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Towards Interoperable Local Energy Communities in Austria

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Abstract

To ensure continued reliable operation of the energy grid in the face of a rising number of Local energy communities (LECs), they need to be integrated in a way that ensures that they do not negatively impact, but support the overall system, e.g., by providing flexibility. Project ECOSINT aims at intelligent, digital integration of LECs to achieve this goal. This includes the development of an adequate software architecture, which is currently in progress and has yielded a conceptual model as a first result. Among the numerous collected requirements regarding LECs, interoperability has been identified as a crucial factor. This is addressed by incorporating the VLab framework, which is presented and demonstrated for a simple EV charging scenario.

1. Introduction and related work

In Austria, LECs in the form of “Erneuerbare Energiegemeinschaften” (EEGs), aim at increasing the number of renewable energy resources while providing financial benefits to its participants but not for the EEG itself. Communities such as these are geographically limited by their substation and subsequently the low-voltage grid they are connected to. While the decreased fees offer the incentive to invest in renewables this should be done in a way that is grid-friendly and socio-economically fair. In addition, as additional IT infrastructure is needed to accommodate the creation of LECs, security and privacy are important factors to consider in all stages of IT architecture development. In a nutshell, this is the goal of the project ECOSINT, which has already been described in [1].

The central task of phase two of the project is the development of the software architecture. Currently, the project is in the middle of the corresponding process, and first, initial results in the form of a conceptual model are shown. In addition, the intended way to achieve interoperability using VLab is presented and demonstrated for a simple scenario for EV charging.

The article is structured as follows: some background about interoperability and modelling frameworks is shown in Section 2. In Section 3 the architectural part consisting of the collection and organization of requirements, the generation of the conceptual model, and the module view of the use case scenario are shown. Then, VLab is described and applied to this use case in Section 4. Finally, a conclusion and an outlook are given in Section 5.

2. Background

Interoperability is a critical enabler of smart grid potential and should be considered an inherent component of any smart grid application being developed from the start. It is a design consideration, so considering it early on saves time and resources. Furthermore, when engaged partners and stakeholders have a better understanding and documentation of automation interfaces, dependencies, and expectations, communication becomes more effective and easier. As part of its discussion of the advantages of interoperability, NIST 4.0 [4] notes that these include, on the one hand, reducing the time and effort needed for successful integration and, on the other, identifying automation points that might lead to the provision of value-added services on top of an existing solution and infrastructure. Yet an-

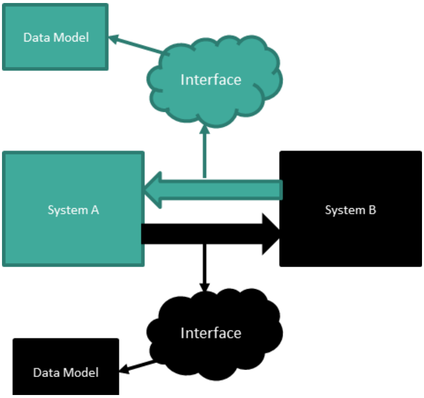

Figure 1: A simplified meta-model of interoperability between two systems [6]

other benefit is interchangeability, which makes it possible to quickly swap out one component for another similar one.

To demonstrate the concept of interoperability, Figure 1 displays a meta-model. The model depicts a relatively simple situation in which two systems (System A and System B) are interested in exchanging information with one another in order to work toward a shared objective. Two fundamental notions must be made available by both systems in this fundamental situation. These include concepts like a data model and an interface. The interface, as defined by the IEEE Standard Computer Dictionary, is the shared boundary that serves as a conduit for data communication between the two systems in this instance. A data model, on the other hand, is an abstract model that organizes a system's properties and structure in a way that other systems could find useful to know.

The process of estimating a system's interoperability is complicated as it is not a simple yes/no answer. Instead, interoperability can be evaluated using a maturity scale like the one shown in Figure 2. This approach, proposed by the GridWise Architecture Council, divides a system's interoperability into three categories: pragmatics, semantics, and syntax. Then, each of these groupings is separated into two or three tiers further. The model suggests that there is a mechanism for creating physical and logical links between systems at the lowest level of interoperability, "1. Basic Connectivity," while the highest level of interoperability, "8. Economic/Regulatory Policy," is reached when all parties involved have a common understanding of the political and economic goals in policies and regulations.

