Developing emerging standards for power system data exchange to enable interoperable and scalable operational modelling and analysis

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Abstract- **Novel information architectures, the IEC 61970 Common Information Model (CIM), and related standards could enable solutions for effective information exchange required to facilitate interoperable smart grid and supergrid development. Meeting the need to integrate heterogeneous energy management systems to control electricity networks handling an increasingly variable injection of power and demand management is essential. Information modelling and the requirement for common semantic references to base data exchanges upon, now become critical to European electricity business development. We discuss some of the challenges to utility information model exchange and conceptual solutions from developments in the CIM, based on experience gained within National Grid, the GB transmission system operator.**

Index Terms- **Decarbonisation, Common Information Model, interoperability, smart grid, supergrid.**

I. Nomenclature

CIM – Common Information Model
CPSM – Common Power System Transmission Model
DH – Data Historian
EMS - Energy Management System
EBS – Energy Balancing System
ESB – Enterprise Service Bus
ENTSO-E – European Network of Transmission System Operators for Electricity
EPRI – Electric Power Research Institute
IEC – International Electrotechnical Commission
mRID – Master Resource Identity
OLTA – Offline Transmission Analysis
UCTE – Union for the Coordination of Transmission of Electricity
UML – Universal Modelling Language
UUID – Universally Unique Identifier

II. Introduction

The UK Government has set a target to produce about 30% of the UK's electricity from renewable energy and reduce carbon emissions by around the same amount (based on 1990 levels) by 2020 [1]. Over the same time about 25% of the UK generation capacity (mainly coal and nuclear) will reach the end of its life and need replacement, imposing an unprecedented decade of change on electricity infrastructure. Furthermore, a pan-European high voltage supergrid, as well as an integrated range of technologies managing power flows from domestic metering to variable distributed generation and storage, known as the 'smart grid', are anticipated. These technologies are also essential to Europe meeting its carbon reduction targets. Interoperability between hitherto autonomous power systems and utilities will be critical to managing and forecasting within this dynamic scenario. International model exchange is already being addressed at the European level within the Union for Coordination of Electricity (UCTE), and more recently the European Network of Transmission System Operators for Electricity (ENTSO-E), whose requirements for a standard model exchange format have influenced some of the recent developments and enhancements to the CIM within the IEC working groups [2]. They are working in parallel with organisations affiliated to the Electric Power Research Institute (EPRI) in the USA.

Although it is not the only ontological information model amongst standards concerned with grid systems interoperability, the CIM provides a valuable, developing basis for integrating a range of overlapping standards [3]. It provides a structured, scalable and extensible semantic reference for the artefacts of the power industry [4]. The use of profiles such as the CPSM, (IEC 61970-452) [5] and the ENTSO-E (UCTE CIM) profile [6], are key to exchanging network data models between applications used by transmission [6] and network operators [7] and continue to develop, while their semantic and logical structures grow with their use.

To address the growing need for interoperability, National Grid are embarking upon data model exchange between the online control environments of the Energy Management System (EMS) and Energy Balancing System (EBS). Offline data storage and planning environments, such as the Data Historian (DH) and Offline Transmission Analysis system (OLTA) will also interoperate with online systems. These projects aim to introduce interoperability within a legacy environment of point-to-point and manually-interfaced information architectures.

The process of implementing a standards-driven information model exchange architecture between operational systems has shown the need to address the wider information integration context within the utility. This issue of model management spans from high-level commercial objectives to low-level network solutions, and ultimately concerns the opportunity to leverage the value of corporate data. In this paper, we report on some of the key challenges faced so far, and conceptual solutions to a standards-driven interoperable information culture within National Grid, in preparation for a more dynamic electricity operations environment.

III. Utility Information Integration

When National Grid, as GB national electricity transmission system operator, published it's '*Gone Green for 2020'* scenario [9] in response to the UK Government's vision for decarbonisation, it highlighted the need to implement a previously unseen level of system *intra*-operability within the company, which must increasingly *inter*-operate with external organisations as well. To not replicate point-to-point architectures at the time of system replacement, and leverage data to achieve company-wide access, required a fundamental re-appraisal of data ownership and its link to the business use case for mapping to an information exchange mechanism like the CIM. Implicit also within the above aims, was to align the offline models used for event analysis and forecasting (OLTA), with the operational online models in the EMS and EBS.

Taking a high-level perspective, further analysis of the way data ownership arises revealed how commercial and regulatory imperatives drive the need for a functional purpose within the company and that these in turn call for assets to support those functions (eg. efficient network operation and balancing unit despatch). Different IEC metamodels, mapping to different parts of the business, would then contribute to the concept of a shared company data model.

