Evolve Project

Knowledge Sharing Report Number 1
Milestone 3

Using the CIM for Electrical Network Model Exchange

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Prepared by

Contents

Glossary of Terms

Term	Definition
AEMO	Australian Energy Market Operator
ADMS	A term that has arisen recently and used in the industry to describe an Advanced DMS.
Aggregator	An Aggregator is an organisation that provides an integration point and control mechanisms for a large number of DER assets.
ANU	The Australian National University
BAU	Business as Usual
CIM	Common Information Model, a standard for data exchange for network models, based on the IEC 61970, 61968 and 62325 family of standards.
DER	Distributed Energy Resource. Disruptive technologies being connected to distribution networks, including PV, EV, demand response solutions storage and wind farms.
Distribution Substation	A location where one or more transformers are located. The transformer(s) change the voltage level from HV to LV. The distribution transformers are typically rated from 10kVA to 1500kVA
DMS	Distribution Management System. A computer system which is used to control an electrical distribution network.
DNSP	Distribution Network Service Provider, as defined with the National Electricity Rules.
DSO	Distribution System Operator; this term refers to the functions of Distribution Level coordination and optimisation of multiple DER aggregators in multiple markets, and connecting at the distribution network level.
EMS	Energy Management System. A computer system which is used to control an electrical transmission network.
EPRI	Electric Power Research Institute. www.epri.com/#/about/epri?lang=en-US
ESRI	A GIS product used by some of the DNSP partners.
EV	Electric Vehicle

Term	Definition
GIS	Geographic Information System. A computer system that incorporates geographical features with tabular data in order to help manage the assets in an electrical network.
HV	High Voltage – 6.6kV to 66kv. Sometimes also referred to as MV. These are typical voltages used by distribution network to transport.
IEC	International Electrotechnical Commission
IEC TC57	TC 57 is an IEC Technical Committee responsible for development of standards for information exchange for power systems and other related systems. https://en.wikipedia.org/wiki/IEC_TC_57
IEEE	Institute of Electrical and Electronics Engineers. www.ieee.org/about/index.html
Linear Asset	A conductor or cable that has a non-zero length.
LV	Low Voltage – 400 V phase to phase. This is used for the last km of electricity reticulation in Australia.
MV	Medium Voltage - 6.6kV to 66kv. Sometimes also referred to as HV.
NFM	The name used to describe the Energex GIS.
Point Asset	Transformers, switches and circuit breakers (for example) that have no length.
PKI	Public Key Infrastructure; a set of roles, policies and procedures to manage digital certificates and public key encryption.
PV	Photovoltaic – refers to solar generation.
SCADA System	Supervisory Control and Data Acquisition System – a sub-system of the PowerOn Fusion DMS.
SINCAK	An application used by some of the DNSPs for performing load flow and fault level studies of the distribution network.
SDKC	Software Development Life Cycle
Smallworld	Smallworld is GE GIS product used by some of the DNSP partners.
SWER	Single Wire Earth Return – a type of distribution network used for long rural feeders.

1. Executive Summary

This report has been prepared as part of the knowledge sharing requirements of the Evolve Project, under the ARENA agreement “2018/ARP154, Zeppelin Bend evolve DER Project”.

The objective of the Evolve Project is to develop and demonstrate a system for coordinating distributed energy resources (DERs) that will ensure the secure technical limits of the electricity distribution network are not breached.

More information on the Evolve Project can be found in Appendix B - Evolve Project overview. The system being developed by the Evolve Project will be referred to for the remainder of this document as the Evolve Platform.

One of the objectives of the Evolve Project is to develop technical capabilities in the evolve Platform using standards, where possible and appropriate. Standards, in this context, refers to a pattern or model that is generally accepted by the industry that is using it. Based on this definition, various relevant standards were identified during the project inception and the design blueprint phases:

1. For communications between the evolve Platform and the DER Aggregators - the IEEE 2030.5 protocol.
2. For Authentication of DNSP and Aggregator systems communicating with the evolve Platform - the OAuth2 protocol.
3. For the exchange of electrical network model and measurement data between existing DNSP systems and the evolve Platform - the IEC Common Information Model (CIM) set of standards.

Using standards when creating new technologies can have a number of potentially positive outcomes. However, standards can also inhibit innovation and slow down the development process where existing standards do not anticipate new requirements or ways of working, or are poorly developed or have low adoption rates.

The major conclusion in this report is that the subset of CIM standards relevant to the Evolve Project – those concerned with the exchange of electrical network asset and measurement data, are an invaluable resource for the industry to agree on a common ontology for sharing electrical network asset data between organisations and systems.

However, not all aspects of the standard are being adopted by the Evolve Project. In particular, we have concluded the use of the CIM XML serialisation aspects of the standard for model exchange is problematic.

Instead of XML based serialisation, we are implementing serialisation mechanisms using gRPC1. As part of this, we are also implementing electrical network asset model libraries, expressed as CIM classes, in several programming languages including Java, JavaScript and C# that will be used as the basis for many of the higher-level functions to be performed by the Evolve Platform.

This document is organised into chapters, as described below.

Chapter 1	Introduction and Overview
Chapter 2	Discusses the role of standards in general terms.
Chapter 3	Describes the CIM standard, and the parts that are relevant to the Evolve Project.
Chapter 4	Provides information on how the DNSP partners have been using the CIM for their own internal projects.
Chapter 5	Describes how the CIM standard has been used in the Evolve Project.
Chapter 6	Discusses the CIM in the Australian Context.

2. The Role of Standards

A typical dictionary definition of a Standard is:

a pattern or model that is generally accepted [2]

something considered by an authority or by general consent as a basis of comparison; an approved model [3]

A large number of regional and international standards are accepted, approved of and used by the electricity industry to allow equipment and systems to be integrated at both a hardware and software level. This helps complex "systems of systems" to be developed in an economical fashion to support the operation of the overall electricity supply system.

2.1 The Advantages of Using Standards

Standards facilitate mutual understanding of complex problem and solution spaces between people and organisations. For the Evolve Project, standards are being used to support the exchange of data between different systems and organisations.

The systems in question are the asset management and control, customer and metering systems within the DNSP project partners, and DER management and aggregations systems being developed by the Aggregator project partners.

Standards can form the basis for the introduction of new technologies and innovations, and ensure that products, components and services supplied or developed by different organisations will be mutually compatible. As the Evolve Project is developing technologies that will form a sub-set

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[2] www.dictionary.cambridge.org/dictionary/english/standard

[3] www.dictionary.com/browse/standard

of larger technical solutions in the future, it is important that these technologies can be readily integrated. Standards provide one mechanism for facilitating this integration.

"Standards also disseminate knowledge in industries where products and processes supplied by various providers must interact with one another. Standardization is a voluntary cooperation among industry, consumers, public authorities, researchers and other interested parties for the development of technical specifications based on consensus." (CENELEC, 2020)

The International Electrotechnical Commission (IEC) is an international standards organization that develops international standards for all electrical, electronic and related technologies.

IEC standards are widely adopted and are applied by manufacturers, trade organizations, purchasers, consumers, testing laboratories, governments, regulators and other interested parties. As such, standards developed by the IEC are of particular interest to the Evolve Project.

Since International Standards generally reflect the best experience of industry, researchers, consumers and regulators worldwide, and cover common needs in a variety of countries, they constitute one of the important bases for the removal of technical barriers to trade.

For this reason, in its TBT (Technical Barrier to Trade) Agreement[4], the WTO (World Trade Organization) recommends its members to use International Standards rather than regional or national ones whenever possible. Adopting IEC International Standards or using them for reference in national laws or regulations facilitates trade in the field of electrotechnology (Uslar et al. 2012).

Standards Australia is an independent, non-governmental, not-for-profit standards organisation that is Australia's representative of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC).

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[4] www.wto.org/english/tratop_e/tbt_e/tbt_e.htm

According to standards Australia, there are six key benefits to using standards (Standards Australia n.d.):

1. “Boost confidence: Thanks to standards, businesses and consumers can feel confident that the products and services they develop and/or use are safe, reliable and fit-for-purpose.
2. Enhance innovation: Standards are a launch pad for exciting new ideas. They can be created, evolved or discarded according to our changing world. New standards are developed to reflect the latest technologies, innovations and community needs.
3. Give products a competitive edge: In the eyes of consumers, products that comply with Australian Standards offer added value. International Standards give Australian exporters an instant competitive advantage when moving into overseas markets.
4. Reduce barriers to international trade: Regardless of where a product is made, standards mean it can be sold and used around the globe. Opening new doors to international trade, standards help Australian businesses compete globally and to a wider market.
5. Reduce red tape: Standards assist with harmonisation across Australia’s laws and regulations. They offer an alternative to regulation, reducing business costs and decreasing red tape, but still providing security for businesses and consumers.
6. Help businesses thrive: Standards are central to Australian business. They make business transactions simpler and more efficient, assi-sting with risk mitigation and compliance. Put simply, standards help our businesses thrive.”

In summary, it is apparent there are many advantages in adopting a standards-based approach when developing technical solutions, and this is the overwhelming sentiment in the various commercial, government and academic organisations that make up the electricity supply industry.

However, standards often follow behind technical innovation, and the pathways to the creation of widely adopted and hence successful standards is not always linear. For this reason, the use and in some cases the interpretation of existing standards should always be approached with caution when developing new technologies. Some of the potential problems with the adoption of standards are discussed next.

2.2 Potential Pitfalls of Adopting Standards

Using standards incorrectly or inappropriately can have a negative impact upon a desired outcome, as can using standards that are poorly designed or overly complicated, or have not been widely adopted by the industry they serve, or are themselves built on technologies or standards that are being deprecated.

A mature, well understood and well adopted standard has clear benefits. However, such standards only exist where they have successfully captured a set of technical requirements and in many cases where they compel co-operation between multiple parties for successful market outcomes.

Many attempts to establish standards fail in the creation process, and this failure can take many years to become apparent. An example of a "failed" standard was the entire set of Open Systems Interconnection standards (OSI) published by ISO/IEC and the International Telecommunications Union.

OSI was a body of standards for creating a new way for computer interconnection. This development took nearly 10 years of work on the part of ISO/IEC JTC1 and the ITU. It was mandated by multiple governments (most notably the US Government OSI Protocol [GOSIP]) and was made a major focus of development by many large IT companies. The adoption of OSI failed in the market with the advent of the TCP/IP stack promoted by an alternative standards organization, the Internet Engineering Task Force (IETF)5.

The problem with the OSI protocol was that it was a technically driven and the revolutionary changes that its implementation required were highly complex, and required significant expertise to implement correctly. In addition, initial implementations and test suites were lacking after the early deployments were made, which resulted in multiple interconnection issues.

On the other hand, the IETF with its concept of 'rough consensus and running code' provided a much simpler solution to the computer interconnection challenge, which could be implemented by all vendors. (Cargill 2011).

Although the OSI standards were not adopted as such, the OSI protocol did help teach the industry at large how to structure, create, and standardize protocols, as well as providing an impetus to move away from proprietary communications protocols implemented by the major vendors of the time such as IBM and DEC. From this point of view, the OSI standards could be considered highly successful.

In some ways, the rapid changes that were occurring in the computing communications space 20 years ago that eventually resulted in a stable and widely adopted set of standards in the TCP/IP protocol, could be compared to the changes that are now occurring in the electricity supply chain:

1. There is a growing need for the currently disparate systems used by the various industry entities to communicate with each other using a common language to describe the electrical network assets, generation and loads and their operational data.
2. There are a large number of legacy systems in use, provided by large vendors such as General Electric, Schneider and ABB, that will not easily adapt to the significant changes that are expected to occur in the way electrical network assets are managed and operated with increasing penetrations of DER.
3. The operational systems currently in use in most DNSPs tend to be monolithic and closed, with a limited set of API's that generally do not follow any standards, in much the same way as vendors such as IBM and DEC had their own proprietary communications protocols for computer to computer communications in the 90's. Current operational technologies can be networked using TCP/IP and run on operating systems such as linux and Windows, but they only have a limited ability to integrate with other systems at the application layer.
4. Similar levels of investment have been made in development of the CIM standards since the mid 90's as the ISO standards. In fact, the CIM standards have been under development for over 20 years.

If this comparison is valid, then it follows that the evolution of the CIM over the next few years could have similar outcomes to the evolution of the OSI standards. Indeed, the National Rural Electric Cooperative Association (NRECA) – a not for profit organisation based in the USA to serve the needs of a large number of small rural electricity providers created a set of specifications called "Multispeak"[6] that have been adopted by several technology vendors in the USA, and that could potentially usurp the CIM.

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[6] www.multispeak.org/what-is-multispeak

Alternatively, some elements of the CIM that are mature and particularly germane to current industry requirements could be adopted, with other non CIM standards adopted or created that complement the CIM standards.

Another concern with adopting standards is the rate at which standards are developed and modified through standards organisations such as the IEC. Consider the diagram below in Figure 1.

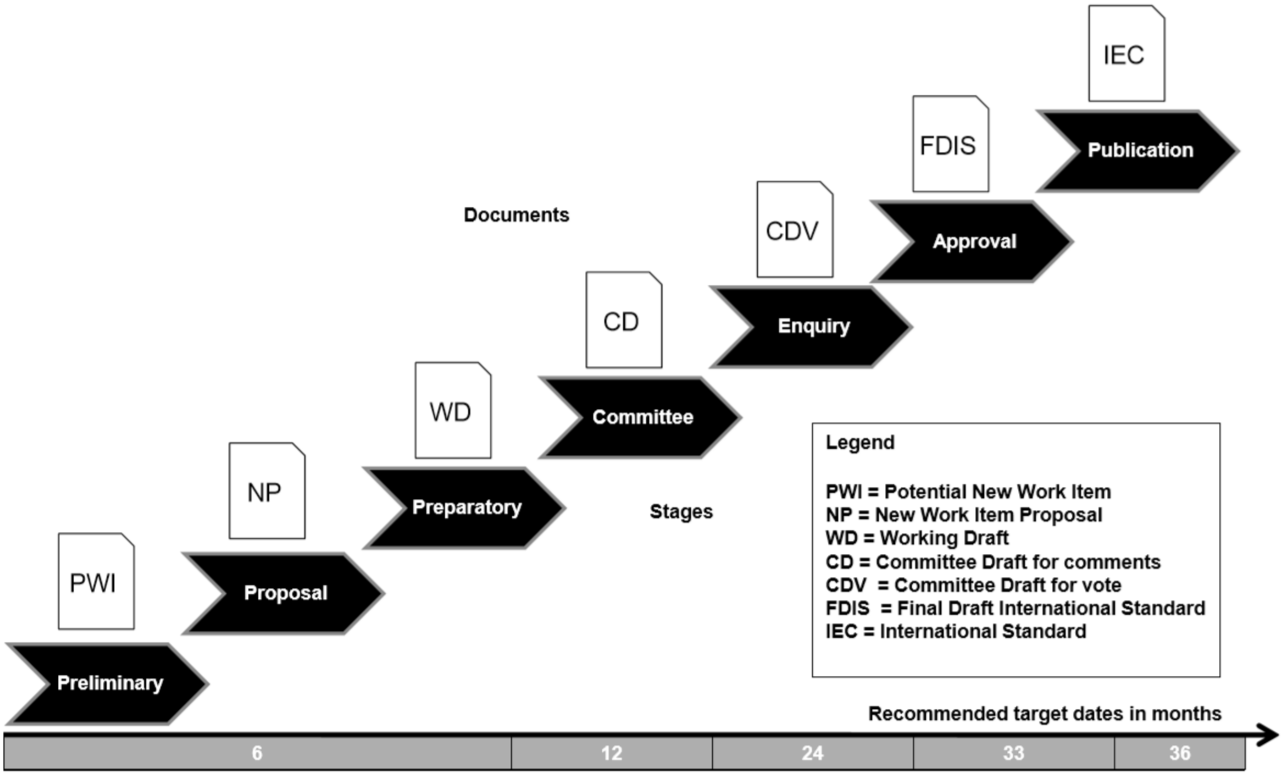

Figure 1: Timeframe for development of IEC standards.

This shows the typical stages and timeframes for the development of a new IEC standard. Once the first draft of a standard is published, subsequent iterations on the standard follow a similar process. For defining standards in emerging and evolving problem and solution spaces, this type of approach is not conducive to rapid development and innovation.

In much the same way as the Agile movement was created in software engineering in an attempt to provide mechanisms to accelerate and improve outcomes in the development of new software solutions, alternative pathways to the creation of new standards also need to be explored in some cases where the technical requirements and outcomes of the standards are themselves influenced by the development process of the standards.

In summary, the main conclusions we have drawn is that the adoption of a standard that is not currently widely used (such as the CIM set of standards) should only occur after careful consideration of the likely future path of that standard.

In the case of the CIM, there are aspects of the standard that we believe are worth pursuing, but others that are either not fit for purpose or involve an ongoing development methodology that is not appropriate to current industry needs, and in these cases, we are creating alternative technical implementations.

The use of the CIM in the Evolve Project is described in detail in Chapter 5.

3. The IEC Common Information Model

3.1 History of the CIM

Originally the CIM was created to address the problem of the Energy Management Systems (EMS) vendor lock-in. The lock-in problem caused large financial and human resource investments in the purchase and support processes for an EMS, and replacing the EMS became prohibitively risky and costly – creating a vendor lock-in problem that did not encourage innovation.