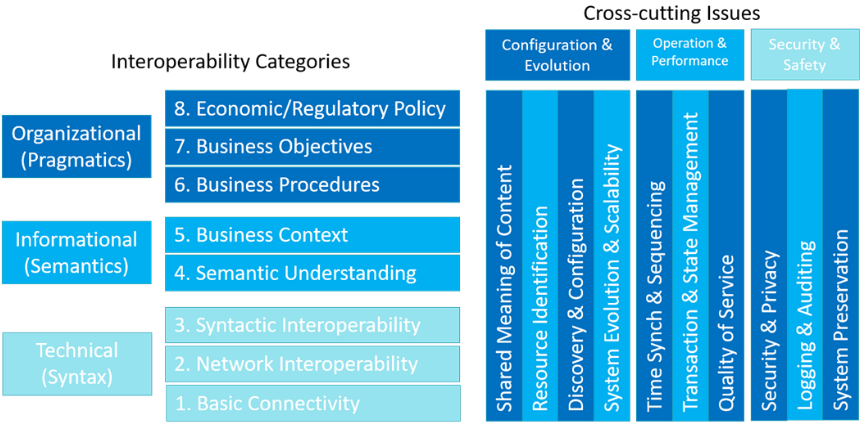

Figure 2: GridWise Architecture Council's Interoperability Context Setting Framework [7].

Two models and frameworks are relevant for the discussion on the design and development of interoperable smart grid solutions. The first is the NIST Smart Grid Conceptual Model which is part of the NIST 4.0 smart grid interoperability framework [4]. The conceptual model, shown in Figure 3, presents the smart grid as several high-level domains (customer, distribution, generation including der, market, operations, service provider, and transmission) along with the ICT and electrical interactions among them. The model is aimed at making communication easier and more understandable among various stakeholders.

The second important methodology is the Smart Grid Architecture Model (SGAM) [3], a three-dimensional architectural framework, shown in Figure 4. It is a reference model as well as a methodology for designing and visualizing smart grid solutions in an interoperable way. There are five interoperability layers, and each layer is a two-dimensional plane. This plane is divided into domains and zone that corresponds to different areas of the power system. Smart grid use cases, when defined for example using the IEC62559-2 [5] template, can be visualized using the SGAM model to have them interpreted in an interoperable way.

Figure 3: NIST Smart Grid Conceptual Model [4]

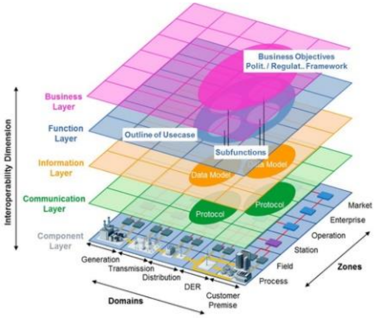

Figure 4: Smart Grid Architecture Model [3]

3. Architectural Process of ECOSINT

3.1 Collection and organization of requirements

As the main goal of the project is a software architecture for LECs, in the first step, requirements have been collected in a stakeholder workshop including stakeholders from industry, academia, and an association that supports the foundation of clean energy projects (Ökostrombörse). Subsequently, these broad requirements were then assigned one or more of five labels (economic, technical, ICT, inter-operability, and sociographic) in a multi-labelling process.

3.2 Generation of the conceptual Model

Out of these requirements the following six main objectives for the software architecture have been selected.

1. Grid-friendliness (provide flexibility, decrease peak loads, predict flexibility, optimize self-consumption, avoid concurrent effects, island mode of LEC)
2. Modularity of architecture
3. Openness (including interoperability)
4. Scalability of the system
5. Resilience (includes communication within LEC, includes island mode)
6. Security and Privacy

These are mainly technical requirements. Note that the software architecture must be able to handle various tariffs but itself cannot ensure economic or sociographic requirements. One of these requirements is interoperability which is the focus of this paper. As one of the requirements, we also aim at using the already existing structure, especially for the near future scenarios.