A conceptual representation of how this could be realised however, would need to be designed around the principle of data ownership and identity. This issue, encountered at the start of the information integration challenge, goes right to the heart of how data models are exchanged using the CIM and associated metamodels. It also offers the opportunity to visualise how utility information may be integrated around a common model comprised of contributions from the principal data sources. Fig. 1, illustrates how the three principal systems corresponding to Commercial, Functional and Asset

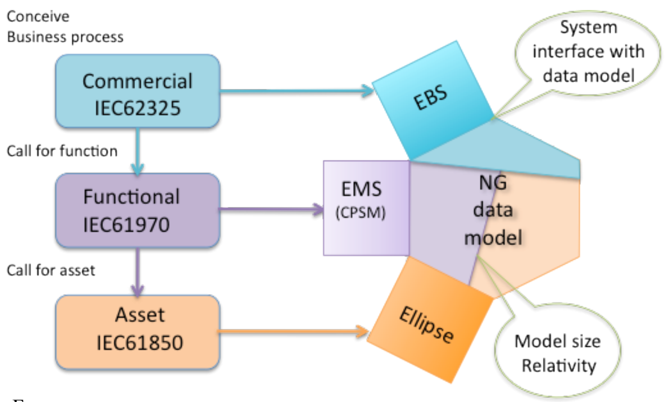

Fig. 1. Conceptual relationship of business-driven data ownership contributing to operational data model through system interoperability and metamodel interaction.

management roles within National Grid may interoperate through information model exchange around an overlapping, common data model.

Data model exchange takes place within the context of utility information integration and is a key part of the interoperable *glue* between corporate objectives in terms of business positioning, and system solutions which enable the enterprise to orientate itself as intended. The *form* of the information architecture will *inform* the function of the enterprise. The need for an enterprise architecture coherent with corporate objectives and regulatory constraints therefore is clear. Connecting this to the 'solutions level' of the enterprise, especially in times of rapid market change, places greater emphasis upon information integration and the removal of legacy system obstacles such as data silos and manual trans-literation interfaces between bespoke systems. Tolk [10], has summarised these entities in the context of the smart grid and observed that the "*conceptual ideas of the enterprise and the implementation details of the systems*" often do not connect.

Fig. 2, depicts these concepts in relation to CIM implementation at National Grid. Use of the CIM will contribute to information integration and link business process requirements to technical solutions by spanning the *informational processes* and *technical solutions* layers of the 'business information grid'. We identified that the potential for information organisation and exchange within National Grid could conceptually reflect the framing of the interoperability issues of the smart grid, as defined by Ambrosio and Widergreen [11], and then also be replicated outside of the company to create the kind of very large information architecture necessary for utility interoperability.

Fig. 2. Conceptual framework for positioning the CIM to support National Grid's corporate objectives and how this may reflect upon smart grid interoperability issues.

As Fig. 1. suggests, at the heart of operational information integration, we position the concept of a common network model for asset management, planning and operations. With an effective translation layer between the heterogeneous systems that operate within these domains, we aim to deliver interoperability between the EMS, DH and EBS in the first instance. The use case for the CIM as a translation layer will be discussed in the next section. We foresee that an important development beyond this step would be to integrate the network models and asset data from the offline systems (OLTA and Asset Management) to create a unified company network model, or 'union model' from a Venn Diagram perspective, Fig. 3.

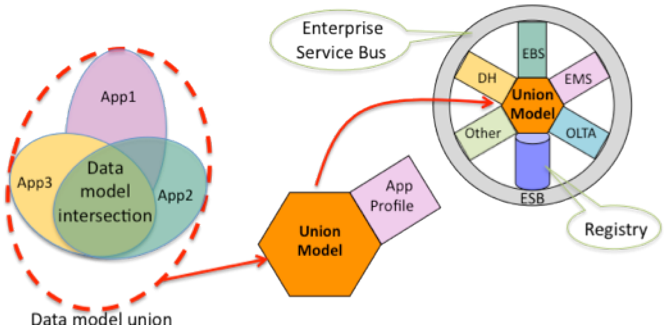

Fig. 3. Conceptual framework for positioning the CIM to support National Grid's corporate objectives and how this may reflect upon smart grid interoperability issues.

