SENSE: Semantic-based Explanation of Cyber-physical Systems

Deliverable 5.2: PoC implementation in smart grid domain

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Abstract

Deliverable D5.2 reports on the implementation of the smart grid PoC's using the SENSE technology stack. It provides brief descriptions and web links to the repositories which hold the PoC configurations and can be used to run the PoC.

History

Version	Date	Reason	Revised by
0.9	01.03.2025	Initial version	KD
0.95	10.03.2025	Revision	JS, AE, DH
1.0		Final Version	

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Executive Summary

This deliverable briefly outlines the smart grid PoCs developed within the SENSE system. The PoC's and all data required to initialize and run them can be found in the respective gitlab repositories:

BIFROST PoC
Configuration Repository: https://git.ai.wu.ac.at/sense/bifrost_v2
Branch: main

Seehub PoC
Configuration Repository: https://git.ai.wu.ac.at/sense/seehub
Branch: seehub-demo-production-env-v2

More detailed information on the PoC definitions and the SENSE architecture can be found in the respective deliverables.

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1 Introduction

The SENSE project aims to enhance the efficiency and user-friendliness of complex technical systems, by applying neurosymbolic AI approaches in combination with AI agents to provide meaningful insights, explanations and suggestions of system events to key stakeholders.

SENSE planned and implemented two proof of concept (PoC) in the smart grid domain, which were defined and planned in great detail in the SENSE deliverable "D2.3 PoC Definition"[1].

This deliverable provides a comprehensive overview of the two use-cases and points to the repositories which hold the PoC definitions and can be used to instantiate the PoC on premise.

2 PoC BIFROST

Configuration Repository: https://git.ai.wu.ac.at/sense/bifrost_v2
Branch: main

In this PoC, the SENSE System is tested in a simulation of a smart grid environment using BIFROST as a virtual testbed. The PoC aims for explaining events to the energy community operator (ECO) and the distribution system operator (DSO). Deliverable 2.3 outlines the setup, introduces stakeholders' scope and objective of the PoC, human machine interface requirements, as well as scenarios and explanations for ECO and DSO.

As described in D2.3 PoC Definition [1] the use case refers to simulation of local energy communities in a low-voltage distribution section. To operate the energy community, the operator must make sure that the community adheres to an operating envelope, i.e. active power limit, issued by the distribution system operator which limits the maximal generation/consumption of the energy community.

As outlined in previous deliverables the PoC was set up to detect and explain envelope violation states. Within this PoC the SENSE system can distinguish between feed-in and demand violations. Additionally, we can distinguish if a detected violation was caused by the energy community or the grid participants which are not part of the community. In the case of a community violation, the system is further able to identify if the community deliberately violated the envelope (by generating a schedule for the community load/feed-in which violates the envelope in advance) or if this happened due to other circumstances.

A detailed definition of the system including platforms, sensors, state types and the event state mappings can be found in Seehub_SystemData.xlsx which is in the PoC's repository.

A sketch of the system architecture of the BIFROST PoC is shown in figure 1.

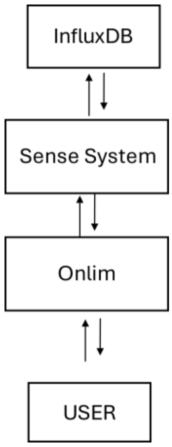

Figure 1: System Architecture BIFROST PoC

The architecture follows the general system architecture of SENSE as described in deliverables 3.1 [2] and 5.1 [3], where the ONLIM chatbot interface allows for the interaction between user and SENSE system. Additionally, the SENSE system can be queried via a REST API.

The BIFROST PoC will be published as a reference system on github and serves as a first test system for future users of the SENSE technology. The public repositories to access the SENSE system as well as the public PoC, including all relevant files necessary to start and test it will be made available under:

https://github.com/wu-semsys/SENSE-Core

3 PoC Seehub

Configuration Repository: https://git.ai.wu.ac.at/sense/seehub
Branch: seehub-demo-production-env-v2

The Seehub PoC concerns utilizing the SENSE system in the context of a charging infrastructure which hosts 8 e-chargers and is supported by a PV battery system. If the charging infrastructure would serve all charging requests directly, this would violate the contractually agreed operational limit at the grid connection to the public distribution grid. Therefore, to keep the grid and grid installations within their operational limits the distribution system operator (DSO) will actively issue "operating envelopes" towards the charging infrastructure. The charging facility uses the battery energy storage system as flexibility managed by an intelligent controller to comply with the operating envelope.

