value stacking”, it is possible to have multiple instances of *ProductBid* for the same set time intervals, one set for each relevant *MarketProduct*.

Figure 12: Price-Sensitive Offers/Bids

Reproduced with the permission of UCAIug



ProductBid is a container which has two associations: the top being the *MarketProduct* (Energy, Reserve, Regulation, etc.) and the bottom association being the *BidPriceSchedule*. The *BidPriceSchedule* class captures data on three axes signifying:

- 1) The time window, e.g. from 6:00 to 7:00
- 2) The amount of service, e.g. 1 MWh
- 3) The asking price, e.g. 20 €/MWh

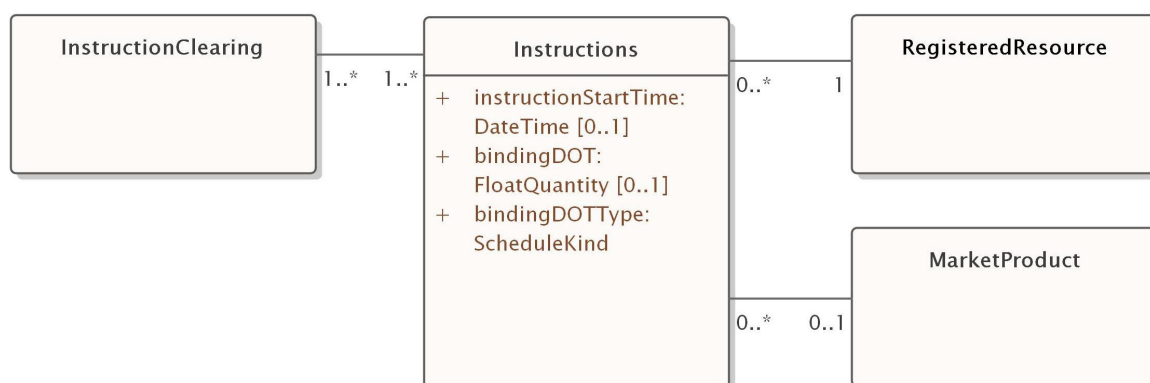
ResourceBid is specialized into *DistributedBid* to support DER constructs, specifically a link to the proper resource identifier available as a *RegisteredDistributedResource*, but also to capture DER-specific attributes that distinguish DERs from traditional grid resources, most importantly the assignment of a *scheduleType* (details of which are discussed in Section 4.3.4)

4.3.6 Dispatch Modelling

After the market clears one or more intervals, each resource must be informed of its award - essentially the amount of each offer/bid which was accepted. IEC 62746 leverages the dispatch instructions modelling from IEC 62325, as illustrated in Figure 13.

Figure 13: Dispatch Model

Reproduced with the permission of UCAIug



Each clearing of the market is documented in the *InstructionClearing* class, and the clearing may result in different setpoints over time which are documented in the *Instructions* class. The dispatch operating target (the *bindingDOT* attribute in the *Instructions* class) carries the amount of the bid/offer selected, along with the *bindingDOTType*, which documents the meaning of the operating target using the *ScheduleKind* enumeration discussed in Section 4.3.4. The product and resource are referenced through the *MarketProduct* and *RegisteredResource* associations, respectively.