In the next step, actors were selected and revised. Although this project is European, actors were chosen based on the NISTIR 7628 Rev.1 cybersecurity guidelines [2]. The benefit of this approach is the utilization of the security guidelines in the following stages. Then, actors for the distribution grid were pre-selected after mapping these actors in the SGAM model [8]. Out of this pre-selected list, the final list of actors was selected manually. As the project focuses on the addition of LECs, most actors at the customer premise remained while many specific actors from operations or distribution were removed. The result of this process is shown in the conceptual model of Figure 5. As interoperability and usage with existing solutions are among the main goals, the Operations part contains the existing EDA platform (Energiewirtschaftlicher Datenaustausch) that handles the secure data exchange between utilities and between utilities and external customers. The conceptual model shows that the solution is a pure ICT solution: energy production and consumption are only influenced (i) directly by the operations (independently of the envisioned solution) or (ii) indirectly by changing the behavior of the households in response to received information such as information about current or future tariffs.

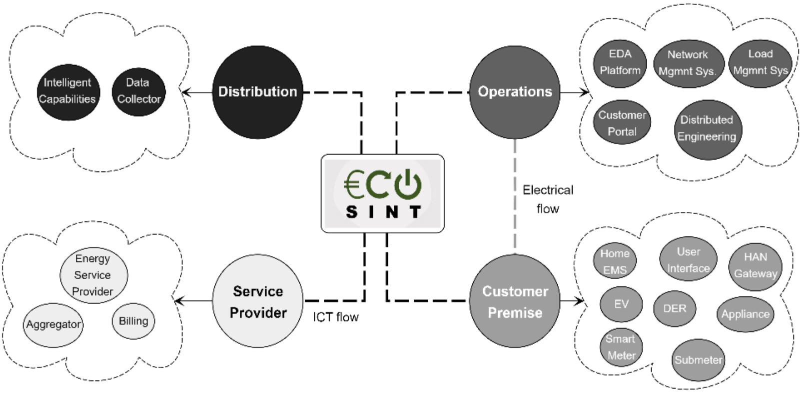

Figure 5: Conceptual model showing that the envisioned solution purely focuses on ICT flows, whereby electrical flows are only influenced indirectly.

3.3 Module view of the EV charging process

The EV charging process as modelled here extends two currently existing use cases. The first one is the metering use case where the LEC gets the metering data, i.e., the measured consumption and production values in 15-minute time resolution at the end of each day. In other use, an intelligent charging point acts on behalf of the user and tries to minimize the charging costs. In the extension (Figure 6), the envisioned solution forwards the metering data to the intelligent charging point that therefore has the option to charge the car with excess energy of PV production which in turn is beneficial to the grid.

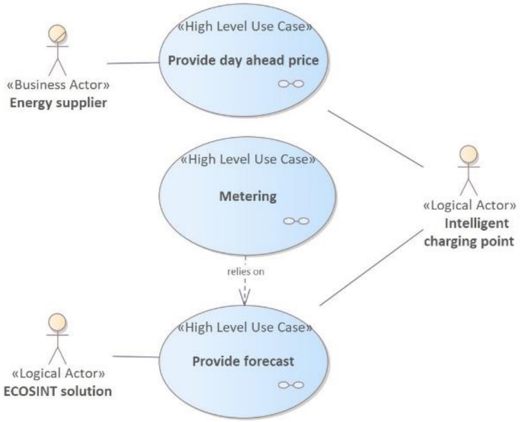

Figure 6: EV charging use case model.

Figure 7 shows how smart meter data that is provided by a household within a LEC may be used in conjunction with day-ahead prices for energy to control the charging of an electric vehicle (EV) connected to an intelligent charge point. This works by aggregating the smart meter data of all households, which is already sent to the Distribution System Operators (DSO), within a LEC and then passing it to ECOSINT's intelligent forecasting algorithms. The results of this forecasting, timeslots for EV charging optimized to use as much of the LEC's self-produced energy as possible while taking grid-friendliness into account, are then sent to the intelligent charge point. In a first step, this information may be provided to the user alongside the day-ahead price for external energy to help them decide on charging times for their EV. A more advanced scenario would then include fully automated systems based on the information provided by energy service providers and ECOSINT's algorithms.