A project was stood up by US-based organisation EPRI, and was known as the EPRI CCAPI (Control Centre Application Program Interface) project. This led to the development of the IEC61970/61968 standards that form the CIM, as well as the IEC61850 standard for substation automation (EPRI 2008).

The Multispeak specification had similar objectives to the EPRI CCAPI project, and has been running along a parallel path to the development of the CIM standards, as previously mentioned.

While there has been some adoption of both the CIM and Multispeak standards, and some attempts to harmonise the CIM and Multispeak, this has not yet had a really significant impact on the EMS vendor oligopoly it was intended to disrupt.

More recently (in 2017), the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (DOE-OE) established a project called GridAPPS-D to develop an open-source, standards based ADMS application development platform.[7]

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[7] https://gridappsd.readthedocs.io/en/releases-0.1/overview

ADMSs (Advanced Distribution Management Systems) are used for operation of distribution networks, as opposed to EMSs (Energy Management Systems) which are used for the operation of transmission networks.

The "Data Bus" proposed for the ADMS platform will be based on the CIM. This project has similar objectives to the EPRI CCAPI project which was seeking to disrupt the large EMS vendors, as it is seeking to disrupt the oligopoly of large ADMS vendors and encourage innovation in the development of operational technologies. The GridAPPS-D platform is being actively developed as of the time of writing of this report.

According to (Uslar et al. 2012):

"The aim of the IEC 61970/61968 standards families is to support integration of applications and devices and reduce the "distance to integrate". When integrating applications from several vendors, several approaches exist. If no standards exist custom integration is needed which in general is the most costly approach regarding maintenance. Standards based integration promises higher quality and lower maintenance costs in the future but requires the availability of existing standards. Within standards-based integration mainly three types of standards can be distinguished:

1. *Standards aiming at syntactic interoperability, providing interface descriptions,*
2. *Standards focusing on semantic interoperability, in addition to syntactic interoperability a common semantic data model is provided,*
3. *Plug and play standards, (ideally) no additional customization is needed applications just have to provide fully specified interfaces and exchange of data will be able*

The CIM focus on semantic interoperability and apart from providing a common semantic data model within IEC 61970, 61968 and 62325 a set of profiles, interface descriptions and use cases are provided. The development of the IEC CIM data model comprises several steps from its initial creation till the provisioning of a new version of the electronic model."

Essentially, what this is saying is that the CIM standards are not intended to be used as plug and play standards, in the way a standard for Wi-Fi connectivity would be used by a chip manufacturer for example. Rather, they are intended to provide reference models that different software development teams can use to simplify and reduce the cost and design process for integrations between systems.

This is the approach we are taking with the Evolve Project by using the CIM network asset models as a reference for the creation of software libraries and data streaming mechanisms that provide developers with an accelerated pathway to building working software.

3.2 Overview of CIM Standards

The Common Information Model (CIM) is a set of standards that provide a detailed data model (domain ontology) and interface specifications and technology (communication and serialisation) (Uslar et al. 2012).

The electric utility sector worldwide is involved in standardisation activities through the CIM users group[8] and the leadership of the IEC Technical Committee 57 ("IEC - TC 57 Dashboard > Scope" n.d.).

There are three main standards that form the CIM, with each of these having different parts:

1. IEC 61970 – contains the core data models applicable to both distribution and transmission networks, as well as interface specifications intended to facilitate the integration of computer systems used for transmission level operations.
2. IEC 61968 – contains extensions to the data models in IEC 61970 to cater for distribution networks, as well as interface specifications intended to facilitate the integration of computer systems used for distribution level operations.
3. IEC 62325 – contains extensions to the data models in IEC 61968 and IEC 61970 to cater for market systems, as well as interface specifications intended to facilitate the integration of computer systems used for market operations.

The Evolve Project is not directly concerned with market operations, and consequently the CIM standards that are relevant to the Evolve Project only include IEC 61970 and IEC 61968. The various parts to the overall CIM standard are illustrated in the diagram Figure 2 on the following page.

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[8] https://cimug.ucaiug.org/

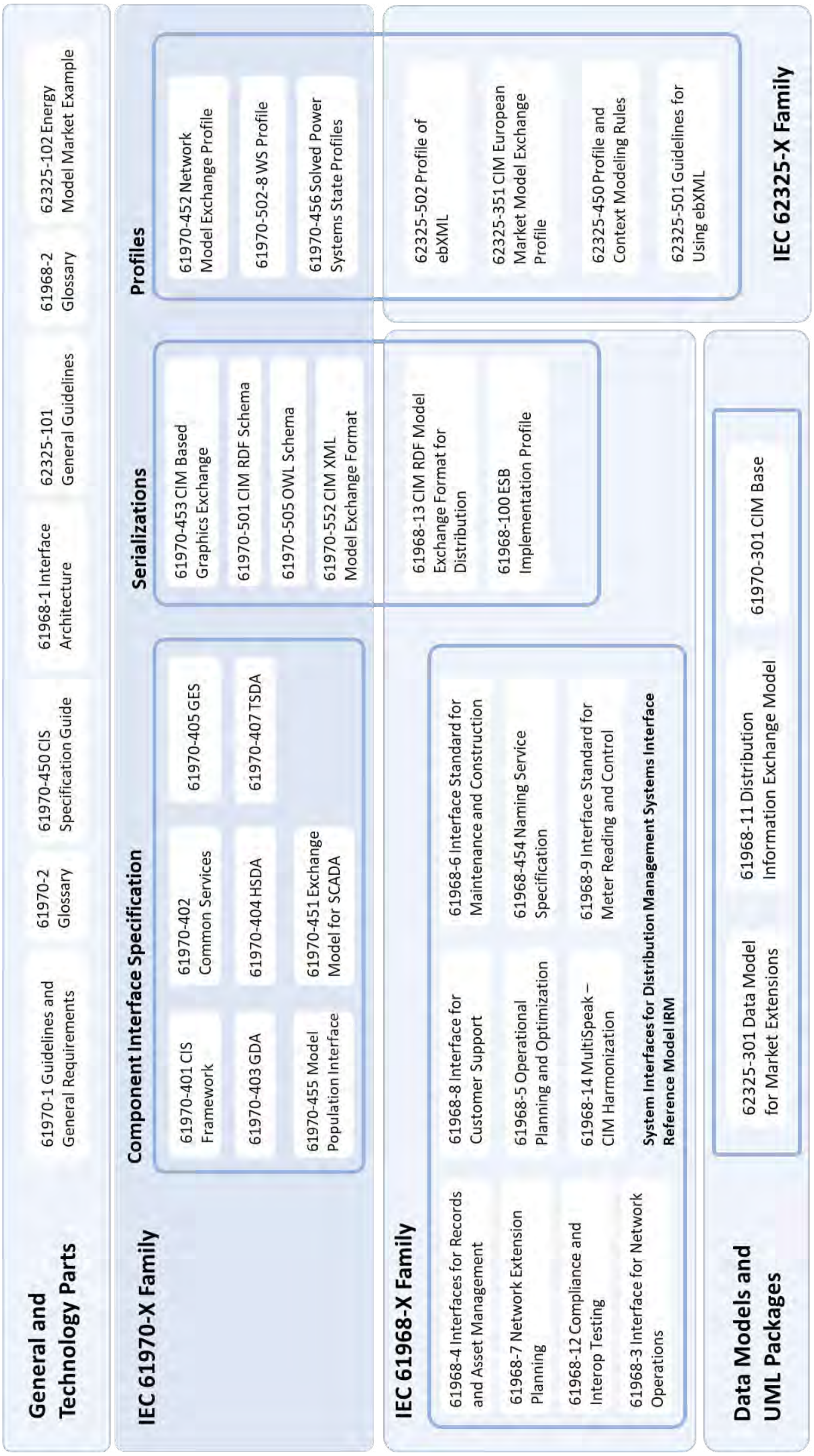

Figure 2: The CIM standard – an overview

3.3 CIM Profiles

The CIM standard includes parts that define what are known as "Profiles" – the electrical data model in the CIM is capable of describing the network assets in multiple ways. The profile defines how the CIM standards are used to describe the electrical assets. The intent is that different profiles are used for different use cases. For example, the data needs for a load flow study will be different to those needed by an asset management system.

We have developed a profile that defines a use case for data which is required to be exchanged within CIM for the Evolve Project.

As part of the open source components of the project, it is available at the following url:

https://zepben.bitbucket.io/cim/evolve

The CIM standards also include parts that define serializations – that is, how to extract the model into a form that can be sent from one computer or one system to another.

We see the serializations techniques defined by these parts of the CIM as problematic, and for the Evolve Project, we are developing alternative serializations mechanisms that are not part of the current CIM standards. These are described further in the document in Chapter 5.

3.4 CIM Governance

3.4.1 The IEC role in the CIM standards

The CIM standards are published by the International Electrotechnical Commission (IEC). IEC nominates itself as "the world's leading organization for preparation and publication of international standards for all electrical, electronic and related technologies" ("IEC - About the IEC" n.d.) .

The IEC members are National Committees (NCs), with one per country. Each NC appoints experts and delegates from industry, academia, government bodies and associations to participate in IEC technical and conformity assessment work.

Australia has full member status and is represented by the associated NC of Standards Australia (SA) (Standards Australia, 2020). The standardization activities are the responsibility of the Standardization Management Board (SMB), which creates technical committees (TC) for different fields of technical activities (also known as scopes). The TCs may create Subcommittees (SCs) depending on the extent of its work programme (IEC 2020).

TC membership is composed of the IEC NCs, all of which are free to take part in the work of any given TC, either as:

- *Participating Members (P-Members): Members with the obligation to vote at all stages and to contribute to meetings, or*
- *Observer members (O-Members): Members who can receive committees' documents, submit comments and attend meetings.*

Both TCs and SCs prepare technical documents on specific subjects related to their scope. More than 200 IEC TCs are active at the moment of writing this report (About TC/SCs, 2020). The TC 57 has as part of its scope the preparation of international standards for *"power systems control equipment and systems including EMS (Energy Management Systems), SCADA (Supervisory Control And Data Acquisition), distribution automation, tele-protection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems" (TC 57 Scope, 2020)*.

Within the scope of the TC 57, several working groups (WGs) have been created to deal with the CIM family standards, namely:

- *WG 13 - Energy Management System Application Program Interface (EMS -API)*
- *WG 14 - System Interfaces for Distribution Management (SIDM)*
- *WG 16 - Deregulated Energy Market Communications*
- *WG 19 - Interoperability within TC 57*

The primary role of the IEC TC 57 for the CIM standard family is defining and revising the public version of the associated standards following the rules of the standard developing organization. Participation in the process of standardization is possible in two ways:

- *Direct participation: Joining IEC WGs using the NC nomination or participating in national mirror committees.*
- *Indirect participation: Through associations, user groups (e.g., CIM users group) or other standardization bodies and working groups which have liaisons with the IEC.*

3.4.2 The CIMug role in the CIM standards development

One official channel to make suggestions to the CIM development is the CIM users' group (CIMug)[9]. This group is a cooperation space for utilities, vendors, consultants and integrators who have some interest in the CIM implementation and application.

CIMug was created in 2005, as a subgroup of the Utility Communication Architecture (UCA) International Users Group. This group provide a forum for users, consultants, and suppliers to cooperate and leverage the IEC CIM international standards and advancing on the interoperability across the utility enterprise. The main objective of this group is "to share technology basics, best practices and technical resources while Advancing Interoperability for the Utility Enterprise".

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[9] https://cimug.ucaiug.org/

The CIMug has two regularly scheduled meetings each year. The first is located in Europe, (typically in June) and the second takes place in the U.S., typically in November. Participation in this space could be a strategic approach for international knowledge sharing of the Evolve Project.

3.4.3 The development process and lifecycle management of the CIM standards

As the CIM standards are one of the international standards published by the IEC, their development process and lifecycle management follow the general directives established by ISO/IEC. The development of an International Standard within IEC (or the International Standards Organization (ISO)[10]) is a result of a consensus between the participating NCs. This process is undertaken in seven stages (ISO/IEC, 2016).

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[10] This process has been defined in the joint directive ISO/IEC DIR 1 (ISO/IEC 2016).

Project Stage	**Definition**		**Recommended Target Dates (months)**
	Name	**Abbreviation**	
Preliminary Stage	Preliminary work item	PWI	6
Proposal Stage	New work item proposal	NP	6
Preparatory Stage	Working drafts (s)	WD	6
Committee Stage	Committee draft (s)	CD	12
Enquiry Stage	Enquiry draft	ISO/DIS, IEC/CDV	24
Approval Stage	Final draft International Standard	FDIS	33
Publication Stage	International Standard	ISO, IEC, or ISO/IEC	36

As we can see in the recommended target dates, the development of an international standard is a time-consuming activity that needs to consider a minimum period of 36 months from a first draft until the approval of the standard.

On the other hand, the IEC standards go through a lifecycle from their initial creation to their final retirement, passing over stages of publication and maintenance. In Figure 3, we can see a complete summary of the lifecycle of an IEC standard. The lifecycle initiates with the "Initial creation" stage, where several consensus-based procedures are undertaken within IEC during typically three to five years.

After this period, the initial standard version is ready for publication. In the publication stage, different formats can be used, including paper or electronic versions. Additionally, further artefacts such as models can be included in the publication. These IEC publications, including the CIM standards, can be obtained in the IEC Webstore[11].

Optionally a stability date can be defined for the published document. After the stability date, the replacement of the publication must be considered, initiating the maintenance period, where the decision can be reconfirmed, amend, publish a new version or retire the standard.

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[10] https://webstore.iec.ch

Due to the number of actors involved in this process, and the temporal and geographic displacement of the participants, this process of iteration can be slow, and can act as an inhibition to innovation as described in section 2.2.

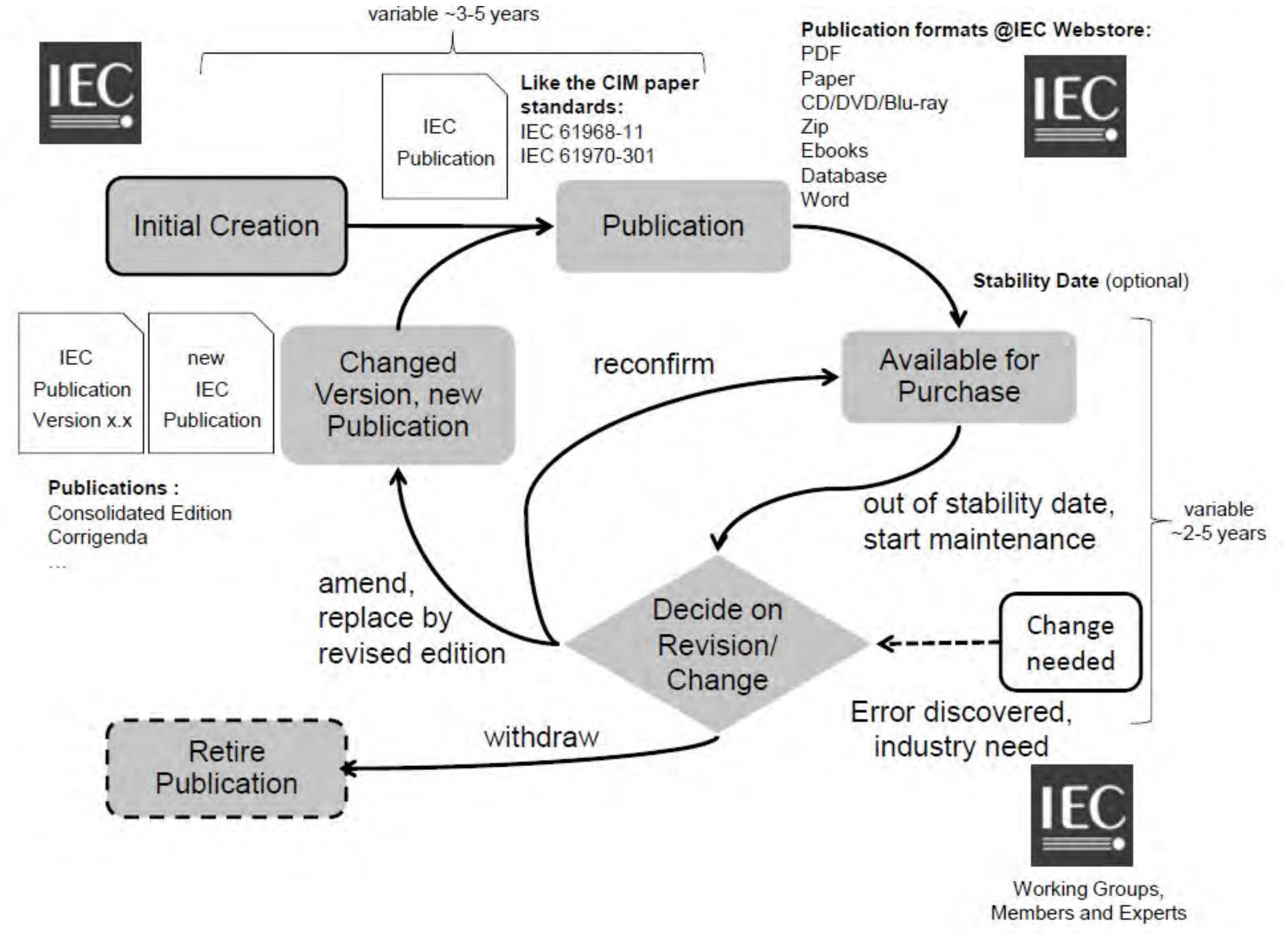


Figure 3: IEC Publication lifecycle. Reprinted from (Uslar et al. 2012)

3.4.4 The Standards Australia Role in the CIM standards development

Standards Australia is the nation's peak non-government and not-for-profit standards organization in Australia. The SA development activities are divided into industry sectors, including the Electrotechnology and energy sector, where more than 100 Technical committees are responsible for the development of the standards in this sector.