In the interest of conforming to international standards, extensions to the metamodels will be minimised where possible by the implementation of standardised semantics describing modelled artefacts. However it is anticipated that some extensions to standard profiles, such as the Common Power System Model (CPSM) and UCTE profile may be necessary to accommodate corporate data definitions. It is also conceivable that the role currently planned for the DH may eventually be taken over by an Enterprise Service Bus (ESB) as more systems become interoperable and overcoming data latency more critical.

Extending the concept of utility information integration to a very large scale, required for interoperability between utilities, we are researching novel technologies such as scalable, secure, cloud computing facilities which could be employed as 'data processing hubs' in support of smart grid and supergrid scenarios. In this use case, CIM based utility models held and exchanged in the cloud, could be used to provide virtual services such as merged forecasts (Day+1, Day+2), and merged intra-day national and international powerflow analyses for example, Fig. 4. These services could extend the interoperability and scalability of the similar functions which are being developed and provided today by CORESO and TSC as Regional Coordination Initiatives.

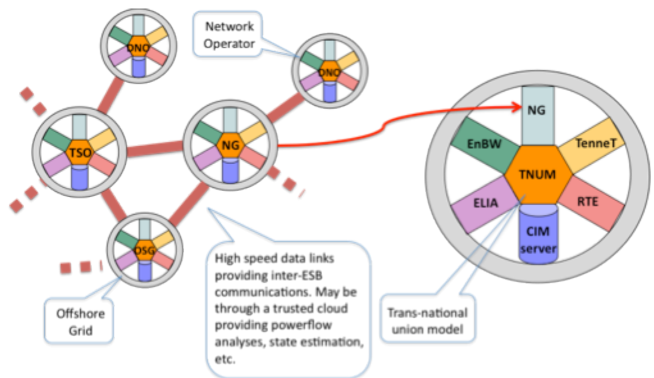

Fig. 4. Conceptual framework for very large scale information integration and cloud computing facilities

IV. THE CIM

The CIM offers National Grid part of the solution to its data integration challenges, as mentioned in the previous section. Understanding what it can offer and where to apply this is of importance to leverage the value of company data, Fig. 5.

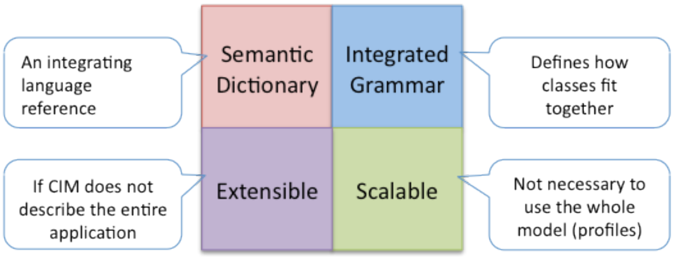

Fig. 5. Essential attributes of the Common Information Model

In our preparation for standards-based information integration we have been mainly concerned with the application of the IEC 61970 and 61968 groups of standards. These include the IEC 61970-301 (CIM) and IEC61970-452 (CPSM) standards, upon which the ENTSO-E and UCTE profiles are based. Profiles are reduced sets of the metamodel classes which draw focus to a particular context for a specific business purpose.

At the solutions level we face some important questions which we will now address in the rest of this paper. They can be summarised as follows:

A. The importance of common semantics
B. Interoperability and the persistence of unique IDs
C. Do we need to share every piece of available data?

A. The importance of common semantics

At National Grid we have found that within our native EMS model, some artefacts, such as a transformer, are described in a way not directly map-able to equivalent class-components provided in the CPSM. In addition, two systems may model the same artefacts differently, and therefore can present different perspectives of the same network model for example. This raises the issue of semantics and also when to extend a CIM profile to suit our naming convention or to adopt the naming convention provided by the CIM ontology. Ultimately the answer to this question will be a trade-off between the value of conforming to a widely adopted standard and the effort involved in implementing a semantic structure which will impact upon multiple systems within the company. It does however, highlight the desirability of aligning the company semantic model with that of the standard information model, to avoid divergence and the need to maintain non-standard extensions.

B. Interoperability and the persistence of unique IDs

The question of persistence of universally unique artefact identifiers (UUIDs) is connected to the one of data ownership, introduced in the previous section. It would seem sensible that a singular global, or universally unique ID, was attributed to artefacts of the company information model at their conception. We have found this not to be the case in practice as different systems model artefacts using 'local' IDs as model authorities were not established originally for wide-ranging automated interoperability. Therefore the persistence of which identity the CIM Master Resource ID (mRID) is associated becomes directly relevant to the degree of system interoperability. Especially if the locally-generated ID is assumed as a UUID. From this, we can observe how interoperability is dependent on, and proportionate with, the degree of artefact ID uniqueness and presistance.

