BRIEFING

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Data ontologies: A key tool for plug and play in smart-energy places

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Introduction

Interoperability is a critical part of the modernisation and digitisation of the energy sector. It is particularly crucial as a component of smart local energy systems (SLES) approaches to smart-energy places, which involve the management of complex interactions within and between different systems.

The Energy Systems Catapult's Energy Digitalisation Taskforce states in their recommendation 'Deliver interoperability' that "*As the energy system becomes increasingly interdependent with other systems such as telecoms, interoperability will be key to maintain safety, security, and efficiency*" and recommends that the industry "*Adopt network data standard: Develop a GB Common Information Model (CIM) profile for Electricity Networks and develop a solution for Gas Networks*" (Energy Systems Catapult, 2021).

While the Common Information Model can provide a basis for a degree of interoperability, what is needed for true 'plug and play' operation and in particular, artificial intelligence (AI) applications, is a common data ontology.

This report sets out to answer the following questions:

- Why do we need plug and play?
- What is a data ontology?
- How have they been used in the energy sector to date?
- Why are they important for smart-energy places?
- How should the industry approach ontology development?

Why do we need Plug and Play?

'Plug and play' as a term first came to popularity with the launch of the Microsoft Windows 95 operating system. The principle was that when a user connected a device to their computer, the computer would be able to detect and interact with that device without the user having to configure anything. At the time, this often still required some input from the user (e.g. installing device drivers) but in the years since this has expanded to the point where almost any device intended for use with a personal computer will be plug and play. This has been invaluable for the ease of use of personal computers and for ensuring the widest range of users are able to utilise the widest range of potential devices (Jirkovsky et al, 2018).

It is clear, therefore, why a similar plug and play approach would be desirable for smart local energy systems. SLES are complex, and if manual configuration of both new or upgraded devices, and of the devices which they will interact with, is needed, then this presents a significant barrier to a truly 'smart' SLES, one which can easily be modified to reflect the changing a growing needs of its users. However, plug and play requires a high degree of interoperability and the ability of devices to understand and communicate with one another. For this problem to be solved we require common structures, standards, and importantly, languages, or in other words, ontologies (Morris and Mcarthur, 2021).

What is an ontology?

The most common definition of ontology is "a formal, explicit specification of a shared conceptualisation" (Malik et al, 2015). In this definition, **conceptualisation** means an abstract logic model created from the identified aspects of the domain being modelled, **shared** means the model captures agreed upon knowledge, **explicit** means that the concepts and their relationships are defined, and **formal** means machine-readable, or capable of being understood and processed by computers (Atkinson et al, 2006).

An ontology can therefore be thought of as a kind of model which consists of an agreed vocabulary for the concepts and categories within a knowledge domain that define their properties and relationships.

Ontologies have been an important concept in the field of AI for the past 25 years, and have become increasingly prominent in computer science over the last decade (Caldarola and Rinaldi, 2016).

Example 1: Plug and Play Local Energy Trading

Multi Agent Systems (MAS) are comprised of a collection of intelligent agents interacting in the same environment. Each agent has own goals and capabilities, with this autonomy allowing for agents to co-operate and co-ordinate to achieve their individual goals. The independence of agents and their goals allows for MAS to be extendable and adaptable, as agents in the system can adapt to the removal or modification of existing agents, or addition of new agents.

An MAS approach was taken to facilitate the trading of energy between a range of simulated SLES. The use of MAS to allow inter-unit energy trading brought down the costs of balancing the individual SLES between 10%-15%, while also increasing their income between 15%-25% by reducing reliance on the wider grid. The MAS architecture design took a flexible plug and play approach which could accommodate new market participants joining while others left over time, and could accommodate a range of technology options (Morris and Mcarthur, 2021).

How are ontologies used in the energy sector?

A number of ontologies have been proposed in the literature for a wide range of applications. These include energy markets (Energy Markets Ontology, EMO: Ma et al, 2019), network management (Ontology for Energy Management Applications, OEMA: Ma, 2019), and smart home integration (Smart Appliances Reference ontology, SAREF: Daniele et al, 2015).

There are also a number of ontologies which are used in practical applications, such as the Semantic Sensor Network (SSN) ontology (Compton et al, 2012) that is used to manage smart sensors, the EnArgus ontology which is widely used in Germany and provides a central information system for energy research funding (Hirzel, 2017), and the SEMANCO ontology which provides access to environmental data about a number of cities in Europe (Corrado et al, 2015).

Common Information Models (CIM) are a type of 'semi-formal' (i.e. only partially machine readable) ontology which also have practical applications in the energy industry. IEC 61970-301 and IEC 61968 define the CIM for electricity, including definitions of the configuration and operation of electrical networks (ENTSO-E, 2022). CIMs are less well-suited to plug and play applications, as they are usually not defined with machine-readability as a central focus, relying on context that users of the ontology are expected to possess (Quirolgico et al, 2004).

Example 2: Ontologies for Battery Energy Storage Systems

Battery energy storage has many applications within SLES, requiring a complex energy management system capable of supporting a wide range of use cases. An energy management system ontology (EMSOnto) allows for the design and testing of battery control applications (Zanabria, 2018a). This ontology facilitates the translation of engineering requirements (such as information sources, technology platforms, and desired control actions) into a deployable implementation (Zanabria, 2018b).

Why are ontologies important for smart-energy places?

As discussed above, (formal) ontologies can enable the use of AI techniques, such as Multi-Agent Systems, to facilitate a wide range of functions that are vital to the operation of SLES approaches to smart-energy places.

AI techniques are highly suited to meeting three main requirements for SLES:

1. **Flexibility** – SLES use cases are likely to evolve and expand over the lifecycle of an SLES, including the connection, upgrade, and replacement of devices and device types, across a range of energy vectors (e.g. heating, electricity, and transport).
2. **Scalability** – an SLES solution must be capable of dealing with growth, both in the number of connected generation devices and the loads and types of these devices.
3. **Reusability** – for an SLES solution to be viable, it must be possible to deploy all or part of the solution to solve similar problems in different locations.

The complicated nature of meeting all of these requirements makes decentralised intelligence and decision-making a key requirement, something which is difficult to achieve without a common language and common data structures for all potential devices.

How should ontology development be approached?

There exist already a range of ontologies relevant to the functions of an SLES, some of which are detailed above. Therefore one method for developing a broader SLES ontology would be to map concepts between these ontologies, either manually, or through the use of ontology mapping AI techniques (Catterson et al, 2005).

However, for an ontology that provided the greatest functionality, domain experts would need to work together with knowledge engineers to create a common understanding of all the functions of an SLES (Xie et al, 2013).

A GB CIM as proposed by the Energy Digitalisation Taskforce in any form would be desirable. But the possibilities for plug-and-play operation would be greatly enhanced if this were conceptualised as a formal ontology. This, in turn, would improve both the reusability and scalability of SLES solutions, bringing down both the cost and complexity of implementing these solutions and making SLES a more desirable option and facilitating the delivery of smart-energy places.

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