Table 1 shows a general overview of the different AS-TCs that are participating on the IEC -TCs in scopes related to Smart Grids and power systems management, control and communications ("Standards Development Public Portal : Standards Australia" n.d.).

TC Name	TC Code	IEC - TC
Smart grids	EL-062	PC 118: Smart grid user interface
Management of network assets in power systems	EL-065	TC 123
Grid Integration of Renewable Energy Generation	EL-064	TC 8 / SC 8A
Energy network management and safety systems	EN-004	No active participation
Power system control and communication	EL-050	TC 57: Power systems management and associated information exchange

Table 1. AS-TCs that are participating on the IEC -TCs in scopes related to Smart Grids and power systems management.

The Standards Australia TC EL-050 is constituted by eight (8) institutions, namely:

- *Australian Industry Group*
- *Australian Information Industry Association*
- *Chamber of Commerce and Industry Queensland*
- *Electric Energy Society of Australia*
- *Energy Network Australia (Testing Interest Australia)*
- *Energy Networks Australia*
- *Engineers Australia*
- *Victoria University*

This TC acts as NC in the IEC TC 57 and is currently active. Likewise, the EL-0050 committee has two (2) associated sub-committees (EL-050-00 and EL-050-01 Advisory committee on IEC TC 57) and has published more than 42 AS standards. The TC EL-050 standards production has been focused on Supervisory control and data acquisition (SCADA) systems and Telecontrol equipment and systems.

However, at the moment this report was written, there is not any Australian Standard adopted in the data exchange scope or from CIM Standards family (IEC 61970, IEC 61968 and IEC 62325). According to this scenario and considering that the data exchange scope is a key area to deal with the challenges of the new electrical grid, a more active role from the TC - EL-050 in this scope would be desirable.

3.5 What the CIM does not address

The CIM provides a comprehensive ontology for an electrical network through a set of classes, relationships and attributes representing the physical assets in electricity networks at all levels.

It does not however provide any way to model the temporal, data quality and completeness aspects of those assets. This may be partly attributed to the provenance of the CIM standards, which were formulated to describe transmission networks. Distribution networks have different characteristics and different drivers for asset operation and management.

Finally, the CIM is not a “plug and play” standard. It provides an excellent semantic model that can be used to describe the elements of an electrical network, but it does not provide an unambiguous specification of how to exchange electrical network model data between systems. These issues are discussed in more detail in the following sections.

3.5.1 Temporal Modelling

Temporal Modelling refers to the ability of the model to describe how network assets change over time. Transmission networks have small asset counts compared to distribution networks and do not change quickly. Distribution networks have many more assets. These assets are smaller and less complex, but in terms of the numbers of discrete assets, distribution networks are perhaps two orders of magnitude larger than transmission networks.

Moreover, the rate of change of distribution networks per unit of time is much higher due to both the number of assets involved and incremental augmentation and modification of the network assets which occur in response to changes in population centres and consumption patterns. The changes occur over periods of months for distribution networks, as opposed to periods of years for transmission networks.

For use cases involving forecasting load growth and planning asset augmentation, and for asset management and workflow support, the evolution of the network over time is an important consideration. For the Evolve Project, this has implications for the development of operating envelopes for longer planning horizons.

As the drivers for temporal modelling for distribution networks are more significant than transmission networks, and given that the main drivers for the CIM originated at the transmission level, we can conjecture that the provenance of the CIM can help explain why temporal modelling was not part of the original standard.

Another explanation may simply be that temporal modelling is complex, and adding additional complexity to an already complex standard may have been considered a step too far by the Technical working group (IEC TC57) for the IEC CIM standards.

3.5.2 Data Quality and Completeness

In terms of describing data quality and completeness, the CIM is also silent. For transmission networks, it is generally assumed that the operators of the networks have accurate models of the assets, and relatively high penetration of sensors with reliable telemetry that can provide near real time data about the power flowing through the network and voltages at the network's nodes: Accurate models and measurements are assumed.

For distribution networks, due to historical design and control paradigms that assumed a lack of control of load or assets in much of the network, and the effort and expense needed to accurately model the LV network, the same business drivers to capture accurate details of the LV network did not exist, and for this reason data quality and completeness about LV assets in source systems such as the GIS is generally poor.

Data quality and completeness about LV networks in source systems is a major impediment to the development of systems that will allow higher penetrations of DER. In the absence of complete and accurate data, the next best thing is to attempt to derive or estimate the data that is missing, and to describe where this has been done in the exchange of model data between systems. The CIM does not provide any guidelines on how to go about doing this.

3.5.3 Plug and Play Integration

As described in section 3.1, the CIM is focused on semantic interoperability. It is not intended to be a "plug and play" standard.

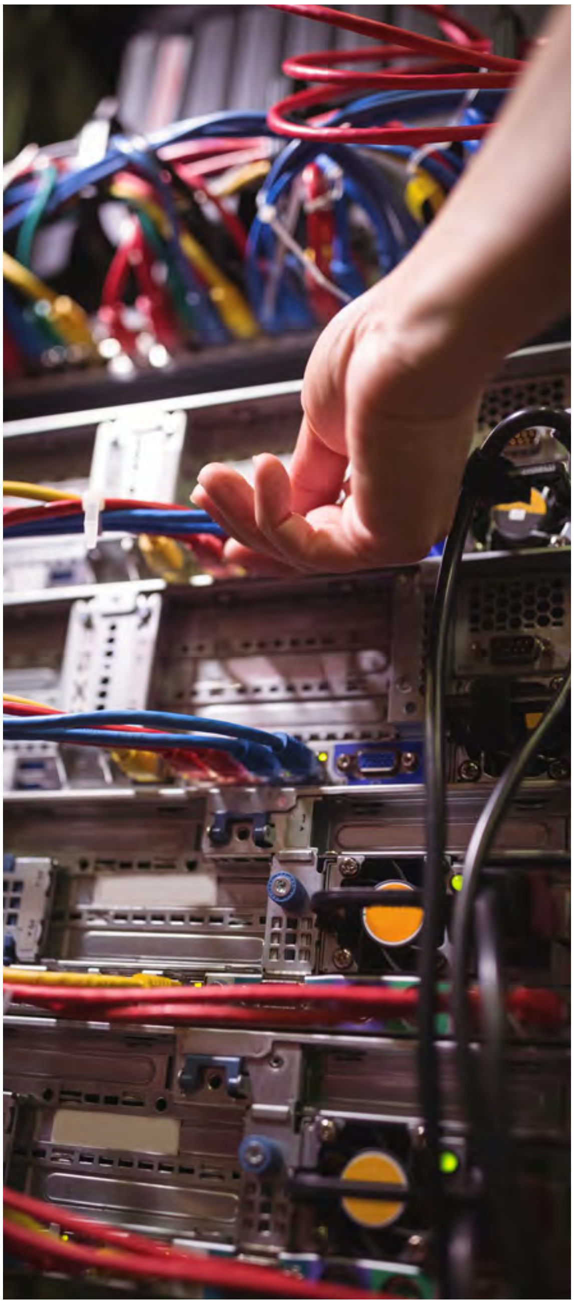
There have been attempts by the CIM User Group to test and certify interoperability outcomes, and part of the standard describes a way of serialising electrical model data into XML format; however, the nature of XML allows a great deal of variability in how the CIM model can be expressed by different implementations of the XML serialisation.

The intent of the CIM standards has been to provide reference models, rather than strictly defined interfaces for model exchange. This does provide flexibility and is a reasonable aim for the technical committee.

However, along with other issues in using XML to express electrical model data, the lack of a well-defined mechanism for implementing practical model exchange integrations within the CIM standards has not guided industry to converge on a particular set of implementations to develop practical and easy to use integrations between systems.

The complexity of the standard, and the flexibility it allows, means that it is difficult for vendors to cater to every possibility that could be encoded within CIM XML when creating CIM based interfaces.

In practical terms, this results in a lack of easy system interoperability amongst vendors.



4. How the DNSP Partners are using the CIM

As part of the development of this report, workshops were conducted with all the DNSP partners to explore how the CIM standards were being used, and what aspirations existed to continue or expand their use of the CIM.

4.1 Major Systems

In order to describe how DNSPs are currently using the CIM and provide commentary around different proposed uses for the CIM in the future, it's helpful to provide an overview of the systems typically used by DNSP's, and the types of data flows that exist between these systems. In general, the following major systems are used by DNSPs:

Advanced Distribution Management System (ADMS)

The ADMS supports short term planning horizons for the operation of the network, from real time to several weeks in advance. The ADMS is a so called "operational technology" that includes real time remote monitoring and control functions (SCADA) for network assets, outage management functions to support activities associated with restoration of supply following asset failure and workflow support for planned work on the network assets.

Geographic Information System (GIS)

Geographic Information Systems (GISs) are used by DNSPs for asset management outcomes. The GIS provides the most complete database of electricity network assets in the DNSPs, but is not an operational system updated in real time. It contains the "As-built" model. The ADMS has the "As-operated" model.

The representation of the network data model in the ADMS is generally more abstracted with less detail than in the GIS.

Historically, the focus of the GIS has been on physical location of the assets, and in many cases the topology or connectivity of the network assets was not modelled explicitly in the GIS, or was not modelled well – particularly in the LV network where the capture of this information for operational needs was not important.

Historians

These systems are data stores for time series data obtained from the SCADA sub-system of the ADMS, metering systems and other forms of telemetry. They generally provide functions that can display and perform analytics on time series data.

These systems, provided by Vendors such as OSI PI12, have been successful over traditional relational database technologies that have short coming when dealing with time series data. Systems such as OSI PI have built complete eco-systems for the development of operational technology front ends, and the time series data store in this type of product is now only a part of the overall product.

More recently, a number of open source time series[13] databases have appeared that are starting to challenge the traditional providers of historians to DNSPs. None of these are “CIM compliant”.

Customer Information Systems (CIS)

Customer Information Systems are primarily used by DNSPs for billing functions, including integrations with AEMO systems. They also provide data to customer facing systems that provide advice to electricity consumers about connecting DER to the networks, and to customers that want to connect new load to the networks.

Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure (AMI) refers to systems that measure, collect, and analyse energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule.

Works and Asset Management Systems (WMS)

These systems are used to schedule, plan and cost work and record information about assets for financial reporting and maintenance. They are sometimes part of the Enterprise Resource Planning (ERP) system.

ERP Systems

These include modules to manage finance tracking, reporting and forecasting, procurement, supplier management, human resources and property management.

Planning and engineering applications

DNSPs need to do load flow and fault level studies on their networks in order to understand where the assets are overloaded or voltage issues are present, or where there are protection setting issues. These applications require models of both customer load and generation, and the electrical network.

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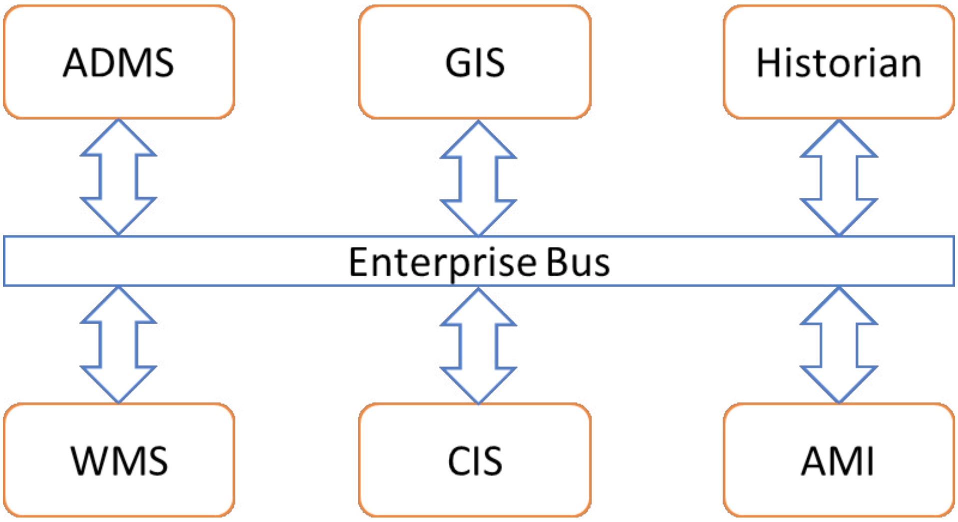
[13] https://en.wikipedia.org/wiki/Time_series_database



4.2 The Enterprise Service Bus

The ESB is an integration model for of information technology solutions. The basic concept is illustrated below, where a "bus" (actually a software application) is used to co-ordinate communications between multiple systems.

In practical terms, ESB's have been successfully used by DNSPs to integrate some of these systems, in particular using the CIM standards relating to billing and customer support in IEC 61968. However, ESB's have not been used successfully by any of the DNSP partners to implement model exchange between the ADMS and GIS.

The authors of this report are also aware, through long term involving in the sector, that few if any DNSPs anywhere have successfully implemented model exchange between the ADMS and GIS using ESBs.

We could conjecture this is because ESB's are designed for relatively small atomic transactions, whereas the CIM XML serialisations for network models create very large XML payloads that cannot be handled performantly by the ESB.

An example of an actual implementation of various CIM based integrations by one of the DNSP partners between major information technology systems is provided below in Figure 4.

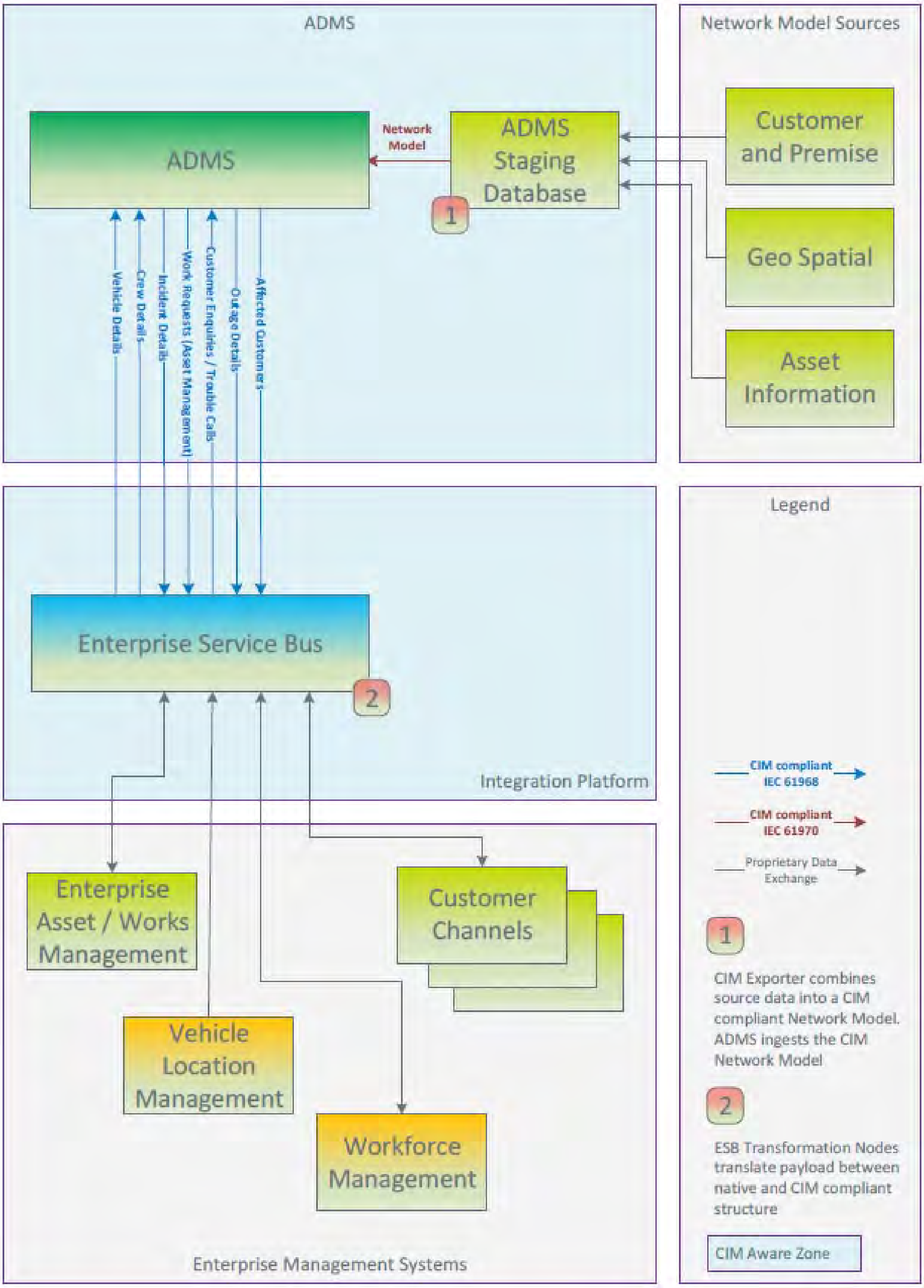


Figure 4: Practical Example of DNSP integrations involving the CIM

4.3 Data Migration Patterns used for ADMS Implementations

Three of the DNSP partners are implementing new ADMSs at the same time as the Evolve Project. All three are using the CIM XML/RDF standards to express (serialize) the electrical network models to send data from source systems to the new ADMS. Two different patterns are being used for this model exchange, as described in the following sections.