SENSE is used to detect and explain envelope violations caused by the charging infrastructure. As outlined in the SENSE deliverable 2.3. [1], four potential reasons for the violation of the envelope were defined and implemented in the context of the PoC. A detailed definition of the system including platforms, sensors, state types and the event state mappings can be found in SeeHub_SystemData.xlsx which in the PoC's repository.

The system architecture of the PoC is sketched below in Figure 2. In contrast to the BIFROST PoC, where the Onlim chatbot interface is used to enable the interaction between a user and the SENSE system, here a different approach was used as data of the production environment must not leave the company's premise.

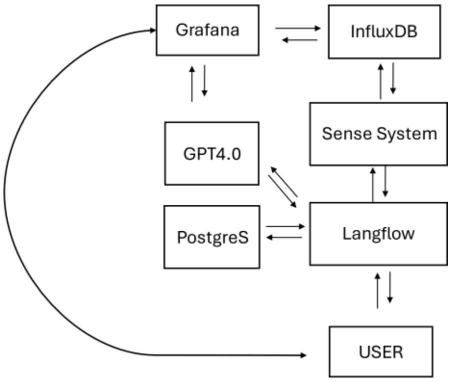

Figure 2 System Architecture Seehub PoC

For conversing with the SENSE system, a local Langflow instance in combination with a shielded (i.e., company internal) GPT-4.0 instance and PostgreS is used. Additionally, to get information regarding specific events, the system allows for looking at event-related timeseries data via a Grafana dashboard, which can be accessed via a link directly from the SENSE dashboard.

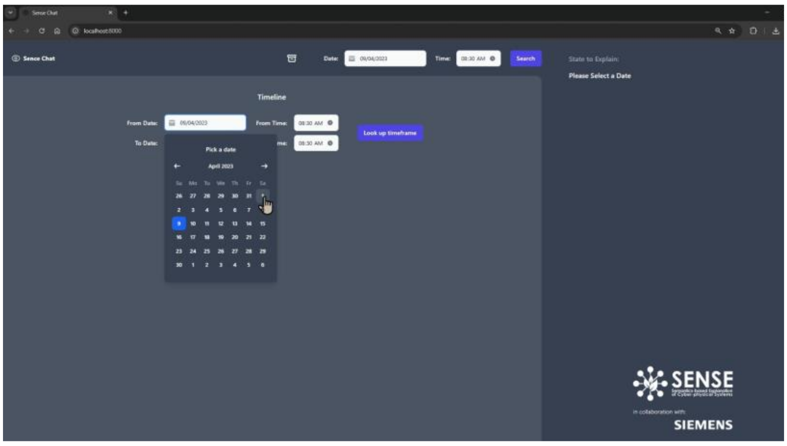

Figure 3:Date selection SENSE Seehub dashboard

Given that a UI was developed for this PoC which was not described in any previous deliverable it is shortly outlined within this deliverable:

When logging into the system the user can select specific timepoints as well as time-ranges where they are interested in events (see Figure 3).

Upon selecting an event the user can query the SENSE system regarding the events that happened (see Figure 4), the right-hand side of the dashboard depicts the causal relationship which was determined by SENSE to be the cause for the trigger event.