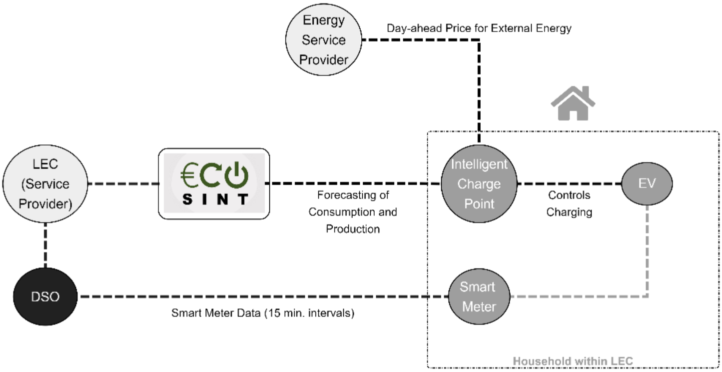

Figure 7: How forecasting provided by ECOSINT may be used in the optimization of charging patterns for the LEC's EVs

4. Application of AIT VLab

4.1 AIT VLab

The AIT Virtual Lab (VLab) is a framework that consists of a methodology and a toolkit for support in developing smart grid solutions that can attain higher levels of interoperability. The framework advocates creating a shared understanding of both the problem and solution domains first so that the functional objectives of the solution can be aligned with the implementation needs. In this way, it also aids in closing the knowledge and comprehension gap between the teams responsible for requirements and implementation. System architects and developers, along with most other stakeholders, can equally benefit from the framework.

The main input to the framework is the specification of the solution described using a Microsoft Excel template. In the template, a solution-level data model is defined that is then shared among the individual modules when specifying the interfaces and the data models, in accordance with the interoperability meta-model shown in Figure 1. This input is then processed with the toolset for the generation of virtual Docker-based environments with mock-ups and then can be used for prototyping, development, and/or integration testing.

4.2 Application of VLab framework for the EV charging process

The AIT VLab framework is used for creating a prototype for the EV charging use case described in Section 3 above. The virtual mock-up environment contains the modules for an EV controller, an intelligent charge point controller, a smart meter, a LEC service provider module, and an energy service provider module. Each of these components provides various REST APIs for interacting and triggering/executing the provided functionalities. Furthermore, each component is configured to emit Prometheus[1] measures that are then displayed using a Grafana[2] dashboard. The generated virtual environment will be made available publicly on GitHub[3] and Docker Hub[4] and can be executed by cloning the repository for experimentation, and analysis. The environment is extendable and can be adapted to suit the needs of another scenario, for example with multiple instances of some of the selected components (EV controller for example). This capability further provides the possibility to use the environment for scalability and replicability analysis.

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[1] https://prometheus.io/

[2] https://grafana.com/

[3] https://github.com/ecosint

[4] https://hub.docker.com/

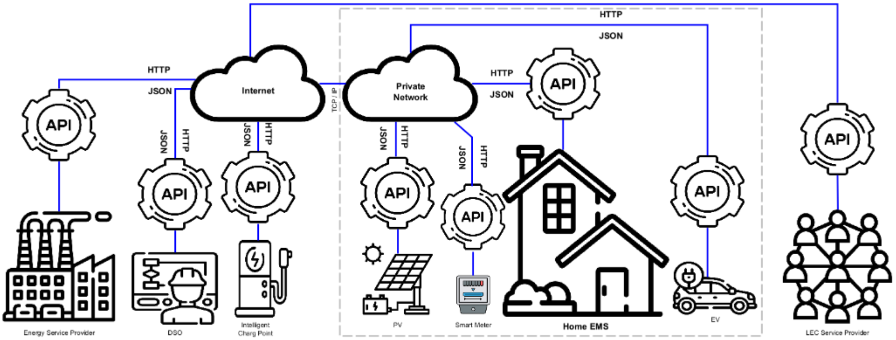

Figure 8: Overview of the AIT VLab's generate virtual test environment.

5. Conclusion and Outlook

Summarizing we showed the first steps towards an architecture that employs VLab to achieve interoperability. These steps are demonstrated for a simple, high level use case.
Future work will tackle an extensive list of use cases, moreover several of these use cases will be modelled with more details than the one presented here.

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