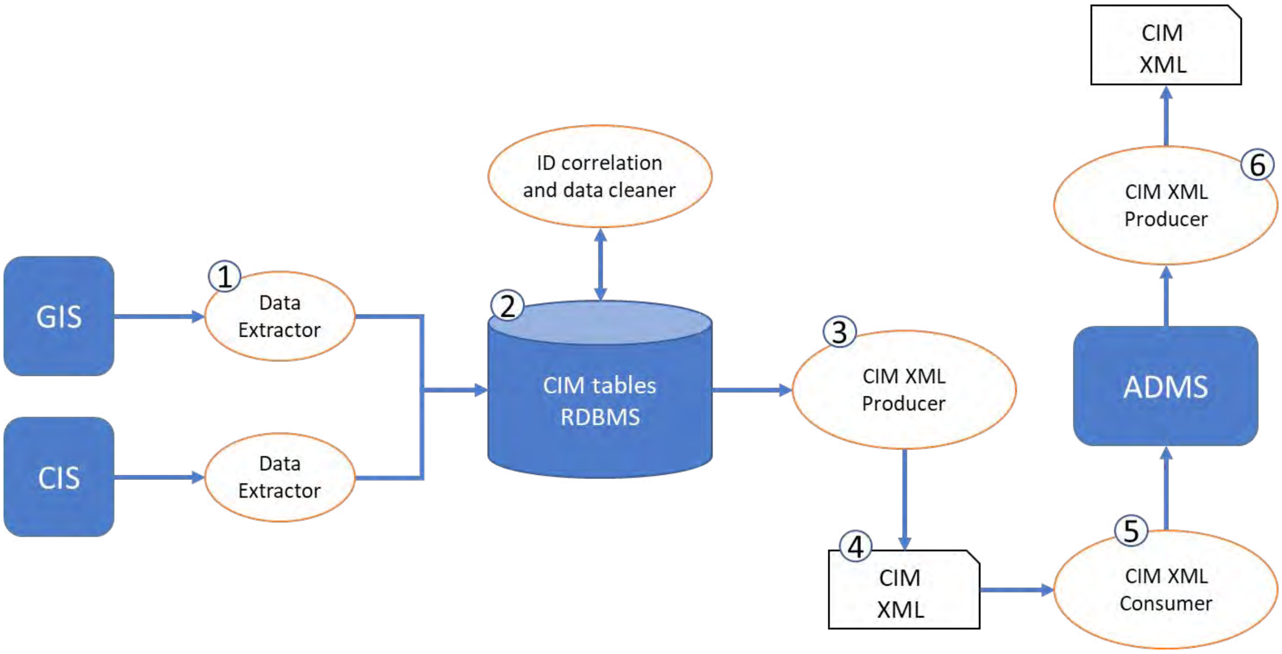


Figure 5: CIM XML Integration Pattern 1

4.3.1 Pattern 1

This pattern is being used by one of the DNSP partners. In this pattern, the vendor of the ADMS solution has provided a relational database (RDBMS) schema with tables representing concrete CIM classes. The DNSP data migration team has developed custom data extraction mechanisms from source systems such as their GIS and CIS to marshal the data into the RDBMS CIM schema.

The ADMS vendor has built a tool that turns the CIM RDBMS into XML/RDF, and then another tool that consumes the XML/RDF to populate the underlying model in the ADMS.

The ADMS vendor has also build a CIM XML/RDF export tool. This is the input the Evolve Project will use to obtain the network model for this particular DNSP partner.

In this scenario, the use of the CIM has provided a way for the vendor to specify the required data to populate the ADMS, using the well-established “language” of the CIM.

This has allowed the customer to stage the data needed for the ADMS implementation without needing to concern themselves with the complexity of implementing a CIM XML translator, and ensuring that it works with the vendor’s XML importer.

The ADMS vendor has removed that complexity from their customer by implementing both the CIM XML Producer and CIM XML consumer.
In this use case, there does not seem to be any benefit in performing the translation to and from CIM XML. The vendor could have developed a single consumer application that read directly from the CIM RDBMS and wrote directly to the ADMS.

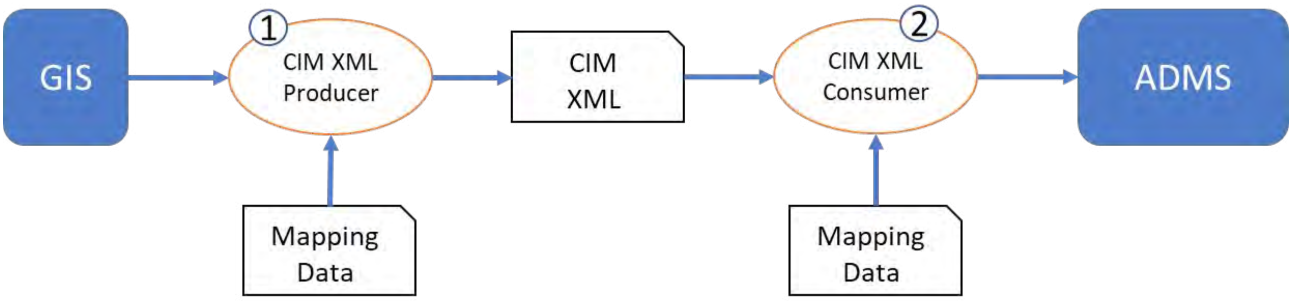


Figure 6: CIM XML Integration Pattern 2

4.3.2 Pattern 2

This pattern is being used by two of the DNSP partners. In one of these cases, the vendor of the ADMS is also the vendor of the GIS and CIM XML is used as an intermediate format to build a model in the ADMS from a GIS source. In the other case, the ADMS vendor is not the same and the GIS vendor and DNSP technical staff are responsible for building the CIM XML serialisation mechanism.

In both cases, data is exported from the GIS (and potentially other systems) into a CIM XML format. Mapping data needs to be supplied by the DNSP to map their specific GIS data model to the correct CIM objects.

Data is imported from the intermediate CIM XML format into the ADMS's underlying database model. Again, mapping data needs to be supplied by the DNSP to map their ADMS-specific data model to the correct CIM objects. Neither the source or destination systems have internal data models that resemble the CIM.

In the case of one ADMS implementation, not all the data needed by the ADMS arrives via the CIM XML – there are a number of other data feeds not shown on the diagram to add customer information, using proprietary data exchange formats.

In one of the ADMS implementations, this data migration will be a once off exercise: Once the model is established in the ADMS, it will be maintained independently of the GIS in the ADMS using the ADMS network model edit tools.

In the other case, the process will be made repeatable, so that the GIS becomes the source of the network model for the ADMS using daily model updates.

As with pattern 1, it is not clear what the advantage of using the intermediate CIM XML format is in this example. Especially in the case where it is the same vendor for both the ADMS and GIS. It would be more effective to use a direct translation from source to destination formats.

It could be argued that a different GIS vendor would be able to provide a CIM XML format suitable for use by the ADMS CIM XML consumer, however as the CIM is not a "plug and play" protocol, it would be almost inevitable that additional data processing would need to be done to translate from one CIM XML expression to another.

4.4 Conclusion

The following conclusions can be made about how, in general terms, the IEC CIM standards are perceived and are being utilised by the DNSP partners.

Firstly, all DNSPs involved in the project expressed in-principle support for the adoption of the IEC CIM standards within the overall enterprise, however it was also generally agreed that how this was intended to be achieved was not well understood.

It was generally agreed that it would not be practical to simply request the vendors of the major systems such as the ADMS, GIS and CIS to refactor or re-write their systems to be “CIM Compliant” in their underlying data models. This would be prohibitively expensive.

Amongst the participants in the workshops, those enterprise architects and other IT professionals and engineers that have working in the industry for some time were able to provide anecdotes of attempts to implement the CIM as part of particular projects. One of the impediments to this was the additional perceived cost burden of adopting the CIM standard where the preferred vendors did not already support the required CIM standard.

CIM compliant transactional XML interfaces did tend to be implemented where they were already available in the vendors product, as in these cases there were no additional perceived cost or risk issues. In fact, in these cases, the CIM compliance was seen as a positive thing.

One of the DNSP partners in particular has strong executive support to implement a new works and asset management system that has been assessed as strongly aligned to the CIM.

None of the DNSPs are currently actively engaged with any of the working groups in the IEC TC57. However, they all expressed an interest in becoming involved in a local working group that would have representation on TC57.

5. The Use of the CIM in the Evolve Project

5.1 Overview

The Evolve Platform is being designed to express DNSP data in a format based on the Common Information Model (CIM) standard. This standard is described in IEC standards 61970 and 6196814, and is intended to be used as a standard for the exchange of data representing distribution networks.

For the Evolve Project, Zepben has developed a CIM profile, which indicates the fields and formats that are required for input into the evolve platform, and this profile is expected to be further developed over the course of the project. One view of the Profile is maintained as part of the Evolve Project open source code base in bitbucket:

https://zepben.bitbucket.io/cim/evolve

This online version is intended to show major parts of the standards and the relationships between objects. This will be updated during the course of the project.

The full evolve CIM profile, which includes more detail about attributes and objects, as it stands at the time of production of this report, is provided in Appendix A - CIM profile for Evolve Project.

The data needs for the Evolve Project are also summarised in a simple fashion in Appendix B - Evolve Project overview. The data requirements described in the Evolve CIM profile are aspirational. What does this mean?

Historically, asset data for the LV network has not been maintained particularly well in DNSP source systems - data about LV network assets such as connectivity and conductor types are often missing or inaccurate.

This introduces challenges for the project (which were understood during the inception and design phases), as accurate analysis on the LV model in regards to the impact of DER on the network is difficult to achieve without accurate models of the LV network. Additionally, monitoring of power system parameters such as voltage and power is typically not done for assets in the LV network,

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[14] https://www.iec.ch/smartgrid/standards

however this has improved over the past few years and power system data is increasingly becoming available from DER installers/aggregators.

So, the DNSP source systems will not contain all the data elements in the evolve CIM profile, and/or coverage of the elements for all the network. The intent is to provide a specification for all the data the project thinks may be required in an ideal world, and then refine that profile as the data extraction utilities are developed, and the evolve calculation engines are developed.

5.2 Data Sources and Flows

Within the project consortium, aggregators will be responsible for sourcing and supplying DER data. The supply of this data will be via the evolve API (based on the IEEE 2030.5 protocol), which is being refined through collaboration between the consortium partners and external stakeholders involved in the development of an industry wide DER API.

DNSPs will supply data about their electrical networks from their GIS and ADMS and via their own telemetry via SCADA and AMI systems. Adapters are being built that obtain data from these source systems and send this data to the evolve platform via CIM-based messages.

Within the evolve platform, the exchange of network derived measurement data and network models will be via CIM-based messages.

The overall data flows are illustrated below in Figure 7: High level data flows.

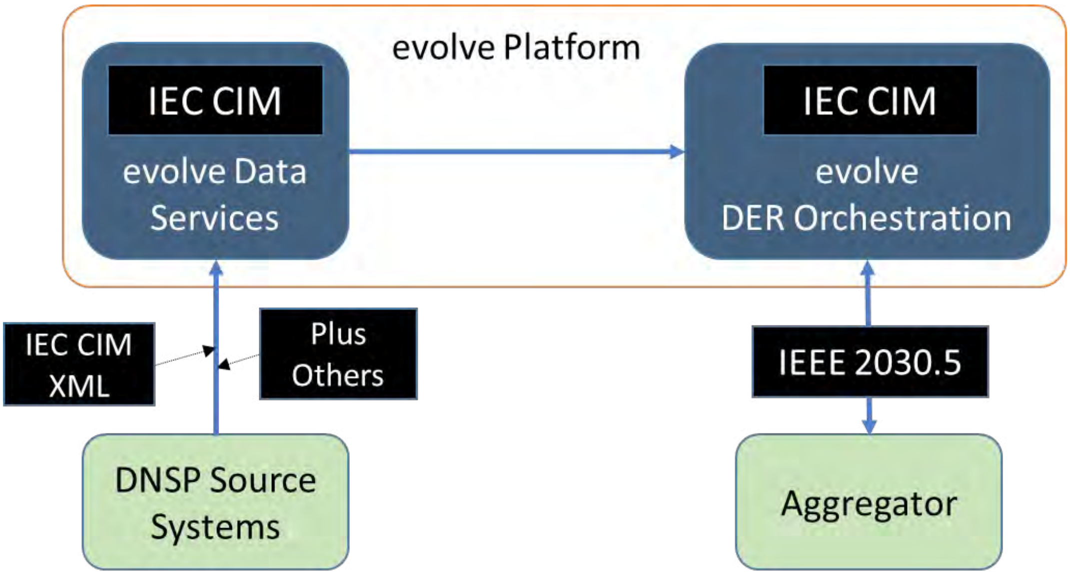

Figure 7: High level data flows

5.3 Parts of the CIM Standard used by Evolve

The parts of the CIM standard that have been adopted are those parts that deal with the issue of describing electrical network models and measurement data: the 61968-11 and 61970-301 standards.

Our rationale for using this part of the CIM standad was simple:

- *Electricity networks are complex and an asset heavy businesses.*
- *The IEC CIM standards include a substantial body of work that provides a comprehensive ontology for electrical networks.*
- *That is, classes that describe the assets, their relationships and their attributes in an object oriented way. These models map easily to object oriented programming languages.*
- *It's a very valuable resource – engineers have been refining it for 20 years.*
- *Why would we start from scratch?*

5.4 Parts of the CIM Standard not used by Evolve

Many parts of the overall CIM standard, involved with interface definitions for asset management, planning and markets were simply not relevant to the Evolve Project. Others were of interest, but not directly relevant.

Even though we did need ways to send network model and measurement data between systems, we chose not to use the IEC CIM 61970-501, 61970-552 or 61968-13 standards for serialisation using XML because:

- *There are performance and payload size issues in using this form of serialisation,*
- *It does little to help the software engineer who has to use it,*
- *We believe the "XML eco-system" is in decline, and*
- *There are better alternatives.*

Criteo labs conducted benchmarks of XML serialisation against various other serializations mechanisms using large data sets.

This benchmark[15] was particularly relevant as it included testing with large complex data messages – a characteristic of CIM electrical network models.

One of the key results of the benchmark is the file size (payload) for the same data, expressed as XML compared to other techniques. The XML payload was around 5 times larger than some others. As illustrated below:

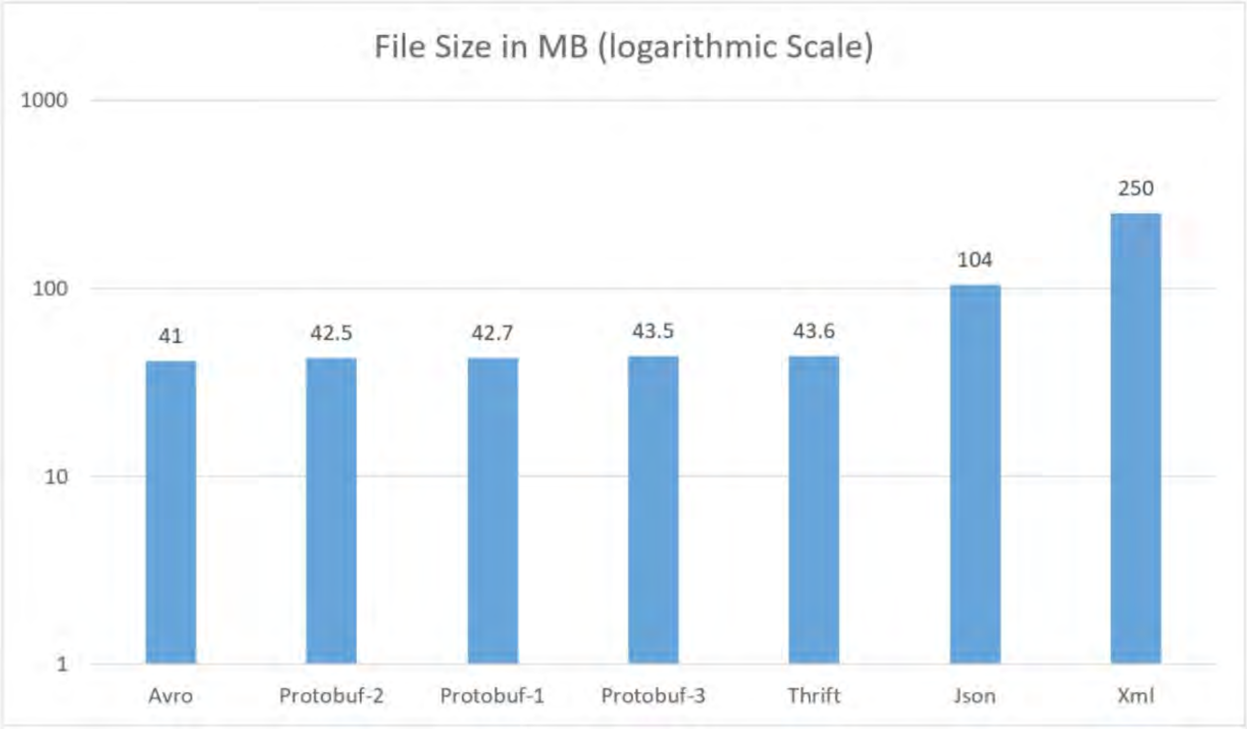

Figure 8: XML message size comparison

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[15] https://labs.criteo.com/2017/05/serialization

The data payload size is perhaps not such a concern as compression of the XML will generally be very effective in reducing its size. However, this comes at a cost, and another key result was the time taken to serialise and de-serialise the data, with the XML serialisation taking significantly longer compared to other methods.