Within the process of network model translation from system to system, there is the need to establish a flexible naming protocol which can manage persistence of local system artefact IDs, linking them to an mRID, so that each artefact can be correctly identified despite being described differently. This becomes even more imperative when data models are exchanged across national boundaries to secure networks for international electricity trading facilitated by the supergrid and a common electricity market. Successive releases of the CIM are evolving to offer a more flexible UML modelling structure to capture the detail of real-life naming conventions, which addresses the artefact identity issues encountered in data model exchange. CIM15 for example, is being designed to associate multiple instances of 'Name', each with a 'NameType' and optional 'NameTypeAuthority' to a singular 'IdentifiedObject' class.

But the issue of how information architectures at system interfaces manage cross-boundary naming remains non-standardised and open to more than one approach. If practical solutions to this are simply approached from a systems level, the establishment of a logical model naming authority must pay regard to the persistence of IDs within other systems as well as data visibility in comparison to the overall data model. For example, some EMS systems may re-use artefact IDs after an asset has been deleted or modified within a network. In another case, the scope of data usage required by one system will not match that of another and so the need to establish a hierarchical model naming authority arises. In practice, multiple systems will contribute to a company data model and therefore a strict model naming authority hierarchy should be implemented logically, along the lines already proposed based on data ownership. This suggests the need for a higher-level approach to model management than may

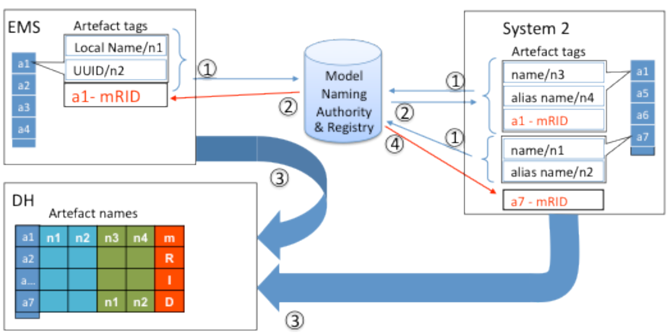

Fig. 6. Conceptual architecture for model naming management. (1) - Systems interrogate the naming authority for record of an mRID associated with artefacts within their internal models. (2)- If an mRID exists on record, this is applied to local data ID's before, (3) model export to data Historian. (4) -If no record exists then a new, persistent mRID is generated and applied to artefact.

be practically maintained within CIM translation interfaces at a system level.

Such an approach could use a 'centralised' model naming authority and registry which maintains the persistence of artefact IDs, Fig. 6. One advantage of this approach, which resembles the *Authoritative name server* hierarchy as deployed in the World Wide Web, Domain Name Server (DNS) architecture, would be that it has full data vision across multiple systems and may be easier to maintain than individual translation interfaces, with partial data vision, situated at a lower-level perspective.

C. Do we need to share every piece of available data?

Establishing an 'enterprise semantic model' is one step towards preparing data for sharing between systems. But the question, 'Is there a business case for this data usecase?' should also be raised. This would help to align the *need* for data mapping to information models to the *support requirements* of business processes and objectives. For example, it has been estimated that the EMS at National Grid uses approximately 26% of the available SCADA analogue readings and only 1% of their corresponding status points to perform its principal function of Power Network Analysis (PNA). At least some of the rest of this data must be modelled and exported through the CIM for business-case-backed functions in the EBS. But what the business case is for modelling and exchanging the rest of the data is currently unclear, apart from the option to perform post event analysis upon that data.

Similarly, the question of whether to exchange data in a 'raw' form also arises. If system A can only export data to system B by extending the CIM profile because the reference model does not offer classes or attributes corresponding to the product of A's processed data, then the question of which system should process the data occurs. In the interests of standardisation it would make sense for system B to process A's raw data, as this is the system requiring a certain data product, and for system A to export a standard form of the information model pointing to the raw data.

V. CONCLUSIONS & FUTURE WORK

In summary, this work has framed several conceptual solutions to the challenge of information integration at National Grid. It also raises several questions about the overall approach to such a project and highlights the need for high-level objectives to engage with solutions-level practice through the medium of information integration, in which the CIM plays an important translational role. The degree of system interoperability has been related to the persistence of unique data artefact IDs and the need for vigilance over their use in models cannot be underestimated. A model naming authority and registry system has been proposed as a way of addressing such ID persistence issues and will be further investigated in future research.

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