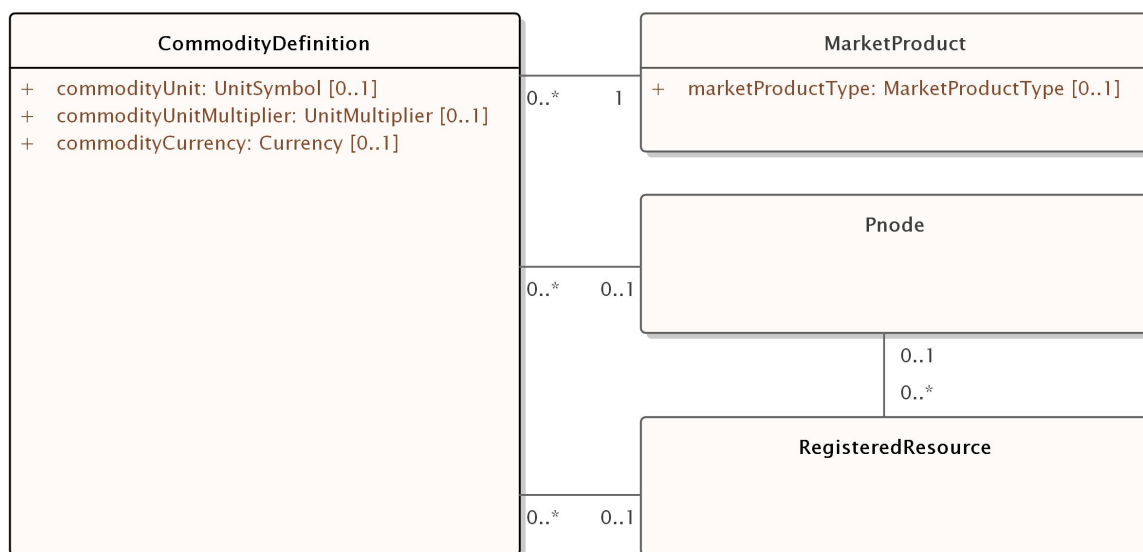
4.3.7 Commodity & Price Modelling

Price transparency is an important feature of wholesale electricity markets and may likely be a feature in future distribution/retail markets. This modelling is especially important for price-responsive resources that are operated autonomously, responding to prices with their own logic and not necessarily utilizing the bid/offer, clearing, and dispatch process described in previous sections.

IEC 62746 leverages the commodity pricing constructs in IEC 62325 and is most easily understood in two pieces: the slowly changing information related to commodity definitions (as shown in Figure 14) and the rapidly changing information related to the prices of those commodities (as shown in Figure 15).

Figure 14: Commodity Model

Reproduced with the permission of UCAIug



A grid service is defined by the *CommodityDefinition* class, with the attributes of *commodityUnit* and *commodityMultiplier* to describe the unit-of-measure for the service, such as MW, MWh, or MVA, and a currency, such as dollars or euros.

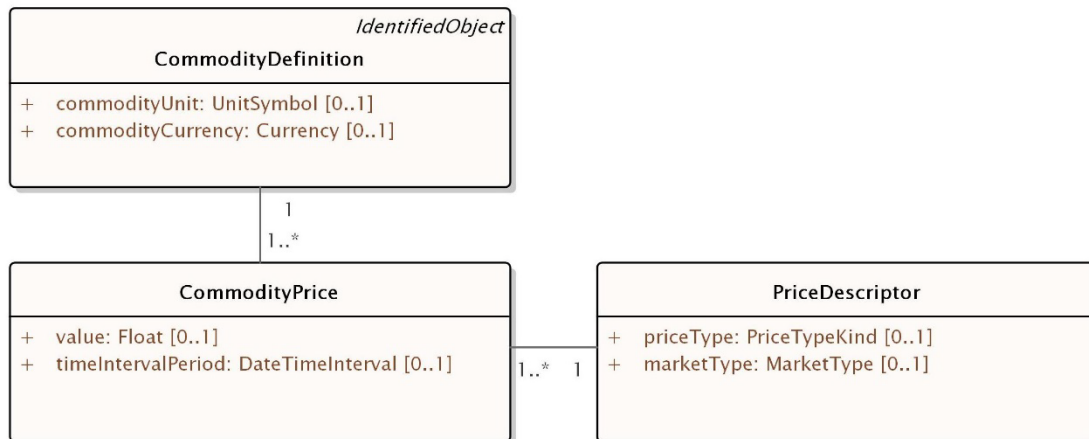
The commodity is also defined by two associations. The first association is to the *MarketProduct* class (as above, energy, reserve, regulation, etc.). The second association has two options. If pricing is locational, as described in Section 4.3.2, the association to *Pnode*, specialized as an *IndividualPnode* or as an *AggregatedPnode*, is used. However, it is possible to have multiple DERs at the same *Pnode* with different contracts and hence different, separately negotiated, prices. Optionally then, a commodity can be resource-specific, and hence an optional relationship with *RegisteredResource* is provided.

Once the *CommodityDefinition* is established, the *CommodityPrice* class is instantiated for each individual price to be published across time. Prices have a numerical value (with the *commodityUnit* and *commodityCurrency* established in *CommodityDefinition*), and a

DateTimeInterval over which the price is valid. The *DateTimeInterval* stereotype is flexible, covering scenarios like annual processes which define a value for the coming year to real-time calculation which lead to minute-by-minute price changes.

Figure 15: Price Model

Reproduced with the permission of UCAIug



The *PriceDescriptor* class is used to document the characteristics of any published price. The *marketType* (see Table 6) attribute is used to differentiate prices calculated in different markets, here again DAM or RTM are the common options. The *priceType* (see Table 6) attribute can be used if different “flavors” of prices are published; for example, one might publish a “total” along with the “congestion” price component and a “losses” price component if the market operator wishes to break down the individual constituent components of a given energy price.