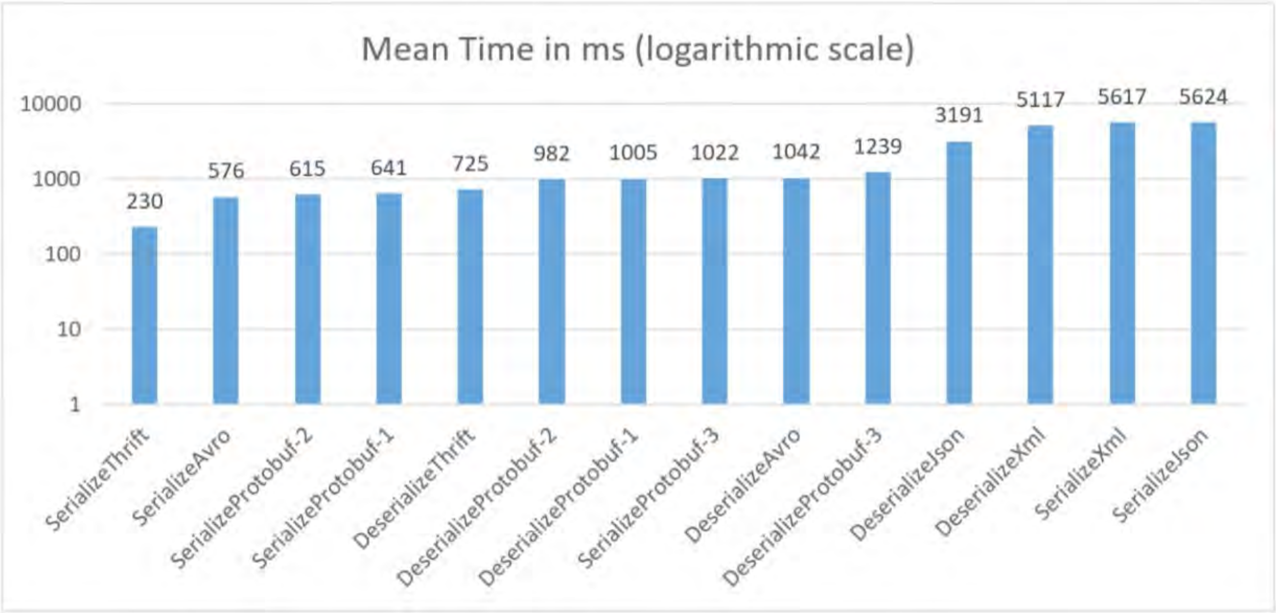

Figure 9: XML serialisation time comparison

These benchmarks provide a strong disincentive for using XML. However, a more compelling reason for looking at alternatives from our point of view was to provide support to the development team working on the Evolve Project, and potentially other development teams in the future.

XML is not easy to work with!

We researched several potential alternatives to XML, and after researching options, we elected to use gRPC[16], which is based on Google protocol buffers[17] to provide the CIM serialisation mechanisms and language agnostic message definitions.

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[16] https://grpc.io

[17] https://developers.google.com/protocol-buffers

This approach provides several advantages over the current set of XML based CIM standards for serialization:

1. **It is significantly more efficient,** both in terms of network bandwidth required to send data between systems, and in terms of processing power required to parse the XML,
2. **It provides significant productivity benefits to implementing new applications.** It is no longer necessary for new applications to first include code to parse XML payloads to create in-memory objects that can be used by application software – these are available immediately via the library,
3. **It is a contemporary technology.** Its "eco-system" is very strong with a very large user base of developers working across multiple problem domains, resulting in good tooling, supporting software, support and continual enhancements of the core technology, as opposed to the "XML serialisation developer community" which is not as well supported,
4. **It makes it significantly easier for other developers** to produce libraries with common, higher-level functionality based on existing code bases of CIM classes.

Although the evolve data platform is not using the XML based serialisation standards for internal communications, adapters to ingest network data from CIM-based XML data sources will still need to be developed for the Evolve Project, and at some of the DNSP partners will be providing the evolve platform with network data using CIM XML.

A graphic showing the parts of the protocol that were adopted, as well as those not relevant to the Evolve Project, those parts that were problematic and those parts that were of interest is provided on the following page in Figure 10: CIM Parts used by the Evolve Project.

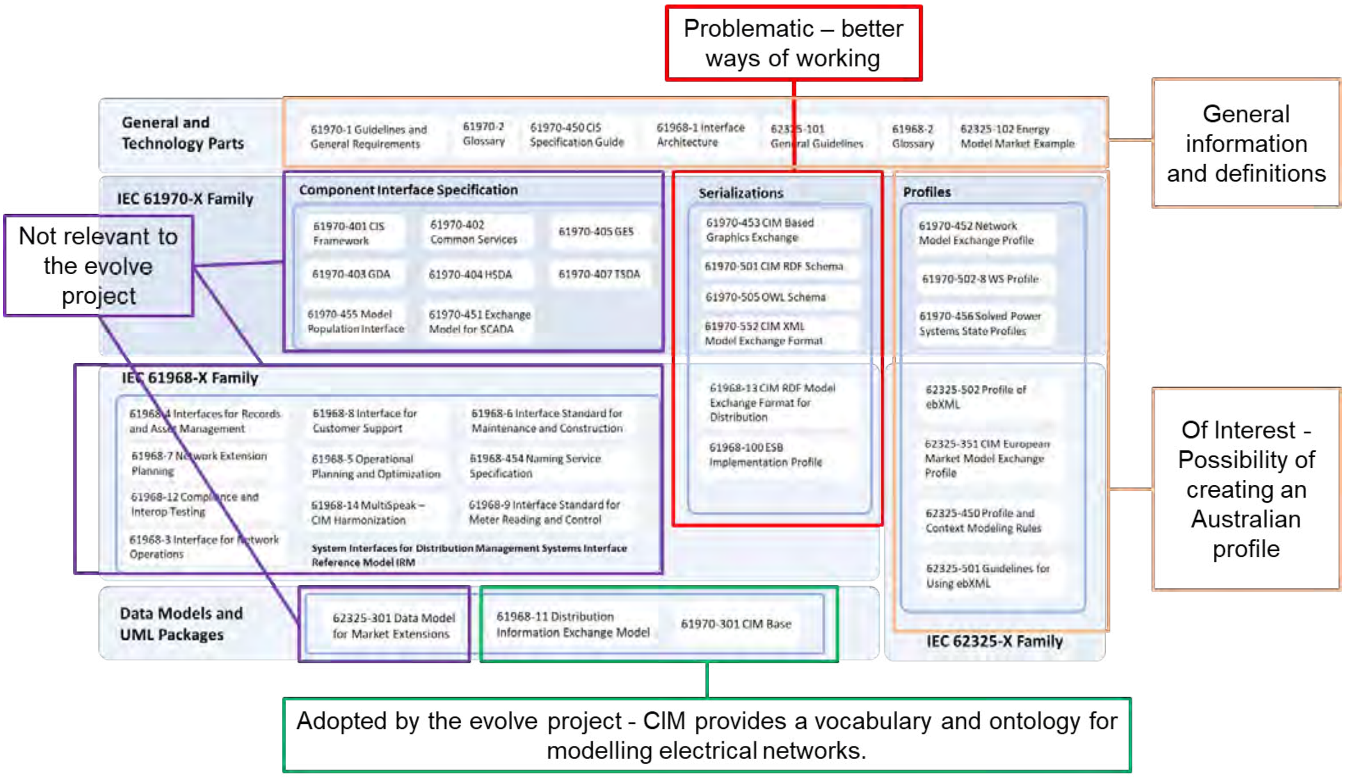


Figure 10: CIM Parts used by the Evolve Project

5.5 Major Elements of the Evolve CIM Profile

Zepben has developed a CIM profile which indicates the types, fields, and formats that are required for input into the evolve platform to support the operation of the operating envelope calculation engine. This profile is expected to change over the course of the project as need arises.

This profile has been built as a data model into all the evolve data platform components and is based upon common libraries to simplify integration and keep language and meaning consistent across all components.

The evolve CIM profile includes two main sections,

1. a definition of the network assets and connectivity model, and
2. definitions for network measurements.

For the network model the construct EquipmentContainer has been used to house the equipment in a network. An EquipmentContainer is extended to represent both a Substation and its Feeders, with a Substation having potentially many Feeders attached to it.

Within each Substation is housed the equipment that makes up the substation, and the connecting equipment to each Feeder. Within each Feeder is housed all the equipment and the connectivity model of that equipment via ConnectivityNodes and Terminals. This gives a canonical way of defining the connectivity of the network, which will be consistent for every DNSP.

Terminals represent the end points of each piece of ConductingEquipment, and each Terminal is associated with exactly one ConnectivityNode. This model provides a standard way of representing any possible connections between two or more separate pieces of equipment in the network. This also provides a standard way of navigating and tracing the network.

These relationships are illustrated in Figure 11: Core asset model.

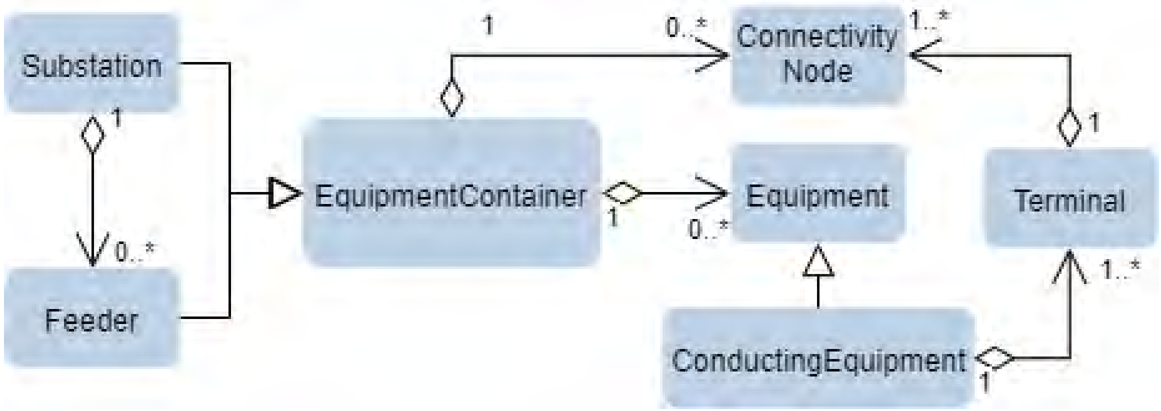


Figure 11: Core Asset Model

A ConductingEquipment object can represent any piece of equipment through which energy flows. In our current profile this includes all equipment in the following diagram as a basis, but can include more as they become necessary.

The following diagram depicts the basic equipment types necessary for the Evolve Project. These types are the absolute minimum required to build an electrical network, allowing us to represent conductors, open points, generators of energy, loads, and transformers.

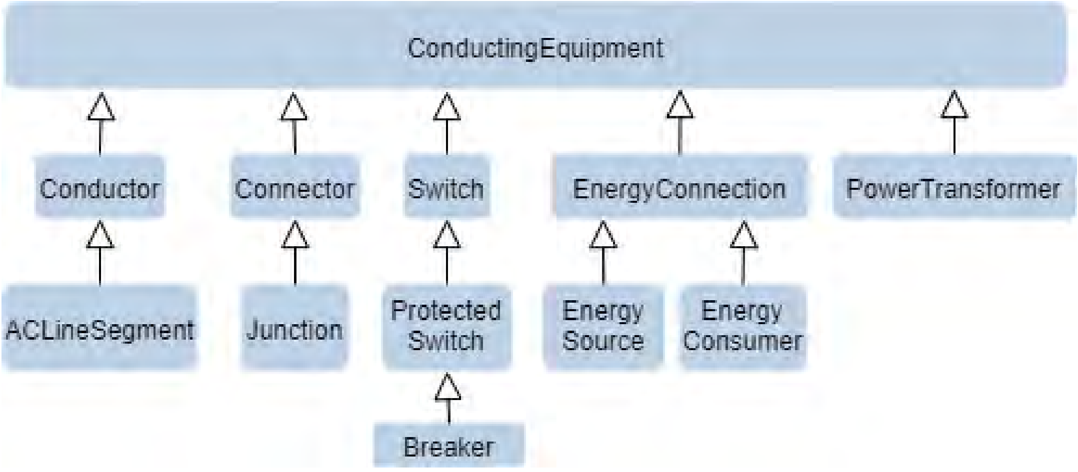


Figure 12: Conducting equipment inheritance

The other aspect of the evolve CIM profile relates to metering and measurement data for equipment on the network. The energy usage data readily available is from customer meters. These are represented through our CIM profile as Meters associated with UsagePoints, where a UsagePoint is associated with a set of Equipment. It is then possible to store MeterReadings against a particular meter and map it back to a point on the network as illustrated below in Figure 13: Meter Reads

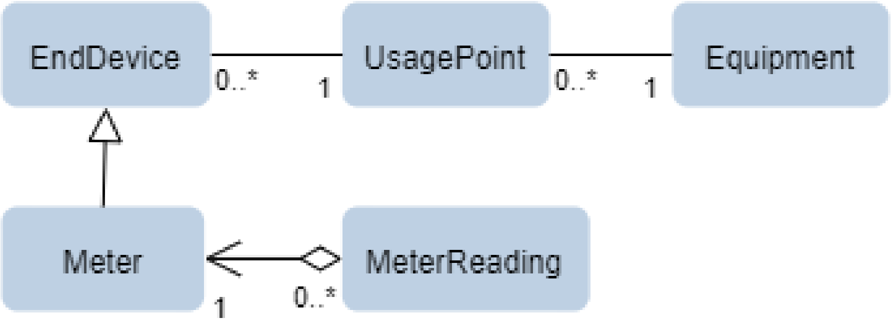


Figure 13: Meter Reads

For measurement data from the network itself, the "Meas" part under IEC61970 is utilised, which allows the association of Measurements directly with a PowerSystemResource as illustrated below in Figure 14: Measurements.

CIM provides a highly flexible method of supporting measurements of any particular unit and multiplicity through this package, however this flexibility comes at a cost of high complexity, and instead we intend to only support dedicated measurement types of base units.

We enforce this through our API endpoints, which only accept a particular type of measurement and unit for each measurement device. An example of this would be createVoltageReading which accepts Measurement with a value for a voltage (in volts) to be associated with a PowerSystemResource through powerSystemResourceMRID.

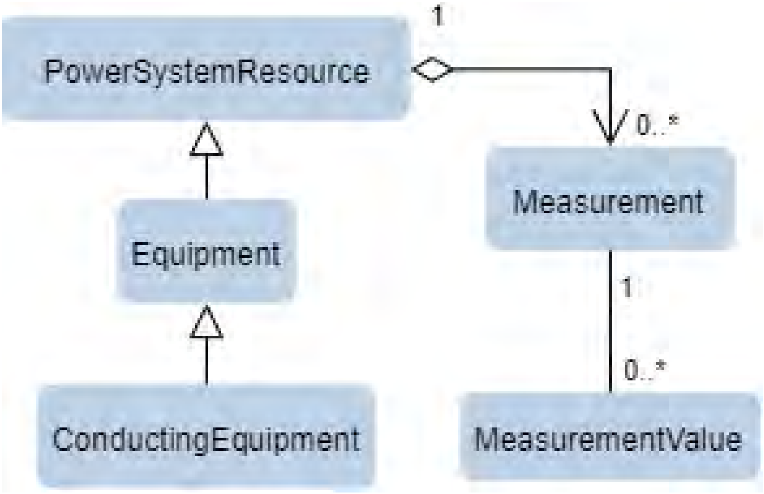


Figure 14: Measurements

This accounts for the basics of the CIM profile developed for the Evolve Project, and the extent that it needs to be understood for integration with the evolve data platform.

It is worth noting that what has been outlined here is just the basic framework of the profile, and does not include all classes and relationships. The full profile includes a higher level of detail and documentation for the types and fields that are supported. The current profile is included in Appendix A - CIM profile for Evolve Project.