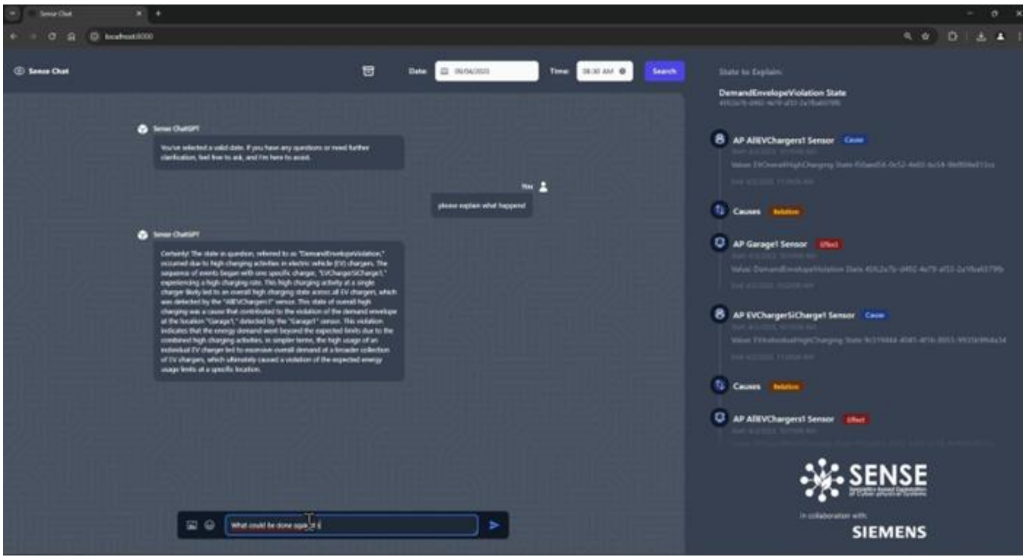

Figure 4: Conversing with the SENSE system

The system only uses an explanation on the event structure received from the SENSE system to give context on the event. This could be improved in the future, (e.g., by using retrieval augmented generation RAGs to provide more detailed information) by supplying documentation and other information which could be provided as a context to the LLM when conversing with the user regarding system events, thus improving it's responses without the need of finetuning.

When clicking on the causal relationships depicted on the right panel, one is forwarded to the Grafana dashboard which depicts the timeseries involved in the event and event detection for a deep-dive manual inspection as shown for an example in Figure 5.

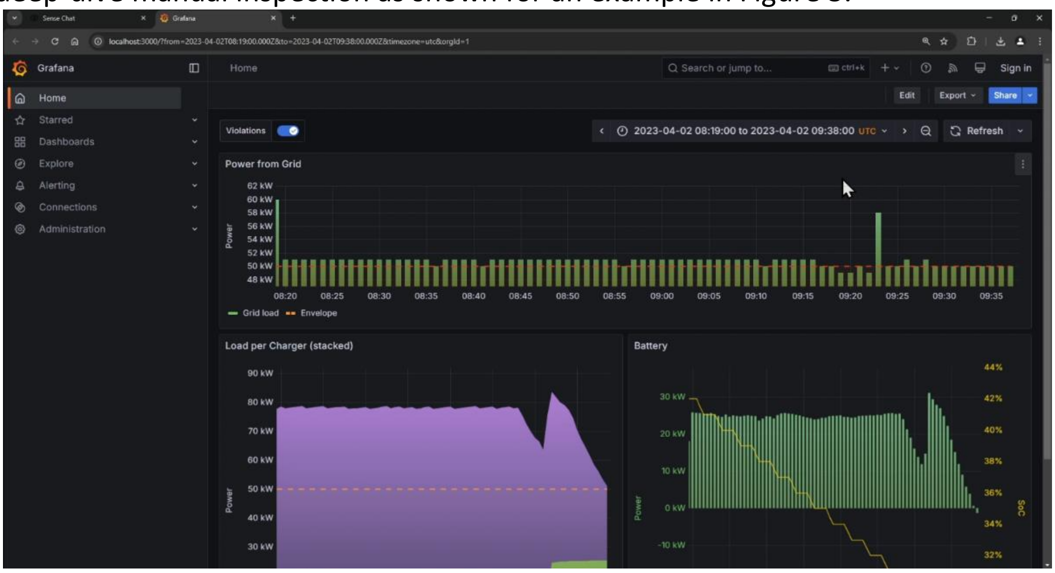

Figure 5 Grafana Dashboard Seehub PoC

In combination this allows a user to converse with the SENSE system, however for now limited in terms of context as well as inspecting events.

4 Summary

This deliverable summarizes the smart grid PoCs which were developed within the SENSE project. The main deliverable in this context can be seen as the PoCs themselves. These can be accessed and run via the following gitlab repositories:

BIFROST PoC
Configuration Repository: https://git.ai.wu.ac.at/sense/bifrost_v2
Branch: main

Seehub PoC
Configuration Repository: https://git.ai.wu.ac.at/sense/seehub
Branch: seehub-demo-production-env-v2

References

[1] Poelmans et al. “Deliverable 2.3: Definition of PoC's”, SENSE project 2024
[2] Frühwirth et al., "SENSE Deliverable 3.1 Auditable SENSE Architecture," 2024.
[3] Frühwirth et al. “Deliverable 5.1: Technology Stack Implementation”. SENSE project 2025