This model is reflected in all aspects of the evolve platform, and thus encourages users of the platform to follow suit and make use of the profile for their own applications.

5.6 CIM Serialisation and CIM Libraries

The evolve data platform has been built on top of a common set of libraries that are intended to be used by applications wishing to interact with the platform. If an application wishes to obtain electrical network or measurement data, it uses a library in one of a number of languages to obtain the data expressed as CIM classes within the memory space of the application.

These libraries are written and maintained against the evolve CIM profile described above, and are thus consistent in their implementation, greatly reducing the learning curve for working with the system.

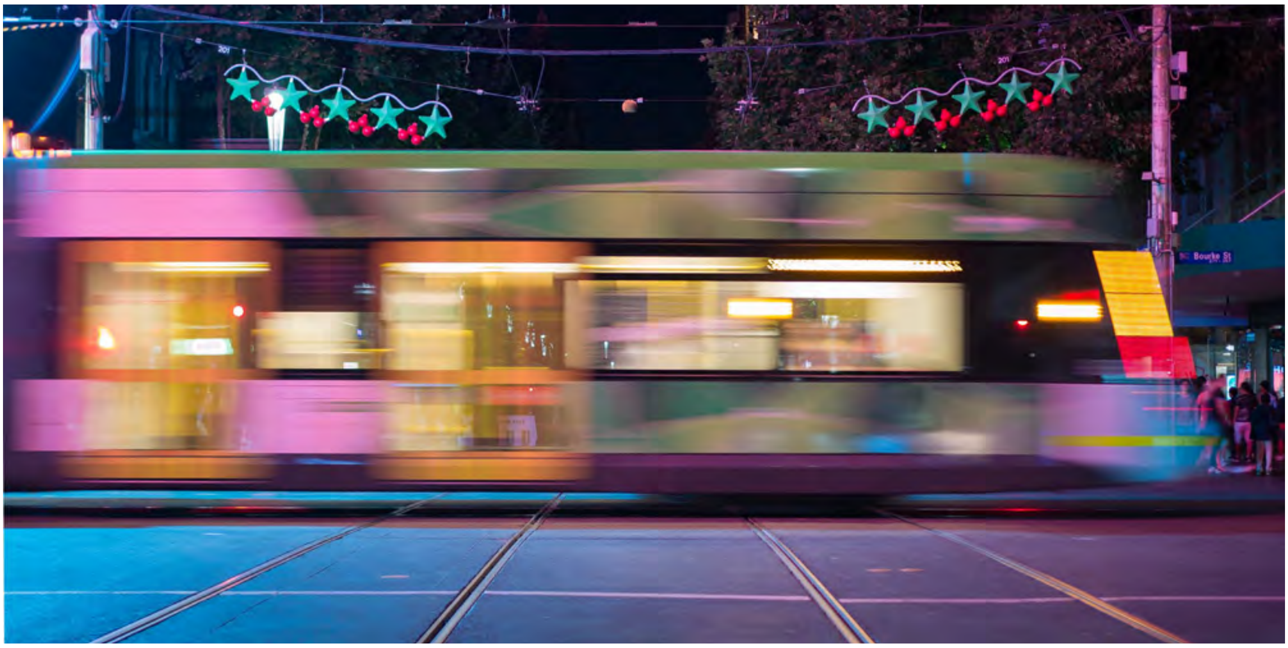
5.6.1 Creating CIM Libraries

The libraries are developed by firstly defining CIM class constructs in a way that is agnostic to the final programming languages that will be targeted.

gRPC uses ***protocol buffers*** as the Interface Definition Language (IDL) for describing both the service interface and the structure of the payload messages. In our case, the payload messages are created to represent CIM classes.

The code snippet below provides an example of the definition of a CIM object in the IDL. Comments have been omitted so it fits neatly in this document.

```
message PowerTransformer {
   bool normallyInService = 4;
   string baseVoltageMRID = 5;
   repeated iec61970.base.core.Terminal terminals = 6;
   repeated iec61970.base.wires.PowerTransformerEnd powerTransformerEnds = 7;
   iec61970.base.wires.VectorGroup vectorGroup = 8;
   repeated iec61970.base.diagramlayout.DiagramObject diagramObjects = 16;
   string assetInfoMRID = 17;
   iec61968.common.Location location = 18;
   iec61970.base.meas.Control control = 19;
   iec61970.base.meas.Measurement measurement = 20;
}
```



The actual IDL for the PowerTransformer can be found here:

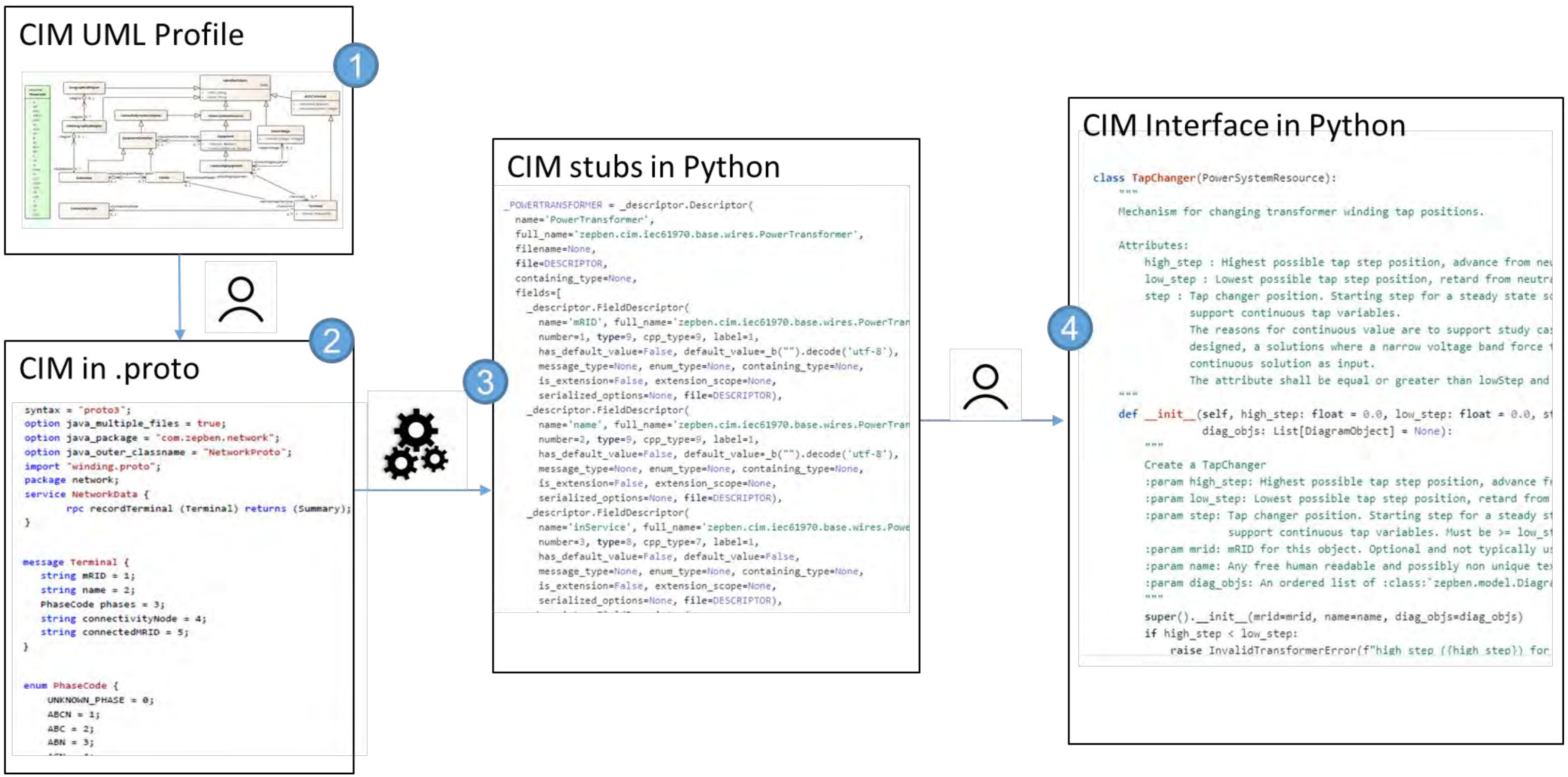
https://github.com/zepben/evolve-grpc/blob/main/proto/zepben/protobuf/cim/iec61970/base/wires/PowerTransformer.proto

This IDL is then used as an input into the protobuf compiler to create “stubs” in different languages.

Finally, additional code is added to the library to provide a developer friendly interface that performs common actions for producer and consumer clients, as well as providing debug and metrics functions, as illustrated in the following example.

https://github.com/zepben/evolve-sdk-jvm/blob/main/src/main/java/com/zepben/cimbend/cim/iec61970/base/wires/PowerTransformer.kt

This process is illustrated in the diagram on the following page.



```
syntax = "proto3";
option java_multiple_files = true;
option java_package = "com.zepben.network";
option java_outer_classname = "NetworkProto";
import "winding.proto";
package network;
service NetworkData {
        rpc recordTerminal (Terminal) returns (Summary);
}


message Terminal {
   string mRID = 1;
   string name = 2;
   PhaseCode phases = 3;
   string connectivityNode = 4;
   string connectedMRID = 5;
}


enum PhaseCode {
    UNKNOWN_PHASE = 0;
    ABCN = 1;
    ABC = 2;
    ABN = 3;
```

```
_POWERTRANSFORMER = _descriptor.Descriptor(
  name='PowerTransformer',
  full_name='zepben.cim.iec61970.base.wires.PowerTransformer',
  filename=None,
  file=DESCRIPTOR,
  containing_type=None,
  fields=[
    _descriptor.FieldDescriptor(
      name='mRID', full_name='zepben.cim.iec61970.base.wires.PowerTran
      number=1, type=9, cpp_type=9, label=1,
      has_default_value=False, default_value=_b("").decode('utf-8'),
      message_type=None, enum_type=None, containing_type=None,
      is_extension=False, extension_scope=None,
      serialized_options=None, file=DESCRIPTOR),
    _descriptor.FieldDescriptor(
      name='name', full_name='zepben.cim.iec61970.base.wires.PowerTran
      number=2, type=9, cpp_type=9, label=1,
      has_default_value=False, default_value=_b("").decode('utf-8'),
      message_type=None, enum_type=None, containing_type=None,
      is_extension=False, extension_scope=None,
      serialized_options=None, file=DESCRIPTOR),
    _descriptor.FieldDescriptor(
      name='inService', full_name='zepben.cim.iec61970.base.wires.Powe
      number=3, type=8, cpp_type=7, label=1,
      has_default_value=False, default_value=False,
      message_type=None, enum_type=None, containing_type=None,
      is_extension=False, extension_scope=None,
      serialized_options=None, file=DESCRIPTOR),
```

```
class TapChanger(PowerSystemResource):
    """
    Mechanism for changing transformer winding tap positions.

    Attributes:
        high_step : Highest possible tap step position, advance from ne
        low_step : Lowest possible tap step position, retard from neutr
        step : Tap changer position. Starting step for a steady state s
               support continuous tap variables.
               The reasons for continuous value are to support study ca
               designed, a solutions where a narrow voltage band force
               continuous solution as input.
               The attribute shall be equal or greater than lowStep and
    """
    def __init__(self, high_step: float = 0.0, low_step: float = 0.0, s
                 diag_objs: List[DiagramObject] = None):
        """
        Create a TapChanger
        :param high_step: Highest possible tap step position, advance f
        :param low_step: Lowest possible tap step position, retard from
        :param step: Tap changer position. Starting step for a steady s
                     support continuous tap variables. Must be >= low_s
        :param mrid: mRID for this object. Optional and not typically u
        :param name: Any free human readable and possibly non unique te
        :param diag_objs: An ordered list of :class:`zepben.model.Diagr
        """
        super().__init__(mrid=mrid, name=name, diag_objs=diag_objs)
        if high_step < low_step:
            raise InvalidTransformerError(f"high step ({high_step}) for
```

Figure 15: CIM Library creation process

1. Subject matter experts and application developers work on the definition of the CIM profile in UML
2. A software engineer manually translates this into the Interface Definition Language (IDL), in this case .proto
3. A software engineer uses the protobuf compiler to generate stubs in different languages
4. A software engineer incorporates additional features into the language specific libraries to be used by application developers – clients of the library.

From a developer's perspective creating data extraction applications, a CIM-based network can be easily built from source systems with the help of the library. Most of the complexity for this task will be in the queries that extract data from the source systems. Simple function calls to the library are provided to verify and send their network to the evolve data server.

Likewise, for application developers wishing to utilise network models that have been sent to the evolve server, subsets of the network can be brought into their program's memory space through calls to functions provided by the library.

This approach means the tedious process that would otherwise be needed to create and parse XML representations of the network can be avoided, and more effort can be focused on application development.

Over time we expect the libraries to become more like drivers; providing connection, query, and data load facilities, as well as more complex analytical functions such as network tracing. The data exchange between on-premise sources systems within the DNSPs and the cloud hosted evolve platform will be achieved through the evolve CIM libraries.

Converting the evolve CIM profile into a Google protobuf model allowed us to take full advantage of modern technologies that are far more efficient and usable than the XML based methods. However, this was not a completely straight-forward process, and was not without some trade-offs.

The XML for CIM takes advantage of the inbuilt flexibility of XML to design a complex schema to represent the CIM, allowing for inheritance within the document. This is not possible through the use of protobuf as there is no inheritance support, and thus the messages must be componentised to encapsulate the type hierarchy. All types in the hierarchy are represented by a specific message, which is included in any immediate child type. The drawback of no typical inheritance support here is that programmatic access to parent type fields can become unwieldy when you have multiple layers of inheritance. We have mitigated this issue by removing the need for users to directly work with the protobuf messages by providing our CIM libraries as an abstraction layer.

This componentised structure is still incredibly efficient in comparison to XML as protobuf messages pack their data into messages which is not impacted by the number of fields or layers of fields, or the naming of fields, and thus the extra fields to represent inheritance have no real impact on the serialised size of the messages.

We originally flattened all the messages and duplicated parent fields across them to represent each CIM type, and while this was efficient we found it produced some usability issues in our libraries, and thus we switched to the current format (example AcLineSegment can be seen below), which provides us an easier interface for dealing with the hierarchy.

5.6.2 Protobuf CIM Implementation decisions

An example of the componentised structure for AcLineSegment and some of its parent types up to ConductingEquipment can be seen below.

```
message AcLineSegment {
   Conductor cd = 1; // Parent type as component of the message
   string perLengthSequenceImpedanceMRID = 3;
}
   message Conductor {
   core.ConductingEquipment ce = 1;
   double length = 2;
}
   message ConductingEquipment {
   Equipment eq = 1;
   string baseVoltageMRID = 2;
   repeated string terminalMRIDs = 3;
}
```

Our libraries will take a CIM AcLineSegment and convert it to this form for the user when transferring network data between our systems.

Association relationships between types are reflected across all messages, as one would expect in CIM. For example, the below EquipmentContainer message contains references to the equipmentMRIDs associated with the container, and the Equipment message contains MRID references back to any EquipmentContainers it is associated with.

```
message EquipmentContainer {
   ConnectivityNodeContainer cnc = 1;
   // Reference to associated Equipment
   repeated string equipmentMRIDs = 2;
}
message Equipment {
   PowerSystemResource psr = 1;
   bool inService = 2;
   bool normallyInService = 3;
   // Reference to associated EquipmentContainers
   repeated string equipmentContainerMRIDs = 4;
   repeated string usagePointMRIDs = 5;
   repeated string operationalRestrictionMRIDs = 6;
}
```

Note that any field suffixed with MRID[s] is an associative relationship in the CIM, and should contain an MRID of the relevant type as specified in the prefix (e.g operationalRestriction)

For any CIM type that doesn't inherit from IdentifiedObject we have simply created these types reflecting the CIM type and used them as sub-types in other messages. For example, a Location has PositionPoints and a StreetAddress associated with it, however in our protobuf model these are simply referenced as sub-messages rather than MRID references.

```
message PositionPoint {
   double xPosition = 1;
   double yPosition = 2;
}
message StreetAddress {
   string postalCode = 1;
   TownDetail townDetail = 2;
}
message Location {
   iec61970.base.core.IdentifiedObject io = 1;
   StreetAddress mainAddress = 2;
   repeated PositionPoint positionPoints = 3;]
}
```

It's worth noting that because we've wrapped all the complexity of the data exchange into our provided CIM libraries, and users don't need to know about how the protobuf model works under the hood. Our libraries are intended to guide the user to correctly populate the network model and then provide simple remote procedure calls to send that network model to an external system (i.e, the evolve data platform).

The underlying API for our CIM libraries is built on top of gRPC, a Google protobuf-enabled remote procedure call (RPC) framework. gRPC allows protobuf messages to be trivially sent between systems as function calls that take a message and return a message. Our end goal is that the user will be able to populate their network model using our library, and make a simple RPC call to deliver that network to the evolve systems, or conversely, receive a network from the evolve system.

```
    rpc CreateBaseVoltage(CreateBaseVoltageRequest) returns
(CreateBaseVoltageResponse);

    rpc CreateConnectivityNode(CreateConnectivityNodeRequest) returns
(CreateConnectivityNodeResponse);

    rpc CreateFeeder(CreateFeederRequest) returns (CreateFeederResponse);

    rpc CreateGeographicalRegion(CreateGeographicalRegionRequest) returns
(CreateGeographicalRegionResponse);

    rpc CreateSite(CreateSiteRequest) returns (CreateSiteResponse);

    rpc CreateSubGeographicalRegion(CreateSubGeographicalRegionRequest) returns
(CreateSubGeographicalRegionResponse);

    rpc CreateSubstation(CreateSubstationRequest) returns (CreateSubstationResponse);

    rpc CreateTerminal(CreateTerminalRequest) returns (CreateTerminalResponse);
```

The above shows an example of some gRPC calls that can be made to transfer data into the evolve data platform from a DNSP's or aggregators producer client. The intention is that these calls will be abstracted away inside the libraries and users would call the equivalent of a send(Network) function that takes our CIM profile and translates it to protobuf and sends it to the server.

The consumer API allows a lot more flexibility in querying a network from a server, however works in much the same way as the ingest API, except that the client libraries have more functions the user can call to request a network.

```
service NetworkConsumer {

rpc getIdentifiedObject (stream GetIdentifiedObjectRequest) returns (stream
GetIdentifiedObjectResponse);

rpc getNetworkHierarchy (GetNetworkHierarchyRequest) returns
(GetNetworkHierarchyResponse);

}
```

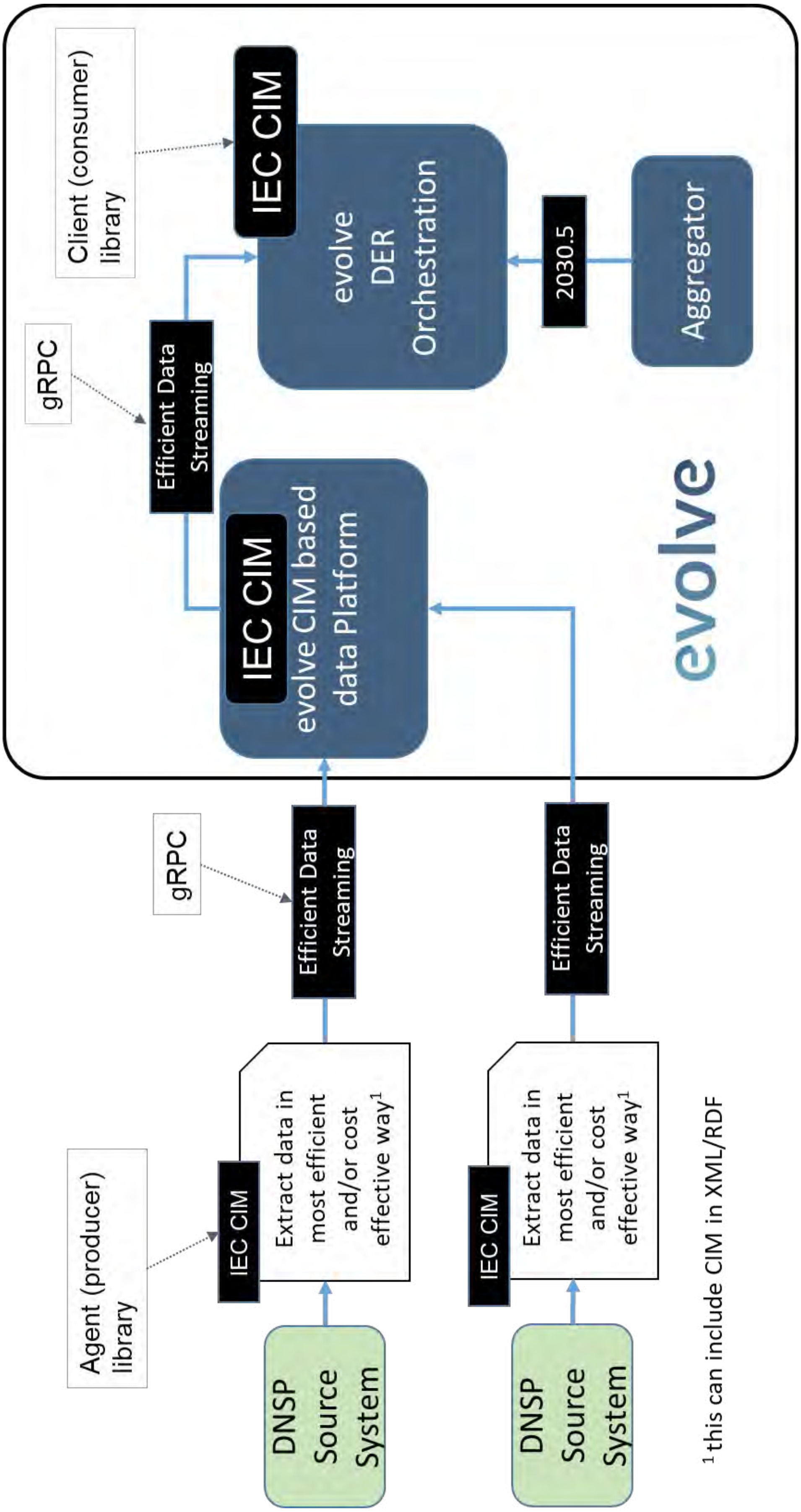
getNetworkHierarchy() and getIdentifiedObject() are likely to be the most common RPCs called from clients, and allow clients to query the structure of the network by GeographicalRegion → SubgeographicalRegion → Substation → Feeder and to retrieve the objects associated with that segment of the network respectively.

getIdentifiedObject() allows all types present in the CIM protobuf model to be sent to the client in a continuous stream. This allows a client to retrieve the structure and then stream all objects within a subset of that structure down to the Feeder level. Over time we will be adding many more methods to increase visibility of the servers internal network, and allow the client to query and trace that network.

We believe our CIM libraries, protobuf, and gRPC, are primed to create an extremely efficient development environment for our consortium partners. Providing unambiguous modelling and language for interaction between DNSP and evolve systems, as well as simple yet effective API's for use by both the DNSP's and the evolve envelope engine. This framework will hopefully reduce uptake costs and thus increase adoption of the system, and at the very least, we believe our CIM libraries and data platform can be used as a basis for developing a production envelope engine system in the future.

5.7 Architecture and Dataflows

The diagrams below illustrate the contextual data flow for the evolve platform, illustrating where the CIM standard is being used, and the overall platform architecture.



[1] this can include CIM in XML/RDF

Figure 16: Evolve Data Flows

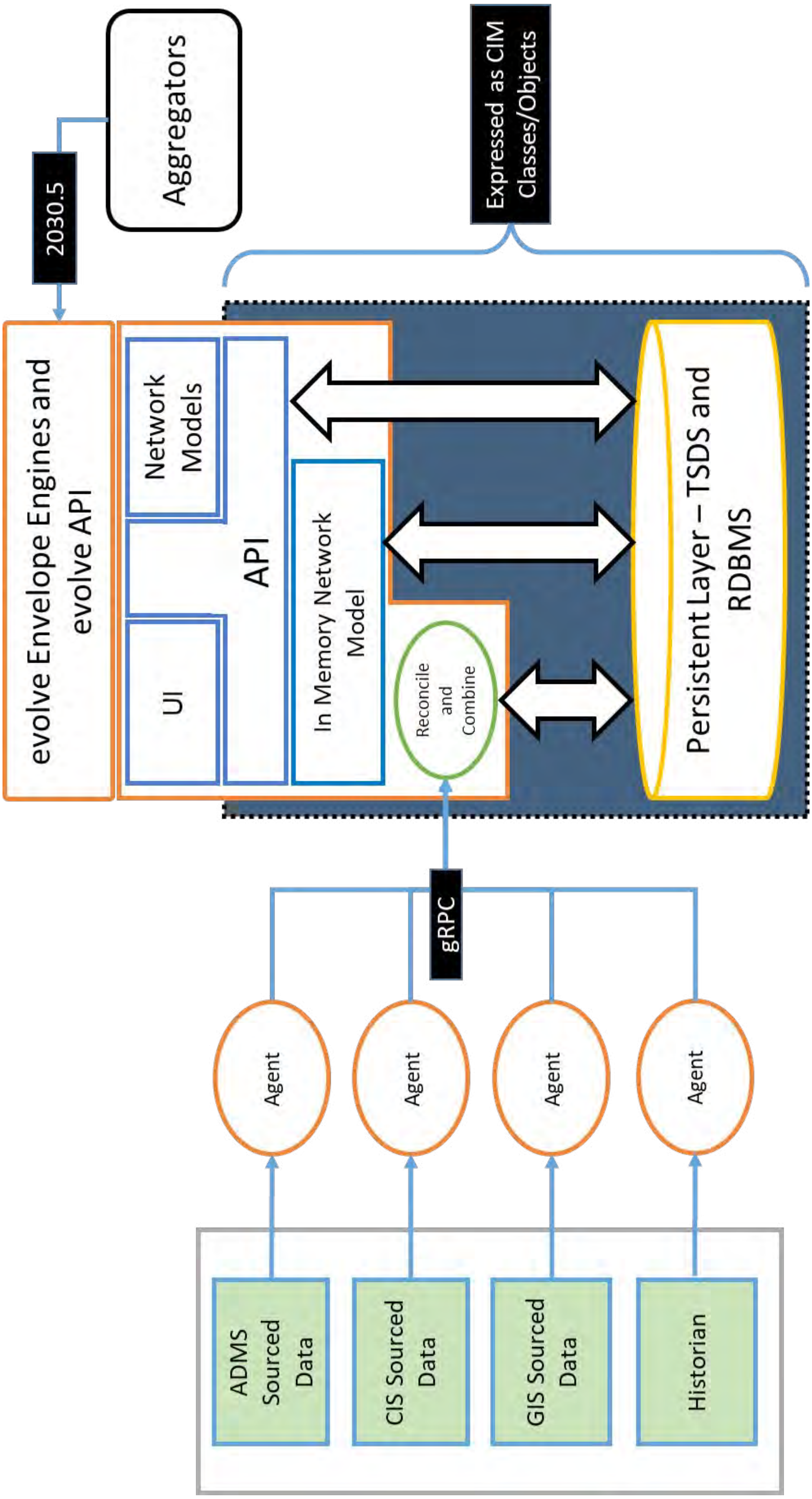


Figure 17: Evolve Platform architecture

6. CIM Models in Australia

6.1 SWER Systems

Australian distribution systems have some unique characteristics in comparison with US and European systems. Long distribution feeders are essential components in the Australian distribution system architecture; these long feeders are often Single Wire Earth Return (SWER) systems, which are used in less densely populated areas including most of the regional areas in Queensland (Haidar, Muttaqi, and Sutanto 2015).

A SWER system is a single-wire distribution system, where all the conducting equipment is grounded to earth and the load current returns through earth (Kashem and Ledwich 2004). A typical SWER system configuration is presented in Figure 18.

In this diagram, an isolation transformer is connected to a three-phase distribution system. In the secondary this transformer connects the SWER system through a protection device. The lines of the system are typically long, loads have low load density (0.5 kVA/km), and a maximum average demand of 3.5 kVA. Finally, a distribution transformer is commonly installed to connect the customers using centre tapped transformers.

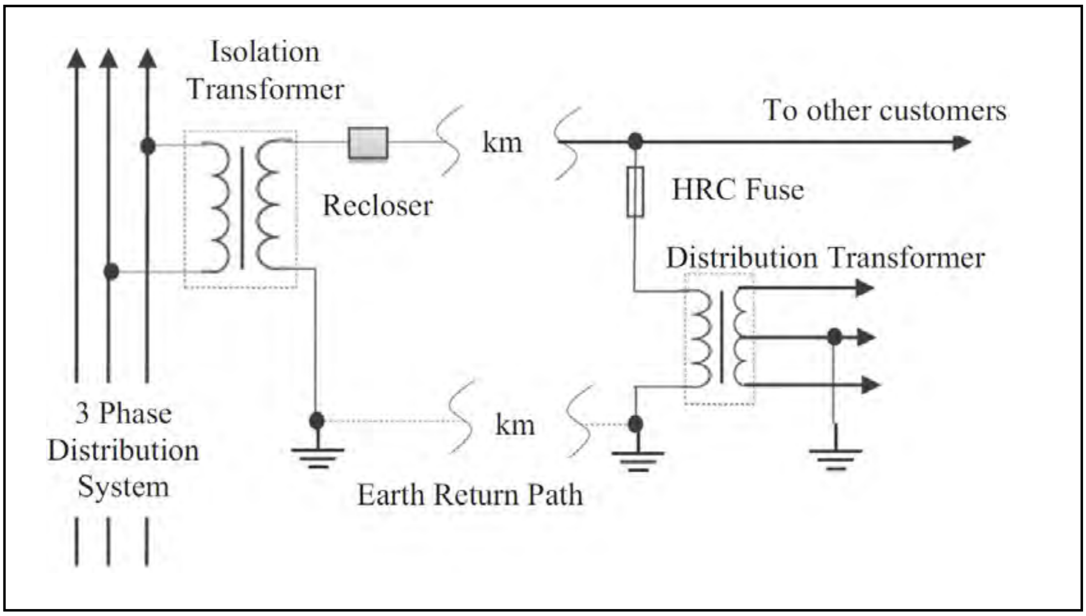


Figure 18: Typical SWER system. Reprinted from (Haidar, Muttaqi, and Sutanto 2015

The SWER system makes the Australian distribution system significantly different from US and European counterparts, and this situation creates asset modelling challenges in the CIM. Traditional CIM profiles available in the main vendor CIM exporting/importing tools (e.g., CPSM, CGMES) were designed for exchanging transmission system models.

Efforts for distribution systems have been performed more recently and the development of profiles for specific application in distribution systems is in progress (e.g., CDPSM Ed. 2).

The approach selected in the Evolve Project for SWER system modelling is based on the CIM100 model18, which offers s1N and s2N as PhaseCode connection attributes for single-phase centre tapped transformers (isolation transformers or distribution transformers in SWER systems) and WindingConnection in the PowerTransformerEnd (for describing the single-phase connection). In this case the VectorGroup attribute of the PowerTransformer is not used.

6.2 Advanced Metering Infrastructure

The Evolve Project will make use of data provided by Advanced Metering Infrastructure (AMI) where it is available. AMI data not only provides data required for the billing function (energy consumption) but can also provide time series power and voltage data, and event records.

The CIM standards provide a complete representation for exchanging Metering data obtained from AMI (Neumann et al. 2016). These parts of the standard are being used by the Evolve Project.

Along with using those aspects of the CIM standard concerned with electrical network asset modelling, we have also observed that the parts of the standard concerned with metering are most commonly used by the partner networks.

6.3 Establishing a CIM Working Group in Australia

Through the various workshops conducted with DNSP's involved with the project, and AEMO, it was recognised by the workshop participants that there are compelling reasons to set up a working group in Australia to help define how electrical network model data will be exchanged, so as to provide support for:

1. the AEMO proposed Australian Energy Simulation Centre,
2. regulatory reporting,
3. other DER Projects,
4. Academic research, and
5. data platform solutions and tooling to help DNSPs and other vendors develop new Information Technology solutions.

The Evolve Project is working with DNSPs and AEMO to help establish this working group as part of AEMO's broad role as the market operator.

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Appendix A

CIM Profile for Evolve Project

The CIM Profile for the Evolve Project is described here:

https://zepben.bitbucket.io/cim/evolve/

This profile will be updated periodically as the project proceeds. It is automatically generated by the Sparx enterprise architect (EA) tool[19] after changes are made on the model in the EA tool by an engineer.

Unfortunately, the html version produced by this tool is only useful for describing the class relationships and attribute names in diagrammatic form. The associated text for describing the classes and their attributes is not well handled by the EA export tool.

For this reason, we have embedded additional information about the CIM classes and their attributes in the open source projects for the CIM implementation.

For example, a PowerTransformer and its attributes are described in comments in the following code:

https://github.com/zepben/evolve-sdk-jvm/blob/main/src/main/java/com/zepben/cimbend/cim/iec61970/base/wires/PowerTransformer.kt

Work will be done by the project to consolidate the documentation for the evolve CIM profile into a single HTML document accessible on line once the development effort is nearing completion for the CIM implementation.

---

[19] https://sparxsystems.com/products/ea

Appendix B

Evolve Project Overview

B.1 Project Motivation

It is expected that significantly more DER assets such as solar PV, energy storage, demand control mechanisms and Electric Vehicles, will be connected to electricity distribution networks in coming years. Increasingly, DER assets are becoming active participants in delivering energy, and stabilising and balancing services to the energy, ancillary and network services markets.

A representation of the current state of the system can be seen in Figure 19. In this diagram we can understand that DER are already participating in:

1. Energy and ancillary services markets in the National Electricity Market (NEM).
2. Network services markets being developed and demonstrated by most distribution network service providers (DNSPs) nationally.

Additionally, real-time and historical operational and aggregate data is available from most DER aggregators and would be very useful to both AEMO and the DNSPs for decision support over a range of planning horizons. The dotted line in Figure 1 represents the availability of real time operational data is not currently leveraged by AEMO and the DNSPs.

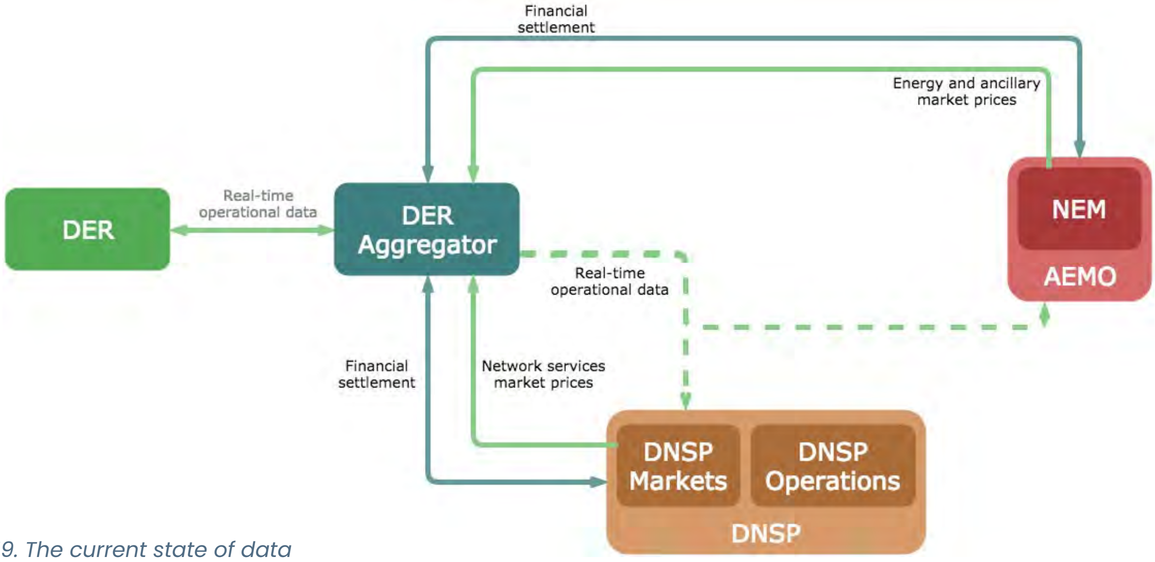


Figure 19. The current state of data flows and market participation

From Figure 19 we can realise that there are a number of potential concerns with this model of operation:

- *The DNSPs have no visibility of the generation or demand consequences of market (NEM) responsive DER assets.*
- *AEMO and the NEM market participants have no visibility of the generation or demand consequences of network responsive DER assets.*
- *AEMO, market participants, and the networks are not able to coordinate the behaviour of DER assets and the virtual power plants (VPPs) they collectively create. This reduces security and reliability of supply across the control, optimisation and planning timescales of operation.*

In this context, the major concern is that there is no effective coordination of DER participation in both energy and network markets. This potentially results in DER causing contingency events or interruptions of network service to customers. At the same time, it is important to ensure that DER is encouraged to participate in energy, ancillary and network services markets as it represents a low cost, flexible mechanism for supporting long-term energy reliability and security for the electricity system, in Australia and globally.

In this context there is considerable need for a distributed system operator (DSO)[20]. While there is some early thinking about proposed operating models for a DSO, it is far too early to know which operating model will prove to be most suitable. With this uncertainty, it is widely recognised that it is important to support ongoing trial and demonstration projects that demonstrate and develop capabilities that could underpin and support potential DSO models. This is one such demonstration project.

There is increasing interest in a model of DSO operation where existing market mechanisms are augmented by capabilities that ensure the secure technical limits of the electricity networks are not breached. This is achieved by publishing operating envelopes to individual or aggregate DER. Fundamentally, an operating envelope defines a range of real and reactive power set points that is permitted for that endpoint, over the current and future intervals of operation.

Individual or aggregate DER assets are then able to optimise within the range defined by the operating envelope based on local and market incentives. By restricting their behaviour to within the operating envelopes, DER assets can ensure that their market participation activities will not breach the secure technical limits of the electricity distribution network.

The Evolve Project aims to demonstrate this model of DSO operation. The project will implement systems and capabilities that calculate and publish (via a software API) the operating envelopes for individual and aggregate DER in the distribution network. This model of DSO operation is shown in Figure 20.

It is worth noting that the Evolve Project is not creating or operating markets or market intermediaries for energy, ancillary or network services markets. For this reason, the project is an important complementary activity to existing work being undertaken in this area by GreenSync (deX), the CONSORT consortium (Bruny Island Battery Trial), and others.

---

[20] *OPEN ENERGY NETWORKS Consultation Paper https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2018/OEN-Final.pdf*

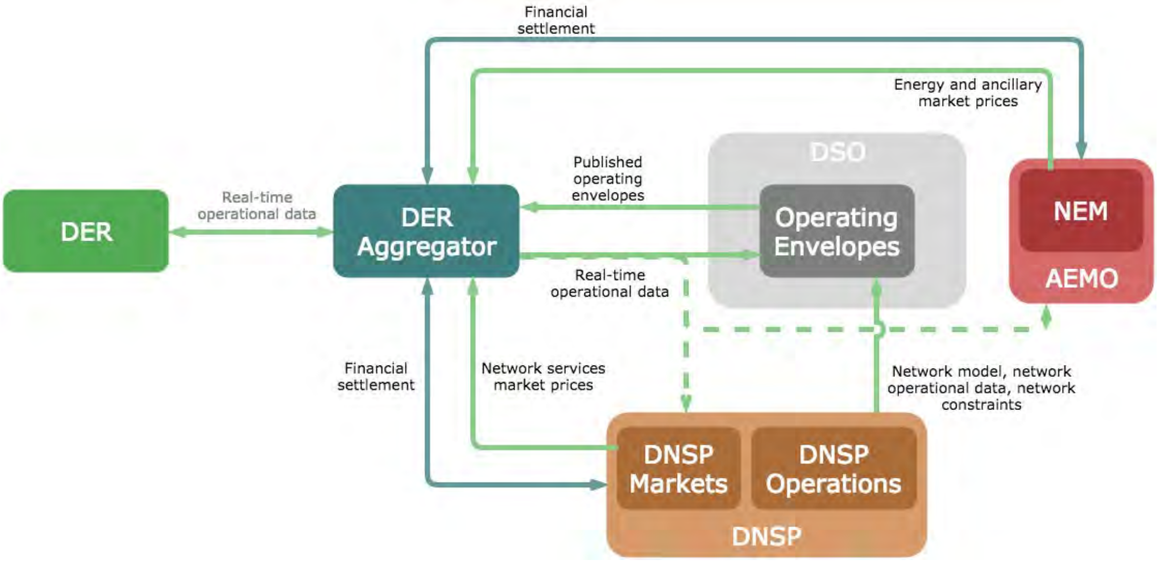


Figure 20. The proposed DSO model that evolve is testing

B.2 The Contribution of this Project

The Evolve Project will demonstrate the operational mechanisms by which these operating envelopes can be calculated, published and utilised. The market and regulatory mechanisms that would allow these mechanisms to be exercised are beyond the scope of the project.

To calculate the operating envelopes for DER assets, this project will undertake the following activities using data from a variety of sources:

1. Develop a live (and forecast) reference model for the low voltage (LV) segment of the grid. This will include the as-switched network model, and the current and forecast operating state of connected DER and virtual power plant (VPP) assets.

2. Develop a live (and forecast) reference model for the medium voltage (MV) segment of the grid. This will include the as-switched network model, and the current and forecast operating state of any connected assets.

3. Use the LV and MV references models, to calculate the operating envelopes for each NMI endpoint using a combination of techniques drawn from mathematical optimisation, optimal power flow analysis, and power systems analysis domains. Initially, we anticipate these envelopes being calculated based on the following constraint scenarios:

    a. Nominal voltage constraints in different segments of the distribution network.

    b. Capacity constraints of different networks elements within the distribution network.

    c. Thermal constraints of different networks elements within the distribution network.

    d. Contingency and emergency constraints that arise for operational reasons, such as network faults or planned work that results in temporary limitations in network capacity.

    There is scope in future to include additional constraint scenarios into the envelope calculation. This would allow the evolve platform to also support constraints that arise from frequency or asset ramp rate requirements that may arise in the operation of electricity distribution networks nationally.

4. Publish these operating envelopes to the DER aggregators using a mutually agreed API developed during this project. Existing industry standards such as IEC 61968 and IEEE 2030.5 will be leveraged where possible; however, this project is proposing the development of new interactions between established market participants and new market entrants. We also anticipate the emergence of a new function/role in the supply chain (the DSO). Consequently, we do not expect established technical standards used by the industry will provide all the outcomes needed by the API. For this reason, one of the outcomes of the project will be to help develop and evolve standards for communications between DNSP's and aggregators.

5. Publish this data to other interested parties. This information will be used as the basis for the data that will be provided to the AREMI platform to allow general access to the data using map based visualisation.

In achieving these outcomes, technologies will be developed that will provide opportunities for commercialisation outcomes for Australian industry in the global market for DER integration solutions.

B.3 The Benefits of Operating Envelopes Demonstrated in this Project

We believe there are several important benefits that arise from demonstrating the use of operating envelopes in the proposed project. The project will show that:

- Operating envelopes can be loose or tight and can be updated and published as needed including during emergencies. This provides important operational flexibility for networks in responding to unforeseen events caused by operational or environmental (i.e. weather) considerations.

- Operating envelopes can potentially be calculated days in advance, making DER forecasts for energy and network market participation firmer. By publishing an operating envelope, DER assets can participate in markets only up to the limit of the operating envelope. This ensures that market participation cannot infringe the safe and secure operating limits of the grid.

- Operating envelopes can be deployed progressively into different segments of a distribution network. This incremental approach to testing, validation and deployment reduces operational risks for networks.

- Operating envelopes promise to be simple to implement across a variety of different DER assets, and do not require the use of sophisticated local control and optimisation systems. This will increase adoption and compliance from different DER assets installed in Australian electricity distribution networks.

- Operating envelopes provide a mechanism to allow transparent reporting (i.e. by prosumers and VPPs) against network constraints for future network planning.

- Thus, it will be possible to understand how network constraints impact the value of DER participation in energy, ancillary and network services markets.

- Opportunities are created for novel behind the network element models and markets by allowing trading of capacity (outside of the DSO). This includes creating opportunities for community energy models. It may also support addressing equity issues between those who have DER devices and those who don’t by allowing operating envelopes to be traded between consumers and prosumers.

- Methods for calculating operating envelopes could be leveraged to support novel market mechanisms like congestion pricing etc.

B.4 The Customer Benefits of this Project

This project will demonstrate a mechanism to ensure that customer DER assets can participate in energy, ancillary and network services market without infringing the secure operating limits of the electricity system.

In the absence of the mechanisms proposed in this project, there could be a motivation by network and system operators to:

- limit customer DER connection approvals
- reduce or prevent energy export from DER assets as a component of new connection standards, and
- limit or remove the rights of DER assets to participate in the delivery of services that support energy reliability and security.

The coordination mechanism this project demonstrates is also intended to be easy to implement for DER manufacturers and aggregators. This will ensure that customers do not pay more for coordination-compliant DER assets. Ultimately, this provides guarantees for the long-term value of DER assets through ensuring their ongoing participation in a variety of energy and network services markets.

As outlined in the previous section, this project also demonstrates a transparent mechanism for customers to quantify the lost value of market participation because of physical and operational limits in the electricity system. This empowers customers to play a central role in justifying network planning decisions into the future, which is a key element of how network tariffs are calculated. More efficient planning mechanisms could reduce electricity costs for all customers.

Finally, this project will also demonstrate how we can better understand the geographic limits and opportunities for DER based on existing network infrastructure. This further empowers customers to make decisions about the acquisition of DER assets. Customers will have a better understanding of the value that those individual assets can provide in different regions of a given distribution network.

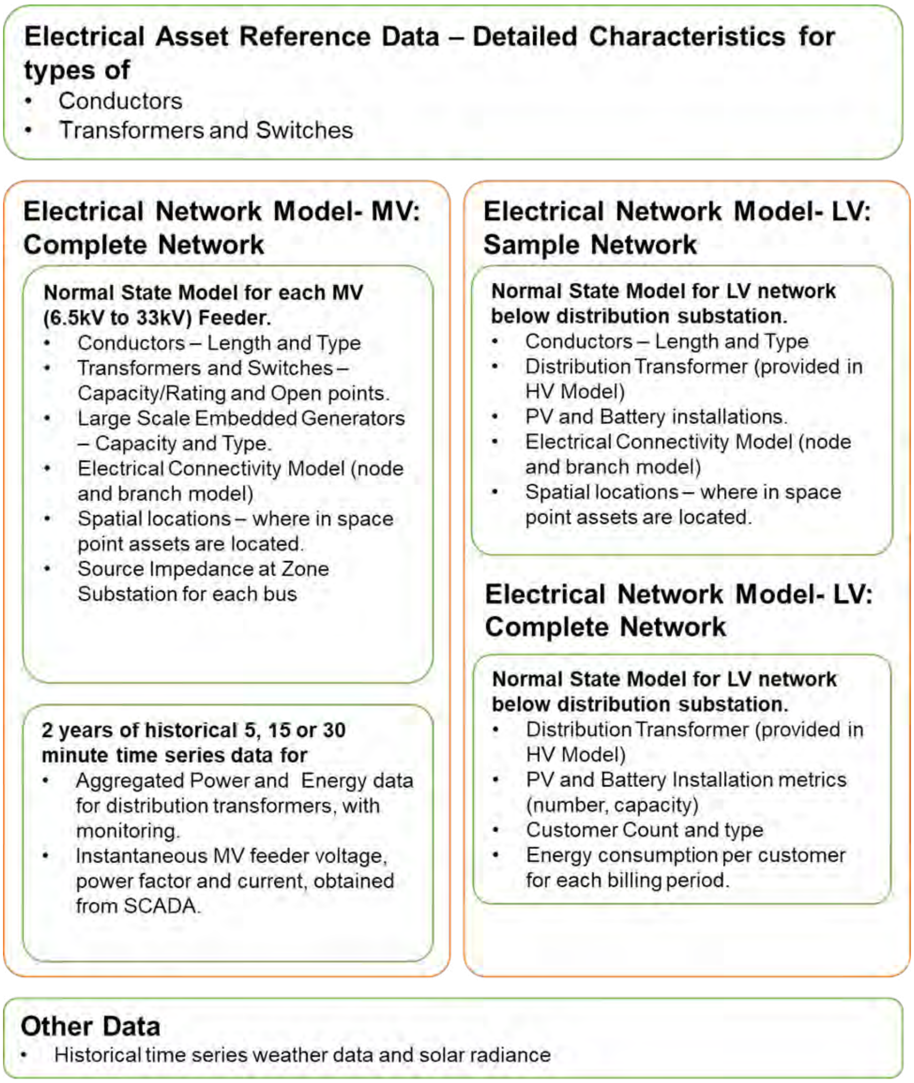
B.5 Data Requirements for the Evolve Platform

To understand what parts of the CIM are relevant to the Evolve Project, we need to understand what the data requirements of the Evolve Project will be.

In order for the evolve Platform to perform its intended functions, the following information is required:

1. detailed information about the electricity network assets,
2. historical and real time measurement data for power and voltage in different parts of the network,
3. historical and forecast weather data, and
4. Energy data from individual consumers.

The data requirements are summarised in the graphic below.



Electrical Asset Reference Data – Detailed Characteristics for types of
- Conductors
- Transformers and Switches

Electrical Network Model- MV: Complete Network

Normal State Model for each MV (6.5kV to 33kV) Feeder.
- Conductors – Length and Type
- Transformers and Switches – Capacity/Rating and Open points.
- Large Scale Embedded Generators – Capacity and Type.
- Electrical Connectivity Model (node and branch model)
- Spatial locations – where in space point assets are located.
- Source Impedance at Zone Substation for each bus

2 years of historical 5, 15 or 30 minute time series data for
- Aggregated Power and Energy data for distribution transformers, with monitoring.
- Instantaneous MV feeder voltage, power factor and current, obtained from SCADA.

Electrical Network Model- LV: Sample Network

Normal State Model for LV network below distribution substation.
- Conductors – Length and Type
- Distribution Transformer (provided in HV Model)
- PV and Battery installations.
- Electrical Connectivity Model (node and branch model)
- Spatial locations – where in space point assets are located.

Electrical Network Model- LV: Complete Network

Normal State Model for LV network below distribution substation.
- Distribution Transformer (provided in HV Model)
- PV and Battery Installation metrics (number, capacity)
- Customer Count and type
- Energy consumption per customer for each billing period.

Other Data
- Historical time series weather data and solar radiance

Figure 21. The data requirements for the Evolve Project

Appendix C

CIM Workshops

In developing this report, the DNSP partners and AEMO were engaged through a series of workshops to obtain feedback, with the attendees, dates and locations described in the table below.

Workshop	Attendees	Date	Locations
1	Endeavour Energy	9th Dec 2019	Huntingwood and Canberra
2	AusNet Services and AEMO	20th Jan 2020	Melbourne, Sydney and Canberra
3	EQL (Ergon and Energex)	22nd Jan 2020	Brisbane
4	Essential Energy	29th Jan 2020	Port Macquarie
5	Ausgrid	30th Jan 2020	Sydney and Canberra